On Debunking 9/11 Debunking

Examining Dr. David Ray Griffin's Latest Criticism
of the NIST World Trade Center Investigation

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31 August 2007	Release	1.0	Initial public release
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Abstract

In this paper, we examine the claims of Dr. David Ray Griffin regarding the NIST investigation into the World Trade Center disasters, and find those claims to be unfounded. All 18 major claims are discussed and rigorously dismissed, and a further analysis of the text reveals an overwhelming density of factual and logical errors. This paper refutes Dr. Griffin's major claims, supporting with evidence that the aircraft impacts were expected to significantly damage the structures, that the resulting fires were of both sufficient temperature and duration to cause structural collapse, that a progressive collapse resulting in total destruction of the Towers was the likely result, and that the "controlled demolition" hypothesis is speculative and unsupported by any evidence. We also discuss the anticipated NIST report on World Trade Center Seven. The author highlights the fundamental sources of errors present in Dr. Griffin's research and provides a template to evaluate future claims using resources available in open literature.

About the Author

Ryan Mackey is a research scientist at the NASA Jet Propulsion Laboratory, specializing in vehicle autonomy and Integrated Systems Health Management for aircraft and spacecraft. He is a graduate of the University of California, Santa Cruz and the Graduate Aeronautical Laboratories at the California Institute of Technology (GALCIT). He has authored sixteen NASA Tech Briefs and Technical Reports, and received two United States Patents for his original research. He has contributed to numerous projects including the Joint Strike Fighter, NASA's New Millennium Program and Project Constellation. His introduction to fringe beliefs regarding September 11th and the works of Dr. Griffin came through informal Internet discussions hosted by the James Randi Educational Foundation, a nonprofit organization dedicated to raising public awareness of paranormal and pseudoscientific fraud. While the author pursues this effort independently of these and any other organizations, he is indebted to them for their contributions to science, education, and critical thinking.

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Dedication

This work is dedicated to the forgotten heroes of September 11th – those who willingly grappled with the full horror of the tragedy for long weeks afterwards, toiling to recover the dead, identify the victims, heal the injured, console the grieving, shelter the homeless, and seek justice for the fallen. *"It is only through labor and painful effort, by grim energy and resolute courage, that we move on to better things."* (Theodore Roosevelt)

A Note on Fair Use

The author acknowledges that this review article contains an unusual number of excerpts, and lengthy ones at that, from Dr. Griffin's original text. Review of this book presents an extraordinary problem in that Dr. Griffin presents a fantastically large number of ideas, frequently providing little support or even mention of them again outside the paragraph in which they appear. This style of writing makes summarization difficult without potentially altering his intended message, and in any event summarization is little better than direct quotation with respect to plagiarism. It is difficult, therefore, to adequately address his arguments in the comprehensive fashion he demands without either severely cropping the arguments themselves, in which case the risk of misquoting increases; or instead presenting the arguments faithfully, meaning a large fraction of the text must be copied *verbatim*. The author has chosen the latter, fully respectful of Dr. Griffin's copyright. While we may disagree wholeheartedly with his conclusions, we do not begrudge his right to free enterprise, any more than we would impeach a work of intended fiction.

While the fractional portion of this review that is quoted from Dr. Griffin's book is abnormally high, the author confidently states that such quotation falls within Fair Use guidelines, based on the following list of reasons, which includes mitigations undertaken deliberately by the author:

- This review is intended to present a dissenting but factual and scientific viewpoint on the events of history and the investigations that followed. To the best of the author's knowledge, all ideas put forth are factual in nature.
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- By choice, this review is restricted to one of the four major chapters in Dr. Griffin's book, and no quotations are taken from any of the other chapters, the introduction, or conclusion.
- The sum total of quotations from the text included in this review comes to about 6700 words, less than 26% of the chapter reviewed, or approximately 5.3% of the book in total.
- Over a sixth of the above total is composed of words quoted by Griffin from other sources, rather than his original writing.
- Quotations from Dr. Griffin's book, including his words and our reproduction of his quotations, make up only about 7.5% of this review.
- By comparison, quotations from various sources that do not appear in Dr. Griffin's book total 13,000 words or 14% of this article, as befitting a properly referenced factual review.
- All quotations are faithfully transcribed in their original context, and the author has taken great care in an attempt to represent Dr. Griffin's position accurately.

Introduction

Dr. David Ray Griffin is an emeritus professor of theology and religious philosophy at the Claremont Colleges in Southern California. He has established himself as an outspoken representative of the self-titled "Truth Movement," a loose confederation of critics united in their belief that the conventional understanding of the September 11th attacks is deeply mistaken. He has authored and contributed to several books advancing the theme that, in stark contrast to the findings of official and professional investigations, agents of the United States Government or perhaps a "shadow government" [1] were responsible for the attacks. His previous works, including *The 9/11 Commission Report: Omissions and Distortions* [2], have helped motivate other authors disagreeing with his opinions to publish rebuttals, with the most well-known being *Debunking 9/11 Myths: Why Conspiracy Theories Can't Stand Up To the Facts* [3] from the editors of *Popular Mechanics* magazine.

As background for those unfamiliar with the debate, members of the Truth Movement may be divided according to their beliefs into two major camps, known as "LIHOP" and "MIHOP." The former acronym stands for Let It Happen On Purpose, and the latter stands for Made It Happen On Purpose. The LIHOP contingent believes that the September 11th attacks were conducted by roughly the same people and in the same fashion as determined by the *9/11 Commission Report*, but that the United States Government, being aware of the impending disaster and seeing advantage in letting it proceed, deliberately hampered investigators and defense systems that should have thwarted the attacks. The MIHOP group, on the other hand, contends that the plan was conceived and executed by the United States Government, or at least powerful figures therein, and that the real attacks happened in a completely different fashion, since the MIHOP hypothesis is totally incompatible with al-Qaeda sponsorship. Within each camp is a dizzying diversity of beliefs with respect to specific details, but a more in-depth treatment of Truth Movement folklore is not required for this review.

The most common explanation of *"why"* treats the attacks as "a new Pearl Harbor," referring to a brief passage in the *Project for a New American Century* papers [4] that speculated about a dramatic future event on American soil serving as a possible transformation point in global and military policy. This suggests, to many researchers in the Truth Movement, that some within the government eagerly hoped for – or brought about – such an event. This is unsurprising given that Pearl Harbor itself also remains a magnet for conspiracy theories. To use Pearl Harbor as an illustration, a Pearl Harbor LIHOP theory is that President Roosevelt was aware of the impending attack, but prevented commanders from learning this information, desiring a surprise military defeat as a pretext for revenge and open war. A Pearl Harbor MIHOP theory would require that the Imperial Japanese Navy did not attack at all, but instead that the United States scuttled its own warships or perhaps attacked itself, blaming the attack on an innocent Empire of Japan, in what is frequently termed a "false-flag operation."

For reasons that should be obvious, the LIHOP conspiracy theory is much simpler and more popular in the case of Pearl Harbor – indeed there are such theories even today, even though all of them have been thoroughly repudiated in official investigations and the popular press. With respect to September 11th, oddly enough, the MIHOP conspiracy theories have proven to be more popular, despite the drastically higher burden of proof associated with such theories. Dr. Griffin is soundly in the MIHOP camp, as he explains in the introduction of his latest book.

Dr. Griffin's book is a re-argument of his previous claims directed squarely at his detractors, and is thus titled *Debunking 9/11 Debunking* [5]. This book is broken into four primary chapters, as follows:

- "9/11 Live or Distorted," criticizing the *9/11 Commission Report* [6] with respect to NORAD;

- "The Real 9/11 Conspiracy Theory," a response to Kean and Hamilton's book highlighting difficulties in the *9/11 Commission* investigation;

- "The Disintegration of the World Trade Center: Has NIST Debunked the Theory of Controlled Demolition?" which is the focus of this review;

- And finally, "Debunking 9/11 Myths," where he responds specifically to the *Popular Mechanics* critique.

This analysis will only consider the third chapter, having to do with the final report of the World Trade Center Investigation conducted by the National Institute of Standards and Technology, hereafter referred to as the "NIST Report." This decision is motivated by several factors. First, Dr. Griffin's opinions are based on many different but interdependent observations regarding September 11th, including those he names as responsible parties, the motives and methods of these hypothetical actors, and the scientific analysis of evidence; of these claims, scientific inquiry is the most objective and therefore the most definitive, and thus consideration of NIST is least open to interpretation. Second, the NIST Report [7] is readily available, and while the report may be criticized, errors that Dr. Griffin makes regarding its contents may be factually verified with no uncertainty. Third, as we will see in the following sections, the errors made by Dr. Griffin are so numerous and substantial as to discourage further analysis of his claims.

Approach

The number of claims made or implied in this chapter is extremely large. While the author will endeavor to address all of them, it is not always possible to sense every nuance of every argument, nor is it possible to adequately describe them all without reprinting the entire source text. The author has attempted to summarize the contents of every section, extracting relevant sentences or paragraphs where detail is required, and to address the claims accordingly.

Given the sheer number of errors uncovered by this analysis, and the ongoing adversarial relationship between Dr. Griffin and his many critics (made evident even in the book's title), it is expected that he or his supporters will attempt to seize upon any perceived *gaps* in this analysis, rather than address the analysis itself. Unfortunately there is no possible way to eliminate all such gaps, particularly if Dr. Griffin applies an unexpected interpretation to his words. Rather than considering this analysis as a point-by-point refutation, our presentation should be understood to include the following:

- A refutation of all major claims and central themes contained in this chapter;
- Examples of the standard of proof required for Dr. Griffin to meet before making these, derivative, or future claims; and
- A method of examining any of Dr. Griffin's claims contained here or elsewhere for accuracy and relevance.

Any claim that we do not expressly examine in this work should not be considered true by default. Likewise, if perhaps 10% of Dr. Griffin's propositions are unaddressed while the other 90% are repudiated, this does not mean that the remaining 10% should be accepted or understood to support Dr. Griffin's position. Instead, our refutation of his major claims should demonstrate the lack of trustworthiness and thoroughness that pervades his latest book, and provide a template for examination of the remainder.

Dr. Griffin and many of his colleagues have adopted the argument that, since they are merely questioning a theory rather than presenting one of their own, only a single question must be correct (that is to say, "unanswered," as a question contains no veracity on its own by definition) in order to disprove the so-called "official theory" of the September 11th attacks. This is illogical and scientifically unsound. The NIST hypothesis is not a "house of cards" that disintegrates utterly at the first hint of inaccuracy or missing detail. There are missing details in virtually every theory produced in history. For example, nobody has yet observed a graviton particle, but this does not mean that gravity does not exist. Whether Dr. Griffin states this or not, each of his questions must in fact be compared against a competing hypothesis, and questions only serve to differentiate and rank these competing ideas. Dr. Griffin does provide his own, loosely stated hypothesis in this chapter, which we will examine in addition to his questions and observations on the NIST hypothesis. Our analysis will show conclusively that criticism of his theory is vastly more justified than Dr. Griffin's own criticism of the NIST hypothesis.

Chapter Overview

Before we consider the chapter's contents, it bears pointing out that the first problem occurs with the chapter's title: "*Has NIST Debunked the Theory of Controlled Demolition?*" In choosing these words, Dr. Griffin is already attempting to shift the burden of proof. To begin, Dr. Griffin has not identified any coherent theory of "controlled demolition," here or in any previous text. In his book he cites the work of Dr. Steven Jones [8], but also numerous other, incompatible theories, without selecting any particular candidate. As he states in his Note 16 to this chapter:

> I am using the term "explosives" very broadly to refer not only to explosives in the technical sense, such as RDX, but also to incendiary mixtures, such as thermite and thermate, and any other substances or devices that can be used to produce explosions. [9]

With such poor specificity, Dr. Griffin is not advancing any theory, but rather speculating about an entire multidimensional space of possible theories. Furthermore, while Dr. Steven Jones hypothesizes incendiaries, namely thermite and its variants, he does not require production of "explosions" thereby, and so Dr. Griffin's space of theories is so large that it requires redefinition of the term "explosives." The only common element to these theories is that buildings were damaged deliberately by "substances or devices," understood to be destructive devices placed in the WTC buildings prior to aircraft impact. What Dr. Griffin demands is proof of a negative, and this is a logical fallacy.

The NIST study was conducted to answer specific questions about building performance [10], not to address any alternate theory, and certainly not to address an entire universe of incomplete speculations. Despite this, NIST did speak to this ill-posed question directly in an interim document known as the NIST FAQ [11], as follows:

> NIST's findings also do not support the "controlled demolition" theory since there is conclusive evidence that:
>
> - the collapse was initiated in the impact and fire floors of the WTC towers and nowhere else, and;
>
> - the time it took for the collapse to initiate (56 minutes for WTC 2 and 102 minutes for WTC 1) was dictated by (1) the extent of damage caused by the aircraft impact, and (2) the time it took for the fires to reach critical locations and weaken the structure to the point that the towers could not resist the tremendous energy released by the downward movement of the massive top section of the building at and above the fire and impact floors.
>
> Video evidence also showed unambiguously that the collapse progressed from the top to the bottom, and there was no evidence (collected by NIST, or by the New York Police Department, the Port Authority Police Department or the Fire Department of New York) of any blast or explosions in the region below the impact and fire floors as the top building sections (including and above the 98th floor in WTC 1 and the 82nd floor in WTC 2) began their downward movement upon collapse initiation.
>
> In summary, NIST found no corroborating evidence for alternative hypotheses suggesting that the

> WTC towers were brought down by controlled demolition using explosives planted prior to Sept. 11, 2001. NIST also did not find any evidence that missiles were fired at or hit the towers. Instead, photographs and videos from several angles clearly show that the collapse initiated at the fire and impact floors and that the collapse progressed from the initiating floors downward until the dust clouds obscured the view.

The burden of proof issue is significant because, even if NIST's response above and its meticulous final report could be shown to be incorrect, it would still not imply that "explosives" of any kind were responsible for the WTC collapses. It is possible for both NIST and Dr. Griffin to be wrong. One would still need to advance evidence supporting the explosives hypothesis before it could have any merit. In phrasing his question reactively, Dr. Griffin is declining to outline the case for his own, positive claim, or even to define the claim itself with clarity. Instead he is satisfied to simply cast doubt upon the NIST FAQ and NIST Report, while never accepting his own burden of proof.

Regardless of this logical error, we may of course proceed to examine the NIST publications even without a coherent competing theory – this will merely prevent us from formulating an alternative if mistakes are found. As Dr. Griffin states himself:

> These considerations should not, of course, lead anyone to prejudge the NIST documents. They must be evaluated on their own merits. But these considerations should lead us to study NIST's writings carefully ask if they explain the destruction of the World Trade Center buildings in a way that is adequate to the relevant evidence. … That judgment must be made on the basis of actually studying them. [12]

Dr. Griffin's primary claims, the majority stated as questions, are organized as subject headings in his book. We reprint these below and will investigate them in turn:

- Why did the airplanes cause so much damage?
- How did impact damage help induce collapse?
- How did the fires help induce collapse?
    - Were the fires hot enough?
- What actually caused the Towers to collapse?
    - Tweaked computer models
    - A thoroughly unscientific hypothesis
- What about controlled demolition?
    - Other hypotheses obviated by NIST's account?
    - Must controlled demolitions be bottom-up affairs?
    - No evidence of explosions?
    - No other evidence of controlled demolition?
- What about WTC 7?
    - Prior recognition of WTC 7's special difficulty
    - Challenges WTC 7 presents to NIST
    - The very appearance of this collapse
    - Two more unique features of this collapse
    - What will NIST say about WTC 7?

We group these claims into three major sections. The first treats claims regarding the aircraft impacts and the collapses of the World Trade Center Towers. The second section considers the case for and against "controlled demolition." The third is devoted to World Trade Center Building Seven. After examining Dr. Griffin's claims, we then turn to a discussion of Dr. Griffin's approach and the scientific method in general, other criticisms of the NIST Report, and close with a summary of findings.

Impact and Collapse Claims

The first portion of Dr. Griffin's critique addresses NIST's analysis, focusing on damage caused at impact and factors that led to the eventual collapse of WTC 1 and WTC 2.

Why Did the Airplanes Cause So Much Damage?

Dr. Griffin argues that the NIST Report overestimates the damage caused by the initial impacts, based on the following reasons:

1. Designers claimed to have studied aircraft impact prior to the Towers' construction, and found that they would have survived the impact of a Boeing 707; the damage from a 707 and the actual 767's should be comparable.
2. Frank DeMartini commented after construction, but prior to September 11th, that the Towers were designed to survive a 707 impact, and that he believed the Towers could survive multiple impacts.
3. Leslie Robertson also claimed the Towers were designed to survive a 707 impact.
4. John Skilling claimed the Towers would suffer a "horrendous fire… but the structure would still be there" in the event of such an impact.
5. The NIST Report does not include all of these comments, suggesting bias.

This first topic raised by Dr. Griffin sets the tone of his discussion, and sets it poorly. Not one of his points above contains anything other than speculation.

In the NIST Report, specifically NIST NCSTAR1-2 [13], the NIST team calculates a range of possible impact damages using highly detailed models of the buildings and impacting aircraft. Dr. Griffin has the opportunity to criticize this calculation and its conclusions, but does not even mention it in this section. He also has the opportunity to produce his own or other researchers' calculations if those support a different conclusion. He has not done this either. Dr. Griffin is attempting to dispute NIST's calculations with *opinions*, and does so as a classic "appeal to authority" fallacy. Let us examine his arguments individually:

1. As Dr. Griffin indicates [14], the NIST Report does acknowledge [15] that some cursory study of a high-speed airliner impact was performed in the 1960's. NIST was unable to find this calculation, and apparently Dr. Griffin does not have access to it either. It is fact that structural modeling in general, impact modeling, and particularly fire modeling were dramatically less sophisticated in the 1960's, and thus is it not obvious that such a study would be of any value at all, let alone superior to the NIST study. The burden of proof remains on Dr. Griffin, not on NIST. The NIST methods and conclusions are available for scrutiny and criticism, whereas this alleged calculation is not. No further comment is needed.

   Regarding the comparison between a 707 and 767, this author accepts that hypothetical impacts of these two different aircraft could be materially similar in

result despite their differences in mass and maximum speed. This is supported in evidence by the qualitatively similar results from American 11 and United 175, which were nearly identical aircraft but impacted with a speed difference of approximately 100 miles per hour [16], leading to almost a 50% difference in kinetic energy. Dr. Griffin's attention to this point, while valid, is irrelevant.

2. Frank DeMartini's comment that "the building was **designed** to have a fully loaded 707 crash into it" [17] (emphasis added) is incorrect. While such an impact was considered by the designers, this consideration was not in response to an ordinary design requirement and aircraft impact did not appear in any ordinary building code, as explained in NCSTAR1-1 [18]. Any such requirement would be a special customer requirement, and without documentation describing this requirement, we cannot evaluate it with any clarity. Mr. DeMartini's comment is also unsupported by any calculation, and thus should be considered as speculative. Perhaps his belief was simply mistaken. We cannot seek clarification, because tragically, Mr. DeMartini was killed on September 11th.

3. Dr. Griffin refers to an interview that Leslie Robertson, Engineer of Record for the WTC Towers, conducted with the BBC. Dr. Griffin states that Mr. Robertson claims "they were designed to withstand the impact of a Boeing 707." This is misleading. Mr. Robertson's comments to the BBC, taken in context, include the following:

   > We had designed the project for the impact of the largest airplane of its time, the Boeing 707. The 767 that actually hit the WTC was quite another matter again. First of all it was a bit heavier than the 707, not very much heavier, but a bit heavier. But mostly it was flying a lot faster. And the energy that it put into the building is proportional to its square of the velocity, as you double the velocity, four times the energy. Triple the velocity, eight times the energy and so forth. [Sic; actually triple velocity means nine times the kinetic energy.]
   >
   > And then of course with the 707 to the best of my knowledge the fuel load was not considered in the design, and indeed I don't know how it could have been considered. But, and with the 767 the fuel load was enormous compared to that of the 707, it was a fully, fully fuelled airplane compared to the 707 which was a landing aircraft. Uh, just absolutely no comparison between the two. [19]

   As we can plainly see, Mr. Robertson does not support Dr. Griffin's assertions. He suggests that the WTC Towers *were* designed to handle a 707 impact, but that the actual requirement stipulated a much lower speed collision, with "absolutely no comparison" between the requirement and the actual events of September 11th. Mr. Robertson also indicates that a thorough analysis would have been impossible with the tools of the time. It also bears pointing out that his firm LERA was a contributor to the NIST Report, rather than disputing it, as Dr. Griffin suggests.

4. It is unclear to the author how the late John Skilling's comments are at variance with the actual events of September 11th – both towers were struck, but remained standing, and there were "horrendous" fires. To my knowledge, Mr. Skilling never claimed that the Towers would remain standing indefinitely, particularly given the fires and the impossibility of fighting them. Even if he had, there are no

calculations given in support, nor has anyone been able to replicate such a result. The burden of proof remains upon Dr. Griffin.

5. It is difficult to take this final point of Dr. Griffin's seriously, for two reasons. First, as we have seen above, three of the four supposedly contrary points of view appear to confirm NIST's conclusions rather than dispute them, and the remaining point of contention is so vague as to be unusable. Second, the NIST Report was a scientific study, and not in any way required to survey opinions and speculations prior to the fact. Unless supported by calculations, which NIST did indeed attempt to find [15], such opinions cannot be evaluated for accuracy, and thus are not relevant for purposes of the study.

This first section closes without Dr. Griffin having raised a single technical criticism, either of his own or produced by any other. Of his five criticisms, three are attempts to shift the burden of proof, one is a gross mischaracterization of a designer's opinions, and the last is simple well-poisoning. Since there is no technical criticism offered, the burden of proof remains upon Dr. Griffin to demonstrate that NIST's conclusions about the aircraft impact damage are in any way suspect.

Since Dr. Griffin has failed to introduce any actual criticism, the author is in no way obligated to support the NIST conclusions, but support is easy to provide. For example, Dr. Frank Greening has produced a useful whitepaper [20] that, among its other relevant conclusions, estimates the pre-impact kinetic energy of the aircraft and the energy needed to completely destroy all supports of a single floor of a WTC Tower. Dr. Greening finds that the aircraft energy (for the slower North Tower impact) is approximately five times greater than the columns of a single floor could withstand, had the collision been directed solely at the columns. Of course, the destructive process was not 100% efficient for several reasons: Some energy would be transmitted to the rest of the tower; some was needed to destroy the aircraft; more than one floor was struck; a large amount of debris passed completely through the structure; and other building contents including floor systems, furniture, exterior cladding, utilities, and interior walls further absorbed and dispersed the impact. Nonetheless, even if 95% of the impact energy is accounted for in this fashion, leaving only 5% directed at the columns, we still estimate that the impact could destroy one quarter of the columns over an entire floor, which is comparable to the NIST findings. Admittedly this is a rough calculation, but it serves as a useful "idiot check" to verify that the NIST conclusions are plausible. Other related, independent calculations exist in published literature, notably the paper by Drs. Bazant and Zhou [21]. These findings support the NIST results, and further refute the claims of Dr. Griffin.

How Did Impact Damage Help Induce Collapse?

This second, much longer section shifts in focus as it progresses, inhibiting concise summarization of the argument. Rather than summarize Dr. Griffin's position, we will consider the various foci in order of appearance.

Dr. Griffin begins the section by asking the following: "How could the WTC towers have collapsed without a controlled demolition since no steel-frame, high-rise buildings have ever before or since completely collapsed due to fires?" [22] He then paraphrases the NIST Report, noting that (as NIST correctly states) there are no previous incidents of structures suffering a comparable aircraft impact followed by fires. While Dr. Griffin agrees with this sentiment, he observes that this alone is not sufficient to explain how the collapses took place.

While there may be no examples of *high-rise office* buildings *completely* collapsing due to fire, it bears pointing out that there have been many steel-frame structure collapses due solely to fires. The McCormick Place exhibition hall is one such example, which collapsed in 1967 only 30 minutes after a small fire was accidentally started [23]. Another prominent example is the Mumbai High North Oil Platform [24], constructed of steel and seven stories high, which completely collapsed after burning for two hours following a shipping accident that ruptured oil lines. A third example, occurring after Dr. Griffin's manuscript was finalized, is the collapse of the Interstate 580 overpass in the MacArthur Maze [25] near San Francisco. This overpass, supported only by steel beams, suffered no impact but collapsed due to the heat of an 8,600 gallon gasoline fire, burning in the open below, after nineteen minutes.

Because of incidents like these, the risk of collapse due to fire is well understood by the construction industry. Richard Schulte in the International Code Council editorial column *Fire Protection* made the argument, prior to the NIST investigation, that the fires in the World Trade Center were vastly beyond any reasonable design criterion:

> Does the fact that both of the World Trade Center towers collapsed on the morning of September 11 validate the concept of "balanced" fire protection and does the World Trade Center towers collapse indicate that additional fire protection should be required in 100 story high rise buildings? The answer to both of these questions might be affirmative if the fires in the World Trade Center towers were typical fires which occur in high rise buildings, but the fires in the World Trade Center towers were anything but typical. The key question which must be answered in this debate is not whether the high rise building provisions contained in our model building codes are adequate, but what are our expectations regarding the structural stability of high rise buildings? It appears that the witnesses before the Congressional Committee have assumed that there is a consensus that buildings should remain stable, regardless of the magnitude of damage done to the building by terrorists (or the cost to construct such buildings). [26]

While Mr. Schulte's remarks about "expectations" were directed at the architectural community, Congress, and the American public, one could make a similar charge at Dr. Griffin. He has, thus far, given no scientific reason why the WTC Towers should not have collapsed; he has merely observed that the collapse was rare. This comes as no surprise, since the damage inflicted upon them was also rare, and large skyscraper fires in general are extremely unusual. Under ordinary circumstances, we expect skyscraper fires to be handled differently from fires in other structures (such as oil platforms) because skyscrapers are occupied, leading to rapid detection of fires and an inherently safer working environment; and because skyscraper fires are usually fought, constraining the fires and protecting the structure. The WTC fires could not be fought due to their sheer

size and the damage to infrastructure (such as standpipes and elevators) caused by the aircraft impact. In every way the event was unusual.

Dr. Griffin is correct to observe that the mere abnormality of conditions does not, by itself, explain why the buildings collapsed:

> For us to believe that the destruction of the towers was in fact caused by this combination, NIST would need to convince us that the damage to each building was so massive and the fire in each one so big and hot that this combination could do something that was previously thought impossible. [22]

As we have seen above, Dr. Griffin speaks only for himself when he claims the collapses were "thought impossible." The balance of the NIST Report, however, does explain why they collapsed, and does not merely rely on the argument that the situation was unusual. Dr. Griffin's request is handily met by the NIST Report, as we shall see in later sections.

Dr. Griffin next turns to the impact, and acknowledges the NIST Report estimates of exterior and core columns damaged, destroyed, and stripped of fire insulation by the impacts. He then notes that approximately 85% of the columns were not destroyed, and suggests that this does not qualify as "massive" damage. Finally, he provides us with an astonishing statistic, citing the *Engineering News Record* from 1964, claiming that the Towers were designed to withstand incredible damage:

> [T]hese reports said that "live loads on these [perimeter] columns can be increased more than 2000% before failure occurs" and that "one could cut away all of the first-story columns on one side of the building, and partway from the corners of the perpendicular sides, and the building could still withstand design live loads and a 100-mph wind force from any direction." [27]

To begin, it should be obvious that the *impact damage alone* was not in itself enough to destroy the Towers. Neither Tower fell until after it had burned, and their condition gradually and visibly degraded as the fires raged. Nobody is claiming that severing 15% of the columns was, by itself, decisive. Of greater significance among the statistics that Dr. Griffin cites is that the fireproofing was stripped from an estimated 80% of the core columns in WTC 2, and 90% in WTC 1. This damage does not affect the structure at time of impact, but is of profound importance when the subsequent fire is considered.

Let us now consider the comments Dr. Griffin cites in the *Engineering News Record* [28], taken from an interview with John Skilling, chief architect of the Towers. Is it true that the columns were overdesigned by 2000%? The answer, of course, is no. The perimeter columns are sized to resist the wind load, not just the live load. As explained in the exact same article:

> The structural engineers adopted this particular design because of the great length of the columns, use of different grades of steel and their plan to take wind stresses in the exterior columns only.
>
> Walls resist wind. In designing the record-height towers against wind, Worthington, Skilling, Helle and Jackson adopted a scheme that does not rely on the core at all to take wind. Each tower will act as a vertical, cantilevered hollow tube. The giant Vierendeel trusses forming the loadbearing exterior walls will provide the required rigidity and strength to resist wind. All the

> horizontal shear will be resisted by the sides of the building parallel to the wind, and most of the overturning moment will be taken by the exterior walls normal to the wind. For economy in resisting the stresses, the wall columns will be made of high-strength steels, as indicated in the diagram above. [28]

The wind load is potentially a great deal higher than the live load. In the NIST Report, the design requirements combining the different loads are quantified in NCSTAR1-1 [29], summarized briefly on page 54:

> In the 1960's, ultimate strength design was standardized only for reinforced concrete. As shown in Table 4-5, the three codes from the 1960's referenced ACI 318-63, which includes the following load combinations to establish the design loads (U) for structural members:
>
> 1. For structures where wind and earthquake loads may be neglected, U = 1.5 D + 1.8 L.
> 2. For structures where wind load must be included, U = 1.25 (D + L) or U = 0.9 D + 1.1 W, whichever produces the most unfavorable condition for the member.

It should be clear by now that there was no requirement for the columns to withstand 2000% of *all* loads. The effect of the wind is relatively large, and can be visualized using the NIST baseline model, described in NCSTAR1-2A in figures 5-6 and 5-14. These figures demonstrate how parts of the perimeter columns facing the wind can actually wind up in tension, as the wind load can totally overwhelm the gravity loads. This clearly demonstrates how wind, not gravity, is the dominant load in the exterior columns.

Hence, the live loads are only a minor contributor to the design load on the perimeter columns. As an analogy, a car with four seats might easily withstand the load of eight people, but it is highly unlikely that it could withstand the weight of an entire second car without damage to its suspension. Furthermore, while the columns themselves might withstand 2000% of the live load – provided all other loads were below their design limits – other structures in the Towers would not. As an example, NCSTAR1-1, section 5.2, describes destructive testing requirements of structural elements:

> In regard to strength requirements, the member or assembly must be capable of supporting the following (note: no specific reference to a particular type of building material is given in this section of the Code):
>
> 1. Without visible damage (other than hairline cracks) its own weight plus a test load equal to 150 percent of the design live load plus 150 percent of any dead load that will be added at the site, and
> 2. Without collapse its own weight plus a test load equal to 50 percent of its own weight plus 250 percent of the design live load plus 250 percent of any dead load that will be added at the site.

This test more adequately captures the true design requirements, but even this is particularly conservative, only applying "if such computations as prescribed in these standards cannot be executed due to 'practical difficulties.'" Thus, the 2000% figure presented by Dr. Griffin is out of context, and irrelevant.

Regarding "cutting away" the columns, it is important to note that Skilling speaks of cutting the exterior columns *at the first story*. This is because, below Floor 7, the Towers

had only a third of the exterior columns, with each column at ground level branching into three columns above Floor 7. Spacing exterior columns in this fashion was required to avoid interference with building entrances. The design compensated with a great deal of core bracing below Floor 7, as explained in NCSTAR1-1 on pages 9-10:

> Since the lateral loads are resisted mainly by the exterior walls in a framed tube system, the interior core columns do not contribute to the over-all lateral stiffness of the building. For the WTC towers, both the exterior columns and the core columns were designed to support an approximately equal amount of the total gravity loads (see NIST NCSTAR1-2). … The columns in the interior core of the towers were designed to carry mainly the gravity (vertical) loads, except in the atrium area (below floor 7 to the foundation), where there were fewer perimeter columns in the outer walls; bracings were used in the outer perimeter of the core area to increase lateral stiffness. In the lower part of the towers, the outer core columns were designed to resist a portion of the lateral forces.

Thus, while it is counterintuitive, the first floor is in fact the *best* place to cut exterior columns, if building survival is desired. At the first floor, the core can be counted on to resist lateral wind loads thanks to its bracing. Loss of exterior columns above Floor 7, where the core was not so heavily braced, would be substantially more hazardous.

In summary, Dr. Griffin's claims that the impact was relatively light, and that NIST incorrectly assessed the structures' remaining strength, are incorrect. The statements above are wholly consistent with NIST's findings. When read carefully, these statements contain subtle nuances that, if not properly accounted for, make them seem far more significant than they really are.

Dr. Griffin now discusses his impressions of the NIST impact simulation results, which are contained in NCSTAR1-2. He begins by quoting Eric Douglas, a contributor to the web-based publication *"Journal for 9/11 Studies"* (erroneously claiming to be peer-reviewed), stating that the results cannot be trusted simply because they were produced with computer simulations. He then focuses his attention on the South Tower, for which models predict 10 destroyed core columns, whereas the North Tower only suffered an estimated six core columns destroyed. He states this is impossible, given that the South Tower was hit lower where core columns were thicker; the South Tower was hit off-center, and one engine of Flight 175 never hit the core at all; and that the wings of the aircraft could not have destroyed any core columns. He finishes by calling attention to the fact that NIST ran a range of cases, predicting 10 columns destroyed at most and only 3 at least, and states that NIST selected the worst case because, and only because, it was the only case that would lead to a collapse.

To begin, there is nothing particularly sinister about using computer simulations. The NIST tools used for structural and impact modeling are SAP2000 and LS-DYNA [30], both commercial modeling tools with a long and successful history in practical applications. These tools use the same basic structural equations that exist in solid mechanics textbooks, generalized to handle far more variables than anyone could ever compute by hand. This allows much more detailed modeling of the structures under consideration, which in turn provides a more accurate result. While there is the potential to make mistakes in creating the models, NIST validated their baseline models against the

original design specifications, and verified that their model provided the correct wind response of the Towers, based on accelerometer data taken prior to the attacks. NIST also gradually built up their impact models to permit unit testing and independent verification and defect detection. Without stating *specific* criticisms of the models, Dr. Griffin's complaint is analogous to casting doubt upon an arithmetic result simply because it was computed on a hand calculator.

It is not surprising that WTC 2 suffered more core damage than WTC 1. Dr. Griffin and Mr. Douglas are correct that some of WTC 2's affected core columns were thicker at the point of impact than WTC 1's and that portions of Flight 175 passed beside the core, but they conspicuously neglect other factors that explain why the damage was more severe. To be specific:

- Flight 175 impacted at an estimated 542 MPH, as opposed to Flight 11's 443 MPH [31]. This means that Flight 175 impacted with approximately 50% more kinetic energy than Flight 11.
- Flight 11 struck the North Tower while pitched down at approximately 10 degrees. This means that most of the aircraft had to either pass through, dislodge, or deflect off a concrete floor slab before reaching the core columns.
- Flight 175, in contrast, struck the South Tower pitched down at an estimated 6 degrees, meaning more of the aircraft would pass straight through the office space and impact the core directly, without needing to first encounter a floor slab.

Taken in combination, it is hardly surprising that Flight 175 inflicted more core damage. NIST contrasts its estimates of the two impacts in much more quantitative detail in NCSTAR1-2A, and confirms that this impression is correct.

What about the right engine of Flight 175? It is true that this engine never contacted the core. However, the engine weighs approximately 9,000 pounds [32], or only about 4% of the weight of Flight 175 at time of impact. This means that no more than 4% of the total kinetic energy missed the core because of the engine's path. This correction is insignificant compared to the difference between Flight 175 and Flight 11's kinetic energies, and is also smaller than energy variation due to the uncertainty in Flight 175's speed. Furthermore, rather than passing harmlessly through the building, the right engine destroyed several perimeter columns, giving up an estimated 90% of its kinetic energy during the impact before exiting.

Dr. Griffin's examination of the wings individually is specious, for reasons that should be obvious. He states without proof that the wings alone could not sever any core columns – a point which was examined by NIST [33], and found to be true only if the wings were first shattered and their fuel contents dispersed by the perimeter columns. In Finding 13 of NCSTAR1-2, NIST writes a similar finding regarding the perimeter columns, demonstrating the difference between an empty wing section and a fuel-filled one:

> **Finding 13:** Impact of an empty wing segment from approximately mid-span of the wing normal to the exterior wall produced significant damage to the exterior columns but not complete failure.

> Impact of the same wing section, but filled with fuel, resulted in extensive damage to the external panels of the tower, including complete failure of the exterior columns.

Because the wings "could not destroy the core columns," Dr. Griffin supposes they had no effect at all, and dismisses them. He goes on to conclude that only a single core column should have been severed, that being the one hit by the port engine. This is clearly not the case. All of the parts of the aircraft, including the fuselage which he has completely neglected, *contribute* to damage inflicted on the core. His argument is akin to stating that because a single sheet of paper dropped on one's head will not hurt, it is impossible for a truckload of paper to inflict any damage. In point of fact, since from the above we know that fuel itself is responsible for much of the impact damage, it is perfectly reasonable to expect all the tiny fragments of airplane, broken up by the perimeter columns, to contribute to one massive aggregate impact, and this impact as we saw previously has enough energy to destroy *all* of the core columns. The only reason it doesn't is because the impact is not 100% efficient, and does not only impact the core.

We can demonstrate the actual impact effect by considering another building impact, namely that at the Pentagon. Study of the American 77 impact into the Pentagon confirms that the majority of damage to interior columns is not caused by large fragments, but rather by a blast phenomenon made up of the fast-moving, heterogeneous cloud of aircraft pieces, fuel, and parts of the building exterior. While the Pentagon was constructed quite differently from the WTC Towers, it was hit by a similar aircraft at a similar speed. More importantly, the Pentagon did not totally collapse, and unlike the WTC Towers, nearly all of the columns and floor slabs that were hit could be found and examined afterwards to determine how they failed. Thus we know what happened at the point of impact directly, rather than relying upon simulation. The NIST and ASCE conducted a similar investigation on the Pentagon [34], and had this to say about the nature of column failure, on page 29 of the Pentagon Building Performance Report:

> Several columns were substantially distorted, exhibiting lateral displacement at the column midheight equal to at least three times the diameter of the spiral cage. Some highly distorted columns were bent in uniform curvature with discrete hinges at each end (figure 5.20), while others were bent into triple curvature (figure 5.21). In these cases, the vertical column steel remained attached to the foundation below and the second-floor beams above (figure 5.22). The deformed shapes of the columns with this damage were smooth curves: generally they did not have discrete deformation cusps.

What this means is that damage was not caused by blunt impact with large fragments – this would lead to "discrete deformation cusps," or dents somewhere along the column, and columns with kinks rather than smooth curves along their height. Since we did not see this, the above proves that the combined force of small pieces and fuel was what destroyed the interior columns. We expect similar phenomena in the WTC Towers. Dr. Griffin, however, neglects this effect entirely and without justification.

Finally, we examine the variation in NIST's impact cases. For both WTC 1 and WTC 2, NIST ran three different impact cases – a baseline, a less severe case, and a more severe case. However, this was not done, as Dr. Griffin claims, to fudge the results. This is because the inputs to the model are imprecisely known. Tables 7-3 and 7-8 in

NCSTAR1-2 show the model inputs, including the speed and angle of the aircraft, and the material strength of the aircraft and the building interior. Aircraft data values are derived from analysis of videos, since both Flight Data Recorders were completely destroyed, and this method is subject to significant uncertainty. In like fashion, the building contents and aircraft materials all vary in composition, and there is some uncertainty in estimating an average factor for all of the materials. NIST ran three cases because it needed to see how sensitive its models were to the input conditions. It is important to note that at this stage of the investigation, *all of these inputs are completely reasonable* – the "more severe" case is effectively the one-sigma upper bound, while the "less severe" case is the one-sigma lower bound, meaning these inputs are all within the accuracy of measurements.

NIST did not, as Dr. Griffin states, select the "more severe" cases because those and only those led to collapse. This is totally false. Each simulation produced a number of outputs, some of which – like the damage to core columns – could not be estimated from photographs and videos of the event, but others could be compared to additional evidence directly. NIST describes its selection criteria in brief in NCSTAR1-2, page *lxxiii*:

> The less severe damage case did not meet two key observables: (1) no aircraft debris was calculated to exit the side opposite to impact and most of the debris was stopped prior to reaching that side, in contradiction to what was observed in photographs and videos of the impact event and (2) The subsequent structural response analyses of the damaged towers indicated that the towers would not have collapsed had the less severe damage results been used.

Dr. Griffin is fixating on the second criterion, but completely ignores the first. He also ignores the more detailed selection criteria presented on pages 267-291 of NCSTAR1-2:

> The observable evidence available to help validate the global impact analyses included the following:
> - Damage to the building exterior documented by photographic evidence
> - Floor damage visible from the building exterior documented by photographic evidence
> - Aircraft debris external to the towers as documented by photographic evidence
> - Eyewitness accounts from survivors who were inside portions of the building.
>
> Another observable was that each tower remained standing after sustaining the impact-induced structural damage. Analyses of the structural response of the damaged towers immediately after impact, presented in NIST NCSTAR1-6, showed that this observable was met for both towers.

In short, Dr. Griffin's claim, that NIST selected the most severe case solely in order to guarantee a collapse, is wrong. The base case also would have led to a collapse. Furthermore, while we do not have photographic or eyewitness evidence of the state of the core columns for either impact, we have a litany of other evidence that was found to best match the "more severe" cases.

Additionally, it is not entirely clear that, even had the less severe impact conditions applied, the structures would have survived. NIST did a preliminary assessment that reached this conclusion, as remarked above, but a competing analysis by Dr. Usmani *et al.* at the University of Edinburgh [35], suggests that even if the impact damage was negligible, the fires would have destroyed the Towers:

> The results are illuminating and show that the structural system adopted for the Twin-Towers may have been unusually vulnerable to a major fire. The analysis results show a simple but unmistakable collapse mechanism that owes as much (or more) to the geometric thermal expansion effects as it does to the material effects of loss of strength and stiffness. The collapse mechanism discovered is a simple stability failure directly related to the effect of heating (fire). Additionally, the mechanism is not dependent upon failure of structural connections.

Because there is disagreement among experts about whether any impact damage at all was necessary for collapse to occur, Dr. Griffin's claim that NIST deliberately overestimated the impact damage in order to force collapse to occur is completely unsupportable. His commentary in this section is false with regard to the actual contents of the NIST Report, and grossly distorts its logical conclusions.

This section closes with Dr. Griffin disputing NIST's estimate of insulation removal by the aircraft impact. He suggests that even if all insulation was removed over six floors, there is still no reason to suspect collapse of the structure. He also disputes the methodology of NIST's estimate, claiming that the impact was not sufficiently energetic to dislodge the fireproofing.

Dr. Griffin's first complaint can only be described as bizarre. He makes the following statement in his book:

> NIST claims that [stripping of insulation] occurred on six floors of the South Tower. Even if that could be believed, it would mean that the insulation would have remained intact on 104 of the building's 110 floors. NIST's own simulations indicated that "none of the columns with intact insulation reached temperatures over 300C," which means that "the temperature… would not have increased to the point where they would have experienced significant loss of strength." This consideration does not bode well for NIST's theory that column failure, due to softening of stripped core columns by the fires, led to the total collapse of the buildings. [36]

The author is at a loss to understand how intact insulation on the other 104 floors is relevant to the fire on the six impact floors, or how the temperature of columns with intact fireproofing relates to that of stripped core columns. This argument seems akin to stating that a man wearing a bulletproof vest could shoot himself in the head without fear of injury.

The only possible line of argument the author can detect is that, perhaps, Dr. Griffin accepts that the stripped insulation would lead to a *partial* collapse – that of the six impact floors, no longer insulated and vulnerable to fire – but that the rest of the structure should have survived a *total* collapse, as it was not weakened by the fire. As we will explore later, this is incorrect. The remainder of the structure had nowhere near enough strength to survive once the upper floors started to move, whether fully intact or not. Nowhere does NIST claim that the lower structure had to have been weakened by fire for a total collapse to occur. This may not be what Dr. Griffin has in mind, although he states a similar line of reasoning further along in the chapter. In any event, the author can determine no other possible relevance to his comparison. Fireproofing away from the fire is of no value.

Dr. Griffin's complaints about how NIST treated the spray-on fire insulation are often repeated. He echoes the remarks of a colleague in the following statement:

> However, former Underwriters Laboratories executive Kevin Ryan, being curious about this method, discovered that NIST's "test for fireproofing loss, never inserted into the draft reports, involved shooting a total of fifteen rounds from a shotgun at non-representative samples in a plywood box Flat steel plates were used instead of column samples." [36]

While it is correct to say the NIST tests "involved" a shotgun-based apparatus, there are numerous other tests that Ryan and Dr. Griffin fail to mention. While the "shotgun approach" did not appear in the draft report as it was not yet complete, a full description of the approach appears in the final report as Appendix C of NCSTAR1-6A, on page 263, and is in no way hidden from view. In the preliminary report, these tests were not completed, and the preliminary results were based on the industry standard "pull-off" tests, along with mathematical arguments from acceleration. The shotgun test appears to have been brought in to provide additional testing *in response to criticism* that the industry standard tests were a poor fit to the aircraft debris impact. In other words, what Dr. Griffin and Ryan are criticizing is, in fact, NIST going above and beyond to provide additional, innovative, and more realistic testing.

NIST describes the impact test methodology as follows:

> The SFRM on the steel plates and bars was subjected to a field of impacting projectiles fired from a universal receiver (a modified gun) at various orientations. For the high-speed low-mass impact, a debris field was simulated by buckshot fired from a modified shotgun. Since firing of conventional shotgun shells would result in average buckshot speed in excess of 682 mph (304 m/s), controlled firing with custom-made shot shells was needed to reduce the impact speed within the range found for the debris field in the aircraft impact analyses of the WTC towers (NIST NCSTAR1-2). … An average speed of 341 mph (152 m/s) was chosen for the debris impact velocity for the high-speed low-mass impact tests. For low-speed high-mass impact tests, an average speed of the projectiles ranging between 112 mph (50 m/s) and 201 mph (90 m/s) was selected.
>
> The desired impact speed was achieved but the universal receiver could only accommodate small projectiles, which did not represent actual debris shapes and sizes. Therefore, *the impact kinetic energies from the projectiles were significantly lower than those from actual impacting debris in the WTC towers due to differences in size (mass).* However, when the impact kinetic energies were normalized by the impact area, the impact conditions used in the tests approximated those in the towers, based on the following order-of-magnitude analysis. … For the purpose of this study, it was assumed that the energy of the debris impacting the SFRM was distributed through a debris area that was about five floors high (60 ft or 18 m) and 150 ft (45 m) wide. [37] (Emphasis in original)

In other words, this testing is not as haphazard as Dr. Griffin suggests, but is instead calibrated carefully to represent realistic, reduced velocities. Additionally, as seen in Figure C-2, there were additional tests involving a large, air-pressure operated universal receiver with a 3-inch barrel, firing projectiles that were themselves representative objects, rather than using hunting loads in every test. Furthermore, Ryan errs in stating the impacted objects were "non-representative," in that bars were also tested, sized and coated to be accurate representations of the floor truss materials. The flat steel plates are

meant to represent floor decking material rather than column sides – columns were not the subject of this test, because the columns were fireproofed with gypsum board, and this test only applies to the SFRM (sprayed-on fire resistant material).

Continuing on the same page of Dr. Griffin's book, Ryan and Dr. Griffin err further in presenting an energy argument:

> there was, as Ryan points out, "simply no energy available to cause fireproofing loss. … NIST's tests indicate that 1 MJ of energy was needed per square meter of surface area to shear the fireproofing off. For the areas in question …, the extra energy needed would be several times more than the entire amount of kinetic energy available to begin with."

This is a mystification of the NIST summary of findings presented on page 273 of NCSTAR1-6A. Here NIST reports that SFRM would be completely dislodged "by direct impact with solid objects that had a kinetic energy … approaching 10^4 to 10^5 ft-lb / ft^2 (10^5 to 10^6 J / m^2)." Mr. Ryan has disingenuously used the upper end of that scale, incorporating the full extra factor of 10. However, this is irrelevant, because Ryan also makes the assumption that the SFRM *absorbs* all of this energy. The NIST summary does not suggest that this energy was absorbed. Instead, it says that projectiles require a certain kinetic energy to transfer the needed shock to break the SFRM loose – but afterwards, those projectiles would retain most of their energy, either ricocheting or smashing the formerly fireproofed building contents out of the way. The SFRM absorbs only a tiny fraction of this energy, leaving the rest to break loose other SFRM or damage the building structure. This is clearly seen in NIST's results, such as Figure C-4, where the shotgun pellets passed through the SFRM, retaining enough energy to destroy the pellets themselves, while the SFRM – untouched except for a dozen small holes – falls off in a single piece. It is obvious that the only energy absorbed by the SFRM itself was in resistance to the pellets (minimal; SFRM is hardly bulletproof) and damping oscillation of the steel plate as it vibrated after being struck, prior to shaking the SFRM loose. Both contributions are extremely low, and the vast majority of the SFRM that falls away is undamaged. Therefore, the energy is not absorbed, and thus Ryan's claim that the total energy of impact is too low to dislodge the SFRM is completely wrong.

Now that we understand NIST's results, we can address whether or not NIST's estimate for how much insulation was dislodged or destroyed is reasonable. NIST argued that the insulation could be considered stripped as follows [38]:

- All SFRM and gypsum board insulation considered stripped or dislodged in regions where impact simulation indicated a debris field that could damage or destroy adjacent furniture and wall partitions
- All gypsum board insulation considered stripped away from structural members where impact simulation predicted the structural member in question had suffered heavy damage

The results of the "shotgun test" above make it clear that the debris field had sufficient energy to dislodge all SFRM, on plates and bars, within the field. And while the gypsum board is stronger than the SFRM, it is far weaker than the steel columns and beams

underneath, so much so as to be negligible in terms of strengthening those members. It is therefore clear that a gross deformation to the underlying structural steel would require if not induce damage to the fireproofing.

Dr. Griffin's argument regarding fireproofing is, therefore, unsupportable. The errors he and his quoted sources make regarding the energy requirements are deceptive and easily refuted.

How Did the Fires Help Induce Collapse?

In the lede to this section, Dr. Griffin makes the argument that, since steel conducts heat, the fire would have to be exceptionally large, hot, and long-lasting, enough to heat a considerable fraction of the entire structure:

> Steel is an excellent conductor of heat. If heat is applied to one portion of a steel beam, that portion will not be quickly heated up to the temperature of the flame, because the heat will quickly be diffused throughout the beam. Also, if that beam is connected to another one, the heat will be dispersed to that second beam. And if those two beams are interconnected with hundreds of other beams, the heat will be diffused throughout the entire network of beams. [39]

Steel is actually not a particularly good conductor of heat [40]. Mild carbon steels, such as the A36 alloy that dominated the Towers' load-bearing structure, conduct roughly 50 Watts per meter-degree Kelvin [41], or about an eighth that of copper, which is a good heat conductor. Furthermore, the specific heat of steel is about a third higher than copper, meaning the steel not only transmits less heat, but it takes more heat to reach any given temperature. Combined, this makes copper about twelve times as susceptible to sympathetic heating as mild steel. As an unrelated point of interest, most alloys of steel, such as 304 Stainless, are even worse conductors – stainless steel transmits a third as much heat as mild steel or about $1/25^{th}$ as much as copper.

Besides steel being at best a mediocre heat conductor, there is also the matter of great distances for this heat to be conducted. Suppose we consider a fire on six floors of the WTC towers, and we make the argument that the nearest six floors must also be heated, effectively cutting the fire's efficiency in half. This means the heat flows through up to three floors' worth of steel, or about eighteen meters, in both directions. The further we go from the source, the less heat is conducted, and eighteen meters is a considerable distance. At eighteen meters, we expect $1/18^{th}$ as much heat flow through any given column compared to the heat flow one meter away from the fire. To transmit to the entire structure, we are dealing with over 300 meters of steel – this means a rise in temperature of 1,000 degrees Celsius at the impact point, if we were to let the structure reach thermal equilibrium, results in less than 4 degrees Celsius increase at ground level, and given the physical properties of structural steel it would take roughly a week of continuous burning at the impact floors for this to happen. Clearly we should not expect the entire structure to be heated significantly, but that is exactly what Dr. Griffin claims.

In contrast, any blacksmith will readily confirm that steel can be partly heated to a working temperature, while keeping the remainder cool enough to handle, using perfectly

ordinary fires. This is particularly true of slender objects like sword blades, horseshoes, and structural columns, because the slender profile of such objects presents a narrow conduction path, restricting heat flow. A similar effect can be recreated in the home, where cast-iron cooking pots can be heated to broiling temperature, yet still held without gloves via cast-iron handles only 20 or 30 cm long. To summarize, steel is not such a good conductor after all, and heat does not conduct quickly in any material when the distance is large compared to the cross-section.

Were The Fires Hot Enough?

Here we have another long section with numerous independent claims. Again we will treat them in order of appearance.

Origin of "Melted Steel" Claims: Dr. Griffin begins by acknowledging that NIST never claimed, nor does it need to claim, that the steel structure actually melted. He claims that this misconception was created by early reports and speculative analysis of the Tower collapses, and not by members of the Truth Movement.

As this observation is not germane to the NIST Report itself and is merely a finger-pointing recap of past discussions, it does not require further comment.

Physical Evidence of Heated Steel: Dr. Griffin next remarks that NIST leads the reader to believe that some of the steel reached 1000° Celsius, whereas NIST's own metallurgical analysis disputes this and indicates a much lower temperature:

> Although NIST does not quite say this is what happened, it clearly tries to lead the reader to believe that it is saying this. And insofar as this claim is implied, it is an empirically unsupported claim. NIST reports that its metallographic analysis of recovered steel found "no evidence that any of the samples had reached temperatures above 600° C [1,112° F]" – and this is a statement about recovered steel of every time, not simply steel from core columns. [42]

Dr. Griffin cites page 88 of the overview report NCSTAR1 for this observation. In actual fact, this quote is found on page 90. However, this quote is taken out of context. The NIST Report also makes it clear that hardly any of the steel samples recovered were from the impact floors. On page 87 and 88, NIST describes the steel samples as follows:

> Over a period of about 18 months, 236 pieces of steel were shipped to the NIST campus, starting about six months before NIST launched its Investigation. These samples ranged in size and complexity from a nearly complete three-column, three-floor perimeter assembly to bolts and small fragments. Figures 6-3 through 6-5 show some of the recovered steel pieces. Seven of the pieces were from WTC 5. The remaining 229 samples represented roughly 0.25 percent to 0.5 percent of the 200,000 tons of structural steel used in the construction of the two towers. …
>
> In all, 42 exterior panels were positively identified: 26 from WTC 1 and 16 from WTC 2. Twelve core columns were positively identified: eight from WTC 1 and four from WTC 2. Twenty-three pieces were identified as being parts of trusses, although it was not possible to identify their locations within the buildings.

> Overlaying the locations of the specimens with photographs of the building exteriors following the aircraft impact (for perimeter columns and spandrels) and the extent-of-damage estimates (Section 6.8) (for core columns) enabled the identification of steel pieces near the impact zones. These included five specimens of exterior panels from WTC 1 and two specimens of core columns from each of the towers.

In other words, of the 229 pieces of WTC 1 and 2 steel, only nine were column fragments from the impact zones, and of those, only four were in the interior. Since the exterior pieces understandably would have been cooler by convection with outside air and their placement at the edge of the fires, we are more interested in the core column fragments.

These are described in greater detail in NCSTAR1-3B, Chapter 4. In Figure 4-1, we see the original location of the two fragments from WTC 1, samples HH and C-80, originating as part of core column 605 from floor 99 (approximately three floors above aircraft impact) and core column 603 from floor 93 (two floors below the aircraft impact). Figure 4-2 shows the origin of samples recovered from WTC 2, samples C-88a and C-88b, both of which are fragments of core column 801, one sample being approximately one floor above impact, the other sample essentially at the point of impact. Sample HH is photographed in Figure 3-12 on page 42, and C-88a and C-88b are shown in Figure 3-13 on page 43. Sample C-80 is photographed in Figure A-8.

The metallurgical overview report NCSTAR1-3 goes into further detail about the passage quoted by Dr. Griffin. In Section 6.8.5, it explains that the microstructure analysis was only applied to the *perimeter sections*, and not the core. As we have explained above, it is entirely expected for many perimeter sections to have been cooler than core sections. Regarding the core, this is treated very briefly in Section 6.8.6, where it is explained that only those sections with paint remaining could be examined, and few areas had any paint to test. The paint test is a much simpler one, with temperatures above 250 ^{o}C producing a "mud cracking" pattern, and temperatures below showing no effect. Temperatures well in excess of 250 ^{o}C will simply destroy the paint entirely, preventing the test.

We can identify each column's original horizontal location using Figure 2-12 in NCSTAR1-1, or figures such as 6-49 and 6-62 in NCSTAR1-5. Here we see that Column 605, the relevant column in WTC 1, is one row back from the long edge of the core, roughly centered, facing the point of impact. Column 801, struck in WTC 2, is at the edge of the short face of the core, again centered. We neglect Column 603 in WTC 1 since it was below the impact and exposed to relatively light fire.

Understanding where these samples came from, it is now quite unremarkable to find no evidence of extreme fire temperatures in the samples. Figures 6-43 and 6-44 of NCSTAR1-5 show the predicted structural temperatures of Floor 99 in WTC 1, the location of recovered sample HH, for Fire Case A and B respectively. We see that not a single one of the columns is predicted to reach elevated temperatures on this floor. The core cross-members below, on the other hand, do reach elevated temperatures by virtue of the fire on lower floors and the extent of predicted damage to their fireproofing, whereas there is no fireproofing damage predicted on Floor 99. Thus the NIST result is

completely consistent with minor heating on Column 605 at Floor 99, and does not require the column to be heated in its collapse model.

Similarly, Figures 6-50 through 6-55 show the predicted structural temperatures for Floors 79 through 81 of WTC 2, fire cases C and D. The fire is concentrated in the corner opposite Column 801, and the fire model, again, predicts only slight heating in this column. Here, unlike the recovered samples from WTC 1, we do predict fireproofing damage on our recovered samples, which is obvious since the column itself was fractured by impact. Instead, we see here that the impact pushed combustible materials towards the other side of the structure, and left a gaping hole exposing our column to fresh air, and thus it is entirely expected for it to have remained relatively cool. Interestingly, immediately above Floor 81 where the floor structure is intact, Column 801 begins to show heating as in Figure 6-57, Case D, where Column 801 eventually reaches temperatures of over 600 degrees Celsius, but Column 801 is expected to remain cool in the impact zone, and in the lesser impact damage Case C on all floors.

In summary, Dr. Griffin's observation, while correct on its own, is misleading and does not support his conclusion. The analysis of recovered steel showing that no recovered fragment reached a greatly elevated temperature is entirely expected, once we understand where the fragments came from and what they experienced. Furthermore, we also expect steel that *was* heated to have been weakened considerably, and thus would not be expected to survive the collapse intact or with any identifiable marking remaining. It is therefore unsurprising that no such samples were recovered. A search through debris will naturally be biased towards intact pieces, and these pieces by definition were exposed to less damage and less heat.

Temperature of the Fires: Dr. Griffin next uses the presence of black smoke as an argument that the fire was oxygen starved, and therefore at temperatures well below 1000 degrees Celsius. He further cites James Hoffman as stating that temperatures of 800 to 1100 ^{o}C can occur in building fires, but only for brief, unsustainable periods known as "flashovers." He then remarks at length that, since "ordinary" fires are generally in the 650 ^{o}C range, NIST must prove that the WTC fires were extraordinary.

In reality, the presence of black smoke is neither a sign of oxygen starvation nor of a cool-burning fire. To reuse just two obvious examples from above, oil wells burning in the open atmosphere are about as well-ventilated as possible, yet leave choking plumes of dark, black smoke, and routinely heat steel structures enough for them to deform and collapse. The gasoline tanker fire under the 580 Freeway near San Francisco sent up a plume of black smoke as well. This assertion is overly simplistic. Smoke coloration is dependent on the combustion products, and the actual fire temperature may vary considerably from its center to its edge. Even if smoke color could be used to estimate the *average* fire temperature, it would be impossible to estimate the *maximum* fire temperature from a gross evaluation of smoke color.

Hoffman's assertion regarding maximum fire temperatures is contradicted by professional fire scientists. As one example, a reference office fire test [43] conducted in

the United Kingdom, as part of the Cardington experiments in 1998, demonstrated that "cellulosic," or largely wood- and paper-based fires, can easily send atmospheric temperatures 10 cm below roof decking above 1000 ^{o}C and sustain this temperature for several minutes, and remain over 800 ^{o}C for over half an hour. This same test showed temperatures 1.8 m below the decking to rise as high as 1200 ^{o}C, and remain above 1000 ^{o}C for ten minutes. Modern offices, containing more plastics, are seen to reach even higher temperatures of up to 1300 ^{o}C, after which they approximate the cellulosic curve. They do not only attain these temperatures during a "flashover." NIST itself gathered similar results by conducting its own full-scale fire test, found in NCSTAR1-5E, in which a series of cubicle offices were built in a faithful recreation of a WTC floor, and set alight with carefully measured quantities of jet fuel. The results from this experiment, seen in Figures 6-6 through 6-12 of this report, show temperatures peaking well above 1000 ^{o}C for substantial periods of time, consistent with the Cardington results and completely refuting Hoffman's claims.

The WTC case is also an unusually large fire, moving slowly from one side of the building to another, and can thus sustain local areas of extremely high temperatures for much longer than a simple office fire can. What NIST predicts in the WTC fires is relatively modest compared to these observed limits, as described in NCSTAR1-5F, Section 6.6.2:

> The simulations and the visual evidence suggested that the duration of temperatures in the neighborhood of 1,000 ^{o}C at any given location on any given floor was about 15 min to 20 min. The rest of the time, temperatures were predicted to have been in the range of 400 ^{o}C to 800 ^{o}C on floors with active fires.

In other words, the NIST model predicts and is dependent upon fires that are completely within the realm of expected behavior, remarkable for their size but typical with respect to temperature.

Dr. Griffin appears to backpedal from his remarks about smoke color, and cites Hoffman as stating that the presence of flames, not absence of black smoke, indicates a hot fire:

> [NIST] says merely that nearly all large indoor fires produce black smoke, and that is correct. But some large indoor fires have, as Hoffman points out, "produced bright emergent orange flames," because they were not oxygen starved and were, accordingly, hotter. [44]

Unfortunately for Dr. Griffin's argument, orange flames are evident all over the WTC fires. Examples include Figures 8-9 through 8-11 of NCSTAR1-5A, where orange flames can be seen emerging from windows, some with tongues rising for several floors outside the structure. NIST goes even further in Figure 8-7, where an infrared image is presented – while this is uncalibrated with respect to temperature, it demonstrates that underneath the concealing smoke, a much larger portion is burning hotly than is apparent from the flames themselves.

Finally, Dr. Griffin's observation about the "ordinary" character of the WTC fires is baffling. WTC 1 and 2 were at the time, in terms of involved floor area, the largest single-structure office fires in history. The author is confident that this fact alone

qualifies the fires as extraordinary, even before including the additional factors caused by the aircraft impacts. These records have only been broken once – they were eclipsed later that same day by WTC 7.

Broken Windows: Dr. Griffin closes this section by claiming that there is evidence for a cooler fire, such as the lack of broken windows, and complaining that NIST did not examine the remainder of structural steel, the only way to prove the true temperatures of the fire.

Let me tackle the question of broken windows. As Dr. Griffin correctly implies, there are many other indicators of fire intensity, with window fracture from heat being among them. However, Dr. Griffin states the following:

> There are reasons to believe, moreover, that the fires were not even that hot. For example, in some other high-rise building fires, the fires were hot enough to break windows. Photographs and videos of the towers while they were burning, however, provide no evidence that their fires were breaking windows. [45]

This statement, referenced to Eric Hufschmid's *Painful Questions: An Analysis of the September 11th Attack*, is a lie. Photographs and videos clearly show window breakage, smoke issuance from windows, and fires emerging from broken windows, progressing steadily over time. This information was used by NIST as a major input to its fire simulation, as the window condition greatly influenced ventilation on the fire floors. NIST details its findings on the windows in NCSTAR1-5A, in Chapter 5, with results tabulated in Appendices C-J. The NIST Report describes literally hundreds of windows being broken by the fire, which supports its observations about the fire temperature.

Window condition is not the only quantity tracked. The NIST Report also specifies whether fire was seen behind windows, emerging from windows, or obscured by smoke, as a function of time. The appearance of fire at any given window is of greater value than many appreciate. Fire progression requires fuel and a source of ignition (which may be assumed to be omnipresent in this case), but also a minimum temperature to sustain combustion. As a result, tracking the front edge of the fire as it moved from window to window gives a fairly accurate time history of different locations reaching that sustaining temperature, which is dependent in turn on the fire distribution and its heat output. This is an extremely useful verification of the fire simulations, and thus further supports NIST's temperature estimates.

We have already addressed the question of recovered steel. Hardly any of the steel from the impact zones or hottest areas of fire could be expected to survive the collapse in such good shape as to permit positive identification of the pieces. There is also the problem of disambiguating between the fire before collapse and the fire afterward. Regardless, Dr. Griffin is wrong in stating that recovery of steel is the only way to verify the fire temperature. As he himself attempts to argue, broken windows are another indicator, and there are several more besides, chief among them being progression of the fire over time. All of these factors are contained in the NIST Report, and they support NIST's conclusion.

Were the Fires Sufficiently Big and Long Lasting?

Next, Dr. Griffin challenges the idea that the fires could have been of sufficient size and duration to materially affect the structure. He begins by selecting comments from one firefighter and one survivor who didn't see a huge fire. He then comments that the burning time, roughly an hour for WTC 2 and 100 minutes for WTC 1, isn't enough time to heat the steel. He again argues that the steel would have conducted heat to other steel members, and claims that certification by the Underwriters Laboratories proves the steel should have survived up to 2000 degrees Fahrenheit for six hours, remaining on this point for some time. Finally, the section closes with comparison to the 1988 First Interstate Bank fire, the Philadelphia One Meridian Plaza fire, and the Caracas Parque Central fire, noting that none of these led to collapses.

Dr. Griffin leads with these two paraphrased observations:

> The evidence, however, counts against this claim [that the fires were unusually large], especially with regard to the South Tower, which collapsed only 56 minutes after it was struck. The point of impact was between floors 78 and 84, so the fire should have been largest in this region. And yet Brian Clark, a survivor, said that when he got down to the 80th floor, "You could see through the wall and the cracks and see flames . . . just licking up, not a roaring inferno, just quiet flames licking up and smoke sort of eking through the wall." A similar account was given by a fire chief who, having reached the 78th floor, reported finding only "two isolated pockets of fire." [46]

It should be obvious that an individual inside the building would be at a disadvantage to appreciate the full size of the fire, compared to one watching from outside, observing its progress across multiple faces and multiple floors. Even without this observation, both accounts selected by Dr. Griffin are completely consistent with the NIST conclusions.

Brian Clark was one of only 18 lucky survivors from the upper portion of WTC 2 who managed to find Stairway A passable and descend. The impact destroyed two of the three stairways, but only damaged the third, which was farthest from the path of Flight 175, as shown in Figure 7-1 on page 99 of NCSTAR1-7. He passed through the 80th floor along this stairway. Video and photographic evidence, as described in NCSTAR1-5A Chapter 9, shows the fires being concentrated along the south and east walls, opposite the core from Stairway A, with the northwest side of the building relatively unburnt. In particular, the west face showed no smoke at all until 9:10 AM, seven minutes after impact, and that smoke appears to have been smoke moving through the building rather than evidence of fire itself. It is, therefore, not at all surprising for Mr. Clark to have seen relatively few flames. The flames would have been ten meters away or more, behind rubble and still partially intact interior walls, from his vantage point. Had the 80th floor been fully involved at that time, it is unlikely that he could have survived.

The fire chief that Dr. Griffin is referring to is Chief Orio Palmer of 7 Battalion FDNY, who reached the 78th floor, and called for "two hand lines" to handle "isolated pockets of fire" [47] shortly before he was killed in the collapse. This is quite a bit more than it seems – two hand lines support on the order of 600 gallons per minute of water, enough to empty the 500 gallon tank of an FDNY engine in 50 seconds, indicating an estimable

amount of fire. Furthermore, it is important to recall that Floor 78 was a skylobby floor, and thus contained far less combustible material than the other floors. Far from contradicting NIST, his comments compare well to NIST's results, as explained in NCSTAR1-5F, Section 6.4.1, page 88:

> There was only light fire activity observed on the 78th floor (Fig. 6-26), and this behavior is reflected in the numerical simulation. The impact analysis (NIST NCSTAR1-2) predicted that a small amount of jet fuel was released on this floor. Given the modest number of window openings and the estimated light core damage, the numerical simulation of the fire (Fig. 6-27) did not predict any areas of significantly high temperature.

Figure 6-27, accompanying this description, indeed shows exactly two areas of relatively small fires – one near the point of impact in the southeast corner, and a larger one corresponding to the denser area of combustible furniture in the northeast corner. Thus, NIST's results are totally consistent with Chief Palmer's comments.

Aside from these two accounts, Dr. Griffin offers no rebuttal in this section to the size of the fires. Regarding the duration of the fires, Dr. Griffin concentrates on WTC 2, which collapsed sooner. He writes:

> The reader is supposed to infer, accordingly, that steel in the South Tower from which the fireproofing had been stripped could have reached the temperature of 1,000 ^{o}C (1,832 ^{o}C [sic, should be 1,832 ^{o}F]) within 56 minutes. That inference would be absurd, even if the fires had been as big and hot as NIST suggests, because of the enormous amount of interconnected steel in the South Tower: some 90,000 tons. It would have taken a very long time for even some of that steel to have been heated up to the temperature of the fire itself, even if the fire was directly connected with 25 percent of the steel. It is absurd to suggest that this could have occurred in 56 minutes. [46]

We have already addressed the heat conduction issue – there is no reason to suppose that the heated volume of steel was large. For sake of argument, double the volume of steel contained in the impact floors themselves would total less than 3,000 tons. As for the time itself, NCSTAR1-6B shows calibrated tests of subscale and full-scale steel WTC floor truss structures exposed to fires, and even with the fireproofing material intact, the steel temperature reaches plateaus of over 800 ^{o}C (1500 ^{o}F) after approximately 80 minutes, as seen in Figures 6-4 and 6-5. Without fireproofing in place, the time to reach these temperatures would be considerably shorter.

The NIST investigation also provides much more thorough quantification. For example, Table 3-1 and Table 3-2 of NCSTAR1-5G list the time for the core columns (made up of far heavier steel than the floor trusses) to reach a given temperature as a function of the fire-heated gas temperature and the insulation thickness. For unprotected steel, the temperature to reach 700 ^{o}C in the presence of 1100 ^{o}C gas, stripped of insulation, is under six minutes for light box-shaped core columns and under 15 minutes for heavy box-shaped core columns. This result is intended to demonstrate the importance of fireproofing damage in the study, but also serves to refute Dr. Griffin's claims that the fires were too brief to have any significant effect on the steel structure.

The overall fire simulation results are perhaps best seen in Figures 12-1, 12-2, 12-4, and 12-5 of NCSTAR1-5G, which show the relative column temperatures and resultant remaining strength for the four fire cases tested (two per tower). Few of the core columns are actually predicted to exceed 400 degrees Celsius. Just as the NIST Report does not require exceptionally hot fires, the NIST hypothesis does not require massive volumes of steel heated to extremely high temperatures. The heating that is required for structural collapse is much smaller than Dr. Griffin believes, and therefore his argument that the fires were too small, too cold, or too brief are simply incorrect.

Following this section, Dr. Griffin echoes an oft-repeated claim originating from Kevin Ryan, formerly of Underwriters Laboratories. A lengthy retelling of Ryan's legal troubles with UL is outside the scope of this paper, having nothing to do with the NIST Report proper, and will be left to Appendix A. We will, however, examine the claim itself, stated by Dr. Griffin as follows:

> Since . . . the temperature of jet fuel fires does not exceed 1,800° Fahrenheit and Underwriters Laboratories (UL) certified the steel in the WTC towers to 2,000° Fahrenheit for six hours, how could fires have impacted the steel enough to bring down the WTC towers?
>
> To rebut the premise of this question, NIST wrote: "UL did not certify any steel as suggested. . . . That the steel was 'certified . . . to 2000° Fahrenheit for six hours' is simply not true."
>
> NIST's statement is technically correct but again deceptive. It is technically correct because Underwriters Laboratories, as Kevin Ryan has pointed out, certified the steel to 2,000°F (1,093°C) only for the times stipulated by the New York City code at the time, "which required fire resistance times of 3 hours for building columns, and 2 hours for floors." [48]

The full quote by NIST regarding the UL certification, contained in the NIST FAQ [49], is as follows:

> UL did not certify any steel as suggested. In fact, in U.S. practice, steel is *not* certified at all; rather structural *assemblies* are tested for their fire resistance *rating* in accordance with a standard procedure such as ASTM E 119 (see NCSTAR 1-6B). That the steel was "certified ... to 2000 degrees Fahrenheit for six hours" is simply not true.

Had Dr. Griffin read NCSTAR1-6B, he would have understood NIST's statement. NCSTAR1-6B describes an ASTM E 119 test of the floor assemblies, carried out by Underwriters Laboratories as part of the investigation. From the abstract on page *iii*:

> However, NIST found no evidence that fire resistance tests of the WTC floor system were ever conducted. As a result, NIST conducted a series of four standard fire resistance tests (ASTM E 119). In this series of tests, the effects of three factors were studied: (1) thickness of sprayed fire-resistive material (SFRM), (2) test restraint conditions, and (3) scale of the test. The tests were conducted by Underwriters Laboratories Inc. under a NIST contract and represented both full-scale (35 ft span) and reduced-scale (17 ft span) floor assemblies constructed to represent the original design as closely as practical. … The restrained full-scale floor system obtained a fire resistance rating of 1 ½ h, while the unrestrained floor system achieved a 2 h rating. For the unrestrained test condition, specimens protected with ¾ in. thick sprayed fire resistive material were able to sustain the maximum design load for approximately 2 h without collapsing; in the unrestrained test, the load was maintained without collapsing for 3½ h.

The test conducted here is precisely the test that would have been conducted (except perhaps larger in scale), possibly by UL, prior to the Towers' construction. It demonstrates several points that conflict with Dr. Griffin's statements:

- The fire rating only applies to the *complete structural system*, which includes, in particular, undamaged fireproofing material. Therefore, after an aircraft impact which damaged the fireproofing, the rating is no longer valid.
- The fire rating is only an approximate measure of the actual time an assembly can be expected to withstand a fire – each rating level has its own specific test requirements, which may or may not be representative of any individual fire.
- Fire rating is not, as Dr. Griffin claims, to any particular temperature. The "2000 ^{o}F" temperature he cites refers to the *maximum furnace temperature*, not the temperature observed in the steel itself. As an example, Figure 6-1 shows the furnace temperature measurement against the ASTM E 119 standard, which only reaches 2000 ^{o}F at the end of the test, over 200 minutes after test start.

While other assemblies in the Towers would have had different constructions and different rating requirements, the overall conditions of any test would be similar. In particular, the temperature is an approximate maximum furnace temperature and has no direct relationship with the temperature reached by the steel, and the rating achieved is invalid if fireproofing is dislodged. This demonstrates that the answer given in the NIST FAQ is entirely correct, and Dr. Griffin's claim that it is "misleading" is nonsense.

Because Dr. Griffin apparently believes the temperature is in fact the realized temperature of the steel, it is possible that he also believes the rating stands for how long the steel would survive if *held* to that temperature. In case this is his misconception, let me simply state that the strength of steel is a function of its temperature only, and not of the duration at which that temperature is maintained. Steel does not "cook" like a loaf of bread, nor does it separate into its constituent metals (until it gets much closer to its melting temperature). At or below 2000 ^{o}F its strength is a function of its temperature alone, and once that temperature is reached, it does not strengthen or weaken if kept at that temperature. The only time-relevant effect is a phenomenon called "creep," which applies if the steel is loaded while it is heated, and is discussed starting in Chapter 4.2 of NCSTAR1-6D. As the name implies, creep refers to a very slow stretching or flowing of structural materials under load, ordinarily taking years or more to be noticeable, but accelerating when materials are heated. Creep describes how a material behaves in between being plastic and truly elastic, and is an important feature of the NIST collapse model. However, creep is only significant with respect to the entire structure as-built, and the ASTM fire tests would not have captured the full effect. If Dr. Griffin thinks the ASTM test was designed to heat the steel itself to a high temperature, and then hold it there for several hours, he is greatly confused.

Dr. Griffin apparently believes that, since NIST did not find evidence of fire rating, NIST is implying the structural systems would have failed these tests, and that is why NIST believes the fires destroyed the Towers:

> As this history shows, NIST's claim that the steel in the Twin Towers had not been certified is more than misleading; it is a lie. It is, of course, a lie that is essential to NIST's position, according to which steel columns in the South Tower failed after being exposed to fire for 56 minutes. Even if there had been enormous fires burning at 1,832°F (1,000°C), as NIST suggests, these fires would not have caused the steel columns to lose most of their strength within 56 minutes, given the fact that the steel was certified to withstand even hotter fires (2000°F; 1093°C) for at least three times that long. [50]

This, too, is nonsense. Nowhere does the NIST Report claim that the steel failed because it was uncertified. NIST did its own testing and evaluation, and found that while records of testing were incomplete, the structure would have likely passed the tests, possibly excepting the floor assemblies which were tested to a slightly lower rating than in the original requirements. Instead, once again, NIST's hypothesis requires *removal of fireproofing material*, which would greatly reduce the fire resistance of the structure, regardless of its pre-impact rating.

In the final act of this section, Dr. Griffin argues that collapse was unexpected on the basis of analogy, drawing parallels to past high-rise fires. By now it should come as no surprise that he leaves out important details of each case study. He begins with the First Interstate Bank fire in Los Angeles in 1988:

> In 1988, a fire in the First Interstate Bank Building in Los Angeles raged for 3.5 hours and gutted five of this building's 62 floors, but there was no significant structural damage. [50]

There are several important differences that contributed to this fire's less catastrophic outcome. First, there was no loss of fire resistive material, as there was in the WTC Towers. Second, there was much less ventilation for the fire, unlike the WTC cases where the impacts left huge holes and numerous broken windows at the outset. Third, the fire was fought by the Los Angeles Fire Department, thanks to its start on a relatively low floor and the availability of working elevators. Fourth, the fire (like most ordinary fires) is thought to have started at a single location, rather than being initiated across several floors at once like the WTC cases, and thus took time to develop and grow. These differences are outlined in the University of Manchester's case studies, including the following:

> The fire was finally put out by fire brigade at 02:19. The estimated fire spreading rate was 45 minutes per floor and burned intensely for approximately 90 minutes on each level. Two floors were heavily involved in fire at any point during the fire.
>
> It was found that smoke and heat traveled vertically above the 12th floor through the floor openings, lift shafts and even the pressurised stairwell. A minor fire occurred in a storeroom on the 27th floor, ignited by fire products escaping from an HVAC shaft that originated on the 12th floor. This fire self-extinguished due to oxygen deficiency.
>
> The total burnout of four and a half floors did not cause damage to the main structural members due to a good application of sp[r]ayed fire protection on all steelwork. There was only minor damage to one secondary beam and a small number of floor decks.
>
> In fact, minor fire spreads also occurred through the floor service openings for electricity and communications. This highlights the importance of applying effective fire stopping system to all floor and wall openings to ensure the effectiveness of fire compartmentation.

> It was also shown that if fire protection to structural members is adequately designed and applied with quality control, fire damage to fire exposed members will be minimised and structural collapse can be prevented. [51]

Thus, given the differences between this fire and the WTC fires, this case study in no way contradicts NIST's findings.

His next case study is the One Meridian Plaza fire:

> In 1991, a huge fire in Philadelphia's One Meridian Plaza lasted 18 hours and gutted eight of the building's 38 floors, but, said FEMA's report on the fire, although "[b]eams as girders sagged and twisted . . . under severe fire exposures . . . , the columns continued to support their loads without obvious damage." [50]

The One Meridian Plaza fire's long duration is a factor of the unrelenting response of the Philadelphia Fire Department, who fought the fire in person for 11 hours, then continued to train master streams on the fire from other, nearby high-rises (and to pressurize the building's incomplete sprinkler system through standpipes) after the decision was made to evacuate. As a result, the fire progressed much more slowly, and would not have developed as high temperatures as it would if it had not been fought. Indeed, while the fire eventually spread to the 30th floor where it was extinguished, it took seven hours to climb the final four floors – a rate of nearly two hours per floor, much slower than in the First Interstate Bank case.

Also like the First Interstate Bank fire, the fire protection was fully intact, and considered state-of-the-art. The result here would no doubt have been different had the fireproofing been damaged, as it was in the WTC. While the structure did not collapse, there was every indication that it might. From the incident report:

> All interior firefighting efforts were halted after almost 11 hours of uninterrupted fire in the building. Consultation with a structural engineer and structural damage observed by units operating in the building led to the belief that there was a possibility of a pancake structural collapse of the fire damaged floors. Bearing this risk in mind along with the loss of three personnel and the lack of progress against the fire despite having secured adequate water pressure and flow for interior fire streams, an order was given to evacuate the building at 0700 on February 24. At the time of the evacuation, the fire appeared to be under control on the 22nd though 24th floors. It continued to burn on floors 25 and 26 and was spreading upward. [52]

The structure was so heavily damaged by the fire that for years afterward, owner and insurer disputed [53] whether it was possible to repair the structure or whether it must be demolished. It was finally demolished (dismantled) in 1999 [54]. The fact that the One Meridian Plaza building suffered such extreme damage from fire alone would seem to support the NIST hypothesis, rather than the other way around.

Finally, Dr. Griffin turns to the Parque Central fire in Caracas, Venezuela:

> In Caracas in 2004, a fire in a 50-story building raged for 17 hours, completely gutting the building's top 20 floors, and yet the building did not collapse. Unlike the fires in the WTC towers, moreover, the fires in these buildings were hot enough to break windows. [50]

The author has already corrected Dr. Griffin's errant claim that the WTC fires did not break windows. Regarding the Parque Central fire, like the other case studies above, the fire broke out in only a single location, took place in a structure with intact fireproofing, was not as ventilated as the WTC fires were due to aircraft impact, and was fought continuously – in this case, including water drops from above by helicopter, though firefighting was hampered considerably by nonfunctional sprinklers and standpipes. Additionally, the fact that the building did not collapse can be attributed to its construction, which is primarily reinforced concrete rather than steel. From the *National Fire Protection Association Journal*:

> The reinforced concrete structure consists of perimeter columns connected by post-tensioned concrete "macroslabs" that are each 10 feet (3 meters) deep and above the second–floor mezzanine, the 14th, 26th, 38th, and 49th floors. There's no central core.
>
> Individual floors between the macroslabs have a steel-deck floor supported by steel beams, all protected underneath with spray-on Cafco Blaze Shield DC/F mineral glass fiber wool with cement fireproofing. According to Cafco's Manny Herrera, the floor was designed to meet U.S. standards for a two-hour fire resistance rating. However, the overall fire compartmentalization of each floor slab was decreased by the addition of several unrated floor panels to provide access to mechanical and plumbing systems.
>
> Five structural bays rest on four lines of columns in each direction supporting the steel deck. In effect, the concrete structure includes five stacked steel buildings, each supported by a macroslab. During the fire, two steel decks partially collapsed; other than that, there was no collapse inside the building. However, deflection in some steel beams was severe. [55]

The relative fire resistance of concrete as opposed to steel is well understood. In fact, since the September 11th attacks, several new skyscrapers have opted to use a concrete core or a core of steel encased in concrete. This includes the new 7 World Trade Center and the AOL Time Warner Building in Manhattan [56], and the Comcast Center in Philadelphia [57]. Accordingly, it is unsurprising that the Parque Central tower's concrete "macroslab" structure did not collapse, while the steel decking between concrete elements did partially collapse. This situation is similar to the frequently cited Madrid Windsor fire [58] – here, too, the steel structural components failed, while the concrete structure remained standing.

The very last case study cited by Dr. Griffin is, amazingly, the same Cardington experiments carried out in the United Kingdom that we cited earlier, which demonstrate that expected fire temperatures are higher than Dr. Griffin claims. While he is clearly aware of these experiments, his observations are limited to two features:

> FEMA, having reviewed these experiments, said: "Despite the temperature of the steel beams reaching 800-900°C (1,500-1700°F) in three of the tests. . . , no collapse was observed in any of the six experiments." The temperatures here, it should be stressed, are not merely air temperatures. They are the temperatures actually recorded in the steel, and they approach the temperatures that, according to NIST's speculations, were reached by some core columns in the towers. [50]

This analysis completely misses one important feature of the tests – the Cardington test structure did not have any insulation on the beams or their connections, which were fully exposed to the fire, but it did have insulation on the columns [59]. Therefore, the beam temperature was quite a bit higher than the column temperature. This is borne out in the raw data from the tests. While beam temperatures soared above 800 degrees Celsius, the highest measured temperature at any point in any column was only 333 ^{o}C in the Office Fire demonstration. This fact also further repudiates Dr. Griffin's earlier assumption that the interconnected steel would conduct heat well between attached members – in this test it clearly does not, since adjacent steel members are seen to have temperature differences of over 500 ^{o}C.

Because the columns were protected and reached modest temperatures, it is not surprising that the Cardington test structure did not collapse. Additionally, while it did not collapse, it was heavily damaged [59], and there is little question that, had the columns also been unprotected and deformed by the fire, the structure would have collapsed. Photographs of the test clearly show the deeply bowed beams supported by undeformed columns, a situation quite different from the WTC Towers.

Dr. Griffin further has an answer to the difference in intact fireproofing – one that exposes the source of his confusion:

> These comparisons bring out the absurdity of NIST's claim that the towers collapsed because the planes knocked the fireproofing off the steel columns. Fireproofing provides protection for only a few hours, so the steel columns in the buildings in Philadelphia and Caracas would have been directly exposed to raging fires for over 10 hours, and yet they did not buckle. [50]

While the *total* duration of fires such as One Meridian Plaza and Parque Central may have been ten hours or more, no *single floor* experienced fires approaching this duration. Unless there is an external source of fuel, office fires generally do not persist beyond 90 to 120 minutes in any single location. Both fires Dr. Griffin refers to moved upwards floor by floor, giving a total duration of many hours, but no individual element of structure was ever exposed to more than a small fraction of the total fire duration. This is why ratings of approximately 2-3 hours are adequate for most fires, and why the loss of fireproofing was so significant in the WTC cases.

To summarize Dr. Griffin's selected case studies, all three skyscraper fires are significantly different from the World Trade Center situations. While burning longer and on a comparable number of floors, all three occurred in structures that had intact walls and intact fireproofing, limiting ventilation and heating of structural elements. All three were battled by fire brigades. All three fires moved more slowly upwards, indicating effective firefighting efforts and lower availability of oxygen. Of the three, one was comparatively minor; one structure was evacuated out of fear of collapse; and the third experienced a partial collapse of its steel components, only escaping total collapse due to its concrete construction. It is therefore impossible to claim, on the basis of these three case studies, that the WTC Towers should not have collapsed. Similarly, the Cardington fire tests were partially fireproofed, with columns never approaching the temperatures

seen in the World Trade Center, and thus performed in a manner totally consistent with our expectations.

Even if the differences between the WTC Towers and other cases were not so significant, these cases would still not disprove the NIST conclusions. Fire and structural response is to a large degree a random process. Two fires in identical houses need not have identical outcomes. If we were somehow able to repeat the WTC fires, there is no guarantee that the fires would have progressed in the same way, or that the buildings would have collapsed at the same time. These differences would be amplified further if there were significant differences in the nature of the fire and the underlying construction, as there is between the WTC cases and the examples above.

What is important to learn from these case studies is not what *did* happen, but what *reasonably could* happen in a high-rise fire. As we have explored above, when we take the special concerns of the WTC fires into consideration, the phenomenology of the fires and the eventual collapse can be traced back to specific and exceptional characteristics of those fires. But there are few mysteries remaining. Even without complicating factors, a skyscraper fire can place the building's structural integrity into severe jeopardy. With complications, there should be no doubt at all that collapse due to fire is a distinct possibility, and recognizing this fact, structural engineers are already improving their designs in response to these lessons.

What Actually Caused the Towers to Collapse?

This section, the longest of the chapter, contains Dr. Griffin's interpretation of the progressive collapses experienced by both towers. Before treating his claims in turn, it is important to note that there is some disagreement of terminology – the NIST Report distinguishes between *collapse initiation* and *progressive collapse*. This is important because the phenomenology of the earliest stages of collapse is quite different from the larger collapse mechanism. Dr. Griffin appears to concentrate on the latter.

Dr. Griffin begins by claiming that NIST attempts to mislead readers into thinking that progressive collapse is a common event:

> By thus giving it a name (which it used 15 times), NIST implied that the collapses of the towers belonged to a general class. It thereby suggested this by saying that after the conditions for collapse initiation were reached, "collapse became inevitable."
>
> … Further explaining the importance of this point for a document that is supposed to be scientific, Hoffman says: "The fact that there is not a single example of total top-down progressive collapse outside of the alleged examples of the Twin Towers makes it entirely unscientific to presuppose that the alleged phenomenon was operative here." [60]

Nobody has suggested that progressive collapse is a common event, particularly since skyscraper collapses of any kind are unusual. And while it is difficult to find an example of "*total* top-down progressive collapse," there are historical examples of progressive collapses, and the mechanism has long been understood by structural engineers. The

most famous example is perhaps the 1968 Ronan Point accident, which, triggered by a simple cooking gas explosion on the 18th floor, led to a cascade of damage shearing off nearly the entire corner of the structure:

> The collapse was initiated by a gas-stove leak on the eighteenth floor in apartment ninety. The resident struck a match to light the stove to make a cup of tea, and was knocked unconscious by the resulting explosion. The force of the explosion knocked out the opposite corner walls of the apartment. These walls were the sole support for the walls directly above. This created a chain reaction in which floor nineteen collapsed, then floor twenty and so on, propagating upward. The four floors fell onto level eighteen, which initiated a second phase of progressive collapse. This sudden impact loading on floor eighteen caused it to give way, smashing floor seventeen and progressing until it reached the ground. [61]

The term "progressive collapse" appears in the *Engineering News Record* as early as 1970, and possibly earlier. NIST did not invent this term, nor are they proposing a wholly new and unjustifiable mechanism, as Dr. Griffin and Hoffman claim.

Dr. Griffin and his colleagues have been made aware of the Ronan Point incident and its significance, although it does not appear in this book chapter. Other members of the Truth Movement have attempted to explain away this case, including this example taken from Hoffman's site *9-11 Research*:

> Any comparisons of the Ronan Point incident to the collapses of the Murrah Federal Building and the World Trade Center skyscrapers are constrained by the fact that the section of the Ronan Point building that collapsed was not part of the support structure of the building. Rather, the collapsed balconies were short cantilever sections supported by the building's main structure. This contrasts with the collapse of a large structural section of the Murrah Building, and the total collapses of the World Trade Center s[k]yscrapers. [62]

While this is correct, this in no way obviates the value of the example. The Ronan Point case clearly demonstrates the potential for a "domino effect" where a local collapse that fails a single floor causes an overload on the floor below, which then adds mass and momentum, making failure of the second floor even more likely, and so on. The Ronan Point incident did not involve the core of the building and was thus confined to the structure's edge, but had the core been involved, a much larger if not total collapse would be quite expected.

Dr. Griffin's next topic confuses the issues of collapse initiation and collapse of the entire structure, and complains that NIST did not adequately explain why a partial collapse should lead to a total collapse:

> NIST's new document, perhaps in response to Hoffman's critique, acknowledges the fact that "[a] key critique of NIST's work lies in the complete lack of analysis supporting a 'progressive collapse' after the point of collapse initiation." The lack of any quantitative analysis, however, is not remedied in the NIST's new document. It simply makes vague statements like the following:
>
> *Based on [its] comprehensive investigation, NIST concluded that the WTC towers collapsed because [after the planes caused damage, the fires] significantly weakened the floors and columns with dislodged fireproofing to the point where floors sagged and pulled inward on the perimeter*

> *columns. This led to the inward bowing of the perimeter columns and failure . . . , initiating the collapse of each of the towers.* [60]

The first quoted passage above presumably comes from Hoffman. The cited passage from NIST has been italicized to distinguish it from Dr. Griffin's words. Editorial text above appears in Dr. Griffin's book, excepting only my note afterwards.

The author infers that Dr. Griffin is confused because, with reference to NIST's statement above, NIST is thoroughly quantitative. The amount of inward pull from sagging floors was computed as a function of time, based on the fire and structural simulations and observations of the perimeter columns. The strength of core and perimeter columns, with and without this inward pull, with and without impact damage, was computed. Several cases each of impact and fire were computed to give a bounding envelope of the expected behavior. For Dr. Griffin to claim that the above statement taken from NIST is "vague" and not supported by quantitative analysis suggests that he has not read the NIST Report. Additionally, in this excerpt, Dr. Griffin speaks of the *progressive collapse*, but he cites a NIST passage that was never intended to explain the progressive collapse. The NIST excerpt is only concerned with the collapse initiation.

It would be fair to say that the NIST Report does not consider the progressive collapse in detail, and particularly not with the thoroughness that it investigates collapse initiation. Reasons for this are manifold:

- NIST's mandate was to find out why the Towers collapsed, and how to prevent future occurrences, as outlined in the National Construction Safety Team Act, reprinted in the preface of every section of the NIST Report.
- The best way to prevent future collapses is to keep the collapse from starting in the first place. This fact should be obvious even without doing any structural calculations at all (but for examples of such calculations, see below). This is because when the structure is *moving*, we can never predict perfectly how it will move. When the structure is *static*, before it begins to collapse, we have a much better idea of what the conditions are, and we can design better as a result. The static problem is much simpler.
- Building a structure to handle a greater static load, or with greater static reserve capacity, is much easier than building a structure with similar reserve dynamic capacity. This is why dead loads and live loads are treated so differently in structural engineering.
- The NIST Report uses simulation only where it can be partially verified, either through evidence such as photographs and videos or through laboratory tests on subscale models or components. The progressive collapse phase, due to its speed and the shroud of opaque dust that fell with it, inhibits event reconstruction. Even the duration of the collapse is difficult to estimate, as demonstrated by Dr. Griffin's inaccurate claim of collapse time shortly following this discussion.
- Simulations of dynamic cases are inherently far more difficult than static cases. The NIST quasi-static models are already at the bleeding edge of technical capability. A dynamic simulation of the collapse, with similar precision and

reliability to the simulations contained in the NIST Report, would have been impossible in 2005 and are impossible today.

- Despite Dr. Griffin's complaints, there is no compelling scientific reason to model the full collapse in the first place. Even simple physical arguments will readily demonstrate that the time of collapse is reasonable. As for the inevitability of the collapse, published papers before the NIST investigation was concluded demonstrate that immediately after collapse initiation, the dynamic load presented to the remaining structure was many times that of the static load to which it was designed, and thus a total collapse was the expected outcome.

We will return to the last two items, namely mathematical evidence for the inevitability of the collapse and its expected high speed shortly, where Dr. Griffin argues using his incorrect estimate of the collapse duration.

Before we consider that point, Dr. Griffin takes two separate issues with the progressive collapse hypothesis, the first being as follows:

> In other words, as we saw earlier, when the planes impacted the buildings, they severed not only many of the perimeter columns but also some of the core columns and damaged still others. Given this destruction of several core columns and then the softening by fire of many others (from which the insulation had been stripped), these columns soon "buckled" under the weight of the floors above. Then when the weight of all those floors above the point of impact fell on the floors below, the collapse of the entire tower followed
>
> To call this theory problematic would be an understatement. One problem is simply the fact that NIST's "theory" is a bare assertion. There is no explanation of why the core columns would "buckle" or even what this might mean. [60]

It is statements like these that make Dr. Griffin difficult to take seriously. The NIST theory is *not* a bare assertion – even without doing a single calculation, the basics of the theory are directly observable from a careful examination of videos taken in the minutes leading up to collapse, and this is outlined in detail, with photographs included, in NCSTAR1-5A.

Also, "buckling" is well understood in the structural engineering community. NIST is not using it in an unusual sense, nor does it need to provide a definition. Even *Wikipedia* contains a concise definition [63]: *"In engineering, buckling is a failure mode characterized by a sudden failure of a structural member that is subjected to high compressive stresses where the actual compressive stresses at failure are smaller than the ultimate compressive stresses that the material is capable of withstanding. This mode of failure is also described as elastic instability."* Graphic descriptions included further illustrate the meaning of column buckling – rather than being squashed until they fractured, the columns began to deflect laterally, kinking somewhere in the middle – some exacerbated by inward pull from the heated floor trusses, others due to loss of floor connections or other bracing destroyed by the aircraft impact. A column that remains true can support much more weight than a column that is deflected sideways, which leads to a condition called eccentric loading. This factor, combined with the loss of many columns at impact and material weakening caused by the fire, is to blame for the

structural collapse. Dr. Griffin's complaint that this terminology is unclear merely exposes his lack of expertise and research.

His second complaint, from the same page of his book, is the following:

> A second problem is that, as we have seen, there is no evidence that the fires were anywhere near hot enough or big enough to weaken the steel columns, let alone soften them up so much that they would lose virtually all their strength. And yet if the columns buckled all the way down, NIST's theory would seem to entail that the columns of the South Tower were heated up to 1,832°F (1,000°C) all the way from the impact zone (about the 80th floor) to the ground in 56 minutes – a completely impossible theory. (NIST would probably deny that its theory entails this, yet without this assumption, how does NIST's theory even begin to account for the breaking or buckling of the massive core columns in the lower floors?) [60]

We have explored above why there is indeed evidence of both sufficient fire size and heat. As for the rest of Dr. Griffin's argument, this is simply a strawman. NIST never states that the core columns were heated all the way to the ground. Quite the opposite, in fact: Its own simulation results, as we have already seen in our discussion of the recovered fragments, predict hardly any heating of core columns beyond the impact zones, such as at the 78th and 84th floors of the South Tower. Dr. Griffin seems to realize that he has put forth a strawman argument by stating "NIST would probably deny that its theory entails this."

As for the question of breaking or buckling columns on the lower floors, the theory is quite simple, and requires no heating at all. After the initial collapse, the descending pile of material grows in both size and speed. The resulting load on lower floors, as they are hit one by one, exceeds their strength by a huge margin even if they are completely undamaged and unweakened. Columns are buckled by overload and by impact – quite unlike a static load, impact creates pressure waves in the steel members, and this leads to highly non-uniform stresses and local fractures.

In his criticism of the progressive collapse hypothesis, Dr. Griffin provides absolutely no calculations of his own, nor any support from anyone who has. He is therefore arguing from "common sense," also known as an argument to incredulity. Unlike Dr. Griffin, the author does have peer-reviewed calculations supporting his position, but before providing formal evidence of this, let me argue in kind with my own appeal to "common sense."

Consider two automobiles, identical except that one is out of fuel. The second automobile can be used to push the first with little difficulty. How fast can the first one be pushed? The dominant force on the pushing vehicle (assuming a flat road, brakes are not applied, and there is little rolling friction) will be the wind resistance felt by the first car, which increases with speed. However, the second car can push the first to quite high speeds without any fear of damage, even 100 km/h or more – so long as they remain in direct contact.

In contrast, if the two cars actually collide, both cars are likely to suffer some damage at contact speeds as low as 5 km/h. A collision at 100 km/h will probably destroy both cars completely. Even a relatively gentle impact will cause fenders and frame members to

"buckle," i.e. crumpling and bending with the shock of impact, rendering them much weaker than they were before even if they are not actually broken apart. This is because, unlike the pushing case, in a collision there is not just a static force applied – the *momentum* of both cars must also be equalized, in milliseconds. This leads to a huge, if brief, contact force, one that exceeds the strength of the cars' materials.

In the World Trade Center collapses, even if only a single floor's worth of columns gives way, this means the upper floors will hit the lower floors at about eight meters per second, or 29 km/h. Damage is guaranteed.

Another point to take away from this "common sense" argument, relevant later on, is that the damage suffered by the two cars may not be identical. They may be more susceptible to damage when hit in particular places, and damage patterns may be quite different if they do not hit perfectly square. The potential for asymmetry increases as speed increases, because the precise geometry of collision has a greater effect on the results.

This argument from "common sense" does not prove that the progressive collapse scenario is correct. It does, however, prove that Dr. Griffin's argument is insufficient. In order to answer this question definitively, we need to provide a thorough calculation explaining the effect in detail. To date, *there has not been a single published, peer-reviewed paper disputing the progressive collapse hypothesis* – not from any person in any department, in any field, in any country in the world. On the other hand, there have been several published results in support of the progressive collapse hypothesis. Perhaps the best known is from Drs. Bazant and Zhou, who concluded the following, regarding the situation after the first floor's collapse:

> To arrest the fall, the kinetic energy of the upper part, which is equal to the potential energy release, would have to be absorbed by the plastic hinge rotations, i.e., W_p would have to be larger than W_g. Rather,
>
> $$W_g / W_p = 8.4 \qquad (3)$$
>
> So, even under the most optimistic assumptions by far, the plastic deformation can dissipate only a small part of the kinetic energy acquired by the upper part of the building. [64]

And, regarding the second and successive floor collapses:

> When the next buckle with its group of plastic hinges forms, the upper part has already traveled many floors down and has acquired a much higher kinetic energy; the percentage of the kinetic energy dissipated plastically is then of the order of 1%. The percentage continues to decrease further as the upper part moves down. [64]

This is part of the reason why NIST did not consider the entire duration of the collapses. Early results from engineers and scientists indicated that, once the upper stories began to fall, the complete collapse of the structure was not in doubt, and there was no credible result to the contrary. There still are none.

Much like the Ronan Point collapse, Dr. Griffin and his colleagues are well aware of this paper, although neither they nor anyone else has put forth any proper challenge. While they are either incapable of or perhaps simply not interested in publishing a different viewpoint, Hoffman has an entire page devoted to this paper on his *9-11 Research* website. He disputes its findings as follows:

> Zdenek Bazant and Yong Zhou must be super-geniuses. They were able to understand how two skyscrapers could crush themselves to rubble, a newly observed behavior for steel structures, and write a paper about it in just two days. …
>
> There are two major fallacies in this assertion:
>
> - It implies that the columns were capable of supporting only twice the gravity loads they were bearing above the impact zone. This ignores the fact that the upper floors, lacking standing-room-only crowds, were not carrying their design live loads, and it implies that reserve strength ratios (the extra strength designed into a structure beyond what is required to resist anticipated loads) are two-to-one instead of the five-to-one typical in engineered steel structures.
> - It implies that a failure of the columns to support the gravity loads above the impact zones would automatically lead to total collapse, despite the absence of a single example of a local collapse event leading to total collapse in any steel-framed building. [65]

The first claim is wrong but also irrelevant – while the assumption used in Bazant & Zhou is a simplification, their final result demonstrates that the columns would have to have been designed to handle over *sixteen times* their actual load before collapse could have been arrested. Hoffman further provides no evidence of his five-to-one safety factor, even though it would be insufficient anyway. NCSTAR1-1 verifies in detail that the structure did not contain even a five-to-one reserve capacity.

The second claim is simply wrong. Far from assuming that the failure would lead to a total collapse, Drs. Bazant and Zhou provide the calculations demonstrating that it would, as summarized above. Hoffman's complaints are incorrect and simply do not refute Bazant & Zhou's hypothesis.

There are also a handful of disputing viewpoints produced by the Truth Movement appearing in other, similarly unscientific forums, such as the whitepaper produced by Gordon Ross [66] which Dr. Griffin cites beginning on page 168. Ross's whitepaper appears in the "*Journal of 9/11 Studies*" considered previously, which as we have mentioned before is not a peer-reviewed journal of any kind. Since Ross's whitepaper has not been peer-reviewed, it does not warrant a published response. There have, however, been several informal responses [67] [68] revealing the flaws in his reasoning:

- Ross does not consider buckling in his model, but instead assumes columns compress to failure, overestimating the energy needed to destroy each floor.
- Because Ross does not consider buckling, he assumes the complete lower structure of the building is able to absorb momentum like a giant spring, with dozens of lower floors compressing at the initial impact – video shows that if this effect took place at all, it is limited to only a few floors, and much less absorption.
- Ross assumes the concrete in each floor must be completely crumbled to dust before collapse can proceed, rather than allowing concrete to remain largely intact

and crumbling as part of its fall, or spalling as a result of fire. While Ross has backtracked from this position in revisions and other writings, he now merely notes that the pulverization energy sink is negligible compared to his enormous multiple-floor absorption assumption, rather than accepting that concrete destruction at this stage is totally unnecessary and should not be included at all.

- Ross assumes the upper and lower floors absorb energy equally on impact, which while possible, is highly optimistic.
- Ross does not take into account that the second floor to collapse would be within the impact and fire zone, and would be substantially weaker than an undamaged floor – even accepting all of Ross's other dubious assumptions, the collapse of two floors rather than one leads to a progressive collapse in Ross's own model.

Ross and Hoffman, in producing these two amateur and wildly inaccurate claims regarding the likelihood of progressive collapse, illustrate the disparity between scientific arguments, such as that put forth by Bazant & Zhou, and unreviewed opinions, which are typical of those coming from the Truth Movement. If claims such as those made by Ross were mathematically correct, it would be a simple matter to repackage them for publication in any of dozens of journals dedicated to architecture, structural engineering, physics, or solid mechanics. If there was a concern about publication in the United States, there are plenty of suitable journals in the United Kingdom (where Ross resides), Canada, France, Italy, Russia, India, or elsewhere. Nonetheless, it has been over five years since Bazant & Zhou appeared in the *Journal of Engineering Mechanics,* and there has been no alternate viewpoint published anywhere.

Let us return now to Dr. Griffin's book. He offers a third reason to doubt the collapse, namely the speed at which it occurred:

> But perhaps the most incredible part of NIST's theory is its attempt to deal with one of the stubborn facts that simply could not be ignored: the fact that the towers came down at virtually free-fall speed.
>
> … Even if we suppose, as we did in the case of the South Tower earlier, that each floor would have taken half a second to collapse, that would mean the collapse of the 90 floors below the North Tower's impact zone would have taken 45 seconds. And yet the North Tower came down in about 11 seconds. So the pancake theory could not be true.
>
> NIST's progressive collapse theory faces essentially the same problem, as NIST acknowledges in stating one of its frequently asked questions: "How could the WTC towers collapse in only 11 seconds (WTC 1) and 9 seconds (WTC 2) – speeds that approximate that of a ball dropped from similar height in a vacuum?" [69]

There are numerous errors in this argument. For starters, NIST does not calculate an expected duration of collapse. It is, therefore, impossible to dispute NIST's computed time. The only argument that Dr. Griffin can make is that the *observed* time of collapse is too short to fit the NIST model. However, Dr. Griffin offers no calculation, and besides that, he gets the observed time of collapse wrong.

The quoted time of collapse of 11 and 9 seconds respectively is taken from NIST FAQ, where NIST clarifies the meaning of these two measurements:

> NIST estimated the elapsed times for the first exterior panels to strike the ground after the collapse initiated in each of the towers to be approximately 11 seconds for WTC 1 and approximately 9 seconds for WTC 2. [11]

In other words, these times do not represent the complete collapse time – they only represent the time between the first large pieces of structure tearing free, and when those large pieces hit the ground. Since these pieces were, in fact, in "free fall," it should be no surprise that the timing reflects a "virtually free fall" speed, the only difference being the fraction of a second between collapse initiation and ejection of those fragments.

The actual time of collapse can be estimated from any of the videos of the event, which all demonstrate that the collapse time is in excess of 15 seconds. It is difficult to estimate precisely due to the large volume of smoke and dust obscuring the event, and the difficulty in observing the base of the structures from a safe vantage point. Similarly, seismic records demonstrate that the collapses took at least 15 seconds. The NIST FAQ explains this, and also clarifies the collapse time NIST really believes:

> The seismic spikes for the collapse of the WTC Towers are the result of debris from the collapsing towers impacting the ground. The spikes began approximately 10 seconds after the times for the start of each building's collapse and continued for approximately 15 seconds.
>
> From video evidence, significant portions of the cores of both buildings (roughly 60 stories of WTC 1 and 40 stories of WTC 2) are known to have stood 15 to 25 seconds after collapse initiation before they, too, began to collapse. Neither the duration of the seismic records nor video evidence (due to obstruction of view caused by debris clouds) are reliable indicators of the total time it took for each building to collapse completely. [11]

The fact that the cores (well below the impact zones) remained standing longer than the rest of the structure makes any estimate of collapse time open to some interpretation. If we include the time the cores remained standing, our estimates will be as high as 40 seconds. If we do not, and consider the time it took for the roof of each structure to hit the ground, we will arrive at an estimate of 15 to 20 seconds. Disappointingly, Dr. Griffin deliberately confuses NIST's statements to make the collapse seem shorter than it really was, just so he can advance his "free-fall" argument, even though anyone can detect this error by reviewing a video of the event.

While the actual timing (not counting the core remnants) is longer than Dr. Griffin claims, it still falls well short of his estimated 45 seconds, or one half-second per floor. It should be obvious that this claim is not grounded in any physical reasoning. Since the collapse is driven by gravity, we may expect the falling upper section to accelerate with time, moving faster and faster as it descends, rather than maintaining a constant rate of 0.5 seconds per floor. This expectation is borne out by video of both collapses. Dr. Griffin has not explained why he thinks each collapse would progress at a constant rate – which would imply a perfect balance between gravity and resistive forces, even though the mass above is increasing over time, meaning the gravity force is not constant – and he has not justified his choice of 0.5 seconds per floor. This claim is rejected out of hand.

It is not clear to the author why an accelerating collapse is problematic only for the "pancake theory" (in which floors tear free, falling on other floors, tearing them free as a result) or NIST's progressive collapse theory (in which floor remain attached, pulling columns until they buckle to failure, the falling mass then hitting lower floors and buckling them, pulling the next floor's worth of columns inward, until the falling mass is moving so fast that it no longer makes any difference), and not to *any* theory, including Dr. Griffin's. Even if, as Dr. Griffin fervently believes, explosives triggered the collapse, we would expect the collapse to accelerate as it progressed. The author is unaware of any mechanism at all that would result in a constant rate of collapse. Dr. Griffin must be suggesting that explosives were used to destroy *every single floor*, and not just to trigger the initial collapse – an enormous amount of explosives, and carefully sequenced.

Dr. Griffin briefly complains about NIST's wording where it says, in the NIST FAQ, that "(the structure below) was unable to stop or even slow the falling mass." He states:

> Instead of reading this as a statement about the strength of the lower structure prior to 9/11, we could read it as merely stating that once the building started to collapse, the structure below had no strength to stop or even slow the material falling down from above. And this was obviously true – because, one might suppose, explosives had been used to destroy its strength.
>
> But the task of NIST, of course, was to convince readers that the towers came down at virtually free-fall speed even though explosives were not used. It must, therefore, count on readers to take its statement as saying that although the lower structure was still fully intact when the upper floors fell on it, this lower structure was "unable to stop or even to slow the falling mass." And with this interpretation, NIST's account is, as Hoffman says, "absurd," because it "requires us to believe that the massive steel frames of the [lower structure of the] towers provided no more resistance to falling rubble than [would] air." [70]

It is true that the wording of the NIST FAQ is slightly inaccurate. It should be clear that the lower structure did indeed slow the collapse, slowing it by perhaps five to ten seconds compared to actual free-fall from a similar height, now that we have disabused Dr. Griffin of the mistaken impression that the collapses took only 9 and 11 seconds. However, that is all it is, a simple exaggeration.

Many in the Truth Movement have expanded on this point: While admitting the collapses took longer than an actual free-fall from that height, they still contend that 15 to 20 seconds is "virtually" free-fall speed, and thus unexpected. To my knowledge, none presenting such an assertion has provided a supporting computation, with the lone exception of Dr. Judy Wood [71], who proposes a number equal to or exceeding Dr. Griffin's 45 second estimate. However, her model assumes the descending mass *stops completely* every time it contacts a new floor, thus violating conservation of momentum, and is totally incorrect. In response, supporting the NIST hypothesis, a more accurate assessment has been recently presented by Drs. Bazant, Le, Greening, and Benson, submitted to the *Journal of Engineering Mechanics*, concluding that the seismology matches their computation of the "crush-down" phase (the collapse of the lower structure, but not including the collapse of the upper block or core remnants):

> Thus it transpires that the seismic records imply the crush-down phase to have lasted 12.59 ± 0.5 s for the North Tower, and 10.09 ± 0.5s for the South Tower.

> These durations match reasonably well the durations of the crush-down phase calculated from Eq. (2), which are 12.73 s and 10.53 s for the North and South towers if the resisting force F_b due to column buckling is calculated assuming that F_b is reduced by factor 0.75. If the full range of β is considered, $\beta \in [0.6, 0.9]$, the calculated mean durations are 12.74 s and 10.54 s, respectively. [72]

While this may be counter-intuitive, the difference between a 9-second collapse time and a 10.5-second collapse time is enormous, and represents a huge amount of energy expended to destroy the structure. The author offers a simple calculation confirming this in Appendix B.

Despite these results, Dr. Griffin continues to ridicule the idea:

> NIST … would have us believe that these upper 16 floors of the North Tower, having fallen only one story and hence having little velocity and hence momentum, would not have been stopped or even slowed down by hitting the lower part of the structure, with its more than 435,000 tons. This idea would surely be a candidate for the most absurd idea ever articulated in a supposedly scientific document. It is similar to suggesting that if a sports car going 30 miles per hour ran into the rear of a huge truck stopped at a traffic light, the car would simply continue at the same speed, pushing the truck ahead of it. [70]

Hyperbole aside, Dr. Griffin's analogy is incorrect. He neglects that, as the collapse progressed, gravity continued to add energy to the collapse with every new floor that failed. In order to use his analogy, we would have to add the condition that, with every $1/80^{th}$ of the truck's length (say every 15 cm), the combined mass of the sports car *and* however much of the truck it had crumpled so far were somehow given a kick of kinetic energy, enough to accelerate them from a stop to 30 kilometers per hour, adding to whatever kinetic energy and whatever speed it had achieved at that time. With this oversight corrected, the result he discounts no longer seems so far-fetched.

Dr. Griffin briefly entertains the notion of air resistance, which is irrelevant in this context given that he, again, has badly underestimated the actual time of collapse. Due to the large size (and hence volume-to-area ratio) and high density of construction materials, a simple calculation will show that the anticipated time of fall for a large wall fragment falling from an impact floor is expected to be lengthened by only a fraction of a second, much less than could be discerned through video analysis.

Next, Dr. Griffin expresses his confusion at the concept of momentum:

> [NIST] at least appeared to [account for the collapse times listed in the FAQ] by saying, after its statement that the lower structure was unable to slow the falling mass: "The downward momentum felt by each successive lower floor was even larger due to the increasing mass."
>
> Here again, it is not clear exactly what NIST means. To explain why the towers fell faster than a ball dropped from the top of the towers would have fallen, NIST would need to mean that the velocity of the falling matter increased as it progressed downward. But this would violate the law of the conservation of momentum, according to which each floor, with its inertial mass, would have decreased the velocity of the falling matter (assuming, for the sake of discussion, that NIST's theory is otherwise possible). [73]

In the progressive collapse hypothesis, the momentum of the descending mass increases because its mass increases *and* its velocity increases. Despite Dr. Griffin's claim above, this does not violate conservation of momentum. Whenever the falling mass encounters a new floor and fractures more of the structure, it does decelerate briefly as it accelerates the new floor to match its speed. However, it does not come to a halt. The first floor hit has less than a tenth of the mass of the descending material, and thus the new combination decelerates by under 10%, according to the law of Conservation of Momentum. Afterwards, the descending mass *gains* about 8.5 meters per second, and does so at every floor. Over time, the fraction of new mass being accelerated becomes smaller and smaller compared to the descending mass, but the velocity gain from gravity is constant per floor. As a result, the descending mass gains both mass and speed.

Dr. Griffin fails to grasp this point, as we see from his continued commentary:

> However, what NIST actually says is that the momentum increased because, according to its theory, each successive floor was added to the body of falling material, increasing its mass. And since momentum is the product of mass times velocity, the momentum would be increased even if the velocity decreased – if, at least, the increased mass in each case more than compensated for the decreased velocity.
>
> It is possible that NIST deliberately crafted this ambiguous wording so that the statement could be interpreted differently by different audiences. On the one hand, NIST could hope that the general public, not distinguishing between velocity and momentum, would think it explained why the towers fell faster than free-fall speed through the air. Or on the other hand, if NIST were to be challenged by fellow scientists (perhaps in a court case bringing charges against the NIST scientists for participating in the cover-up of a crime), it could point to the second interpretation, which is at least arguably defensible. [73]

Once again, the author is baffled by Dr. Griffin's assertions. The collapse time was in no way "faster than free-fall," making the rest of his complaint moot. There is no detectable ambiguous wording – as the collapse progressed, the momentum increased. There is no reason to confuse velocity and momentum, for they are different if related quantities. And if a scientist wished to challenge the NIST hypothesis, which is certainly permitted, it would be in the form of papers or conference proceedings where a competing theory was presented, backed by calculations or measurements, not in a court of law. There have been such alternate conclusions, such as the University of Edinburgh results mentioned previously [35], demonstrating the willingness of the scientific community to take issue with NIST's findings had they been erroneous. Yet there is not a single published example of a scientist claiming, as Dr. Griffin does, that the progressive collapse hypothesis is impossible – this is unthinkable if it was truly as obvious as he claims. We have no choice but to conclude that he is mistaken.

As this section at last draws to a close, Dr. Griffin invokes a new tack, calling NIST's theory into question on the basis of the large volume of dust created as the Towers collapsed. He first cites the words of Dr. Judy Wood, whom we have considered above, stating that the dust itself, since it is fine enough to float suspended in air, cannot contribute to the mass driving the collapse downwards. We accept that there were some losses of material, some falling over the side and some being ground into such fine

particles that it was expelled by the blasts of air which occurred with the collapse of each floor. However, Dr. Wood offers no reason to believe that the total mass lost in this fashion was significant. We know from surveys of recovered dust that the dust itself, such as Lioy *et al.* published in *Environmental Health Perspectives* [74], that the dust contained virtually no trace of structural steel, and was about evenly divided between fibrous and nonfibrous materials. Of the nonfibrous materials, concrete is present but wallboard is the dominant species. It is therefore clear that the vast majority of heavy building materials could not have been pulverized into dust, and thus there is no significant correction to the falling mass calculation due to dust creation.

Next, Dr. Griffin cites Dr. Steven Jones as support of his dust argument, as stating [75]: "… But then – and this I am still puzzling over – his block turned mostly to powder in mid-air! How can we understand this strange behavior, without explosives? …" The author finds Dr. Griffin's choice to cite Dr. Jones at this juncture curious, because in September 2006 he produced a whitepaper specifically for the purpose of refuting Dr. Wood's position, and included the following passage:

> As we examined the WTC-debris sample, we found large chunks of concrete (irregular in shape and size, one was approximately 5 cm X 3 cm X 3cm) as well as medium-sized pieces of wall-board (with the binding paper still attached). Thus, the pulverization was in fact NOT to fine dust, and it is a false premise to start with near-complete pulverization to fine powder (as might be expected from a mini-nuke or a "star-wars" beam destroying the Towers). Indeed, much of the mass of the MacKinlay sample was clearly in substantial pieces of concrete and wall-board rather than in fine-dust form. …
>
> It seems that the 9/11 truth community likewise "has been slow to understand" that the WTC dust particles in greatest abundance are the "supercoarse" variety rather than "fine" particles, and that significant chunks of concrete were also found in the WTC rubble. [76]

Since even Dr. Jones appears to disagree with Drs. Wood and Griffin's hypothesis, the author sees little reason to comment further. To address Dr. Jones's question, however, of how the falling block might appear to suddenly "mostly turn to powder in mid-air," there are two obvious mechanisms. The first is that, at the moment of collapse, an enormous volume of smoke would have been expelled. We may assume from photographs of streamers rising from points higher in the structure that much of each tower above the point of impact was filled with smoke, and all of this would have been forced out or escaped as the collapse broke all remaining windows and compressed the floors together. Second, as found by Dr. Lioy and company, a large fraction of the dust was wallboard. Anyone who is familiar with sheetrock will be aware that, when cut or smashed, wallboard creates large quantities of thick, opaque dust with relatively little energy input. And whatever the cause, it is simply not enough to state that the upper block *looked like* it disintegrated – we do not have a clear enough view to state this with any certainty.

Had explosives been used to disintegrate the upper block at this juncture, however, we would expect to see and hear visible evidence of their use, including shock waves, shrapnel, and possibly bright flashes. There were none. Explosives large enough to

instantaneously pulverize 25,000 tons or more of structure would be difficult to mistake. This speculation of Dr. Jones is totally unsupported and of little value.

The third and final citation, from Charles Thurston, makes the astonishing claim that the Towers did not collapse at all. "They instead exploded," writes Dr. Griffin, and quotes Mr. Thurston as follows:

> At the onset of destruction for each Tower, we do see that the top part of each building began to fall, and this, no doubt, is what gives the initial impression that a collapse is taking place. In both cases, however, the upper block of floors somehow quickly disintegrates and is lost in the growing cloud of dust and debris. There are no intact portions of either building that survive the wave of destruction that moves down each Tower. [77]

The passage cited does not, to the author, indicate anything inconsistent with the NIST hypothesis. The falling and growing debris could be termed a "wave of destruction," and the energy surplus has already been shown to be so great that discussing the collapse as "disintegration" seems to be nothing more than semantics. Ironically, this quotation is taken from a website [78] subtitled "The Semantics of Deception and the Significance of Categories." The majority of his article focuses on what he considers misuse of words like "collapse," "falling," and even "explained," and has very little in the way of scientific justification, or anything that could be considered support, however weak, for Dr. Griffin's hypothesis. What little it does contain centers on the following totally unsupported assertions:

> Anyone who's ever played with an Erector Set knows that as long as the structural members remain well-connected, a framework may become twisted and distorted if it falls to the floor, but it will never just collapse into pieces under any scenario involving self-related and self-proportional forces. Steel-frame buildings that have fallen in earthquakes also demonstrate this resistance to disintegration.
>
> If a force large enough to cause total destruction was actually applied to the top of one of the Towers, the continuous vertical strength of the specially fabricated multi-story core columns with their welded connections and dense cross-bracing, along with the high-strength perimeter columns and the integrity of the structural concept as a whole, would cause the building to respond as an entire assembly, splitting out or buckling asymmetrically over a multi-floor region, much like pushing down on a bundle of archery bows. [78]

Thurston includes two photographs of structures that toppled over rather than collapsed, as if to suggest that the WTC Towers should also have toppled over. What Thurston apparently fails to recognize is that his photographs are of concrete structures approximately ten stories tall, and that the taller a building is, the less likely it is to topple intact. This is because the angular momentum required to topple the structure scales as the square of its height, while the ability of a column to withstand such bending decreases with the square of its length. As a result, a 100-story building toppling over would experience 100 times as much stress as a 10-story building, and columns would be 100 times less able to resist buckling. This is why tall structures, including those of relatively high strength-to-weight such as radio towers, almost never topple without buckling or breaking apart in at least one location in mid-air. This also explains why very small structures, such as Erector sets, often topple intact. Thurston's claim that an Erector set

adequately predicts the WTC Tower collapse behavior is not worthy of serious consideration.

As we come to the end of this long section, let me summarize and correct the many and repeated errors made by Dr. Griffin:

- While rare, progressive collapse is a danger long understood by the structural engineering community, and not a new concept invented by NIST.
- NIST did not need to consider the late stages of building collapse in any detail, since earlier calculations demonstrated a total collapse was virtually inevitable once the impact floors collapsed.
- A total collapse is expected even without any damage or significant heating to areas well below the impact floors, because even if undamaged, the lower floors are not strong enough to dissipate the momentum of the falling section.
- Dr. Griffin's claims that the collapses took 9 and 11 seconds are based on a misreading of the NIST FAQ, and video confirms that the collapses took several seconds longer, which is not "faster than free-fall" or even "virtually free-fall."
- Dr. Griffin's estimate of 45 seconds for total collapse is based on his unsupported estimate of one half-second per floor, and his belief that the collapse would not accelerate, somehow counteracting the acceleration due to gravity.
- The only support for his 45-second collapse time comes from Dr. Wood, whose analysis violates conservation of momentum and is totally indefensible.
- While it is true that some mass was lost in the form of dust, analysis of the dust reveals few heavy construction materials, and there is no evidence that this was a significant effect with respect to collapse time or speed.
- There is no credible evidence for explosions as the towers collapsed.

It also bears pointing out that the paper by Bazant *et al.* mentioned above [72] also treats the energy of pulverization and loss due to ejected materials rigorously in its energy balance equations, yet still agrees with the observed time of collapse for both towers. Unless this paper is seriously challenged, we have no reason to accept the unsupported speculations of Dr. Griffin. Neither he nor any of his quoted sources have presented a single valid calculation, and they have not met their burden of proof.

Tweaked Computer Models

While the previous section departed heavily from discussion of NIST, choosing instead to focus on issues that NIST considered superfluous, here we return to the NIST Report. Dr. Griffin again makes the argument that the computer models were "tweaked" until they achieved a predetermined outcome. We have already examined and discarded this argument in of our critique of the section "*How Did Impact Damage Help Induce Collapse?"* and need not repeat it in detail. Briefly, Dr. Griffin's errors (and those of Douglas, Ryan, and Jones) are these:

- All three input cases for each tower impact are based on estimates of the structure and the aircraft that are within experimental error. Both cases for each tower fire are based on impact damage estimated above, and fuel loading estimates also within experimental error.
- There is no "tweaking" of computer models, other than using at most the one-sigma upper and lower bounds of these measurements.
- Impact model results were evaluated against numerous evaluation criteria, as outlined in NCSTAR1-2, pages 267-291. Similar fire model evaluation is described in NCSTAR1-5F, pages 78 and 100, and the overall model results are compared against observations in NCSTAR1-6, page 235.
- The models were not "tweaked" until they resulted in a collapses – where parameters were adjusted, they were chosen to match directly observed evidence, such as the amount of perimeter column bending; no parameter was adjusted because it did not lead to a collapse.

Dr. Griffin's excerpts from Dr. Jones [79] include comments on the impact model as well as the structural response model contained in NCSTAR1-6. About the latter model, Dr. Jones remarks that "the pulling forces on the perimeter columns by the sagging floors were adjusted." This statement is correct, but there are two important points missing from this statement. First, the pulling forces could be matched to directly observable evidence – namely the inward bowing of perimeter columns, which has been estimated accurately from photographs and video, such as Figures 2-25 and 2-37 of NCSTAR1-3C. Instead of adjusting the pulling forces upward until it resulted in a collapse, NIST adjusted the pulling forces to match the photographic evidence. Second, the pulling force estimates are a result, not an input, and therefore do not affect whether or not the Towers were expected to collapse. NIST discusses the uncertainties in NCSTAR1-6D on pages 37-39. Regarding WTC 1, NIST writes the following on page 40:

> As the floors sagged, they imposed tension force on the exterior wall, and the exterior wall was pulled in. However, sagging of floors in such a wide range over five floors was not predicted by the full floor model analyses. Possible reasons for floor sagging in areas not predicted by the full floor analyses include loss of insulation outside the areas considered by NIST when formulating the temperature time histories, the additional structural softening caused by concrete cracking and spalling, and debris weight from different sources including the aircraft, accumulation of debris from the impact, and partial floor collapse, none of which were modeled in the full floor analysis. … The magnitude of the pull-in force was determined, by trial-and-error, by matching the observed bowing magnitude as discussed in Section 3.2.1.

It should be made clear that NIST's prediction of the inward pulling forces is subject to relatively large uncertainties, and this fact is a valid point of criticism – but this uncertainty *in no way* affects the prediction of collapse. It is the actual column displacements and hence their eccentric loading that determines column strength and stability, not the pulling forces. These displacements were input directly to the NIST model based on the photographic evidence, not any prediction, and therefore the pulling force error *has no effect* on the prediction of if or when the Towers would collapse. NIST only models the pulling forces to explain the source of the inward pull, not to estimate its magnitude. If it had turned out that the adjusted pulling force values were unreasonably high, NIST would have evidence of a different mechanism causing those displacements,

but as it turns out the pulling forces, while somewhat larger than predicted, are quite plausible – on the order of 5,000 pounds or less at each anchor point.

Dr. Griffin also quotes Kevin Ryan, identifying what he believed to be a problem with the floor truss fire test data:

> The results [of the test] were that . . . the floors barely sagged – only about 3 inches, despite the use of double the known floor load and two hours of fire exposure (i.e. over twice the duration of fires known to have existed in the failure zones). NIST then added this 3 inch sag to their computer model, and . . . it suddenly became 42 inches of extreme sagging. . . . Without a doubt, one rarely finds more shameful and obvious examples of the distortion of science. [79]

The distortion here is by Ryan, not by NIST. Ryan is referring to the floor truss fire tests conducted in NCSTAR1-6B which we have already mentioned above. These tests were designed to estimate the fire rating of the floor assemblies *as built*, not to provide inputs to the fire response model, as Ryan claims.

Of the four tests, Assembly Number 4 showed the least deflection on its bottom chord, reaching an average of about 3 inches after 110 minutes, as seen in Figure 5-61 of NCSTAR1-6B. The other three assemblies had greater deflections, Assemblies 1 through 3 experiencing roughly 5, 4, and 8 inches respectively. Assembly 4, the one that Ryan has chosen for discussion, was one of the seventeen-foot subscale test assemblies, not one of the larger, full-scale assemblies. Also, unlike the situation in the Towers, Assembly 4 was fireproofed with ½ inch of SFRM, although its bridging trusses were not protected. Furthermore, the relatively low deflection measured in Assembly 4 does not indicate that it fared better than the others – this was one of two tests that were stopped early (the other being Assembly 1) because the collapse of the entire test article was imminent, as explained by NIST on page 95.

Because this test was subscale and represented an undamaged floor assembly, we should not expect floor deflection in the WTC Towers, both larger and with damaged fireproofing, to be the same. Thus, the WTC Tower floors would not be expected to sag only 3 inches. NIST's floor sagging is computed in NCSTAR1-6D, Appendix A, and the maximum deflections are presented in tables A-1 through A-4, representing the four different fire scenarios. The maximum deflection estimated is on the order of 90 inches, but that is for the most severe fire case, and measured at the edge of estimated floor damage, where the floor would be essentially hanging in empty space. For areas where the floors are mostly intact, merely stripped of fireproofing, the maximum deflections are on the order of 30 to 40 inches. This also occurs on the long-span floor trusses, not the shorter 35-foot trusses – thus we would need to scale up the 17-foot-span Assembly 4 test several times, even if it was directly applicable.

The 42 inch value that Ryan cites is taken from the component test in Section 5.4.9 of NCSTAR1-6C. This computational experiment is similarly a bad fit to the Assembly 4 test. In the computer model, the truss spans 713 inches (59 ft 7 in, or about three times the span of Assembly 4), as shown in Figure 5-25. The model does not include any fireproofing whatsoever. And finally, the maximum deflection occurs when the truss is

allowed to buckle, which rapidly increases sagging in the truss. From NCSTAR1-6C, page 77:

> At 445 °C, when the end diagonal struts began to yield, the horizontal displacement at the exterior column began to decrease. At 565 °C, the truss sag became large due to the buckling of web diagonals, and the exterior columns were pulled in.

As explained above, Assembly 4 was not allowed to buckle – the test was stopped before this could take place. The time to reach this point is a mismatch because Assembly 4 was partially fireproofed, while the computer model above assumes otherwise. And Assembly 4 was about a third the size of the computer model. In short, there is no reason whatsoever to conclude the three inch sag observed in the Assembly 4 test implies that the test above should have also experienced only three inches of sag.

Much larger floor displacements, predicted by NIST in NCSTAR1-6D Appendix A, are also verified by photographic evidence. NCSTAR1-3C contains numerous photographs of "hanging objects," which can only be objects suspended from floors above or the floors themselves, irrefutably demonstrating that the floors sagged significantly – several feet in many cases – as the fires progressed. This is clearly seen in photographs such as Figure 2-41 of NCSTAR1-3C.

We have now demonstrated that the NIST models do not rely upon unsupported "tweaking" of models. Rather, Dr. Griffin and his colleagues are mistaken about the sources of information used to develop those models. As a result, Dr. Griffin's charge, that the NIST model conclusions result from circular reasoning, is incorrect.

A Thoroughly Unscientific Hypothesis

Dr. Griffin closes this first major division of the chapter with a brief coda in which he describes alternate ways to investigate the collapses. Before we examine these ideas, let me remark that the best way to begin a re-investigation, be it scientific, legal, or criminal in nature, is to first understand what is wrong with the previous investigation, and design a new approach that can overcome those limitations. Thus far, we have discarded every one of Dr. Griffin's alleged errors in the NIST Report, making it unclear exactly what part of it requires revision.

Dr. Griffin's first idea, building on the notion that steel-frame high-rise collapses are almost unheard of, is to conduct a full-scale test of the event:

> It might be thought, to be sure, that performing the needed experiments would be too expensive to be practicable. But this is not so. The experimenters could simply choose some steel-frame high-rises with similar designs (having both core and perimeter columns) that are already scheduled for demolition. Then some old Boeing 767s that need to be replaced could be flown by remote control into the buildings. [80]

The idea of conducting such a full-scale test is not only expensive, but also problematic. Unfortunately, Dr. Griffin does not list any actual candidates of structures that he has in

mind – the author would be surprised if any suitable examples existed. First, the WTC Towers were built only about 40 years ago and were revolutionary in their design, meaning that there are few acceptably similar structures in the world, and that they are all relatively recent and thus unlikely candidates for demolition. Second, without exception that the author is aware of, such structures are all located in densely populated areas, and it would be impossible to conduct such a test without grave risk of destroying numerous other structures – the two WTC impacts led to the destruction or condemnation of at least nine structures and damage in several others (WTC 1 through 7, St. Nicholas Church, 90 West Street, 130 Cedar Street, Deutsche Bank Building, Verizon Building, One Liberty Plaza, World Financial Center 3, and 30 West Broadway) [81], not to mention considerable damage to infrastructure, such as transportation and utilities. Third, for reasons of safety, the entire city center would have to be evacuated for the test. Fourth, it is presently illegal to fly any aircraft at that speed and altitude, or a remotely piloted aircraft at that altitude and any speed, outside specially designated airspace that does not include any city (although if the city were to be evacuated completely, it is possible that this regulation could be waived). There are also problems of environmental protection, disruption of travel corridors, and exposure to insurers. For Dr. Griffin to propose this at all, let alone to contend that it could be done easily, stretches his credibility thinner still.

Supposing a suitable test structure could be relocated or constructed in an acceptable test setting, such as Edwards Air Force Base, China Lake, or White Sands, the test would still be prohibitively expensive. The NIST effort totaled approximately $20 million ($16 million in directed funds plus $3.4 million in redirects from NIST's normal operating budget [82]), a total that Dr. Griffin and others have criticized as inefficient use of tax dollars. By comparison, the best parallel to Dr. Griffin's proposed test ever carried out was the Full-Scale Transport Controlled Impact Demonstration, described in a NASA Technical Report [83], led by NASA Langley and executed at Edwards Air Force Base. This program, begun in 1980, culminated in the deliberate crash-landing of a Boeing 720 aircraft by remote control in an effort to study new technologies and phenomena in a potentially survivable crash. It involved seventeen aerospace companies in the United States and France, four branches of the United States government, four NASA centers, and the British Royal Aircraft Establishment, among others. The cost of the aircraft test alone, conducted on 1 December 1984, was reported [84] at $11.8 million (or roughly $25 million in current dollars). This cost did not include acquisition of the aircraft itself – the Boeing 720 used in the test was taken from the FAA's instructor training fleet, having neared the end of its useful lifespan. Taking this experiment as a baseline, and then adding the cost of constructing or reclaiming, instrumenting, and later disposing a test structure comparable to a WTC Tower, there is no question that Dr. Griffin's proposed test would greatly eclipse the NIST investigation in terms of cost.

Some members of the Truth Movement are well versed in the Controlled Impact Demonstration, including Mr. Hoffman who mentions it specifically on his website [85]. The observation drawn by the Truth Movement is that the Controlled Impact Demonstration proves that remote control of jetliners is technically possible. This is true; however, the Demonstration also proves that such remote control is technically *difficult.* As described in the NASA Technical Report, over the course of several months the

NASA team conducted a total of 14 test flights, all with real pilots on-board to carry out difficult tasks or rescue the aircraft if the remote control system failed, prior to its final flight with no one aboard. Despite these precautions, the test flight itself crashed wide of its target with significant yaw and roll, where a flat belly landing was desired. This error interfered with one major test objective, but the crash still provided a wealth of data pertaining to aircraft structure and survival systems.

While autonomy technologies and automatic piloting systems have improved since the 1980's, Dr. Griffin's test would require the drone aircraft to hit a much smaller target, and would fly much faster than the 170 knot test condition of the Controlled Impact Demonstration. These hurdles are not insurmountable, but given the added complexity and the failure in the 1984 test, we would require an even more thorough development and preparation effort than they had, which in turn pushes the cost higher still.

Such a test would no doubt be instructional, to say nothing of technically challenging and even entertaining, but we should have a solid technical reason to propose such a test. Dr. Griffin's mistaken impressions of the NIST Report are simply not enough. This test could be reasonably expected to cost hundreds of millions if not billions of dollars. Dr. Griffin observes that such a cost is still marginal in comparison to the cost of the ongoing Operation Iraqi Freedom, but frankly the author fails to see why this political comment lends any weight to his argument. We would need to justify this multi-year, multi-million dollar proposal on its own merits. So far Dr. Griffin has not done so.

Another idea, one that has been voiced by many and that Dr. Griffin attributes to Hoffman, is to use subscale models to investigate the behavior of the Towers, in particular the mechanics of progressive collapse. This is certainly possible, but scaling is much more difficult than it appears to the untrained. Recall the full-scale and half-scale tests of the short-span floor truss systems conducted by Underwriters Laboratories for NIST as reported in NCSTAR1-6D. Despite there being only a factor of two between the different test articles, and only in a single dimension, NIST was surprised to find that the equivalent fire rating did not scale as they had predicted. Similarly, the Cardington fire experiments were conducted on a full-scale structure, despite the cost, simply because subscale models cannot always be reliably extrapolated to real-world conditions.

Many phenomena simply do not scale. To choose a simple example, a slender steel column that is shrunk in every dimension by a factor of n experiences elastic buckling under exactly the same static load as the original, because it retains the same slenderness ratio. But its mass will be n^3 less than the original. This is important because the weight of structural elements was a major contributor to the Towers' progressive collapse. As a result, a one-tenth size model of the Towers would be effectively a thousand times as strong as the original with respect to buckling, unless we were able to take this effect into account through careful design and selection of materials. However, this is only true with respect to buckling failure and static load – compressive failure scales differently, so the smaller column would fail in a totally different way than the larger column, making the model invalid. Dynamic loads and impact effects have different scaling laws, as does the

total gravitational energy. There are similar problems with fires and heating, convection and air flow, and also a need to scale time and physical properties as well as size.

It will be impossible to construct a single subscale model that faithfully recreates all of the observed phenomena, including impact damage, fires, structural response, and collapse. This is one of the reasons why computer simulation is so attractive: Simulations can be conducted at "full scale" with no additional cost or complexity. Nevertheless, it would be possible to construct a physical subscale model that *only* replicated the progressive collapse. The author encourages Dr. Griffin to pursue this if he feels it is important, only reminding him that it is much more complicated than it may appear, and that he should enlist the help of qualified experts if he is serious about his research.

Dr. Griffin's closing words in this section are telling:

> In reality, of course, NIST will not support this proposal and no experiment will be done, because both NIST and the government know that the official theory is false. They know that the buildings were brought down by explosives in the procedure known as "controlled demolition." But NIST, of course, publicly had to deny that this is what happened. [86]

This is a serious and unsupported charge. It is not clear to the author that NIST would necessarily withhold support from such experiments, given their interest in other ongoing investigations, notably the work of Purdue University [87] in constructing a much more graphically detailed simulation of the aircraft impact. Regarding what Dr. Griffin claims about NIST's motivation, and his insistence that they are active participants in a cover-up, the author only remarks that he has not provided a shred of evidence that this is true.

Controlled Demolition Claims

Dr. Griffin now turns away from discussion of the NIST Report directly, and raises his own theory, namely that the WTC Towers (both of them, presumably) were destroyed by some combination of malicious devices that activated well after the jetliner impacts. His use of "controlled demolition" is understood to mean employment of these unspecified devices, even though in ordinary use the term refers to careful demolition, meticulously designed to minimize damage to other structures (hence "controlled"), which clearly does not apply in the WTC Towers case.

Dr. Griffin observes that NIST did not specifically test for residue or traces of explosives. This is not strictly true, since any known explosive would have left telltale objects in the debris field, and furthermore none of the structural steel recovered by NIST failed in a manner consistent with explosives. Still, we agree that NIST did not perform any *chemical* tests specific to explosives. We must, however, also point out that it is in no way clear that NIST could perform such tests, given the chemical complexity and scale of the fire that burned the debris pile for weeks afterward. Chemical explosive residue tends to be in forms such as nitroaromatic compounds [88], which are particularly susceptible to heat and fire, and thus unlikely to survive. It would be further difficult to distinguish these from the vast variety of ordinary combustion products given off by burning plastics, such as the high concentrations of aromatic compounds found in the smoke by Lioy *et al.* [89]. There is also site contamination to consider, and the sheer volume of debris. For these reasons, it is not at all remarkable that NIST did not conduct tests for residue of explosives. Dr. Griffin's observation therefore does not implicate NIST, nor does it provide evidence that there were any explosives. It would also be useful for Dr. Griffin to specify what type of explosive he suspects, so that we could identify the particular testing methods for that explosive, and better evaluate the feasibility of such tests.

Other Hypotheses Obviated by NIST's Account?

Next, Dr. Griffin comments on NIST's explanation of why it did not consider explosives. He correctly states that the primary reason NIST contradicts his explosives hypothesis is that NIST provides a reasonable hypothesis that does not require explosives. He then returns to his previous claims that the NIST Report is flawed, and he appears to disagree with the logic of this statement itself. We have already addressed his complaints about the NIST Report in detail, and found them to be incorrect. The only remaining question, then, is the validity of the logical argument.

Even without the NIST calculations, video evidence demonstrates that the structures gradually degraded as they burned, with remaining exterior columns bowing inwards until the structures buckled and then collapsed. In order to disprove the NIST hypothesis, one must first prove that either the structures could not degrade in such a fashion without help, that buckling of the exterior would not start a collapse, or that the collapse itself would be self-arresting. The NIST Report directly contradicts the first two statements,

and the work of Dr. Bazant and others contradicts the third. Without disproving all three elements, we must accept that the structures would have collapsed without any explosives, and therefore any explosives that we may hypothesize served no useful purpose. Furthermore, thus far Dr. Griffin's "evidence" of explosives centers on his claims that nothing else could explain the observed phenomena, and so NIST's results eliminate his evidence, thereby refuting his hypothesis.

Even if all of the above was false, however, it would *still* not prove the case for explosives – it would still be possible for a different structural collapse mechanism to explain what happened. Yet this is moot, as Dr. Griffin does not even attempt to disprove any of these statements here, relying instead on previous arguments that we have already addressed.

Must Controlled Demolition Be a Bottom-Up Affair?

In this brief section, Dr. Griffin makes the argument that, despite all ordinary controlled demolitions producing a collapse starting at or near ground level, there is no reason why a collapse could not have started from higher in the structure. He states that simply because the collapses both started from the point of impact, this does not prove that it wasn't a deliberate demolition.

Even overlooking the fact that Dr. Griffin still has the burden of proof to show explosives were present, and the fact that he is again merely complaining that NIST hasn't proven a negative, this is a strange argument. The author readily agrees that, hypothetically, the Towers could each be completely destroyed by a moderate amount of explosives preset at a higher level. This is because the author accepts the work of Bazant *et al.* in describing the gravity-driven progressive collapse mechanism. Their calculations show to my satisfaction that if a single floor (at or below roughly the 98th floor) were to be destroyed, even if the rest of the structure was totally undamaged, we would expect a total collapse of the entire structure. Dr. Griffin, however, rejected this argument, and therefore must believe that a much larger amount of explosives would be needed – to destroy not just a single upper floor, but also many other lower floors or to weaken critical areas in the moments prior to collapse. Dr. Griffin's rejection of the progressive collapse theory actually makes his proposed explosives scenario more difficult to support.

In ordinary controlled demolitions, the collapse is generally initiated at ground level for two reasons. The first is because this causes most of the structure to be broken apart at ground level rather than at an upper story. Pieces that are broken away as the collapse progresses are not falling from a great height, and as a result the debris field is under better control. In contrast, the WTC Towers spread their materials over a much wider area, causing tremendous secondary damage as a result. The second reason is that initiating collapse lower in the structure means more of the structure's mass moves at the start, thus there is more initial momentum and a quicker release of gravitational energy. More energy at the start means less explosives and less dependence on weakening elsewhere in the structure. These effects make controlled demolitions cheaper and safer.

If safety is not a requirement, then a collapse initiation high in the structure is certainly doable, and the great height of the Towers means there is an enormous amount of gravitational energy that can be harnessed to help the collapses. Dr. Greening [20] estimates that about 5×10^8 J of energy, or approximately 300 pounds of TNT, would be enough to destroy a single WTC floor, assuming perfect placement leading to 100% efficiency. If the columns were also weakened prior to placement of explosives, the amount needed would be perhaps half of that. By comparison, the tallest building ever demolished by explosives was the J. L. Hudson Department Store in Detroit. This 23-story structure was taken down by Controlled Demolition, Inc., who used roughly 2,700 pounds of explosives [89] in the implosion. (It is reasonable to suppose that if safety was not a factor, it could have been destroyed with less explosives; the large number of explosive charges gave better control of how and when the structure would fall.)

However, recall that Dr. Griffin claims the Towers could not experience progressive collapse as driven by gravity. Therefore, he requires a minimum of roughly 150 pounds of TNT equivalent at several floors, if not every floor. Dr. Griffin does not explicitly state how many floors he believes contained explosives, but from his commentary, we may assume that it is large. He cites Thurston again:

> But, if one considers all the evidence, it quickly becomes apparent that the Towers didn't cave in, fall or give way – they were systematically and progressively exploded from the top down, starting from the impact zone in each Tower. [90]

Supposing Dr. Griffin believes that 20 floors would have to be "systematically and progressively exploded," we estimate that he requires upwards of 3,000 pounds of explosives. This number may not accurately reflect his belief – it would be helpful if Dr. Griffin would provide some details about his theory – but regardless of the precise value, it is clear that Dr. Griffin assumes a very large and complicated demolition scheme, comparable to or larger than the J. L. Hudson demolition.

Dr. Griffin does not mention two critical and obvious factors contrary to the explosives hypothesis, stated below. These problems apply to both his multiple progressive demolition as well as the simpler, single-floor detonation the author proposed above:

- The initial collapse happened on floors that were heavily damaged by aircraft impact, with many structural elements displaced, and fireproofing (and everything else) stripped away from many beams and columns down to the bare steel. This is predicted by modeling and partially verified with direct photographic evidence.

- The collapse floors burned bright and hot for extended periods of time. This too is predicted by modeling and partially verified by photographs and video of the fires.

If we assume there were explosives, we must also assume there were explosives at the impact floors, because collapse started at the impact floors. We must further assume the explosives were there *before* impact, because fire and debris would have hindered any

effort to place them afterwards, not to mention there simply wasn't enough time. If we claim explosives were in place before the impact, we need to explain why these explosives survived the impact and the fires. Explosives used in demolitions are either packed close to the structural members, or use shaped charges that are extremely sensitive to geometry, and since we know the jetliner impacts fractured some columns outright and stripped others to the bare metal, either situation would be disrupted. Explosives also tend to burn or detonate when exposed to heat, and even those that do not will degrade chemically. Detonators, wiring, and connections between explosives are sensitive components. It is difficult to imagine any method of explosive demolition that could be expected to survive such conditions.

While Dr. Griffin does not propose any explanation, the author presents one possible approach for sake of argument – a single, large explosive could, in theory, be sufficiently fireproofed and armored to withstand the impact and resulting fire. This also has the advantage of only requiring a single point of detonation, allowing multiple redundant detonators and radio receivers to be triggered in sequence without fear of partial activation, thus providing more simplicity and a lower chance of total system failure. There is a critical drawback, however: We would need much, much more explosives. The effectiveness of an ordinary explosive scales somewhere between the inverse square and inverse cube of the distance (depending on geometry, explosive type, and reflection), and we cannot avoid this here by using directed effects such as shaped charges. This is why, in ordinary demolitions, a large number of tiny explosives are used rather than a single large one – the tiny explosives can be placed right against different parts of the structure, making each blast far more efficient. Where 150 pounds of explosives would be needed in an ideally efficient application, we now require 20 to 100 times as much. The report, fireball, and shock wave from this explosive would be impossible to conceal.

Again, it should be pointed out that Dr. Griffin does not propose use of a single, large explosive. However, this is not a strawman argument, because he does not propose anything at all. His insistence on explosives – without specifying what type, how many, where, how applied, how detonated, or any physical evidence of explosives – is too vague to permit any analysis. The author welcomes any attempt to describe, in detail, a proposed method of demolition, but there is none in Dr. Griffin's book.

No Evidence of Explosions?

In this lengthy section, Dr. Griffin argues with NIST's contention that there were no explosions seen that were inconsistent with the fires.

Dr. Griffin's complaints are based on precise wording, which are reprinted here. From the NIST FAQ [11]:

> Video evidence also showed unambiguously that the collapse progressed from the top to the bottom, and there was no evidence (collected by NIST, or by the New York Police Department, the Port Authority Police Department or the Fire Department of New York) of any blast or explosions in the region below the impact and fire floors as the top building sections (including

> and above the 98th floor in WTC 1 and the 82nd floor in WTC 2) began their downward movement upon collapse initiation.

In brief, NIST states that, contrary to what Dr. Griffin claimed in the previous section, there is no sign of floors being "progressively and systematically exploded" during the collapse. Curiously, Dr. Griffin modifies the NIST quote, leaving out a crucial part of the sentence. Here is Dr. Griffin's excerpt:

> NIST's third reason for dismissing the hypothesis of controlled demolition is that "there was no evidence (collected by NIST, or by the New York Police Department, the Port Authority Police Department or the Fire Department of New York) of any blast or explosions in the region below the fire and impact floors." [91]

In editing this quote, Dr. Griffin has changed the question, no longer referring to hypothetical explosives triggering during the collapse ("as the top building sections began their downward movement" from the original NIST sentence), but to any explosion at all, including those taking place long before the collapse. His criticism of the NIST FAQ is, therefore, based on a distortion of the NIST position. Even more surprising, he goes on to relax the remaining restrictions as well, rephrasing his question to suit his own needs:

> NIST's claim, revised to remove these two restrictions on evidence, would read: "there was no evidence collected by reliable sources of any blast or explosions in the regions above or below the impact and fire floors." [91]

The author is perfectly willing to examine other "reliable sources" than those collated by NIST, but it should be perfectly clear that explosions *above* the impact floors cannot contribute to the controlled demolition Dr. Griffin has in mind – explosives here may even hinder collapse by breaking up the upper block and ejecting mass, lessening the upper block's impact on the floors below. It appears that Dr. Griffin is no longer interested in collapse *per se*, but rather looking for any anomaly, any evidence at all for explosives.

Regardless of this tortured logic, we may examine his alleged evidence for explosives anyway, no matter where or when they supposedly detonated, whether or not they caused any structural damage, or whether the source is among those collected by NIST. Dr. Griffin lists nineteen carefully selected witnesses that he feels support his hypothesis. From their words as quoted in this section, these nineteen are organized as follows:

- Witnesses who saw explosions: 10
- Witnesses who felt or heard, but did not see, explosions: 6
- Witnesses who felt the ground shake only: 3
- Witnesses who saw or heard explosions during the collapse: 8
- Witnesses who saw explosions, during the collapse, below the point of impact: 2
- Witnesses who sensed explosions well before the collapse but after impact: 3
- Witnesses who sensed explosions at the same time as impact: 2
- Witnesses who sensed explosions before the aircraft impact: 3

These figures also give Dr. Griffin the benefit of the doubt – nearly all of his witnesses, for instance, speak of the event as "what appeared to be at first an explosion" or otherwise describe their experience using indefinite terms. Even with this liberal interpretation, there are only two who saw explosions during and below the collapse, and thus only two that could possibly support Dr. Griffin's purported demolition, the others being irrelevant or obviously incorrect. At this point we could dismiss these accounts as falling below the standard of proof. However, since Dr. Griffin has already gone through a complete cycle with his critics, it appears that we must review the statements exhaustively to address his claim to his satisfaction. Individual statements are as follows:

Fire Captain Dennis Tardio

> "I hear an explosion and I look up. It is as if the building is being imploded, from the top floor down, one after another, boom, boom, boom." [91]

Even if we remove the qualifier "as if," there is nothing about this statement that provides evidence of explosives. The fact that Captain Tardio "heard an explosion" does not mean that there was an explosion, nor that there were explosives. It is clear that he heard the early stages of collapse, which would have sounded rather like an explosion. Video and audio of the event is widely available for comparison.

Dr. Griffin also claims this is evidence of explosives *above* the impact and fire floors. He can only be referring to Captain Tardio's comment that the building was collapsing "from the top floor down." It may well have appeared that way to Captain Tardio from his location far below, and floors above the fire would also have been obscured by smoke. Video, however, proves definitively that collapse did not progress from the top floor down, but rather started at the impact floors.

Chief Frank Cruthers

> "There was what appeared to be at first an explosion. It appeared at the very top, simultaneously from all four sides, materials shot out horizontally. And then there seemed to be a momentary delay before you could see the beginning of the collapse." [91]

Chief Cruthers is describing the collapse of WTC 2, as archived by the New York Times [92]. Again, there is nothing here that suggests explosives. Chief Cruthers, standing at street level, must be describing the initial collapse event at the impact floors, not "at the very top," because video clearly shows there was no such event at the very top. As before, this does not support Dr. Griffin's claim that there were explosions above the fire floors, nor does it provide evidence of explosives.

Wall Street Journal Reporter John Bussey

> "I … looked up out of the office window to see what seemed like perfectly synchronized explosions coming from each floor. … One after the other, from top to bottom, with a fraction of a second between, the floors blew to pieces." [91]

For the record, the full quote is this:

> Unknown to the dozens of firefighters on the street, and those of us still in offices in the neighborhood, the South Tower was weakening structurally. Off the phone, and collecting my thoughts for the next report, I heard metalic [sic] crashes and looked up out of the office window to see what seemed like perfectly synchronized explosions coming from each floor, spewing glass and metal outward. One after the other, from top to bottom, with a fraction of a second between, the floors blew to pieces. It was the building apparently collapsing in on itself, pancaking to the earth. [93]

It is disappointing to see that Dr. Griffin removed Mr. Bussey's description that he heard "metallic crashes" rather than "explosions," an unwarranted omission given that Bussey was awarded a Pulitzer Prize for this article, and certainly considered his words with care. Nonetheless, at most the collapse "seemed like" explosions, which is hardly definitive evidence of explosions or of explosives. Once again, Dr. Griffin states this is evidence of explosions taking place above the impact floors, which is simply a distortion and easily shown to be incorrect by considering the video of the event.

Teresa Veliz

Dr. Griffin quotes her as seeing explosions on or below the 47th floor of WTC 1 as she descended, taken from Dean Murphy's book *September 11th: An Oral History*. The quote is as follows:

> "There were explosions going off everywhere. I was convinced that there were bombs planted all over the place and someone was sitting at a control panel pushing detonator buttons. … I didn't know where to run." [94]

From reading this excerpt, the author had assumed that the explosions she witnessed took place immediately following the impact, and thus could not have been in any way associated with the collapse. Such an experience would also be consistent with jet fuel traveling down the core of the building and igniting, producing large fireballs on numerous floors. Figure 6-1 of NCSTAR1-7 shows, in tabular form, the phenomenology experienced on each floor after impact but prior to evacuation of WTC 1. Notably, Floors 43 through 45 all had reported fires, and Floor 44 also reported actual fireballs. Fires were reported as low as floor 31 and even the basement, which is unsurprising given the "stacked" nature of the elevator shafts in the WTC Towers, allowing jet fuel to run downward a great distance in the moments after collision.

Based on the analysis above, the author surmised that the explosions Ms. Veliz's saw were at or near Floor 44, a short distance below her original position on Floor 47, and therefore shortly after impact. Given the presence of jet fuel, and given that many common household items can explode in even an ordinary fire, there seemed no reason to conclude there must have been additional explosives. Furthermore, as there was no sign of building collapse beginning anywhere near Floor 47 or any floor below, it was unclear what effect, if any, such hypothetical explosives could have had.

However, as pointed out to the author by Mark Roberts, careful scrutiny of the original quote reveals a very different account, one that is totally incompatible with Dr. Griffin's claims. A larger excerpt from *An Oral History* is presented below:

> Veliz went down a staircase with a coworker to the concourse level. In the mall, they got onto an up-escalator as the South Tower collapsed, causing a rush of wind which knocked them down. In the pitch black, Veliz and her coworker followed someone carrying a flashlight:
>
> "The flashlight led us into Borders bookstore, up an escalator and out to Church Street. There were explosions going off everywhere. I was convinced that there were bombs planted all over the place and someone was sitting at a control panel pushing detonator buttons. I was afraid to go down Church Street toward Broadway, but I had to do it. I ended up on Vesey Street. There was another explosion. And another. I didn't know where to run." [95]

When we read the original source, rather than the misleading fragment provided by Dr. Griffin, it is immediately clear that the explosions Ms. Veliz describes did not happen inside the World Trade Center at all. Instead, these took place *outside* the buildings, some happening over a block away. This account is, therefore, not support for explosives "in the region below the impact and fire floors," as Dr. Griffin claims [94].

Now that we have the full story, Ms. Veliz's experience is not surprising. The South Tower collapse threw literally thousands of tons of flaming debris in all directions, often hundreds of feet, damaging everything below and starting secondary fires. There are numerous reports of vehicle fires and gasoline explosions as a result. Ms. Veliz's experience, while remarkable, is in no way inconsistent with the conclusions of NIST, and cannot possibly be construed as evidence of explosives inside the North Tower.

Genelle Guzman McMillan

Dr. Griffin cites her story from the article in *The Record* from Bergen County, New Jersey [96], as describing an explosion well before the collapse:

> Guzman, the last survivor to be rescued from the rubble, reports that when she got down to the 13th floor some 20 minutes before the North Tower came down, she heard a "big explosion" and "[t]he wall I was facing just opened up, and it threw me on the other side." [97]

The full quote actually seems to describe something much different – rather than 20 minutes before collapse, it appears to describe the collapse itself. The following longer excerpt is from Mike Kelly's article in *The Record*:

> On the 13th-floor landing, McMillan stopped. Her 2-inch heels seemed like 10-foot stilts.
>
> McMillan reached down to pull them off. She would walk the rest of the way barefoot.
>
> She never took a step.
>
> McMillan heard a rumble. "A big explosion," she now calls it.
>
> "The wall I was facing just opened up, and it threw me on the other side," she says.

> McMillan looked for Gonzalez.
>
> "I was still holding Rosa's hand," McMillan says. "But she pulled away."
>
> McMillan remembers Gonzalez trying to climb the stairs.
>
> "I got up," McMillan says. "And I tried to go behind her. That's when the rubble just kept coming down."
>
> She never saw Rosa Gonzalez again.
>
> "Everything just kept coming harder and harder," McMillan says. "I just kept my head down. I don't know how I ended up the way I was. I don't know how I landed."
>
> It was complete darkness.
>
> She heard a man's voice.
>
> "Help. Help. Help," she remembers him calling.
>
> Then silence.
>
> Then the building shook again. More debris fell.
>
> "I thought I was really going to go down," McMillan recalls. "But I didn't."
>
> Then the shaking stopped and the silence began.

The author cannot find any mention of this taking place 20 minutes prior to collapse. Following this passage, Ms. McMillan claims to have been "entombed" until her rescue, so unless the above describes the actual collapse, she must have missed the collapse entirely. The author therefore concludes that her experience above is *during* the collapse, and not 20 minutes earlier, as Dr. Griffin claims.

There are three distinct phases in Ms. McMillan's remarkable account: The first "rumble" in which a wall nearby was damaged; a second collapse evidently only a few seconds later that resulted in prolonged falling debris; and a third, final event a short time later, possibly less severe than the second from her perspective. This is consistent with the observed collapse. The initial collapse of the impact floors would have shaken the building and possibly damaged already weakened interior walls, but left the building passable at the lower floors. Five to ten seconds later, the progressive collapse would have reached Ms. McMillan, resulting in "everything coming harder and harder." Then an estimated 10 to 25 seconds afterward, the core remnant that survived the initial collapse tumbled, falling on or near her position. Her account matches this well, and is therefore extremely credible.

What is significant in her account vis-à-vis Dr. Griffin's claims is that she describes "rumbles" and "shaking." These are not signatures of nearby explosives. Such would be characterized by shock waves, sharp sounds, sudden jerks, and flying debris. What Ms. McMillan describes is totally consistent with the collapse as NIST has described it.

The author remains mystified as to the source of Dr. Griffin's claim that this took place 20 minutes prior to collapse. Lacking further explanation, the author can only assume that he has confused two separate accounts, or else invented this detail out of whole cloth.

Firefighter Louie Cacchioli

Dr. Griffin includes a brief passage, quoted from the *Arctic Beacon* [98], stating that he heard a huge explosion like a bomb while he was in one of the elevators. Rather than limiting this analysis to Dr. Griffin's tiny excerpt, let us consider the original quote:

> "Tommy Hetzel was with me and everybody else also gets out of the elevator when it stops on the 24th floor," said Cacchioli, "There was a huge amount of smoke. Tommy and I had to go back down the elevator for tools and no sooner did the elevators close behind us, we heard this huge explosion that sounded like a bomb. It was such a loud noise, it knocked off the lights and stalled the elevator." [98]

This quote is relatively unremarkable compared to other excerpts, at least with respect to explosions. Another excerpt reads as follows:

> "I somehow got into the stairwell and there were more people there. When I began to try and direct down, another huge explosion like the first one hits. This one hits about two minutes later, although it's hard to tell, but I'm thinking, 'Oh. My God, these bastards put bombs in here like they did in 1993!'" [98]

The article does make it clear, however, that Mr. Cacchioli knows perfectly well that what looks or sounds like an explosion may not be caused by bombs. Later on, he describes hearing the South Tower collapse as he worked his way down the stairwell:

> "Then as soon as we get in the stairwell, I hear another huge explosion like the other two. Then I heard bang, bang, bang - huge bangs – and surmised later it was the floors pan caking on top of one another." [98]

What is most interesting about this article, however, is that Cacchioli is setting the record straight that *he never said that there were explosives in the Towers.* This entire article focuses on his disgust at being misquoted:

> Furthermore, Cacchioli was upset that People Magazine misquoted him, saying "there were bombs" in the building when all he said was he heard "what sounded like bombs" without having definitive proof bombs were actually detonated.
>
> After that unfortunate journalistic blunder, a little angry and a little disgusted, he pretty much disappeared into the New York landscape, his story only appearing in an obscure book released called "American Spirit," and his 2004 testimony given in private to the 9/11 Commission never released to the public in the commission's final report.
>
> So, it's safe to say Cacchioli's story, the story of an American hero, is probably unknown to most Americans even though 9/11 will be forever etched in everyone's hearts and souls for all time. [98]

Dr. Griffin does not misquote Mr. Cacchioli, but he does use Mr. Cacchioli's account as support for his thesis that there were explosives in the Towers. Mr. Cacchioli himself makes it very clear that he does not know whether there were, and further makes it clear that what he saw could have another explanation. We therefore cannot use his account as evidence for explosives.

The author is sympathetic to Mr. Cacchioli's feelings, and hopes that the analysis above adequately captures his true intent.

EMS Captain Karin Deshore

Dr. Griffin next quotes from the World Trade Center Task Force Interview with Captain Deshore:

> Somewhere around the middle of the World Trade Center, there was this orange and red flash coming out. Initially it was just one flash. Then this flash just kept popping all the way around the building and that building had started to explode. The popping sounds and with each popping sound it was initially an orange and then red flash came out of the building and then it would just go all around the building on both sides as far as I could see. These popping sounds and the explosions were getting bigger, going both up and down and then all around the building. [99]

Captain Deshore is describing what she saw on the North Tower, several minutes before its collapse but after the collapse of WTC 2, which she had experienced without knowing the precise cause. Because this took place a significant period of time before the collapse of the North Tower, it stands to reason that this is not evidence of explosives used for demolition. It is, however, an interesting account in its own right. There are, naturally, numerous ordinary things that could be expected to cause scattered and fiery explosions during the fire. The NIST Report describes events like this, for example in Section 5.3 of NCSTAR1-5A, pages 52-53:

> During the review of the image databases, and particularly videos, a number of observations were made of behaviors that are not characteristic of "typical" building fires. … There were fires in the towers that burned for much longer periods than [the usual tens of minutes], perhaps indicating the presence of unusually high fuel loads. There were also occasional flare ups of flames suggesting some change within the towers. …
>
> In both towers, there were occasions when large amounts of smoke and/or dust and sometimes flames were pushed simultaneously out of multiple open windows covering several floors and faces of the tower. These events were typically short lived (on the order of a few seconds) and will be referred to as "puffs". The occurrence of puffs suggests the generation of pressure pulses within a given tower that are transmitted through open pathways to remote locations and drive smoke and other material from the tower. The pressure changes required are not large and can be generated by events that result in relatively small volume changes, such as collapsing walls and ceilings, partial floor collapses, and sudden openings of ventilation pathways (e.g., an internal door).

This phenomenon is consistent with Ms. Deshore's account, and her account is *not* consistent with explosives. The "orange and red flash[es]… go[ing] all around the building" can be nothing other than fire and illuminated smoke, pushed out by such a pressure pulse. One reason we know the red and orange light is from fire, not explosives,

is simply because of the color and duration of the flash – demolition charges tend to create a very brief flash if any, unless they are large enough to heat the air or other materials to moderate temperatures. There is also the problem that smoke would obscure the flash from such explosives, meaning they would have to be *very* large. Explosives can even extinguish nearby fires, and rarely excite them.

Of greater significance is that such "puffs" are seen coming from all around the structure. This suggests a sizable volume but low pressure flow of air, as mentioned above. Small explosives do not produce this effect, instead creating a brief and local region of large overpressure that rapidly decays with distance. It might be possible to replicate this effect with a single explosive at the center of the structure, or else a multitude of small explosives placed all around the building, but this is purely speculative, and again raises the question of how these explosives could have survived the impacts and fires.

In any event, Dr. Griffin leaves us to wonder why anyone would detonate explosives at that location and time in the first place. These events are well before the Tower collapse. If there were explosives planted here and detonated deliberately at this point in time, it would seem to be an almost capricious act, one with no significant effect on the structure, and one with the potential to raise suspicions. We therefore reject the claim that it is evidence of explosives:

- The phenomenon can be explained without explosives.
- The effects of explosives would likely appear different from what was observed.
- Explosives are not likely to survive the fire.
- If it was caused by explosives, it implies an extremely unusual placement and timing of those explosives, which makes no logical sense.

The NIST Report also discusses two specific events in detail, the first being smoke forced out of WTC 1 by the pressure pulse from the collapse of WTC 2, on page 288 of NCSTAR1-5A:

> The collapse of WTC 2, starting at 9:58:59 a.m., generated a pressure pulse within WTC 1 that forced smoke and fire from windows on all four sides of the tower. This was especially apparent for the intense fire burning on the western half of the 98th floor on the south face. Following the collapse, there was a short period of time when smoke flow from WTC 1 was greatly reduced.

The event Ms. Deshore refers to, however, took place after WTC 2 collapsed, so it can only be the latter event, described on page 290:

> At 10:18:48 a.m., a pressure pulse pushed large amounts of smoke and fire out of open windows on multiple floors and faces of WTC 1. The most dramatic effect of this pressure pulse was on the 92nd floor, where a long line of smoke appeared from open windows on the north face. Up until this time, there had been very little smoke coming through the open windows from the widespread fires burning on this floor. … The pressure pulse at 10:18:48 a.m. also seemed to cause a fire burning in a room in the northwest corner of the 95th floor to suddenly intensify and to extend flames from north face windows.

To summarize, NIST has apparently already reported what Ms. Deshore saw, and offers a more compelling explanation. Even if it had been ignored, her account would not appear to support the explosives hypothesis. It is also unclear what purpose such explosives could possibly have had.

What is also unclear is why Dr. Griffin refers to this as "Explosions Below the Fire and Impact Floors." Ms. Deshore can only be describing events *on* the fire and impact floors, not below them. Video eliminates any possibility of such behavior elsewhere between the collapse of WTC 2 and WTC 1.

Firefighter Kenneth Rogers

Again, this account does not describe "Explosions Below the Impact and Fire Floors." Dr. Griffin quotes Mr. Rogers, using an excerpt from his World Trade Center Task Force Interview [100], clearly and unambiguously describing the collapse of WTC 2. He is describing the progressive nature of collapse, nothing more. There is nothing about his testimony that cannot be explained by the progressive collapse mechanism demonstrated by Dr. Bazant, cited by NIST, and still unrefuted by Dr. Griffin.

Firefighter Timothy Burke

Dr. Griffin claims that Firefighter Burke's testimony, rather than providing evidence for an explosion, is instead evidence that the collapse of WTC 2 began below the impact and fire floors. If so, this would support his claim that the NIST theory is incorrect, since NIST describes the collapse as beginning on the impact floors.

Mr. Burke's interview [101] does state that "the building popped, lower than the fire" in the initial stages of collapse. However, Mr. Burke was at ground level and almost adjacent to the building, and would have been poorly positioned to estimate the exact height of events transpiring 80 floors above him. He does not state how much lower the "pop" occurred. And once again, we have clear video of the collapse, which shows conclusively that the collapse *did* initiate at the impact floors. Mr. Burke must be mistaken, and this mistake would be perfectly ordinary given his view of the event.

The author surmises that Mr. Burke's "pop" is actually NIST's "puff" of smoke, expelled at a lower floor – possibly a ventilated mechanical floor – as the upper block began to move. This puff would have been much easier to see than the initial downward movement of the upper block, and could easily have been mistaken for a fuel explosion. As before, there is no compelling evidence of destructive devices causing the collapse.

Firefighter Edward Cachia

Dr. Griffin next quotes Mr. Cachia in an excerpt from his Task Force interview [102], in an argument almost identical to that of Mr. Burke. Like Mr. Burke, Mr. Cachia was at ground level, standing on the "hill" near the WTC 1 garage, and in a poor position to estimate the precise height of the collapse initiation. While he claims in clear terms that

"it actually gave at a lower floor, not the floor where the plane hit," this again is contradicted by video, and we understand that he simply underestimated the precise height of the initial collapse.

A careful examination of Mr. Cachia's words can actually provide additional support for the NIST theory, rather than criticism. From the interview on page 5:

> As my officer and I were looking at the south tower, it just gave. It actually gave at a lower floor, not the floor where the plane hit, because we originally had thought there was like an internal detonation explosives because it went in succession, boom, boom, boom, boom, and then the tower came down.

All testimony is subject to human error, as well as apparent anomalies caused by individual perspective. Nonetheless, if we take Mr. Cachia's words literally, we reach the following conclusions:

- *The tower "just gave:"* The collapse was not preceded by flashes, ejection of material, or fireballs, such as a demolition would normally require and Dr. Griffin has suggested elsewhere
- *"It actually gave at a lower floor, not where the plane hit*:" Technically, the progressive collapse would begin one floor below impact. Nonetheless, this statement is problematic for *any* hypothesis, thus we should rely on the video.
- *"It went in succession, boom, boom, boom, boom, and then the tower came down:"* Mr. Cachia describes exactly four discrete sounds before the collapse became essentially disordered with respect to individual floor collapses. The weakened area of WTC 2 spanned between four and six floors. Since the initial four floors would have taken approximately 1.7 seconds to collapse according to the progressive collapse model, it is entirely possible that Mr. Cachia is accurately describing the sound and the timing of the impact floors failing in succession.
- Dr. Griffin's explosives theory would require *more* "boom" sounds, one for each floor explosively destroyed to trigger the collapse, and one for each floor that collapses afterward. There is no reason to assume these two types of "booms" would sound anything alike – the explosive boom is supersonic in nature, while the initial floor collisions would be blunt impacts. Mr. Cachia seems to be describing four similar sounds.
- Dr. Griffin further has stated repeatedly that he believes there were explosions on *many* floors, not just the few that Mr. Cachia describes.

Again, witness testimony is always subject to interpretation, and we should rely on the video. The author also freely admits that the conclusions above may be reading far too much detail into the few words of the interview. However, Dr. Griffin is attempting exactly the same thing, namely extraction of highly subjective conclusion from a literal reading of Mr. Cachia's statements. A more careful reading reveals more problems than support for Dr. Griffin's theory.

BBC Correspondent Steven Evans

Dr. Griffin quotes Mr. Evans as stating that there were explosions at ground level. Curiously, Dr. Griffin edits the quote heavily:

> Some witnesses reported evidence of explosions still lower. For example, Stephen Evans, a New York-based correspondent for the BBC, said: "I was at the base of the second tower … that was hit. … There was an explosion. … The base of the building shook. … [T]hen there was a series of explosions." [103]

Taken at face value, this suggests that there were several spontaneous explosions, one of which was enough to shake the building. However, the use of four ellipses in such a short excerpt is suspicious. Dr. Griffin only cites this as "BBC, 11 September 2001." The author is unable to find an official transcript or unedited recording of this broadcast. Fellow supporter of the Truth Movement David McGowan reprints the excerpt without ellipses, and we will assume this accurately reflects the original broadcast:

> I was at the base of the 2nd tower, the second tower that was hit. There was an explosion -- I didn't think it was an explosion, but the base of the building shook. I felt it shake, then when we were outside, the second explosion happened and then there was a series of explosions. [104]

Without the editing, this quote appears to refer to events that happened only seconds after WTC 2 was hit by Flight 175 – and Dr. Griffin has left out the fact that Mr. Evans "didn't think it was an explosion." Also, the published BBC News article from 11 September 2001 confirms that he is referring to the aircraft impact, not the building collapse:

> Stephen Evans, BBC's North America business correspondent, was on the ground floor of the centre when the first plane crashed.
>
> "There was a huge bang and the building physically shook," he said. "Seconds later there were two or three similar huge explosions and the building literally shook again." [105]

The BBC News article leaves no doubt that Mr. Evans is describing the secondary explosions caused by aircraft fuel, shortly after the aircraft impact. Evans' initial statement was less definite, but there can be no question from the follow-up. We therefore understand these explosions to be due to the large quantities of fuel that flowed down the elevator shafts immediately after the collision. In any event, since they took place very shortly after impact, they cannot be triggering events for the collapse.

Again, this witness statement does not support Dr. Griffin's theory, as it is not evidence of explosives. It would have been impossible for Mr. Evans to distinguish explosives detonating *simultaneously* with the aircraft impact, and he makes no such claims. It is further unclear why Dr. Griffin modified the original quote so heavily, or why he did not refer to the unambiguous printed word rather than a poorly sourced live broadcast.

Assistant Fire Commissioner Stephen Gregory

Dr. Griffin now jumps back from the moment of aircraft impact to the moment of collapse. He next quotes Mr. Gregory as seeing "flashes" in WTC 2, at ground level,

right as it began to collapse. A larger excerpt of his Task Force interview [106] is presented below:

> [Gregory] No. I know I was with an officer from Ladder 146, a Lieutenant Evangelista, who ultimately called me up a couple of days later just to find out how I was. We both for whatever reason -- again, I don't know how valid this is with everything that was going on at that particular point in time, but for some reason I thought that when I looked in the direction of the Trade Center before it came down, before No. 2 came down, that I saw low-level flashes. In my conversation with Lieutenant Evangelista, never mentioning this to him, he questioned me and asked me if I saw low-level flashes in front of the building, and I agreed with him because I thought -- at that time I didn't know what it was. I mean, it could have been as a result of the building collapsing, things exploding, but I saw a flash flash flash and then it looked like the building came down.
>
> [Interviewer] Was that on the lower level of the building or up where the fire was?
>
> [Gregory] No, the lower level of the building. You know like when they demolish a building, how when they blow up a building, when it falls down? That's what I thought I saw. And I didn't broach the topic to him, but he asked me. He said I don't know if I'm crazy, but I just wanted to ask you because you were standing right next to me. He said did you see anything by the building? And I said what do you mean by see anything? He said did you see any flashes? I said, yes, well, I thought it was just me. He said no, I saw them, too. I don't know if that means anything. I mean, I equate it to the building coming down and pushing things down, it could have been electrical explosions, it could have been whatever. But it's just strange that two people sort of say the same thing and neither one of us talked to each other about it. I mean, I don't know this guy from a hole in the wall. I was just standing next to him. I never met the man before in my life. He knew who I was I guess by my name on my coat and he called me up, you know, how are you doing? How's everything? And, oh, by the way did you ... It was just a little strange.

Gregory was positioned in front of World Financial Center 1 at the time of WTC 2's collapse, approximately 100 to 150m away from WTC 2 when this took place, and looking in the right direction since he saw flashes. Had these been explosives, in particular explosives sufficient to destroy structural members per Dr. Griffin's theory, it stands to reason that he would have also recalled shattering windows, the sound of the explosions, feeling the shockwave, or even being injured. He reports none of these events. Neither does anyone else. Only the "flashes" seem to be real.

Mr. Gregory himself indicates that he does not believe they were explosives, and lists a number of other, more credible alternatives, without prompting, in his interview. There is another possibility as well. The author suspects (but cannot prove, of course) that the flashes were actually reflections, caused by windows flexing as the lower stories pressurized during the collapse. The pressure rise inside the building would be transmitted at roughly the speed of sound, reaching from the 80th floor to ground level approximately one second after the progressive collapse began, or around eight seconds before the first structural debris fell next to the building. It would be helpful to analyze video of the ground levels during the collapse, if there is any to be found, to verify this hypothesis. In any event, Mr. Gregory himself discounts the explosives theory, and there are many better explanations.

William Rodriguez, Felipe David, and Jose Sanchez

Dr. Griffin's next evidence concerns accounts of those in the sublevels of the World Trade Center. He recounts the story of William Rodriguez as follows:

> Back in the North Tower, some witnesses reported explosives even further down, in the basements. Janitor William Rodriguez reported that he and others felt an explosion below the first sub-level office at 9AM, after which co-worker Felipe David, who had been in front of a nearby freight elevator, came into the office with severe burns on his face and arms yelling, "explosion! explosion! explosion!" [107]

Before we examine Mr. Rodriguez's account, we must correct Dr. Griffin on his claim that the above took place at 9 AM. This is inaccurate at best. Mr. Rodriguez has claimed that this explosion occurred slightly *before* the North Tower was struck at 8:46 AM. Nowhere does Mr. Rodriguez state that this happened afterward, as Dr. Griffin suggests in his book. Dr. Griffin sources this to the 24 June 2005 article in *The Arctic Beacon* [108], which does not give a precise time. Whether this is a deliberate distortion or carelessness, it does not reflect Mr. Rodriguez's story accurately.

The most precise statement from Mr. Rodriguez is that from his appearance at the NIST Public Meeting on 12 February 2004 [109]. In this meeting Mr. Rodriguez presents a statement during the question and answer section, found on page 70:

> The fire, the ball of fire, for example, I was in the basement when the first plane hit the building. And at that moment, I thought it was an electrical generator that blew up at that moment. A person comes running into the office saying explosion, explosion, explosion. When I look at this guy; has all his skin pulled off of his body. Hanging from the top of his fingertips like it was a glove. And I said, what happened? He said the elevators. What happened was the ball of fire went down with such a force down the elevator shaft on the 58th – freight elevator, the biggest freight elevator that we have in the North Tower, it went out with such a force that it broke the cables. It went down, I think seven flights. The person survived because he was pulled from the B3 level. But this person, being in front of the doors waiting for the elevator, practically got his skin vaporized.

From this statement, it seems perfectly obvious that he, too, is describing the fuel explosion that immediately followed the aircraft impact. This is clearly not evidence of other explosives, and it surely is not evidence that the Towers were demolished, as it took place roughly at the time of impact rather than during the collapse.

Mr. Rodriguez is a problematic source, however, because he has repeatedly modified his story, and now apparently does believe there were explosions (caused by explosives) that detonated *immediately before* the jet impact. From the Arctic Beacon:

> "Seconds after the first massive explosion below in the basement still rattled the floor, I hear another explosion from way above," said Rodriguez. "Although I was unaware at the time, this was the airplane hitting the tower, it occurred moments after the first explosion."
>
> … "I know there were explosives placed below the trade center. I helped a man to safety who is living proof, living proof the government story is a lie and a cover-up." [108]

What is not explained of course is how Mr. Rodriguez determined, from his position in the basement, which of the many loud noises he heard was the aircraft impact, or how he

accounted for the delay as those sounds were transmitted at different speeds through the structure and through the air. Besides the impact itself he could also have heard large pieces of debris hitting the ground outside, as well as the impact of falling elevators, notably the large service elevator near to his position. It is unclear which of these would seem loudest from his perspective. We must therefore conclude that his insistence that the aircraft impact took place afterward is sheer speculation.

The "corroborating" account of Jose Sanchez similarly does not suggest explosives:

> "It sounded like a bomb and the lights went on and off," said Sanchez in the tape recording. "We started to walk to the exit and a huge ball of fire went through the freight elevator. The hot air from the ball of fire dropped Chino to the floor and my hair got burned," said Sanchez in the tape recording. "The room then got full of smoke and I remember saying out loud 'I believe it was a bomb that blew up inside the building.'" [108]

Here Sanchez admits that his first thinking, namely that it was a bomb, was his first reaction – before he had any way to know that an aircraft had struck the building. This account also makes it clear that the explosion in the basement levels took place at least a few seconds *after* the initial event.

The explosion they experienced, the one that damaged the freight elevator, bears all the hallmarks of being caused by jet fuel, and none that match explosives. The "fireball" is proof of a deflagration rather than a detonation. We also have corroboration that jet fuel traveled throughout the Towers from virtually every occupant – as NIST reports in NCSTAR1-7A, 72% of those interviewed from the North Tower recalled smelling jet fuel in the stairwells.

Mr. Rodriguez's account has also changed significantly over time, casting further doubt upon his conclusions and his split-second accuracy. This is outside the scope of this paper but is treated in detail by researcher Mark Roberts [110].

Even supposing we take Mr. Rodriguez's speculation at face value, it is unclear how this supports Dr. Griffin's hypothesis. The explosion he describes here happened at approximately the same instant as the aircraft impact, well before collapse of either tower. Furthermore, if it was an explosive, it was not particularly powerful – it was close enough to Felipe David to burn him severely in a fireball, but it did not kill him, pierce him with shrapnel, or bury him in debris. Such a bizarre explosive would be of no value at all in terms of demolishing WTC 1.

Engineer Mike Pecoraro

Dr. Griffin's final account of explosions is the widely repeated commentary from Mike Pecoraro, a support engineer for the WTC Complex. Dr. Griffin's excerpts are the following:

> Engineer Mike Pecoraro … said that after an explosion he and a co-worker went up to the C level, where there was a small machine shop. "There was nothing there but rubble," said Pecoraro. "We're talking about a 50 ton hydraulic press – gone!" They then went to the parking garage, but

> found that it was also gone. Then on the B level, they found that a steel-and-concrete fire door, which weighed about 300 pounds, was wrinkled up "like a piece of aluminum foil." Having seen similar things after the terrorist attack in 1993, Pecoraro was convinced that a bomb had gone off. [107]

Mr. Pecoraro's commentary first appeared in *The Chief Engineer* magazine [111]. There are several important details that serve to clarify his comments:

1. A "50 Ton Hydraulic Press" is a press that exerts up to 50 tons of *force*, not one that *weighs* 50 tons. These are commonly used in manufacturing. A 50 ton press can be a benchtop device or a stand-alone appliance. One example of the larger type is the Beckwood Model 207 [112], which is approximately the size of a large refrigerator, weighing roughly 3000 kg. Some types of presses are considerably smaller.
2. It is clear that when Mr. Pecoraro says something is "gone," he does not imply that it is "missing." He also refers to the parking garage as being "gone," but clearly there is no empty space left behind – rather, it was heavily damaged and covered in debris. It therefore stands to reason that his comments mean the machine shop (and the hydraulic press) was also buried in debris.
3. Mr. Pecoraro makes it clear that he initially suspected a bomb because of his past experience in the 1993 WTC Bombing. As described in *The Chief Engineer* article, upon leaving the sublevels he heard a rumor that the damage was caused by a helicopter crash, and he believed this to be true until learning the full story. Clearly he did not believe what he witnessed was inconsistent with an aircraft impact.

With this added information, it is obvious that Mr. Pecoraro is also describing the jet fuel explosions immediately after impact. Dr. Griffin makes no mention of this occurring after impact, leaving the reader to wonder whether this was a separate event. Mr. Pecoraro makes it very clear that it is not.

Other Witnesses

Dr. Griffin also cites a few people who felt vibrations concurrent with the Tower collapses. He attempts to seize on minor semantic details of their statements in an effort to prove that they felt such vibrations *before* the collapse began. Without returning to the witnesses in person, it would be difficult to prove one way or the other what they originally intended with their statements. It is also possible that they perceived the shaking before they could see the collapse, which would be understandable given that all of them were at ground level, and would not easily see the first second or two of motion as the Towers collapsed.

Rather than deal with the claims in such fashion, let us assume for sake of argument that Dr. Griffin is correct in his interpretation, and *every single one* believes that a vibration preceded the actual onset of collapse. If this is true, and if a vibration strong enough to be felt and remembered among the chaos of that day really preceded the collapses, then it must have been detectable on seismographs.

However, the seismographs tell a different story. The Lamont-Doherty Earth Observatory captured both aircraft impacts and both collapses on their seismographs, as reported in Vibration Data magazine [113] and elsewhere, and there is no trace of activity preceding either collapse. Additionally, Brent Blanchard of Protec, a service company focused on controlled demolition and structural engineering support, penned an excellent whitepaper [114] directly addressing the claims of Dr. Griffin and others. While this whole paper is worth a read, we focus on the question of seismography, about which Mr. Blanchard writes the following:

> [Page 1] Protec technicians were operating portable field seismographs at several construction sites in Manhattan on 9/11. These seismographs recorded the events at Ground Zero, including the collapse of all three structures. These measurements, combined with seismic and airblast data recorded by other independent entities, provide an unfiltered, purely scientific view of each event.
>
> [Page 6] In all cases, these recordings indicate single vibration events when the buildings collapsed. At no point during 9/11 were independent or secondary vibration events documented by any seismograph, and we are unaware of any entity possessing such data.
>
> This evidence makes a compelling argument against explosive demolition. The laws of physics dictate that any detonation powerful enough to defeat steel columns would have transferred excess energy through those same columns into the ground, and would certainly have been detected by at least one of the monitors that were sensitive enough to record the structural collapses. However, a detailed analysis of all available data reveals no presence of any unusual or abnormal vibration events.

The correct inference is that the witnesses Dr. Griffin cites – those who felt vibrations prior to collapse, but reported no shock, no explosions, no breaking windows or flying debris – were simply mistaken about the exact timing of the vibration. A correction as small as a few seconds would be enough to reconcile their impressions with the quantitative and precise work referenced above. In order to maintain his assertions, Dr. Griffin must take a highly selective approach to the evidence he presents.

Summary

The sixteen witnesses (not counting those who merely felt shaking) have wildly varied stories – eight of them have to do with the collapse, three are well prior to collapse, and five refer to the impact. With the exception of Mr. Rodriguez and his two friends, none of them state definitely that they still believe explosives were present; the remainder use terms like "bomb" as a simile or to describe their immediate impressions only.

Of the sixteen witnesses cited by Dr. Griffin who actually saw or heard explosions, not a single one of them presents anything that cannot be readily explained by the NIST theory, not even with an extremely literal reading as Dr. Griffin has done. It is also significant that not a single one of Dr. Griffin's cited witnesses has any experience with demolition or explosives, or at least none that can be determined from their statements or their profession. All of these accounts are essentially those of amateurs – first responders, reporters, and workers in the World Trade Center, all relaying their impressions of a horrifically chaotic and deadly experience. There is no reason whatsoever to consider

their statements in any way superior to those of experts, either present or reviewing information after the fact, and these experts are overwhelmingly opposed to Dr. Griffin's theory of planted explosives.

Perhaps the strongest argument against Dr. Griffin's claims is that they lack any hint of *consistency*. Recall earlier how we remarked that Dr. Griffin's theory of "controlled demolition" is extremely vague, as he presents no details regarding where or how explosives were placed, what explosives they were (or if they were explosives at all, since he also considers incendiaries in his nebula of theories), when they were triggered, by whom, or why. If we use the witness statements that he has hand-picked to flesh out this theory, we must conclude that the explosives were set off just before collapse, significantly before collapse, during impact, *and* slightly before impact. We would have to accept that explosives were set at the point of impact, on many floors below, at or near ground level, and even in the basement. We would somehow have to explain why some of these explosives created fuel-rich fireballs, why others left no visible damage but merely flashed, and why some shook the ground but had no other noticeable effect. With such a bewildering array of explosive placement, type, effect, and timing, the author states without fear of contradiction that such an outrageous production would resemble no demolition, controlled or otherwise, ever conceived. It is therefore clear that at least *some* of Dr. Griffin's interpretations must be false – and upon closer examination, we find that all of them are suspect.

The burden of proof remains squarely upon Dr. Griffin. His consideration of witness statements puts him no closer to a coherent theory of any kind, let alone one that is backed by solid evidence, or even by mere testimony.

No Other Evidence for Controlled Demolition?

The final section having to do with the WTC Towers is a very long, punctuated list of what we will term "anomalies" perceived by Dr. Griffin. He also continues to focus on the NIST FAQ rather than the NIST Report itself, which, as we have already seen, explains quite clearly why the controlled demolition hypothesis is unsupported. Paradoxically, Dr. Griffin claims this flat rejection itself is *evidence* of controlled demolition:

> NIST's new document moves beyond this self-imposed restriction by discussing some of the phenomena to which advocates of the controlled demolition hypothesis appeal. NIST discusses only a few such phenomena in this document and its discussion of these is very inadequate. But the very fact that it has discussed them is significant for two reasons. First, it has thereby admitted that such phenomena are relevant for choosing between its hypothesis and that of controlled demolition. Second, it has opened itself to the question of why it discussed only a few such phenomena. [115]

There is, of course, another interpretation, namely that NIST was merely responding to questions. Dr. Griffin and others have been vociferous in their claims (as evinced by his several books on the subject), and it is understandable, even commendable, for NIST to address their questions. While the explanation appears to have been unsatisfactory to Dr.

Griffin, this does not absolve him of the burden of proof. Let us now consider his many "anomalies" to determine whether they are, in fact, evidence of a demolition.

The Speed of the Collapses

Dr. Griffin's first "anomaly" is the "free-fall speed of the collapses." We have already treated this in depth. Dr. Griffin has underestimated the time of collapse, and calculations exist in peer-reviewed literature predicting the ordinary collapse time accurately. See also Appendix B for a simplified energy argument verifying this result. The actual time of collapse is consistent with the NIST Report, and therefore does not support any theory of controlled demolition.

"Puffs of Smoke"

In the previous section, we discussed the ejection of smoke and debris described in NCSTAR1-5A, where NIST describes them as "puffs." NIST contends that pressure pulses of relatively small magnitude caused smoke to occasionally billow out from broken windows, and by inference the building collapse would lead to smoke being expelled from many locations. Dr. Griffin lists four reasons why he does not accept this conclusion:

> One problem lies in the very description of these horizontal ejections, sometimes called "squibs," as "puffs of smoke." This description begs the question, which is whether the material ejected was simply smoke from the fires or whether it included pulverized concrete produced and ejected by powerful explosives. [115]

The author argues that this criticism itself begs the question, namely it asserts without any proof or evidence that pulverized concrete (or other materials) was so pulverized by explosives. We have seen no evidence of this. Dr. Griffin's logic is circular.

The "puffs" NIST describes occur *before* collapse. Before collapse, there will be relatively little pulverized material. During the collapse there will be much more pulverized material, and such material would certainly be part of the ejected clouds. The NIST collapse hypothesis predicts this material, and thus there is no need for explosives.

His second reason returns to his previous tactic of citing witness statements from non-experts:

> A second problem with NIST's explanation is that it does not match some of the eyewitness descriptions of the collapses. For example, firefighter James Curran said: "When I got underneath the north bridge I looked back and … I heard like every floor when chu-chu-chu. … [E]verything was getting blown out of the floors before it actually collapsed." If material was being blown out from floors before those floors collapsed, then the ejections cannot be explained as resulting from the collapse. [116]

If Dr. Griffin was precise in his wording when he wrote "a second problem… is that it does not match *some* of the eyewitness descriptions," then he will only be satisfied if NIST's explanation matched *every* eyewitness description – an impossibility, as we have

already seen that many statements are contradictory. Eyewitness accounts invariably contain a few errors, or unusual features owing to individual perspective. Nonetheless, Mr. Curran's account is completely consistent with NIST's explanation. As already described, NIST supposes that material was ejected by pressure. The pressure wave would be transmitted through the structure at close to the speed of sound, which is much faster than the progressive collapse. It is thus completely expected for smoke (and some debris) to be ejected from any given floor before that floor collapsed.

Dr. Griffin's third criticism, vaguely worded, seems to be that the "puffs" (now referred to as "squibs" with no quotation marks) appear similar to smoke features in controlled demolitions. This is apparently based on his own interpretation of videos, as he gives no citations or references of any kind. The author rejects this as speculation. Even if the "squibs" were similar to those seen in controlled demolitions – which they are not, as we will see below – this alone is not sufficient to conclude explosives were being detonated. It is not possible for explosives to produce one feature without the others, such as shockwaves and flying debris, none of which are present. Without *all* the features of explosives, this argument is wrong, because it discounts other possible explanations for the smoke clouds.

Other arguments against the "squibs" are that they are both too few in number, and too slow to be evidence of explosions. We do not see "squibs" on all perimeter columns, or even on a majority, nor do we see them in any symmetric pattern. In fact, even Hoffman's website only claims evidence for *six* "squibs," plus broad smoke emission from a mechanical floor. Because Dr. Griffin does not describe these in any detail, we instead will consider Hoffman's argument in depth. His many claims below are all taken from his website [117]:

- The squibs contain thick dust of a light color, apparently from crushed concrete and gypsum. But these materials would not have been crushed until the pancaking floors above impacted the floor emitting the squib. Thus the dust would not be produced until the air was already squeezed out, so there was no source of the dust for the squib.

Comments: Gypsum crushes readily. We may also be looking at smoke. Cameras and lighting alter shades of grey, and the video stills on Hoffman's site are of extremely low quality. There is no reason to suppose that dust would not be created until "the air was already squeezed out," since any grinding including the aircraft impact would create dust, and some floors had partially collapsed internally before the Towers began to fall.

- The squibs emerge from the facade 10 to 20 floors below the exploding rubble cloud inside of which the tower is disintegrating. The thick clouds appear to contain the pulverized concrete of the floor slabs, which was the only concrete component of the tower. But the piston theory requires that the floors have already pancaked down to the level of the squib, making them unavailable for the production of the concrete dust more than 10 floors above.

Comments: The "piston theory" *does not* require that the "floors have already pancaked down to the level of the squib." The collapse creates higher pressure which can transmit all the way through the entire building, and will be stronger closer to the onset of collapse. 10 to 20 floors' distance is not problematic in any way.

- The piston theory requires a rather orderly pancaking of the floor diaphragms within the intact sleeve of the perimeter wall. Such a process should have left a stack of floor diaphragms at the tower's base at the end of the collapse. But there was no such stack. In fact, it is difficult to find recognizable pieces of floor slabs of any size in Ground Zero photographs.

Comments: The "piston theory" does not require an orderly pancaking, nor does it require that floors would survive later events as the Towers continued to collapse. Any mechanical motion will create the pressurization in the Towers, whether orderly or not, whether complete floors or only portions thereof.

- The North Tower exhibits three distinct sets of squibs at different elevations of the building. Each set is visible as two distinct squibs on the same floor, one emerging from about the horizontal center of each of the tower's two visible faces. This pattern is is [sic] far too focused and symmetric to be explained by the piston theory, which would produce similar pressures across each floor and over successive floors.

Comments: Ordinary controlled demolitions have much more than six "squibs." The sheer size of the WTC Towers and its over 240 columns would require hundreds, if not thousands, if explosives were actually used. The existence of only three sets of two is meaningless by comparison – if we see these six, why not hundreds of others? Hoffman gives no justification for his claim that this is "far too focused and symmetric" – there are simply too few events to discern *any* pattern.

- The pancaking of floors within the perimeter wall would have created underpressures in the region above the top pancaking floor. But we seen no evidence of dust being sucked back into the tower.

Comments: This is incorrect. The upper block is falling at the same speed as the "pancaking" floors, if not actually *pushing* those floors. There is no reason at all to expect an underpressure in the upper block.

As we can see from Hoffman's comments above, the features are easily explained and even expected in the NIST model of collapse. In no way do they suggest explosives. We only see isolated examples on a few floors, insignificant compared to the larger structure. Such smoke features can be caused by broken windows at lower floors or by vents, which were present on the mechanical floors.

Dr. Griffin's fourth and final complaint refers again to the unsupported claim that the WTC Towers actually blew apart rather than collapsed:

> A fourth problem with NIST's explanation, according to which the top floors were exerting tremendous pressure on the lower floors like a giant piston coming down, is contradicted by the visual data. Referring to the same phenomenon discussed above by Judy Wood and Steven Jones, James Fetzer says that NIST's account "might have been true if the floors had actually collapsed as the government maintains, but they were blown up from the top down." [116]

To this, we simply state that the video of collapse initiation shows, without any possible doubt, that the impact floors collapsed. They were not blown apart.

It also bears pointing out that the three supposed experts that Dr. Griffin cites, Drs. Wood, Jones, and Fetzer, all disagree completely with respect to their beliefs. Dr. Fetzer appears to believe, like Dr. Griffin, that explosives were used [118]. Dr. Jones, in contrast, believes that incendiaries similar to thermite were used to weaken the structure, but while he leaves the door open for explosives, he does not require them [8], and he certainly does not agree with the magnitude of explosives described in Dr. Griffin's claim. Dr. Wood, incredibly, has suggested that the WTC Towers were destroyed by "directed energy weapons," presumably fired from orbit [119]. She too discounts the explosives hypothesis, simply because it isn't extreme enough.

Dr. Griffin's pronouncement that the NIST theory "is contradicted by the visual data" is thus unsupported, and his claim that it proves the existence of explosives is disputed even by members of his own camp. The burden of proof remains squarely on his shoulders.

Seismic Spikes

Dr. Griffin next claims that there *may* be evidence of seismic events prior to collapse initiation, which could be interpreted as shocks caused by explosives. However, even Dr. Griffin admits the evidence is extremely weak:

> Whether NIST is correct about this is something I cannot judge. Some students of the collapses who accept the controlled demolition theory believe that the seismic evidence shows that there were pre-collapse explosions. Others do not. [116]

We are able to demonstrate conclusively that those who do believe in pre-collapse seismic signs of explosives are in error. Dr. Griffin cites Christopher Bollyn, along with a whitepaper in the *Journal of 9/11 Studies* produced by Gordon Ross and Craig Furlong. The website by Bollyn [120] contains no numerical data and cannot be evaluated for accuracy. The paper by Ross and Furlong [121], on the other hand, is provably false.

To begin, Dr. Griffin errs about the conclusions of the paper – Ross and Furlong claim that there were seismic spikes *before the aircraft impacts*, not before the collapses:

> On September 11, 2001, the seismic stations grouped around New York City recorded seismic events from the WTC site, two of which occurred immediately prior to the aircraft impacts upon the Twin Towers. Because these seismic events preceded the collisions, it is clear they were not associated with the impacts and must therefore be associated with some other occurrence. [121]

It is totally unclear to the author how or why anyone would have detonated explosives *before* the aircraft impacts, or how these two remarkable events seem to have gone unreported by anyone (with the possible exception of Mr. Rodriguez). However, not even the suspect claims of Mr. Rodriguez match this account, since according to Ross and Furlong, these explosions must have occurred 14 seconds and 17 seconds before WTC 1 and 2 were hit, respectively – much longer than Mr. Rodriguez suggests.

This baffling claim is quickly revealed as a simple failure of research. Ross and Furlong base this conclusion on timing data supplied by the Lamont-Doherty Earth Observatory, and summarize their inputs in Table 1, found on page 2 of the whitepaper. In it, they

state that LDEO detected seismic signals beginning at 8:46:26 and 9:02:54 AM respectively, contrasting with the *9/11 Commission* impact times of 8:46:40 and 9:03:11 AM. This claim immediately raises some suspicion, because if it is true and the LDEO times reflect these mystery events, then LDEO did not detect the aircraft impacts at all. LDEO detects only two events total prior to the collapses, not four.

As it turns out, the seismic event times quoted by Ross and Furlong are inaccurate. Returning to the November 2001 *Vibration Data* article [113], Table 1 on page 5 lists the same times as Ross and Furlong, but it lists them as the *origin times*. This is a critical detail. The "origin time" refers to the start time of an individual seismic record, and not the time of an event located within that record precise to the second, as they assumed.

This is more clearly seen at the Lamont-Doherty Earth Observatory site itself [122]. The second figure shows, as red insets, details of impact and collapse events. Each of these insets has its own scale of time, listed in seconds, and shows the event taking place at about +16 seconds. This larger view verifies that there were no other events anywhere near the times listed, so there is no risk of confusion with another event, such as a real earthquake.

Clearer still is the graphic provided by *Popular Mechanics* [123], where the second graph displays closeups of both impact and both collapse events. The times cited by Ross and Furlong are the time indices *at the left edge of the graphs*, i.e. the "origin," not the actual start time of the event. This is why each index, accurate to one tenth of a second, happens to start on an even second rather than some fraction. All four of the seismic events start later, approximately 16 seconds into each record. A third view [124] provided by the LDEO uses a different origin time – for instance, the first figure shows the first impact occurring at 12:46:30 UTC + 12 seconds to the start of the event. Whichever graph we use, we arrive at the same actual impact time of 8:46:42 EDT, and we again confirm that the time cited by Ross and Furlong is the incorrect time.

In these graphs, the seismic events are in the middle of the seismic records by convention. The LDEO prefers to show events on similar time scales, rather than some sped up and others slowed down, because this would change the apparent frequency of shaking – a consistent time axis makes comparison easier. LDEO also includes a significant time period *before* each event because this allows the reader to understand the background signal, and thus visualize how strong the event is compared to the background. If the extract started at the event, rather than 10 to 20 seconds after, it would be impossible to estimate when the event had finished, because we would not be able to recognize ordinary background. Because Ross and Furlong never account for this ~16 second offset, they are using the wrong time for the seismic event. This is the source of their "anomaly." It has nothing to do with explosives.

Despite the fact that the error above is easily found and verified, and the author has personally informed Mr. Furlong of his mistake [125], the whitepaper still appears, uncorrected, at the "*Journal for 9/11 Studies.*" Mr. Ross, co-author, is also an editor of

that website and thus doubly responsible for its content. This should serve as an example of the integrity and accuracy typical of that publication.

In closing, there is no compelling evidence for seismic signals prior to collapse, or prior to impact for that matter. Instead there is compelling evidence that there were *no* seismic signals prior to collapse, which itself is sufficient to refute Dr. Griffin's controlled demolition hypothesis. Nonetheless, he states the following:

> As this difference of opinion shows, although good seismic evidence for such explosions would certainly strengthen the case for the controlled demolition hypothesis, such evidence is not essential to this case. [116]

Dr. Griffin again has misallocated the burden of proof. The "difference of opinion," caused in reality by basic errors in research, in no way shows that seismic evidence is not essential. Because we now must accept that there *is no* such evidence, Dr. Griffin's theory must be changed to somehow explain this fact. Dr. Griffin does not present, either here or elsewhere in the text, any explanation of how his proposed explosives escaped detection. In any event, this is certainly not evidence *for* his case.

Molten Metal in the WTC Basements

Dr. Griffin next spends nearly four pages on the issue of molten metal appearing after (in some cases, long after) the collapses.

Before we consider the claims individually, it is important to distinguish between mere *molten metal* and *molten steel.* The melting temperature of steel is roughly 1300 ^{o}C, which while theoretically attainable for brief periods in a modern office fire, is a few hundred degrees higher than the maximum gas temperatures predicted by the NIST models. At this temperature, steel glows with a white-hot radiance. By comparison, the melting temperature of copper is about 1000 ^{o}C, aluminum melts at about 660 ^{o}C, and many other metals have even lower melting points, such as zinc (used to galvanize the steel floor decks) melting at 420 ^{o}C, and tin (found in electronics) at 250 ^{o}C. NIST predicts that all of these metals could have been melted at various locations in the fires. While melted, different metals or mixtures thereof are difficult to identify without proper testing. It is therefore important not to confuse molten steel with the other molten metals. Molten steel is remarkable, but molten metal of unknown type is not.

Dr. Griffin begins by claiming that Dr. John Gross, one of the NIST project leads, ignored credible reports of molten steel. Dr. Griffin cites an Internet video [126], but the video may be misleading – in the video, Dr. Gross's response is cut in mid-sentence, and it is impossible to evaluate whether or not he is being fairly quoted.

Whether or not Dr. Gross accurately represented NIST's investigation, Dr. Griffin's argument has two critical flaws. First, regardless of witness comments, there is no way for them to have identified molten metal as steel, and there is no corroborating evidence

that steel itself had melted. Second, even if there was irrefutable evidence of molten steel, this fact would not support a controlled demolition hypothesis.

Dr. Griffin quotes five individuals, including Mark Loizeaux of Controlled Demolition, Inc., and Leslie Robertson, mentioning molten steel. Unless there is some reason to believe they somehow tested the molten metal to verify its chemical composition, we have no reason to believe these comments are accurate either. None of these individuals performed such a test, nor is there any report anywhere of such a finding. We may conclude, therefore, that any "molten steel" they observed was a different liquid entirely, such as molten aluminum, or even melted glass.

We also question the accuracy of the sources themselves. In Note 152, Dr. Griffin reveals that the statements from Mr. Loizeaux and Peter Tully were not ever public, but relayed via Chris Bollyn, who allegedly heard both Mr. Loizeaux and Mr. Tully claim to have seen molten steel on the telephone. Dr. Griffin adds that Bollyn cannot recall the precise date. More recently, Mr. Loizeaux stated to Mr. Ron Wieck, in another telephone conversation, that he "was in no position to see the molten metal and would not have been able to judge whether it was steel or not." [127] Since this is a flat contradiction of Bollyn's claim, we should view his claim as suspect. Other investigators have also followed up on Leslie Robertson's comment and found similar problems. As related in the web log *"Conspiracy Smasher"* [128], Robertson's comments apparently are not a direct quote, but rather originate in an article appearing in the *Newsletter of the Structural Engineers Association of Utah* [129], and may have been exaggerated or misquoted. Robertson's assessment was not part of any official opinion or report, but merely an off-hand comment. In addition, the web log author claims to have contacted Robertson, who then stated that he did not recall making such a statement, and that he would not have been in a position to know whether there was molten steel or not.

Next, Dr. Griffin cites three people who reference steel beams. Two of these accounts speak of steel being "cherry red." Steel at this temperature may be as cool as 400 ^{o}C, and certainly no more than 1100 ^{o}C [130], temperatures well below melting and easily achievable by an ordinary fire – this is actually evidence *against* Dr. Griffin's claim.

The third account does not mention color, but does mention liquid and solid steel in contact with each other:

> Greg Fuchek, vice president of a company that supplied some of the computer equipment used to identify human remains, reported that "sometimes when a worker would pull a steel beam from the wreckage, the end of the beam would be dripping molten steel." [131]

It is clear that Mr. Fuchek was merely in the area, and not working to recover steel, and it is also likely that he has no particular expertise in metallurgy. Furthermore, for molten steel to drip off of a steel column, when both have been in place for some time, the column and dripping steel would have to be in thermal equilibrium. Since steel has a significant heat of fusion, we must assume the liquid and a portion of the solid steel were at the same temperature. If this were true, portions of the steel column would have softened to virtually zero strength or even melted around the edges, and it would be

impossible to pull the beam free without grossly distorting it or actually leaving the half-melted portions behind. It is obvious to the author that the molten metal was not steel at all, but rather some other material with a lower melting point. Once again, this account is not consistent with the claim of molten steel.

Dr. Griffin's next citation is, again, of Dr. Jones. However, here he begins deliberately confusing molten steel and molten metal:

> The existence of the molten metal is very well known, partly because Steven Jones' famous essay begins with this issue. After quoting several people who reported "observations of molten metal in the basements of all three buildings," Jones added:
>
> *[S]ome six weeks after 9/11, the observed surface of the metal was still reddish orange. This suggests that there was a large quantity of a metal with fairly low heat conductivity and a relatively large heat capacity. It is, therefore, more likely to be iron or steel than aluminum.* [131]

Dr. Jones's words are italicized to distinguish them from Dr. Griffin's. As before, a reddish-orange surface color indicates a temperature too cold to be molten steel. It is also important to point out that the collapsed material, far from merely cooling over time, continued to burn fiercely for weeks afterward. This would have sustained the temperatures for a lengthy period, making it unnecessary for the materials to have a "low heat conductivity and a relatively large heat capacity." The *New York Times* reported the following about the debris fire:

> It is no mystery why the fire has burned for so long. Mangled steel and concrete, plastics from office furniture and equipment, fuels from elevator hydraulics, cars and other sources are all in great supply in the six-story basement area where the two towers collapsed.
>
> Water alone rarely can quench this kind of fire, which will burn as long as there is adequate fuel and oxygen and as long as heat cannot escape, fire experts said.
>
> The longest-burning fire on earth, in southeastern Australia, is thought to have been started by a lightning strike 2,000 years ago and is slowly eating away at a buried coal deposit. In Centralia, Pa., a fire that began in a landfill in 1962 spread to old coal mines and has been burning ever since. [132]

Because of this, there is no evidence at all that the materials in the debris pile were much hotter earlier on, and therefore no evidence that they could have reached the melting temperature of steel.

Dr. Griffin now returns to the various statements in the NIST FAQ, attempting to show that NIST neglected critical evidence. Dr. Griffin's argument is summarized as follows:

1. NIST reports that there is no evidence of steel melting prior to collapse of the towers.
2. Dr. Griffin argues that, since molten steel ("or iron;" he further confuses the issue here) was found in the debris pile, it had to have come from somewhere, and NIST claims it didn't come from the fire.

3. NIST states that the condition of steel found in the debris pile is not relevant to the question of what caused the collapses.
4. Dr. Griffin disagrees, claiming that steel found in a molten state is evidence that the same steel was cut by explosives.

This entire argument is wrong. As we have seen above, there is in fact no evidence, apart from a few uncorroborated and speculative statements from non-experts, that steel was *ever* melted, either before, during, or after the WTC collapses. Those few witness statements all reflect the debris pile, not the Towers prior to collapse, thus there is no evidence whatsoever of melted steel before the collapses. NIST is correct in this regard.

Dr. Griffin (and each of his quoted sources) continues to confuse melted *steel* with melted *metal*, and he even brings up melted *iron* at one point (impossible; iron melts at a higher temperature than structural steel). The existence of melted *metal*, as noted previously, is not the least bit surprising – aluminum cladding, electrical wiring, aircraft components, and even some office furniture would be expected to melt over a wide area, and even Dr. Griffin admits the fire could have reached this temperature.

Furthermore, the presence of melted metal (or even melted steel) in the debris pile does *not* guarantee that such metal was melted prior to the collapse. As we have seen, the pile burned fiercely for weeks on end. It is possible, even likely, for these temperatures to have been much higher than the fire temperatures prior to collapse. This is why NIST correctly states that the condition of steel in the debris pile does not necessarily reflect its condition before the collapse. Supposing there was molten steel found in the debris pile, it would not prove that there was molten steel present at any point while the Towers were still standing.

Finally, Dr. Griffin's assertion that molten steel suggests explosives is baffling. Explosives, particularly those used in real controlled demolitions, do *not* melt steel. They destroy steel through impulse, and the very brief shock only heats the steel slightly, that heating caused by internal friction rather than heat from the explosives themselves.

As an extreme example of this, consider the action of artillery shells. These shells are typically pure high explosive contained by a steel jacket – a much more concentrated example than any conceivable controlled demolition scenario. Upon detonation, the steel jacket does not melt. Instead, it fragments, these fragments traveling at high velocity and inflicting most of the shell's damage [133]. When found, these fragments often still bear rifling imprints, threading, and even markings painted on the shell before firing. It is therefore clear that explosives do not normally melt steel, even when the ratio of explosives to steel is extremely high.

Another type of explosive is the shaped-charge, sometimes used in demolition in the form of a linear shaped charge. In this arrangement the explosive is shaped to create a convergent blast wave, which in turn focuses and accelerates a thick coating of metal into a single thin rod or sheet traveling at extremely high velocity. At the instant of detonation, this metal is not strictly liquid or solid – it is essentially extruded at such a

high speed that neither classification is wholly appropriate, instead being sometimes referred to as a "self-forging penetrator" for this reason. Linear shaped charges are sometimes used in demolition to cut through structural elements, and the sheer heat of friction between the penetrator and the structure can indeed melt steel. However, this melting is extremely localized. The most powerful shaped charge ever tested [134] was able to penetrate over three meters of armor steel, but as the photographs of the test show, actual melting was quite limited, essentially no greater than the diameter of the hole blasted by the penetrator. Steel that is melted emerges from the hole as small droplets at high speed, and these rapidly cool and disperse. There is no conceivable way for shaped charges to produce a *pool* of molten steel, which is what Dr. Griffin claims, because the droplets thereby melted do not remain hot for long – they are small, meaning they have a large ratio of surface area to volume, and will cool rapidly by convection, usually in a matter of seconds.

Shaped charges are also precluded by the other available evidence, in particular the nonexistence of seismic or audio evidence of their use. The sound of a shaped charge destroying a steel column is at best no quieter than the sound of that same column being broken mechanically, which is quite loud. There are no signs of penetrator materials or of secondary damage from shrapnel or pieces of penetrators. Placement of shaped charges is also critical, as both distance and alignment must be carefully adjusted for the penetrator to form correctly.

The only possible scenario that could be supported by molten metal, as Dr. Griffin is attempting to argue, is that of Dr. Jones. This theory involves no explosives at all, but rather postulates that high-temperature incendiaries, such as thermite or a similar chemical formulation, were used to heat steel columns until they weakened or actually melted. One of the unmistakable problems with this theory is that, unlike the shaped charge above, thermite or any variant creates a large volume of molten iron, and rather than dispersing it explosively, this molten iron needs to be concentrated in one place to facilitate heat transfer to the structure. Containing thermite is nearly impossible (it can melt through most containers as well and tends to flow straight down as a result).

The thermite hypothesis implies that we *must* find large pools of formerly molten iron in the debris pile – the leftover puddle from the thermite device itself. There are no such blobs or pools of iron. Since, as Drs. Griffin and Jones suggest, the fires in the debris pile were not hot enough to melt steel, they should also not be hot enough to melt these iron blobs, and thus they would be expected to survive indefinitely. The amount of thermite required is also large, since approximately 140 kg of thermite is needed to melt each ton of steel, assuming perfect heating efficiency and no losses whatsoever due to thermal conductivity in the steel itself. We should, therefore, expect to find literally tons of formerly melted iron blobs in the debris pile. We have found none. Similarly, Dr. Griffin himself has presented no hard evidence of melted iron, even though he is clearly motivated to do so.

Rejoining Dr. Griffin's argument, he next continues his reasoning that NIST erred by not considering the possibility of explosives. Citing James Fetzer, he argues that the molten

metal in the debris pile is "relevant" to the collapse, because the debris pile was caused by the collapse. NIST, again, has stated that since it showed the collapses could have occurred without explosives, and there is no evidence of explosives, it needed not consider explosives. On this basis, Dr. Griffin accuses NIST of circular reasoning. It is perhaps best to consider Dr. Griffin's unedited words:

> We have here a perfectly circular argument: NIST articulated its theory. Critics responded that this theory did not explain the molten metal. NIST replied that the molten metal was irrelevant because it plays no role in NIST's theory, which accounts for the collapses entirely in terms of impact damage and fire. [135]

There are several logical errors in this chain of reasoning as well. First, the NIST theory *does* explain the molten metal – melted aluminum and other substances, in large quantities, are predicted by the NIST model. Second, this does play a role in the NIST theory, because this verifies NIST's claim that the fires were hot enough to weaken (but not melt) the structural steel. Third, Dr. Griffin has misinterpreted NIST's response – once again, NIST states that, because of the mechanics of collapse and because the debris pile burned hotly for weeks, structural steel and other materials retrieved from the pile were expected to be slightly or severely more damaged than they would have been just prior to collapse.

Dr. Fetzer's comment that the collapse and the debris pile are "related" is naïve – while the collapse did lead to the debris pile, the debris pile cannot be reconstructed to explain the collapse. Evidence was damaged and destroyed over time, and this process is irreversible. Similarly, Dr. Griffin's contention that the NIST theory does not explain all of the observed evidence is wrong. He has no hard evidence for molten steel, and other molten materials are predicted by NIST's theory.

Dr. Griffin closes this item with another quote from Dr. Jones, and another confusion between molten steel and molten metal:

> It would be interesting if underground fires could somehow produce molten steel, but then there should be historical examples of this effect, since there have been many large fires in numerous buildings. But no such examples have been found. It is not enough to argue hypothetically that fires could possibly cause all three pools of molten metal. One needs at least one previous example.

To this, the author can only restate that *there is no hard evidence of molten steel.* The fires in the debris of the WTC Towers were exceptional and almost without precedent; however, until we have a sample of this allegedly melted steel, there is little point trying to prove that melted steel was possible. Since not even Dr. Jones or Dr. Griffin can point us to an actual remnant of melted steel, no matter how small, we must conclude that this was at best a highly local phenomenon. Otherwise we would expect to see a great deal of melted steel, given that over 10% of the debris was steel and that it sat burning for weeks.

Total (Global) Collapse

This is the first of nine phenomena that Dr. Griffin considers "suggestive of controlled demolition" and "even more damaging to NIST's theory." He begins by stating that the height of the rubble pile was too short:

> As photographs of the site show, the towers, which had been 110 stories high, ended up as piles of rubble about seven stories high. How was that possible, given the fact that each tower, in addition to its 240 perimeter columns, had 47 core columns, which were massive steel box columns? [136]

The author fails to see how the *number* of columns in any way determines the size of the rubble pile – if the WTC Towers had each contained twice as many columns, each half the total footprint, the rubble pile should have been roughly the same size. Nonetheless, Dr. Griffin even errs in his estimation of the debris pile. While it extended for six or seven stories above ground, it also filled the sublevels, for a total of thirteen stories:

> The sheer size and instability of the debris pile posed further complications. The mountain of mangled debris rose six stories above ground and descended seven below; voids within caused ever-changing shifts and constant hazards. [137]

If we suppose that the interior volume of the WTC Towers was about 7/8ths empty space before collapsing, we predict each 116 story structure (counting the sublevels prior to collapse) to collapse into a pile roughly 116 / 8 = 14.5 stories high. This is the height we would expect, to first approximation, if absolutely none of the debris spilled outside the original Tower footprints – and naturally, some did, roughly 20% by some estimates. Therefore, the height of the debris pile is not in any way unusual.

Dr. Griffin continues to err in this section. He next argues that the mere existence of the core columns is one reason why the "pancake theory" was rejected:

> This fact provided one of the major problems for the pancake theory, articulated by Thomas Eagar and endorsed by the 9/11 Commission. … But if that is what had happened, the 47 core columns would still have been standing (even if, as the theory had it, the loss of support from the floors had caused the perimeter columns to fall down). … The 9/11 Commission, in any case, solved this problem by simply denying the existence of the 47 core columns, saying: "The interior core of the buildings was a hollow steel shaft, in which elevators and stairwells were grouped." [136]

As it happens, some of the cores of both WTC 1 and WTC 2 *did* remain standing for a few seconds after the floors and exterior columns had been destroyed, as we saw earlier. This lends some weight to the "pancaking theory" late in the collapses, after perhaps 40 floors or so had failed and the descending mass had reached a high speed. The 9/11 Commission of course did not "deny the existence" of core columns – the passage quoted is a mere figure of speech. The WTC impacts, fires, and collapses are treated in Chapter 9 of the *9/11 Commission Report* [6], and does not contain any mention of "columns" at all, since it is not an engineering report. The only mention at all is in the notes, where readers are referred to the then-current FEMA report.

NIST rejected the "pancake theory," not because it had to "distance itself" from the earlier hypotheses as Dr. Griffin claims, but because a more careful study of the evidence supported a different conclusion. NIST's reasons are the following:

1. Close examination of video prior to the collapses proved that the exterior walls were being pulled inward, which suggests floors remained attached up to the moment of collapse.
2. Photographs also showed floors sagging severely but still attached to the walls.
3. Modeling of the perimeter wall bowing proved that the amount of inward pull required to bow the exterior columns was not enough to sever the floor truss connections.
4. Modeling of a single floor tearing free and falling onto an undamaged floor suggested that the undamaged floor would not be destroyed, thus casting doubt on the ability of the "pancake theory" to sustain a progressive collapse.

Taken together, this provides strong evidence that the "pancake theory" is incorrect, at least during the early stages of collapse, and supports the NIST theory where still-attached floor trusses helped eccentrically load the perimeter columns contributing to the failure. However, with respect to the survival of the perimeter and core columns, neither theory is problematic. The "pancake theory" would *initially* leave core and perimeter columns standing, but it would also remove all horizontal bracing, leaving the columns unable to support their own weight without buckling, let alone able to survive the tremendous vibrations and random events of the full collapse. There is also the descending upper block to consider, which would by itself have enough momentum to cause those elements to buckle. The final result of either "pancake" or NIST-authored progressive collapse would be the same. These two hypotheses only differ with respect to cause and to the first few seconds of collapse.

Dr. Griffin's next complaint is that after the collapse, the columns were broken into small pieces of perhaps 20 to 50 feet long. He also states that there are professional demolition services available that can break steel columns into such pieces:

> My point here, of course, is that the controlled demolition theory could account for the post-collapse condition of the steel columns. [136]

The author sees no reason whatsoever to connect these two statements. In order to state that his theory "could" account for this observation, Dr. Griffin has to treat the observation individually, ignoring all of the numerous other factors that preclude controlled demolition. He also has to prove that the steel columns could not have been broken in any other way.

The NIST theory predicts steel column fragments of this size. The initial stages of collapse show buckling failure of columns in lengths up to approximately three stories high, as verified by photographic evidence. Large pieces of debris falling outside the collapse zone include perimeter columns of approximately this size as well. Wherever floors remain attached and cause buckling failure, we can expect to find columns broken into pieces one to a few stories in length. Bazant and Zhou [21] demonstrate, in a peer-reviewed paper, that the collapse has the momentum to destroy the columns *at every single floor* and still progress.

Another counterargument against Dr. Griffin's theory that columns must have been broken by explosives is that some survived in much larger and much smaller lengths. The most famous is the WTC façade [138], hundreds of feet in width and almost 13 stories high. This cannot have escaped his notice. While most steel pieces were a few stories in height (incidentally, similar to the size of original pieces prior to assembly), there were a great many that were larger, and others that were much smaller as well. Before we can consider his theory complete, Dr. Griffin must explain why we see such variation in the lengths. If, as he claims, the columns could *only* have been broken by explosives, then for every single break in steel structural elements, there was at least one explosive charge. This means there must have been *tens of thousands* of explosives planted in the WTC Towers, which is utterly absurd. Random variation in the chaos of a gravity-driven collapse, on the other hand, explains all of these observations perfectly.

Vertical Symmetrical Collapse

Here Dr. Griffin argues, again, that the Towers should have fallen over rather than straight down. He begins by stating that a vertical collapse is a hallmark of controlled demolition when in close proximity to other structures, and cites Mark Lozieaux, president of Controlled Demolition, with the following excerpt from *New Scientist* magazine:

> "to bring [a building] down … so … no other structure is harmed," the demolition must be "completely planned," using "the right explosive [and] the right pattern of laying the charges." [139]

There are several logical flaws in this position. To begin, the WTC Tower collapses harmed every structure within hundreds of meters, several to the point of complete destruction. There is, therefore, no compelling reason to have brought them down vertically, if this was in any way challenging or suspicious. Second, if the WTC Towers were demolished intentionally, Mr. Loizeaux's comments suggest that Dr. Griffin should be able to provide an estimate of the type and the pattern of the charges used. He has done neither – his vague theory includes every possible explosive compound, and even thermite, which is not an explosive at all, and he has not identified any explosive pattern in time or space. Third, Dr. Griffin ignores the fact that a great many controlled demolitions are *not* strictly vertical. Fourth, even if this is typical of controlled demolition, this in no way serves as evidence unless there are no other explanations – this is again an *affirming the consequent* logical fallacy.

We can gauge the value of this comparison by again considering the J. L. Hudson demolition, the tallest building explosively demolished in history, and in close proximity to other buildings. Video of this event is widely available on the Internet [140]. Like the WTC Towers, the J. L. Hudson collapse was primarily vertical, but unlike the WTC Towers, the J. L. Hudson collapse was preceded by several seconds of carefully timed, easily audible explosions, and did not collapse all at once. While it fell vertically, one end of the structure began to fall first, with some walls standing almost to their full height and only collapsing after the initial collapse had nearly completed. These differences are seen even more clearly in a second video [141], taken from a closer distance.

It is, therefore, simply not enough for Dr. Griffin to state that the WTC Towers "should have" toppled or "looked like" a controlled demolition. He is, once again, arguing from personal incredulity. Before we accept that the WTC Towers should have fallen over rather than straight down, Dr. Griffin must prove that this is in fact what science predicts.

Dr. Griffin does not prove this. His only justifications are the following two excerpts:

> If the 110-story Twin Towers had fallen over, they would have caused an enormous amount of damage to buildings covering many city blocks. But the towers came straight down, rather than falling over. And this was cause for surprise, as illustrated by the reaction of structural engineer Joseph Burns, a partner in the Chicago firm of Thornton-Thomasetti Engineers. Saying that he was "in absolute shock over the whole thing," he exclaimed: "It just came straight down. I've seen buildings collapse like that, but they are buildings set for demolition." [139]

Comments: The Twin Towers *did* cause an enormous amount of damage to buildings covering many city blocks. The shocked reaction of Mr. Burns is no doubt to the horror of the event in total, and certainly does not provide scientific evidence that they should have fallen straight down.

> The main problem is that for the buildings to have come straight down, as Hoffman has pointed out, "All 287 columns would have to have weakened to the point of collapse at the same instant." [142]

Comments: Hoffman is wrong, which is unsurprising given his lack of expertise in structural engineering. What Hoffman and Dr. Griffin neglect is that rotation or other motion of the structure would stress the remaining connections, and cause surviving supports to be broken rapidly after the initial failures.

The NIST hypothesis of collapse initiation does not require all of the columns to fail at the same instant. This is clearly explained in NCSTAR1-6, and even quoted by Dr. Griffin on page 187. Since Dr. Griffin has apparently misinterpreted NIST's comments, let me explain, in my own words, why a slightly more gradual failure is predicted:

The total load on the structure is approximately constant up to the moment of collapse. The structure supporting this load is slowly weakening, through a combination of loss of material strength (caused by heating and annealing), a loss of strength in individual members (caused by creep and inward pulling leading to an increase in strain), and a loss of system capacity (caused by inward pulling leading to eccentric loading, reducing the columns' maximum strength before buckling). Not all structural supports are affected to the same degree or at the same time.

The critical moment of collapse is called the *loss of stability*. Up until this time, an individual structural support can fail without causing a collapse. The load formerly borne by a failing support is redistributed to other supports, usually those nearby, in milliseconds. Any support that "fails" at this time will sag slightly, but will still be attached, and from a distance appears to still be carrying its load, when in reality its strength will be only a small fraction of what it was previously.

When the stability point is reached, there is no longer enough reserve capacity *locally* to prevent a larger scale motion of the building. At this point, when a structural element fails, the nearby elements do not have enough capacity to take the added load. Some of these elements will also fail. Supports close to the local failure will either buckle or tear free. Supports far away from the local failure will also see some increase in their load, and some of these may fail as well, but in others including the WTC case, these elements remain – for a little while.

Local instability leads to local motion, and the upper structure begins to sag in the area of the failure. The surviving structural elements, away from the local failure, begin to see rotation in addition to their increased static load – this rotation creates the "plastic hinges" described in Bazant and Zhou [21]. Supports closer to the rotation will experience a greater share of the remaining load, and a greater twisting motion as the upper structure rotates, and these will fail next. As these supports fail, the load is redistributed further and further away, and soon every support will fail. Twisting will either cause the columns to break free at their connections, or to buckle leaving the connection relatively intact, depending on the relative strength of the connection and the column itself. In either case, the amount of twisting that these columns can survive is not large – structural steel typically flexes only about 3% before strain hardening begins, and rotation can lead to a significant leverage effect in the connections. All such connections will fail before the far corner of the structure descends by a single floor. This means that the local collapse leads to a global collapse in a period of less than one second.

In order for the structure to actually topple over sideways, the upper structure would have to rotate by, say, 45 degrees, which would put the centroid of the WTC 1 upper block approximately at the edge of the lower block. Recall that the structure was 208 feet across. Rotation by 45 degrees means that, if the hinge point is along one exterior wall, the opposite side of the upper block must fall "through" about 163 linear feet of the structure below. If the hinge point is at the center, the descending side must crush through 82 feet, while the ascending side must somehow rise, breaking all of its supports through tension. Despite this damage, the supports at the hinge must continue to support the full load of the upper block as it rotates. Even assuming the upper block and the hinge would survive this behavior, it is therefore impossible for the upper block to topple over without first "falling vertically" through an enormous part of the lower structure. For this reason, claims that the Tower should have toppled *instead of* collapsing vertically are nonsensical – you cannot have toppling without some vertical collapse, although you can have vertical collapse without toppling. The toppling collapse also requires this crushing to be asymmetric, only occurring on one side, which is simply not plausible – as the leading edge of the rotating block crushes structure below, the crushed structure resists, and this reactive force will tend to keep the upper block centered, meaning the likely outcome is either a downward collapse or no collapse at all. For these reasons, in a structure of these dimensions, the vertical collapse is strongly favored energetically, even discounting the fact that the upper structure also tends to break up under its own weight when rotated.

If all the supports had failed simultaneously, as Hoffman insists, neither of the WTC Towers would have displayed the rotation seen above. In reality, both Towers did rotate a few degrees, which is precisely what we expect in a gradual collapse mechanism. There is, therefore, no reason to believe the supports failed simultaneously, or that they must in the NIST model. NIST never makes this claim.

Dr. Griffin still insists that his belief is "obvious," again shirking the burden of proof:

> NIST again did not explain a very obvious feature of the collapses. The fact that it did not even try suggests that it, knowing it could not explain it, simply had to hope that most readers would not notice. In any case, although this feature of the collapse cannot be explained by NIST's theory, it can readily be explained by the controlled demolition theory. It is, therefore, another part of the evidence for the truth of this theory. [142]

If the above was correct, it should be a simple matter for any engineer, physicist, architect, or materials scientist to publish a paper describing why toppling behavior of the Towers would be expected. There is no such paper, not even in the "*Journal of 9/11 Studies*." In contrast, there are several papers describing how the collapse could indeed progress vertically, and even prove that it could happen through more than one mechanism [21] [143]. Far from being obvious, Dr. Griffin's claim is unsupported and contradicted by science, i.e. wrong.

Pulverization and Dust Clouds

The next claim is a reiteration of Dr. Griffin's position that the large dust clouds were unexpected or in some way abnormal. Dr. Griffin claims that "virtually all" of the nonmetallic contents were reduced to a fine powder, and then states that this observation is "not controversial," citing two off-the-cuff witness statements and an environmental health study that found the dust contained microscopic glass fragments.

These unsupported and subjective statements are insufficient, and it comes as no surprise that small glass fragments were present in the dust. While a significant fraction of the materials was pulverized into fine powder, the notion that "virtually all" of it was so pulverized is not only controversial, but incorrect. As we have already seen, even Dr. Steven Jones, whom Dr. Griffin frequently cites, has stated in print [75] that this is a "false premise." Phillips and Jordan, Inc., reported [144] that 806,000 tons of nonmetallic debris was screened and processed at the Fresh Kills landfill, and we may assume that none of this was in the form of fine powder, as that inhibits screening.

Dr. Griffin next claims that the energy of collapse would be insufficient to create this dust. This claim is particularly revealing of both his poor scholarship and the details of his controlled demolition theory:

> This fact creates another enormous problem for NIST's theory, according to which the only energy available was the gravitational energy. Although this energy would have been sufficient to break most of the concrete into fairly small pieces, it would not have been close to sufficient to pulverize most of the concrete and other non-metallic contents of the buildings into extremely tiny particles.

> … The dust clouds produced at the Twin Towers differ [from those at the Seattle Kingdome or Reading Grain Facility demolitions] only by being much bigger, which is what could have been predicted, given the fact that these buildings were much larger, so they would have required more powerful, and a greater number of, explosives. [145]

Dr. Griffin's claim that the gravitational energy is insufficient is supported by no calculations, no estimates, and no cited sources. He merely presents this as an assertion. The author demands a calculation explaining this claim before it can be taken seriously.

While Dr. Griffin has presented no calculation, others such as Drs. Bazant *et al.* [72] have, and this work demonstrates that the collapse had sufficient energy to pulverize all concrete contained in the Towers into 100 micron sized particles, and still collapse in the time observed. Dr. Bazant's calculation includes the energy of dust creation along with all other energy costs. This flatly disproves Dr. Griffin's assertion.

Let us for the moment overlook this error, and follow Dr. Griffin's line of reasoning. He has stated that the dust created – or a majority thereof – must have been caused by explosives. His evidence is that the gravitational collapse energy is insufficient. He admits that he has no other evidence, since the dust clouds "differ only by being much bigger" than conventional demolition. He then concludes that the explosives used were "more powerful" than those used to demolish the Seattle Kingdome.

The Seattle Kingdome was imploded by Controlled Demolition, Inc., using roughly 4,700 pounds (2,200 kg) of explosives and 21.6 miles (35 km) of detonating cord [146]. For sake of comparison, the DELTA group [147] estimated the gravitational energy of the Towers at 5×10^{11} J, or 2.5×10^{11} J released in each of the two collapses, which is equivalent to the energy output of roughly 60,000 kg of TNT per tower. (Our own rough estimate, presented in Appendix B, is slightly higher at 100,000 kg TNT per tower.)

When Dr. Griffin claims that the WTC Towers contained more explosives than were used at the Kingdome, this means his theory requires over 2,200 kg per tower. However, since he has also stated that the gravitational energy was insufficient to create the dust, and that explosives must have been responsible, this raises the bar much higher – his theory now requires that more than 60,000 kg of explosives were detonated *in each tower*. This is greater than the payload capacity of two B-52 heavy bombers per tower.

60,000 kg of high explosives – 60 metric tons – is an enormous amount by any measure. Historically, there have only been a handful of non-nuclear detonations of this size or larger, all creating enormous fireballs and shock waves strong enough to visibly compress water vapor from the atmosphere. Despite the extremely unusual nature of such a large event, Dr. Griffin has *no conclusive evidence* of explosives – no sounds, no flashes, no shockwaves, no shrapnel, no chemical residue, no seismic activity, and no physical remains of any explosives. Hundreds of thousands of people would have personally witnessed this. Glass windows sheltered from debris were not shattered, helicopters flying nearby were not destroyed, and a few lucky survivors were even pulled alive from the lower levels after the collapse had ended. Dr. Griffin provides no

explanation of how this is possible. He also has produced no explanation of how such a staggering amount of explosives could have been smuggled into the Towers without detection, how it could have been placed without being seen, how many individuals would have been required to plant it all, or how long this process would have taken. Just one of the hurdles would have been wiring the explosives – using the Kingdome as a reference, this explosion would have required almost 1,000 km of detonating cord to be strung in each tower.

Dr. Griffin's claim also drives a wedge between his own theory and that of Dr. Steven Jones. Earlier in Dr. Griffin's book [8], he left open the possibility of "incendiaries" rather than explosives, but incendiaries do not create dust. Because Dr. Griffin claims the dust was created by "controlled demolition," he has no alternative to explosives except to propose that explosives were used *in addition* to incendiaries, or unless he embraces a theory involving science-fiction weaponry such as that proposed by Dr. Wood.

On the basis of the analysis above, it is now clear why Dr. Griffin refuses to present any details of his controlled demolition theory. The details that may be inferred from his conclusions prove its absurdity, even if there was no ready alternate hypothesis available, such as the NIST Report provides.

Returning to Dr. Griffin's comments, another of his objections is that much of the dust was created quickly – in the first few seconds of collapse – making gravity an "unsuitable" source of mechanical energy. He quotes Hoffman as follows:

> You can see thick clouds of pulverized concrete being ejected within the first two seconds. That's when the relative motion of the top of the tower to the intact portion was only a few feet per second. [145]

He also quotes Jeff King, adding the comment that Mr. King was "trained as an engineer" (in an apparent reference to the Electrical Engineering degree that King received prior to beginning medical practice in the 1970's), with the following:

> very fine concrete dust is ejected from the building very early in the collapse… [when] concrete slabs [would have been] bumping into each other at [only] 20 or 30 mph. [148]

Once again, neither source presents any calculations. Both also make the assumption that the dust ejected early in the collapse was actually composed of concrete. It is possible that the dust at that time was made up of gypsum wallboard (which creates dust readily) and smoke, with the concrete fracturing taking place later in the collapse or after collision with the ground. It is also important to remember that the initial dust creation was *on the fire floors* – and concrete, after being exposed to lengthy fires, tends to spall, leading to flaking and general weakening of the concrete affected:

> Spalling can be described as the breaking of layers or pieces of concrete from the surface of a structural element when it is exposed to the high and rapidly rising temperatures experienced in fires (as defined in CIRIA Technical Note 118).
>
> There are three main types of concrete spalling:

- **Surface spalling** affects aggregate on the concrete's surface, whereby concrete fragments typically up to 20 mm in diameter become detached.

- **Corner break-off** or sloughing off. This tends to occur in the later stages of a fire and affects more vulnerable concrete on wall corners where it is heated on two planes.

- **Explosive spalling** early rapid heat-rise forcibly separates pieces of concrete at high pressure, with an 'explosive' effect. The most dangerous form of spalling.

> The conventional theory of explosive spalling is that it is chiefly caused by the build-up of water vapour pressure in concrete during fire. If the concrete is not very permeable, water vapour formed within it during heating will not be able to dissipate and pressure is formed. When that pressure exceeds the tensile strength of the concrete, explosive spalling will result. [149]

Furthermore, Mr. King's claim about concrete only fracturing due to the *speed* of impact is totally irrelevant. Concrete fracture under compressive strain can occur at any speed, even creeping speeds, provided there is sufficient force, energy, or momentum. Given the incredibly high load and impulse delivered by the descending upper block, the fact that it was traveling at "only" 20 or 30 miles per hour is of no consequence – we are talking about *thousands of tons* of concrete moving at those speeds, and later in the collapse moving much faster still.

Dr. Griffin's final claims are to seize upon Dr. Shyam Sunder's use of the word "floors pancaking" in a press conference, and to remark that dust was also formed "far above" the point of impact. Both are non sequiturs. The word "pancaking" is imprecise, and Dr. Sunder's use of it in this context in no way contradicts the NIST hypothesis. Video shows no evidence of dust forming above the collapse zone (which began at the impact floors) until the upper block had fallen and begun to disintegrate, and such dust is also easily confused with smoke. Again, Dr. Griffin has argued from, in the words of Dr. Steven Jones, "a false premise."

Horizontal Ejections of Pieces of Steel

Dr. Griffin's next observation is that a number of large steel fragments (as well as aluminum cladding) were found several hundred feet away from the original sites, with as much as 600 feet claimed. He states without proof or support that the steel could not have traveled so far in a gravity-driven collapse. This, to him, also proves that "large and powerful explosives" were to blame:

> According to NIST's theory, the only energy available was gravitational energy, which is strictly vertical, causing matter to fall straight down. It is hard to imagine what could account for the horizontal ejections of extremely heavy pieces of steel, except very powerful explosives. [148]

The author can imagine several other explanations. Because the Towers were of great height, it would take a relatively small horizontal velocity to travel 600 feet – for example, a piece ejected from the 50th floor would remain airborne for at least 6.3 seconds, and thus could travel the 600 foot maximum distance if it had an initial horizontal velocity of only 95 feet per second, or 65 miles per hour. It is easy to see how

such a piece could acquire this velocity through either elastic collision, as a fragment thrown off in a violent column failure, or potentially thrown off through leverage if a partially intact assembly was hit off-center and rotated by the falling mass (much as an automobile can launch a shovel a great distance by running over the blade).

Let me consider the first and simplest example, that of a ricochet. Suppose a large piece of steel is broken loose and swept along with the upper block at the very edge. This piece then experiences a hard collision with the lower block – say the beam-framing of one of the mechanical floors – and ricochets outside the falling mass, becoming an effectively free ballistic projectile until it hits the ground or another building. If the piece ricochets elastically, which is possible for a steel-on-steel collision, then it can rebound with almost the same speed at which it was falling before the collision. To reach 600 feet distance, the piece can be ejected lower in the structure at which point it will have picked up more speed; or it can be ejected higher, in which case it will ricochet with less speed, but it will have more "hang time" in which to travel.

There are many ricochet solutions possible in the WTC collapses. To pick one at random, a piece pushed at the front of the upper block until ricocheting horizontally at the 50^{th} floor would be ejected with a speed of about 95 feet per second, using the "crush down" velocity profile predicted by Dr. Bazant *et al*. Upon bouncing off horizontally, it would still have 6.3 seconds to fall, and would reach a distance of 605 feet away from the former Tower perimeter. If the piece bounced at a slight upward angle, but still rebounded elastically, it could reach an even greater distance. (This calculation does not include aerodynamic drag, but a large, dense, slender object like a steel column will have a high ballistic coefficient, and drag will have a relatively minor effect.) Many such possible scenarios can be computed. Therefore Dr. Griffin's assertion, that the NIST theory *cannot* explain this event, is false.

Regarding Dr. Griffin's preferred theory, it should be pointed out that explosives rarely impart much momentum to solid objects, unless the explosive is actually contained – material making up a solid casing will be fragmented and sent at high velocity (i.e. shell fragments), but nearby solid objects will hardly move at all. This is because explosives create a *pressure shock* that moves at supersonic speeds. The explosive may exert a high pressure on nearby objects, but the pressure rapidly "washes over" those objects and thus does not have time to impart a large impulse. Unless the pressure wave is somehow contained, the wave will rapidly move beyond nearby objects, at which time they are no longer accelerated. This effect is reminiscent of big-wave surfing – a truly large wave moves too fast for a surfer to gain much of a push from it and it will simply pass him by, unless he has either a longer, faster board or is towed into the wave by a jet ski.

For a worked example, Rememnikov [150] presents a typical charge of 100 kg TNT exploding at a distance of 15 meters. A series of objects placed at this distance would experience 272 kPa or just under 40 PSI, but would only experience the overpressure for 17.2 milliseconds, including the reflection of the blast, after which the pressure wave has passed the objects. Let's assume we're discussing a section of unattached, hollow square steel column 3 m high by 20 cm wide, with walls 4 cm thick. This object presents a

maximum of 0.6 m^2 to the blast front, so it experiences a maximum force of 272 kPa x 0.6 m^2 = 163,200 N for 17.2 milliseconds, for a total impulse of 2807 Newton seconds.

It should be noted that the simplified calculation above grossly overestimates the total impulse, because we have assumed the *peak* pressure is sustained for the entire duration, when in reality a lower average value is expected. The actual expected impulse per facing area, seen in Table 1 of Rememnikov's paper, is a mere 955 kPa-msec, or only 573 Newton seconds imparted to our column as above. We therefore are using a *very* generous estimate, almost five times higher than we actually expect. We will use our simplified estimate rather than the lower, more accurate number to silence any doubts that we have potentially underestimated the maximum imparted velocity.

The total impulse is equal to the mass of the object times the change in velocity. In this case, our column contains 256 cm^2 x 3 m of steel or 76,800 cm^3 of steel, for a mass of approximately 600 kg. The column would, therefore, be accelerated by 2807 N s / 600 kg = 4.7 meters per second, or about 10 miles per hour – hardly a remarkable value compared to the ricochet scenario described above. In order to propel this column at the speed required, say 30 meters per second, we would need charges of at least 700 kg TNT equivalent – very large and clearly audible explosives indeed, even accepting our generous assumptions above.

What these examples prove is that, while explosives *can* impart large objects with a significant velocity, it requires either enormous explosives indeed, or very large explosives at extremely small distances. Gravitational energy is capable of ejecting steel comparable distances until the explosives reach many tons of TNT equivalent in size.

Also missing from Dr. Griffin's analysis is that, if large pieces of steel were propelled by explosives, then smaller pieces should have traveled further still – as a material shrinks in size, its surface area to volume ratio rises. A piece of steel scaled down by 50% would experience four times less impulse, but would weigh eight times less, and thus receive twice as much initial velocity. This means that, if explosives had propelled steel fragments, we would see small pieces propelled much further than large pieces – and this is not the case. If explosives had driven a large fragment 600 feet, then very small pieces would have been ejected like shrapnel, damaging buildings and killing onlookers at distances of hundreds or even thousands of meters; this too did not happen.

In contrast, in the gravity-driven ricochet model, all pieces fall at the same rate regardless of their size, and therefore can ricochet similar distances; in this case larger pieces will travel slightly farther as they are less susceptible to drag. This is consistent with observations, and with the NIST theory. Again Dr. Griffin has failed to provide any evidence of explosives.

Sulfidization of Steel

Dr. Griffin next remarks on the fact that a few fragments of recovered steel appeared to have been "sulfidized," i.e. found in an eroded state with sulfurous chemical impurities in the metal itself, and claims that this, too, is evidence of explosives.

First, let us look at the evidence for sulfurization. Dr. Griffin cites Drs. Biederman and Sisson at the Worcester Polytechnic Institute with the discovery, and also quotes them accurately as stating that it was a *eutectic reaction*, though he makes no comment on this important fact. He also quotes Jonathon Barnett as follows:

> Another WPI professor, Jonathon Barnett, specifically pointed out that fire and structural damage "would not explain steel members in the debris pile that appear to have been partly evaporated in extraordinarily high temperatures."[190] [151]

The note 190 appears in Dr. Griffin's original text. Elsewhere the author has removed his notes to avoid confusion with those in this paper, but his note is included this time because it is important, and clarifies a source of misdirection on his part. The note reads:

> 190 Glanz, "Engineers Suspect Diesel Fuel in Collapse of 7 World Trade Center." I have here quoted Glanz's paraphrase of Barnett's statement. [152]

This note reveals not one, but two examples of selective quoting where Dr. Griffin has deliberately attempted to change the intent of his quoted source. First, as the reader can probably ascertain, the sulfidized steel may have nothing to do with the WTC Towers, but instead comes from World Trade Center Building 7. We will treat Building 7 in the following chapter, but in the meantime, Dr. Griffin fails to inform the reader of this fact. He is, instead, attempting to use a piece of steel from Building 7 to argue that there were explosives in Buildings 1 and 2. (Dr. Biederman notes that there was also a single example of sulfidized steel from one of the Towers, but cannot even identify which one, making it difficult to investigate further. We will remark on this sample below.)

The second misleading editorial maneuver is that he is "quoting Glanz's paraphrase" rather than Dr. Barnett's actual words. Glanz is James Glanz of the *New York Times*, who reported on this subject on 29 November 2001, and the words extracted by Dr. Griffin are Mr. Glanz's, not Dr. Barnett's. This calls the word "evaporated" into question – not least because the vaporization temperature of steel is roughly 2700 ^{o}C, an absurdly high temperature, but also because the article itself has been edited. Comparison of the original archived online [153] versus the final title from the *Times* [154] demonstrates that the Mr. Glanz changed the focus of his column, originally referring to it as "Engineers are Baffled," but later retitling it "Engineers Have A Culprit." Indeed, in the article none of the engineers interviewed, including Silvain Marcus, one of the original engineers who designed WTC 7, states any disbelief or suspicion of explosives. The debate is whether diesel fuel or utility lines were *required* for the structure to fall, or the fire would have caused the collapse even without these additional fuel sources.

Can we verify that no steel "evaporated," according to Biederman, Sisson, and Barnett? Indeed we can, by going directly to the source. Biederman *et al.* reported on their findings as follows:

> The as-fabricated microstructure consisted of a hot worked banded structure of ferrite and pearlite. In severely "eroded" regions where the thickness had been reduced to less than a 1/16 of an inch significant decarburation was observed. In addition, some pearlite bands presented regions that had re-austentized as well as regions where the pearlite had started to spheroidize. These observations indicate that steel had experienced temperature between 550 and 850°C.
>
> An examination of the "slag" that formed on the surface of the steel found iron oxides and iron sulfides. It appeared that the "slag" was liquid at high temperature and easily attacked the grain boundaries. A eutectic microstructure was seen within the "slag" of iron oxides and iron sulfides. If these compounds were pure Wustite (FeO) and Iron sulfide (FeS), the eutectic temperature is 940°C. It appears that the severe "erosion" was due to the sulfidation and oxidation (i.e. hot corrosion) of the steel followed by the liquid "slag" attack of the grain boundaries. [155]

Dr. Biederman clearly indicates that the temperature of the sample had never exceeded 850 °C, which is nowhere near steel vaporization temperature, well below steel melting temperature, and quite plausible in an ordinary fire. Dr. Griffin has therefore completely changed the words of these scientists with his misquoting.

Regarding the sample from WTC 1 or 2, Dr. Biederman sees more evidence of chemical attack, possibly a different corrosive reaction in this case:

> A sample from either Building 1 or 2 presented similar macroscopic observations. In these buildings, the steel was a High Strength Low Alloy Steel (HSLA). The microstructure revealed somewhat different phase distributions. This steel contained less carbon and an alloy addition of copper. The "slag" while comprised of both iron oxides and iron sulfides presented a significantly different microstructure near the surface as shown in Figure 3. [155]

This sample is less relevant because it appears to show a chemical reaction catalyzed by fire, perhaps fire and chemical attack after collapse, rather than proof of a weakened material before collapse, as indicated by the different microstructure. Like the WTC 7 samples, this mixture would have melted at temperatures of 940 °C. This piece probably did not contribute to the collapse and was therefore beyond the scope of the NIST study. This is not conclusive; however, this is also the only known sulfidized fragment from either Tower, and further investigation without more evidence would be difficult.

At this point we should review the critical word *eutectic*. A eutectic mixture is a mixture of two ingredients such that, even though the ingredients may not interact chemically, they mutually impede crystal formation, and as a result the mixture has a melting temperature much lower than that of either ingredient on its own. Think of ice mixed with salt – independently, water melts at 0 °C while the melting temperature of salt is rather high, but the saltwater mixture melts at -10 °C or even lower depending on the concentration. Something similar is happening with this steel sample. Somehow it has acquired sulfur, and though *the eutectic mixture has not melted,* it could melt at a lower temperature than ordinary steel. Dr. Biederman estimated the melting temperature of this particular eutectic mixture at 940 °C. This is the *eutectic temperature*, i.e. the temperature at which the mixture melts and the ingredients will begin to separate.

As a result, the samples recovered from WTC 7 do not prove any extraordinary temperatures. Having said that, the existence of the eutectic mixture was a surprise to

many scientists, and remains one of the details not fully understood to this day. What it is definitely not, however, is evidence of explosives.

Dr. Griffin claims that it *is* evidence of explosives, based on extremely simple reasoning:

> The journal further suggested the significance of the discovery by pointing out the presence of sulfur in this eutectic reaction… This point is especially significant because, as Steven Jones has pointed out, sulfur is a common ingredient in explosives. [151]

This reasoning is also particularly specious. There are innumerable sources of sulfur that do not involve explosives, such as diesel fuel for emergency generators, sulfuric acid found in batteries and uninterruptible power supplies, possibly gypsum wallboard, and even human bodies. On the other hand, sulfur is an ingredient in some low explosives such as black powder, but it is not part of TNT, RDX (and by inference C-4), HMX, PETN, nitroglycerin, dynamite, or any other common or suitable explosive that the author is aware of, with the possible exception of ANFO if the fuel oil just happened to include a high sulfur content. Confused by this statement, we search Dr. Griffin's reference to Dr. Steven Jones, which leads to page 35 of his whitepaper entitled "Why Indeed Did the WTC Buildings Completely Collapse?" We do not find any mention of sulfur or explosives on page 35, but we believe we have the correct passage on page 20, which reads as follows:

> Finally, sulfidation was observed in structural steel samples found from both WTC7 and one of the WTC Towers, as reported in Appendix C in the FEMA report. It is quite possible that more than one type of cutter-charge was involved on 9/11, e.g., HMX, RDX and thermate in some combination. While gypsum in the buildings is a source of sulfur, it is highly unlikely that this sulfur could find its way into the structural steel in such a way as to form a eutectic. The evidence for the use of some variant of thermite such as sulfur-containing thermate in the destruction of the WTC Towers and building 7 is sufficiently compelling to warrant serious investigation. [156]

It is clear that Dr. Jones does *not* claim sulfur is a sign of explosives after all. Instead, he believes the sulfur signal comes from "thermate," which is not an explosive, but merely an incendiary. In the passage above, Dr. Jones – like Dr. Griffin – appears to be leaning towards a complicated scenario involving both explosives *and* incendiaries, although his reasoning can be refuted quickly: His evidence for incendiaries is the sulfidized steel. However, Dr. Biederman *et al.* proved that the steel experienced temperatures no higher than 850 ^{o}C, and would melt, destroying the mixture, at 940 ^{o}C. Thermite and thermate burn at temperatures far higher than this, therefore they could not possibly have left this sulfidized steel as evidence. Thermate also contains barium – roughly ten times as much barium as sulfur, in the form of barium nitrate before ignition – and there is no evidence of barium. Dr. Jones is therefore simply wrong. Dr. Griffin, for his part, seems to have misunderstood Dr. Jones, confusing thermate with explosives in a bid to support his own, still completely unsupported, controlled demolition hypothesis.

Moving on, Dr. Griffin further weakens his own hypothesis:

> The WPI journal, while not mentioning the possible use of explosives, did describe the damage to the metal in a way that would seem hard to explain if explosives had not been used, saying:

> *The significance of the work on a sample from Building 7 and a structural column from one of the twin towers becomes apparent only when one sees the heavy chunks of damaged metal. A one-inch column has been reduced to half-inch thickness. Its edges – which are curled like a paper scroll – have been thinned to almost razor sharpness. Gaping holes – some larger than a silver dollar – let light shine through a formerly solid steel flange. This Swiss cheese appearance shocked all of the fire-wise professors, who expected to see distortion and bending – but not holes.* [151]

Italicized words are those of Joan Killough-Miller [157] as cited by Dr. Griffin on page 190 of his book. The author states as self-evident that the phenomenology reported – reduced thickness, shaved and curled edges, and circular holes in a solid piece of steel – bear all the hallmarks of chemical attack, and none of explosive impact. If the steel was so damaged, it should also be bent or broken by the force of the explosive. We also know that the steel was sulfidized, which implies chemical activity, and that the steel was weakened thereby, making it even less likely to endure an explosion with only holes and scouring as a result. Dr. Griffin has not explained why this suggests explosives to him, and the author is unable to conceive of any possible reasoning leading to this conclusion.

Dr. Griffin closes this set of observations by remarking that the initial FEMA report identified the sulfidization and called for further inquiry, while the NIST Report did not mention it. This is correct, but irrelevant – the FEMA report mentions this as part of its report on WTC 7. At time of writing, NIST has not yet issued its report on WTC 7. It is premature to criticize NIST for not addressing this question. It may (and should) address this issue in the final report.

North Tower Antenna Drop

The next claim is that the North Tower (WTC 1) antenna, indicative of the behavior of the "hat truss," was not treated by NIST. Dr. Griffin cites the FEMA report:

> the transmission tower on top of the [North Tower] began to move downward and laterally slightly before movement was evident at the exterior wall. This suggests that collapse began with one or more failures in the central core area of the building. [158]

Dr. Griffin states that, since the NIST Report does not mention this event, and because the "hat truss" should guarantee that the antenna and perimeter walls would remain bound together, it would be impossible for the antenna to fall before the perimeter walls. Thus he reasons that NIST is incorrect. He further suggests that this is "perhaps only possible" if the core columns had been "sliced by explosives."

The NIST report does in fact briefly treat the antenna drop. For example, on page 151 of NCSTAR1-6, NIST points out that the antenna may have merely appeared to sink first from some vantage points when, in reality, it was an illusion caused by tilting of the upper section. Regardless, even if we take Dr. Griffin at his word, his argument is difficult to follow. One would have expected Dr. Griffin to claim instead that the *hat truss* must have been "sliced," rather than the core columns, but he does not. In any event, the FEMA observation, as well as Hoffman's concurrence that the antenna appeared to drop first, is actually in complete agreement with the NIST theory, as we will

now explore. From NCSTAR1-6D, the official NIST collapse sequence includes the following, on page 314:

> With continuously increased bowing, as more columns buckled, the entire width of the south wall buckled inward. Instability started at the center of the south wall and rapidly progressed horizontally toward the sides. As a result of the buckling of the south wall, the south wall significantly unloaded (Fig. 5-3), redistributing its load to the softened core through the hat truss and to the south side of the east and west walls through the spandrels. The onset of this load redistribution can be found in the total column loads in t WTC 1 global model at 100 min in the bottom line of Table 5-3. At 100 min, the north, east, and west walls at Floor 98 carried about 7 percent, 35 percent, and 30 percent more gravity loads than the state after impact, and the south wall and the core carried about 7 percent and 20 percent less loads, respectively. The section of the building above the impact zone tilted to the south, as column instability progressed rapidly from the south wall to the adjacent east and west walls (see Fig. 5-8), resulting in increased gravity load on the core columns. The release of potential energy due to downward movement of the building mass above the buckled columns exceeded the strain energy that could be absorbed by the structure. Global collapse ensued.

What this means is the following:

1. At the critical moment of failure, only the south wall had effectively failed. The other three perimeter walls were nearing capacity but still providing support.
2. The core, on the other hand, had compressed due to broken columns and creeping behavior. It had "unloaded" through the hat truss, meaning the hat truss was partially suspending the core.
3. After the south wall buckled completely, the core, already weakened, failed simultaneously with or slightly before the other three walls.
4. Prior to failure, the load in the core area was greater than that of any perimeter wall, as seen in Table 5-3. At floor 98, the core load was 15% greater than any two perimeter walls combined. This reflects the fact that the core was the heaviest part of the structure, particularly at higher floors.
5. For this reason, at the moment of failure, we do indeed expect the core to collapse slightly before three of the four perimeter walls, and the fourth wall would be partly supported by the spandrels in addition to the hat truss. The hat truss will therefore buckle in the center first. This explains the "antenna drop" seen by FEMA and others.

Having understood NIST's actual theory, the author sees no inconsistency whatsoever, and thus no evidence for explosives. While NIST may not discuss the antenna drop in detail, it does discuss the behavior of the hat truss. The motion of the hat truss, supporting the antenna, is for all intents and purposes equivalent.

South Tower Tipping and Disintegration

Dr. Griffin next turns to WTC 2, and claims that (1) the upper block should have fallen outside the building footprint, and (2) the block's rotation should have continued as it fell, both according to conservation of momentum.

This, perhaps more than any other passage, confirms Dr. Griffin's poor grasp of elementary physics. Suppose we are treating the upper block, after all connections to the lower block have failed. If we treat it as a rigid object, it will be subject to two major forces: Gravity, acting through the center-of-mass and always pulling downward; and reactive forces from impacts with the lower structure, pushing predominantly upward, but acting at the point of contact and not necessarily through the center-of-mass. In our simplified model, apart from these two forces, the upper block retains its initial momentum, which is *downward* with some rotational momentum as well.

Before breaking completely free, the upper block will tilt around a loosely-defined hinge point, as discussed previously. The hinge creates a "force couple" – gravity pulling through the center balanced by an opposing force, at the hinge, pushing upwards and off-center. This is what leads to rotation. However, *at no time is there a horizontal force*, unless the upper block rotates so far that a hinge is a poor model of the interaction. This is not predicted. The "hinge" is likely to be a surviving series of columns bending but still supporting their load. These columns are predicted to buckle, snapping off at or near the hinge point, after only a few degrees of rotation – NIST estimates that the upper block rotated 7 to 8 degrees in one axis, and 3 to 4 degrees in another, prior to breaking the hinge [159]. The steel columns simply cannot provide support after being bent ten or twenty degrees. Also, if the "hinge" is closer to the middle and thus the center of mass, horizontal forces will be even smaller. This is true in this case – the hinge is predicted to pass through the core at an offset and an angle, as shown in NCSTAR1-6D in Figure 4-89 on page 256. As a result of the central location and small rotational tolerance of the hinge, the horizontal forces applied to the upper block are small, and thus there will be little or no horizontal movement.

The upper block would need a *large* amount of horizontal force in order to side-step the lower structure. Recall that the Towers were 208 feet, about 63 meters, across. This means that the upper block would have to be translated at least 104 feet before it would tumble over the side, and it would have to do so in only a few seconds – let's assume five seconds. To translate 104 feet in five seconds would require a steady lateral acceleration of 8.3 feet per second^2, and if we loosely estimate the upper block at around 25,000 metric tons, this means we require a continuous horizontal force of 14 million pounds (65,000,000 N), or approximately two times the thrust of the Space Shuttle at liftoff.

It is not even clear if the upper block could survive such a force intact, let alone where it would come from. If this force was the natural result of gravity causing it to "slide off," since this force is over 25% of the force of gravity, it implies that the reactive force must somehow work at an angle as if the upper block was sliding down a steep ramp. There is no reason whatsoever to expect such unusual behavior – the contact forces will be almost totally vertical. There is also not enough reactive force to provide this thrust, not even if it could somehow be applied at 90 degrees. We can estimate the maximum average resisting force from the speed of collapse. Because the lower structure is crushed within 11 or 13 seconds, according to Bazant *et al.*, the average reactive force supplied by the lower structure is a small fraction of the static gravity load, and thus the total impulse is

insufficient to supply the needed thrust, even if we could somehow explain why it is horizontal instead of vertical.

Furthermore, if the upper block experienced such a lateral force, Newton's Third Law requires an equal and opposite reactive force. While the lower structure would flex rather than translate (assuming this side force did not fracture the structure), there is simply no sign of this force in the lower structure, though admittedly the falling debris and dust makes it difficult to be certain. But the dust and debris provides further evidence of no such horizontal force. In one scenario, the debris accumulating below the lower block would be mainly cast the opposite way, accounting for the "thrust;" but as these pieces were smaller and less cohesive, some of them would have been thrown *enormous* differences. In another, the debris is carried along with the falling block, meaning the horizontal force required is much larger still. This simply did not happen. Instead, the smaller debris falls, snaps, and rebounds away with moderate but essentially random velocities in all directions, rather than being biased to any side as the toppling case would dictate. There is no support for toppling whatsoever.

The argument from conservation of angular momentum is similarly flawed. Dr. Griffin and Hoffman both assume that conservation of angular momentum guarantees that the upper block would continue spinning at the same rate. But this is only true if the upper block does not come in contact with the lower structure – angular momentum is only conserved so long as there are no external forces affecting the mass off-center. Since the upper block tilts, it first comes in contact with the lower structure at the down-tilted corner. Impact here, off-center, provides opposite angular momentum. Similarly, as it falls a bit further, contact at the up-tilted corner will add angular momentum. This will tend to rock the upper block back and forth as it settles through each floor. However, if the block continues to rotate, the down-tilted corner will fall farther than the up-tilted corner, and experience more and larger impacts, which work against rotation. Because of this geometry, the rotation is a self-regulating process to some extent.

What we expect, therefore, is that the upper block will *slow* in its rotational rate, but probably not all the way to zero. The impacts of floors below adding to and subtracting from this rate are going to be somewhat random and partially average out. This is, in fact, what is seen in the video – the upper block does rotate a bit further before it disappears from view.

Because Dr. Griffin and Hoffman misapply the laws of conservation of momentum, either assuming horizontal momentum where there is none or neglecting other contributions to angular momentum, their expectations about the trajectory of the upper block are also wrong. The behavior of the upper block is as expected.

Dr. Griffin returns, again, to his inexplicable claim that the upper block "exploded," and now suggests that this is what stopped it from tipping:

> And then, in the words of Steven Jones quoted earlier, "this block turned mostly to powder in mid-air!" This disintegration stopped the tipping and allowed the uppermost floors to fall straight

> down into, or at least close to, the buildings footprint. As Jones asked, "How can we understand this strange behavior, without explosives?" [160]

This set of assertions is hard to parse. As we've already discussed, the block did not turn "mostly to powder," as confirmed by the video and analysis of the debris at Fresh Kills. What is more baffling is the claim that the "disintegration stopped the tipping" – if the upper block disintegrated, how can it be thought of as cohesive, and how can we even estimate its tipping? If we can calculate the tipping, it must remain a mostly solid object. It is also not clear how explosives would counteract the rotational momentum, unless those explosives were all concentrated on one corner, and also exceptionally strong. This would naturally lead to secondary effects, such as flash and shock waves made visible in the dust and smoke. There are none.

We can explain the video quite easily without any explosives. The "turning to powder" is a result of impact with the lower structure. We expect the lower corner of the upper block to contact first. As it hits, the impact pulverizes some of the structure, and transmits an off-center force to the rest, simultaneously adding to the debris cloud and counteracting the rotation. This explanation requires no explosives, and no exceptional physical understanding whatsoever.

In the only other support of his thesis, Dr. Griffin cites Mark Loizeaux again as stating that controlled demolitions can include complicated sequences and kinematics. Assuming this quote is even accurate, this in no way proves that explosives were used. This is, again, an *assuming the consequent* logical fallacy.

Removal of the Steel

Dr. Griffin's next comment is that the structural steel was removed before it could be inspected, leaving NIST without enough steel to conduct a proper investigation:

> Although, as we have seen, a little steel was recovered, making its examination possible, it was very little. Virtually all of the steel – 99.7 percent of it, meaning about 90,000 tons – was removed and sold to scrap dealers, who put most of it on ships to Asia, before it could be properly examined. [160]

This statement is grossly misleading. NIST details the process of recovery in NCSTAR1-3B, Chapter 2. Because confusion over the scope and purpose of NIST's steel recovery effort is widespread, the author presents a large excerpt below:

> Beginning in October 2001, members … began work to identify and collect World Trade Center (WTC) structural steel from the various recovery yards where debris, including the steel, was taken during the cleanup effort. Dr. J. Gross, a structural engineer at the National Institute of Standards and Technology (NIST) and a member of the FEMA/ASCE BPS Team, was involved in these early efforts.
>
> There were four major sites where the debris from the WTC buildings was shipped during the clean-up effort in which the volunteers worked. These were:
>
> - Hugo Neu Schnitzer, Inc., Fresh Kills Landfill in Staten Island, New Jersey;

- Hugo Neu Schnitzer East, Inc., Claremont Terminal in Jersey City, New Jersey;
- Metal Management, Inc., in Newark, New Jersey; and
- Blanford and Co. in Keasbey, New Jersey.

The volunteers searched through unsorted piles of steel and other debris for pieces from the WTC buildings, specifically searching for (McAllister 2002):

- Exterior column panels and interior core columns from WTC 1 and WTC 2 that were exposed to fire and/or impacted by the aircraft;
- Exterior column panels and interior core columns from WTC 1 and WTC 2 directly above and below the impact zones;
- Badly burned pieces from WTC 7;
- Connections from WTC 1, 2, and 7 (e.g., seat connections, single-shear plates, and column splices);
- Bolts in all conditions;
- Floor trusses, including stiffeners, seats, and other components; and
- Any pieces that in the engineers' professional opinion might be useful.

NIST estimates that the inventory recovered in this fashion, almost entirely from WTC 1 and 2, is between 0.25 percent and 0.5 percent of the 200,000 tons of structural steel used in the Towers. This agrees with Dr. Griffin's estimate. However, what he fails to appreciate is that the total above is the amount that was *collected*, not the amount that was *examined*. The overwhelming majority of structural steel was examined in the search, and discarded simply because it did not meet the criteria above – the remaining steel, in the professional opinion of the engineers, displayed no unusual or important characteristics needed for the investigation.

Furthermore, of the NIST inventory, a considerable fraction is in the form of "coupons," or small pieces removed from larger steel elements to facilitate easier storage and protection from the elements. Because of this, the NIST inventory represents a larger fraction of the original steel than its raw weight would indicate. But in any event, Dr. Griffin's assertion that the steel was all shipped off to Asia "before it could be properly examined" is simply wrong.

Dr. Griffin also repeats the commonly echoed misconception that "removing any evidence from the scene of a crime is a federal offense." This is similarly misleading. It would be illegal for an anonymous individual to remove material from the collapse site, of course, but the search and rescue operation, followed by the recovery and firefighting efforts, followed by reclamation, were always under the control of the Federal Bureau of Investigations and FEMA. Such removal of *potential* evidence lay within their jurisdictions. There is, therefore, nothing illegal about the steel removal, provided it was officially conducted. We may argue about whether the Senior Agent in Charge should have been more concerned about preserving debris for future engineering studies, but ultimately this was a human decision, and one influenced by many factors.

Dr. Griffin also includes two lengthy notes, further explaining his sentiments. From the first of the two notes:

> 209 The official investigators reportedly found that they had less authority than the clean-up crews, leading the House of Representatives' Committee on Science to report that "the lack of authority of investigators to impound pieces of steel for examination before they were recycled led to the loss of important pieces of evidence." [161]

This clarifies the problem – it was not one of the steel removal being *illegal*, but rather one of conflicting priorities, and soon corrected. This is a solved issue.

The other note discusses the use of Global Positioning Systems to track debris trucks, although it is not clear what relevance this has to Dr. Griffin's thesis. The GPS was added in response to steel removal that *actually was* illegal, as well as to accelerate the cleanup process:

> In late September of 2001, only weeks after the World Trade Center disaster, officials uncovered a criminal scheme to divert sheet metal beams from the Ground Zero rubble to Long Island and New Jersey. In late October, some 250 tons of scrap metal were found at unofficial dump sites in both those areas.
>
> On November 26, the city initiated use of an in-vehicle GPS tracking system to monitor locations of trucks hired to haul the debris to Fresh Kills, the official dump site on Staten Island. [162]

This makes clear the distinction between illegal and legal removal of debris. The steel removal cited by Dr. Griffin was legal, albeit potentially deleterious to the investigation.

Dr. Griffin then cites the *New York Times* and *Fire Engineering Magazine* as complaining about the loss of evidence. These complaints were well-justified; however, Dr. Griffin is out of date. It is these and similar complaints that led to the initiation of the NIST study in the first place. Neither publication has repeated these sentiments since NIST began its investigation.

The reader will note that nowhere is any mention made of explosives, or any actual criticism of the NIST Report at all, except for the final paragraph, where Dr. Griffin indulges in speculation:

> If NIST's primary purpose had been scientific investigation in order to determine the true cause of the destruction of the World Trade Center, it surely would have pointed out that its investigation was greatly handicapped by the removal of the steel, which could reasonably be interpreted as an attempt by authorities to cover up crucial evidence. But the NIST scientists – not surprisingly when we recall they were working on behalf of the Bush-Cheney administration's Commerce Department – did not even mention this removal, although it was surely the most massive destruction of evidence in history. [163]

There are many logical errors in this paragraph:

1. Dr. Griffin has overestimated the amount of steel removed before NIST could examine it, as described above.
2. He assumes that the steel that was actually removed prior to investigation contained unique evidence. Since the amount removed was a small fraction of the

total, it is unreasonable to assume without proof that the remaining steel was not representative of the full volume.

3. He assumes that the NIST investigation was actually "handicapped" by this missing information. Given the conclusive nature of the NIST Report, it is unclear that additional evidence would in any way change their findings.
4. He assumes that if NIST was so handicapped, that it would report this loss of evidence as the limiting factor. This is only one of the many sources of evidence and one of the many problems. For instance, a much larger problem – more destructive of evidence – was the long-lasting and chemically complex fire that degraded the debris pile for weeks afterward. There is no reason for NIST to single out debris removal, even had its work been inconclusive, which it is not.
5. He assumes that this item is "missing" from the report because of political pressure within the United States. Even if the omission was significant, this link remains unproven.
6. He assumes that President Bush or Vice President Cheney is responsible for organizing a "cover-up" and ordering destruction of evidence. There is no evidence of a cover-up. Even if there was, it would not guarantee that such a cover-up originated from the White House.

All of these assumptions have mundane explanations. Dr. Griffin does not support his own inferences, which are, as we have seen, based on an incorrect assessment of the evidence. And even if we accepted his miscalculation *and* all of the logical leaps above, this still would not provide any conclusive evidence of explosives.

WTC Security

This final and most hyperbolic claim offered in support of Dr. Griffin's explosives hypothesis is that Wirt Walker III and Marvin Bush, a cousin and brother of President Bush respectively, were associated with a company that helped provide security in the WTC Towers – Mr. Walker being CEO of Securacom from 1999 to 2002, and Mr. Bush being a director of Securacom from 1993 to 2000. Dr. Griffin claims that this "coincidence" explains how explosives could have been planted without the couriers being caught. He also notes that the NIST Report does not report this "coincidence."

Dr. Griffin has made this claim in print for a considerable length of time, and has already been corrected in an excellent, fully-sourced on-line article [164]. Following this article, reprinted below are the two major errors in Dr. Griffin's claim, along with support:

1. Securacom had only a minor interest in the WTC Towers security, limited to designing and installing electronics. This work was closed out in 1998 and carried on by a different contractor. Wirt Walker III was not the CEO until after this handoff had taken place:

> Securacom got the $8.3 million World Trade Center security contract in October 1996 and received about $9.2 million from the WTC job from 1996 (a quarter of its revenues that year) to 1998. But in 1998, the company was "excused from the project" because it could not fulfill the work, according to

former manager Al Weinstein, and the electronic security work at the WTC was taken over by EJ Electric, a larger contractor. [165]

2. Wirt Walker III is not actually a relative of the President after all, even though there are financial ties to the Bush family. Margie Burns, who originally reported on this detail, wrote the following:

A former colleague of the head of the company, Wirt Dexter Walker III, suggested to me that Walker is a distant relative of the Bush family. While any blood relationship to the Bush Walkers would have to be remote (the first Wirt D. Walker, two generations ago, was based in Chicago; the second in McLean, Virginia, in the DIA), there is no doubt that the company, Kuwait's Al Sabahs, and Bush financial interests were closely linked for years. [166]

Even if Dr. Griffin's claims were accurate, this in no way provides evidence that explosives were used. It is not even clear that it would provide evidence that explosives *could be* used – the electronic systems that Securacom was partly responsible for would have no effect on the Port Authority Police or security guards, the bomb-sniffing dogs frequently deployed in the Towers, or the thousands of ordinary people who would have their working environment disrupted by preparation for what would easily be the largest demolition in history.

The author reminds readers that Dr. Griffin's thesis requires in excess of 120,000 kg of explosives *and* an indeterminate volume of thermite between WTC 1 and 2 alone – the logistical problem here is far, far greater than merely allowing a loophole in building access for a few individuals. Even that is predicated on the assumption that President Bush and his family, years prior to his taking office, planned the attacks in the first place. As before, there is no evidence of this assertion.

Summary

We find that Dr. Griffin has failed to provide any positive evidence of explosives. In examining his claims closely, we have been able to assign some numerical limits to his explosives hypothesis, adding some detail that he refuses to provide.

Dr. Griffin, however, states that it is the *absence* of evidence that matters:

> NIST claimed that it "found no corroborating evidence for alternative hypotheses suggesting that the WTC towers were brought down by controlled demolition using explosives planted prior to Sept. 11, 2001." How exactly that statement should be interpreted is not clear: NIST might have simply meant that it found no such evidence because it did not look for it. Or NIST might have meant that it was already aware of such evidence, so there was no need to find it. But this statement should not, in any case, be taken to mean that no such evidence exists. [167]

The author can clarify that statement for Dr. Griffin: *NIST is not and never has been aware of any such evidence. Evidence for explosives does not exist. The NIST study proves that the collapses were expected, in the manner and timing they were observed, without explosives being involved in any way.* Furthermore, if there had been explosives, the collapses would not have taken place in the way that they did. In discussing Dr. Griffin's claims, we have consistently compared the evidence that he feels is significant,

holding up to both the NIST and his own explosives theory. Without exception, the evidence is either irrelevant or actually confirms the NIST account.

Having examined all of Dr. Griffin's claims, we can now confidently state that no such evidence exists. And since Dr. Griffin has also not found any problems with the NIST hypothesis, as we saw in the previous section of this report, Dr. Griffin has no valid reason – either because he believes he has evidence, or because he believes there is an absence of evidence – to suspect explosives.

WTC 7 Claims

The third and final major division in Dr. Griffin's chapter discusses the collapse of World Trade Center Building 7. Criticism of NIST regarding WTC 7 is somewhat ill-posed, as NIST has not yet released its final report.

Dr. Griffin's first criticism is over this delay. He questions NIST's staffing decisions and budget, and places undue importance on the conclusions of the WTC 7 study:

> And yet the official interpretation of what happened on 9/11 has been used to justify wars in two countries, which have cost hundreds of billions of dollars and caused hundreds of thousands of deaths. From a scientific, a moral, and a public policy point of view, finding an answer to the puzzle of why WTC 7 collapsed was of the greatest importance. The effort to find this answer should not have been put on hold for over a year. [168]

This argument is politically rather than technically motivated, and as such is merely Dr. Griffin's opinion, to which he is entitled. The author would argue, however, that the precise engineering details over the collapse of WTC 7 are of no bearing whatsoever to geopolitics.

Furthermore, given the unfounded disdain with which Dr. Griffin holds the WTC 1 and 2 report, it is unclear to the author why Dr. Griffin looks forward to the release of the WTC 7 report with such enthusiasm. If his past behavior is any guide, we expect him to reject the WTC 7 report out of hand, citing his own lack of physics understanding and his own amateur opinion of photographs and carefully selected witness statements.

Dr. Griffin begins the first steps along this path in the remainder of the chapter, voicing his beliefs and his interpretation of the evidence. He concludes that "giving a plausible non-demolition explanation of WTC 7 is even more difficult than for the Twin Towers." We will now examine the reasoning behind his statement.

Prior Recognition of WTC 7's Special Difficulty

The first argument presented echoes that given for WTC 1 and 2: *No building like WTC 7 had ever collapsed because of an uncontrolled fire.* Rather than reiterate our previous commentary, we refer readers to pages 10-11 of this discussion. In brief, many large steel structures have collapsed solely due to ordinary fires. The fires in WTC 7 were also quite extraordinary, as we will describe later.

Dr. Griffin next remarks on the results of previous investigations, namely the FEMA and *9/11 Commission* reports. Regarding the FEMA report, he correctly notes that their investigation was inconclusive, describing a potential collapse scenario that had "only a low probability of occurrence." This is correct, and is part of the impetus for the more detailed NIST study. It should be pointed out, however, that the FEMA scenario has a "low probability of occurrence" only because it involves a number of steps that, while

plausible, are largely speculative, as we will revisit below. One purpose of the NIST study is to evaluate these steps, attempt to support them with evidence, and to determine whether there are other explanations or mechanisms that are also plausible. By the same token, Dr. Griffin's controlled demolition hypothesis also has a "low probability of occurrence" – an extremely low probability, since the steps he requires are not only speculative and not backed by evidence, but implausible as well.

The *9/11 Commission* did not include any discussion of WTC 7, as Dr. Griffin notes, but this should come as no surprise. The *9/11 Commission Report* is not an engineering report, and its entire commentary on the mechanics of the attacks themselves spans a mere 57 pages. Its primary purpose is to discuss the criminal actors and planning that led to the attacks, not the physical damage that resulted. The purpose of the *Commission*, clearly stated at the outset, was as follows:

> The National Commission on Terrorist Attacks Upon the United States (also known as the 9-11 Commission), an independent, bipartisan commission created by congressional legislation and the signature of President George W. Bush in late 2002, is chartered to prepare a full and complete account of the circumstances surrounding the September 11, 2001 terrorist attacks, including preparedness for and the immediate response to the attacks. The Commission is also mandated to provide recommendations designed to guard against future attacks. [6]

Since WTC 7 was not attacked, and collapsed due to secondary damage and fire, it lies outside the scope of the *9/11 Commission Report*. In like fashion, the *Commission* did not study WTC 3, 4, 5, or 6, or any of the other buildings damaged as a result of the WTC collapses. Dr. Griffin's criticism of the *Commission* is invalid. Yet he further accuses the *Commission* of willfully avoiding the issue:

> Given the 9/11 Commission's behavior with regard to other matters (as discussed in the previous chapter), a reasonable supposition is that the Commission, having seen that FEMA had no plausible explanation for this collapse, decided it was simply best not to mention it and hope that most readers, including members of the press, would not notice or at least not comment. And the press did not disappoint. [169]

This "reasonable supposition" of Dr. Griffin's is as irresponsible as it is wrong. Similarly, it is irresponsible for him to accuse the news services of complicity. A much more reasonable supposition would be that WTC 7 lay outside the mandate of the *9/11 Commission*, since its instructions said so; and that the press, unlike Dr. Griffin, understood the *Commission*'s true intent, and realized there were no such omissions.

Despite these errors, Dr. Griffin continues to complain about the role of media, going as far as to claim "there appears to have been a concerted effort to keep the collapse of this building from being widely known." In support he claims that videos of the collapse have "seldom been shown" on mainstream television, repeats that the *9/11 Commission* did not report on the collapse, mentions a Zogby poll indicating that only about half of those polled were aware of the collapse, and presents a clumsy misreading of the NIST "Fact Sheet" [82]:

> NIST says that one of its primary objectives is to determine "why and how the World Trade Center buildings 1, 2, and 7 collapsed after the initial impact of the aircraft" – thereby perhaps suggesting to unknowing readers that WTC 7, like 1 and 2, was struck by an airplane. [169]

The author flatly rejects Dr. Griffin's claims of a concerted effort to cover up WTC 7's collapse. Just to name a few, the *New York Times*, CBS, CNN, NBC, ABC, NPR, and Fox, along with foreign media such as the BBC, all reported directly from the scene of WTC 7, and have all run follow-up stories afterwards. This is rather strange behavior for media in a "concerted effort" to suppress such information. Moreover, if the collapse of WTC 7 was *premeditated*, as Dr. Griffin believes, such reporting could have been diverted or suppressed from the very beginning. Awareness of WTC 7's collapse may be lower simply because, to those surveyed, it was insignificant compared to collapses of WTC 1 and 2, and to the acts of terrorism that were responsible. Regarding the NIST "Fact Sheet," it is true that WTC 7 collapsed after, and indeed indirectly because of, the aircraft impacts into WTC 1 and 2 – the intent of the statement seems eminently clear.

Challenges WTC 7 Presents to NIST

Dr. Griffin leads the next section by shifting the burden of proof:

> Being unable to employ any of these ideas [effects of aircraft impact], NIST will evidently need to rely entirely on fire damage plus external damage caused by debris from the towers. It is far from obvious that such an explanation could even appear to be plausible.
>
> NIST's task – to debunk the claim that WTC 7 was brought down by explosives – is made even more difficult by several other factors. [170]

NIST's task is not to debunk the explosives claim made by Dr. Griffin or others. Neither Dr. Griffin nor anyone else has presented a single defensible claim. Again, Dr. Griffin has not specified *what* explosives were used, *where* they were placed, *who* placed them, *when* they were placed, *how* they were detonated, or *why*. There is nothing for NIST to debunk. NIST's task is to find and support the most likely cause of collapse, and whether or not that cause includes explosives will be dictated by the evidence.

We next consider each of the factors that Dr. Griffin finds problematic, in order of appearance:

Location of Initial Collapse Event

Dr. Griffin states that, while the Towers collapsed from the top, WTC 7 collapsed from the bottom, making it difficult to avoid concluding that explosives were used. This is an interesting reversal for Dr. Griffin, who claimed in his section "*Must Controlled Demolitions be Bottom-Up Affairs?"* that the "top down" nature of the Tower collapses was perfectly feasible for controlled demolition – he has already argued that the perpetrators of September 11th could demolish a structure from any location to disguise the cause of collapse, making the initial collapse location irrelevant to his analysis. Yet,

here he claims collapse initiation low in the structure is significant, as if to suggest the perpetrators simply forgot that it would appear suspicious.

In any event, this argument is moot because Dr. Griffin again has his facts wrong. The WTC 7 collapse also had initial collapses at the top, preceding the much more visible exterior collapse which did appear to initiate low in the structure. From the NIST WTC 7 Preliminary Report [171], we reproduce the Failure Sequence Timeline from page 26:

Time Interval (sec)	**Total Time (sec)**	**Observation from CNN Net Dub 7 47.avi** *[One specific video of the WTC 7 collapse]*
0.0	0.0	Movement of east penthouse roofline
0.9	0.9	East penthouse kinks between columns 44 and 45 2 windows at floor 40 fail between columns 44 – 45
0.3	1.2	4 windows fail at floor 40 East penthouse submerged from view (now inside building)
0.4	1.7	3 windows break at floors 41 to 44
0.5	2.2	East penthouse completely submerged
1.8	4.0	Windows break along column 46 at floors 37 and 40
3.0	7.0	North side of west penthouse moves Movement of entire north face of WTC 7 (visible above floor 21)
0.2	7.2	West end of roof starts to move
0.5	7.7	East end of roof starts to move Façade kink formed along column 46-47
0.1	7.9	West penthouse submerged
0.3	8.2	Global collapse occurs as windows fail between floors 33-39 around Column 55

Table 1: World Trade Center Building Seven Failure Sequence Timeline

We will revisit this table later in this section. However, for the time being, merely note that multiple initiating events at the *top* of the structure preceded the collapse by as much as eight seconds. Dr. Griffin's description of the collapse is excessively simplistic.

Sudden Collapse and "Virtually Free-Fall Speed"

The NIST timeline above proves that the collapse was not particularly sudden, and also refutes any claim of "virtually free-fall speed." The timeline demonstrates that 8.2 seconds transpired between the initiating events and the *onset* of global collapse, making the total collapse time roughly 15 seconds in duration. Dr. Griffin has badly estimated both, and as a result, his argument proceeds from a false premise.

Resemblance to a "Planned Implosion"

Dr. Griffin states, with no support or references, that the collapse of WTC 7 was "a perfect imitation of a planned implosion – which is what NIST will have to claim." Dr. Griffin, having no training in demolition or even the physical sciences, is not in a position

to make this statement, particularly given the obvious ways in which WTC 7 was *not* a "perfect imitation" – such as being on fire for hours beforehand.

In order to estimate whether or not the WTC 7 collapse did resemble a controlled demolition, since this is a subjective quantity, we must turn to demolition experts for their opinions. The author is aware of only one demolition expert who has answered in the affirmative, namely Danny Jowenko of Jowenko Explosieve Demoltie B.V. In a series of interviews [172], he was shown video footage of the WTC 7 collapse taken from a single side, and concluded that "this was obviously a building that's been imploded." To the best of the author's knowledge, Mr. Jowenko still believes this to be the case, even though several individuals have forwarded additional information to him, such as other camera angles, firefighter comments, and videos of the smoke and fires.

Jowenko is, however, contradicted by other demolitions experts, including those who have accessed much more information than a single video angle. In particular, Brent Blanchard writes the following:

> Any detonation of explosives within WTC 7 would have been detected by multiple seismographs monitoring ground vibration in the general area… No such telltale "spike" or vibratory anomaly was recorded by any monitoring instrument.
>
> Several demolition teams had reached Ground Zero by 3:00pm on 9/11, and these individuals witnessed the collapse of WTC 7 from within a few hundred feet of the event. We have spoken with several who possess extensive experience in explosive demolition, and all reported hearing or seeing nothing to indicate an explosive detonation precipitating the collapse. As one eyewitness told us, "We were all standing around helpless… we know full well it was going to collapse. Everyone there knew. You gotta remember there was a lot of confusion and we didn't know if another plane was coming… but I never heard explosions like demo charges. We knew with the damage to that building and how hot the fire was, that building was gonna go, so we just waited, and a little later it went." [114]

Because there is some difference of opinion, we will give Dr. Griffin partial credit – visually, the collapse of WTC 7 may have resembled a controlled demolition, at least from some perspectives. However, the collapse could not be a "perfect imitation." The resemblance is limited strictly to the video, and contradicted by vibration, audio, and preparation, in the opinion of demolitions experts. Such a limited resemblance could quite plausibly be explained by other collapse mechanisms. As a result, this cannot be construed as proof of a controlled demolition.

Totality of Collapse

Dr. Griffin here recycles two arguments – the first being that WTC 7 totally collapsed, although he does not list any alternatives; and that the resulting debris pile was "compact," suggesting to him that explosives were used to break structural elements into smaller, more manageable pieces.

Once again, there are no calculations performed here of any kind. We do not know what size of fragments to expect from the WTC 7 collapse, therefore we have no basis of comparison. Dr. Griffin does not measure *any* of the pieces, nor does he quantify the size

of the pile. He is, therefore, attempting to compare two quantities when he does not have nor has defined either one of them. This is sheer speculation.

As we saw above while considering the WTC Towers collapses, Dr. Griffin underestimated the pile size as well as the ability of gravitational collapse to fragment structural materials. Also, like the WTC Towers cases, Dr. Griffin has not accounted for why *some* of the debris from WTC 7 was not in "small, manageable" sizes. Photographs after the collapse (see [173] for an example) demonstrate clearly that much of the debris was in large fragments, some many stories in height. Dr. Griffin, again, has provided no reason to doubt that the effects seen were expected, even without explosives.

Symmetry of Collapse

Similar to his argument in the WTC Towers, here Dr. Griffin claims (and cites Dr. Jones in support) that the vertical collapse would require the simultaneous failure of all of the support columns.

We have already described, for the WTC Towers, why this is not correct, and how *instability* leads to multiple failures over a period of seconds to fractions of a second. This explains why the collapses are, to first approximation, symmetrical. We have also described why a tall structure cannot topple sideways, viz. due to the inability of long columns to support this motion without buckling.

Furthermore, the NIST Timeline above proves, without a doubt, that the failure of WTC 7 supports was *not* simultaneous. The first movement in the structure occurred 8.2 seconds before the total collapse began, indicative of some structural elements failing internally. The south face of the structure began to collapse 1.2 seconds before the rest of the structure. These simple facts, discernable from video of the event, demonstrate that Dr. Griffin's premise is false.

Molten Metal

Dr. Griffin again presents no sources or evidence for molten metal. In particular, he does not describe "molten steel." As we have already explained, molten metal such as aluminum is easily created in an ordinary fire. WTC 7 burned on multiple floors for over six hours before it collapsed. Any molten metal found can be assumed to be an ordinary result of this fire unless proven otherwise.

Additionally, we have also already explained why explosives do not usually lead to the creation of molten metal. Its existence cannot strengthen his hypothesis, even if it was unexpected.

"Evaporated" Steel

This topic, too, was discussed in the WTC Towers sections above. Contrary to Dr. Griffin's claims, the properties of the sulfidized steel prove that it never exceeded a

temperature of 940 ^{o}C, which is perfectly reasonable for an office fire. The steel could not have "evaporated," as this requires a temperature more than a thousand degrees higher. The steel similarly shows evidence of a chemical attack, possibly heat-catalyzed, and no evidence whatsoever of explosive impact. Explosives do not ordinarily contain sulfur. This strange steel behavior does not support Dr. Griffin's theory in any way.

"Squibs"

The last and longest entry in this section has to do with puffs of smoke, allegedly created by explosives that Dr. Griffin again incorrectly refers to as "squibs." He begins by citing Dr. Jones:

> [H]orizontal puffs of smoke and debris, sometimes called "squibs," emerge from the upper floors of WTC 7, in regular sequence, just as the building starts to collapse. The upper floors have evidently not moved relative to one another yet, from what one can observe on the videos. In addition, the timing between the puffs is less than 0.2 seconds, so air expulsion due to collapsing floors, as suggested by defenders of the official account, is evidently excluded. [174]

As the NIST Timeline demonstrates, if this occurred, as Dr. Jones claims, "just as the building starts to collapse," then there were internal failures and local collapses for several seconds previous to this event. We also know that WTC 7 was filled with smoke from the six hours of unfought fire. However, as NIST argued in reference to the WTC Towers, we do *not* expect sequential "puffs" of smoke to be caused by floor failure. Instead, we have already seen that internal failures, even small ones, can lead to pressurization of the structure. This pressure wave would also traverse from one floor to another in well under 0.2 seconds, which is about the limit of temporal accuracy available from an ordinary video recording. Therefore, the internal failures themselves could easily create the phenomena seen here.

Dr. Jones' account is also contradicted by Brent Blanchard, who as we saw above stated that demolition crews on scene during the collapse neither heard nor saw anything indicative of controlled demolition. These "puffs" arguably could have been hidden from their view, but they would certainly have heard any explosions, particularly the firecracker-string signature of a controlled demolition affecting multiple floors in a fraction of a second. The lack of auditory evidence refutes Dr. Jones' interpretation.

The next account is that of an unidentified emergency worker, quoted in the Internet video *9/11 Eyewitness*, which Dr. Griffin feels is evidence of explosions:

> We were watching the building actually 'cause it was on fire … and … we heard this sound that sounded like a clap of thunder. … turned around – we were shocked to see that the building was ah well it looked like there was a shockwave ripping through the building and the windows all busted out. … [A]bout a second later the bottom floor caved out and the building followed after that. [175]

As for the sounds reported, this could be nothing more than the sound of collapse itself. There is nothing here consistent with the "regular sequence" seen by Dr. Jones, nor does the sound of explosions imply explosives in general.

Regarding the "shockwave" comment, it is clear that there was *no* shockwave. This would have been heard by everyone present, including the witness above. This would also have destroyed windows in nearby buildings only a fraction of a second later. Neither event occurred. The window breakage is included in the NIST Timeline, and is thought to be caused by building flexure, which would quite possibly destroy all the windows on one or a few floors simultaneously. The NIST Timeline describes five separate occurrences of this in the seconds leading up to collapse.

The third account, from Peter DeMarco of the *New York Daily News*, reports similar phenomena with the windows. This account also fits the NIST preliminary report, and not Dr. Griffin's explosives hypothesis, for the same reasons as listed above.

Finally are the comments of Michael Hess, who Dr. Griffin cites as stating there was an "explosion" while he was inside the building with another individual. This account clearly refers to events shortly after the evacuation order in WTC 7, i.e. after the collapse of WTC 2 and many hours before WTC 7's collapse. We surmise that the "explosion" he is referring to is in fact debris impacting from the collapse of WTC 1 or a secondary utilities explosion, not any explosive device, and clearly not in any way related with the "squibs" Dr. Griffin imagines – since those did not appear until over six hours later.

This interpretation can be verified by a corroborating account in the *Traverse City Record-Eagle* [176], where Barry Jennings identifies himself as the person with Michael Hess, and confirms that this happened at the time of WTC 1's collapse. Some within the Truth Movement dispute this, taking Mr. Jennings' timeline and vagaries in other commentary to mean that the event must have taken place *before* WTC 1 collapsed, or in fact even before WTC 2 collapsed, but our interpretation can be verified in two ways. First, an isolated explosion of that size would have been detected by seismographs, and would also have left visible damage on the outside the building. The seismic records prove there was no such event – only the two aircraft impacts, the two collapses, and related effects like air blast appear between 8:40 AM and noon, nothing else. There are also no corroborating reports, such as from the many rescue workers who had set up a triage center in the lobby of WTC 7, evacuating after WTC 2 collapsed and damaged the lobby area. Video also shows WTC 7 standing undamaged until WTC 2 collapsed.

Second, Mr. Hess and Mr. Jennings were briefly trapped in WTC 7, and were not freed until well after WTC 1 had collapsed, yet they only report these events above. It is not credible for them to have felt a minor explosion prior to the collapses, and then failed to notice the impacts from the collapse of WTC 1. We therefore understand that there was no such explosion, and these events are one and the same. Even if this mystification of Mr. Jennings' statements was valid, it is unclear why an explosion would have been triggered so long before WTC 7 collapsed, as it could serve no useful purpose.

This is not the first time Dr. Griffin has attempted to conflate reports of explosions *during collapse* with those occurring *long before* collapse. In the WTC Towers examples, to defend his theory, Dr. Griffin was faced with the uncomfortable prospect of explaining *how* not to mention *why* explosives were detonated simultaneously with the aircraft

impacts. In this case, if he seriously believes Michael Hess's account indicates explosive devices rather than a simple accident arising from debris impact, he must explain how and why this explosion was timed to go off *with the debris impact* – a nearly unpredictable quantity.

The rational interpretation is, of course, that there were no explosives at all. All of these accounts can be explained easily as smoke artifacts and building flex in the early stages of collapse, or as damage arising from the impact of debris as WTC 1 collapsed. Dr. Griffin cannot explain these events in any other way without contradicting solid physical evidence, including video of an intact WTC 7 and seismographs proving that there were no such explosions.

The Very Appearance of This Collapse

In this short section, perhaps expanding upon his earlier comments, Dr. Griffin now cites Danny Jowenko and three other professionals who state that, on the basis of appearance, WTC 7 looks to have been imploded deliberately. We have already addressed Jowenko above, as the only demolitions expert to make such a claim, and we will instead consider the other three accounts.

The first two are taken from a single article of the *Tages Anzeiger* [177], where both Hugo Bachmann and Jorg Schneider, both emeritus structural engineering professors of ETH in Switzerland, are quoted very briefly as stating that they believe "with a high probability" that WTC 7 was "blown up." However, the quotes also reveal that they base their opinion solely on video of the event, much like Mr. Jowenko. Dr. Bachmann's biography [178] and bibliography [179] show that he is an expert in vibration and seismic design, but apparently has no particular expertise in demolition. Prof. Schneider, much less published, works with Risk&Safety AG [180] in areas such as civil engineering risk analysis and design requirements for building safety. He too has no apparent experience with demolition. Because both individuals are associated with a major research institution, it stands to reason that they are familiar with the academic standard of proof, and they are invited to publish their findings regarding WTC 7 for proper review and criticism. Until they do so, we may discount their opinions as mere speculation.

The third quoted expert is Dr. Heikki Kurttila, who has written a relatively simple whitepaper in which he calculates an average "resistance factor" for a structure collapsing to the ground – a "resistance factor" of 1.0 means that the structure can support its own weight, but with no remaining margin, and a factor of 0.0 meaning it has no load-bearing ability at all. His findings are the following:

> The observed collapse time of WTC 7 was 6.5 seconds. That is only half a second longer than it would have taken for the top of the building to fall to the ground in a vacuum, and half a second shorter than the falling time of an apple when air resistance is taken into account. The apple is 6 cm in diameter and weighs 100 g (thereby fulfilling the EU requirements).
>
> With the observed collapse time we obtain the resistance factor n = 0.16 by using equation (15).

> The great speed of the collapse and the low value of the resistance factor strongly suggest controlled demolition. [181]

There are several problems with his derivation, sufficient to make his conclusion worthless:

1. As we have already seen, the actual collapse time was closer to 15 seconds. The building suffered from internal collapses, greatly weakening the structure, prior to total collapse. This is not represented in his collapse model.

2. Dr. Kurttila models the structure as a homogeneous solid, and computes kinematics based on force-balancing. Structures are not homogeneous solids. This approximation may be acceptable for average quantities, such as total potential and kinetic energy, but it is completely invalid for force arguments. The resistive force will vary wildly, dropping momentarily to zero with each element that buckles, and so the *total* resistance is a strong function of the average length at which the structure buckles. This length, which defines how much of the collapse is essentially in free-fall, is not included in this model. Compare this derivation to my own in Appendix B.

3. Dr. Kurttila assumes that the "resistance factor" and hence the strength of the structure remains constant *as it collapses*. This is false. As the structure suffers damage, its strength may drop precipitously.

Dr. Kurttila is also welcome to submit his findings to an engineering journal, but on the basis of the errors described above, the author would discourage him from doing so – it will not be accepted without major revisions.

Two More Unique Features of This Collapse

Dr. Griffin now presents two arguments based on the behavior of officials and emergency personnel in the hours leading up to WTC 7's collapse. He remarks that the collapse of WTC 7 was predicted well before it actually happened, and that the debris was excavated quickly, both with no apparent cause.

He states his first objection as follows:

> Given the fact that fire and external damage had never caused a steel-frame high-rise building to collapse, why would people in Giuliani's office have concluded around noon that WTC 7 was going to collapse? Although the Twin Towers had just come down, the fact that these buildings had been hit by airplanes, whereas WTC 7 had not, could well have seemed relevant. Also, there were, in addition to the Twin Towers, five buildings in the WTC complex, some of which were pounded by debris from the tower much more heavily than was WTC 7, and yet evidently only the latter was expected to collapse. [182]

In the same paragraph, he answers his own question thus:

> This unique expectation is explainable, and arguably only explainable, on the supposition that someone in the Office of Emergency Management knew that there were explosives in WTC 7 that were going to be set off. [182]

It is no difficult matter to explain why the collapse of WTC 7 was expected, and the explanation has nothing at all to do with explosives.

First of all, Dr. Griffin feels there is a great distinction between "being hit by an airplane and burning" and "being hit by debris and burning." The total impulse of the debris that hit WTC 7 may have exceeded that of the aircraft impacts into WTC 1 and 2 – this is unknown, and may be explored in the final NIST report. In any case, it is not clear even today that WTC 7 suffered comparably less damage than WTC 1 and 2 did prior to their collapse, although the aviation fuel and fireproofing situations would be quite different. Emergency personnel might well have suspected that WTC 7 could collapse, whether or not they were familiar with the historical statistics of skyscrapers in fires. Their decisions would be based instead on the specifics of the WTC 7 situation, and not based on a preconceived notion that skyscrapers are impervious to any and all fires.

Those specifics strongly suggested that WTC 7 was going to collapse, for several reasons:

1. *The size and intensity of the fires.* WTC 7, as remarked previously, was the largest office fire in history. While some – including Dr. Griffin, in the following section – will dispute the size or heat of the fires, firefighter accounts leave no reasonable doubt that the fires were extraordinarily large. Photographs also show the enormous column of smoke rising from the structure.

> *Firefighter Tiernach Cassidy:* It was fully engulfed. That whole building – there were pieces of tower two in building seven and the corners of the building missing and whatnot. But just looking up at it from ground level, however many stories it was, 40-some-odd, you could see the flames going straight through from one side of the building to the other. That's an entire block. [183]

2. *Inability to fight the fires.* The collapse of WTC 2 and 1 had destroyed the water services in the area, the risk to firefighters was significant, and it was impossible to conduct ordinary firefighting operations. For this reason, firefighters were ordered to fall back and establish a "collapse zone," which is a standard precaution when fighting a tall structure to prevent others from being hit by debris, minor collapses, or total collapses, at around noon.

> *Firefighter Eugene Kelty, Jr.:* And 7 World Trade was burning up at the time. We could see it. There was concern. I had gone up to take a look at it, because I knew that the telephone company building, which is 140 West Street, was next to 7 World Trade Center, and there was a concern that if 7 World Trade came down, what would happen to this building? We went in there, we checked it out. There were some people in there. We made them evacuate and I went back to see what was happening.
>
> The fire at 7 World Trade was working its way from the front of the building northbound to the back of the building. There was no way there could be water put on it, because there was no water in the area. [184]

Fire Captain Michael Donovan: Chief Cruthers told me that they had formed another command post up on Chambers Street. At this point there were a couple of floors burning on Seven World Trade Center. Chief McNally wanted to try and put that fire out, and he was trying to coordinate with the command post up on Chambers Street. This is after searching for a while.

He had me running back and forth trying to get companies to go into Seven World Trade Center… Yeah, and it was really in disarray. It really was in complete disarray. We never really got an operation going at Seven World Trade Center. [185]

3. *Visible and audible signs of structural distress*. Firefighters reported numerous indications that WTC 7 was weakening, even measuring the lean of the structure with surveying equipment.

Fire Captain Chris Boyle: Then we received an order from Fellini, we're going to make a move on 7. That was the first time really my stomach tightened up because the building didn't look good. I was figuring probably the standpipe systems were shot. There was no hydrant pressure. I wasn't really keen on the idea. Then this other officer I'm standing next to said, that building doesn't look straight. So I'm standing there. I'm looking at the building. It didn't look right, but, well, we'll go in, we'll see.

So we gathered up rollups and most of us had masks at that time. We headed toward 7. And just around we were about a hundred yards away and Butch Brandies came running up. He said forget it, nobody's going into 7, there's creaking, there are noises coming out of there, so we just stopped. And probably about 10 minutes after that, Visconti, he was on West Street, and I guess he had another report of further damage either in some basements and things like that, so Visconti said nobody goes into 7, so that was the final thing and that was abandoned. [186]

Deputy Chief Peter Hayden: Early on, we saw a bulge in the southwest corner between floors 10 and 13, and we had put a transit on that and we were pretty sure she was going to collapse. You actually could see there was a visible bulge, it ran up about three floors. It came down about 5 o'clock in the afternoon, but by about 2 o'clock in the afternoon we realized this thing was going to collapse. [187]

Dr. Griffin is also incorrect when he states that emergency crews believed Building 7, and only Building 7, could collapse. Relaying the words of firefighters, Vince DeMetri of CBS-TV reported that WTC 5 was also in danger of collapse. Deputy Chief Nicholas Visconti also discussed the danger of WTC 6 collapsing:

So now I was in contact with Jay. I found out what kind of shape he was in and I kept getting reports back from people that we're not there yet, we're working our way, there's a collapsed area in 6. I'm standing not too far from Frank Fellini. He says, Nick, I'm really worried about this building. We were all worried because there was a lot of fire in it and we were concerned about the building collapsing. We weren't sure that it was stable enough that it wasn't going to collapse.

Firehouse: Which building was that?

Visconti: Building 6. So I had put a battalion chief with each of the groups that went into 6. [188]

Based on these numerous, corroborating accounts, coupled with video of the fires in WTC 7 and the fact that it burned for over six hours, there is indeed a better explanation than explosives for why the collapse was expected. There is some disagreement between firefighter accounts about exactly how many floors were burning or how intensely, but

there can be no dispute that the fire persisted for hours, that the structure weakened, or that firefighters believed on this basis that the structure was likely to collapse

Dr. Griffin is faced with a difficult problem. He is attempting to equate prediction of the collapses with conspiracy to demolish WTC 7, or at the very least cognizance thereof. As numerous accounts indicate, both in official interviews and ordinary reporting, the FDNY collectively knew that WTC 7 was in danger of collapse hours before it finally fell. If Dr. Griffin wishes to maintain his theory, then he must make a painful choice:

1. Accept that the FDNY was part of the plot to destroy WTC 7.
2. Accept that the FDNY knew of the plot, but did nothing to stop it, and to this day refuses to talk about it.
3. Propose that someone "in the know" tricked a high-ranking member of the FDNY into *thinking* that it would collapse, and:
    a. This duped individual convinced many more firefighters that it would collapse;
    b. Those so informed believed it would collapse;
    c. Not a single FDNY member expressed doubts about what they were told, based on their own experience and the actual condition of WTC 7; and
    d. The structure burned and showed unmistakable signs of weakening anyway.

All of these three choices suggest (and insultingly so) highly unlikely behavior on the part of the firefighters. None has the slightest support in evidence. The rational conclusion, again, is that their training and observation led them to conclude, correctly, that WTC 7 was in danger of collapsing.

Dr. Griffin's other "unique feature of collapse" is the quick removal of WTC 7 debris. He states:

> Because everyone was removed from the building several hours in advance, no one was killed when it actually did collapse. This fact undermines the reason that was given for the rapid removal of the steel: the claim that some of the victims might still be alive in the rubble, so the steel needed to be removed to aid the search-and-rescue operation. [189]

Dr. Griffin does not provide a source for the "given reason" above. While it is true that WTC 7 was fully evacuated, this was not known for certain, and the intermingled rubble of WTC 1 and 2 contained many trapped people, including rescue personnel who had been trapped near WTC 7 by the earlier collapses. Immediately after WTC 7 tumbled, the search-and-rescue operations began:

> At 5:20, No. 7 finally falls. They've been waiting for it to go so they can move the firemen and search-and-rescue teams in. With the thunderous collapse, firemen bolt up from where they've been camped, on the south side of the Embassy Suites. Some have been sitting on plush hotel furniture carted into the street, eating food from the Mexican restaurant next door. There's a stampede over pickaxes and oxygen tanks. They head out toward the crushed fire trucks. "They're looking for their brothers," says an ambulance driver. [190]

There is also an additional reason, found in the FEMA report, Chapter 7, detailing the effect of debris on peripheral buildings. The debris pile from WTC 7, more so than that from WTC 1 and 2, presented a significant lateral load on nearby buildings, leading to fears that they too could collapse if it was not removed:

> On the east (Washington Street) side of the [Verizon] building, most of the damage appeared to be due to the lateral pressure of the spreading debris at the base of WTC 7 (Figure 7-7). Two of the columns between the 1st and 2nd floors were deflected into the building by as much as 2 feet (with most of the rotation occurring at the column splice just above the 1st floor); at one of the columns, very little contact remained at the column splice (Figure 7-9). Even so, the columns did not buckle, and structural bays above did not collapse or deflect significantly. Similarly, the structural bays supported by the column between the 6th and 8th floors that was completely destroyed by the impact of projectile debris were essentially undamaged.
>
> Damage [to 30 West Broadway] was concentrated along the south face at and below the setback at the 15th floor. Portions of the south façade from the 15th floor collapsed. A vertical section of the perimeter wall extending five floors down from the setback at the center of the south façade was raked away. Local collapse also occurred at the southwest corner. The majority of the glass panes were knocked out on the south façade, in a triangular pattern that extended to the full width of the base. The south side of the building was unstable and required bracing. Floors 9 through 14 had two collapsed bays, and floors 3 through 6 had up to three collapsed bays. No structural damage was observed one bay away from the impact damage. [191]

In summary, the "unique features" of WTC 7's collapse are completely logical, and were obvious to the rescue workers on site. Dr. Griffin's suspicion, namely that the knowledge of collapse and more rapid removal of debris is proof of a conspiracy to destroy WTC 7, has no grounding in reality.

What Will NIST Say About WTC 7?

Dr. Griffin now attempts to second-guess the NIST WTC 7 Final Report. Before considering his claims, it should be mentioned that NIST will continue to follow a process whereby a *draft* report is first issued, followed much later by a final report, expressly for the purpose of eliciting comments and criticism from industry and academia. This is in addition to the many public hearings and progress reports already completed. Such was followed in the NCSTAR1 report for the WTC Towers. Dr. Griffin is invited to participate in this process, much as he and his sources are welcome at any time to submit their findings to any of the myriad scientific and engineering journals.

In one of the first comments, Dr. Griffin expresses suspicion that the NIST WTC 7 study is already being predetermined to consider column failure on a restricted range of floors:

> We can be quite certain, in other words, that NIST will not seriously explore evidence that the building was brought down by explosives. Some indication that this line has been ruled out in advance is provided by NIST's statement about awarding a contract ... "detailed floor analyses will determine likely modes of failure for Floors 8 to 46 due to failure of one or more supporting columns." Besides seeming to imply that NIST told ARA in advance what its analysis must conclude, the restriction to floors 8 to 46 is especially interesting in light of the statement by [demolition expert] Stacey Loizeaux, quoted earlier, that "[w]e only really need to work on the first two floors, because you can make the building come down that way." [189]

Dr. Griffin, by his comments, clearly does not understand the process of investigation, and not understanding assumes deception in every case. The full text of the award includes the complete, unedited sentence cited by Dr. Griffin, and reveals that the ARA work is, unsurprisingly, merely one component of a larger team effort:

> ARA will conduct nonlinear dynamic collapse analyses using LS-DYNA that include analyses of detailed full floor models and global models. The detailed floor analyses will determine likely modes of failure for Floors 8 to 46 due to failure of one or more supporting columns *(at one or more locations), and aid the development of a more coarse model for use in the global analyses that captures essential behaviors and failure mechanisms.* [192] (Emphasis added)

In other words, the ARA effort will model, at high fidelity, behaviors on Floors 8 to 46, and this will be used to drive a larger (but by computational necessity coarser) global model that represents the entire structure. This is standard engineering practice, as we saw in the NIST investigation into the WTC Towers, for example the high-fidelity floor models supporting a coarse global model in NCSTAR1-6D.

Similarly, the special treatment given to Floors 8 to 46 is not in any way suspicious, but instead reflects the composition of WTC 7. On these floors, the structure had a traditional design. Below Floor 8 the structure was radically different, with a complicated cantilever arrangement designed to support the structure above a pre-existing ConEdison utility station. As reported by FEMA:

> The typical floor framing shown in Figure 5-2 was used for the 8th through the 45th floors… Below the 8th floor, floors generally consisted of formed slabs with some limited areas of concrete-filled metal decks. There were numerous gravity column transfers, the more significant of these being the three interior gravity column transfers between floors 5 to 7 and eight cantilever column transfers in the north elevation at the 7th floor. [193]

At the other extreme, Floor 46 is only one floor away from the roof of WTC 7. A column failure here would be subject to different boundary conditions, since the column would support very little weight. It is therefore clear that, rather than issue "marching orders" to arrive at a predetermined outcome, NIST has merely divided the analysis problem into subprojects following the different features inherent in the building design. Dr. Griffin's suspicions are simply ignorant.

His next objection, following his strategy in criticizing the WTC Towers report, is to speculate that the fires were not "big and hot." He remarks that some firefighters' comments indicate a large fire, while others suggest a much smaller one, and then presents a most curious argument for focusing solely on the latter:

> One way to decide which of these conflicting accounts to believe is to use a common principle employed by historians in situations of this type, where some members of an organization or movement say things that support its official line, while other members say things that contradict it. All other things being equal, historians give greater credence to the latter. [194]

In stating the above, Dr. Griffin has admitted his bias. He cannot be faulted for having a bias, as most people – scientists included – are given to some bias. The author finds Dr. Griffin's admission both understandable and refreshing. However, having said this, there

are two logical problems with applying this "historian's principle" to the firefighter testimonies:

1. Some of the opinions are from or can be verified against candid interviews and news reports taken during the event in question – long before any "official line" or policy could be formulated, let alone communicated to firefighters. These opinions compare well to those taken from formal interviews. The "official line" cannot apply to these unless the entire operation was premeditated within the FDNY, which would be a preposterous and irresponsible accusation.

2. There is no evidence of any firefighter or other emergency worker suffering retaliation or pressure for not following the alleged "official line." The differences of opinion captured by Dr. Griffin are all taken from the official interviews after the fact. It is, therefore, not clear that any "official line" regarding the magnitude of fires in WTC 7 actually exists. Dr. Griffin begs the question by assuming that there is an official line, and that the official line is that WTC 7 was fully involved in fire.

Dr. Griffin's bias, furthermore, is unhappily aligned with that of confirmation bias – that of any individual to prefer explanations that conform to her prior conceptions. We cannot expect that Dr. Griffin's method is indeed objective. However, the opposite bias is no more acceptable.

For this reason, the author proposes that *all* firefighter commentary in this regard should be deemed as equally credible. There is some precedent for this approach – not only are minor differences in witness testimony to be expected, but the sheer size, duration, and complexity of the WTC 7 fires guarantee that it would look differently at different times, from different angles, to different people. Consider that WTC 7, prior to its collapse, was approximately 186 feet by 329 feet and 47 stories high, with a footprint larger than that of a WTC Tower. It had a complex shape with several acute angles, and was cantilevered over a completely different structure at street level. Add to this variation in the wind; blowing dust and smoke from the WTC Tower collapses and debris at street level; emergence of fires on multiple floors simultaneously; growth, spread, and burnout of fires in different locations over more than six hours; and large but random pockets of debris damage – and it is easy to imagine that the fires might look totally different to any two individuals at any given points in time.

From the firefighter comments, there are a few elements common to virtually every single account that must be considered as credible:

- Fires persisted from the WTC 1 debris impacts up to the final collapse of WTC 7;
- Fires were present on multiple floors;
- Fires were considered a threat to the building's structural integrity.

It is the third point that poses the biggest problem to Dr. Griffin's theory. Not one firefighter interview expresses doubt or surprise at the collapse of WTC 7, even though accounts do differ in other details.

Dr. Griffin quickly shifts to photographic evidence, attempting to infer that the fires were not very hot, in addition to being small and limited to a few floors. As we observed in our consideration of the NIST WTC Towers fire investigation, there is no credible way to estimate fire temperature or average heat output from photographs alone, as the interior may be vastly hotter than the perimeter, and the WTC 7 fires could have been hundreds of feet across and largely hidden by exterior walls. Dr. Griffin's assertion is rejected without further comment. Establishing the heat of the fire is a complex modeling problem, and well outside the expertise of Dr. Griffin.

Dr. Griffin commits several severe errors of reasoning in considering the likely effect of fireproofing:

> Another problem with the claim about a late-blooming fire would be that, if the fires did not really get going until about 3:30, they would have had only two hours to cause damage. And yet the fireproofing was supposed to be good for two hours and then, after it was gone, the unprotected steel was certified for another three hours. Given the fact that raging fires that have gone on for over sixteen hours in steel-frame high-rises have not produced even partial collapse, the idea that a two-hour fire could somehow produce a total collapse is completely implausible. [195]

The errors are as follows:

1. Whether "late blooming" or not, Dr. Griffin cannot discount the almost five hours of fire that occurred before 3:30 PM. This fire, even if relatively cool, would contribute to structural heating and weakening, at least in local areas. The FDNY also detected signs of structural distress, concluding that a collapse was possible, well before 3:30 PM as shown above.
2. Dr. Griffin, perhaps misled by Kevin Ryan, has double-counted the fire resistance rating. Fire certification applies to the steel *and* the fireproofing, not both independently. Bare steel is essentially unrated without special considerations. WTC 7 was by no means designed to handle five hours of fire, as he claims.
3. Raging fires have indeed led to structural collapses, as we treated in our discussion of the WTC Towers. All of the fires cited by Dr. Griffin were fought, unlike WTC 7; all of them had intact fireproofing, whereas WTC 7 likely sustained some damage to its fireproofing; and in two of the case studies, total collapse was only averted because the buildings contained a concrete core, while WTC 7 had no structural concrete.

These errors invalidate Dr. Griffin's conclusion. Total collapse was indeed plausible, as was evinced in the commentary and actions of the FDNY. In every interview studied, no firefighter expressed any doubt that WTC 7 could fall as a result of the fires.

Dr. Griffin next remarks on the likelihood of the large diesel fuel storage tanks figuring in the final report, and that NIST may claim the debris impacts were more significant than

previously recognized, in a set of comments that the author can only describe as sarcastic. He is correct in that FEMA referred to the diesel fuel hypothesis as a "low probability of occurrence," but FEMA clarifies this remark in its report:

> In evaluating the potential that a fire fed by fuel oil caused the collapse, it is necessary to determine whether the following events occurred:
>
> 1. The SSB generators called for fuel. This would occur once the generators came on line.
> 2. The pumps came on, sending fuel through the distribution piping.
> 3. There was a breach in the fuel distribution piping and fuel oil was discharged through the distribution system. …
> 4. The discharged fuel must be ignited. …
> 5. There is sufficient air for combustion of the discharged fuel oil. …
> 6. The hot fire gases reach and heat the critical member(s).
>
> … Further investigation is required to determine whether the preceding scenarios did or could have actually occurred. [196]

In other words, FEMA responsibly identifies this as a "low probability of occurrence" simply because there are a number of steps that it could not properly evaluate. Each of these steps appears to be plausible, even likely, but this is insufficient – before a definitive answer can be presented, each of these steps should be examined in detail. If FEMA's assumptions turn out to be correct, this hypothesis would no longer have a low probability. NIST does not require an active imagination or a higher tolerance for speculation; instead, NIST requires answers to these questions. This is one of many factors contributing to the length of the investigation.

Regarding the severity of debris impacts, NIST has already demonstrated photographically that the impacts were considerable, as seen in the Preliminary Report. We should expect that NIST's final estimates of debris damage, as well as the extent of fires, will be backed by photographs as well. In the meantime, any speculation that NIST is liable to exaggerate this damage for the purpose of obfuscating alternative hypotheses is unworthy of serious consideration.

Dr. Griffin closes with a recap of the features he finds most important to investigate: The symmetry and vertical nature of collapse, the "small" pile of debris left behind, "virtual free-fall," dust clouds, "squibs," molten metal, and the "partially evaporated" steel. All of these ideas have been treated above and discarded as misinterpreted by Dr. Griffin, or performing as expected. His comments suggesting that the NIST scientists are ignorant of the laws of physics due to being in the pay of the Bush Administration are disrespectful and unproductive. So too is his final attempt to shift the burden of proof:

> The burden of proof should be placed on any claim that WTC 7 was brought down by something other than explosives, because this is the wild, empirically baseless hypothesis devoid of historical precedent, which is just the kind of hypothesis that one expects from irrational conspiracy theorists. [197]

Let us objectively examine the "burden of proof," in a prelude to the Discussion section soon to follow. Compared are two theories, stated at an equally coarse level of

resolution, against the known facts of WTC 7's collapse. The first is the general idea that, possibly, debris impact and the resulting fire led to the collapse of WTC 7. The second is that, despite the photographic evidence of debris damage and reports of fire, the collapse would not have occurred were it not for deliberately planted explosives. We compare these two scenarios against a variety of high-level properties, some of them chosen by Dr. Griffin, and find the following:

Impact and Fire		**Planted Explosives**	
Evidence of fire?	Yes	Evidence of explosive devices?	No
Evidence of impact?	Yes	Evidence of detonations?	No
Matches speed of collapse?	Yes	Matches speed of collapse?	Yes
Matches symmetry of collapse?	Yes	Matches symmetry of collapse?	Yes
Explains "squibs?"	Yes	Explains "squibs?"	No
Explains "evaporated" steel?	Inconclusive	Explains "evaporated" steel?	No
Consistent with observed structural degradation?	Yes	Consistent with observed structural degradation?	No
Consistent with fire on multiple floors?	Yes	Consistent with fire on multiple floors?	No
Historical precedent?	Yes (steel portions of skyscrapers, and entire steel structures other than skyscrapers, totally destroyed by fire)	Historical precedent?	No (no explosive implosion of a burning building in history)

Table 2: Evaluation Criteria of Competing Hypotheses

Dr. Griffin will no doubt dispute some of the author's choices of evaluating criteria. He will also fault our previous explanations of why the "squibs" and "evaporated steel" are totally uncharacteristic of explosives, but he has consistently argued these points from personal incredulity alone and is unable to provide a reasoned reply in his book. The point of this table is to demonstrate graphically why Dr. Griffin cannot shift the burden of proof. While the NIST working hypothesis is rough – as it should be, given that even the draft report has yet to be released – for every problem he finds with this hypothesis, his own undefined hypothesis will have many more. For this reason it is totally incorrect to state that the burden of proof lies upon any opponent of his own theory. Even if it should transpire that the FEMA hypothesis and the NIST working scenarios are all totally discredited by further analysis, this does not mean that the controlled demolition hypothesis is correct or even credible. There are numerous other possible explanations for the collapse of WTC 7, many of them completely mundane.

This situation would not be so strongly turned against Dr. Griffin if he could provide any actual evidence of his claims – for example, an unexploded demolition charge or shaped charge debris, leftover detonating cord, or audio recordings of sequenced explosions – or at the very least calculations demonstrating the errors he claims are in the NIST reports, and a detailed explanation of his hypothesis that could be plausibly executed. Having produced none of these, his theory is in no position to be given equal consideration. The plausibility of his hypothesis is an illusion created by its total lack of detail.

Dr. Griffin's Summary Comments

The final word in this chapter is another mystification directed at NIST in general, and contributing scientist Ronald Hamburger in particular. Dr. Griffin criticizes them strictly because the NIST Report proceeded from the assumption that aircraft impact and fire destroyed both structures, leading him (quoting Michael Green) to state that "the question of what caused the Towers and WTC 7 to collapse was never addressed by NIST, no more than NIST addressed the question 'Do pigs fly?'"

This comment, perhaps more than any of the other misconceptions, errors, or outright lies in the chapter, reveals the fundamental problem with Dr. Griffin's thinking. Scientific investigation always proceeds from known facts, and compares competing hypotheses against those facts, refining them as additional facts are discovered. While there are even those in the Truth Movement who will dispute these basic facts, we may conclude without any doubt that aircraft did hit the two WTC Towers, and both towers did experience large fires as a result. These two facts are certain. Similarly, WTC 7 was severely damaged by the collapse of WTC 1, set afire, and burned for hours afterward. These facts are also certain. Explosives, on the other hand, are not – after over 60 pages, Dr. Griffin himself can muster only the most circumstantial support, and only by refusing to add any refinement to his hypothesis. The Scientific Method requires that these two notions – one concrete and accepted as fact, the other speculative – must not be treated equally. For Dr. Griffin to insist otherwise is a rejection of the scientific method.

Discussion

Regardless of what we believe actually happened on September 11th, the sheer volume of the debate is surprising – Dr. Griffin has written entire books criticizing the 10,000 page NIST Report and related investigations. NIST has issued replies, and *Popular Mechanics* has published a book in response to the criticism. Dr. Griffin has now issued this book, *"Debunking 9/11 Debunking,"* as a retort. We have examined the NIST-relevant claims contained in his latest book, spending well over 100 pages in the process, and concluded that they are incorrect in every major detail. This volley of commentary shows no sign of stopping, as clearly neither side can convince the other.

How can this occur? Given that in this discussion we have restricted our study to the most objective portions of the September 11th investigations, eschewing discussions of politics, motive, and opportunity wherever possible, why does Dr. Griffin reach such a radically different set of conclusions than the scientific establishment? Why can neither side be convinced? Who has made the fundamental error, and why does it persist? How can this be avoided?

In this section we will examine the underlying flaws in Dr. Griffin's approach, rather than the specifics of his claims, contrasting his methodology and reasoning against the scientific method. While it is doubtful that such an analysis will sway Dr. Griffin from his argument where so many other responses have failed, it will serve the reader by outlining many classical errors of logic, using his claims as a cautionary example.

Review of the Scientific Method

Science can be thought of as a method to establish what is *fact*, or a concrete and objective understanding of what has happened; and *theory*, an organized understanding of why things happened, in sufficient detail that we can partially predict what will happen in the future. Strictly speaking, there is no single rote process that describes the scientific method, but there are a number of consistent guidelines that apply to any scientific inquiry. These guidelines exist because of common and easily made mistakes that interfere with scientific progress. For example, a scientist must always be careful to eliminate her own bias, which can interfere with observation, hypothesis, and experiment alike. Over the course of history, scientists have developed numerous logical and observational techniques to help prevent these problems; some through experimental design, such as double-blind testing; others through behavioral adaptation, such as peer review. Each of these "traditions" of science exists for a specific reason, and that is to help advance the process of scientific learning in one way or another.

There is a wealth of writings on the scientific method and critical thinking, both on the Internet and in traditional literature, going as far back as Aristotle's *Physica* [198] and culminating in Descartes' *Discourse on Method* [199]. Numerous retellings exist in textbooks, popular literature, and on the Internet. We begin with a typical and accessible

example by Steve Schafersman, describing the scientific method in broad strokes, as summarized by the excerpts below:

> 1. One must ask a meaningful question or identify a significant problem, and one should be able to state the problem or question in a way that it is conceivably possible to answer it. Any attempt to gain knowledge must start here.
>
> 2. One must next gather relevant information to attempt to answer the question or solve the problem by making observations. The first observations could be data obtained from the library or information from your own experience. Another source of observations could be from trial experiments or past experiments. These observations, and all that follow, must be empirical in nature – that is, they must be sensible, measurable, and repeatable, so that others can make the same observations.
>
> 3. Now one can propose a solution or answer to the problem or question. In science, this suggested solution or answer is called a **scientific hypothesis,** and this is one of the most important steps a scientist can perform, because the proposed hypothesis must be stated in such a way that it is testable.
>
> 4. Next, one must **test** the hypothesis before it is corroborated and given any real validity. There are *two* ways to do this. First, one can conduct an *experiment.* This is often presented in science textbooks as the only way to test hypotheses in science, but a little reflection will show that many natural problems are not amenable to experimentation… The second way to test a hypothesis is to *make further observations.*
>
> 5. If the hypothesis fails the test, it must be rejected and either abandoned or modified. Most hypotheses are modified by scientists who don't like to simply throw out an idea they think is correct and in which they have already invested a great deal of time or effort. Nevertheless, a modified hypothesis must be tested again. If the hypothesis passes the further tests, it is considered to be a **corroborated hypothesis,** and can now be published.
>
> 6. The final step of the scientific method is to construct, support, or cast doubt on a **scientific theory.** A theory in science is not a guess, speculation, or suggestion, which is the popular definition of the word "theory." *A scientific theory is a unifying and self-consistent explanation of fundamental natural processes or phenomena that is totally constructed of corroborated hypotheses.* [200]

The underlying purpose of the scientific method is *discovery* – of making new observations, organizing observations in appropriate ways, explaining them, and ultimately predicting them, and in the process discovering the causes and structure of natural behavior. Science is an additive process, and theories may at times lie unchanged for hundreds of years before being newly refined through new observations and thinking.

The NIST investigation is a part of scientific thinking. While the basics of material strength, combustion, and mechanics are well established, we have over time developed ways to understand and predict the behavior of increasingly complicated structures and events. The WTC Towers collapses were unusual events of great complexity, essentially the only full-scale experiments of their kind ever conducted. Thorough study of these events drives scientific tools and theories – such as structural, impact, and fire modeling – to new limits as well. NIST's intention is to understand what caused the collapses, but also to propose additional guidelines for future construction. In order to produce the

most likely explanation and the most efficient recommendations, NIST has applied the methods of science in its research.

There are two sides to the NIST Report. One side is the theory, namely "what could happen," and the other is a set of specific observations, "what did happen." It is important to understand that the WTC collapses are only *two specific examples.* There is always some random element in any experiment, and the WTC collapses were extremely complicated events, both due to their size and the large number of steps between first impact and final collapse. If one was somehow able to recreate an aircraft impact in full scale many times, it is completely possible that just the right combination of speed, angle, impact point, deficiencies in construction, ignition, location of combustibles, mechanical sway and resonance, cracking, fracture, and load redistribution could result in a tower collapsing instantly – an "unlucky" trial of the experiment. It is also possible that a "lucky" trial might never collapse at all. If we were able to run this series of experiments, we would find a distribution of effects, probably concentrated around an average value of time between impact and collapse.

Hypothetically speaking, suppose we run the experiment a thousand times, and find that under such impact conditions, a Tower could be expected to collapse 95% of the time, with an average collapse time of 65 minutes and a standard deviation of 12 minutes. We might also break the event into several phases – for instance, on aircraft impact, we find that on average seven core columns are destroyed, with a standard deviation of three, and we later produce a sharper estimate of the time of collapse as a function of the core damage. In this case, the *theory* is the range of possible outcomes and dependencies between steps, and the *observation* is how any particular trial behaved.

It is also important not to confuse the theory and the observation of the NIST Report. Because we only have two real-world examples, and because these examples are only partially observable, we expect that the theory is not perfect, but merely correct to a given degree of accuracy. Surely we would understand the process better if we had a thousand trials to examine. If we wish to dispute the NIST theory, i.e. to falsify it, we have two options open to us:

- Show the NIST reasoning is incorrect, or demonstrate quantitatively that the NIST explanation of the observed behavior is below any acceptable threshold of accuracy; or
- Provide a superior theory, explaining the observations in more detail and with more accuracy, regardless of whether the NIST theory remains plausible.

In his book, Dr. Griffin has focused primarily on the first approach, attempting to call attention to details and his own interpretation of the observations such that the NIST theory appears to be a poor fit. Unfortunately, this is equivalent to changing the ground rules rather than challenging the theory directly. Some of Dr. Griffin's observations are mere anecdotes, being so limited in scope that they fall under the heading of "acceptable inaccuracy;" others are found to be consistent with NIST under further and more careful scrutiny; and still others are misreadings of the NIST theory or derivations that are

themselves incorrect. In no place does he attempt to quantify the inaccuracies that he perceives, making a fair comparison to the NIST theory impossible. Only rarely does he attempt the second approach, producing simple pieces of theories that he feels apply to a specific observation, but none that apply to the event as a whole. As a result, while the NIST Report can be falsified, Dr. Griffin has not falsified it. Neither is Dr. Griffin's position falsifiable so long as he resists efforts to define what it is that he believes.

By way of analogy, consider the vastly simpler example of automobile accidents. Automobiles are designed to certain crash survivability requirements, and they are laboratory tested using a handful of samples exposed to controlled impacts. In the real world, however, crashworthiness is not a guarantee of survival, simply because there are more variables in a real-world collision, and the quality of any individual automobile is somewhat variable as well. A single example of a collision at moderate speed leading to a fatality does not, by itself, invalidate the testing procedure. Some variation is expected. To prove that the "theory," i.e. the crash safety rating, is incorrect, we would need to either prove that the individual crash was completely inconsistent with the test behavior, or prove through mathematics or further experiment that the testing procedure was inadequate. Both of these methods require a great deal of scholarship, and as such cannot rely on a mere disconnected artifact, mere suspicion, or subjective commentary on the event in question.

The Scientific Method and External Claims

The Scientific Method is also of great use in evaluating and understanding other investigations, even those that are not obviously scientific. A similar approach can be used to examine claims, advertisements, historical accounts, and even beliefs in some cases. Since Dr. Griffin's hypothesis, vaguely worded, does not constitute a complete hypothesis, we cannot treat it on strictly scientific grounds, but it does fall within this expanded category. The techniques are similar, but generalized and possibly easier to grasp for those who have not studied technical subjects.

The late Dr. Carl Sagan, best-selling author and well-regarded astrophysicist, penned numerous essays on the subject of science and critical thinking. Among his best works is the book *The Demon-Haunted World: Science as a Candle in the Dark*, which applies the underlying principles of science to diverse problems including philosophy, metaphysics, fraud, and human nature. In one chapter he describes critical thinking as a "baloney detection kit," and details the tools found in that kit as follows:

- Wherever possible there must be independent confirmation of the "facts."
- Encourage substantive debate on the evidence by knowledgeable proponents of all points of view.
- Arguments from authority carry little weight – "authorities" have made mistakes in the past.
- Spin more than one hypothesis. If there's something to be explained, think of all the different ways in which it *could* be explained.
- Try not to get overly attached to a hypothesis just because it's yours.
- Quantify. If whatever it is you're explaining has some measure, some numerical quantity attached to it, you'll be much better able to discriminate among competing hypotheses.

- If there's a chain of argument, *every* link in the chain must work (including the premise) – not just most of them.
- Occam's Razor. This convenient rule-of-thumb urges us when faced with two hypotheses that explain the data *equally well* to choose the simpler.
- Always ask whether the hypothesis can be, at least in principle, falsified. Propositions that are untestable, unfalsifiable are not worth much. [201]

These principles, described here as straightforwardly as possible, apply to any claim made by anyone, and are especially useful for evaluating the claims made by Dr. Griffin and his quoted sources. If we apply this toolkit to the NIST Report, we find that the results are highly favorable:

- *Independent confirmation:* NIST assembled hundreds of photographs, videos, interviews, documents, and physical samples. NIST contracted independent firms to create and to validate models used in its calculations [202].
- *Encouraging Debate:* NIST produced progress reports and full drafts, eliciting comments from the scientific community a full year before finishing its final report. NIST also sponsored public meetings and conferences to gather additional information, verify its findings, and compare to alternate points of view [203].
- *Arguments from Authority:* While the NIST board and its contractors are all relevant and distinguished experts in their fields, the NIST Report contains little speculation, and is backed by thousands of pages of calculations.
- *Multiple Hypotheses:* The NIST Report originally began with the "Pancake Hypothesis," but concluded that something different had occurred. In component models, NIST varied inputs to create multiple analytical paths to bound the predicted effects.
- *Professional Detachment:* NIST compares its work directly to several other, independent studies [204]. The report gives clear criteria for comparative evaluation between these results, rather than merely asserting its choice.
- *Quantification:* All inputs and all outputs are quantified, along with estimated error where possible. NIST uses this quantification to test its conclusions for accuracy, and reports this even where its results are the weakest, e.g. the pull-in force of sagging floors.
- *Chain of Argument:* The NIST Report clearly lays out the reasoning process in the sub-project reports, organized into eight distinct areas to make the reasoning path easy to follow. NIST's overall conclusion follows a well-defined timeline with numerical and photographic support at every stage.
- *Occam's Razor:* Several sub-projects also include simplified arguments [205], allowing a comparison and "sanity check" against parsimonious explanations.
- *Falsifiability:* The NIST Report was tested against multiple hypotheses and other studies, and defined in rigorous terms its basis of comparison. Had the NIST Report been found inferior to these other conclusions, on that basis it would have been falsified. Therefore, the NIST Report is and has always been falsifiable.

The reader is encouraged to apply the same list of questions to Dr. Griffin's claims, and to become familiar with these techniques for use in a wide variety of endeavors. We will examine a few examples of Dr. Griffin's claims below.

Analyzing Dr. Griffin's Approach

Having reviewed the scientific method and its broader application, we now have a fundamental approach to detect, categorize, and quantify errors in Dr. Griffin's presentation. We are thus prepared to answer the question of why his impressions are so different from those of NIST, all published scholarly papers on the subject, and the overwhelming majority of scientists, engineers, and other experts. The list below considers examples found in his book, but is by no means exhaustive, and is intended to serve as a guide for further independent study.

The logical problems with Dr. Griffin's approach are organized by category, in approximate order of importance.

Anomaly hunting versus an actual theory

Upon reading *Debunking 9/11 Debunking*, the author was surprised to learn that nowhere in this book – and, to the best of my knowledge, nowhere in Dr. Griffin's previous books – does Dr. Griffin articulate his own hypothesis. His entire position can be summarized in two sentences:

- *"9/11 was an inside job."* [206] We understand this to mean that Dr. Griffin believes that the United States Government was responsible.
- *"The World Trade Center buildings were destroyed in a controlled demolition."* [207] Dr. Griffin has also clarified [9] that he does not know whether explosives or incendiaries, a combination of the two, or what particular types were used.

Despite Dr. Griffin's rumination over this theory for nearly five years, personal contact with numerous like-minded thinkers, and an assemblage of facts and arguments that, in his mind, are sufficient to refute the whole of the NIST investigation, there is no additional detail. This hypothesis falls well short of the basic standard of journalism – the six questions of "who, what, where, when, why, and how" – and as such is not a viable alternative to *any* complete hypothesis, let alone one as meticulously researched as that put forth by NIST.

Refusal to present a hypothesis interferes with the Scientific Method as outlined above, and is also contrary to several of Dr. Sagan's tests. In particular: Because there is no clearly stated hypothesis, Dr. Griffin has not "spun multiple hypotheses," or fact any at all, preventing comparison between them and NIST, or between each other. The lack of a clear hypothesis precludes any and all quantification. And because we cannot clearly describe the theory, we cannot falsify it.

Scientists always attempt to formulate a hypothesis, rather than restrict their consideration to a few isolated arguments as Dr. Griffin has done, because coherent statement of a hypothesis helps guarantee *consistency*. Each new idea proposed will have its own consequences and requirements. If these ideas are not woven together in a mutually consistent fashion, there is no hypothesis at all – or one that is self-refuting.

We can see an example of this in Dr. Griffin's writings. Let us start from the idea of "controlled demolition," and then attempt to add detail to this theory. Supposing we accept his assertions and his interpretations of the evidence and quotations that he has provided, we would conclude the following:

- *Dust clouds:* Chemical explosives were planted above and below the impact floors, and detonated during the collapse.
- *Melted Steel:* Large quantities of thermite or a similar incendiary were planted in the structure, and set off well before collapse (leading to the "flow" of metal seen from the fire floors) and during or after collapse (referring to the melted metal seen in the debris pile long afterwards).
- *Eyewitness Accounts:* Explosives were set off before impact, during impact, during the fires, immediately before collapse, and during the collapse.
- *"Free-Fall" Speed of Collapse:* Explosives were set off during the collapse, of sufficient energy to completely destroy the lower structure.
- *Short Lengths of Steel Columns:* Explosive charges were set off throughout the entire structure at intervals of no greater than 25 to 50 feet.
- *Toppling Behavior:* Explosive charges in the upper block were set off in such a way to counteract its rotation.

Even if we neglect the fact that Dr. Griffin has badly misinterpreted or speculated wildly about the evidence that he has considered, and that he has ignored a vast amount of evidence and research, it is still not clear how to thread such disjoint and mutually exclusive requirements into a consistent hypothesis. The best we could do would be to simply include all of these requirements into a single hypothesis, as follows:

Proposed: The WTC Towers contained large quantities of high explosives and incendiaries. These devices destroyed each tower, in the following manner:

- Explosives were detonated just prior to aircraft impact in the basement
- More explosives were detonated during the fires
- Incendiaries were triggered during the fires near the fire floors
- At collapse, a large amount of explosives were detonated:
    - Completely destroying the upper floors
    - Counteracting the upper floors' rotation
    - Completely destroying the lower floors
    - Segmenting the structural steel into lengths of 25 to 50 feet
- At or after collapse, additional incendiaries were triggered

We are still lacking the *who*, the *how*, and certainly the *why*, but at least we have *what*, *where* and *when* covered. Supposing we are happy with this hypothesis, we can test it

against the NIST theory to see which is superior. The theory above fails instantly – it cannot explain the seismographs, which show no explosions at all (except possibly during the precise instants of impact and collapse, hidden by the seismic signal of aircraft impact and falling structure), and it cannot explain how a few individuals survived inside the structure, just to name two reasons out of many. Some facets of the hypothesis are actually self-inconsistent even in this limited reading, for example the destruction *and* rotation, both allegedly by explosives, of the upper block. It also bears mentioning that such a hypothesis is hardly credible with respect to Occam's Razor.

We surmise that Dr. Griffin has not presented a hypothesis, even after years of research and hundreds of thousands of words on the subject, because he is unable to do so. The author welcomes and indeed challenges Dr. Griffin to propose a coherent hypothesis.

Selective fact-finding and quotation, i.e. "Cherry Picking"

In the first objection, we demonstrated how Dr. Griffin fails to use his facts to assemble a consistent narrative. The second objection concerns the facts themselves.

In Dr. Griffin's book, we have observed numerous instances where he has either ignored important facts outright, or has instead relied upon choice wording of individuals to alter their impressions. For example, as we saw before, Dr. Griffin cites Leslie Robertson, one of the designers of the WTC Towers, as claiming that the structures should have survived the impacts, when in fact his complete statement reveals quite the opposite. As another example, he attempts to support his explosives hypothesis by listing some of their effects, such as destructive abilities, while neglecting others like sounds and shock. This leads him to stitch together numerous witness accounts, each of which contains *one* of the effects, but none that capture *all* of the effects that he supposes.

This approach is known colloquially as "Cherry Picking" – an approach to data where the researcher only selects those facts that support his hypothesis, while discarding those that do not. In such an approach, the researcher is imposing his own selective bias. This approach conflicts with several of the guidelines put forth by Dr. Sagan – it restricts one's ability to form multiple hypotheses, it leads to attachment to a particular theory, and it again interferes with falsifiability (in that it rejects facts that could falsify the theory, and only those facts).

Often, this selective approach manifests in the form of a logical error, most frequently an *assuming the consequent* fallacy. In a fallacy of this type, the arguer notes that a certain phenomenon is a possible explanation. The arguer then uses this to suggest the existence of that phenomenon, ignoring alternate explanations. In the most obvious example, Dr. Griffin notes that explosives *can* destroy a building. This, of course, does not mean that explosives *did* destroy the World Trade Center – not unless we identify and exhaust all other possibilities.

A similar but logically opposite case is in Dr. Griffin's repeated statement that "no *high-rise*, *steel-frame* structures have ever *completely* collapsed *due to fires.*" This one assertion contains no less than four instances of "cherry-picking," and leads to an affirming the consequent fallacy, as follows:

- No *high-rise* structure: Many lower structures have completely collapsed due to fires, including those made of steel.
- No *steel-frame* structure: Steel-framed *parts* of high-rises have collapsed, but there are few instances of a pure-steel structure burning in modern times.
- *Complete* collapse: High-rise, steel-framed structures have partially collapsed, and some would have fully collapsed were it not for concrete elements.
- *Due to fires:* The WTC Towers did not only experience fires.
- *Affirming the Consequent:* Dr. Griffin argues that because fires did not lead to such an event in the past, they cannot do so in the present.

As Dr. Sagan indicates, a responsible investigation should incorporate *all* of the facts, not merely those fitting a pre-selected hypothesis. To investigate correctly, we should include knowledge and understanding gained from fires that caused partial collapses, those that caused collapse of structures other than office buildings, and those that caused collapses of structures a mere five or ten stories high. We should also include other information, such as the seismic data, and at the very least we should quote eyewitnesses and experts accurately, completely, and in context. Because Dr. Griffin does none of these things, it is hardly surprising that he arrives at an erroneous conclusion.

Perhaps the strongest criticism of Dr. Griffin in this regard is that, while he and his quoted sources reference the NIST Report about 20 times (mostly through his quoted sources), he references the NIST FAQ twice as often. The FAQ is a summary document, and is often responding to questions that have no bearing on the investigation itself, no relevance, or no grounding in reality. Dr. Griffin's choice to dispute this summary document, rather than the scientific report itself, is classic example of "cherry picking." This is nothing more than an attempt to steer the conversation away from legitimate technical issues, and towards his own selection of topics.

Misquoting and factual error, compounded by lack of verification

In addition to neglecting facts and carefully editing quotes, we find that in a few cases, Dr. Griffin has based his case upon "facts" and statements that are simply wrong. To recount a few examples:

- *Windows broken from heat:* Dr. Griffin claims without support that the fires broke no windows, and uses this assertion to argue that the fires were of low intensity. The NIST team, upon examining hundreds of hours of video and numerous photographs, concluded that hundreds of windows were broken by the heat, and even charts the progression of windows breaking as a function of time.

- *Steel destroyed before examination:* Dr. Griffin stated that 99.7% of the structural steel was shipped overseas to be recycled before it could be properly examined. In actual fact, the NIST-directed team examined the majority of structural steel, but chose to *keep* only about 0.5% of the total mass.
- *NIST altered computer models to fit a pre-determined outcome:* Dr. Griffin repeatedly charges that the goal of the NIST study was to obscure the "obvious" outcome, presumably representative of his own hypothesis. He also cites the impact models and floor-truss pulling calculations as cases where NIST reverse-engineered inputs until they achieved the desired collapse result. In reality, NIST selected an impact case within the observational uncertainty on the basis of its other effects such as debris distribution, and the floor-truss pulling calculation has no effect whatsoever on the collapse model, obviating any need to falsify results to nefarious purpose.

It goes without saying that, to the extent that Dr. Griffin's claims are based upon these mistakes, his hypothesis is unsupported and therefore incorrect. Had Dr. Griffin managed to assemble his ideas into a single hypothesis, these three examples of error would require him to make a significant adjustment to his hypothesis, because his entire claim of controlled demolition is predicated on NIST being wrong, and on the fires being insufficient to cause structural damage.

Dr. Sagan calls special attention to the fact-finding step, noting that "wherever possible, there must be independent confirmation." Besides committing these errors, Dr. Griffin has shirked an additional duty of legitimate research, and that is to *verify* the facts that he presents. In all three of the cases listed above, Dr. Griffin is able to find the correct answer on his own, simply by reading the NIST Report. If doubt remains, it is possible to contact the NIST scientists for clarification. He has done neither.

The same can be said for a multitude of other scientists and eyewitnesses cited by Dr. Griffin. His understanding of the "evaporated steel" is easily corrected by simply reading the original article from WPI. His quotes of individuals like Mark Lozieaux and Leslie Robertson with respect to "molten steel" have turned out to be false, or at the least disputed and retracted. As a researcher, Dr. Griffin has a scientific responsibility to verify the facts upon which he bases his hypothesis, or else he runs the risk of drawing incorrect, and in many cases irresponsible, conclusions.

Inconsistency in approach

Another compelling argument for formulating a hypothesis is that any scientific inquiry is usually narrow but deep, focusing on specific topics and phenomena. Without an overall framework describing the approach, and without adapting this framework whenever there are changes in direction, one runs the risk of focusing on irrelevant details and missing important inferences. This framework is none other than the working hypothesis.

Due in whole or in part to the fact that he has no working hypothesis, Dr. Griffin espouses several contradictory positions at various points in this chapter. We revisit a few examples below:

Amount of Explosives: Dr. Griffin's hypothesis involves explosives, but his investigation diverges with respect to how many explosives were needed. In the first case, he cites puffs of smoke that he dubs as "squibs" as evidence of explosives, and his quoted sources reveal only six such visible features. His theory also would be increasingly plausible if it required only a small number or mass of explosives, given that such explosives were theoretically planted in a clandestine fashion and in a reasonable length of time, presumably by individuals hand-carrying them as they slipped through a hypothetical loophole in building security. However, he cites other sources as stating that, once begun, the collapse should have taken upwards of 45 seconds, and from this he concludes that explosives were needed to destroy virtually every single floor, with little damage inflicted due to gravity. Additionally, he states that the structural steel being broken into relatively short segments is also caused by explosives.

As a result, he has two entirely divergent hypotheses at work – the first, that a relatively small, carefully designed, elegant demolition took place; and second, that a massive, unprecedented, overkill of explosives comprehensively pulverized the structures. The course of our investigation will be quite different depending on which one of these we follow. The first will be sensitive to structural calculations, and requires a refutation of the NIST Report to be credible, which Dr. Griffin has failed to provide. The second runs into numerous problems including the seismometer data and basic questions of logistics, given that such an incredibly large demolition would require an enormous amount of effort and access to every floor, and would be difficult to conceal when it was detonated.

By failing to follow or even construct a working hypothesis, his argument loses all focus. Clearly only one of these scenarios, at most, could have been carried out. If Dr. Griffin's research cannot even distinguish between these two cases, it is extremely unlikely that he can refute a better researched alternative, such as the NIST Report.

Lack of Heated Steel vs. Melted Steel: Dr. Griffin has also made contradictory claims about the role of heat in breaking structural steel. As he correctly notes, none of the NIST recovered and tested steel showed conclusive evidence of reaching over 250 ^{o}C, and he uses this to argue that the fires were too small to have any significant impact. On the other hand, he argues for the existence of not merely heated steel, but melted steel, and claims that melted steel is consistent with explosives. Finally, he also claims that the steel structure was broken into small pieces by explosives.

These statements are mutually inconsistent. Dr. Griffin's hypothesis of explosives cannot be reconciled with NIST's observations, unless he accepts that melting steel is not a feature of explosives, or that the steel structure could have been dissembled by the collapse itself. In either case, to avoid a total self-contradiction, he must accept that the "melted steel" was caused by incendiaries, and he must somehow explain why every steel fragment retained by NIST was totally unaffected by these incendiaries.

Once again, a lack of a stated hypothesis has led to confusion. Dr. Griffin's logical next step would be to identify what specific chemical explosives or incendiaries could lead to melted steel, and what volume to expect, following Dr. Sagan's suggestion to "Quantify." It should be a simple matter to exclude the vast majority of explosives from consideration on these grounds. Regardless, Dr. Griffin does not do this, and as a result must retain a variety of mutually exclusive options in his argument.

Explosives vs. Incendiaries: As we have just seen, some of Dr. Griffin's arguments require incendiaries rather than explosives, if we are to accept his view of the facts. Other arguments, however, cannot be satisfied by incendiaries, but instead require explosives. For example, Dr. Griffin claims the rapid appearance of large dust clouds and a counter-rotation in the upper block of WTC 2 were caused by explosives, and neither effect could possibly have resulted from incendiaries.

The fact that Dr. Griffin's hypothesis requires both should give him and his readers some pause. There is no precedent for both explosives and incendiaries, as building demolition never involves incendiaries of any kind, with the lone exception of visual deflagrations added when such demolitions are also used as movie special effects. But these have almost no thermal effect on the structure, being short in duration and spread over a wide area. In typical demolition, anything that can lead to a fire is a significant hazard.

There is an additional problem in that explosives and incendiaries, in Dr. Griffin's hypothesis, have overlapping effects. Dr. Griffin presumes both of them served the purpose of destroying structural elements, and at the same time. This makes any quantification of how much of each type was required extremely difficult. Additionally, these two types can interfere with each other. Incendiaries are allegedly needed to weaken or melt through steel columns, a process that cannot be instantaneous or perfectly controlled, so the incendiaries would have to be triggered *before* the explosives. This would lead to a risk of setting off the explosives, setting explosives on fire, damaging wiring, or harming detonators nearby, either through direct effect of the incendiary, the incendiary setting off local fires, or the incendiaries failing other parts of the structure.

Again, because Dr. Griffin has not settled on any coherent hypothesis, he is forced to consider an overlap of two completely different hypotheses. There is no ready explanation of why such an absurdly and unnecessarily complex approach would be needed, nor how it could be implemented. Comparing to Dr. Sagan's guidelines again, the absence of a proper hypothesis has interfered with quantification and Occam's Razor, and greatly interferes with falsifiability as well.

Quality of sources cited

As we have noted above, the Scientific Method emphasizes verification of facts, a healthy and open debate, reliance upon data rather than the mere opinion of experts, and

openness to other hypotheses. Such a complicated subject demands careful and balanced treatment of the underlying facts and supporting opinions.

In this chapter, Dr. Griffin lists 254 individual notes, all found on pages 350-363 of his book. The references described in these notes are summarized, according to category, below. Note that the numbers do not total to exactly 254, as some notes contain multiple references, some contain no references, and many quotes are inherited across more than one source.

Governmental Resources	**88**	**Engineering Resources**	**13**
NIST Report	18	Journal articles	2
Other NIST reports	45	Engineering magazines	9
Firefighter interviews	15	Engineering textbooks	1
FEMA publications	8	Engineering websites	1
9/11 Commission	1		
Congressional Record	1		
Mainstream Media	**36**	**Truth Movement Resources**	**108**
Network news and websites	4	Jim Hoffman	30
Newspapers	21	Steven Jones	15
Magazines	3	Kevin Ryan	11
Other media	7	Eric Douglas	9
Other websites	1	Eric Hufschmid	6
		James Fetzer	5
		Charles Thurston	3
		Chris Bollyn	3
		Ed Haas	2
		David Griffin (other works)	2
		Jeff King	1
		Judy Wood	1
		Other Websites	14
		Videos	6

Table 3: Sources Referenced by Dr. Griffin, Listed by Category

The disparity of sources is disappointing, to say the least. The only engineering journal article cited is from Dr. Eagar [143], a paper produced only days after Sept. 11th, in which Dr. Eagar outlines a few basic calculations and suggests the "pancake model" as a possible avenue of investigation. NIST, of course, tested that model years later, using far more evidence, and found it to be incorrect. There have been numerous updated calculations published in engineering journals since then, of which we have examined a few. Where Dr. Eagar and official investigations are cited, i.e. the over 40 references to the NIST FAQ and other summaries, they are usually criticized or contradicted by Dr. Griffin rather than used in support.

In contrast, Dr. Griffin bases a grossly disproportionate amount of his arguments on the assertions of six individuals – 76 out of 245 references, or about 30% of the total, come

from either Eric Douglas, James Fetzer, Jim Hoffman, Eric Hufschmid, Steven Jones, or Kevin Ryan. Unlike the other citations, these are all in support of Dr. Griffin's position.

It is no great stretch of the imagination to suppose that these six individuals – seven if we count Dr. Griffin – could be all mistaken, or driven by an ulterior motive. Between them, there has not been a single journal article published on the subject of the World Trade Center collapses, although Drs. Jones and Fetzer were instrumental in the creation of the *Journal of 9/11 Studies*, a vehicle masquerading as a peer-reviewed publication as we have previously discussed. These seven individuals, as well as the lesser contributors on the list, cite each other's works frequently in their many books, websites, and whitepapers.

What emerges, then, is a clear picture of a small and self-reinforcing group of researchers, totally disconnected from the larger scientific establishment. None of them shows any interest in incorporating the peer-reviewed research of others, nor have any produced any of their own peer-reviewed work on the subject. On this basis, it is no longer so puzzling that Dr. Griffin has drawn, and adheres to, such a different conclusion than NIST, *Popular Mechanics*, the *9/11 Commission*, and the work of structural engineers in many countries.

Forum of presentation, and lack of activity

Another related criticism of Dr. Griffin's approach is the forum in which it appears. Dr. Sagan, again, recommends encouragement of substantive debate wherever possible in matters of scientific inquiry. Dr. Griffin, however, has not participated in such a debate.

The Truth Movement and Dr. Griffin himself have of course been quite active, but not in any scientific fashion. Dr. Griffin has published five books concerning his theories of September 11th, has appeared on C-SPAN and spoken to the Congressional Black Caucus, and held numerous lectures and book signings at the behest of local Truth Movement organizations [208].

What is missing, however, is any attempt to engage any scientific body. Dr. Griffin may well claim he has attempted to bring this about via the "National 9-11 Debate" [209], but this was a mere publicity stunt originally proposed by the Truth Movement, later delayed and ultimately cancelled after it failed to elicit any interest from scientists or the media [210]. The refusal of scientists to participate in such an abnormal proceeding is hardly unusual.

In the ordinary process of science, when results are controversial – a common occurrence, particularly in astrophysics and the biological sciences – competing papers are published in journals, respected magazines such as *Nature*, or at the very least in technical conferences. As Dr. Griffin's difficulties with the NIST Report are of a structural engineering and physics basis, it stands to reason that structural engineering conferences would be the appropriate forum to open his dialogue with qualified experts.

The standards for publication in such conferences are relatively lax, in an effort to foster spontaneous and lively contributions. If any of the various arguments Dr. Griffin has put forth here were correct, he or any of his colleagues would have no difficulty at all bringing such material to the attention of professional and academic scientists.

Besides the academic path, NIST itself held a number of public hearings intended to perform fact-finding, and additionally released a draft edition of its final report for public review a full year before issuing the completed report. Dr. Griffin did not avail himself of these opportunities, either. His colleagues *have* responded to NIST, but not through these channels, instead choosing to open a "petition" demanding certain adjustments [211] after the investigation had concluded. The adjustments they request are a subset of the arguments we have reviewed in this treatise, and as such are easily shown to be incorrect.

Dr. Griffin's behavior is important because the purpose of the scientific method is to advance *discovery* and *learning*, both for the investigator and for the scientific community as a whole. In restricting his efforts to biased venues and the popular, unreviewed press, Dr. Griffin has deliberately avoided the scientific establishment. This in turn retards his ability to learn from experts, and further explains why he reaches such radically different conclusions.

Rejection of the scientific method

As we have seen, Dr. Griffin's approach violates every single tenet of Dr. Sagan's "baloney detector kit," some in several different ways. The NIST Report, on the other hand, tracks well against this *ad hoc* but useful description of the scientific method. Given the isolated, combative, and inconsistent nature of Dr. Griffin's investigation, it is no mystery at all why he arrives at a contrary hypothesis, or why he has resisted each and every attempt to correct his logical and factual errors.

Since Dr. Griffin's approach is not scientific, it may be said to be *pseudoscience*, defined in the American Heritage New Dictionary as "a system of theories or assertions about the natural world that claim or appear to be scientific, but in fact, are not." Pseudoscience covers a wide range of topics, including astrology, faith healing, and psychic phenomena, but also incorporating more physical hoaxes such as perpetual motion machines. These fallacious claims are ubiquitous, usually marketed to the general public directly and publicized in books rather than to any scientific body and in journals, as such fraudulent claims are quickly exposed when examined by professionals.

As with the scientific method, many people have written about pseudoscience. Among the best known works is the book *Fads and Fallacies in the Name of Science* [212] by Martin Gardner, first appearing over 50 years ago and continually updated as new hoaxes appear. Mr. Gardner is a controversial figure, strongly wording his condemnation of pseudoscience and forceful in his philosophy, but he nonetheless leaves us with useful

guidelines for discriminating pseudoscience from real science. In particular, he provides five general characteristics of a pseudoscientist:

> There are five ways in which the sincere pseudo-scientist's paranoid tendencies are likely to be exhibited.
>
> 1. He considers himself a genius.
> 2. He regards his colleagues, without exception, as ignorant blockheads. … Frequently he insults his opponents by accusing them of stupidity, dishonesty, or other base motives. If they ignore him, he takes this to mean his arguments are unanswerable. If they retaliate in kind, this strengthens his delusion that he is battling scoundrels.
> 3. He believes himself unjustly persecuted and discriminated against. The journals reject his papers and either ignore his books or assign them to "enemies" for review. It is all part of a dastardly plot.
> 4. He has strong compulsions to focus his attacks on the greatest scientists and the best-established theories.
> 5. He often has a tendency to write in a complex jargon, in many cases making use of terms and phrases he himself has coined. [213]

We find these general characteristics are a good fit to the ideas in Dr. Griffin's book. We will discard the first characteristic as it is defamatory and vindictive in tone, but the other four can be tested objectively against the material in *Debunking 9/11 Debunking*:

Regard for Fellow Researchers: Dr. Griffin impugns the NIST scientists on numerous occasions, at various times accusing them of deception, "making misleading statements and even telling outright lies" [214], falsifying results [215], and knowingly participating in a government cover-up of the murder of thousands [216]. He uses the fact that NIST did not investigate explosives as support for his argument [217], and simultaneously takes the mention of explosives in the NIST FAQ as "significant" [217].

Belief in Persecution and Discrimination: Dr. Griffin makes an impassioned argument for his belief that there "appears to have been a concerted effort to keep the collapse of [WTC 7] from being widely known" [218]. Regarding the future reception of the as-yet unpublished WTC 7 investigation, he observes that: "The left-leaning press will, moreover, probably again let them get away with it, dismissing any challenges to NIST's account as based on wild conspiracy theories." [219]

Attacks on Leading Scientists and Competing Theories: Dr. Griffin's entire book can be seen to fit this category. In it, he singles out and attacks the *9/11 Commission Report*, the book *Without Precedent* by Kean and Hamilton, the NIST Report, and the book *Debunking 9/11 Myths.* These four publications, two official and two independent, span the best-known and most in-depth legitimate inquiries and responses to his position.

Jargon and Neologisms: While we cannot give sole credit to Dr. Griffin, the Truth Movement is replete with neologisms, many of which are found in his book. The self-bestowed title "Truth Movement" is itself a curious neologism. Also appearing in this chapter are "squibs," repeated misuse of the phrase "controlled demolition," the poorly worded "faster than free-fall speed" [220], and the ubiquitous "9/11 was an inside job."

As we can see, Dr. Griffin definitively meets all four of the objective test criteria. While this is hardly decisive on its own, it lends further insight into the origin of Dr. Griffin's errors. We have shown comprehensively the logical and factual errors in his specific arguments. We have identified his numerous departures from the scientific method. We have also observed traits of his investigation that are consistent with pseudoscience. There can be little remaining doubt as to the cause of his errors or to the value of his opinions on the subject of the NIST Report and its conclusions.

Dr. Griffin and others in the Truth Movement frequently call for "a new investigation" [1], presumably an impartial investigation with no ties of any kind to the United States government. Such an investigation, in order to be of any utility, should follow the basic requirements of the Scientific Method. It is clear from an analysis of Dr. Griffin's approach thus far that he is in a poor position to judge the scientific merit of any investigation. This is in keeping with the fact that, to date, he has yet to identify any valid criticism or any actual errors present in the NIST Report.

Legitimate Criticism of the NIST Report

Members of the Truth Movement, attempting to rationalize why so many scientists and engineers support the NIST hypothesis and reject their claims, typically propose one of two reasons. One typical charge is that scientists are effectively puppets of the Government – as *Popular Mechanics* editor James Meigs found himself accused [221] after his magazine published its landmark expose [222] about the Truth Movement. The other is that the NIST Report itself is unfalsifiable, a document too vague and too dependent upon arbitrary inputs to be properly tested. Dr. Griffin argues both points. We have already considered the scientific viability of the NIST hypothesis, but to further repudiate such aspersions, we offer our own critique and criticism of NIST's conclusions.

The author agrees with Mr. Meigs that the "official theory" of the September 11th disaster is, scientifically speaking, essentially a consensus. However, this does not mean that there is no longer discussion and debate over the conclusions, any more than consensus on evolution means that the theory of evolution is no longer being researched. To invoke Dr. Sagan once again, it is always recommended to include all points of view in a scientific investigation – provided those points of view are, themselves, well founded in fact, reasoning, and scientific principles. This debate still continues in universities, engineering societies, and NIST itself. But it is important to note that there is an instantly recognizable difference in quality between these differing professional opinions, and those promoted by the Truth Movement, as we will now illustrate.

NIST vs. University of Edinburgh and Arup on Thermal Modeling

In 2005, NIST held an invited conference [223] dedicated to reviewing the results, methods, and recommendations of its study. Numerous participants, from within NIST as well as other industrial and university experts, presented their findings and their impressions. An entire conference track was devoted to independent criticism. Perhaps the strongest criticism came from the engineering firm Arup, building upon the work of Dr. Usmani at the University of Edinburgh [35], as we examined previously. The Arup presentation [224], given by Dr. Barbara Lane, identifies a number of potential shortcomings with the NIST investigation, summarized below:

- The NIST global model in NCSTAR1-6D does not consider the full heat response of floor truss elements, in particular their thermal expansion and contraction.
- Floors in the NIST global model are treated as simple diaphragm elements, capable of exerting forces on core and perimeter columns but not treating stress due to thermal expansion.
- As a result, the NIST model must use photographs of perimeter column bowing as an input, rather than predicting the column bowing.
- The NIST model is therefore excessively sensitive to estimates of fireproofing damage.

- Arup models predict that, had there been no structural member damage from impact – only fireproofing damage – the fires alone would have been sufficient to destroy the Towers, whereas NIST predicts column damage is an essential element for collapse.
- Therefore, Arup suggests that the NIST recommendations for future construction are too focused on fireproofing, and diminish the value of carefully planned structural redundancy that could help eliminate the particular fire failure mode of the WTC Towers.

The Arup conclusions, while debatable, are not without merit. NIST makes no secret of the fact that its global response model contains a number of simplifications, among them simplifications of the floor elements. From NCSTAR1-6D:

> It was not practically possible to develop global models that could capture all structural behaviors or failure modes found in the study of components and subsystems and to perform the global analysis within a reasonable period of time. … Since detailed modeling of the floors was not included in the global analysis models, important floor behavioral modes could not be captured in these global analyses. Key floor behavioral modes include floor sagging that imposes pull-in forces on the exterior wall and loss of support of the trusses at the exterior wall resulting in local disconnection of the floor from the exterior wall. To account for these effects, pull-in forces on the exterior wall and disconnections of the floors from the wall were introduced in the global analyses at appropriate times as fire-induced damage. In the process of developing the fire-induced damage, the behaviors predicted by the full floor model analyses as well as the damage observed by NIST in their review of photographic and video evidence were both considered. [225]

It is useful here to recall the purpose of the NIST investigation. The primary goal of the NIST effort was to understand why and how the Towers collapsed. In the case of the floor response and pull-in forces, NIST has a significant amount of direct observation to rely upon, namely the numerous observations of when, where, and how much the perimeter columns bowed inward in the minutes leading up to collapse. Had this not been the case, NIST would have needed to investigate the pull-in mechanism much more carefully. However, since we can treat the existence and magnitude of the bowing as fact rather than conjecture, it would not be correct to state that NIST has not modeled the Towers with enough fidelity to explain their collapse. Still, a model that accurately predicts this effect in onset and magnitude will be superior to the NIST collapse model.

Regarding the pull-in forces, the NIST model contains a few basic but important assumptions:

1. Component testing with single floor models only, where trusses are modeled with higher fidelity, gives sufficient bounds on the thermal expansion behavior of the floors relative to the columns.

2. The thermal expansion behavior is small compared to the sagging behavior, simulated by a simplified truss model, and can be neglected except for small corrections.

3. These small corrections can be inferred from measurements of the column bowing behavior.

4. Errors in this calculation are small compared to other, irreducible uncertainties in the calculation, such as the actual friction behavior and breaking force of the floor connections.

5. For these reasons, increasing fidelity in the model exceeds the point of diminishing returns. Computational uncertainty is already comparable to experimental uncertainty due to imperfect knowledge of the structure and its behavior.

Regarding the fourth point above, NIST clarifies the unknowns in the structure in Section 2.5.2 of NCSTAR1-6D. Some excerpts are reprinted below for context:

- There is considerable uncertainty as to what the actual capacity of the strap anchor system was to transfer pull-in forces from the floors to the walls.
- Creep at high temperature was found to significantly increase the sag of a floor system. … However, full floor models were … not run with creep due to inherent convergence problems…
- In the full floor models, crushing or cracking of the concrete slab was neglected. Extreme temperatures can crack and spall concrete, further reducing the floor stiffness, and increasing both the floor sag and the floor/wall pull-in forces.
- NIST may have underestimated the amount of thermal insulation that was damaged by the aircraft impacts. … Potential loss of insulation due to impact shock and vibration effects was not included. [226]

As we have already discussed, the cumulative effect of these simplifications is not likely to affect the question of how or why the Towers collapsed. It can, however, affect purely hypothetical questions of how the Towers would have behaved under totally different circumstances. This does not hinder NIST in explaining why the collapses occurred, but it does potentially impact NIST's recommendations for future construction.

Let us now consider the alternative hypothesis articulated by Dr. Usmani and Arup. They have produced different finite-element models that capture some of these important features, while making different simplifications. Dr. Usmani's original model [35] was a two-dimensional vertical slice through a section of perimeter wall, containing a number of floor trusses, and assuming the core columns were completely rigid. Dr. Usmani's conclusions were the following:

1. The analysis presented points to a compelling fire induced collapse mechanism rather unique to the type of structure that the WTC Twin-Towers represented
2. This analysis also shows that the collapse is initiated principally by a stability mechanism as a result of geometry changes in the structure caused by thermal expansion effects
3. Furthermore it is quite possible that the geometric changes required to precipitate collapse could result from very low temperatures not high enough to induce significant reduction in the material properties
4. It can therefore be provisionally concluded that these buildings could have collapsed as a result of a major fire event. This is of course assuming that any of the active fire suppression systems would either fail or be unable to control the development of the fire. This is a normal assumption when designing fire protection for buildings [227]

Having said this, his original model was limited by a number of simplifications:

- His model neglects three-dimensional effects;
- It is not a faithful recreation of the WTC Towers design, but rather a generalized model of a similar system;
- It does not include some structural elements, such as the perimeter spandrels, that would also resist perimeter column buckling;
- It does not consider fires in detail, using a simplified model and uniform heating curves; and
- It may be sensitive to dynamic effects such as "backlash" from elastic columns (see comments on "dynamic magnification," [35] page 30).

Limitations notwithstanding, this was a useful experiment that provided valuable insight into the pull-in mechanism. NIST later found this mechanism to be one of the critical ingredients of the Tower collapses. Where NIST and Dr. Usmani differ, however, is in the relative *strength* of the pull-in failure mode – Dr. Usmani, predating the NIST Report, estimated that floors would buckle, leading to a pull-in mechanism capable of destroying the Towers even if there was no core damage at all, whereas NIST determined that without core damage and fireproofing damage, the Towers would have burned out without collapsing. Since both the NIST model and Dr. Usmani's model contained different simplifications, the author suggests that further experiments are necessary to definitively resolve this difference of opinion.

NIST's own review of Dr. Usmani's work is found in NCSTAR1-6, and reads as follows:

> NIST findings also differed from the findings of the University of Edinburgh study. NIST included thermal expansion in its detailed analysis of full floor systems, and did not find that buckling of any floor system occurred. Rather, as truss web members began to buckle, the floors began to sag, which increased over time. The sudden buckling of the first floor in the Edinburgh analysis, followed by the sudden subsequent failure of floors above and below, does not match the observed inward bowing of the exterior walls which increased over time. [228]

Dr. Lane, representing Arup, presented a similar but more sophisticated model in the 2005 conference. This improved approach again considered multiple floors, but instead of taking a two-dimensional slice, one quarter of each floor was modeled in three dimensions. The fidelity of the floor trusses, columns, and spandrels was improved, closer approximating an actual structure. As before, the fires and heat transfer were simplified – what Arup refers to as the "design approach," considering a hypothetical fire load, rather than simulating any particular fire.

With this improved model, Arup stands by its conclusion regarding vulnerability to fire:

> Based on our observations of collapse without aircraft impact included, and NIST's representations of the global response of the structure to fire, we do not consider NIST to be in a position yet to conclude had the aircraft not knocked the fire protection off, collapse would not have occurred [229]

In the author's opinion, this is a valid inference. The NIST model, because of its simplifications, relied upon photographic evidence of the perimeter column bowing and,

to a lesser extent, sag in the floor trusses. It would therefore be impossible for the NIST model to accurately predict a *hypothetical* fire situation, simply because there would be no photographs. The NIST model is thus of diminished utility in predicting the response of other structures, and is limited as a design tool.

In defense of NIST, it is unclear that the NIST model was ever intended to serve in such a fashion. The model was, first and foremost, intended to explain *why the Towers collapsed.* This result is unaffected by its reliance upon photographic evidence, since those photographs are available and are of relatively high quality. While NIST does have a secondary and important duty in recommending changes in future building codes, these recommendations are based upon the *overall conclusions* of the NIST study, and not on hypothetical experiments with little connection to the September 11th attacks. One of the features of the NIST model is its high fidelity in representing the WTC Towers as-built. Any hypothetical design study will naturally have a different structure, as it is unlikely that anyone will replicate the WTC Towers design in the future. For this reason, it is unclear that the NIST model would be of significance for future design studies even if it also contained all the features of the Arup model.

NIST's own take on the Arup presentation is as follows:

> The study by Arup found that the composite truss floors sagged as they were heated and pulled inward on the exterior wall, similar to the findings by NIST. However, the NIST analyses did not find uniform temperatures across an entire floor nor simultaneously on multiple floors, as assumed in the Arup analyses. Further, NIST did not find any insulated truss members reaching temperatures of 800 °C prior to the collapse of either tower. NIST thermal analyses showed that steel temperatures in areas where the insulation remained intact rarely exceeded 400 °C in WTC 1 and 500 °C in WTC 2. The Arup 3D seven-floor model did not include load transfer mechanisms, including the hat truss, the core, and sufficient portions of the exterior wall to provide the arching action observed in the impact faces. [230]

To conclude this review, these criticisms demonstrate conclusively that (a) the NIST model is imperfect, (b) NIST acknowledges its limitations in the NIST Report itself, (c) scientists are able and willing to challenge its assumptions and conclusions, and (d) NIST itself facilitates such reviews and discussions. These independent conclusions, while differing from NIST's own, strongly support the theory that the aircraft impacts and fires were expected to destroy the Towers, through the mechanism that NIST proposes, without any assistance from explosives or other unknown factors.

NIST, Dr. Usmani, and Arup merely conflict over the question of whether core impact damage and/or fireproofing damage was *needed* for them to collapse. This question remains open as there is still room for improvement in all of the analyses so far presented. It is of significance with respect to future building design, and should be resolved. However, it in no way suggests that the collapses themselves were at all unexpected. As we see in this example, responsible scientists agree that there is no evidence of an "inside job," using fully independent investigations and methods.

Modeling Fuel at Impact

In the previous section, we remarked upon some of the limitations of NIST's models and further highlighted the importance of fireproofing damage at impact. One of the most important factors of the impact is the behavior of the jet fuel, estimated at close to 25% of the total mass of each aircraft, and particularly important in the wing impacts since fuel made up over half of the mass of the aircraft wings. Fluid behavior is inherently difficult to model – even compared to the rest of the aircraft impact model – because the fluid is naturally prone to large deformations, unlike structural members which deflect only slightly before failure.

Consideration of the aircraft fuel, while difficult, is important as it has a significant impact over the evolution of the structure as a whole. NIST's conclusions about the fuel, found in NCSTAR1-2B and NCSTAR1-5F, include the following:

- NIST estimated the weight of fuel at 66,100 pounds in American Flight 11 and 62,000 pounds in United 175, or roughly 23% and 22% of the total weight respectively. (NCSTAR1-2B page 71)
- Aircraft wing segments without jet fuel would heavily damage but not destroy perimeter columns at impact (NCSTAR1-2B page 120), whereas wing segments with fuel would completely destroy perimeter columns. (NCSTAR1-2B page 130)
- Aircraft wing sections with fuel would completely destroy core columns as well, but fuel was expected to disperse following contact with the perimeter columns, at which point the impact of the fuel would load and damage but not destroy the core columns. (NCSTAR1-2B page 376)
- Even though the impacts were mostly horizontal, the fuel behavior was expected to create large vertical forces on the interior floors immediately following impact. This also was expected to lead to almost total destruction of building contents, unlike more solid pieces such as engines, which were predicted to travel ballistically, punching holes in furniture and walls. (NCSTAR1-2B page 150)
- The fuel behavior has a significant impact on the removal of fireproofing material and the initial growth of fires, but virtually no impact on the long-term behavior of the fires. (NCSTAR1-5F page 90)

Because the fuel behavior is so important, the difficulties in fuel modeling are significant. After evaluating three different fluid modeling approaches in the component simulations, NIST opted to calculate the fuel flow using a Smoothed Particle Hydrodynamics (SPH) approach. This approach, using kernel functions to smooth and restrict the forces on each individual calculation to a small area of interest, is commonly applied to large, complicated fluid calculations such as star formation [231], thanks to its relative efficiency. This approach is well suited for calculations of mass and momentum, but less suited to accurate prediction of individual particle motion.

NIST's primary interest in this calculation was that of momentum transfer, as it attempted to estimate the effect of the fluid impact on the structure. For this task, the SPH approach

is completely justified. It is, however, less valid for estimation of fireproofing damage or the ultimate distribution of the fuel. NIST was also forced to implement several simplifying assumptions due to the sheer magnitude of the calculation:

- The model imposed a minimum size of any piece of fluid – a "fluid parcel" – of roughly one pound (about 1.5 liters).
- Windows were not included in the impact model, and as a result the model overestimates the volume of fluid exiting the structure.
- Contact with structure was considered elastic, with no fluid wetting or substantial erosive effects.
- The model was run for under one second of simulated time, and thus the effect of gravity leading to fluid pools or fluid flow to lower floors was not included.
- Fluid evaporation, heating through turbulent dissipation, and fuel deflagration (burning) were also not included.

Regarding these assumptions, NIST commented on the difficulty of adequately modeling the situation as follows:

> The physics of fuel impact and dispersion in this type of impact event is complex and no appropriate validation data could be found. The fuel starts as a continuous fluid within the tanks and ends up distributed both on the tower structures and as small droplets that interact with the atmosphere surrounding the impact zone. No single analysis technique is currently available that can analyze this full range of fuel dispersion without significant uncertainties. [232]

The author sympathizes with the inherent difficulty. Again, these simplifications do not appear likely to affect the question of structural damage at impact, which is the primary result from this project of the NIST Report. However, these simplifications will also affect the fluid motion, and in turn affect the predicted damage to fireproofing and fuel load for the fire models. We will focus on these secondary results.

The large uncertainty regarding fuel trajectories is illustrated by NIST in Figures 5-32 and 5-33 in NCSTAR1-2B. These two figures depict the simulation of a wing segment impacting a section of perimeter column, identical except for the fluid modeling approach used in each. Figure 5-32 uses an Arbitrary Lagrangian-Eulerian (ALE) method, in which both fluid and nearby solid objects are considered as two separate meshes; figure 5-33 is the same situation except using the SPH method previously described. The two methods differ greatly with respect to the spread of fluid – unsurprisingly, the SPH method shows much more rapid and elastic dispersal. Ultimately, lacking any way to validate either model, NIST chose the latter for reasons of economy, as the SPH approach was found to be roughly a full order of magnitude faster. Nonetheless, this comparison demonstrates that the trajectory of the fluid has large uncertainties in the NIST model.

Regarding the uncertainties in the fire model, NIST remarked upon the probable causes of these uncertainties as follows:

> **Consequently, the simulated fires described in this chapter were of comparable character to the actual ones, but they did not reproduce all of the observed fire activity because of the**

uncertainty in the initial and boundary conditions of the calculations. Where there were discrepancies between prediction and reality, consider the following:

- The interior damage and jet fuel distribution were very crudely approximated from the impact analysis, which focused on "hard" (columns, trusses, floor slabs) rather than "soft" (walls, furniture, airplane contents) targets.
- The jet fuel distribution on floors that were not directly impacted by the airplane was very difficult to prescribe because it had to be assumed that the fuel leaked through damaged floor slabs, poured down vertical shafts, or was propelled by the initial fire balls.
- The furniture in the model was distributed uniformly throughout each floor, or it was crudely "plowed" away from the impact area. In reality, some parts of the floors were more heavily loaded with combustibles than others. This assumption affected the dwell time of the simulated fires. The observed fires lingered longer in areas with a relatively heavy fuel loading, and swept more quickly through areas with a light loading.
- All office doors were assumed open in the simulations even though many would have been closed because the buildings were only partially occupied at the time of the attacks. There were often significant differences between prediction and reality in regard to the fires' penetration into compartmentalized areas of various floors. [233] (Emphasis in original)

To execute its fire models, NIST assumed that only 40% of the aircraft fuel load contributed to the fire on the focus floors near impact. This was based on estimates that 20% of the initial fuel was ejected from the structure or consumed by the initial fireballs, and that roughly half of what remained would drain away from the focus floors to elsewhere in the structure. We remark that the reasoning above is certainly plausible, but is at best an educated guess. Since NIST found that the long-term fire behavior was insensitive to jet fuel distribution, we accept that these assumptions are not likely to adversely impact NIST's overall conclusions.

What remains open, however, is the behavior of fires *away from* the impact floors. Fires were detected both above and below the point of impact. Those below the impact are unsurprising, given the enormous quantities of fuel and the elevator shafts running the full height of the structure, but those above are more difficult to explain. NIST describes one of these events, from the 104th floor of the North Tower:

> One of the more interesting fire spread behaviors associated with WTC 1 was observed on the west face shortly after the collapse of WTC 2. A video shot from a news helicopter shows that a short burst of flame occurred from a 104th floor window on the south side of the west face at 10:01:15 a.m. A large fire then grew rapidly in this area. By 10:01:33 a.m. the fire had grown large enough to be visible in a very long distance view of the west face shot from a second news helicopter. It is difficult to provide an explanation for the appearance of flames at a location that is three floors higher than any other floor where fire has been observed up to this time and five floors higher than a floor with a major fire. [234]

> It has been speculated that the fires observed on the west face of the 104th floor either were started just after impact due to the fuel gases that were pushed into the vertical shafts by the sudden ignition of atomized jet fuel, or the fires were started as a result of the accumulation of fuel-rich gases in the core shafts over the course of the 100 min. The presence of fire in the shafts on the 99th floor in the simulation provides some support for the latter hypothesis, but no simulations were performed for floors higher than the 99th. [235]

Why is this significant? It may or may not be. A better understanding of the fuel distribution after impact could help our understanding in the following ways:

- If aircraft fuel after impact could plausibly travel unburnt to the 104th floor after impact, or if fuel vapors could accumulate there without ignition, we need not further speculate about unusual fire behaviors away from the impact floors.
- On the other hand, if fuel motion of this kind is implausible, as it appears to be, then some other mechanism must be hypothesized.
- Candidates for alternate explanations include additional sources of fuel such as emergency generators, volatile chemicals or objects present on that floor such as banks of wet-cell batteries used in uninterruptible power supplies, or previously underappreciated office fire behavior.
- If one of these alternate explanations is accepted, we may also have an explanation for unusual chemical behavior detected after the collapses occurred (see below).

While the potential impact of better fluid modeling on the fire simulation and chemical phenomena is admittedly speculative, the value of better fluid modeling in estimating the collision damage has been recognized. Additional work to refine the impact simulations is ongoing, led by Purdue University [236], under a grant from the National Science Foundation. This effort responds to the limitations in simulation capability identified by the NIST study. The Purdue team has overcome several of the limitations present in the earlier study, including the following:

- While still using the SPH approach, the Purdue simulation uses roughly twice as many fluid parcels (90,000) and very small timesteps (1 microsecond).
- Purdue conducted validation experiments of the fluid impact model using aluminum containers of water fired into steel at high velocity [237].
- The Purdue model includes more detailed accounting of structural properties in the building and the impacting aircraft.

This independent effort, still ongoing, has thus far largely confirmed NIST's results. However, it should be pointed out that the Purdue simulation estimates more impact damage than the NIST model, and also predicts more damage to the opposite perimeter than was observed in the real world. Further work would be required to reconcile these results, and in the meantime, the experimental uncertainties in role of jet fuel in impact damage remain large.

As a postscript, we note with amusement that Kevin Ryan, writing on behalf of the *Scholars for 9/11 Truth*, issued an open letter [238] to incoming Purdue president Córdova criticizing their work. He referred to the Purdue effort as "at best, criminally negligent science on the part of a small segment of the Purdue faculty." While a full analysis of Ryan's comments is beyond the scope of this report, we note that the tone of this letter – vindictive, quoting Purdue results out of context, and applauding those results that conflict with NIST's while deriding the others – is wholly consistent with the guidelines for identifying pseudoscience that we examined previously.

A more careful reading of the NIST and Purdue results reveals that, indeed, there are conflicts between the two. These conflicts are representative of the experimental uncertainty in this and any investigation. Furthermore, while NIST and Purdue disagree with respect to the structural damage at impact and the contribution of jet fuel, Purdue in no way disagrees with or even casts doubt upon the most important result, namely that the WTC Towers collapsed as a result of impact and fire, with no sign of or requirement for explosives or any other malicious device. It also should be obvious that better methods, more careful modeling, and overall improvements in the quality of simulations should one day be able to resolve these differences. Independent review and criticism only serves to strengthen our knowledge and our abilities. The fact that the United States Government, via the National Science Foundation, is continuing to support such research, further refutes the notion that the NIST result was predetermined by political forces. What Ryan is complaining about is, in fact, the core mechanism of the scientific method.

The Role of Chemical Attack

Part of the impetus for more accurate evaluation of both the fireproofing and fluid damage estimates is to resolve nagging questions about other, potentially hidden, damage mechanisms. One possible mechanism is that of chemical factors – caustic or corrosive damage, either catalyzed by fires or slowly acting over long time periods prior to the accident – contributing to structural weakening. NIST does not consider this mechanism simply because it is unnecessary, since all observable behavior of the impact, fire, and eventual collapses are explainable through simpler and more obvious mechanisms; and because there is little direct evidence for chemical attack. Because of the paucity of evidence, a collapse hypothesis that requires chemical attack is difficult to falsify, and hypothetical at best, predisposing us to other explanations.

While there is little evidence of chemical mechanisms in the structure, it would be incorrect to say that there is no evidence. There are two separate hints of this behavior, although potentially both could be explained away through mechanisms totally unrelated to the collapses. The evidence is the following:

Sulfidized Steel: As we have mentioned previously, the FEMA report [196] and researchers at the Worcester Polytechnic Institute [155] describe a few pieces of structural steel – most from WTC 7, but one from either WTC 1 or 2 – that became sulfidized, eroding their original structure and severely weakening them. While interesting and thus far unexplained, this is not conclusive evidence of a new collapse mechanism for several reasons:

- It is possible, even likely, that all pieces were sulfidized after collapse, in the fires and complex chemistry of the debris piles.
- Only a very few pieces were found in this condition, so there is no evidence that the effect could have been widespread enough to threaten a building's structural integrity.

- All recovered pieces were (naturally) in poor condition, making identification of their origin within the structures impossible.

Iron Spherules: Another curious phenomenon thought to be linked to the structural steel is creation of tiny spheres of steel or iron, found in the dust after collapse. Several researchers report this, including Lowers and Meeker [239] who documented a few examples of particles found to be nearly pure iron and quite spherical, approximately 7 microns in diameter; and the RJ Lee Group [240], who identified small, round iron particles as evidence of high temperatures. The significance of these spheres is still debated, along the following lines:

- As discussed previously, there is no evidence at all for large amounts of melted steel. If the spheres are formed by melting steel, it must be surface melting or some other highly localized process.
- There appear to be several plausible candidate sources of the iron spherules in office materials or other building contents. One example is magnetic printer toner, used to print financial instruments, that could have been present in printer cartridges or found in a large volume of paper documents. This candidate has the advantage of matching the size, shape, uniformity, and elemental composition of the observed spherules. We cannot discount their origin in building contents, rather than building structure, without much more careful study.
- The quantity of these spherules is unknown, but thought to be very small – the iron-rich content of all dust samples was between 0.1 and 1.3% [241], most of which was not in the form of spherules. A large quantity would suggest melting of steel on large scales, but a small quantity suggests otherwise.
- Small quantities of structural steel or other iron-rich objects could be partially melted through sheer friction, originating in the aircraft impact or the collapses.
- Much like the sulfidized samples, it is impossible to tell whether these spherules were created prior to collapse, after collapse, or both. After collapse, it is plausible for the debris to have reached much higher temperatures.
- There is potential site contamination from salvage operations, in which numerous steel pieces were cut, involving nontrivial amounts of melted steel. It is also possible for the spherules to have been left over from the buildings' original construction.
- Iron that appears to have melted may have merely oxidized [242], and surface chemistry effects of merely heated iron may give rise to tiny amounts of melting even at moderate temperatures.
- Chemical factors, combined with heat, could lead to eutectic mixtures of iron with other elements (such as sulfur) melting and dissociating at relatively low temperatures, potentially creating the iron spherules.

For purposes of this discussion, we will focus on the latter two inferences, and speculate that the spherules may be a result of a chemical process, catalyzed by moderate heat but below the actual melting temperature of steel. It is, therefore, possible (but unproven) that the spherules and the sulfidized steel are related.

To further understand sulfidization, we should begin by attempting to understand the source of the sulfur. Sulfur is an abundant element, with numerous possible sources. The following is a brief list of some possible origins of sulfur:

- Diesel fuel, found in emergency generators and in vehicles in the WTC parking garages, contained a fairly high concentration of organosulfuric compounds, providing a possible source of sulfur in an energetically favorable form. WTC 7, where all but one of the sulfidized samples came from, had exceptionally large stores of diesel fuel to power emergency command and control equipment.
- Large banks of batteries existed in a few locations, as backup for computers involved in the financial services, and could plausibly have provided a significant quantity of sulfuric acid.
- Acid rain could have potentially exposed some surfaces to low concentrations of sulfuric acid over many years.
- Ocean water, bearing sulfate salts, was pumped onto the burning debris piles as part of the firefighting effort.
- Gypsum wallboard, omnipresent in large buildings, is almost entirely composed of sulfur-bearing minerals. However, this sulfur is not in an energetically favorable form, and some other chemical process would be required to react with steel structural members.

The Worcester Polytechnic Institute is continuing to experiment with sulfur compounds in an effort to recreate the reactions seen in the recovered steel. Given the complexity of the debris fires and the many chemicals present, it appears plausible that sulfidization could have occurred after collapse. Whether or not this could occur prior to collapse remains an open question, and if true, could be a factor in future building fires.

A related possibility, voiced by Dr. Greening [243], is that of burning plastics or other chemicals giving rise to other caustic compounds, such as creation of hydrogen chloride (which in contact with water forms hydrochloric acid) from burning PVC (polyvinyl chloride). This is relevant because large quantities of PVC, along with other plastics, are found in modern offices. Chemicals such as this could potentially catalyze sulfur reactions, and also lead to a chemical weakening of steel structural elements, an additional hazard. A historical example of this is the Plastimet Fire in Hamilton, Ontario, in July of 1997. In this fire, roughly 200 tons of PVC and other plastics burned over a period of a few days. Among the fire's effects were reports of localized metal corrosion [244], linked to the creation of HCl gas which was measured at 53 to 930 micrograms per cubic meter.

The volume of PVC burned in this fire was comparable to the amount of plastics in the WTC fire floors, and it is also conceivable that caustic chemicals would be trapped within the structure, raising their concentrations to this level or possibly much higher. However, the use of PVC in construction is not new, and there have been numerous studies on its effects in fires. Industry sources question its ability to weaken a structure through chemical means:

> Burning PVC has resulted in corrosion damage to electrical equipment in the vicinity. This has led to suggestions that PVC should not be used in construction applications. Against this should be set other factors. PVC components can be formulated to combine a good technical performance and high resistance to ignition and flame-spread. Formulations can also be designed to reduce the quantity of hydrogen chloride emitted. There have been suggestions that hydrogen chloride from burning PVC may damage steel reinforcement in concrete, or significantly weaken unprotected steel structures. The UK Fire Research Station has shown that reinforcement is not normally affected. It has also been confirmed that unprotected steel structures are distorted and weakened by heat rather than by hydrogen chloride.
>
> For applications with very high fire risks, for example oil rigs and nuclear installations, more expensive, high performance insulating materials are preferred to PVC. The cost of post-fire clean-up operations must be included in assessing the total cost of fire damage. Just as soot can be removed from affected equipment, so chloride corroded parts can be reconditioned. This is well recognised by fire salvage consultants and by insurance companies. [245]

The author is of the opinion that chemical processes had a negligible effect on the WTC collapses. However, this too is an open question and deserves further attention. The ongoing work of Dr. Biederman *et al.* may provide further insight into the sulfidized steel and other unusual phenomena seen in the WTC fires. The upcoming NIST report on WTC 7 may also address this problem directly. While the NIST Report does not require any chemical weakening mechanism to explain the collapses, a more thorough understanding of the chemical processes in a modern office fire will lead to better recommendations on future construction.

What If NIST Is Wrong?

Let us suppose, for sake of argument, that a critical error was found in the NIST Report that completely invalidated all of its conclusions. We have to start over from scratch. The possible explanations for the collapse would be the following:

1. The impact and fire greatly exceeded the structural design requirements, and collapse was expected in the approximate time and manner observed.

This is the fundamental conclusion of the NIST Report at present, though there could be a different collapse mechanism. Alternate explanations include the following:

2. The structural design did not meet design requirements.
3. The design met requirements, but the structures were not built to design standards.
4. The structures were built with materials that did not meet requirements.
5. The structural design, while meeting requirements, contained a simple design flaw that was not adequately addressed by building code (lack of code coverage).
6. The structural design, while meeting requirements, contained a complex design flaw that cannot be addressed by building code (interference in code).
7. There was a failure of active systems (such as fire suppression systems) due to human factors, incorrect application, or other error.
8. Unusual performance of building contents, such as unrecognized fire or chemical hazards introduced by building occupants, led to the collapses.

The reader will note that *nowhere* on this list do we find explosives, thermite, beam weapons, or any of the various ideas floated by the Truth Movement. The reason for this is simple: *There is no evidence in support of any of these ideas.* If we had found, for instance, unexploded ordnance in the debris, seismographic evidence of powerful explosives, or testimony from those claiming to have planted or observed suspicious devices – and if this evidence withstood review – then we would place explosives on the list. But as we have seen throughout this review, there is no such evidence. These hypotheses are nearly useless, because the primary evidence for them is an absence of evidence for other hypotheses. Yet here, too, there is no support, as the NIST Report describes a plethora of evidence, including video and photography, testimony of survivors, computer and physical models, and recovered debris. We are therefore forced to conclude that even if NIST is totally wrong, there are many other explanations, each at least as plausible as Dr. Griffin's, that do not implicate the United States Government in any way at all.

In the report, NIST addresses nearly all of the alternate hypotheses listed above. The structural design is discussed in NCSTAR1-1 and found to be consistent with design requirements, even though the unique politics of the Port Authority made the WTC complex exempt from many building code requirements. The as-built structure is considered in the NCSTAR1-2 baseline models and found to be consistent with the design calculations. Materials recovered from the structure were tested against their specifications, and examined for signs of material failure inconsistent with the NIST theory, in NCSTAR1-3. Simple and complex design failure are precluded by the results of NCSTAR1-6, where NIST concludes that without impact damage, the Towers would not have collapsed, and that interaction between structural and fireproofing damage and the effects of the fire are all required for collapse. NCSTAR1-7 examines the emergency response, although the particulars of this incident are clearly well beyond the capability of any active response system, then or now. NIST does not specifically evaluate the possibility of especially dangerous contents in the office spaces, such as banks of UPS systems, but this would be quite difficult since there are few records of office contents.

Unlike the Truth Movement, legitimate critics of the NIST Report propose alternate hypotheses fitting the above listing. For instance, the University of Edinburgh and Arup fit into the sixth category, suggesting that the design of the Towers was susceptible to a complicated failure mode that is difficult to address without a nontrivial rethink of construction standards. Dr. Greening's proposed chemical attack hypothesis fits the eighth category. We should not view the NIST Report as the final word on the WTC Towers, but at this point there is no valid reason whatsoever to propose explosives. Scientific review of the report is ongoing, and may eventually settle the differences between NIST and its critics.

One of the more vocal critics of the NIST Report, and one who proposes such review, is Dr. James Quintiere, professor of fire protection engineering at the University of Maryland, and among the contributors to the NIST Report. In October 2005, Dr.

Quintiere addressed the House of Representatives on the NIST findings, and takes issue with the NIST methods and findings. His comments include the following two excerpts:

> Testing by NIST has been inconclusive. Although they have done fire tests of the scale of several work stations, a replicate test of at least & [sic – ¼?] of a WTC floor would have been of considerable value. Why was this not done? Especially, as we have pointed out to NIST that they may have underestimated the weight of the furnishings in the North Tower by a factor of 3. As fire effects on structure depend on temperature and time, this likely longer burning time is significant in the NIST analyses. Other tests of the trusses in the UL furnaces show that the steel attains critical temperatures in short times, and these temperatures correspond to NIST's own computation of truss failure for a single truss. Why have these findings seemingly been ignored in the NIST analyses?
>
> … NIST speaks to the need for education. I left NIST to contribute to that goal. The U.S. produces about 50 fire protection engineers per year when about 500 are really needed. If the fire service would incorporate fire engineers this number would double. There is a big lack of knowledge here, and it contributes to an infrastructure of fire safety that is currently fraught with good intentions, special interests, and ignorance. The Science Committee should recognize this deficiency. [246]

Dr. Quintiere is in the minority with his opinions, but it is important to note that, even if he is completely correct, there is even less reason to suspect explosives were present. He believes that the fire insulation as-built was inadequate, and the fuel load on the fire floors was significantly above the conservative NIST estimate – factors that, if present, would make collapse of the WTC Towers completely inevitable after impact. No explosives at all would be needed, nor even fireproofing damage, if his critique is accurate.

The author has no doubt that more insight remains to be drawn from study of the collapses, and that future adjustments to building code are important and sensitive to these conclusions. It is clear that ongoing study will help resolve some of the possible conflicts and remaining disagreements in the scientific community. It is also clear that, as these studies progress, we will move still farther away from any hypothesis involving explosives.

The debate over the NIST Report is alive and well in the scientific community, but it does not include Dr. Griffin. His hypothesis, never supported to begin with, is simply a dead end. There is no justification for study of planted explosives in the WTC Towers, and given the total lack of supporting evidence or data, no way to begin.

Critical Response

Following the release of this whitepaper, a number of individuals including some within the Truth Movement have either written to the author with their questions and concerns, or published their own rebuttals on the Internet. As we have explored in previous chapters, scientific investigation is always open to question, and indeed strengthened by consideration of alternate points of view. With these principles in mind, we will next examine the contributions of readers and critics of this exposition, and attempt to better understand the events of that day.

It is unfortunate that, to the best of the author's knowledge, Dr. Griffin himself has offered no critique or commentary regarding the points raised in this whitepaper. Dr. Griffin has contacted the author for a copy of this whitepaper, but has issued no response regarding its contents. Similarly, since the initial publication, Dr. Griffin has authored a revised edition of *Debunking 9/11 Debunking* [247], but the revision appears to focus on issues not germane to the NIST Report [248], such as cellular telephone calls from the airliners, rather than correcting or updating anything considered here.

The author continues to welcome a response from Dr. Griffin himself. In the meantime, we will consider the issues raised by other readers, followed by a brief assessment of progress in the scientific community since the initial release of this whitepaper.

Eric Douglas

Mr. Douglas, who is cited by Dr. Griffin in *Debunking 9/11 Debunking*, has published a detailed whitepaper of his own NIST criticisms, entitled "The NIST World Trade Center Investigation – How Real Was the Simulation?" [249] Mr. Douglas's whitepaper was completed well before this monograph and thus should not be considered a response; however, Mr. Douglas contacted the author soliciting opinions on his work and how it compares to observations made here.

Mr. Douglas's work appears on a website [250] alongside several other independent investigations and comments from legitimate scientists, including Dr. Greening, Dr. Quintiere, and Dr. Astaneh-Asl. These papers largely criticize the NIST methodology. With the exception of the paper from Dr. Steven Jones, which has been remarked on in passing throughout this whitepaper, each of these papers should be viewed as constructive criticism and is worth consideration.

Due to the length and detail of Mr. Douglas's whitepaper, a thorough discussion is deferred to Appendix C. Overall, the author finds that many of Mr. Douglas's claims are incorrect and based on a partial misunderstanding of the NIST report, but several others appear to be valid and potentially significant concerns. The author agrees with the following summary of criticisms, and suggest that the list of topics below should have been addressed in the NIST Report:

- *Completeness of Fire Data:* NIST should have included all of its thermocouple data from the workstation tests. This missing information does not cast doubt upon NIST's conclusions, but given the 10,000 page bulk of the Report, there should be no objection to adding a few dozen additional charts.

- *Completeness of Fire Testing:* NIST's single workstation fire tests would be more valuable if the effect of the hood on ventilation (and thus temperature) could be quantified. A seventh test without the hood active would provide this.

- *Heat Content of Furnishings:* NIST's own experiments indicate a significant uncertainty in total heat content between different types of workstations, but the Report does not discuss the potential impact on fire behavior. A better understanding of this could partially explain mismatches in burning time between model and reality, or resolve challenges regarding the total volume of combustibles levied by other researchers.

- *Choice of Jet Fuel Load:* NIST assumed and conducted experiments with 4 L of fuel per workstation, where a cursory analysis suggests that the actual distribution was closer to 12 L per workstation. There are competing factors that make the effect of additional fuel difficult to predict. While we do not expect this change the overall outcome, at the very least a better explanation should have been given.

- *ASTM E 119 Truss Tests:* NIST's tests of the as-built truss structures, with intact fireproofing, reflected the original design, and are of limited value when considering the upgraded SFRM applied as a retrofit. Additional testing with the thicker SFRM would permit a better assessment of hypothetical fire situations. NIST should also have considered tests in this series that incorporated damaged SFRM or fire sprinklers,

- *Verification of SAP2000 Models:* The ASTM E 119 tests, particularly the surprise difference between restrained and unrestrained tests, also could have been used as an excellent verification test of the floor system structural models. Given the expense of full-scale experiments in general and wealth of data provided by these tests, it is unclear why this opportunity was overlooked.

- *Full Factorial Analysis:* NIST's population of different cases is not a full factorial analysis, but rather a more typical sensitivity analysis, ultimately pared down to an "incompressible list" of four cases. NIST should have better explained its choices in restricting itself to four cases. The author also suggests that additional cases, focused on varying the amount and placement of combustible material after impact, would greatly strengthen NIST's hypothesis.

It is unlikely that NIST will revise its report or conduct additional experiments at this point in time. The list above should therefore be treated as guidance for follow-on and independent investigations, and for NIST's upcoming WTC 7 Report, forecast at time of writing for a release in mid-Summer 2008.

Charles Thurston

In sharp contrast to Eric Douglas's commentary, Charles Thurston has authored a brief rebuttal [251] to comments made in this whitepaper, albeit without addressing the NIST Report. Mr. Thurston has not contacted the author at any time with these or other concerns. Mr. Thurston's piece appears on the Internet linked to numerous Truth Movement websites, notably *9/11 Blogger* [252] and the home page of the *Architects and Engineers for 9/11 Truth* [253], where it is listed as a technical publication. In his response, Mr. Thurston repeats his unshakeable belief that the WTC Towers should not have experienced total collapses:

> The self-crushing building theory is another example of the "Plausible Impossible" and tremendous effort has been expended – again involving skillful animation – to sell the plausibility of this notion. But self-crushing steel frame buildings do not actually exist in "real life." [254]

Before we attempt to find a scientific argument in Mr. Thurston's reply, let us first consider the implications if the above were actually true. Supposing there are no "self-crushing" steel-frame buildings, the events of September 11th would leave us with a multitude of baffling questions. If the WTC Towers could not have collapsed on their own, why would the agents allegedly responsible have chosen to make it appear that they did, rather than selecting a "possible" outcome? Mr. Thurston's claim implies that either Mr. Thurston knows more about the mechanics of structural failure than the alleged conspirators themselves, or that the same conspirators deliberately engineered an "impossible" situation, which would seem to be counterproductive to secrecy.

Additionally, there been several published papers explaining different mechanisms for a global collapse, and none claiming that collapse could not occur. Most importantly, we need to explain why Mr. Thurston realizes this, while the overwhelming majority of structural engineers do not. Logically speaking, Mr. Thurston's claim is extraordinary, and we require a thorough explanation before we can accept it.

Mr. Thurston also clarifies that, contrary to the author's inference from his previous whitepaper [78], he does not believe the Towers should have toppled:

> Small wonder that Ryan Mackey is so anxious to dismiss my Erector Set illustration with an insult rather than a useful comment – after deliberately misunderstanding and misstating its purpose. These are tactics, used by someone who has no legitimate opinions. I never suggested that the Towers – as entire buildings – should have "toppled over." What an absurd idea! [254]

The author will endeavor to accurately guess Mr. Thurston's belief, no matter how counterintuitive. If Mr. Thurston believes that a total "self-crushing" collapse was impossible, and further believes that the Towers should not have toppled over, the only readily apparent remaining candidate is for the Towers, or at least a majority thereof, to have remained standing indefinitely. Whatever his true opinion, the author has already cited several examples of published opinions that strongly disagree, claiming instead that not only is "self-crushing" behavior possible in general, but in fact expected in the specific case of the WTC Towers.

We turn next to Mr. Thurston's explanation for his claims:

> I have to assume (in the absence of an explanation) that if Ryan Mackey thinks he has a bona fide reason for dismissing my Erector Set illustration as "not worthy of discussion" it must be based on a tacit assertion that the strength of a structure doesn't scale proportionally to its size – that a large steel framework is somehow significantly weaker *relative to its own weight* than a smaller one, all aspects being proportional. But is this really true? [255]

Mr. Thurston is correct in his assumption: The strength of a structure does not scale proportionally to its size. This assertion is also overt rather than tacit. Again, supposing Mr. Thurston's belief was correct, it is unclear if engineers would have ever developed steel construction in the first place. If structural capacity scaled with size, and strength per weight was constant, there would be nothing preventing engineers from building skyscrapers out of brick or timber. There would also be much less dependence on technique and analysis, and it would be a relatively simple matter to construct buildings of arbitrary height.

To pick a simple example, if Mr. Thurston was correct, it would be a trivial matter (from a design perspective) to construct an upscaled version of a WTC Tower, say at three times the scale. Following his belief, all we would have to do is scale every component by three in each dimension, and the newer, larger structure would be able to handle upscaled loads without any need for further analysis. Such a building would be approximately 192 meters on a side and over 1.2 kilometers in height, substantially eclipsing any structure of any kind, being at least 30% taller than the expected antenna mast height atop the Burj Dubai currently nearing completion.

History, of course, tells a different story. Over time engineers have managed to create taller and taller designs, but ultimately there are practical limits to building height, depending on the materials and techniques used. This is because strength *does not* scale linearly with size. As the author has explained on page 47, resistance to different modes of deflection such as buckling versus compressive failure, i.e. different kinds of strength, do not scale linearly with length, and in fact do not even scale in the same way. This knowledge is among the most basic principles of structural mechanics, of which the author encourages Mr. Thurston to become familiar.

Mr. Thurston also disputes the ability of falling materials to impart momentum to the lower structure:

> An airborne slurry of debris whose diameter is several times the width of the building is NOT a billiard ball. The mythical transfer of momentum, upon which the self-crushing building theory depends assumes highly efficient impacts from solid masses, all concentrated within the perimeter of the structure. [255]

The author disputes Mr. Thurston's estimate, particularly in the early stages of collapse, that the "airborne slurry" was spread out over an area several times the width of the intact structure. Supposing this was true, where would the energy come from to disperse the upper mass so far to the sides? If we suppose the mass of the smaller WTC 1 upper

block, on the order of 30,000 tons, was somehow moved an average of 64 meters (equal to the width of the structure) in a single second, this requires an impulse of 192 million Newton seconds. Afterward, the debris would retain a minimum velocity of 64 meters per second and therefore a kinetic energy equal to 61 GJ. Assuming explosives were the cause, assuming absolutely perfect coupling between explosive energy and debris propulsion, and assuming no energy losses to breaking apart the debris, this would require a minimum of almost 14,700 kg of TNT. As such a vast explosion would be impossible to conceal, the author rejects explosives as a possible means of energy delivery, but sees no obvious alternative other than to conclude Mr. Thurston's observation is greatly exaggerated.

Regarding the "high efficiency" required to propagate collapse, the author reminds readers of papers by Dr. Greening and Dr. Bazant *et al.* [20] [72], in which mass loss is treated as a variable. Their calculations demonstrate that, following the initial contact of the upper block, collapse is predicted to continue even if large fractions of mass are lost outside the lower structure footprint. Collapse is predicted even if the transfer of momentum is not particularly efficient.

Mr. Thurston's conclusion, likewise, is unconvincing:

> **Stay Away From Tall Buildings!**
>
> One of the unavoidable, but unstated, implications of the self-crushing building theory is that ALL steel frame high-rise structures are on the verge of collapse due to their "tremendous weight." They can just barely hold themselves up, apparently, and all it takes for any one of them is some type of trigger and it will come down like a house of cards. [255]

Mr. Thurston, apparently unfamiliar with engineering in general, seems unaware that if structures – steel-framed or otherwise – contained such an enormous reserve capacity, designers would automatically *reduce* this unneeded reserve for reasons of economy. The amount of reserve capacity in any structure is not determined by its materials, but rather dictated by design requirements such as building codes and engineering practice. We may assume, therefore, that a competently-designed building of a given height and purpose would be of similar strength regardless of its materials. Different materials of course have different costs, bulk, and requirements of their own, which is why certain materials are preferred in specific applications.

The NIST Report describes in detail that the WTC Towers, as designed, were not on the verge of collapse. NIST's models show that the design contained a healthy safety factor against static loads, live loads, and wind loads. NIST also describes how this reserve capacity was eroded by impact, fire, and gradual deterioration of the structure.

The author does not advise readers to stay away from tall buildings as a general rule. The author does, however, recommend in the strongest possible terms that readers stay away from tall buildings that are either burning or struck by aircraft, and that readers should attempt to evacuate any such structures as quickly and safely as possible.

Kevin Ryan

A third response entitled "The Short Reign of Ryan Mackey," authored by Kevin Ryan, appears as a whitepaper at the *Journal for 9/11 Studies* [256]. Kevin Ryan is presently listed as an editor of that website. Like Mr. Thurston, Mr. Ryan has not contacted the author regarding these or any other issues. In this rebuttal, Mr. Ryan reopens two specific technical issues regarding the NIST Report, namely NIST's testing of fireproofing materials, and fire certification. The author will address these two issues in depth, followed by a brief discussion of additional commentary from Mr. Ryan.

Fireproofing Material Testing

After commenting on the late completion date and small relative page count of NIST's "shotgun test" documentation, described in Appendix C of NCSTAR1-6A, Mr. Ryan voices his opinion that NIST's choice to conduct these tests rather than the industry standard tests was a mistake:

> The first of these attempts was what Mackey calls the "*pull-off*" test, otherwise known as ASTM C1583-04, a standard test method that evaluates the tensile strength of concrete surfaces and overlay materials. This is not an industry standard test for the removal of SFRM from steel building components by any means, and was never intended for SFRM testing at all, let alone to estimate losses of fireproofing due to shear forces. There is, however, an industry standard test that might have been used to provide some useful information, and that is ASTM E 736, *Standard Test Method for Cohesion/Adhesion of Sprayed Fire-Resistive Materials Applied to Structural Members*.
>
> Unfortunately, instead of performing that relevant test, NIST performed the other, non-relevant test, a modified version of ASTM C1583. Exactly why they did this is not clear, but the report suggests this non-standard test would do a better job of estimating the adhesive and cohesive strength of the SFRM than would the standard test designed for that very purpose. [257]

Mr. Ryan is correct that ASTM C 1583 tests are not standard in this application. NIST justifies its choice to carry out these tests, and limitations of ASTM E 736, as follows:

> The standard test does not provide unambiguous values of cohesive and adhesive strengths and it does not provide tensile strength in a direction parallel to the surface, that is, the in-plane cohesive strength. Thus, tests were conducted by NIST to determine different tensile strength properties of sprayed thermal insulation. …
>
> Tests were devised to determine adhesive strength, cohesive strength normal to the surface, and cohesive strength parallel to the surface of the SFRM. The first two properties were determined by adapting the pull-off test method described in ASTM C 1583, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method). The SFRM layer was cut carefully in two orthogonal directions to create a prismatic test specimen, and a 3/8 in. by 2.7 in. by 2.7 in. aluminum plate was glued to the surface. The advantages of this approach over the ASTM 736 technique are that the resisting area is easily determined and it offers the ability to measure both adhesive and cohesive strengths. [258]

Mr. Ryan also has apparently overlooked an important fact in the NCSTAR1-6A report, namely that the test described above were not carried out *instead of* the industry standard ASTM E 736 tests, but rather *in addition to* those tests. NIST began by verifying its modified test against the ASTM E 736 standard:

> For comparison with the measured cohesive strength normal to the surface, two tests were done in accordance with ASTM E 736. The results of the two tests were in agreement with those obtained by the pull-off technique. This suggests that the ASTM E 736 procedure probably provides a measure of cohesive strength. [259]

Furthermore, actual ASTM E 736 test data is available, not from NIST, but from the Port Authority, who conducted such tests on the World Trade Center prior to its destruction. These tests were part of the fireproofing upgrade (using BLAZE-SHIELD II material) on several tenant floors carried out between 1997 and 1999.

> Port Authority test reports state that tests of upgraded SFRM were performed in accordance with ASTM E 605 for thickness and density (ASTM 1993) and in accordance with ASTM E 736 for adhesive/cohesive strength (ASTM 1992). [260]

A list of tests conducted by the Port Authority is presented in Table 4-2 of NCSTAR1-6A, and results of these tests appear in Chapter 7. Because the Port Authority tests were conducted on the actual structure, whereas any NIST effort would be done at best on a reconstruction, the Port Authority tests are inherently more valuable, unless there is some reason to suspect an error in their testing. Mr. Ryan does not provide any criticism of these data; indeed, he does not appear to be aware of these tests at all.

NIST furthermore discusses why the ASTM E 736 test does not provide sufficient information for dynamic event reconstruction, such as NIST was tasked to perform:

> While the in-place bond strength data of BLAZE-SHIELD II reported by the Port Authority appear to indicate acceptable performance, results of ASTM E 736 tests do not provide sufficient information for predicting whether insulation would be dislodged from structural members under various impact conditions. The standard test does not provide unambiguous values of cohesive and adhesive strengths, and it does not provide tensile properties in a direction parallel to the surface, that is, in-plane cohesive strength. As was mentioned in Section 6.3.4, because of the way a fibrous SFRM is installed, the resulting material is not isotropic. Layers of fiber bundles are deposited parallel to the surface of the substrate. It is expected that the strength perpendicular to the planes of the layers would be less than the strength parallel to the layers. Thus, a series of tests were conducted that would allow different strength properties to be determined. In addition, it was decided to test BLAZE-SHIELD DC/F because the Port Authority data did not include tests of this material. [261]

The author is therefore forced to reject Mr. Ryan's complaint. NIST did not ignore or avoid ASTM E 736 testing, and in fact incorporates such testing – provided by the Port Authority – in its analysis. NIST thoroughly explains both its motivation for and its expectations of additional, nonstandard testing. NIST verifies this new testing against the industry standard, and reports on these results as well. In every way, NIST's approach is knowledgeable of the industry standard, and NIST explains its decisions in detail.

The next issue raised by Mr. Ryan concerns NIST's estimate of dislodgement by vibration: As be briefly notes, NIST could not establish a rigorous estimate of conditions required for such dislodgment, and was instead limited to an argument from first principles as explained in Chapter 7.4 of NCSTAR1-6A. This is not, however, a "fall-back" position, but intended to explain loss of fireproofing observed in areas away from the flow of debris as well, a different scenario entirely:

> These simplified models are intended to provide insight into the important variables that affect the magnitude of the disturbance (that is, acceleration) required to dislodge SFRM from different kinds of structural members. These models do not consider the fact that the applied acceleration in an actual structure subjected to impact would vary with time. Also, these models apply to members not directly impacted by debris. As discussed in NIST NCSTAR1-3C, there was photographic evidence to suggest that thermal insulation was dislodged from exterior columns in regions not likely to have been impacted directly by debris. [262]

We now return to the question of the "shotgun tests," and the ability of the aircraft impacts to dislodge SFRM based on its energy. Mr. Ryan provides much more information about his opinion than was described in Dr. Griffin's book. He begins by stating that his claim of insufficient energy is motivated not by the NIST Report, but instead by the work of Dr. Wierzbicki at MIT, as follows:

> Mackey says this is a "mystification of the NIST summary of findings", when, in fact, my point that no energy was available was not taken from NIST at all, but from calculations done by Tomasz Wierzbicki and other engineers at MIT. These calculations show that all of the kinetic energy available from the impact of the aircraft was consumed in the crushing of the floors and columns in the WTC towers, and in destruction of the aircraft itself. Mackey would have known this if he had referred to the references of the book he was criticizing. [263]

Before we examine Dr. Wierzbicki's results, the author wishes to clarify that no mistakes were made regarding footnotes and accuracy in citation. As reported on page 19 of this whitepaper, Dr. Griffin, on page 151 of *Debunking 9/11 Debunking*, quotes Mr. Ryan in the following excerpt:

> Besides the fact that – to a layman like myself anyway – this seems a most unscientific method for answering the question, there was, Ryan points out, "simply no energy available to cause fireproofing loss. … **NIST's tests indicate that 1 MJ of energy was needed per square meter of surface area to shear the fireproofing off.** For the areas in question … , the extra energy needed would be several times more than the entire amount of kinetic energy available to begin with." [36] (Emphasis added; ellipses in original.)

There can be no question that Mr. Ryan was addressing NIST, not Dr. Wierzbicki, when he made the statement above – which is incorrect. As already explained on page 19 of this whitepaper, NIST does not claim that 1 MJ of energy per square meter was needed. Again, NIST reported, on page 273 of NCSTAR1-6A:

> Based on the observations made in the ballistic impact tests, the SFRM was dislodged by direct impact with solid objects that had a kinetic energy per unit impact area approaching 10^4 to 10^5 ft lb/ft^2 (**10^5 to 10^6 J/m^2**). In addition, SFRM that was not dislodged after the debris impact lost its adhesion to the steel surface in all but one test. The SFRM on the steel plate was dislodged upon impact of the projectiles, except for the ballistic impact at a 60 degree angle to the plate. When the SFRM was taped to the steel plate and the tape carefully removed after debris impact at 0

> degree, no adhesion of the SFRM to the steel plate was found, the same result found for the 0 degree impact test without duct tape. For SFRM on steel bars, the remaining SFRM after impact rotated freely with respect to the bar. [264] (Emphasis added)

The author is not presenting the above to advance a rigorous estimate of the true energy requirement, but merely to clarify that Mr. Ryan did also misrepresent NIST in the passage cited by Dr. Griffin. The summary cited above is totally incompatible with Mr. Ryan's statement, again, that "NIST's tests indicate that 1 MJ of energy was needed per square meter of surface area to shear the fireproofing off." They do no such thing. NIST's own summary statement indicates that it is *impact*, not energy itself, that is required, and that the energy of impacting objects need only approach 0.1 to 1 MJ / m^2, not 1 MJ / m^2 as Mr. Ryan reported. Regarding the table of energy values describing NIST's tests, it is correct that most of the tests are closer to 1 MJ / m^2 than the lower end of NIST's range as Mr. Ryan insists, but this is no excuse for misquoting the conclusion.

The author can also demonstrate that Dr. Wierzbicki's results from his paper "Aircraft Impact Damage" [265] in no way conflict with NIST's estimate of fireproofing damage. As cited above, Mr. Ryan claims that "[t]hese calculations show that all of the kinetic energy available from the impact of the aircraft was consumed in the crushing of the floors and columns in the WTC towers, and in destruction of the aircraft itself." This is completely false. The paper does not *show* that all energy was thus consumed; rather, it *assumes* it. Dr. Wierzbicki's paper includes a greatly simplified model of impact and eventual collapse, and in this simplified model, he assumes that *all energy* is consumed in one of a few simple ways:

> The method that is chosen here involves a logical progression from first principles to a recreation of the complex series of failure models, which set the stage for each Tower's final collapse. There are three basic principles of mechanics that are invoked in the present analysis
>
> - conservation of energy
> - conservation of linear momentum
> - principle of virtual work
>
> Each of the above laws of mechanics applies to a different scale. The energy conservation applies to the global scale of the entire aircraft and the affected parts of the building. It is expressed through the following equation
>
> $$E_{kinetic} = E_{plane} + E_{external\_column} + E_{floor} + E_{core} \quad (1)$$
>
> This equation says that the initial kinetic energy of the aircraft $E_{kinetic}$ (which is known) is converted into the energy dissipated by plastic deformation and fracture of four constituents of the collision problem, i.e., the airframe itself E_{plane} , the external column $E_{external\_column}$, the floors E_{floor}, and the core structure E_{core}. Some energy is also lost by friction and is converted into the elastic vibration of the entire building. These two contributions are small and will be neglected in the present simplified analysis. [266]

Equation (1) reprinted above explains how energy absorption is binned into one of only four categories. In other words, Dr. Wierzbicki's analysis does not include loss of fireproofing as a discrete term – just as it does not include damage to furniture, interior partitions, drywall, plumbing, or elevators, just to pick a few examples. Instead, this simple approach treats all of these as part of the total energy absorbed by the core, the exterior columns, and the floors. Mr. Ryan cannot construe this paper to indicate that fireproofing damage was impossible, as Dr. Wierzbicki does not treat the fireproofing at all. One would be similarly incorrect to state that this paper proves there was no energy

available to damage furniture, break windows, or do any of a hundred other things that are simply not modeled here.

Furthermore, nowhere in Dr. Wierzbicki's paper is it stated that there is a lack of energy. Had the model included damage to contents as an additional energy sink, this would simply mean that the energy budget for the other systems was reduced, since clearly one cannot damage core columns without damaging the contents in front of them. Additionally, Dr. Wierzbicki actually acknowledges loss of fireproofing in his paper, contradicting Mr. Ryan's inference completely:

> one of the most important aspects of this argument is the observation that whatever fire protection the steel was prepared with, was shaken lose by the impact and thus unable to perform as designed. A jet-fueled fire is not what normal office fires are like and thus the safety systems may have been overcome considerably faster than expected. Our analysis does not deny these heat-induced contributions to the collapse, rather we fully agree that the fire effects played a large role in the deferred damage. [267]

There are still more reasons to reject Mr. Ryan's reasoning. Being familiar with Dr. Wierzbicki's paper, the author wishes to point out an error therein which leads Dr. Wierzbicki to substantially overestimate the energy needed to sever each core column. In Section 4.4, Dr. Wierzbicki gives his estimate for the core column dimensions, taken from a photograph of cleanup efforts:

> Inside each tower there were 44 large, concrete reinforced, steel columns, which enclosed elevators, stairways, and utility space. Again, the author's inquiries to ascertain exact values for the core column dimensions failed. However, one is able to estimate these values by comparing the size of core columns to the size of exterior columns as captured in photographs of the site, such as the one shown below. **With an accuracy compromised by the poor resolution of the photographs available, we determined that each column had a thickness of 67mm, and dimensions of 950mm x 312mm in rectangular cross section.** It is not certain if all core columns shared identical cross section, but our calculations could easily be revisited when more precise data on their exact geometry becomes available. It is hoped that we will be able to eventually retrieve exact dimensions of core column in the course of our continuing research. [268] (Emphasis added)

A photograph is also provided. Dr. Wierzbicki's estimate is surprisingly accurate, but the photograph he has selected as representative of core columns is, in fact, a section from the very lowest floors of the structure. As NIST explains, continuing research has revealed that the core columns at the point of impact were considerably smaller, perhaps best seen by comparing the dimensions above to typical dimensions at the impact floors, such as in Figure 2-6 in NCSTAR1-3A. Because of this, Dr. Wierzbicki has overestimated the energy required to destroy core columns by approximately a factor of five on average. Readers are encouraged to compare these calculations to similar calculations in Greening [20], where a much lower energy estimate is provided for core columns, but Greening's other calculations match Dr. Wierzbicki's reasonably well.

What actually happened at impact is that the building's interior – including the passive fire protection – absorbed a substantial amount of energy, and suffered heavy damage as a result. Some energy left the Towers completely as well, as debris passed through to the other side. In Dr. Wierzbicki's calculation, his overestimate of core column absorption

leaves a considerable amount of energy unaccounted for, which contributes to both of these effects. There is, therefore, no shortage of energy implied by this paper.

Dr. Wierzbicki's simple approach, and his overestimate of core column strength, cannot be faulted. This paper was among the first to be published, he acknowledged his gross assumptions with respect to structural details, and his stated intent was to provide a "first principles" analysis rather than a detailed study. With these limitations in mind, readers are encouraged to examine his paper, as it contains a sensible and detailed mathematical approach to understanding the impacts and collapses.

Mr. Ryan next expresses considerable confusion about the nature of the debris field. Let us first skip ahead slightly, and examine his own model of the debris and SFRM dislodgement process:

> With core columns, floor decking (not including bar joists), and exterior columns considered, the surface area involved in this estimate would be over 10,000 m^2. By way of the energies estimated in the shotgun tests, 1 MJ/m^2 would be needed to generate the required shotgun blasts. Even if we allowed that half the energy of each blast remained after the initial impact, to form a now widely scattered ricochet pattern (which would probably not be very effective at removing fireproofing) we would still need to start with at least 5,000 MJ of energy. And this amount exceeds the total kinetic energy available from aircraft impact in either tower, as stated by NIST. [269]

Note that, again, Mr. Ryan is exaggerating the energy conditions specified by NIST. However the bigger problem, as remarked upon before, is that Mr. Ryan's model requires an *individual* "shotgun blast" for each square meter of SFRM. Because Mr. Ryan discounts the remaining energy as "widely scattered" and "probably not very effective," the energy requirement is wildly overestimated. It should be immediately obvious that because we are discussing an enormous number of impacts, mostly contained deep inside a large structure, the likelihood of individual pieces to exit the structure and avoid additional contact (and additional loss of SFRM) following impact is extremely small. Without exiting the structure, there is no way for the debris field to become "widely scattered."

A more realistic treatment of the debris is as follows: At impact, a large percentage of the aircraft breaks up into a mixed field of debris, fluid, and components from the building and its contents. This field can be roughly approximated as a wave sweeping across the structure, its width gradually increasing as debris fans out, and its speed gradually decreasing as energy is lost destroying the interior and transferring momentum to the structure. NIST's LS-DYNA models, described in NCSTAR1-2B, provide a much more detailed view of the debris path. From these calculations, one can estimate an average density, an average velocity, or normalized momentum of the debris field, as a function of its location or time as it passes through the structure. The calculated normalized momentum appears in Figure 9-6 and 9-28 of NCSTAR1-2B.

If we estimate an average momentum per area (or kinetic energy per area) required to shake SFRM from the structure, we can define a contour based on the debris calculations that marks the approximate boundary between total SFRM dislodgement and lighter SFRM damage. These contours can be seen in Figures 2-19, 2-21, 2-23, and 2-25 of

NCSTAR1-6D. For the most part, these contours pass straight across the structure along the initial vector of the aircraft, but on certain floors, the SFRM damage stops well before the opposite side of the building. This reflects the decreasing momentum of particles in the debris field as it loses energy, eventually falling below NIST's estimated threshold.

Mr. Ryan presents a number of surprising objections to this hypothesis:

> Mackey then goes on to refer to what might be called his new Zero Energy Ricochet (ZERO) hypothesis. He implies that the crushed fuselage and wings of the aircraft would somehow be converted into tiny, shotgun-like Aluminum projectiles, but he doesn't tell us exactly how this might have occurred … [270]

The author states as self-evident that the violence of impact would convert a significant fraction of the aircraft, its contents, and the perimeter of the structure – especially windows – into small projectiles. NIST's hypothesis requires neither a precise size nor composition of the projectiles. Mr. Ryan continues:

> Furthermore, Mackey suggests that I "err" yet again by stating that the objects impacted by the shotgun blasts were not representative of the WTC tower building assemblies. Ignoring the fact that even NIST's steel test projectiles were clearly non-representative [of] the Aluminum aircraft materials … straight bars are not "floor trusses", and do not accurately represent the floor assemblies used in the WTC. The joists from the WTC floor assemblies, both primary and bridging, were assemblies of steel rods, curving into and around top and bottom steel chord frames. The few shotgun blasts to establish fireproofing loss from these straight bars, shot directly at them from a distance of six meters, could have at least been aimed at representative WTC floor assemblies, if not from a more realistic angle and distance. [271]

A large fraction of the debris field would not be aluminum, but also steel, titanium, plastics, fabrics, glass, bits of luggage, and fragments of the structure itself. It is also unclear what difference the precise composition of debris fragments would have on NIST's tests. As previously noted, some of the NIST "shotgun tests" used fasteners as projectiles, as shown in Figure C-2 of NCSTAR1-6A, which is certainly a plausible scenario in the impact. Regarding the floor truss structures, the truss assemblies were made from round bars, as shown clearly in Figure 3-1 of NCSTAR1-6A, and Mr. Ryan's insistence that the "curving" and lack of "realistic angles and distance" in any way invalidates NIST's results is not credible without support. Mr. Ryan similarly notes that the floor decking was corrugated, claiming this alone makes comparison to NIST's flat-plate adherence tests invalid, and this too is offered without support.

Rejoining Mr. Ryan's complaints:

> Therefore, starting with zero available energy, Mackey simply assumes that a large aircraft would somehow be converted into many thousands of shotgun blasts, that would then ricochet around the building in every direction until all the fireproofing was removed from the Twin Towers. [270]

It is unclear what Mr. Ryan is referring to with his claim of "*starting with zero available energy,*" as the speed of impact provides a vast source of energy. The fact that aircraft debris passed through the structures is extremely difficult to argue against, particularly since there are numerous photographs and videos of debris exiting opposite the impacts

with considerable speed. Both impacts also created large holes in the perimeter opposite the impacts, which serves to further verify that the flow of debris inside the structures was capable of inflicting significant damage, enough to overwhelm structural members, and certainly enough to dislodge the relatively fragile SFRM.

Mr. Ryan is also exaggerating when he states that *"all the fireproofing was removed from the Twin Towers."* As already remarked, NCSTAR1-6D describes the SFRM damage predicted by NIST, and it covers only a fraction of the impact floors, as one would expect given the size and location of fireballs, and emergence of debris after impact. No one has suggested the SFRM removal was total in either structure, even on a single floor.

We are now ready to discuss NIST's actual treatment of the energy required. As Mr. Ryan acknowledges, NIST describes the debris field having a frontal area approximately 18 m high by 45 m wide, as explained on page 264 of NCSTAR1-6A. Also from that page, NIST's "shotgun test" experiments were based on a rough estimate of the *average* debris field parameters, namely that, partway through the structure, the aircraft fragments had been slowed by 30 to 60%, and that the total mass of debris was a similar fraction of the aircraft's starting mass, i.e. some of the aircraft and secondary pieces had been stopped or absorbed. Using this as a middle value, NIST conducted "shotgun tests" that covered a range of a factor of ten in terms of impacting kinetic energy, some a bit higher reflecting the debris field immediately after impact, and some lower designed to approximate conditions on the opposite side of the structure. In all of these experiments except two – the 60 degree angle oblique impact test, and an apparatus failure that fired at a mere 31 m/s [272] – the SFRM was dislodged.

Above all, it is important to keep in mind that the energy *absorbed* by the SFRM during impact is negligible. The SFRM is neither strong nor massive, and thus cannot absorb much energy either through deformation or momentum transfer. The NIST LS-DYNA models consider progress of the debris field through the structures, taking into account energy lost to destroy the aircraft and structural elements, interior furnishings, momentum transfer to the interior, and momentum transmitted to the intact structure. All of these energy sinks are more substantial, by far, than the energy sink posed by fireproofing materials and especially the SFRM. NIST's models predict exit of debris from the opposite side of the structure, consistent with real-world observations. Mr. Ryan's argument to the contrary appears to ignore these simple facts.

In his last complaint regarding the fireproofing analysis, Mr. Ryan remarks that the "shotgun tests" were never applied to gypsum board, and that the structure's columns were also partially insulated with SFRM:

> Finally, as if Mr. Mackey had not "erred" enough on this subject, he says that the WTC columns were only covered with gypsum board. In fact, most column surfaces in the WTC towers were covered with SFRM, although some core column surfaces were covered with 2 inch thick gypsum planking. Note that no tests were performed by NIST to prove loss of gypsum planking by shotgun or otherwise, and in any case, Mackey's argument here is in direct opposition to his purpose, because the gypsum planking would likely be harder to blast off. [273]

Mr. Ryan is correct that some SFRM was used in the structural columns as well, but primarily in the perimeter columns facing outward, as shown in Figure 3-4 of NCSTAR1-6A. In the case of the core columns, SFRM coverage varied depending on location, principally being used where the gypsum board surrounding the column was not in direct contact with the steel, as explained in Section 3.4.3 of NCSTAR1-6A. This observation, and the observation that the "shotgun test" was never applied to gypsum board, is totally irrelevant, as NIST used entirely different criteria between assessment of the truss fireproofing and that of the columns.

Unlike the SFRM, the gypsum board has a fair degree of physical strength, and is not bound to the structure simply by adhesion. Therefore, while the SFRM can be shaken loose in large pieces by impacts, the gypsum must be physically broken away. As a result, the "shotgun test" does not apply here. Instead, the gypsum insulation was treated differently in the impact and debris simulations. NIST describes its methodology in NCSTAR1-6 as follows:

- Core columns had sprayed fire-resistant material (SFRM), gypsum wallboard enclosures, or a combination of both. Insulation was assumed to be dislodged from the columns if they were subject to direct debris impact that could fail wall partitions in the immediate vicinity. The representative bending strength of building partitions in the impact simulations was 500 psi (NIST NCSTAR1-2), while the representative adhesive and cohesive strength of SFRM measured in the laboratory by NIST was generally less than 12 psi (NIST NCSTAR1-6A). Gypsum column enclosures were also assumed to have a lesser representative strength than wall partitions.

  To consider that insulation on core columns was damaged, the predicted debris impact had to be sufficient to fail building partitions immediately in front of the columns. If the wall partitions remained intact in the core area after interaction with the debris field, then the insulation on core columns behind these partitions was assumed to remain intact. If wall partitions were damaged or destroyed by the debris field, then insulation on core columns behind these partitions was assumed to be dislodged over that floor height.

- To consider that insulation on exterior columns was damaged, the debris impact had to damage or destroy office furnishings (modular office workstations) adjacent to the columns. If the office furnishings remained intact after interaction with the debris field, then the insulation on the inside face of the exterior columns behind these furnishings was assumed to remain intact. If the room furnishings were damaged or destroyed after interaction with the debris field, then the insulation on the inside face of the exterior columns in the same vicinity was assumed to be dislodged over that floor height. The other three faces of the exterior columns were protected by the windows and/or aluminum cladding and were assumed to have no insulation damage. [274]

The "shotgun tests," therefore, have no bearing on the gypsum planking whatsoever.

Fire Resistance and Certification

The other technical issues raised by Mr. Ryan have to do with fire certification, or more specifically the floor truss testing found in NCSTAR1-6B, and the role of Underwriters Laboratories in prior tests. He begins by remarking upon favorable results, presumably from the original construction period of the Towers:

> In fact, UL did test floor assemblies in 1970, that were "similar" to those used in the WTC towers, but this fact has not been repeated by NIST since their progress report of May 2003. The results of those early tests were interesting, considering that they showed the "floor assembly sagged 3 inches… at 120 minutes", which correlates with the August 2004 floor tests done by UL as part of the NIST investigation. Of course, 120 minutes is much longer than the fire times in the failure zones of either tower. [275]

The author has no opinion on whether UL did or did not carry out the ASTM E 119 tests of floor assemblies in 1970, or whether complete documentation from these tests survives – this issue is uninteresting from a scientific perspective. NIST carried out its own testing, and data from the 2004 tests is adequate for purposes of the NIST report, regardless of any prior testing or lack thereof.

Regarding Mr. Ryan's comment that *"120 minutes is much longer than the fire times,"* the reader by now is well aware that the ASTM E 119 tests involved a reference furnace temperature, intact floor trusses, and intact fireproofing, and as such are not comparable to the WTC Towers fires. The implication, namely that the WTC floor trusses should have survived the fires simply because of these tests, is groundless.

Mr. Ryan makes several complaints about the NIST testing, as follows:

> These facts show that, even despite designing these tests in an intentionally deceptive way, the floor models still supported their loads in the furnace. Not only did UL and NIST add twice the known WTC load to the floor models, they also used far less fireproofing than was known to exist at the time. The tests performed by UL included two test specimens with "as built" fireproofing of 0.75 inches, one with "as specified" fireproofing" thickness of only 0.5 inches, and one with the "as specified" condition of essentially no fireproofing. None of the test specimens had fireproofing to represent the "as impacted" condition of 3.25 inches, reported in NCSTAR 1-6A, figure A-60. [275]

The author is at a loss to determine what about the NIST testing strikes Mr. Ryan as deceptive. The doubling of design load, as described in Section 4.1.5 of NCSTAR1-6B, applied only to the subscale trusses, and was carried out to provide the correct stress in truss members, as the truss members themselves were not scaled to a smaller diameter. Loads were normal in the full-scale tests.

Fireproofing amounts, as Mr. Ryan himself indicates, match the specification and the as-built condition of the structure. It is important to recall that these tests were intended to determine if the floor trusses would meet their *original design requirements*, which specified 0.5 inch fireproofing. Figure A-60 of NCSTAR1-6A refers to the *upgraded* fireproofing applied in the late 1990's, and only to a handful of floors, including some in the impact areas. This is irrelevant for purposes of certifiability at time of original construction. Furthermore, only two of the three test points cited by the Material Engineering Division showed 3.25 inches of fireproofing; the third test point listed in Figure A-60 reported only 2.11 inches. Mr. Ryan has apparently cherry-picked the upgraded trusses, as well as the more optimistic measurements thereof, to be representative of the "at impact" state of the Towers.

The author has already noted, in agreement with Mr. Douglas, that an additional ASTM E 119 test conducted on trusses with the upgraded fireproofing would have been a valuable point of comparison – but it is simply incorrect to claim that NIST is being "deceptive" by considering only the original condition of the structure in its attempt to replicate certification testing of the 1970's.

Mr. Ryan next address the furnace temperature of the ASTM E 119 tests:

> to clarify, ASTM E119 is a test for fire resistance of building components in which 2000 F is an average temperature, not the maximum. Mr. Mackey would have known this if he had taken the time to inspect the time-temperature curve for ASTM E-119, which, despite his spurious claims, does not "end" at 2000 F or at 200 minutes. [276]

Mr. Ryan is incorrect regarding the furnace control temperature "average" – readers are, again, referred to Figure 6-1 of NCSTAR1-6B which graphs the ASTM E 119 furnace temperature standard as a function of time. Neither the furnace temperature average nor the maximum is exactly 2000 ^{o}F, nor can it even be defined – the test protocol calls for the furnace control temperature to follow this curve, and the maximum and average temperature is a function of the test duration. After approximately 200 minutes the curve reaches a temperature of roughly 2000 ^{o}F, and this is the highest furnace control temperature in any of the four tests conducted by NIST, as the author indicated previously.

Regarding the specific tests conducted in 1970, the fire rating of the floor trusses would call for a test of 120 minute duration – at the end of these tests, the control furnace temperature would never have exceeded 2000 ^{o}F, and would have averaged significantly less. The ASTM E 119 test can, of course, be run for longer time periods if desired, and the furnace control temperature would rise somewhat beyond 2000 ^{o}F. We see examples of this in NIST's testing, as NIST deliberately ran its tests beyond the normal stopping points to gather additional insight, explained on page 94 of NCSTAR1-6B. There is no reason to assume the 1970 certification tests were run beyond their planned times. Of the four tests described in NCSTAR1-6B, only one (the subscale Test #3) lasted more than 200 minutes, the others being terminated at 116, 146, and 120 minutes respectively. All tests were halted by test engineers based on either imminent collapse of the floor trusses, or floor truss bowing that exceeded the measurement range of their instruments.

Mr. Ryan continues:

> Due to NIST's avoidance of the issue of how the steel column assemblies in the towers were tested for fire resistance, we may never know the exact details of those tests unless UL begins to give honest answers to those questions. But we do know that, at the time the towers were designed, the NYC code called for three hours of fire resistance for the floor assemblies, and four hours of fire resistance for the columns. Those requirements changed to two hours and three hours, respectively, by the time the towers went up, but one thing is clear. The ASTM E-119 tests performed for the WTC building components would definitely have exceeded the fire times and temperatures seen in the WTC fires. [276]

The author remarks in passing that "dishonesty" on the part of Underwriters Laboratories, as claimed here by Mr. Ryan, is entirely speculative. In any event, it is correct that, given

the rating requirements, any ASTM E 119 test applicable would have exceeded the burn times of either WTC 1 or WTC 2, and was probably of comparable temperature. Again, this fact is irrelevant, as the ASTM E 119 test would not represent the damaged state of structural assemblies following impact.

Mr. Ryan next draws attention to the temperatures indicated by analysis of recovered steel from the collapsed Towers:

> Mackey acknowledges that gas temperatures cannot be equated with steel temperatures. So when NIST, throughout their report, refers to gas temperatures of around 1000 °C, that they have no actual evidence for, they are simultaneously admitting to us that the actual steel temperatures were far lower than that. The steel temperatures that NIST can support through testing are far too low to have significantly affected the strength of the steel, at only about 250 ºC. These results were from the testing of WTC steel samples, taken from what NIST's May 2003 progress report called an "enormous amount" of steel and specifically from the fire zones in the towers. [276]

NIST does indeed have evidence for gas temperatures of roughly 1000 ^{o}C, both from its fire modeling effort in NCSTAR1-5F and the multiple workstation burn experiment of NCSTAR1-5E. NIST also has no need to "admit" that the steel temperatures were lower, because NIST explicitly reports this in NCSTAR1-5G. This is perhaps best seen in Tables 12-5 through 12-16 of NCSTAR1-5G, which reports column temperatures in all four fire simulations at various points in time. The highest temperature seen on any floor, in any case, is 938 ^{o}C, for Floor 97 of WTC 1 in Case B, roughly 40 minutes into the simulation. The majority of fire-affected columns predicted to have lost their fireproofing cluster in the 700-800 ^{o}C range, and many remain much cooler in all four simulations. The elevated temperatures are not at all inconsistent with either NIST's own tests or other full-scale fire tests, such as the Cardington experiments [59].

Regarding the temperature analysis of recovered steel, the author reiterates for Mr. Ryan's benefit that *not a single piece of identified, recovered steel was expected to have reached elevated temperatures.* Only four fragments of core columns from the floors of interest were recovered. Two of these were from the same column, at the edge of impact damage, facing fresh air and with all combustibles cleared away; the other two were above or below the worst damage, and NIST expected fireproofing for both to have remained intact. Again, one cannot conclude on this basis that NIST's temperature simulations are incorrect. The pieces recovered have temperature histories that are consistent with NIST's models.

As a parting comment, Mr. Ryan takes issue with a minor detail of this whitepaper:

> *"Hardly any of the steel from the impact areas, where the fire was the hottest, could be expected to survive the collapse in such good shape as to permit positive identification of the pieces"*
>
> Apart from the circular logic applied in this statement, Mackey does not appear to be aware that the impact areas were not where the fires were hottest. In fact, NIST says it was the opposite side of the building in WTC 1, and the east wall of WTC 2, that were the hottest. No matter, it is doubtful that those supporting the NIST report care about those kinds of details anyway. [277]

To clarify for Mr. Ryan and other readers who may have been confused, the author is aware that the hottest fires were expected adjacent to the impact faces, as dictated by motion of combustible materials following impact and modulated by available oxygen. The reference to "*impact areas, where the fire was the hottest"* above was merely intended as a conjunctive rather than an assertion that the two overlapping zones were one and the same. The offending text has been modified accordingly to prevent any similar confusion in the future.

Additional Commentary

Mr. Ryan also includes several paragraphs discussing his ongoing legal matters with his former employer. This issue is largely irrelevant to the matter at hand. The author merely discussed facts of the prior case pertinent to Dr. Griffin's claims, including Mr. Ryan's original letter alleging deception on the part of Underwriters Laboratories, and his claimed whistleblower status. Both claims were rejected by the Monroe Circuit Court, which also concluded that Mr. Ryan had no special knowledge of Underwriters Laboratories fire resistance tests. Readers are referred to Appendix A for details. The author has no comment on any ongoing lawsuit or criminal case, nor personal interest therein, except where relevant to scientific investigations of the World Trade Center.

The author also feels compelled to comment briefly on the unusually high quantity of *ad hominem* behavior presented by Mr. Ryan. *Ad hominem*, or "against the man," is of course the classic logical fallacy where a speaker disagrees with another, not on the basis of the other's argument, but instead based on personal characteristics of her opponent that the audience may find disagreeable. In particular:

> Mr. Mackey refers to himself as a US government scientist, whose work includes the production of "strike aircraft weapon systems." This means that his involvement in the discussion of the truth about 9/11 should be taken with the understanding that the official story of 9/11 supports an historic increase in military spending, and therefore benefits people who work for the military-industrial complex. [278]

The implication, clearly worded, is that the author has a vested interest in misleading readers, because by doing so the author expects to be compensated indirectly through connections to the United States military. Mr. Ryan's comment, in addition to being logically invalid, is incorrect.

Even if Mr. Ryan's claim above was true, it would still fail to prove any statement in this whitepaper was false or even exaggerated. As we have just explored, Mr. Ryan is unable to provide even a single instance of an incorrect argument, even regarding technical matters in which Mr. Ryan claims expertise. The arguments in this or any whitepaper stand on their own, regardless of whether their proponent is a civilian scientist, a military scientist, or no scientist at all. One would be equally incorrect to dismiss Mr. Ryan's arguments out of hand solely because of his presence in the Truth Movement – and the author has not. We have instead carefully examined Mr. Ryan's claims themselves and found them to be false, regardless of whatever his motivation may be.

Unknown to Mr. Ryan, the author's association with the Joint Strike Fighter ended in 2000, prior to the events of September 11th, and prior to development or even award of the JSF contract. The author's work was also strictly limited to new technology research with no specific military application. It is therefore incorrect to state that the author's work "includes the production of 'strike aircraft weapon systems,'" as the author has never been involved with aircraft production or with development of weapon systems of any kind. Regardless of this fact, nowhere in this text does the author apply the fallacy of *Argument to Authority*, asserting that merely on the basis of his credentials or experience that he must be correct. Where the author has speculated, such speculation is clearly indicated, and readers are invited to experiment with alternate conclusions.

As a third and final observation, Mr. Ryan presents a most curious argument regarding writing style:

> One last thing about this paper is worth noting, and that is Mackey's continual reference to the authorship by using the term "we". For example, he says – "we note with amusement" the open letter Kevin Ryan sent to the President of Purdue University. It is not clear whether this use of "we" means that there was actually a group of authors involved, and only one was given credit, or if Mackey now believes himself to be something of a royal figure in the debunking effort. The gratuitous pretension of the piece suggests that the latter option is correct, but who knows. [279]

The use of "we" that Mr. Ryan does not understand is in fact the "*editorial we*," described in *The Columbia Guide to Standard American English* as follows:

> The editorial *we*, used by journals, newspapers, and other media to express the opinion of the editors, as in *We recommend a vote in favor of Proposition Three on the ballot*, is Standard and conventional. So are uses wherein an author or speaker includes the reader in a statement, as in *Next we will consider the opposition's views*, and uses wherein *we* is used as an indefinite pronoun to mean "all of us," "most people," or "people in general," as in *We are none of us in favor of war*. All these uses are effective in both speaking and writing. [280]

In other words, "we" in this context refers to two people, namely *the author* and *the reader*, and does not signify royal heritage. The author is surprised at Mr. Ryan's unfamiliarity with this usage, given its ubiquity in technical writing, and particularly as he is listed as an editor of the *Journal of 9/11 Studies.*

The author would also like to clarify that, without exception, the contents of this whitepaper are his writing alone except where referenced and credited, and were produced without the benefit of government support, either financial or in the form of uncredited co-writers. However, lacking any readily apparent means to demonstrate this claim, the author simply asks Mr. Ryan to take this on faith.

Updates from the Scientific Community

Proper scientific inquiry into the events of September 11th continues, within the United States and elsewhere. In the three months since the first version of this whitepaper, there have been several new and interesting papers relevant to the World Trade Center.

A first example is by Dr. Keith Seffen of Cambridge, entitled "Progressive Collapse of the World Trade Center: Simple Analysis," and appears in the February 2008 issue of the *Journal of Engineering Mechanics*. [281] Dr. Seffen treats the tower collapses to estimate the conditions needed to sustain collapse, and the approximate timing, similar to the work of Dr. Bazant and others. However, where Dr. Seffen's work differs is in the form of his model. Where Dr. Bazant and other investigators have largely focused on the mechanics at the interface, modeling an upper descending mass and the forces involved as it strikes the lower structure, Dr. Seffen instead models the collapse as a local instability that, given sufficient energy input, can propagate down the structure, leaving greatly weakened and unstable structural elements behind it. This model has several advantages; among them, it more correctly models the structure in the all-important transition area, where the sequential failure of floor trusses leads to a complicated buckling situation that is difficult to treat using static methods.

Dr. Seffen's model has numerous simplifications, as any model must, but it provides an independent approach and perspective to a familiar problem. Importantly, Dr. Seffen's model confirms the findings of Dr. Bazant *et al.*, predicting that progressive collapse is expected and not sensitive to changes in the static strength of the structure, or of the amount of mass that falls away from the collapse as it proceeds. His model further predicts a "crush-down" collapse time on the order of 11 seconds, in reasonable agreement with Dr. Bazant, and with video of the collapses.

It is also of interest that this paper attained a measure of notoriety to the Truth Movement in September 2007, after the BBC reported it had been published, when in fact it had merely been accepted for publication. This minor reporting error led some to suspect the BBC and even Dr. Seffen himself of taking part in the supposed conspiracy. [282]

A second paper of interest is from the University of Maryland, including Dr. Quintiere, who as discussed previously has been outspoken in his criticism of the fire modeling in the NIST Report. This paper, entitled "Scale Modeling of the 96th Floor of World Trade Center Tower 1," appears in the November / December 2007 issue of the *Journal of Performance of Constructed Facilities.* [283] In this article, the authors use a scale model of the 96th floor of WTC 1, designed and constructed as a student project, to test an alternate theory of collapse.

In this 1/20th scale model, the team simulated a higher combustible loading – 50 kilograms per square meter, as compared to the 20 and 25 kg/m^2 estimates used in NIST's models – based on published estimates of office contents and their own survey indicating this higher amount was plausible, if not likely. This experiment also differed from the NIST model in that it assumed the fireproofing was largely intact. The model

includes simulated impact damage both to the wall and to the floor, providing ventilation. The model is also quite sophisticated in that it attempts to accurately scale both fireproofing and structural elements. Thus it can be used to model not only fire progression, but also the effects of weakening, the eventual failure mode of the structure, and an appraisal of whether or not collapse would occur under these different assumptions.

The University of Maryland team found that their own set of assumptions also plausibly explained the evolution of WTC 1 – fire progression in similar sequence to that seen on video, eventual sagging of floor trusses, and finally collapse, with a good match to the observed 102 minute span between actual impact and collapse. This model therefore lends credibility to the claim that the World Trade Center design was susceptible to failure caused by large fires, and further suggests that even intact fireproofing would not have prevented the collapses.

There are limitations to this model as well. One such criticism is that it is only a single floor, whereas the work of NIST and the University of Edinburgh independently found that three-dimensional effects were important to understanding the collapse mechanism. NIST also requires much lower floor truss temperatures than were predicted in the scale model. In response, Dr. Quintiere has argued that the fireproofing *must* have been more intact than NIST predicts, or otherwise they would have failed too quickly for the NIST sequence of events, once a higher and more realistic combustible loading is applied.

NIST would counter that it experimented with higher combustible loads as well – modeling up to 33 kg/m^2 as part of its sensitivity analysis – and found that in its model, additional loading would only increase the duration of fires, and could actually slow their progression. Furthermore, NIST's lower combustible loading reflects the *available* amount of combustibles, since NIST's own experiments found that a significant quantity of flammable material, e.g. paper in file cabinets, would be effectively contained and barely contribute to the fires. NIST also argues correctly that its fireproofing damage estimate is supported by mechanical tests of the fireproofing, not an inference from the impact of fires. These hypotheses are still open for debate, yet even if we side with NIST completely, Dr. Quintiere appears to have conclusively demonstrated an *additional* failure scenario, one that is at the very least relevant to future construction.

While the work of the University of Maryland conflicts with NIST to some degree, it provides yet another possible explanation for the collapses. The author speculates that neither NIST nor Dr. Quintiere is entirely correct, but both efforts serve to illuminate important features of the actual collapses, and provide valuable insights for future structural design. The University of Maryland paper is also an excellent example of scaling laws in engineering put into practice, and is thus well worth perusal.

A third paper of interest is an update from the Purdue University investigation [284], also accepted to the *Journal of Performance of Constructed Facilities* and due to be published shortly. In this continuing effort, Dr. Irfanoglu and his team report on the findings of their modeling effort, similar to the one conducted by NIST, but benefiting from several

distinct advantages. Among them, the Purdue team had the time and computing resources to run numerous minor variations on the expected impact case, whereas NIST was limited to only six trials. Also, as we have noted before, Purdue has conducted validation experiments, such as using canisters of water fired at steel test targets to help tune their fluid impact models.

The latest Purdue findings confirm many of NIST's suspicions, among them that even a small change in the precise material properties of the structure can have marked differences in the location and amount of damage. Purdue identified the failure strain, or the amount of "stretch" at which columns actually break, as a major driver of their damage estimate, which should be intuitive: Exactly when a column finally yields has a significant effect on the debris flow and path of its own failed pieces. A column that resists for only an additional tenth of a second may survive the impact entirely, and shield columns behind it. As a result, Purdue estimated their uncertainty in the number of core columns destroyed to be roughly a factor of two, and this uncertainty is consistent with the spread in NIST's and other studies.

What Purdue also found, however, is that the onset of collapse is not particularly sensitive to the exact amount of damage – their simulations support a "simplified construct" of conditions that trigger collapse, largely driven by heat, that applies for many different impact damage cases. Purdue explains that, even with minimal damage, heating core columns to a moderate 700 ^{o}C is sufficient to cause inelastic buckling and core collapse, again consistent with the other investigations. This best supports the Arup study's conclusions, which also found that heat, not impact damage, is the most important factor for collapse. Recall that NIST, on the other hand, found that collapse was unlikely with "less severe" core impact damage, partially conflicting with Purdue's result. However, NIST's "less severe" impact case also predicts a lesser amount of fireproofing damage than assumed by Purdue, so further experimentation is still needed to close the gap between these two positions.

Another yet unreleased and perhaps the most highly anticipated paper is, of course, the NIST WTC 7 investigation report. NIST reported on the status of this paper in a meeting held on 18 December 2007 [285]. NIST currently expects the report to be completed in mid-2008, and will (as before) submit a draft for review prior to its final report. NIST remarks that the "working hypothesis" outlined in the earlier 2004 progress reports remains its leading candidate. Also, comments from the meeting seem to imply that there is less dependence on the large diesel fuel system present in WTC 7 than previously thought, and this would be consistent with the observation that the diesel fuel should have been exhausted well before WTC 7 actually collapsed.

It is also worth noting that two separate and uncoordinated positions were lodged at this meeting by the Truth Movement, one by Richard Gage of the *Architects and Engineers for 9/11 Truth* [286], the other commentary of attorney Jerry Leaphart [287] who has previously lodged complaints with NIST alongside Dr. Judy Wood. Mr. Gage's comments are materially similar to those of Dr. Griffin, and thus unworthy of a repeated examination. Mr. Leaphart, on the other hand, focuses on issues of steel sulfidation

(which he inaccurately refers to as "melting steel" at various places in his submission) observed by Dr. Biederman *et al.*, which the author agrees is a potentially significant and important topic for study. However, the author sees no merit whatsoever to the core hypothesis represented by Mr. Leaphart and Dr. Wood, namely that the World Trade Center was felled by as-yet-unexplained "directed energy weapons," of which the steel sulfidation is allegedly a result. The author instead prefers conventional explanations for sulfidation as presented by Dr. Biederman and explored previously. It is no surprise to the author that Mr. Leaphart carefully avoided presenting any details of his hypothesis in the NIST meeting.

Finally, NIST has also released an expanded Frequently Asked Questions document [288], explaining in its own words why it believes progressive collapse was expected, questions about collection of physical evidence, the basis of temperature estimates, and so on. Readers with interest or a technical background are encouraged to read the reports themselves for a much more detailed treatment, but this simple document should serve as a useful starting point for many who have questions about the investigation.

In summary, these papers, ongoing investigations, and professional disagreements between senior researchers are still further proof that the scientific community is not engaged in a cover-up of any kind. Scientists remain willing and able to challenge not only NIST, but also each other, in pursuit of a deeper understanding of structure failure and the events of September 11th. Yet as before, legitimate scientists still agree on one important detail – the World Trade Center collapses can be explained as an expected outcome of the impact damage and fires suffered by the structures. It remains to be seen, and indeed it may never be known for certain, whether the World Trade Center Towers collapses required significant structural impact damage and fireproofing damage, whether fireproofing damage alone was necessary, or if even the intact fireproofing would have been unable to stand up to the enormous fires that followed. Different teams of scientists have advanced plausible hypotheses, experiments, and results supporting all three of these positions. This stands in contrast to the Truth Movement, which to this date has yet to publish a single peer-reviewed result, and has yet to articulate a coherent hypothesis of its own.

Conclusions

In this review, we have begun with Dr. Griffin's critique of the NIST Report of the World Trade Center Disaster, contained in Chapter 3 of his latest book, *Debunking 9/11 Debunking*. We have examined his claims and his methods, expanded to consider the NIST Report ourselves, and finally discussed the scientific method as a whole. Our findings are as follows:

1. A sequential analysis of Dr. Griffin's claims reveals that, without exception, his claims are unfounded. Sources of error in his claims include (a) quotes taken out of context, (b) reliance on statements from non-experts, (c) reliance on flawed scientific reasoning produced by others in the Truth Movement, (d) incorrect and incomplete reading of the NIST Report itself, and in rare cases (e) fabrication of factual claims. Taken in total, Dr. Griffin fails to provide a single legitimate complaint about the NIST Report anywhere in his new book.

2. Careful analysis of Dr. Griffin's claims produces no coherent alternate hypothesis. Dr. Griffin outlines two seemingly incompatible ideas – those of explosives destroying the structures, and incendiaries merely weakening them to collapse – but upon review, his claims actually require *both* effects simultaneously. The amount of explosives and incendiaries required by Dr. Griffin is implausibly large, totaling roughly 60 tons of explosives alone at minimum per tower, if we have understood his vague implications correctly. This analysis is severely hampered by Dr. Griffin's refusal, either here or in any of his other writings, to clearly articulate his hypothesis, if indeed he has one.

3. Comparison of Dr. Griffin's approach to the Scientific Method reveals substantial and irreconcilable deviations. These include the failure to articulate a hypothesis, persistent arguments from ignorance and incredulity, total reliance upon other researchers who have yet to produce a single peer-reviewed result and whose work is easily falsified, rejection of reviewed and verifiable results from genuine experts, and simple factual error in his presentation. In contrast, Dr. Griffin's method is found to be entirely consistent with typical characteristics of pseudoscience.

4. The NIST Report itself bears up well in comparison to the Scientific Method, as it provides a concise and quantified hypothesis, is supported by evidence as well as experiments, draws upon a large body of researchers and independent validation, and has been supported in many parts by peer-reviewed papers and others still in press.

5. A brief review of current investigations reveals a considerable body of legitimate criticism, and follow-up on the NIST Report taking place in the scientific community, contrary to Dr. Griffin's assertions that the NIST Report is nothing more than an element of an ongoing cover-up. Equally important and revealing is

the fact that none of these critiques suggests that explosives were used, or that the Towers would not be expected to collapse after the impact and fires alone.

6. There are now several attempted rebuttals to this whitepaper, all of them from the Truth Movement, and none from scientists or readers without such affiliation. A careful examination of these responses reveals comprehensive errors in fact and reasoning, including incomplete or incorrect understanding of the NIST Report, unfamiliarity with physical laws and engineering principles, and unrealistic models of structures and dynamics that are biased strongly towards confirmation of their proponents' assertions. In contrast, research continues among leading professional and academic institutions, and without exception, these new published results further contradict claims of the Truth Movement.

None of these findings should come as a surprise. In arguing against the NIST hypothesis, Dr. Griffin is automatically at a disadvantage, simply because there is no body of scientific work supporting his position, and no expectation for one in the future. In the words of *Popular Mechanics:*

> Some critics claim that we "cherry-picked" sources who would be favorable to our "agenda." The fact is, for each question we studied, we simply approached the top experts in that particular field. The irony is that we were unable to find anyone with any degree of authority, in the public or private sector—first responders or university professors, engineers or flight instructors—who agreed with the claims made by 9/11 conspiracy theorists. [289]

While Dr. Griffin will immediately retort that there are experts supporting his position, such as current and former University professors, his reliance on such experts is extremely unstable, being limited to only a few individuals, all of whom are major figures in the Truth Movement itself and all of whom can be easily shown to be in error. More importantly, not even these alleged experts have produced any result worthy of review, let alone anything reviewed and accepted, that supports Dr. Griffin's conclusions. Because the evidence is and will forseeably remain overwhelmingly contrary to Dr. Griffin, it is incumbent upon him to uphold the highest standards of science if he wishes to investigate further. As we have seen, thus far his efforts fall well below the most basic principles of the scientific method. Until this is rectified, there is no reason to take his conclusions seriously.

It should also be pointed out that our review, conclusively refuting Dr. Griffin, considers only one specific document – the NIST Report – covering just the scientific aspects of only one part of September 11th. We have not even begun to examine other investigations and factors of the attacks, such as the criminological investigations, including the exhibits at the trial of Zacarias Moussaoui; statements made by conspirators such as Khalid Sheikh Mohammed and Ramzi bin al-Shibh, including those to *Al-Jazeera* prior to their capture; the "martyrdom videos" released by Al-Qaeda; and continued claims of responsibility from Al-Qaeda figures.

Dr. Griffin's claims are sharply inconsistent with all of these facts and more. In the face of this vast scope of investigation, involving literally tens of thousands of professionals in virtually every category, Dr. Griffin's claims – such as his incredulous assertions that the

fires were too small, the dust clouds were too big, or the collapses happened too fast – merit no attention whatsoever.

Readers are encouraged to investigate on their own. There is an unprecedented volume of information available, free of charge, to even the most casual investigator. As this review principally concerns the NIST Report, readers are especially encouraged to read the Report in detail, as it provides a rare glimpse into accident reconstruction, many disciplines of engineering, and the state-of-the-art in computer simulation. There are numerous other positions available for review, including Dr. Griffin's own quoted sources, and study of these is encouraged as well.
No specific reading list is supplied in an effort to encourage investigation of all facts and all perspectives. The author only suggests that a few basic principles should be kept in mind, consistent with the requirements of the Scientific Method. This list is not all-inclusive, but if followed is sufficient to ensure an advanced and balanced understanding:

- Always consider the source of any given argument.
- Attempt to separate out *fact* from *opinion.*
- Claims that can be verified, either through calculation and experiment or independent confirmation, are the most valuable (and you should consider verifying them yourself, if you are able).
- Avoid arguments from authority – an expert commenting in his field is credible, but the work of an expert that can be verified is much more reliable.
- Always attempt to formulate a working hypothesis, and clearly define factual tests to discriminate between competing hypotheses.
- Seek independent analysis and confirmation wherever possible. Universities are good resources of knowledgeable people who can explain difficult problems, and who are generally open to questions.

In closing, the author motivates the search for truth – the real truth – about September 11th by again quoting Dr. Sagan. His words below are not particular to the Truth Movement (having been written over a decade ago), but are instead relevant to any scientist and any line of questioning. Yet, they are strangely resonant to the problem at hand.

> Finding the occasional straw of truth awash in a great ocean of confusion and bamboozle requires vigilance, dedication, and courage. But if we don't practice these tough habits of thought, we cannot hope to solve the truly serious problems that face us – and we risk becoming a nation of suckers, a world of suckers, up for grabs by the next charlatan who saunters along. [290]

Appendices

Appendix A: Kevin Ryan and Underwriters Laboratories

Among the more often repeated arguments from the Truth Movement is the position, originated by Kevin Ryan, suggesting that the steel used in the WTC Towers could not have been susceptible to fires, since their specification as tested by Underwriters Laboratories precluded this. He expressed this view in a letter sent to NIST team member Frank Gayle:

> We know that the steel components were certified to ASTM E119. The time temperature curves for this standard require the samples to be exposed to temperatures around 2000F for several hours. And as we all agree, the steel applied met those specifications. Additionally, I think we can all agree that even un-fireproofed steel will not melt until reaching red-hot temperatures of nearly 3000F (2). Why Dr. Brown would imply that 2000F would melt the high-grade steel used in those buildings makes no sense at all. [291]

Kevin Ryan's position at Underwriters Laboratories was that of environmental testing, not structural certification or fire engineering. He was fired shortly after writing this letter, which he copied to Dr. Griffin among others, and which appeared in public shortly thereafter:

> "UL does not certify structural steel, such as the beams, columns and trusses used in World Trade Center," said Paul M. Baker, the company's spokesman.
>
> Ryan was fired, Baker said, because he "expressed his own opinions as though they were institutional opinions and beliefs of UL."
>
> "The contents of the argument itself are spurious at best, and frankly, they're just wrong," Baker said. [292]

Since his termination, Ryan has been increasingly visible within the Truth Movement. He also sought retribution from UL, his former employer, and brought a civil suit [293] against them for improper termination, filed in November 2006. He also initiated a "legal defense fund" [294] to support his lawsuit.

UL filed a motion to dismiss, on the grounds that Ryan's termination was legal and justified:

> Plaintiff in this case, a former employee of Defendant Underwriters Laboratories, Inc., ("Defendant" or "UL") made outrageous comments regarding his conspiracy theories about the terrorist attacks of September 11, 2001, and created the impression that those outrageous comments were the opinions of his employer, UL. Plaintiff initially made various statements to UL's Chief Executive Officer that the three World Trade Center ("WTC") towers in New York City had been intentionally blown up by explosive devices placed inside the buildings. Later, using his UL e-mail account, Plaintiff sent a letter containing further bizarre and baseless assertions about September 11th, including that a former UL client, the National Institute of Standards and Technology ("NIST"), had somehow "failed to tell the truth" about what "really" happened on September 11, that UL had tested and certified the steel used in the WTC towers, and

> that he had proof that the building had not collapsed because of the impact of the hijacked airplanes. His letter implied that the collapse was actually the result of something more sinister, a belief he made clear by sending the letter to a group claiming that the United States government itself had intentionally plotted to destroy the WTC buildings, killing thousands of Americans in the process. To further highlight the connections Plaintiff tried to make between UL, September 11th, and outrageous conspiracy theories, the organization to whom Plaintiff sent his letter posted it on the Internet where it could be viewed by the public at large. The letter sent by Plaintiff and posted on the Internet included no indication that it was merely his personal opinion being expressed. Instead, the letter clearly bore his company title and was from UL's email system, thus identifying the author of the offensive letter as a UL employee. UL then terminated Plaintiff's employment because his letter clearly created the impression that the outrageous opinions contained therein were those of the company. [295]

The court granted UL's motion to dismiss Mr. Ryan's amended complaint in August 2007. The court found no support for Mr. Ryan's claim of "whistleblower" protection, based on several factors. One factor is that Mr. Ryan apparently had no particular training or insight relative to the issue, and thus his claim – that the WTC steel was UL certified, and therefore should have withstood the fires – is not valid:

> At the time of his discharge Mr. Ryan, a chemist, was a laboratory manager at UL's South Bend drinking water testing facility, formerly known as Environmental Health Laboratories, Inc., and since renamed as UL's Drinking Water Laboratory. (Am. Compl. ¶¶ 4, 5, 15.) Nothing in the Amended Complaint suggests that Mr. Ryan had any connection to any public contract that UL may have had in connection with NIST or the collapse of the World Trade Center buildings. Nor does Mr. Ryan provide any basis for inferring that he possessed any particular knowledge about how UL executed its contracts. Rather, he says he arrived at his concerns following a "period of study and reflection" shortly after the terrorist attacks. (Id. ¶ 18.) **Thus the Amended Complaint strongly suggests that Mr. Ryan possessed no more knowledge about UL's public contracts than any like-minded citizen of similar background and training**, and that in writing to UL and NIST, he was attempting only to making them aware of his theories and conclusions, not of particular problems with any UL conduct. [296] (Emphasis added)

Additionally, the court found that Mr. Ryan cannot be considered as a "whistleblower" because he was unable to provide any evidence of misconduct by his former employer, or that he reported such misconduct appropriately. Mr. Ryan's complaint does not adequately describe either event, and thus his claim was rejected:

> **The whistle blower statute is not aimed at protecting plaintiffs who believe that their employer's conduct needs to be investigated because a thorough inquiry might reveal violations of law or regulation or misuse or public resources.** Rather it seeks to protect employees who report that, in their employer's execution of a public contract, a law or regulation has been broken or public resources misused. At a minimum, a claim under the whistle blower statute must provide some grounds for inferring (1) that such conduct occurred and (2) that this conduct was reported. Bell Atlantic requires this much.
>
> Mr. Ryan's Amended Complaint falls short on both prongs. The closest it comes to alleging that UL was violating the law or misusing public resources is in the statement "Mr Ryan was fired because he made written whistleblowing reports in writing regarding apparent violations of law and misuses of public resources concerning the execution of public contracts by NIST contractors and NIST officials, and UL itself." (Am. Compl. ¶ 53.) However, this allegation does not directly assert that UL violated the law or misused public resources. On close reading, the use of the word "concerning" is ambiguous (and perhaps deliberately so). Mr. Ryan may be alleging that UL violated the law or misused public funds. Or he may simply be alleging that UL's testing should have revealed violations of law or a misuse of public resources by others.

> This same sort of ambiguity resurfaces four paragraphs later when the Amended Complaint states "Mr. Ryan's letter to NIST was somewhat less explicit than his internal reports to UL but still explicit enough for UL, knowing what it did regarding his preceding internal disclosures to UL, to interpret as an allegation that a crime had been committed and public resources were being misused." (Am. Compl. ¶ 57.) This statement asserts that UL should have realized from Mr. Ryan's letter that he was reporting a crime or misuse of public resources, but a crime or misuse by whom? [296] (Emphasis added)

The ambiguities in Mr. Ryan's complaint, noted by the court, are reminiscent of Dr. Griffin's failure to articulate his hypothesis of how the WTC Towers were destroyed in any discernable detail. This episode serves as merely another example of the poor scholarship, unsupportable claims, and lack of evidence typical in the Truth Movement.

Mr. Ryan and his legal team filed a second amendment to their original complaint. This was dismissed, and the case terminated, on 28 August 2007. [297]

Appendix B: Simplified Tower Collapse Time vs. Energy

Another persistent claim of the Truth Movement, used by Dr. Griffin, is that the speed of collapse of the Towers proves that the lower structure did not absorb a significant amount of gravitational energy. This argument then implies that, since the lower structure should have absorbed a considerable fraction of this energy, it must have been destroyed by explosives or similar methods. In this appendix we will quantify the energies under discussion and estimate, as a function of the observed time of collapse, what fraction was absorbed by the structure as it fell.

The potential energy due to gravity of any suspended object is equal to $U = m\,g\,h$, where m is the mass of the object; g is the acceleration due to gravity (roughly 9.8 meters per second^2 for reasonably sized objects on the surface of the Earth), and h is the distance of suspension. This can be derived from the observation that *work* and *energy* are interchangeable, and *work* is defined as force times distance. The force to lift an object is equal to the force needed to oppose gravity, defined as $m\,g$, and the distance is h.

In the case of a WTC Tower, the calculation is a bit more complicated, because different parts of the tower are lifted to different distances. The massive structure on the first few levels contains less gravitational energy than the top floors, even though the top floors are far lighter in construction, because the top floors have a great distance to fall. On the other hand, since energies can be added together, we can simply find the potential energy for each piece and then add them to find the total.

Suppose we consider the tower as a stack of thin slices, each at a height x and of a thickness dx, and further suppose that the mass per unit height of each is equal to a function of its height called $m(x)$. Then the total mass of the slice is $m(x)$ times the thickness dx, and the potential energy of each slice is equal to $m(x)\,g\,x\,dx$. If we add the contribution of all of these slices, we get the total potential energy. This addition, as the slices get arbitrarily thin, is expressed as an integral:

$$U = \int m(x)\,g\,x\,dx, \quad \text{evaluated from the ground to the top, i.e. } x = 0 \text{ to } x = H.$$

To compute the answer, we need to think about how mass is distributed, i.e. what function to use for $m(x)$. The simplest situation is if the mass is evenly distributed, i.e. $m(x)$ is a constant. In this case, the function is $m(x) = M / H$ where M is the total mass of the tower, and H is its height, as before. In this case, we find the following:

$$U = \int m(x)\,g\,x\,dx = \int M\,g\,x\,dx / H = M\,g\,x^2 / (2\,H),$$

again evaluated from x = 0 to x = H. Therefore $U = M\,g\,H^2 / (2\,H) - 0 = M\,g\,H / 2$.

This answer should be intuitive. This is the answer we would have gotten if, instead of adding up all the slices, we simply decided the average height of the tower was halfway up the structure (viz. H / 2), and used the basic formula U = $m\ g\ h$.

In reality, of course, we do not assume the tower mass to be constant with height. The tower is more massive near the bottom. A truly accurate accounting of tower mass is actually quite difficult, but we only need a rough estimate. For our purposes, let us suppose that the tower mass decreases linearly with height – this is sometimes referred to as "linear taper." In other words, at the bottom, we assume that the tower is twice as massive as it is halfway up the structure, and at the very top, the mass creeps down to zero. In this situation, we have $m(x) = 2\ M\ (1 - x/H)\ /\ H$, or we can rewrite this as $m(x) = 2\ M\ (H - x)\ /\ H^2$. This leads to the following integral:

$$U = \int 2\ M\ (H - x)\ g\ x\ dx\ /\ H^2, \text{ evaluated from x = 0 to x = } H$$

$$U = (2\ M\ g\ /\ H^2) \int (H - x)\ x\ dx = (2\ M\ g\ /\ H^2)\ [(H\ x^2\ /\ 2) - x^3\ /\ 3] \text{ from 0 to } H$$

$$U = (2\ M\ g\ /\ H^2)\ [H^3\ /\ 2 - H^3\ /\ 3] = (2\ M\ g\ /\ H^2)\ [H^3\ /\ 6] = M\ g\ H\ /\ 3.$$

Compare this to the previous result. Both towers have a total mass of M and a total height of H. The tower with uniform mass has a potential energy U equal to $M\ g\ H$ / 2. When we replace this with a tower that gets less massive as we move upwards in a constantly decreasing fashion, we get a value that is 16% lower, or U = $M\ g\ H$ / 3. We will use the latter assumption in our calculations. Again, this is only a crude estimate, but it is more than sufficiently accurate for our purposes.

We can now estimate the amount of potential energy contained in each tower. Each tower was approximately 417 meters tall, but as it turns out, the mass of each tower is known with much less precision. Eagar [143] used a value of 500,000 tons, or roughly 500 million kilograms, per tower, and figures in this range are quoted often. However, it is not certain whether this figure includes the basement and foundation structures, and this figure may overestimate the actual contents of the building. While each tower could have *supported* 500,000 tons or more, it is quite possible that their actual mass was substantially lower. The NIST models, including a conservative estimate of "live load" or building contents not attached to the structure, suggest a value of approximately 300 million kilograms each [298]. We will use this lower value, but remark that the actual value could be considerably different, although it may never be known for certain.

Using these values, and our linear taper model, we find that the potential energy for each tower is the following:

$$U = M\ g\ H\ /\ 3 = (3 \times 10^8 \text{ kg})\ (9.8 \text{ m/s}^2)\ (417 \text{ m})\ /\ 3 = 4.09 \times 10^{11} \text{ kg m / s}^2$$

$$U = 4.09 \times 10^{11} \text{ Joules}$$

This number is difficult to appreciate on its own, but we can describe it in terms of its equivalent in explosives. The standard benchmark is that of trinitrotoluene, or TNT. One kilogram of TNT, when exploded, produces 4,184,000 Joules, or 4.184×10^6 J, of energy. This means that the potential energy computed above is equal to that released by 97,700 kg of TNT – round it up to one hundred tons of high explosive. We have used rough values for the total tower mass and its mass distribution, and we have also only calculated the height above grade, neglecting the six stories worth of basement that also collapsed, so this figure should be understood as a rough estimate.

Immediately, we should begin to suspect that the amount of energy just from gravity alone – almost a ton of TNT *per floor* – is enough to cause the destruction seen on September 11th, once the structure begins to move and allows this energy to be released. Some of this energy, possibly a large fraction, would be absorbed by the structure as it fell. This would, in turn, delay the collapse. But how long? We will next answer this question.

Suppose next we are dealing with the WTC 1 collapse, which began from about the 96th floor, or a point approximately 364 meters above the ground. If we were to drop a heavy, streamlined object from this height, such that air resistance was negligible, it would take a few seconds to land. We can compute this time according to the formula $h = \frac{1}{2} g t^2$, where h is the height, g is again gravitational acceleration, and t is the time in seconds. This equation describes the distance an object travels if it starts from rest and is acted on by a constant acceleration, such as gravity. In this case, h is 364 meters, g is still 9.8 m/s^2, so we find that $t = 8.62$ seconds.

Now suppose, instead of releasing a free-falling object, we watch the progression of the 96th floor down to the ground. This is much like the "crush-down" model proposed by Dr. Bazant, forming the first stage of collapse, where the floors above the impact zone remain relatively intact as they and the accumulated debris fall upon lower floors. The 96th floor will accelerate as it falls, and decelerate with each impact, but over time will roughly follow an *average* acceleration, which we will call a.

In this situation, can estimate the average acceleration by observing the time in which it falls, by using the same equation: $h = \frac{1}{2} a t^2$. For example, if it took 20 seconds for the 96th floor to hit the ground, this equation gives us the average acceleration: $341 \text{ m} = \frac{1}{2} a (20 \text{ seconds})^2$, so $a = 2 (341 \text{ m}) / (20 \text{ s})^2 = 1.7 \text{ m/s}^2$.

By computing the average acceleration, we *also* compute the fraction of potential energy dissipated during the collapse. The average acceleration is related to the average *force* exerted on the falling structure as the still-intact structure resists below. This force, multiplied by distance, is equal to the total *work* done on the lower structure, i.e. the amount of energy dissipated by destroying the structure. The net force on the descending structure is equal to $F = m a$ by Newton's second law, which is the sum of the force of gravity and the resistive force: $F = m a = m g - m r$, where r is the acceleration caused by the resistive force, and $r < g$. We know both g (since it is constant) and a (because we can measure the time it takes for the "crush-down" collapse), so we can find r with ease:

$r = g - a$, or for convenience, $r / g = 1 - a / g$. This fraction r / g is approximately equal to the fraction of potential energy that is dissipated in destroying the structure.

To work through an example, pick the case above where we observed a 20 second "crush-down" collapse. We calculated above that the acceleration $a = 1.7$ m/s^2. In this case, $r = g - a = 9.8$ m/s^2 – 1.7 m/s^2 = 8.1 m/s^2, or $r / g = 1 - a / g = 0.81$. Therefore, approximately 81% of the potential was expended by destroying the structure.

The amount of potential energy released in the "crush-down" phase is almost equal to the total. There is a little bit of gravitational potential left over because the "upper block" has not yet totally collapsed, standing for a few floors, thus it still has some potential energy. However, because the upper block is much lighter, and because it has already given up 80% or so of its potential energy by being lowered to the ground, we will neglect this minor correction (a few percent) in our rough estimate.

Table 4 below shows, for different lengths of time observed for "crush-down," how much energy was expended to destroy the structure as it fell:

Crush-Down Time t	Average Acceleration $a = 2h / t^2$	Energy Fraction Dissipated $(1 - a / g)$	Total Energy Dissipated by Structure	TNT Equivalent Dissipated
8.6 seconds	9.8 m/s^2	0	0	0
9 seconds	9.0 m/s^2	8.2%	3.28 x 10^{10} J	8.2 tons
10 seconds	7.3 m/s^2	26%	1.04 x 10^{11} J	26 tons
11 seconds	6.0 m/s^2	39%	1.56 x 10^{11} J	39 tons
12 seconds	5.1 m/s^2	48%	1.92 x 10^{11} J	48 tons
13 seconds	4.3 m/s^2	56%	2.24 x 10^{11} J	56 tons
14 seconds	3.7 m/s^2	62%	2.48 x 10^{11} J	62 tons
15 seconds	3.2 m/s^2	67%	2.68 x 10^{11} J	67 tons
16 seconds	2.8 m/s^2	71%	2.84 x 10^{11} J	71 tons
18 seconds	2.2 m/s^2	77%	3.08 x 10^{11} J	77 tons
20 seconds	1.8 m/s^2	81%	3.24 x 10^{11} J	81 tons
25 seconds	1.2 m/s^2	88%	3.52 x 10^{11} J	88 tons
30 seconds	0.8 m/s^2	92%	3.68 x 10^{11} J	92 tons
40 seconds	0.5 m/s^2	95%	3.80 x 10^{11} J	95 tons
60 seconds	0.2 m/s^2	98%	3.92 x 10^{11} J	98 tons

Table 4: Collapse Energy as a Function of Time

What this result demonstrates is that, even if the lower structure only delays collapse by a few seconds, an *enormous* amount of gravitational energy is expended destroying the lower structure. If half of the total gravitational energy is needed to break the building, it only slows the fall by about four seconds. If 75% is needed, it only slows the fall by about eight seconds. A delay of about four seconds, corresponding to a "crush-down" time of about 12 seconds – which is what we observe, according to Dr. Bazant *et al.* [72] – means that the lower structure absorbed the equivalent of about **48 tons** of high explosive during the collapse. This is a massive amount of energy, and compares well

with the estimated energy needed to destroy the columns on every single lower floor. This result also proves that, in order to significantly accelerate the collapse process, Dr. Griffin's hypothesis calls for many, many tons of high explosives, much more than could possibly be placed or detonated covertly.

This result refutes claims made by those in the Truth Movement that the structures should have taken much longer to fall, such as the estimate of 47 seconds or more from Dr. Judy Wood [71]. We can clearly see that such a delay would require that virtually all of the potential energy was required to destroy the lower supports. More importantly, the calculation is extremely sensitive at such long delays, with only a three percent error equating to 10 seconds or more difference in the collapse time. None of the calculations from the Truth Movement approach this level of precision, so we may automatically reject them as inaccurate to the point of uselessness.

What we learn from this result is that progressive collapses, when they occur, are expected to take place quickly. Delays of only a few seconds – delays that may not even be distinguishable from "free-fall" without careful measurement – mean that significant or even majority fractions of the total collapse energy go into destruction of building materials. There is no support for slow, gradual collapses of any kind. Buildings can be expected to either collapse quickly, or not fully collapse at all.

What about the Kurttila paper? Earlier in this paper, on page 117, we remarked that a similar calculation by Dr. Kurttila [181] was invalid. He used a homogeneous approximation for the structure, which we criticized as a poor model. However, in the calculation above, we have assumed an "average" rate of acceleration during the collapse, which also implies homogeneous structure. Why can we use this simplification while Dr. Kurttila cannot?

The reason is in the interpretation. In our calculation, we have estimated the *total energy* dissipated by the structure. This total energy is an aggregate quantity. We accept that the actual *rate* of energy dissipation is going to vary wildly from millisecond to millisecond, as each floor is hit by the descending mass, briefly resists, and then breaks leading to another short period where the resisting force is much lower. We do not know the magnitude of the *peak* force, but it doesn't matter – we also do not know the *duration* of the peak force. We do, however, know the product of the two. If the peak force is high, it must only resist for a short period of time, or else we would get a different time of collapse. If the peak force is low, it must resist for a longer period of time. The total amount of work done is equal to the product of peak force times the distance over which the resistance acts – short if it resists for a brief period of time, long if not – which works out to be roughly constant averaged over the entire collapse, for any given collapse time. We never have any reason to calculate the peak force. We are satisfied with the average.

Dr. Kurttila, on the other hand, is *not* estimating the total energy – he is attempting to estimate the *peak force*. He wants to know what the strength of the building is, and extract this strength from observation of the collapse time. Unfortunately, the strength is a static quantity, not a dynamic quantity. Dr. Kurttila estimates (for WTC 7, not the

Towers) that the "resistance factor," i.e. the fraction of resistance similar to our computation above, is about 16%, and concludes that this number is "too low."

He is in no position to draw this conclusion. Suppose, for instance, the structure – even damaged and during collapse – was capable of supporting twice the static load, which we will call F_{static}, but that it could only do so until being deflected by 25 cm. After this, any given floor will snap, and the resistance goes to zero until the next floor is hit 300 cm below. Work, again, is force times distance. The total work done on any given floor would be 2 F_{static} x 25 cm + 0 x 300 cm = 50 F_{static} cm. If we model the structure as homogeneous, supplying instead an average force called $F_{dynamic}$ that acts over the full 325 cm distance of each floor, we can estimate this average force by dividing the total work by the total distance. The total work done in both situations must be the same. Therefore, we can calculate $F_{dynamic}$ = 50 F_{static} cm / 325 cm = 0.15 F_{static}, what Dr. Kurttila would call a "resistance factor" of 0.15, very close to his estimate for WTC 7.

This simple example produces a result similar to Dr. Kurttila's, and explains why Dr. Kurttila's result is in no way unexpected – his model is simply incomplete. Our model, while similar, considers an appropriate average quantity, and therefore does not suffer from this problem.

We remind the reader that our calculations in this section are simplified in several aspects. For a more thorough treatment of the collapse time, readers are referred to Bazant *et al.* [72], which considers the collapse time with variations in mass as a function of height, adds corrections for mass lost over the side during the collapse, and includes specific dissipation mechanisms of the structure as a further verification of the energy balance.

Appendix C: Detailed Discussion of Eric Douglas's Critique

This appendix is concerned exclusively with the lengthy whitepaper by Eric Douglas [249] and its criticism of the NIST Report. Mr. Douglas's overall disagreement is not necessarily with NIST's conclusion, but rather that NIST relied excessively on computer simulation in its reconstruction. Given the complexity of the computer models used and the potential for errors, it is important to conduct validating experiments – tests in subscale, representative samples, or certain phases of the process being modeled – in order to verify that the simulation results are accurate and reasonable. While NIST conducted a number of such experiments, Mr. Douglas believes that these experiments are insufficient, and therefore considerable uncertainty remains regarding NIST's overall conclusion. He also argues that, in some cases, NIST's experiments actually contradict simulation results. His criticisms are concentrated in the following areas:

- Workstation fire experiments
- Fire testing of truss structures (ASTM E 119 testing)
- Impact modeling and global structural modeling
- Fire simulation
- Fire / structure interface

Following this discussion, Mr. Douglas lists a number of observations, mostly taken from witness accounts, that he believes were not given sufficient audience in the NIST investigation and could potentially lead to a different conclusion. While outside the scope of the NIST Report, some of these items have already been discussed with respect to Dr. Griffin's claims.

Workstation Fire Experiments

The first criticism concerns the single workstation experiment, as described in NCSTAR1-5, section 3.2. Mr. Douglas raises a number of concerns about the method and reporting from this test, found on page 4 of his whitepaper. He states:

1. NIST did not report the actual temperature observed in the test, but only the heat release rate and rate of mass loss.
2. NIST may have overestimated the flammability of workstation materials, given that office furniture is often flame-retardant.
3. The role of jet fuel in sustaining fires is neglected without proper explanation.
4. Since office furniture was not located or moved near core columns, there is no evidence that core columns would have been heated significantly.
5. The workstation tests were freely ventilated, whereas the WTC 1 fire was described as "ventilation limited." In contrast, NIST indicates that a fire test in a sealed chamber would burn out in only two minutes.

NIST provides more detail on the results from the workstation burn tests in NCSTAR1-5C. Turning to this report, we explore these claims as described below.

Significance of Fire Temperature

NIST consistently describes the purpose of the workstation fire tests as to find the expected heat release rate, or HRR, of building furnishings. Secondary objectives are to understand the rate of mass loss, and the timing and phenomenology of the fire – how it would start and how it would progress over time. The mass loss rate is related to the heat release rate, with the heat release rate also dependent on chemical effects, e.g. how completely the lost mass is combusted. NIST's experiments also provided some insight into how performance of individual objects, such as collapse of desks and spread of fire to filing cabinets, was likely to shape the heating curve over time.

As Mr. Douglas points out, the temperature curve is not presented for any of the five tests. However, NIST did capture temperature data. As described in Table 2-5 of NCSTAR1-5C, the instrumentation for each test included seven thermocouples, described as mounted underneath the desk to indicate the spread of flame (NIST also reports that protecting these thermocouples from the fire was difficult, and they failed in four of the six tests [299]). Also, from the text on page 10, NIST reports that the exhaust gas temperature was also sampled at eight locations. NIST also presents a normalized temperature curve – one that is unitless, showing the temperature as a fraction of maximum over time, rather than its numerical value – in Figure 3-18. It is thus a fact that NIST has temperature data, but chose not to include it in the report.

NIST is not entirely clear on its reasons for not reporting this data. The author infers from the text of NCSTAR1-5C that it was not presented simply because it is not comparable to the situation in the WTC Towers. The temperature in the test cell is dependent on airflow, and because this test was designed to capture chemical species, it is not a direct analogue to an ordinary fire. NIST describes the apparatus as follows:

> Since a hot, smoky upper gas layer in a room can play a significant role in fire spread, a 3.66 m by 3.66 m (12 ft by 12 ft) ceiling was created here. It consisted of a single layer of 13 mm (1.2 in.) thick calcium silicate board arrayed 2.74 m (9 ft) above the floor of the workstation. The calcium silicate board was supported by a frame formed from steel pipe. Water flowing through the pipe precluded heat damage to the frame. There were only four water pipes flowing beneath the ceiling to minimize heat loss from the hot gases trapped beneath the ceiling. The calcium silicate layer was surrounded on all four sides by a 0.61 m (2 ft) high steel skirt. This allowed the formation of a hot smoke layer above the workstation, providing for radiative heating by the accumulated hot gases.
>
> The entire assembly was placed beneath the hood of the NIST 10 MW calorimeter hood (9 m by 12 m) so as to capture the full smoke plume and allow heat release rate measurements during the burning of the workstation. The air supply to the fire was thus not restricted, and the burning behavior was that of a fully open condition. [300]

What is most important about the passage above is the function of the calorimeter hood. In order to accurately capture the chemicals present in the smoke plume, the hood actually siphons exhaust gases away from the fire. Because those gases do not remain in

the room, above the flames, they may be cooler – or potentially hotter, if drawing them out supports additional combustion – than they would be in an ordinary fire. Additionally, the fires had plenty of airflow and were not oxygen limited. Thus, the temperature in this situation is not particularly relevant to the actual fires.

It is also interesting to note that NIST, recognizing the role of temperature in fire progression, simulated *some* of the conditions that would be found in an ordinary fire, namely their attempt to create a similar upper-layer temperature condition with a partial ceiling. For this reason, Mr. Douglas's concern about accurate temperature appears to be valid. Unfortunately, we do not know how well the partial ceiling matched expected conditions – we do not know that the temperature curves in these tests, and thus the fire progression as dependent on temperatures, were a good match to real-world conditions, but we do not have evidence that it was a poor fit, either. Because of the hood's influence on gas flow and temperature, comparison between these temperature curves and the simulated temperatures from NCSTAR1-5F would also be inappropriate. The author suggests that, had NIST conducted a seventh test solely to gauge the temperature curve, one where the action of the calorimeter hood was absent and with airflow limited, we would be in a better position to assess the potential inaccuracy due to temperature.

Flammability of Workstation Materials

In NCSTAR1-5C and throughout the entire NIST Report, NIST remarks that it has limited information about the furnishings of the Towers. This creates uncertainty in the fire modeling, but also in the impact modeling, where the mass and strength of furnishings as well as their initial placement has a significant effect on the model end-state. For the workstation fire tests, NIST experimented with two different workstation designs: A "generic" workstation, used in five of the six tests; and a "WTC Workstation," which is a near replica of one type that was definitely used in the Towers. NIST's description includes the following:

> The layout, including the placement of the various non-stationary items, was suggested to personnel from the company that supplied office furnishings to the occupants of the noted floors of WTC 1 (Fleck 2003). The mass and distribution of papers and other office clutter is based on information also provided by this source, who was a frequent visitor to these offices. [301]
>
> One of the six tests was of a workstation that was identical in design to one of those on floors 93 to 100 of WTC 1. The principal differences between it and the generic workstations used in the other five tests were as follows:
>
> - The wall panel had a 3 mm (0.125 in.) layer of flame-retarded polyester fiber beneath the outer fabric… This decrease in woody fuel was only about 5 percent of the total available in the desk surfaces. Also, its enclosure deep within the wall panels delayed its burning.
> - The four file cabinets … had a flammable, charring plastic surface on the drawer fronts that added about 10 percent to the exposed flammable area.
> - The chair … had an additional 3 kg (6.6 lb) of mass, and it behaved as if its upholstered surfaces were flame-retarded. The chair was certified to pass California Technical Bulletin 117, which usually requires somewhat flame-retarded polyurethane foam. [302]

NIST presents detailed manifests of the workstations in Tables 2-1 and 2-3, along with a photograph of the generic workstation in Figure 2-2 of NCSTAR1-5C. In the author's amateur opinion, it appears that NIST's reconstructed workstations are reasonable in size, composition, and layout, and there is no exceptional dependence on unusually flammable furniture. The fact that NIST was able to test a near copy of an actual workstation in Test 4 lends validity to their estimate.

However, comparison between the generic and replica workstation tests reveals some interesting differences. The replica workstation, Test 4, is only directly comparable to Test 2 of the generic workstations, as other tests differed in scale, interference of ceiling tiles, and/or introduction of additional jet fuel, as outlined in Table 2-6. Raw heat release rate curves are presented in Figures 3-2 and 3-6, and a summary of results appears in Table 3-1. For purposes of comparison, Figures 3-8, 3-10, and 3-14 provide plots of heat release rate, mass loss rate, and net heat release rate, respectively, for the different workstation types. Comparison of these charts reveals the replica workstation had the highest peak heat release rate, but following this peak it output a substantially lower amount of heat. Numerically, the replica workstation provided only 2.93 GJ of heat, compared to 4.05 GJ in Test 2, or a differential of roughly 25%.

NIST's own assessment of the differences due to workstation type is in Section 3.4.5. Here, NIST focuses on the difference in peak heat release rate, thought to be a factor of the chair's construction; and oxygen availability within the filing cabinets, which contained a large amount of flammable materials but was not expected to burn effectively, described by a very low combustible fraction in Tables 2-1 and 2-3. NIST comments that the general burning behavior between the two workstation types was similar.

NIST does not comment on the 25% difference in total heat output between workstation types. Since the peak heat release rate is both higher and earlier for Test 4 than Test 2, we suspect this difference is not due to fire-resistant materials, but rather due to an overall reduction in combustible fraction – either the mass or heat content of the fuel itself. Again, there seems to be no support for improper handling of fire-retardant furnishings. However, uncertainty in the total heat available does seem to be significant and largely ignored by NIST in its later reports.

In the overall fire simulation, presented in NCSTAR1-5F, the fires are not heat-limited, instead leading to collapse prior to burnout of materials in the case of WTC 2, and being oxygen-limited in WTC 1. It is, therefore, reasonable to suppose that the uncertainty in total heat content revealed above will have little impact on the overall NIST conclusions. Nevertheless, the uncertainty above is sufficiently large to merit propagation of errors and discussion, and this is not provided in the NIST Report.

Role of Jet Fuel

Test 5 and 6 of NCSTAR1-5C involved addition of 4 L of Jet A in an effort to study what effect excess fuel would have on the fire behavior. On page 49, NIST describes these

tests as "comparable to the *uniform* coverage of the five affected floors with Jet A from about half of the fuel in the aircraft." (Emphasis in original.) The author is unclear about the basis of this estimate. 4 L of fuel distributed over the square workstation 2.66 m on a side, or 0.57 L /m^2, appears to be about a factor of three lower than the average fuel load expected from figures NIST provides elsewhere. NIST estimated roughly 24,000 pounds of unburned fuel left on the fire floors, or 40% of the fuel in the aircraft, from NCSTAR1-2B, page 71. This is about 36,000 L, which distributed over the complete area of five entire floors of 64 m square each, would be an average fuel load of roughly 1.8 L per square meter.

It is unclear whether NIST's estimate of 4 L per workstation is due to a lower preliminary estimate of total fuel, other geometrical considerations insufficiently described here such as fuel distribution along wall surfaces, or a simple error. Because of this disagreement, we expect the results of Test 5 and 6 to be instructive, but we anticipate qualitative differences between these tests and a higher, more realistic jet fuel loading.

NIST further justifies its choice of 4 L as follows:

> The impact of the airplanes could be expected to leave varying amounts of Jet A deposited on various surfaces, with some areas being heavily engulfed, and others, further from the impact zone, being dry. Because of its high volatility and heat of combustion, even a limited amount of Jet A has the potential to alter the burning and spread rates of the fire. The quantity chosen, 4 L per workstation, was sufficient to form a continuous layer on the major horizontal surfaces and thus was sufficient to alter the fire growth process substantially. [303]

The comparative impact of the jet fuel is shown in Figures 3-9, 3-11, and 3-15. In all cases, the effect is to accelerate the burning behavior. Peaks for the heat release rate and mass loss do not change in intensity or shape, but are reached much earlier than in tests with no jet fuel. This effect applies to both Test 5 and 6, i.e. with and without the presence of ceiling tiles on top of flammable materials.

Since we do not have a test with a more realistic, much higher fuel load, we can only extrapolate from the qualitative results presented and discussed here. It is reasonable to suppose that additional jet fuel would serve to further accelerate the burning process, moving the peak heat release rate even closer to the start of the test, but this is unlikely to adversely affect NIST's overall results. A limitation of the Fire Dynamics Simulator system is that it predicts combustion of jet fuel too quickly:

> The predicted… increase in the peak from the Jet A [is] similar in magnitude to the experimentally measured results. The simulations… did not predict the more than a factor of three reduction in time to the peak for the addition of Jet A. FDS consumed the Jet A immediately with relatively small effect on the growth of the heat release rate. For the actual fire, the ignition of the Jet A did not occur until about 120 s. Then the ignition and rapid burning of the Jet A caused the entire cubicle quickly to become fully involved, first above the desk surface and then below via dripping from the chair to the carpet. [304]

Because of this limitation, the inaccuracy in FDS applies to *any* amount of jet fuel, not just a higher fuel load. The total heat release rate is plausibly modeled, just not the onset of the peak in the first few minutes. The practical result will be a simulation that

underestimates ignition and spread of fires from one workstation to another, since it does not capture the accelerated heat release, and thus will be biased *against* the fire-induced collapse hypothesis. These limitations can also be mitigated by observations of fire progression from the ground, as was done in NCSTAR1-5F.

NIST also offers a discussion into the likely effects of a higher or lower fuel load than considered in its tests. Excerpts having to do with a fuel increase are reprinted below:

- The presence of a larger volume of jet fuel would be likely to have a greater than linear effect on the peak HRR value. This is because the quantity of fuel consumed during the build-up to the peak HRR would become a smaller fraction of the total volume added and the volume of fuel remaining for pool-like burning at the peak would be disproportionately higher. An upper bound to sensitivity, in the context of a doubled amount of Jet A, was estimated as follows:
    - … The steady state HRR of a deep Jet A pool with area equal to the workstation surface area is approximately 13 MW. Here, the effective layer thickness of the "pool" would be approximately 1.4 mm and for such a thin layer the actual burning would be transient with a significantly reduced HRR compared to the steady state value. …
    - The HRR for full involvement of the "dry" surfaces was estimated as half of the peak HRR from Test 2, or 3 MW.
    - The sum of these three contributions is approximately 9.5 MW, about 30 percent higher than the peak HRR in Test 5. For still more Jet A, the layer thickness on the desk surfaces will not get appreciably deeper nor will the HRR from such wetted surfaces. The results of Ma et al. (2004) do imply that the HRR from the central carpet area could go even higher with higher Jet A loadings. This could have occurred, presumably, very close to the airplane impact area.

- *The presence of jet fuel had only a small effect on the total mass loss and total heat released from the burning workstation.* In Test 5 (generic workstation, Jet A) the mass loss of the workstation at 1500 s, the time at which the ignition burner was turned off, was only approximately 10 percent higher than in Test 2 (generic workstation, no jet fuel). The total mass loss in the two tests was indistinguishable. …
- *Increasing the quantity of jet fuel would not affect further the time to full involvement of the cubicle.* The 4 L of Jet A sharply decreased the time to full involvement of the workstation from 530 s to less than 160 s. As discussed in Sec. 3.2.3, the presence of Jet A and the evaporative cooling effect it provided actually delayed the paper auto-ignition mechanism from 40 s to 70 s seen in "dry" tests to 150 s. While more Jet A could have delayed this mechanism longer, random piloted ignition by flying, burning debris would provide an upper limit to this delay. [305] (Emphasis in original)

This analysis reveals some interesting counteractive effects caused by additional jet fuel. More fuel seems likely to increase the total heat release rate by perhaps 30%, a significant amount, and curiously similar to the difference between workstation types examined above. Additional jet fuel may not accelerate the heat release rate curve any further, and may actually delay it through evaporative cooling – suggesting the shape of the curve, rather than its timing, is likely to change for large amounts of fuel.

In summary, NIST's treatment of jet fuel leaves unanswered questions, but does not appear to affect its overall conclusions regarding the fate of the Towers. The long-term effect of additional jet fuel is at worst comparable to uncertainty in the heat content of

individual workstations. However, the author welcomes an explanation of the discrepancy between the 4 L per workstation fuel load and the anticipated average fuel load in the impacts. If this choice was not simply mistaken, and if we have understood the fuel distribution at impact correctly, NIST's case would be strengthened by a workstation test using the corrected, substantially higher fuel load.

Combustible Furnishings Near Core Columns

Since none of the workstations were located near the columns, consideration of the fuel load in core areas – and of heating throughout the structure – is deferred to other portions of the report. NIST describes its estimate of combustibles in the core in NCSTAR1-5F, section 5.4:

> Figure 5-4 shows how the major elements of each floor were arranged in the model. The combustible items consisted of the carpet, desks, privacy panels, and the "miscellaneous combustibles." To represent damaged furnishings ("rubble") and aircraft debris, the burning rate of the "miscellaneous combustibles" was reduced from 450 kW/m^2 to 300 kW/m^2. The distribution of rubble was a variable in the final simulations, but the overall strategy used to distinguish rubble from undamaged furnishings was as follows: the impact analysis (NIST NCSTAR 1-2) provided estimates of where the heaviest damage occurred. The combustible mass contained within these areas was redistributed over the swath cut by the airplane, an area roughly one third of the entire floor area, extending through the center of WTC 1 from the north to the south face, and through the east side of WTC 2 from the center of the south face to the northeast corner. This strategy conserved the overall combustible load, but shifted it away from the impact area to mimic the "plowing" effect of the airplane debris. At the same time, the rubble burned at a reduced rate to account for the fact that the collapsed furnishings had less exposed surface area. In the model, the geometry of the damaged workstations was not altered; the burning rate was meant to account for the change in the geometry.
>
> … The core area contained elevator and heating, ventilating, and air conditioning (HVAC) shafts, stairwells, storage rooms, toilets, and various other support facilities. It was unclear what the combustible load was in the various core areas. As a first approximation, the carpet that was assumed to be spread over the entire floor was extended into the core area, not necessarily because the core was carpeted but to represent whatever other combustible objects were to be found there. [307]

Earlier in the report, NIST describes the "miscellaneous combustibles" [308] as modeled similar to Group A Plastic, citing previous experience with office fires. These combustibles were given simplified behavior compared to the workstations themselves. NIST assumed that the mass of combustibles in the core was equal to that of carpeting outside the core, with the primary material difference between core and open areas being the heat release rate. From NCSTAR1-5C Table 2-1, the carpeting mass is 38 kg per each 7.5 m^2 area, or 1 lb/ft^2. For comparison, this is equal to one quarter of the combustible mass NIST assumed outside the core.

There is ample room for criticism of these estimates, but it is reasonable to propose that this quantity or more of combustibles was contained in the core. Electrical wiring alone presents a significant source of heat, and incidental furnishings and carpeting were surely found there as well.

Besides the presence of some combustibles in the core area, heated gas from fires outside the core also contributes to elevated core temperatures. This effect is clearly seen in the simulation output contained in NCSTAR1-5F.

Free-Burning versus Enclosed Burning

In the discussion above, we have already considered implications of the calorimetric hood in the workstation fires. The single-workstation tests are not particularly useful in terms of understanding ventilation, expected burning time, or temperature as a result. Treatment of ventilation is deferred to NCSTAR1-5E, which we will consider shortly, and NCSTAR1-5F, where availability of fresh air through broken windows and damaged walls is modeled in much finer detail.

There is, however, an additional consideration discussed in NCSTAR1-5C that contributes to the burning time in the Towers, namely that of ignition from one workstation to the next. This topic is discussed in Section 4.3, and we present a selection below:

> The estimated peak HRR of the fires in WTC 1 was of the order of 1 GW to 1.5GW (NIST NCSTAR1-5F), with fires being observed on the 92nd through 100th floors (NIST NCSTAR1-5A). The peak HRR of the WTC workstation identical in design to those used in the primary impact floors of WTC 1 was approximately 7 MW. These numbers suggest that the WTC 1 peak HRR was the equivalent of about 200 workstations at their peak values. However, it was likely that at any given moment, many of these workstations were not generating their peak heat output because:
>
> - Not all would have been at the same point in their combustion history simultaneously,
> - Many were at least partially covered with debris from fallen ceiling tiles and wall fragments, and
> - Not all would have free access to an unrestricted supply of air.
>
> … Two further factors help alleviate any concern about the timing differences between the experimental and simulated HRR curves seen here. The next stage of the experimental program involved the burning of three workstations within a large enclosure (NIST NCSTAR 1-5E). The ignition of the first workstation was by the same means as here (2 MW spray burner), but the involvement of the other two workstations was the result of a fire spread process after the first station ignited. … For the three stations and also for the full WTC floor simulations (NIST NCSTAR 1-5F), the limiting factor in determining the overall HRR evolution over time was found to be the rate of air supply to the fire. Therefore, the results were relatively insensitive to the types of timing discrepancies seen in the open burns here. [306]

With these words, NIST too defers treatment of this question to NCSTAR1-5E and 1-5F. We will then revisit this question below.

Multiple Workstation Experiments

Next, Mr. Douglas discusses the multiple workstation experiment. His concerns here are summarized as follows:

1. There is no correlation between these results and those from the single workstation experiments.

2. NIST does provide temperature data for this experiment, but only reports a single temperature curve out of six trials, raising the possibility that NIST has exercised selection bias in neglecting the other five results.
3. While intended to validate the FDS simulation, the test was well-ventilated, while the situation in WTC 1 was described as ventilation-limited.
4. Data from the test suggests that peak temperature would be reached after about 20 minutes, and burnout of furnishings would also take about 20 minutes if not disturbed by the impact, which is not a good match to NIST's overall narrative of fire progression and effects in the Towers.

As before, we will consider these objections in order.

Correlation to the Single Workstation Experiments

NIST openly declares the difference between these tests and the single workstation fire tests in NCSTAR1-5C:

> The present study is different in configuration, objectives, and complexity from the single workstation experiments reported in NIST NCSTAR 1-5C. In this study, the workstations were burned in a compartment rather than in the open (under a ceiling), leading to underventilated or oxygen-limited burning, which undoubtedly affected the rates of fire heat release and flame spread. In this study, the use of multiple workstations arranged about a carpeted passageway led to a variety of possible flame spread time-lines. [309]

Because of these differences, comparing results from the two groups of tests will be difficult. Nevertheless, NIST does reference the single workstation tests frequently:

> Measurement during the single open workstation burns yielded peak values of [heat release rate "Q-dot"] equal to 8 MW to 9 MW, depending on the test condition… Over-ventilated fires simultaneously involving all three workstations undergoing the fast burning period, should have yielded a total of 24 MW to 27 MW. The relatively small value of the measured peak heat release rate seen in Fig. 5-1 as compared to this reference value suggests that the compartment fire was ventilation limited. [310]

> The total heat release and the mass loss measured during the single open workstation burns yielded approximately 3.9 GJ and 200 kg on-average … For the three workstations burning in the experiments reported here, the measured total heat release and mass loss per workstation were equal to 4.6 GJ and 227 kg, respectively… These somewhat larger values are consistent with the idea that radiation from a well-developed hot upper layer and the walls of the compartment radiated onto the fuel, leading to faster burning and more complete combustion. [311]

NIST also describes the different approach to the experiments in Chapter 8 of NCSTAR1-5E:

> Blind predictions of the single open workstation burns were made using the material properties obtained during the sprinkler/roof vent study (McGrattan et al. 1998), and then these properties were adjusted to match the results of the experiments. Thus, the single workstation burns served to *calibrate* the model. They were not intended to be *validation* experiments. [312] (Emphasis in original)

This passage serves to distinguish the single workstation tests from the multiple workstation tests once and for all. The single workstation tests are, in essence, an input to the FDS simulation. Without an example of representative materials burning in a controlled condition, FDS cannot accurately predict anything. The single workstation experiments, therefore, provided calibrating data needed to complete FDS. Once this was complete, FDS could predict the results of the multiple workstation experiments, which were carried out to verify the accuracy of the FDS prediction. Once FDS was checked against the multiple workstation tests, varied for different input conditions (e.g. amount of jet fuel, condition of workstations, and insulation due to fallen ceiling tile), NIST could predict the accuracy of the FDS simulation for an arbitrary set of inputs. In this way, the simulation was *validated*, i.e. verified in sufficient differing trials to permit prediction of its performance.

The different intent of these experiments precludes direct comparison. Calibrating experiments and validating experiments should never be combined, as this leads to "overfitting" of models. NIST is well justified in conducting two series of independent tests, and treating them as such.

Temperature Data

It is not strictly correct to say that NIST only provided temperature data from a single test. In NCSTAR1-5E, Chapter 6, NIST presents the gas temperature data from Tree 1 and Tree 4 for all six tests (also note, Figure 6-13 is mislabeled; test data is from Test 2 as marked on the graph itself). This represents roughly half of all gas temperature data taken – there were two other thermocouple trees, also with thermocouples at four distances from the ceiling, between Tree 1 and 4. Data from these two trees appears in Appendix C, although in three tests, data from Tree 2 was lost due to wiring failures.

More usefully, Appendix D of NCSTAR1-5E shows comparative plots of the temperature sensors versus the FDS gas temperature predictions. These plots display only the probes closest to and furthest from the ceiling, but show all four trees for the remaining five tests. Qualitatively, the FDS performance in all of these plots up to the temperature peak (generally ~1000 seconds after ignition) is quite good, both in magnitude and character. After the temperature peak, there is usually a significant discrepancy, where FDS overestimates the gas temperature, then tends to underestimate temperature slightly for times long after the temperature peak as FDS predicts early complete burnout of remaining materials. NIST remarks on this behavior as follows:

> FDS was able to accurately predict the general shape and magnitude of the time dependent heat release rates. The areas under the curves were equal, guaranteed through model calibration based on the heat release rate measurements made during the single office workstation burn experiments (NIST NCSTAR 1-5C). FDS tended to under-predict the late heat release behavior of the slow burning period of the fire when the heat release rate dropped below 1 MW to 2 MW. When this long "tail" in the heat release curve was observed, FDS predicted that the fuel had already been completely consumed. Due to the relatively low heat release rate during this period, however, this behavior was considered to be of secondary significance in terms of the temperature of the upper gas layer and resulting thermal load on a structure. [313]

> According to Eq. 8-1, a 9 percent discrepancy in [heat release rate] corresponds to a 6 percent discrepancy in the temperature rise (= 2/3 x 9%). For temperatures of approximately 1,000 °C, this translates to roughly a ±90 °C temperature difference between measurements and simulations due solely to differences in the measured and simulated values of [heat release rate]. … The thermocouple measurement uncertainty of approximately 100 °C for the peak temperatures was also considered, and the agreement between measurements and simulations, therefore, was regarded as good. [314]

Given that the fires in WTC 2 were interrupted by building collapse in under an hour, and the fires in WTC 1 were largely ventilation limited, we are more concerned with the initial phases of fire and both peak heat release and peak temperature. The experiments of NCSTAR1-5E demonstrate that FDS is accurate in this regime for a number of different test conditions. FDS is less accurate later in the fire evolution, both overpredicting heat release and temperature, but still reasonably close given the other large uncertainties present in the investigation.

Ventilation

If we view the multiple workstation experiments as validating experiments rather than an accurate subscale recreation of the World Trade Center fires, ventilation for the test needs not be representative. Ideally, the ventilation should be varied to exercise FDS in as many different configurations as possible.

As it turns out, the tests of NCSTAR1-5E are not fully ventilated, but are in fact reasonably close to the WTC situations. Mr. Douglas presents an image of the test cell (Figure 4-6 from NCSTAR1-5) showing smoke and flame issuing from wide openings. However, this image by itself can be misleading. A diagram of the test cell, given in Figure 2-2 of NCSTAR1-5E, reveals that the five openings are in fact the only air supply – the test cell is closed on three sides, and the openings make up only about a quarter of the fourth, shorter wall.

These openings are designed to be roughly the same size and spacing of exterior windows in the World Trade Center. Also, the amount of ventilation compared to the test area and available fuel – five windows to three workstations – is similar to that seen in the WTC Towers, where approximately 200 workstations burned on a given floor, ventilated by about 200 broken windows, plus damaged walls and floors, and elevator shafts. It is also possible that the WTC cases were *more* ventilated, because in both impacts, large holes were created on both sides of the structures, whereas in this series of tests, entry of fresh air and exhaust was limited to the same five holes, on the same side of the fire.

The quantitative data taken by NIST also confirms that the fires were not over-ventilated:

> Over-ventilated fires simultaneously involving all three workstations undergoing the fast burning period, should have yielded a total of 24 MW to 27 MW. The relatively small value of the measured peak heat release rate seen in Fig. 5-1 as compared to this reference value suggests that the compartment fire was ventilation limited. [310]

The final test described in NCSTAR1-5E also added the element of variable ventilation. To the left of the five open ventilation ports, NIST constructed four glass windows, two of which cracked and opened approximately three minutes after ignition due to heating. These windows prior to and after breaking can be seen in Figure 3-10 and 3-11.

Burnout of Combustibles

In NCSTAR1-5E, NIST acknowledges that the multiple workstation experiments typically burned out after about 20 minutes. This is seen in Table 8-2, where the time to 50% energy release varies from 1210 seconds to 510 seconds with an average of about 900 seconds. In Table 8-3, the full duration of the fire, defined as time until output fell below 2 MW, varies from 2,540 seconds to 1,450 seconds. As expected, the fastest times correspond to the final test, where additional ventilation was provided by breaking windows.

NIST sees no conflict between a 20-minute burnout time for individual workstations and the considerably longer fires in the World Trade Center.

> Figure 3-14 shows that extensive fire was present at windows 97-110 to 97-116 around 8:50 a.m., which was almost 3½ min after the aircraft impact with the building. NIST found that windows were broken during the aircraft impact and subsequent fireballs. The fire would subsequently spread from this location to the west face.
>
> Figure 3-14 reveals that at any one time, different locations on WTC 1 exhibited different smoke and flame yields as they were at different points in the burning process. Just a few minutes after the aircraft collision, the north face of WTC 1 (see Fig. 3-14) resembles early times during the experiments reported on here, when copious amounts of smoke (see Fig. 3-9) and flames (see Fig. 3-10) were emitted from the compartment. Almost an hour later, Fig. 3-15 shows that similar behavior was displayed on the south face of WTC 1. In this sense, the experiments conducted in this study recreated aspects of the WTC fires that can be thought of as typical of fires burning in compartments. [315]

The full-scale simulations described in NCSTAR1-5F also indicate a characteristic time of 20 to 30 minutes in any given location. Temperature plots are given in increments of 15 minutes, and comparison of each series – such as Figure 6-3 in NCSTAR1-5F – show motion of the red-colored peak fire intensity over time. This indicates which workstations were simulated to reach their peaks at any given time, and is consistent with the timing observed in NCSTAR1-5E.

NIST also has further corroboration for the combustion time of the overall experiments in the form of observations from outside the structure. As NIST reports, the simulations were not re-baselined to match these observations, and therefore the observations can be used as an independent verification of the FDS results:

> It had been suggested early in the Investigation to perform the fire simulations with the fires "prescribed" at their observed locations, and also to stop the calculations periodically to make various adjustments. Neither step was taken, mainly because the intent of the simulations was to predict the behavior of the fires deep within the buildings. Exterior sightings provided some clues, but it would not have been possible to extrapolate the observed fire activity into the buildings' interiors. **Consequently, the simulated fires described in this chapter were of comparable**

> **character to the actual ones, but they did not reproduce all of the observed fire activity because of the uncertainty in the initial and boundary conditions of the calculations.** [316] (Emphasis in original)

NIST frequently refers to exterior observations, collating its assessment of the fire spread in Section 6.6.1 of NCSTAR1-5F:

> The simulations suggested that most of the combustible material in other areas of the impact floors was consumed during the course of 1 h to 1.5 h, with the furnishings in the southeast corner being the last to burn. The fact that the simulated fires encircled the building in roughly the same amount of time as the actual fires supported the estimate of the overall combustible load, 20 kg/m^2 (4 lb/ft^2). *The simulated fires burned for roughly 20 min to 30 min in any one location, consistent with the visual evidence (NIST NCSTAR 1-5A) and the multiple workstations performed at NIST (Chapter 4).* Simulations performed with higher loads required a proportionately longer amount of time to bring the fires around to the southeast because the burn time was roughly proportional to the fuel mass in the oxygen-limited interior of the fire floors. [317] (Emphasis added)

On the basis of these observations, we conclude that there is no inconsistency between the burning time of the workstation experiments, and the larger simulations assembled by NIST. Had the workstation tests led to a longer burn time, NIST would have been forced to conclude there was a lower combustible load in the Towers, which would not be consistent with its estimates as provided in both NCSTAR1-5C and 1-5E.

Floor System Fire Experiments

In the next section, Mr. Douglas discusses the ASTM E 119 tests of the floor trusses, as described in NCSTAR1-6B. He begins by noting a key difference between this test and conditions in the WTC Towers:

> The NIST's ASTM E119 fire tests of the floor assemblies were generally irrelevant to the investigation because they did not simulate the existing conditions of the "all-important SFRM" (Sprayed-on Fire Resistive Material) (NCSTAR 1-6 p6 para1). Although they were used to "validate and provide guidance to the development of the floor models and to the interpretation of analyses results," (NCSTAR 1-6 p5, para3) the greatest relevance the tests provided was to establish that the trusses were likely more robust than those modeled in computer simulation. Even with minimal or no insulation, instead of the 2+ inches of insulation documented to have been on the WTC trusses on 9/11/01, the trusses did not fail the fire tests. [318]

The difference is, of course, that the floor trusses in this test were a reproduction of the as-built articles, undamaged and with varying amounts of intact fireproofing, whereas the trusses on the fire floors in the WTC Towers would have been damaged and with some or all fireproofing dislodged. It is therefore true that the tests were largely irrelevant in terms of reconstructing the fire and collapse sequences.

NIST, however, clearly states that it had never intended these tests to influence the accident reconstruction. Instead, these tests were conducted to determine whether the WTC Towers suffered from a *design flaw*. While these parts of the NIST Report are often overlooked, NIST thoroughly investigated the building code and special design requirements, identified the material requirements and verified material quality from test

records and portions of recovered steel, verified structural calculations using the SAP2000 model, and collected numerous test reports of components and assemblies generated during the Towers' original construction. In this investigation, NIST found that the floor trusses, being an unusual and complicated assembly, would have had to pass the ASTM E 119 destructive test – but NIST could not prove that such a test had been conducted.

Because NIST could not fully document such a test, NIST conducted the test itself, and this is the test that appears in NCSTAR1-6B. NIST never expresses an opinion that the trusses were expected to pass or fail this test, but the original building designers obviously expected they would pass. Because of this, the author disagrees with Mr. Douglas's assertion that the trusses were "likely more robust than those modeled in computer simulation."

It is also important to point out that Mr. Douglas is slightly incorrect – all four of the tests had fireproofing, contradicting his claim of "minimal or no fireproofing" in the quoted passage above. The amount of fireproofing varied between the four tests, meant to simulate the best-case and worst-case as-built condition of the floor trusses. The most heavily fireproofed test was Test 1 with 1.5" of SFRM on the floor trusses and floor decking. The least heavily fireproofed test was Test 4, which had only 0.5" of SFRM on the floor trusses, and none at all on the floor decking [319]. These figures are matches to the specification and inspections done on the completed structure.

It seems likely that the lack of fireproofing on the decking of Test 4 is what Mr. Douglas is referring to above. However, fireproofing in this location is of secondary importance. The load is primarily borne by the steel trusses themselves, and the trusses will only be slightly affected by heating of the floor decking and concrete slab. Missing fireproofing on the floor decking will mean that the 1/16" decking and 4" lightweight concrete slab above are heated faster, and this will reduce the slab's ability to resist bending as well as the composite reinforcement of the slab pouring around the upper knuckles of the floor truss. As a result, missing fireproofing on the floor decking only will reduce the floor system's fire resistance, but only slightly, compared to what would happen if the truss itself was not fireproofed. It also bears pointing out that Test 4 was one of the reduced-scale tests, and diminished fireproofing is expected as part of the scaling – the slab thickness was not scaled, thus the slab would be inherently more resistant to fire compared to the other truss components.

Mr. Douglas also correctly observes that the fireproofing in the WTC Towers was upgraded after their original construction, eventually to an average of 2.2 inches thickness of SFRM but only in select locations. The first upgrade was carried out in 1978 after the Port Authority discontinued use of an earlier, asbestos-based fireproofing material. Additional upgrades were applied in the 1990s to a few floors, responding to renovation, as well as observations that the existing fireproofing was not always applied evenly [320]. None of the four ASTM E 119 tests described in NCSTAR1-6B reflect this greater amount of fireproofing. Nonetheless, NIST conducted the tests to evaluate the

original design against building code, and therefore the upgraded condition – essentially a retrofit to the existing structure – was not relevant to assessment of the original design.

While the author sees no conflict between these tests and their actual purpose, Mr. Douglas is correct in stating that the tests are of limited value at best in terms of understanding the fires and eventual collapses of the WTC Towers. Particularly on floors where the upgraded fireproofing is a factor, there is a significant difference between these test articles and both the damaged and the undamaged floor systems on September 11th. The author also agrees that it would be instructive to test floor system performance with the upgraded thickness of SFRM, compared to the baseline tests, and it is unfortunate that NIST did not perform such a test.

Mr. Douglas outlines several other concerns with this series of tests, summarized as follows:

- If NIST wanted to simulate fire performance with damaged fireproofing, NIST could have built an intact assembly and then damaged the fireproofing by hand prior to carrying out the test. NIST did not perform such a test.
- The NIST estimate of fireproofing also does not take into account the fact that the structure had fire sprinklers, which would further reduce their vulnerability.
- Despite being less protected than the as-built floor systems, none of the four test articles actually failed under load. The maximum deflection seen was 15 inches.

The first suggestion appears reasonable, although it is outside the stated purpose of these tests. The other two observations are less likely to be relevant. A sprinklered test would be of interest, but sprinkler effectiveness is limited by water supply, and the aircraft impacts effectively destroyed emergency water lines. It is difficult to predict how effective surviving sprinklers would have been, but we may assume they were either greatly impaired or totally non-functional on average. Also, two of the four test articles showed signs of impending collapse, halting the tests. With fireproofing damage, it is possible that they could have collapsed, and in a shorter length of time.

In closing this section, Mr. Douglas builds on one of the key observations made by NIST, namely that the restrained full-scale test article actually received a lower fire rating than the equivalent unrestrained article, which is contrary to expectations. Mr. Douglas suggests, since testing contradicted the testers' experience, that the real structure was likely to perform differently than the computer simulation as well.

In the author's opinion, this inference is possible but far from certain. It would be straightforward to execute SAP2000 models of restrained versus unrestrained trusses, under identical reference loads, heated to the same temperatures, to verify that in simulation the unrestrained structure was more susceptible to fire-induced collapse. Unfortunately, we do not have these results. It is entirely possible that the simulation adequately captures the underlying physics, including this unexpected result. Just as real-world tests can surprise experts, so can simulated tests, although in the latter case such surprises must be analyzed carefully to verify that it is not an artifact of input conditions

or bugs in the simulation itself. It would have been highly instructive for NIST to conduct a verification of this result using its SAP2000 models, but without such data, any conclusion that the models *must be* flawed is merely speculative.

Global Structural Modeling and Impact Modeling

Mr. Douglas begins with a common concern, namely the role of the floor pull-in forces with respect to the global collapse model:

> *The times to failure for the collapse sequences, however, are subject to considerable variability, particularly since they are sensitive to small changes in the magnitude of the pull-in forces. (NCSTAR 1-6 p295 para1)*
>
> While it is understandable that NIST desired to have its computer simulation match the observed condition, one wonders why manipulation was required to effect this. One also wonders how extensive this manipulation was. Obviously, if this were a physical test, little or no manipulation would be possible. The results would simply be compared and contrasted to the observed condition and rated for viability. [321]

We previously examined this issue on page 49. In summary, the pull-in forces were adjusted to match direct measurements, namely the photographs of bowing perimeter columns, which were of sufficient quality to estimate inward deflection to within a few centimeters. However, the buckling strength of the perimeter columns is a function of the deflection, not the pull-in forces, and thus no amount of adjustment will affect the collapse model. Interestingly, it is indeed a physical test – a direct measurement of the actual building face – that obviates any need for adjustment of NIST's structural model.

It would also not be quite correct to state that NIST was speculating when it stated that aircraft impact led to exterior, floor, and core damage, weakening the structures; that jet fuel ignited contents, and fire growth was affected by damage to interior and exterior; or that the jet impacts dislodged large amounts of fireproofing material. Mr. Douglas makes this statement on page 9 of his paper. All of these effects were, to a limited degree, directly observable. It would be correct to state that the *extent* of these effects is imprecisely known, and NIST made repeated use of computer simulation to estimate the amount of damage caused and the spread of fires.

Reviewing the physical evidence, exterior photographs clearly demonstrate damage to exterior columns and wrecked floor systems. NCSTAR1-3 contains two core column fragments (from WTC 2) that appear to be damaged by impact, proving that at least one aircraft impact did in fact damage the core; furthermore, we know that large fragments of both aircraft passed entirely through the core, and must have damaged the core en route. Photographs and fragments of structure that fell to the ground immediately after the impacts also showed that some fireproofing was dislodged. Regarding the effect of jet fuel and perimeter damage on the fires, the role of accelerants and ventilation in structure fires is well known, even though there is a wide range of their possible effects in such a large and complicated incident.

Mr. Douglas lists a number of specific concerns about the NIST models on pages 10 through 15 of his paper. His inferences are as follows:

- NIST assumed, rather than determined, that the most severe impact cases were the best matches to the impacts. In fact, the baseline cases were the best matches.
- NIST chose to reject the less severe impact cases completely on the basis of debris pass-through, when in fact none of the cases matched debris behavior seen.
- Because the aircraft fuselage appear unable to damage or destroy core columns, the impact models overestimate core damage.
- NIST's estimate of structural integrity after impact shows substantial reserve capacity in the remaining structures.
- The less severe fire cases were rejected arbitrarily, because they would not have led to Tower collapses.

We will examine and, where necessary, correct these inferences below.

Selection of Impact Cases

Comparison and selection of the best impact models requires a lengthy discussion. This process begins in NCSTAR1-2B, but is not completed until we work through NCSTAR1-6 as well.

NIST discusses its choice of impact cases in depth in Section 9.11 of NCSTAR1-2B. As Mr. Douglas correctly points out, all three levels of severity plausibly met some observables, such as the damage to the exterior panels, and the failure mode of those panels. This should not be particularly surprising. The "less severe" case refers to a speed approximately 10% lower, and 20% less ductility in the aircraft, but this difference is fairly insignificant with respect to the ability of perimeter columns to survive impact. We expect an aircraft even at much lower speed to sever exterior columns. These differences – and other differences between the cases, such as the pitch angle of impact – are of much greater significance to the amount of core damage sustained, and this effect is not directly observable at all.

Regarding the baseline case, it is of course correct to note that the baseline case is the best match to the observed aircraft speed and impact vector. This is the definition of the baseline. However, the baseline is subject to large uncertainties, since there are errors of position and parallax in any video, estimated speed of the aircraft is sensitive to these errors, aircraft weight and strength are imprecisely known, and so on. These errors are particularly large in the case of the WTC 1 impact, where very few video records exist. As a result, the error bars are much tighter for WTC 2. The baseline is the "best guess," and the less and more severe cases are essentially the "one-sigma" bounds for both sets of observed data. Statistically speaking, the less and more severe cases are perfectly reasonable. If other data, such as results of modeling, suggest one of these cases is in fact the correct one, we should not hesitate to reject the baseline hypothesis. This is what NIST eventually concludes.

It also should be pointed out that the NIST "more severe" cases can be completely consistent with *any* of the actual input variables – for instance, if the Flight Data Recorder from American 11 was found indicating an impact speed lower than the expected 521 MPH, this would not necessarily mean the "less severe" case was the best fit, even though this was the case that used such a low input speed. We must be careful not to confuse observations that relate to the *input* and the *output* of the simulations. The speed of aircraft is an input, and this input is conflated with numerous other, uncertain model inputs, one of the most significant being the aircraft strength. Damage to the outer wall is an output, having as much to do with properties of the structure as with the aircraft. The exit of debris from the other side, which is greater in the more severe simulations, is indicative of damage sustained by the core, since core damage must be heavier for greater momentum of debris passing through. Because of this, if we see debris exit in the real world, we need to select the simulation with the correct *output*, regardless of the input that led to that condition. For instance, it is possible for the model to have overestimated the strength of the building, and thus the "more severe" impact case may be the best fit, even if we know for a fact that our impact speed is too high – this combination of competing effects may nonetheless be superior in result. Therefore, selection of the correct case must be driven by observations of the outputs, and only weakly influenced by the inputs. The simulation is much better at predicting damage to the structure than it is at extrapolating the pre-impact vector of the aircraft.

Regarding the additional data, NIST confirms that all three cases, for both towers, match the exterior damage facing the impact:

> The calculated damage to the north exterior wall of WTC 1 for the three different severity impacts is shown in Figure 9-107, along with a schematic of the observed damage. The overall agreement with the observed damage was good for all three analyses, with the base case global impact analysis providing the best match to the observed damage. The calculated damage magnitude was similar in each of the global analyses with small differences, as shown in the figure. [322]

> The predicted impact damage to the south exterior wall of WTC 2 for the three different severity impacts is shown in Figure 9-110, with a schematic of the observed damage for comparison. As was the case in WTC 1, there were small differences in the predictions from each of the global analyses shown in the figure. Overall, the agreement with the observed damage from photographs was very good. The most obvious differences were largely due to portions of panels that may have severed columns in one case or have been removed at the connections in another. [323]

NIST shows the differences in impact wall damage in Figure 9-107 and Figure 9-110. Turning to these figures, we see that – compared visually to the actual impact damage – the differences between the three cases are not at all intuitive. In particular, the more severe case of WTC 1 actually shows *less* removal of facing area than both the baseline and less severe case, most obviously in the seventh panels from left, above the port engine. What has happened here, as hinted at above, is the more severe case was modeled to have actually sliced through this panel, leaving a portion in place, whereas the other cases broke it at its connections, and the entire panel was removed. These differences are subtle and prone to random effects within the model – it is, for instance, entirely credible for the aircraft impact to have broken the panel *and* destroyed its connections, but simulating this effect would be quite difficult. As a result, the

differences between these three predictions should be viewed as minor, and it would be misleading to exclude any of the three cases on the basis of this single observable.

The other observables, however, are substantially different between the cases. The next directly observable quantity is the amount of damage to exterior walls away from the point of impact. In WTC 1, a single exterior panel was knocked free opposite the impact. In WTC 2, the northeast corner of the structure was damaged, with several columns bowed and unbolted but not ejected completely. In the case of WTC 1, the less severe case is definitely not a good fit, since it predicts no aircraft debris reaching the opposite wall, whereas both the base and more severe cases predict substantial impacts on the opposite wall at that location, as seen in Figures 9-118 through 9-120. As described on page 340, while none of the simulations predict actual removal of the exterior panel, the more severe case – and only the more severe case – results in a severe impact at that location, probably enough to cause it to fail had the panel been modeled at higher resolution. In WTC 2, all three cases project aircraft debris through the northeast corner, but as seen in Figures 9-130 through 9-132, the less severe case predicts a very small amount of debris exiting in that area, whereas both the base and more severe cases more plausibly match the exterior wall damage.

Comparison to the outer wall is important because it is one of the few observations that can be made from the outside, and thus is less subjective. This consideration practically rules out the less severe WTC 1 case, and biases us away from the less severe WTC 2 case. Besides the opposite wall damage, NIST describes other, less definite criteria that also bias it towards the more severe cases having to do with the exit of aircraft debris.

In both the WTC 1 and WTC 2 simulations, the less severe cases did not provide a good match to these observations. For WTC 1, a large portion of landing gear exited opposite the impact (probably associated with the exterior damage), and traveled several hundred feet afterwards; this cannot match the less severe WTC 1 simulation, which predicts no debris exit at all. In the WTC 2 case, landing gear fragments exited somewhere near the northeast corner, along with a large portion of the starboard engine, a total amount of material on the order of a ton or so just in these fragments alone. The comparison to the three trials is not as clear here, but the large amount of debris exiting is better fit by the more severe impacts.

There are some interesting details, however. As Mr. Douglas correctly points out, none of the WTC 1 cases simulate the exit of landing gear fragments, and none of the WTC 2 cases simulate exiting engine fragments. This is true but probably of no significance. As explained in NCSTAR1-2B on page 345, the individual trajectory of any single fragment is sensitive to numerous details, such as the precise layout of interior furnishings, that are simply not available. Therefore, NIST places little significance on the precise origin of fragments, instead concerned more with the *aggregate* behavior of all fragments.

The author is inclined to agree with NIST in this respect. The aircraft models, as described throughout Chapter 4 of NCSTAR1-2B, require numerous simplifications, among them great simplification with respect to material strength. Only a few

constitutive relationships – meaning the strength characteristics of any given type of material – exist in the NIST model, compensated with additional weights in some areas, grouping of components in others, and combination of components such as avionics boxes into the fuselage shell elements that carry them. As a result, landing gear fragments, wheel fragments, or any other structural fragments effectively only differ with respect to size, shape, and point of origin, and all of these pieces have been adjusted in several ways. Of the aircraft components, NIST applied the most detail to the engines, as described in Section 4.3.3, but even here are significant simplifications mandated by model complexity. In particular, NIST was unable to model rotation of the engines [324], and this alone could have changed the trajectory of the engine cores and their fragments after contact with major structural members. The real engine may have deflected to the side upon contact with major structural members, whereas the model engine was not spinning and could only fly ballistically.

If NIST were to adjust the point of impact only a fraction of a meter in any direction, well within the margin of observational error, this could produce a quite different trajectory for any single fragment, although again, the overall behavior would be about the same. It is not practical to adjust the input parameters endlessly searching for the best possible fit to observed behavior, and if this was done, NIST could be criticized again for "tweaking" its model. In the opinion of the author, it is more useful from a scientific standpoint to simply report the results as they are, and look to the model for guidance, rather than trying to generate an artificially precise re-creation.

There are other interesting effects that seem counterintuitive without careful reading. For example, Figure 9-134 shows how the starboard engine of WTC 2 actually appears to decelerate more in the more severe case, as opposed to the less severe case. After 0.57 seconds of simulation time, the fastest moving engine fragment is, in fact, from the less severe case. However, it is important to note that in the more severe case, the engine started with a higher velocity, and has traveled farther. This means that in the more severe case, the engine fragment hit more material and gave up more kinetic energy in total. One cannot, therefore, use this graph to claim that the less severe simulation is most consistent with engine fragment exit, even though it may appear so at first glance.

If we accept the above argument that the identity of fragments in the model results is less important than the quantity, then it is straightforward to argue that neither less severe case is the best fit. We do not, at this time, have sufficient information to distinguish between the baseline and more severe cases, and this decision is deferred until later. On the other hand, if we do place importance on the identity of exiting fragments, we are still biased away from the less severe cases, albeit for different reasons. In WTC 1, we cannot match the exit of landing gear with any case, but exit of other fragments can only be explained by the baseline or more severe case. In WTC 2, we cannot match the exit of engine fragments, but we also have a partial landing gear exit, and this was only seen in the more severe case. The other WTC 2 cases did eject some debris, but in the less severe and baseline case, none of this was landing gear fragments, as reported on page 353 of NCSTAR1-2B. Therefore, if we insist on matching particular parts of aircraft, we not only reject the less severe cases, but also the WTC 2 baseline case as well. NIST is

less strict about this distinction, and keeps both baseline cases viable through the end of the analysis in NCSTAR1-2B.

Following NIST's argument, we next attempt to distinguish between the baseline and more severe cases by considering additional observables. Given the difficulties in viewing the interior structure, NIST relies instead upon exterior evidence, namely the structural evolution over time as the fires degrade structural integrity. The major criteria and timelines are listed in Chapter 6 of NCSTAR1-6, and compared to the simulation results in Section 7.5. The majority of these observations are consistent with both the baseline and more severe cases, but there are some that suggest one or the other, as briefly summarized below:

- In the floor component models, after temperature models were applied, only the more severe case predicted floor sagging in WTC 1 along the east side, where inward column bowing was observed.
- For WTC 2, both baseline and more severe models led to floor sagging, but the more severe case was reportedly a better match.
- In the WTC 2 more severe case, floor sagging led to inward perimeter wall bowing as expected in the south side of the east wall. In contrast, the baseline case led to inward bowing in the north side of the east wall over a wide range of inward pulling conditions, and could not plausibly match observations.

Taking the sum total of these comparisons between the different models and the many images and measurements of the Towers, NIST has justified its claim that the most severe impact cases lead to the best model results. This decision was made without any consideration of whether or not the Towers would actually topple in any particular simulation, or even the length of time required to reach global instability, although that too is a valid observation for purposes of discerning the best model.

It is important to emphasize, again, that NIST is selecting the best model on the basis of its *output*. For example, in selecting the most severe impact case, NIST is not stating unequivocally that WTC 2 must have had ten core columns destroyed by the impact – the actual result could have been more or less, or in slightly different locations. NIST is claiming instead that out of all the various cases that it examined, the most severe case was the best match to the observed events. Logically, this means that we should look to these cases first to estimate performance in the interior for which we have no observations, i.e. condition of the core structure after impact. But we should also keep in mind the other cases, and understand the many similarities between them. It is possible, even likely, for the real situation to have overlapped several different simulations in different respects. NIST's ultimate conclusion is that collapse of the Towers due to impact and fire is *plausible*, even likely, under a range of conditions that can be estimated numerically from these experiments. It is not nor should be construed as an attempt to accurately determine everything that went on inside the Towers at a level of individual structural elements. The simulations provide the mechanisms of collapse, and one plausible evolution towards collapse, but this is only the best guess or most probable outcome.

As a final parting comment before we close the issue of selecting the most severe cases, the author again points out that NIST's damage estimates are in family with every one of the other professional, independent estimates of impact damage, and indeed is conservative by comparison. Regarding core damage, as summarized in Table 9-15 of NCSTAR1-2B, even the more severe NIST cases fall well within the MIT range of estimates and substantially below the Weidlinger Associates study. Additionally, ongoing study by Purdue [236] [284], in many ways more detailed and with fewer simplifications than the NIST impact models, predicts similar but slightly higher average impact damage to the NIST more severe cases, and further highlights the sensitivity to small changes in input conditions. In every way, NIST's estimate – and its claim that the more severe cases are the best fit – is justified.

Role of Aircraft Fuselage in Core Damage

As part of Mr. Douglas's doubts regarding NIST's impact damage estimates, he questions whether the aircraft fuselage could be a major contributor, as follows:

> From this simulation we learn that an impact by the most dense and massive component of the aircraft, the engine, could cause, at most, only one column to fail – and only if it were aligned perfectly and struck the column directly. In WTC 2, one of the engines (and a landing gear) exited the building without significant obstruction. ([NCSTAR1-6] p390 para5) So, if the engines could fail, at most, one column in WTC 2 and two columns in WTC 1, what could have failed all of the other columns? Was it the fuselage? This is not likely, based upon the description of the simulation. [325]

Mr. Douglas follows this with a series of quotations from the NIST Report, explaining the heavy damage suffered by the fuselage as it impacts the exterior columns and the floor system. On this basis, he concludes that the fuselage would not have survived, and is not a major contributor to core structural damage.

This inference is incorrect. We know for a fact that the fuselage did heavy damage to the core in both cases, because in both WTC 1 and WTC 2, large portions of landing gear passed entirely through the core – and the landing gear was contained in the fuselage. The intact landing gear, or even large pieces thereof, would have been unable to pass through the core cleanly due to their sheer size. This observation is far too coarse to make an estimate of how much damage was done, but it proves that some occurred.

Regarding the fuselage breakup, there is no inconsistency in the LS-DYNA results, as Mr. Douglas supposes. Rapid breakup of the fuselage is anticipated, simply due to the relatively light construction of the aircraft and its relative material strength. However, fuselage breakup does not preclude further damage to the structure. Whether intact or not, the pieces of aircraft still retain enormous *momentum*. As we have also seen previously, the aircraft fuel alone can destroy structural elements if sufficiently concentrated, despite having no material strength at all. We also observed, in the case of the Pentagon impact, how the majority of destroyed columns – spirally-reinforced concrete, in this case – bear few signs of impact with solid pieces, but were instead stretched over their entire height before failure. All of this proves that whether broken up

or not, the fuselage, which contained over half the mass of the aircraft as well as much of the fuel, is expected to cause severe core damage. There is nothing unexpected in NIST's LS-DYNA results.

Mr. Douglas also makes an extrapolation regarding the quality of various simulations and the amount of damage predicted. Noting that the MIT and Weidlinger Associates studies predicted more core damage, and were both less detailed than the NIST models, he speculates that an even more detailed simulation might predict still less damage:

> One might conclude from the above that NIST's simulation is conservative. Conversely, one might conclude that by simulating the aircraft impact with a ten-fold increase in accuracy, fewer columns are shown to have failed. Would an even more finely modeled simulation show even fewer failed columns? [325]

These two conclusions are not converses of each other. Inherent in any scientific experiment, including simulations, are two different types of error – so-called "systematic error," meaning inaccuracies that are recurrent and dependent upon the problem setup, and "random error," which refers to limitations in measurement accuracy or phenomena that are unrepeatable and affect different trials to different degrees. Using the analogy of a marksman firing at a target, random error (sometimes called "precision") refers to the size of his shot pattern, whereas systematic error manifests as the entire grouping being centered away from the bull's-eye. It is possible to produce extremely precise results with a large systematic error; to follow the analogy above, an excellent marksman with a badly mounted telescope is likely to produce very tight groupings that are well off-target.

When dealing with computer simulations, most errors are systematic in nature, simply because the experiment itself – essentially a grossly complicated arithmetic problem – can be repeated with extreme precision. There are on occasion round-off errors or convergence problems that can lead to unpredictable results, but in general, if two simulations are run with precisely the same inputs, they will produce precisely the same answers. For the WTC impacts, many of the inputs themselves also carry uncertainties, such as the speed and precise location of impacts, but these types of errors are usually treated by running several cases in an effort to establish a performance envelope rather than treating them as random error. As a result, we are concerned with systematic error only. This is to our advantage, as systematic errors always have a cause, and if these causes are understood, we can often reconcile results from experiments that appear to be in conflict.

If we compare the Weidlinger Associates study in particular with the NIST results, we see a number of systematic error sources that explain why the NIST result seems to be lower. NIST describes the differences as follows:

> The WAI impact analysis predicted much higher core column failure and damage than the NIST estimates. One reason for the higher damage prediction may be attributed to the lack of internal tower contents, such as workstations and other live loads, in the WAI model. This study found that the internal tower material absorbed a significant amount of the impact energy and, therefore, reduced the loads applied to the core columns. Another reason for the higher damage prediction in the WAI study could result from the aircraft model. As noted above, the WAI aircraft impact

> simulation overpredicted the extent of column damage and failure on the exterior wall. It is possible to assume that the aircraft model would also overpredict the damage to the core columns, especially that this damage resulted in an unstable tower (Levy and Abboud, 2002). [326]

As we see here, the problem isn't a lack of detail, but rather a lack of significant building components. It would be reasonable to extrapolate along these lines – for instance, if we were to remove the exterior columns from the Weidlinger Associates model, the core damage estimate would be higher still – but it is simply not correct to say that an decrease in *detail* leads to a higher estimate. Therefore, we have no reason to believe that a better simulation than NIST's would produce a lower estimate, not unless we identify a significant energy sink that isn't present in NIST's model.

This inference can be verified. The ongoing Purdue study is indeed more detailed than the NIST model, in terms of more model elements, less reliance upon simplifying assumptions, and greater validation against real-world impact experiments. Thus far, the Purdue study actually predicts slightly more damage than the NIST model, and repeated experiments with slight variations bracket NIST's conclusions nicely.

Mr. Douglas is also slightly confused about the different NIST cases on page 11 of his whitepaper, stating that NIST appears to contradict itself by first stating the base cases were the best matches to observables, while later on claiming that Cases B and D were the best matches. NIST stated that the base *impact* cases best fit the *exterior panel* damage, as we have discussed below. Cases B and D are not just impact cases, but also include long-term fire effects, and thus cannot be directly compared to the impact cases alone. When NIST also considers the effects of the fire, and compares performance to multiple observables such as inward bowing over time, NIST concludes that Cases B and D are better matches than Cases A and C respectively. There is no contradiction.

As a final comment in this section, Mr. Douglas remarks that, following the impact, none of the surviving columns in the impact models were predicted to be overloaded. This is correct, and in fact a requirement that NIST imposed, on the basis that neither Tower collapsed at once. Failure of additional columns due to gravity load following impact would potentially lead to a progressive collapse. It also is worth pointing out that NIST chose to attenuate the "more severe" impact case for WTC 2 out of concerns that it would cause too much damage to the structure:

> For the more severe WTC 1 analysis, 125 percent and 80 percent of the baseline values were used for the aircraft and tower failure strains, respectively. For the more severe WTC 2 analysis, 115 percent and 90 percent of the baseline values were used. The more severe WTC 2 analysis was the final global impact analysis performed. Based on the previous analyses, the variation in damage levels indicated that the WTC 2 more severe impact analysis would produce impact damage state that was not viable (e.g., the amount of debris exiting the north wall). [327]

Fire Dynamics Simulator

In this section, Mr. Douglas repeats a number of misconceptions that we have already explored above. These are reprinted below, in brief:

- *Reasons for rejecting the "less severe" impact cases:* As previously explained, NIST rejected these cases based on numerous observable criteria, such as the lack of debris passing through the core. They were not rejected on the basis of "not leading to collapse." This decision was made even before running the fire models.
- *Significance of specific pieces of debris:* The impact models are simplified, thus the identities of modeled pieces of debris are less relevant than the total amount of debris predicted to pass through the structure. However, even if we insist on matching correct pieces, we can still reject the less severe WTC 2 case for not matching engine pass-through, and the less severe WTC 1 case for not passing anything of significance at all.
- *Reasons for rejecting fire scenarios "A" and "C:"* Once again, these cases were *not* rejected because they would not lead to collapse. Nowhere in the text does NIST state that cases A and C would not cause a collapse, although the results indicate the collapses would occur later than the actual Tower collapses. In contrast, NIST does state that the "less severe" impact cases would be likely to remain standing after total burnout, but NIST does not say this for the "baseline" impact cases A and C. NIST instead notes that over time, the structural evolution and in particular the quantified inward bowing of the perimeter is better fit by cases B and D.

The author does agree, however, that the description presented in Figure 9-2 of NCSTAR1-5, implying that a full factorial set of test cases would be the ordinary method of investigation, is misleading. Given the relatively few and qualitative validation criteria available, it is unlikely that a full set of 81 different combinations would be performed, or even useful. It makes little sense, for instance, to compute the maximum fire case with minimum structural heat coupling as well as the minimum fire case with maximum heat coupling – these two stages of the experiment are not truly independent, as we lack enough information about the real fires to make a comparison based on partial results.

What is much more typical in this type of experiment, and what NIST performed, is instead to identify all parameters that would affect the results and vary them individually, otherwise known as a "sensitivity analysis." Each of these experiments is simpler than a full-blown trial, and intended to estimate what the effect of change or uncertainty in any parameter is with respect to the outputs. Once this is understood, complete trials are assembled from combinations of changed variables – for instance, in the aircraft impact models, NIST adjusted *all* of the variables that would lead to greater or lesser damage, i.e. speed, material strength, angle of incidence, and so on, rather than change each parameter individually.

NIST describes its sensitivity analysis of the fire models in Section 5.2 of NCSTAR1-5F. In Table 5-1, we see the five parameters varied between the different cases. In Table 5-2, NIST presents a simple "confusion matrix," denoting the approximate effect of varying each of the five parameters. Since many of the effects are similar, rather than running 3^5 or 243 different tests, NIST needs only run six so-called "orthogonal" tests, meaning tests

that will have a different qualitative character from each other. This selection process is similar to NIST's down-selection of final cases in NCSTAR1-6.

Therefore, while figures 9-2 and 9-3 in NCSTAR1-6 are misleading, NIST's process of elimination is not at all unusual. There is little reason to expect unique and valuable insights from each of 81 different simulations. Having said this, we may ask the reasonable question of whether NIST's reduction to only four cases is adequate. The author accepts NIST's reasoning for discarding the "less severe" impact results. But NIST's results, as well as those of other ongoing investigations, highlight the importance of combustible furnishings – and where these combustibles are located following impact – as a major driver of building performance. The geometry of furnishing distribution is complicated, and cannot reliably be captured in only two cases.

The author speculates that NIST's decision to only run two cases per tower, particularly with respect to amount and distribution of combustibles, reflects the very large and irreducible uncertainties in those parameters. Put another way, NIST could have created perhaps ten different cases for combustible loading, each defined in much more detail, all of them reasonable given what we know about the Tower furnishings and mechanics of impact, all producing substantially different results. However, this added detail would only be guesswork, and the results would therefore be of limited value. The best results of these more detailed trials would not necessarily correspond to the most accurate input conditions.

As we noted before when discussing the differences between NIST's and Arup's conclusions, the NIST results are a plausible example of what *could have* happened, and as such adequately describe why the Towers collapsed. However, owing to uncertainties and limitations of the models, the NIST results are much less useful in determining what *might happen* under different circumstances, e.g. whether collapse could occur with no structural damage due to impact, or if higher combustible loading would be able to overwhelm intact fireproofing. NIST's models are imperfect, and the small number of cases treated in NCSTAR1-6 is both a cause and symptom of this imperfection.

In the last part of this section, Mr. Douglas questions the severity of the actual WTC fires, comparing them to the hypothetical severe arson situation proposed by NIST. This discussion is tangential to NIST's investigation, however Mr. Douglas has a number of misconceptions here as well that bear correction:

- Jet fuel, compared to the hypothetical arson scenario, does burn off quickly and does not appear to contribute much to total heat release, as Mr. Douglas states. However, it is the spread of fires from one location to another, partially limited by available oxygen, that determines the total duration of fires. This was explored above in contrasting the single workstation vs. multiple workstation burn tests.
- As above, the WTC 1 case was oxygen *limited*, but not necessarily oxygen *starved*. There is an important distinction between these two terms. Oxygen availability limited the duration and spread of fires in WTC 1, partly because

there were much larger holes on the impact side than elsewhere, but the fire in WTC 1 had sufficient oxygen to burn fiercely.

- Removal of fireproofing, as established by NIST, requires much less energy input than moving heavy objects such as furniture, and the fireproofing itself fragments much more readily as well. The impacts did indeed move the combustibles, as NIST notes in its explanation of why the fires were most intense opposite the impact faces. There is no contradiction between NIST's theory of fireproofing damage and its estimate of interior furnishings damage and displacement.

Despite these misunderstandings, it is correct to say that NIST's models "came very close to having buildings that just wouldn't fall down." In NIST's analysis, the collapse required multiple ingredients – loss of fireproofing, significant core damage, failure of floor systems and long-span trusses in particular, continued attachment of failed floor systems to perimeter walls, and sufficient heating to create creeping behavior and weakening in core columns. Absent any of these ingredients, NIST's models are uncertain, but suggest the Towers would have remained standing. Fortunately, we may be confident in this chain of events because the majority could be partially observed in photographs, and the remaining two – core damage, and core column shortening and weakening over time – can be reasonably inferred from observations of debris pass-through and structural leaning and settling. Furthermore, the work of other independent researchers suggests that, if anything, the NIST models were overly conservative.

Fire / Structure Interface

In this section. Mr. Douglas primarily considers the structural models, first piecewise and then assembled into a global model, and their reaction to the fire simulation. Again, some of Mr. Douglas's concerns stem from misconceptions about the NIST results:

- *Stability of the Core Model:* Mr. Douglas, noting that the "severe impact" core models did not converge and remarking upon NIST's decision to substitute the baseline core damage, claims:

  > This means that the severe case impact results could not be used to perform the temperature evaluation because the buildings fell down too soon. So, NIST used the base case impact damage to evaluate the base case and severe case temperature histories. The conflict here is that NIST's final conclusion is that the buildings only would have failed if the most severe cases were used at every step. [328]

  This is not an accurate summary. The convergence problem means that, *treated by itself*, the core could not stand on its own. The buildings did not fall down too soon – instead, the simplified boundary conditions used in the core-only model proved to be too simple. In the actual structure, the perimeter and especially the hat truss supported the core, and this was not carefully modeled, intentionally, in the core-only analysis. There is no conflict between this result and the final NIST conclusion, based on the global analysis, which does include the perimeter and hat truss.

Mr. Douglas remarks on the hat truss being absent from the core model later on the same page, but neglects the global model – including the hat truss – to come later in the Report.

- *Significance of Column Buckling in the Isolated Core Models:* Mr. Douglas argues that NIST's models predict column buckling in the base case of WTC 1, but do not predict buckling for the "more severe" case of WTC 2, thus the "more severe" case should be rejected. This argument is confused and invalid. The actual NIST results, seen in NCSTAR1-6 pages and 188 and 192, are that *both* WTC 1 cases experienced buckling, while *both* WTC 2 cases did not – there is no distinction between baseline and "more severe" possible based on observations of buckling alone. The absence of buckling in either of the WTC 2 cases is easily visualized, due to the column damage along the corner of the core rather than centered along one face. In WTC 2, the core response is to tip, becoming unstable before additional columns buckle, whereas the WTC 1 cases sag in the middle leading to localized buckling.

- *Fire Insulation and Temperature Histories:* Mr. Douglas focuses on the facts that, in the core, columns were insulated by gypsum board and not SFRM, and that there were few combustibles inside the core. He then states:

  Considering the lack of combustibles and the use of the more durable gypsum board, why did NIST believe that the "temperatures and stresses were high in the core area"? We are not given a reason. [329]

  As a reminder, on page 185 of NCSTAR1-6, NIST refers readers to Chapter 5 for the description of cases A through D, providing a thorough explanation. Chapter 5 discusses all of these items – 5.2.3 describing damage to the fireproofing of core columns in general, 5.3 discussing specifics of WTC 1, 5.4 describing the WTC 2 inputs. The thermal histories are from NCSTAR1-5G, as explained on page 186 of NCSTAR1-6. Because NIST uses consistent notation in its description of cases A through D, there should have been no confusion on this point.

- *Confusion Between "Oxygen Starved" and "Oxygen Limited" Fires:* As discussed above, the WTC fires were oxygen limited, but not starved. There is no reason, therefore, to believe the fires should have behaved as though in a sealed chamber, and thus have been "very near the two-minute burnout," as Mr. Douglas suggests on page 18. Likewise, this is not a cause of "incorrect modeling," as he terms NIST's simplified wall connections in the floor subsystem-only analysis.

- *Hanging Objects:* The author disagrees with Mr. Douglas's claim that the "hanging objects" in NCSTAR1-6 Figure 9-16 look identical at the two times presented. The photograph is presented with additional clarity as Figure 9-2 and Figure 9-81 of NCSTAR1-5A. Detailed reading of NCSTAR1-5A leaves no doubt about the changing nature of the "hanging objects" over time. Figure 9-51 or Figure 9-63 of NCSTAR1-5A is perhaps the clearest view.

- *Bowing of Exterior Walls:* This is the key issue cited by Dr. Griffin, as we explored on page 49 of this review. As before, while the floor bowing was not observed – as the floor was not predicted to sag at the perimeter, except where it broke free of the perimeter wall entirely – the exterior wall sagging could be quantified with reasonable accuracy from exterior photographs. It is this bowing, not the floor sagging, that was input to NIST's global collapse model. Floor sagging was only computed to provide an explanation for why the walls bowed. NIST's models predict collapses regardless of the mechanism that created the exterior bowing. Inaccuracies in NIST's floor sagging models have no effect on NIST's prediction of collapse.

- *Pulling and Disconnection:* Mr. Douglas seems confused by NIST's statement that the collapse progression involved "aircraft impact, core weakening, floor sagging and disconnection, inward bowing of the south wall, and collapse initiation." It should be apparent that NIST means that *some* floor connections disconnect, but not all of them, with the remainder of connections supporting the exterior bowing.

Mr. Douglas then turns to an important technical issue, namely the strength of the floor connections to the perimeter walls. He correctly notes that the limiting factor in the connections is the bolt, which according to NIST NCSTAR1-6 Table 4-4 fails at a shear strength between 44,000 pounds to 4,000 pounds, depending on the temperature. Mr. Douglas further presumes a temperature of 600 ^{o}C, which corresponds to a failure strength of 9,000 pounds. To him it appears that this is inconsistent with NIST's bowing hypothesis, which states 12,000 pounds per column on three levels is required to create instability.

The "three levels" remark is in fact one of the critical observations. As explained on page 115 of NCSTAR1-6, the force applied to Case 8 of the exterior wall analysis is 12,000 pounds per column, but applied on three floors. This works out to only 4,000 pounds per connection which is well within their capacity, even if heated beyond 600 ^{o}C. It should be noted, however, that in this model NIST has assumed that each column had an equal amount of pulling force, whereas in the actual tower construction the floors were only mounted on every other (odd numbered) column with the remainder connected by lightweight straps, as shown in NCSTAR1-6 page 69. Without a thorough treatment of the straps, we may assume the equivalent stress on each floor connection in this particular model is somewhat higher than 4,000 pounds per connection, but surely no higher than 8,000 pounds, which is still within the limit supposed by Mr. Douglas.

If we wish to further assess the reasonableness of this estimate, we can refine the temperature estimate using the prediction in NCSTAR1-5G. Chapter 9 and 11 contain temperature-time profiles of floor trusses and, more relevant to the truss seats, perimeter columns for the "more severe" cases. With only a few exceptions, the temperatures of either are predicted to remain below 525 ^{o}C, even where involved in the fire. The hottest section is, of course, the east face of WTC 2, where large sections of floor are predicted

to exceed 600 ^{o}C for extended periods of time, but even here only a handful of perimeter columns ever exceed 500 ^{o}C or so. Not coincidentally, the east face of WTC 2 was the most extensive site of bowing observed.

In any case, according to Table 4-4 of NCSTAR1-6 the failure strength of the seat connections drops significantly between 500 and 600 ^{o}C, from 21 to 9 thousand pounds, so it is possible the actual strength is slightly to greatly higher. Lacking a more precise estimate of the connection temperature, we opt to err on the side of caution and agree with Mr. Douglas that 9,000 pounds is a reasonable worst-case value. Provided the NIST hypothesis does not require pull-in forces above this magnitude, we should accept the hypothesis as plausible. These are only the component experiments, not the global model, and are thus permitted slightly exaggerated boundary conditions. The pull-in force used here may be higher than the final pull-in estimate, and thus we need not necessarily meet the connection strength requirement, so long as we meet it later.

NIST's experiments with the pull-in forces were unable to match the amount of bowing observed for WTC 1, as Mr. Douglas remarks. However, this is due to modeling limitations rather than posing a problem to the hypothesis. As explained in NCSTAR1-6 on page 215, tests of Case B where the pull-in force was gradually escalated were unable to produce any further deflection after reaching 9,370 pounds per column, due to convergence problems. In this case, the structure would have been close to collapse and too susceptible to random errors to provide a reliable solution. This is not an indictment of the modeling approach so much as further evidence of just how precarious the real structure would have been after suffering so much damage Likewise, for WTC 2, a lower pull-in force of about 6,000 pounds was used to avoid convergence problems, and this too did not match the observed deflection. But it is important to note that in every experiment of Chapter 7, NCSTAR1-6, NIST has again treated the walls in isolation, underestimating the gravity loads and in particular the extra loading via the hat truss, and this would also contribute to further bowing. This is why the pull-in forces of the global model are much lower.

In the case of WTC 2, NIST describes its results on pages 218 through 220. Here, forces of about 5,000 pounds per column maximum, considerably less in places, were expected. In contrast to the WTC 1 case, the WTC 2 simulation could easily exceed displacement seen in real life, perhaps because of the shorter burning time before WTC 2 collapsed.

The important point of this discussion is that none of these experiments require pulling forces that are implausible with respect to the predicted floor connection strength. The WTC 1 pull-in forces were greater in magnitude, but the WTC 1 temperatures are also considerably lower, meaning the connections would be stronger. We also must look to the global model for the final bowing analysis. As explained on page 227 of NCSTAR1-6, NIST's global analyses assume inward pull of 4,000 to 5,000 pounds in WTC 1, 1,000 pounds for the south wall of WTC 2, and 4,000 pounds for the east wall of WTC 2. None of these forces is problematic in light of the connection strength anticipated.

Mr. Douglas does not add any commentary on the global model, but merely points out several of its limitations as admitted by NIST. As we saw in the discussion of other efforts such as the ongoing Arup investigation, these limitations are real and prevent definitive answers to certain questions, i.e. whether or not the Towers could have remained standing had there been no fireproofing damage. Yet this does not raise serious doubts with respect to the central question facing NIST and concerning Mr. Douglas, namely whether or not the Tower collapses can be explained by impact and the subsequent fires. The NIST model is an approximate solution to this problem, with numerous shortcuts taken along the way in response to technical limits or incomplete information. It is not perfectly accurate, nor is it meant to be, but it does outline a likely sequence of events. Within a broad range of tolerance, we therefore must accept the NIST hypothesis as a viable solution.

Additional Evidence

In a lengthy appendix, Mr. Douglas presents a large quantity of additional information either not considered or peripheral in the NIST Report. This information can be grouped into four categories, all of which appear to be related to explosions or explosive devices, presumably Mr. Douglas's leading alternate explanation. The categories are as follows:

- Witness statements and other commentary alluding to explosions
- Damage occurring lower in the structure following impact
- Horizontal trajectory of debris during the collapses
- Smoke pulses and other fire anomalies, including flows of molten material

Many of these specific observations have already been considered in this whitepaper, such as the comments by Firefighter Burke, and also the ejection of debris, which was seen to be plausible for gravity-driven phenomena but to require unreasonably large explosives.

Regarding the damage on lower floors and deflagration effects in the basements, the author agrees with Mr. Douglas that NIST's evaluation is superficial and may overlook important structural vulnerabilities, as remarked upon in previous chapters of this whitepaper. However, given that NIST estimates roughly five tons of jet fuel drained into the lower structure of each Tower, that the energy per unit mass of jet fuel is about ten times that of TNT, and given the multitude of ignition sources following impact, large explosions and widespread overpressure events in the lower structures are not surprising.

Like Dr. Griffin, Mr. Douglas does not present an alternative explanation, either involving explosives or otherwise. In the author's opinion, none of these observations is incompatible with the NIST hypothesis, nor does any constitute proof of explosive devices.

Summary

Considering Mr. Douglas's whitepaper, the author believes that many of his concerns are based on incomplete or mistaken readings of the NIST Report itself. Some of these are exacerbated by unusual or unclear wording within the Report. Other issues raised here echo limitations acknowledged by NIST itself. Having said this, a number of objections are valid, and a few others are not quite correct but instead lead one to additional fine points of valid criticism. In the author's opinion, the following list of items should have been included, clarified, or explored in the NIST Report, as suggested directly or indirectly by Mr. Douglas:

- *Completeness of Fire Data:* NIST should have included all of its thermocouple data from the workstation tests. While this presents no reason to doubt NIST's conclusions, given the 10,000 page bulk of the Report, there should be no objection to adding a few dozen additional charts.
- *Completeness of Fire Testing:* NIST's single workstation fire tests would be more valuable if the effect of the hood on ventilation could be quantified. A seventh test without the hood active would provide this.
- *Heat Content of Furnishings:* NIST's own experiments indicate about a 25% discrepancy in total heat content between different types of workstations, but the Report does not discuss the potential impact on fire behavior. If NIST explored the impact of this on the larger fire model, this could partially explain mismatches in burning time between model and reality, or resolve challenges regarding the total volume of combustibles levied by other researchers.
- *Choice of Jet Fuel Load:* NIST assumed and conducted experiments with 4 L of fuel per workstation, where a cursory analysis suggests that the actual distribution was closer to 12 L per workstation. While we do not expect this to make a large difference overall, at the very least a better explanation should have been given.
- *ASTM E 119 Truss Tests:* NIST's tests of the as-built truss structures, with intact fireproofing, reflected the original design, and are of limited value when considering the upgraded SFRM applied as a retrofit. Additional testing would permit a better assessment of hypothetical fire situations. NIST should also have considered tests in this series that incorporated damaged SFRM or fire sprinklers in order to better quantify the range of expected responses.
- *Verification of SAP2000 Models:* The ASTM E 119 tests, particularly the surprise difference between restrained and unrestrained tests, also could have been used as an excellent verification of the floor system structural models. Given the expense of full-scale experiments in general and wealth of data provided by these tests, it is unclear why this opportunity was overlooked.
- *Full Factorial Analysis:* NIST's population of different cases is not a full factorial analysis, but rather a more typical sensitivity analysis, ultimately pared down to an "incompressible list" of four cases. NIST should have better explained its choices in restricting itself to four cases. The author also suggests that additional cases, focused on varying the amount and placement of combustible material after impact, would greatly strengthen NIST's hypothesis.

As noted in the main text, the author does not expect NIST to revisit its report at this time. It remains to be seen if other ongoing investigations resolve these questions, and whether there is any effect on the collapse hypothesis as a result. The author anticipates no impact on the core NIST hypothesis, but surmises that these questions, if resolved, will help to reconcile differences between NIST and other scientific studies.

Notes

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