Chapter 2.2 Professionalism

ethos

n. the distinctive character, spirit, and attitudes of a people, culture, era, etc.: the revolutionary ethos.

[from Late Latin: habit, from Greek]

Why **Ethics?**

Professionalism?

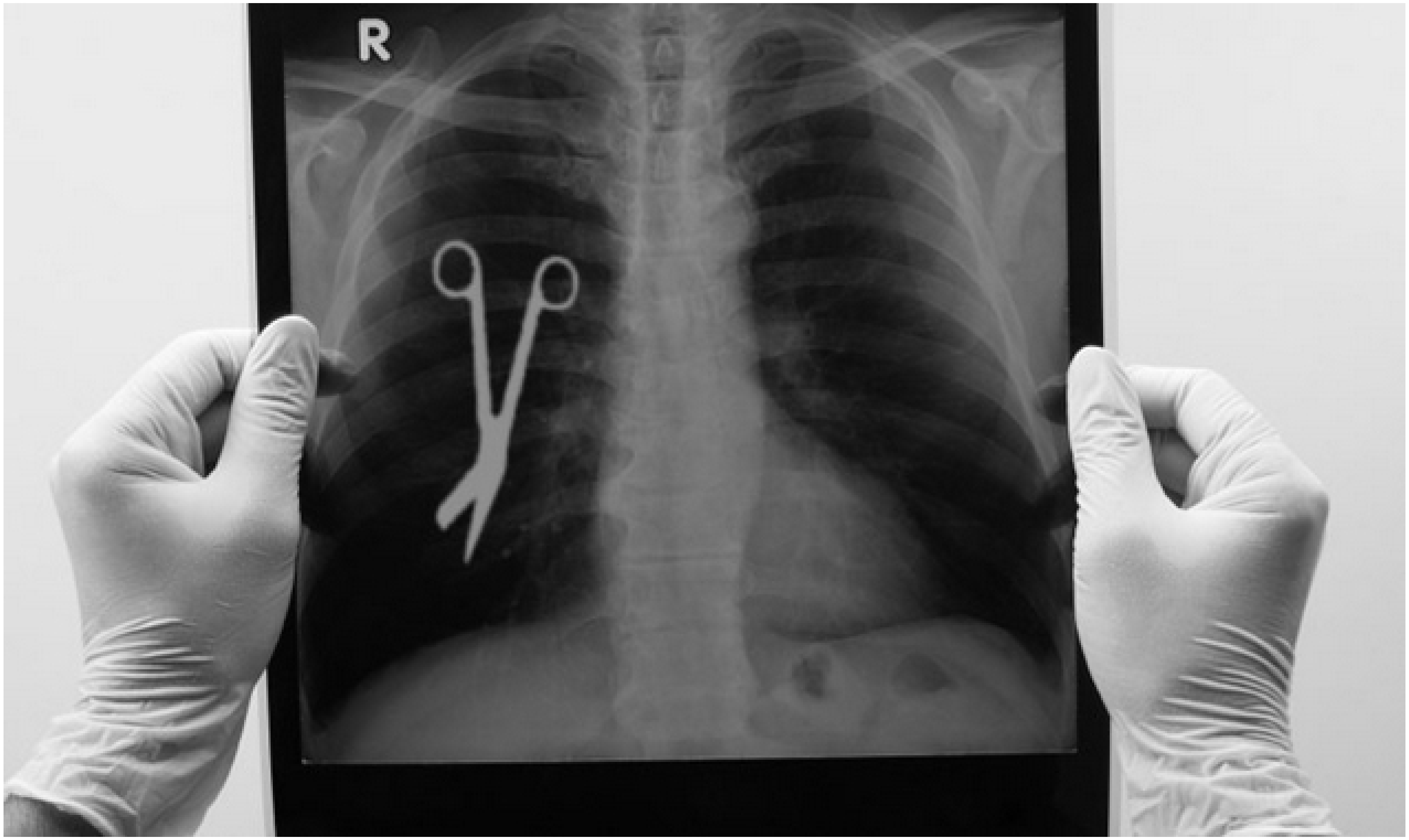
What do you expect when consulting a professional, e.g. a surgeon?

•Complexity: **We cannot control every aspect of our lives. We depend on others in multiple ways.**

•Interdependence: Our society is based on trust. Sometimes that trust is broken.

•Examples:
Business: Madoff, Mortgage securities
Medicine: Malpractice
Law: Malpractice

Ethics failures range from the criminal (e.g. bribery, falsification) to neglect (failure to ascertain relevant facts) and ignorance.



Failure to rigorously adhere to engineering ethics principles can lead to economic losses and to loss of life.

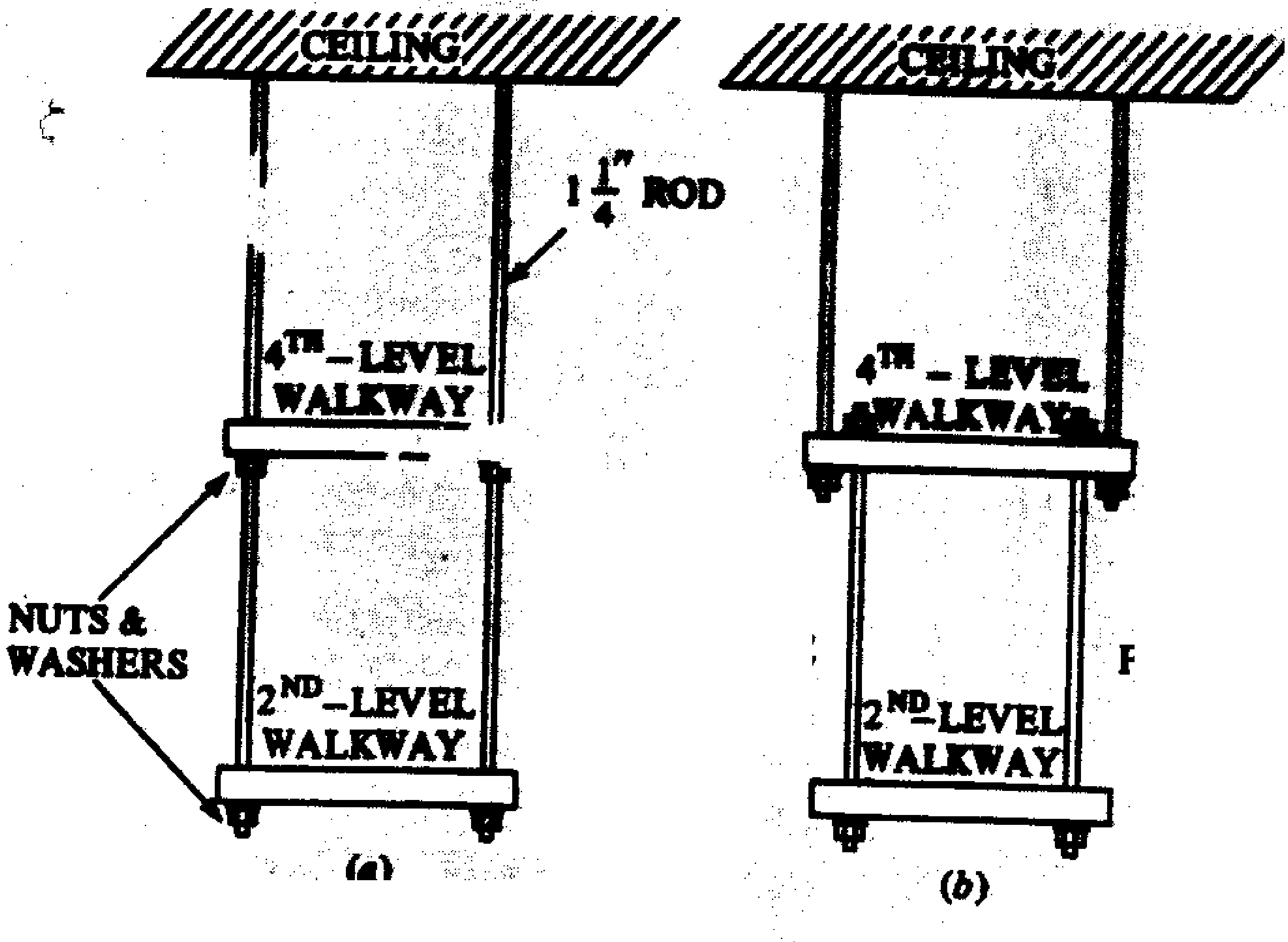
There will always be failures that are NOT the result of crime or negligence. Sometimes failures result from insufficient knowledge about the behavior of engineered products.

ENGINEERING ETHICS

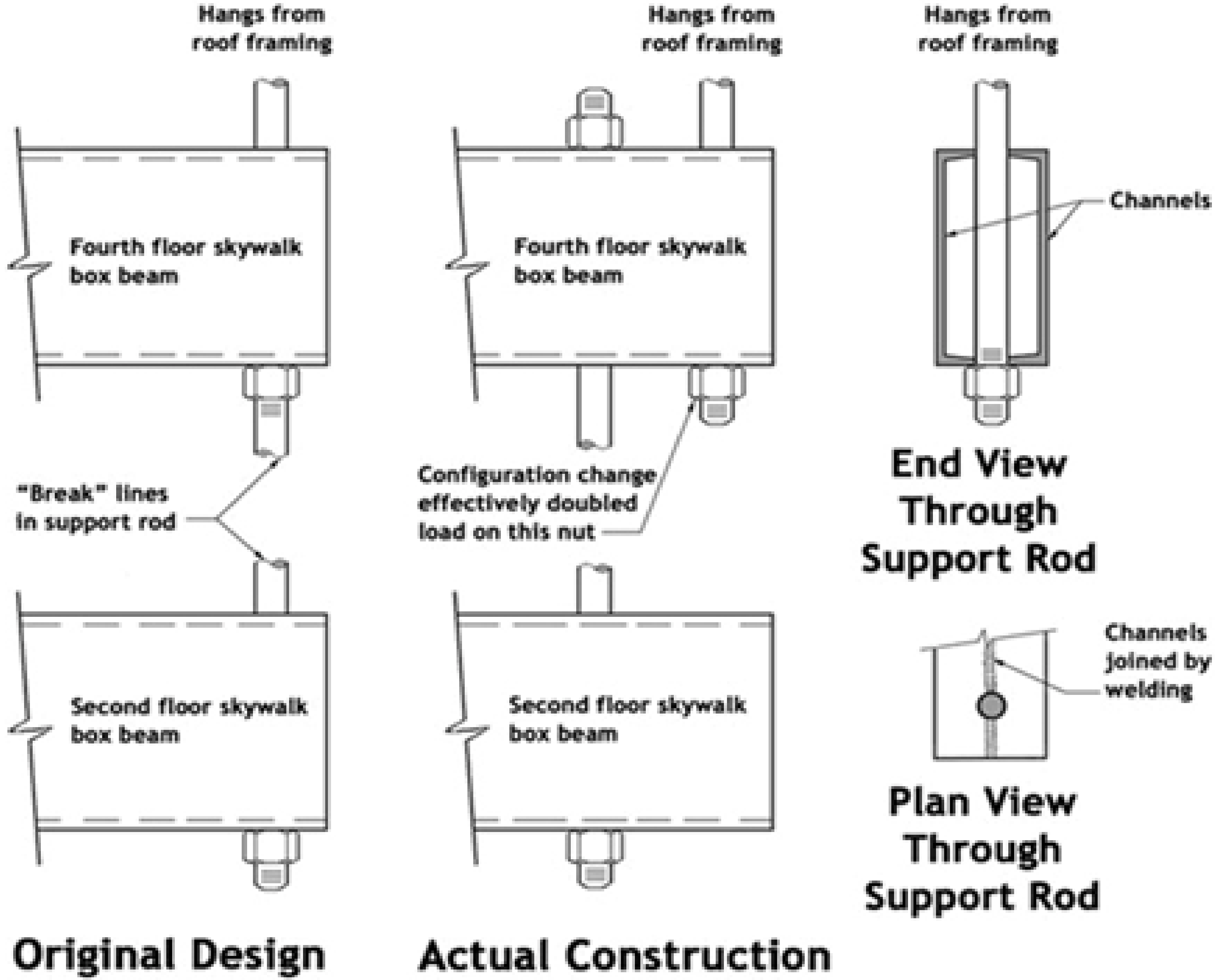
The Kansas City Hyatt Regency Walkways Collapse

An Engineering Design Case

Hotel Atrium Walkway Design



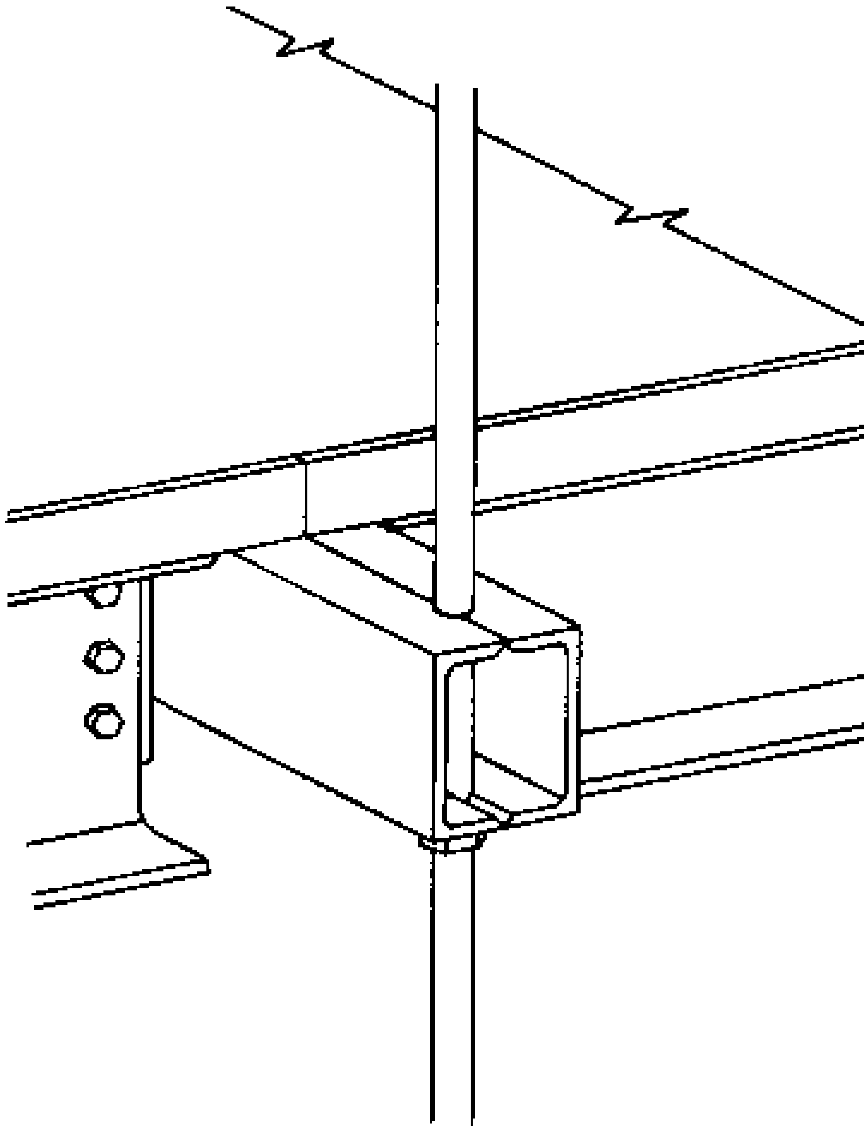
An Engineering Design Case



An Engineering Design Case

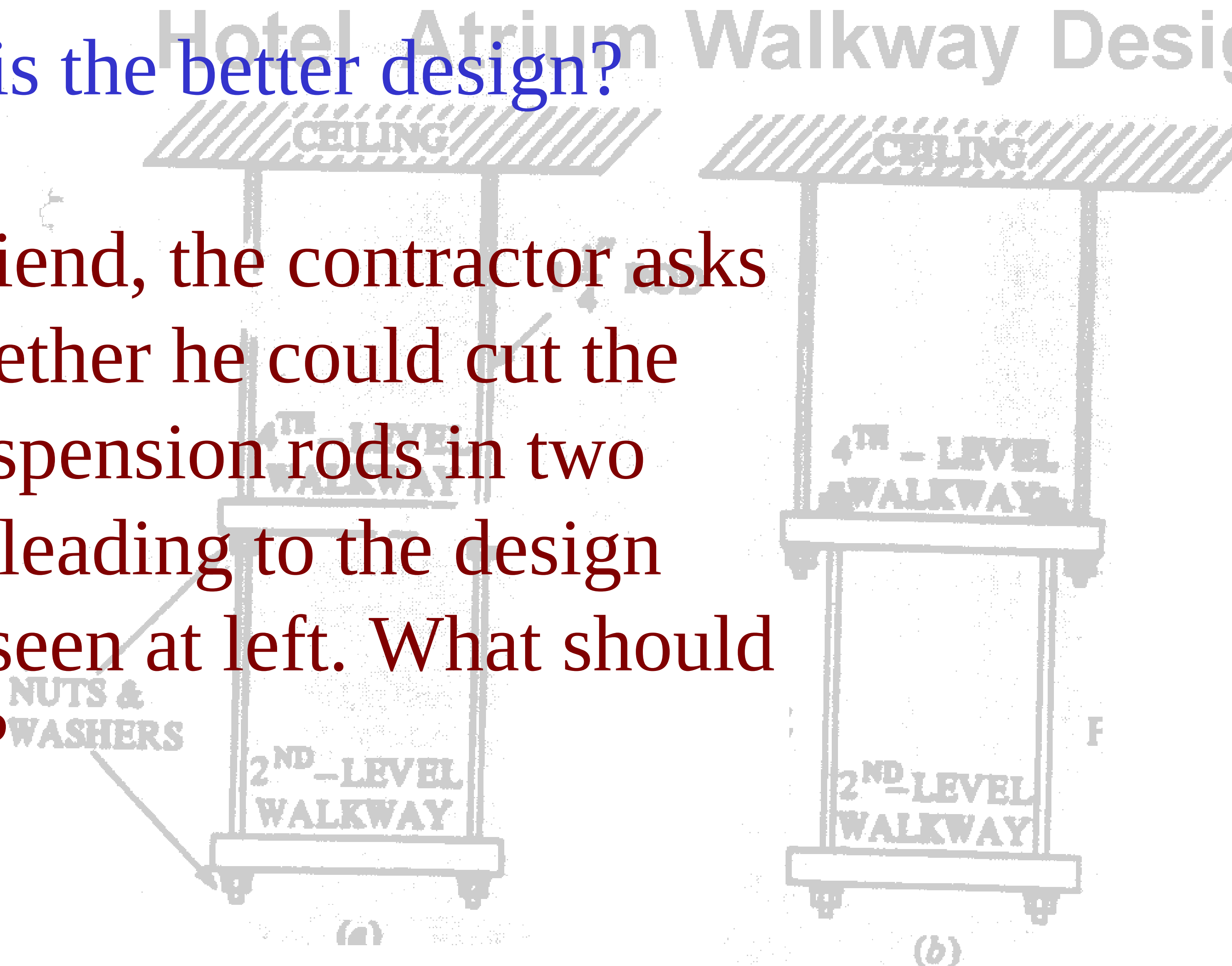
Walkway

Initial Design
Detail



An Engineering Design Case

Which is the better design?



Your friend, the contractor asks you whether he could cut the long suspension rods in two halves, leading to the design choice seen at left. What should you do?

Introduction To The Case

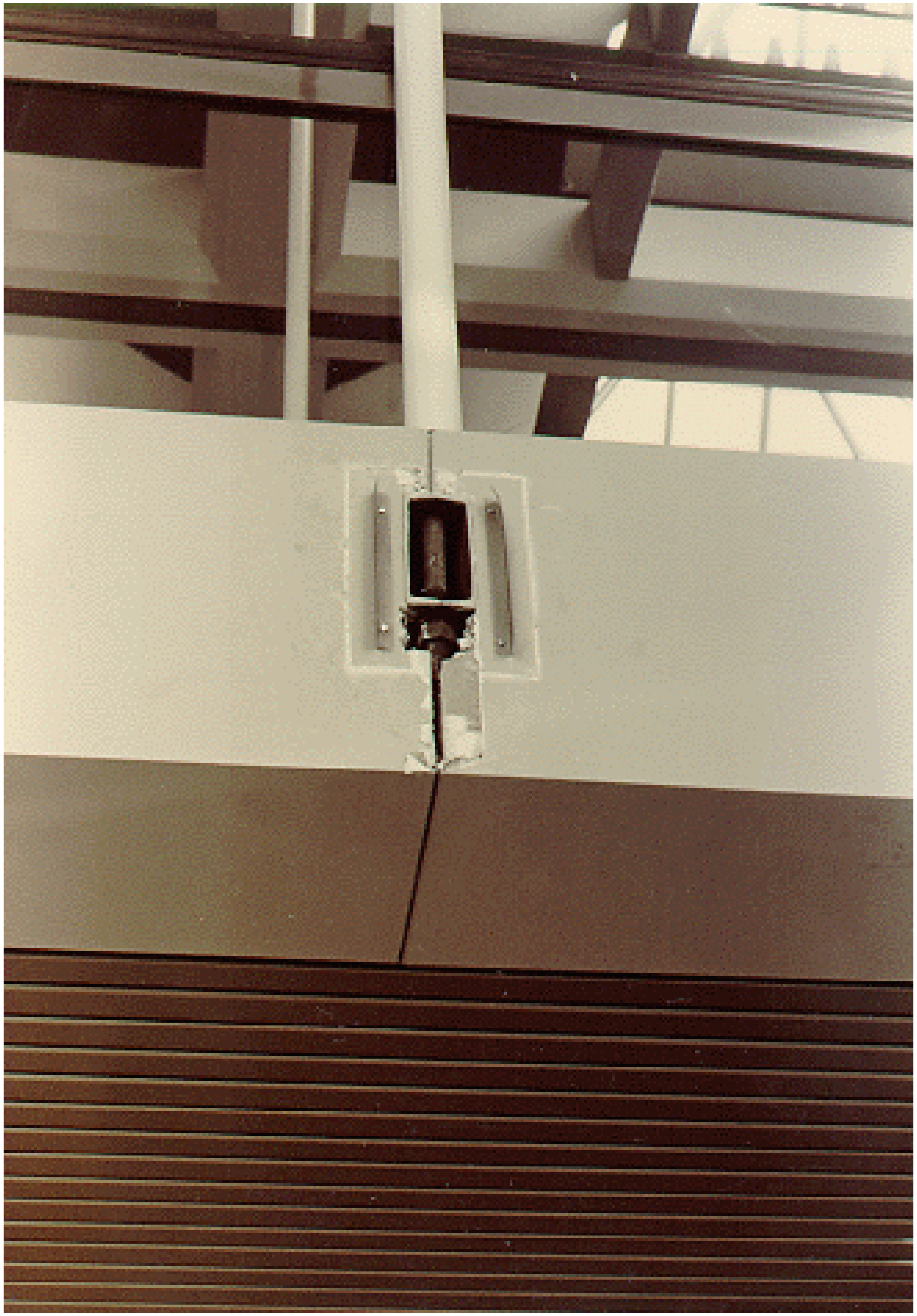
On July 17, 1981, the Hyatt Regency Hotel in Kansas City, Missouri, held a videotaped tea-dance party in their atrium lobby. With many party-goers standing and dancing on the suspended walkways, connections supporting the ceiling rods that held up the second and fourth-floor walkways across the atrium failed, and both walkways collapsed onto the crowded first-floor atrium below.

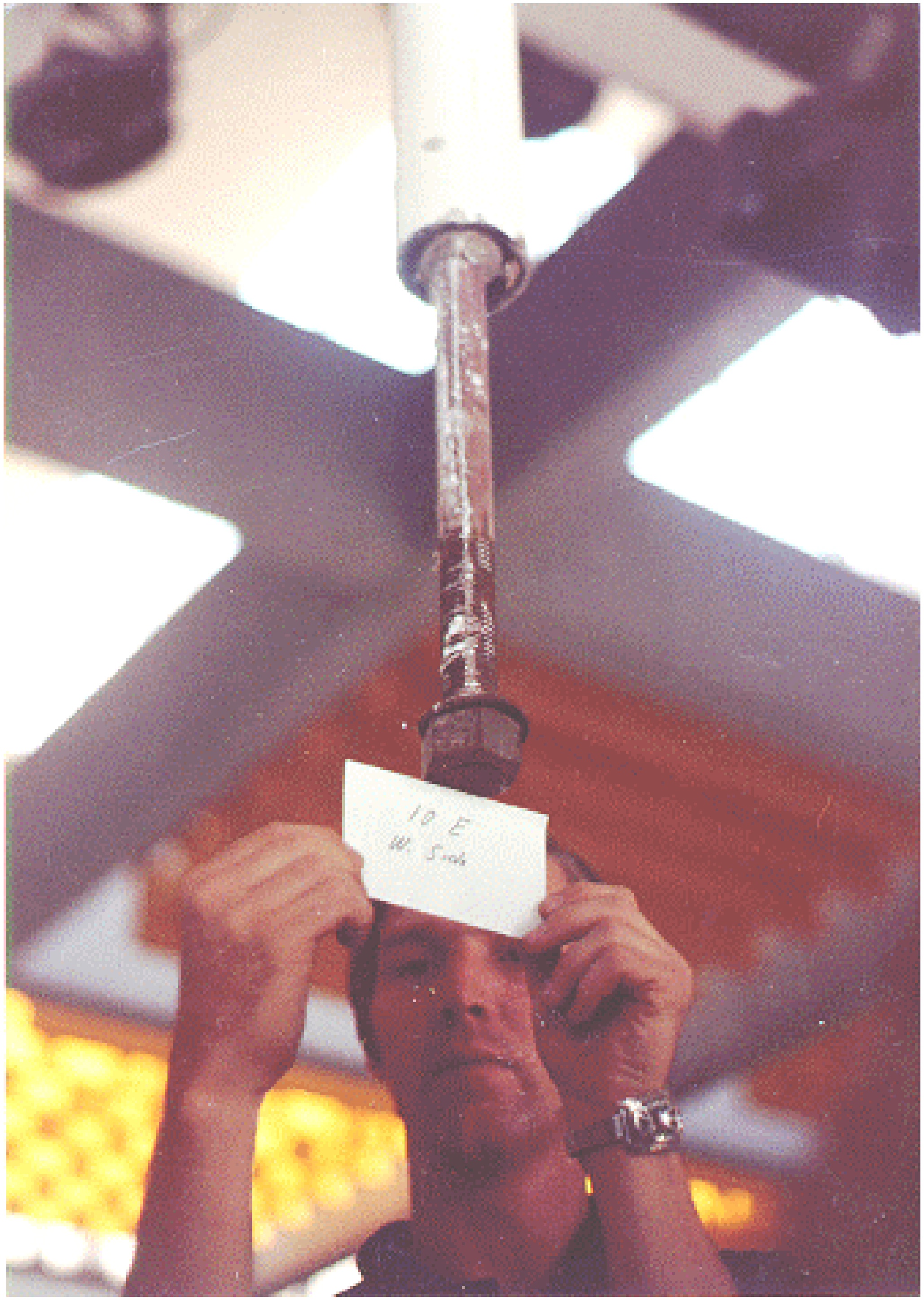
General view of the lobby floor, during the first day of the investigation.

The fourth-floor walkway collapsed onto the second-floor walkway, while the offset third-floor walkway remained intact. As the United States' most devastating structural failure, in terms of loss of life and injuries, the Kansas City Hyatt Regency walkways collapse left 114 dead and in excess of 200 injured. In addition, millions of dollars in costs resulted from the collapse, and thousands of lives were adversely affected.

Close-up of third floor hanger rod and cross-beam, showing yielding of the material.

The flanges have been bent significantly, and the webs are bowed out against the fireproofing sheet rock.





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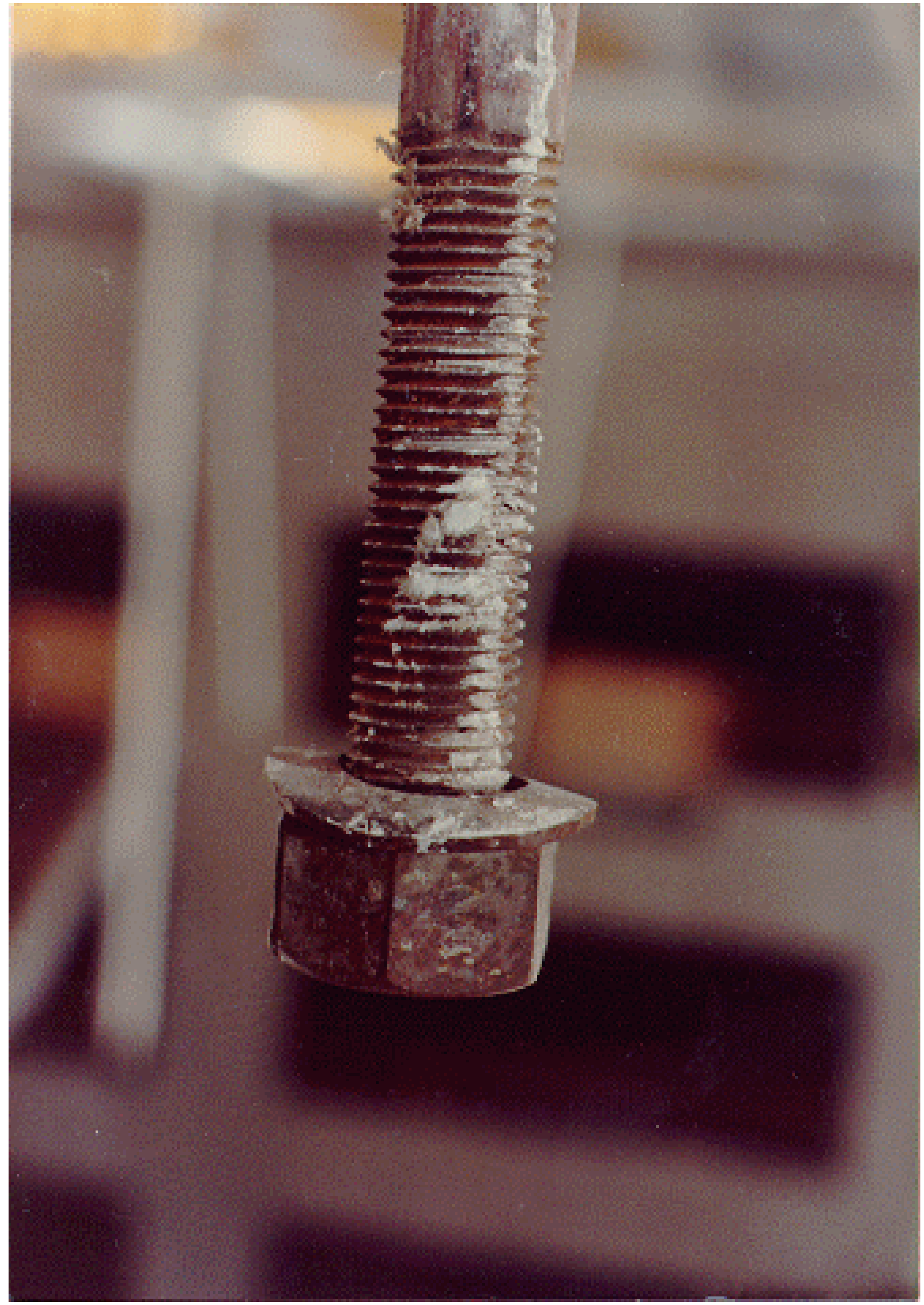
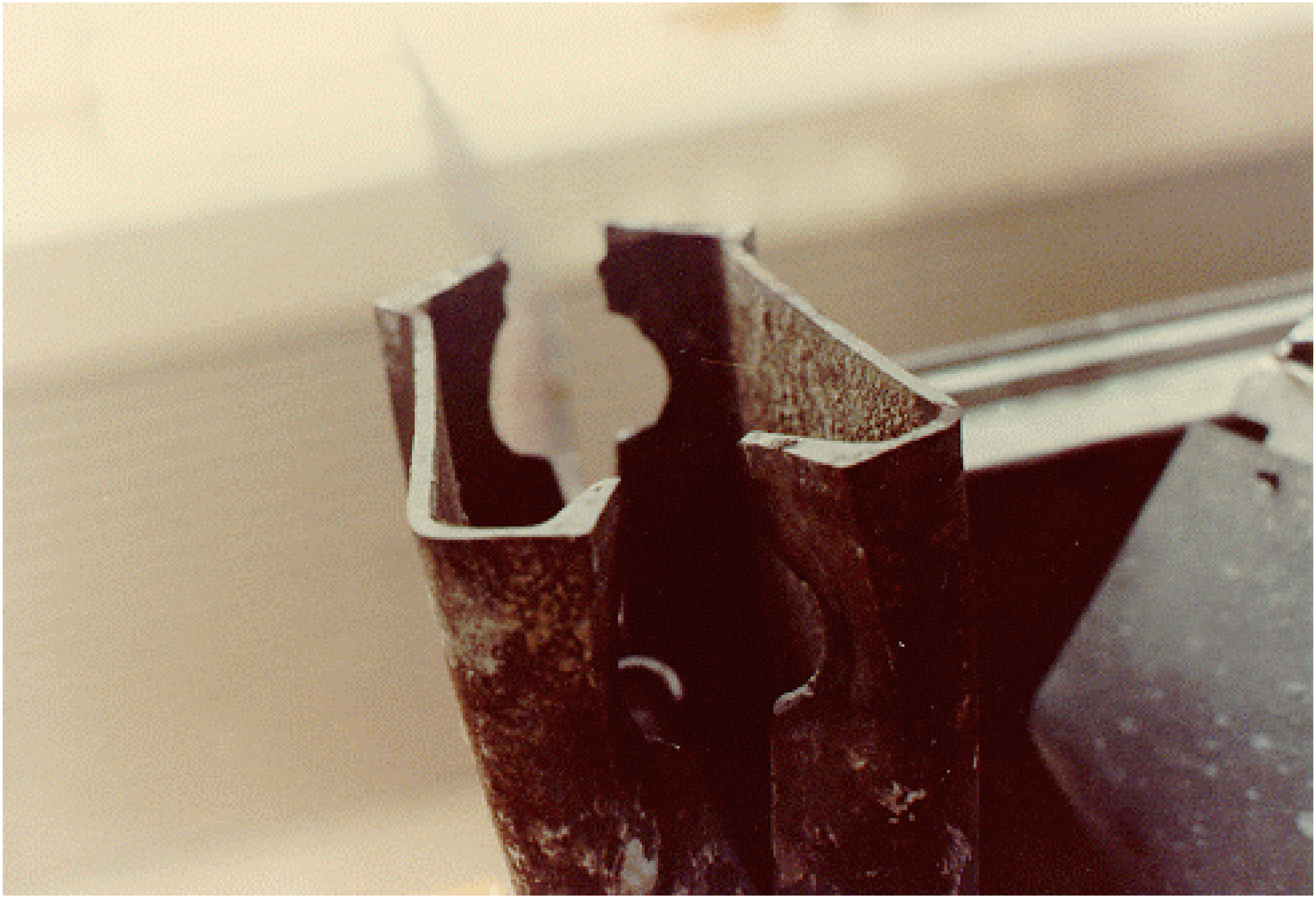
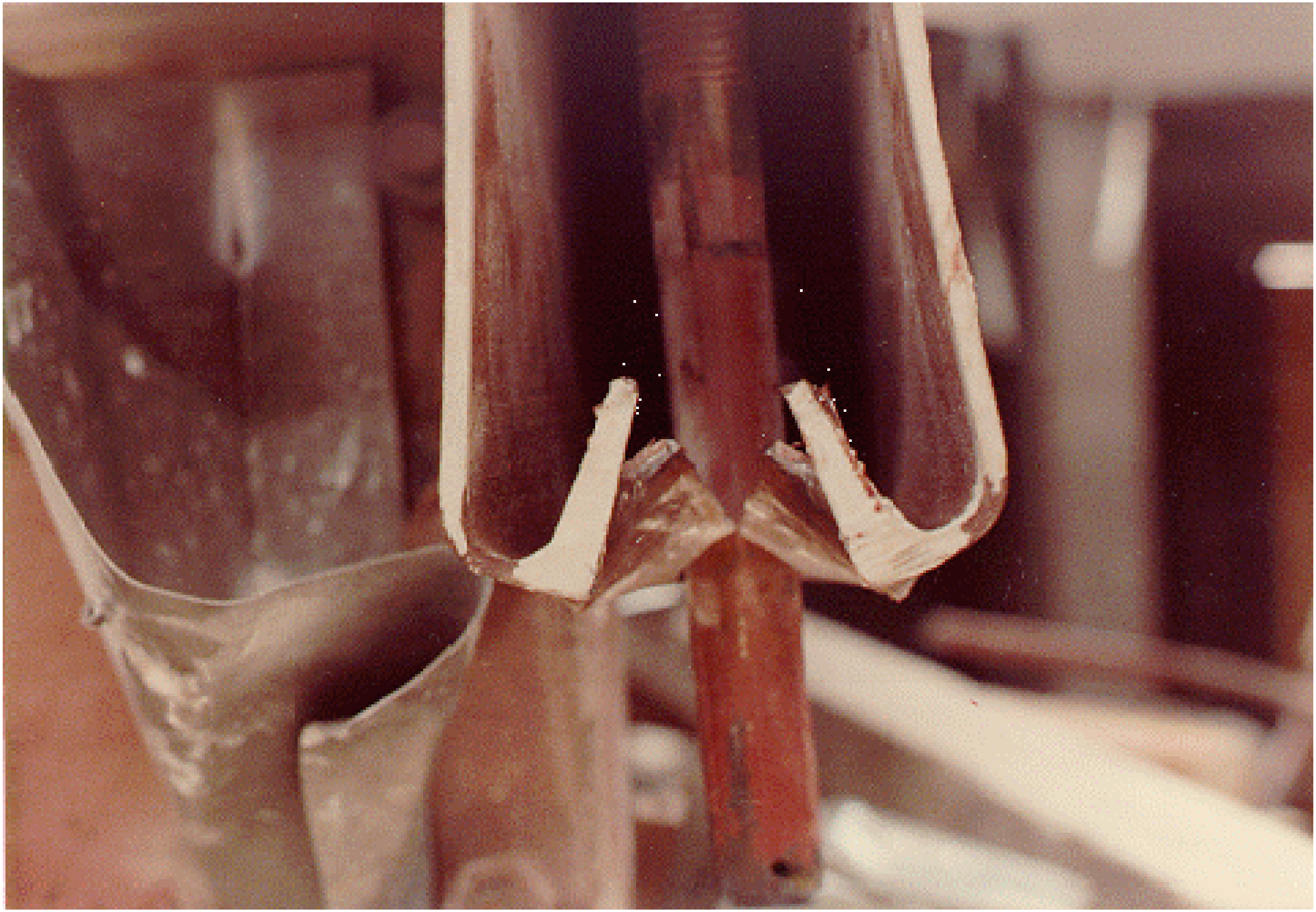
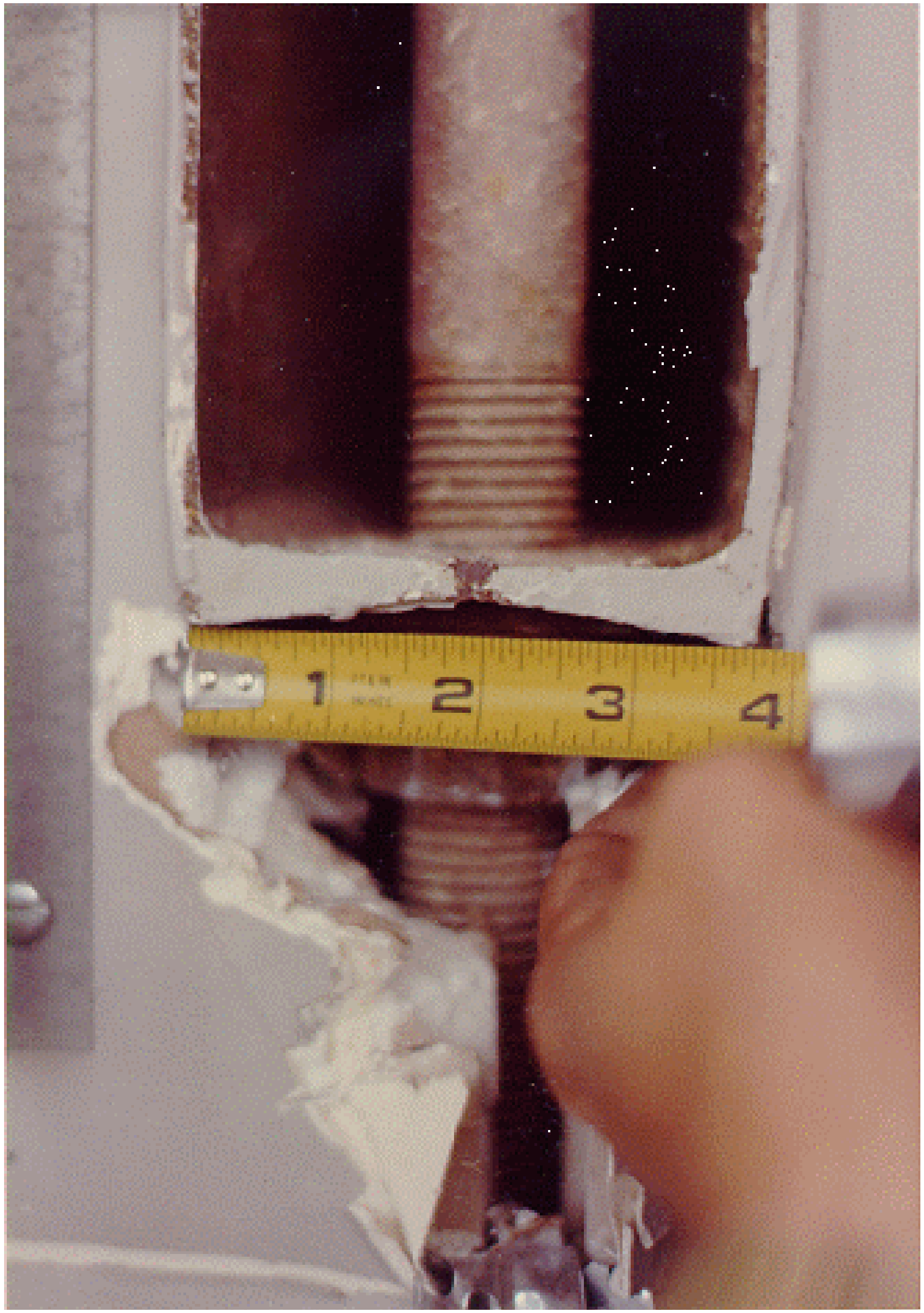
Close-up photo of the hanger rod threads, washer and supporting nut. Note the deformation caused in the washer as the beam slipped around it.





Underside view of one of the 4th floor beams.

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ENGINEERING ETHICS

Kansas City Disaster

Fact 1: The fabricator changed the design from a one-rod to a two-rod system to simplify the assembly task, doubling the load on the connector, which ultimately resulted in the walkways collapse.

Fact 2: Even as originally designed, the walkways were barely capable of holding up the expected load, and would have failed to meet the requirements of the Kansas City Building Code.

Fact 3: Due to evidence supplied at the Hearings, a number of principals involved lost their engineering licenses, a number of firms went bankrupt, and many expensive legal suits were settled out of court.

November, 1984: Duncan, Gillum, and G.C.E. Inc. found guilty of gross negligence, misconduct and unprofessional conduct in the practice of engineering. Subsequently, Duncan and Gillum lost their licenses to practice engineering in the State of Missouri.

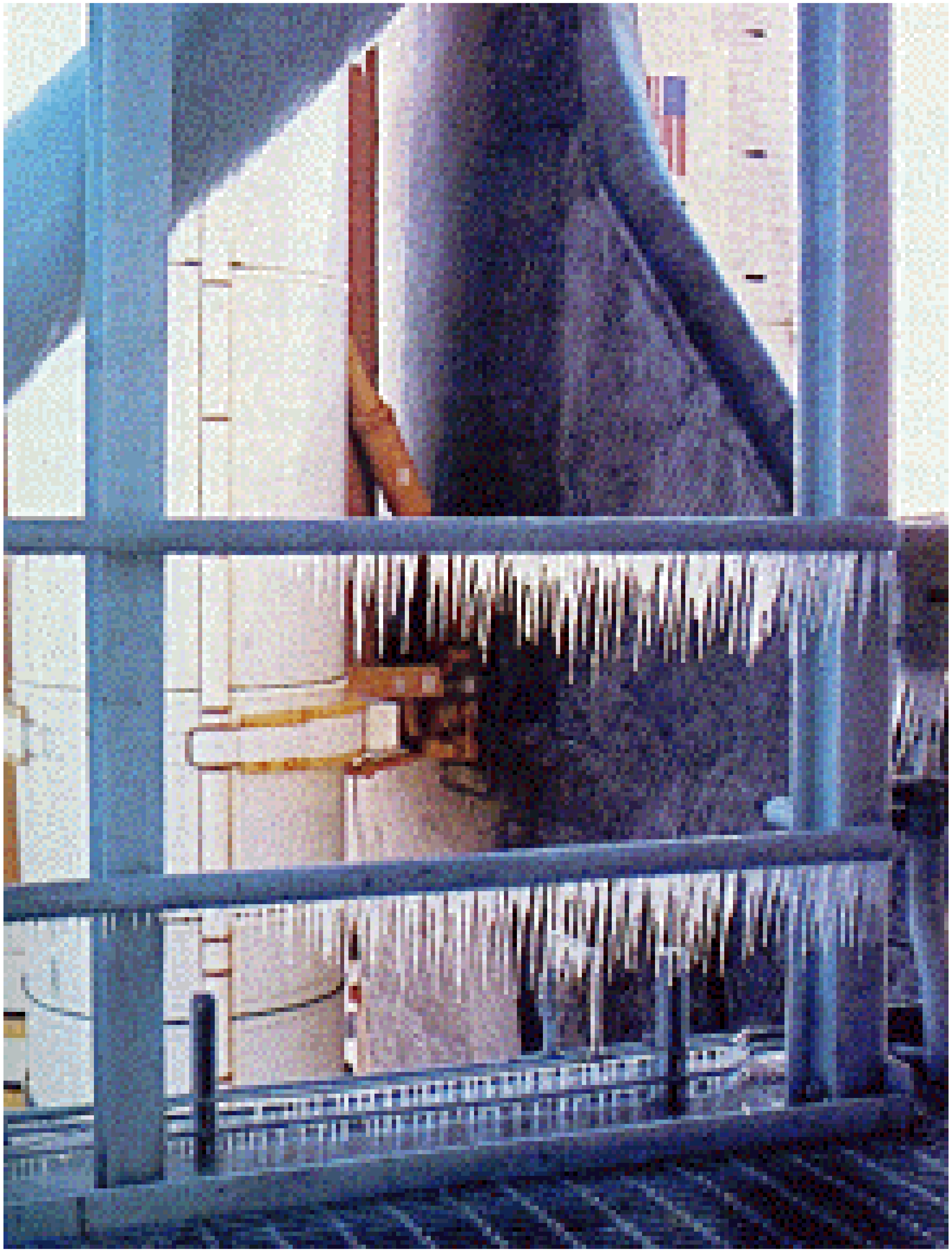
The Challenger Disaster

Engineering Issues (Professionalism)

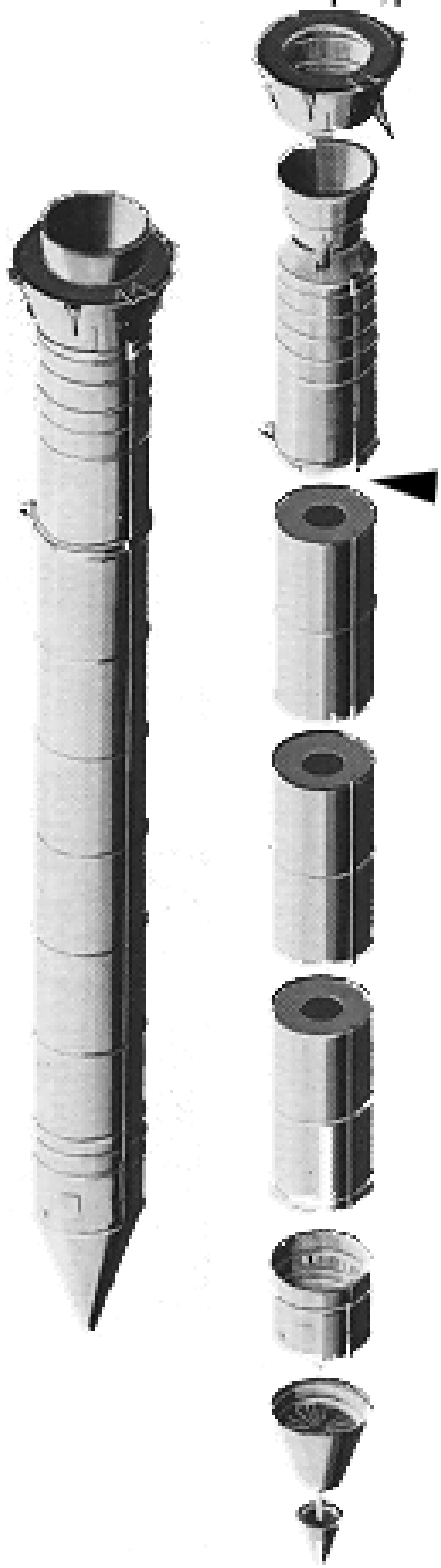
Management Issues
(Ethics and Whistleblowing)

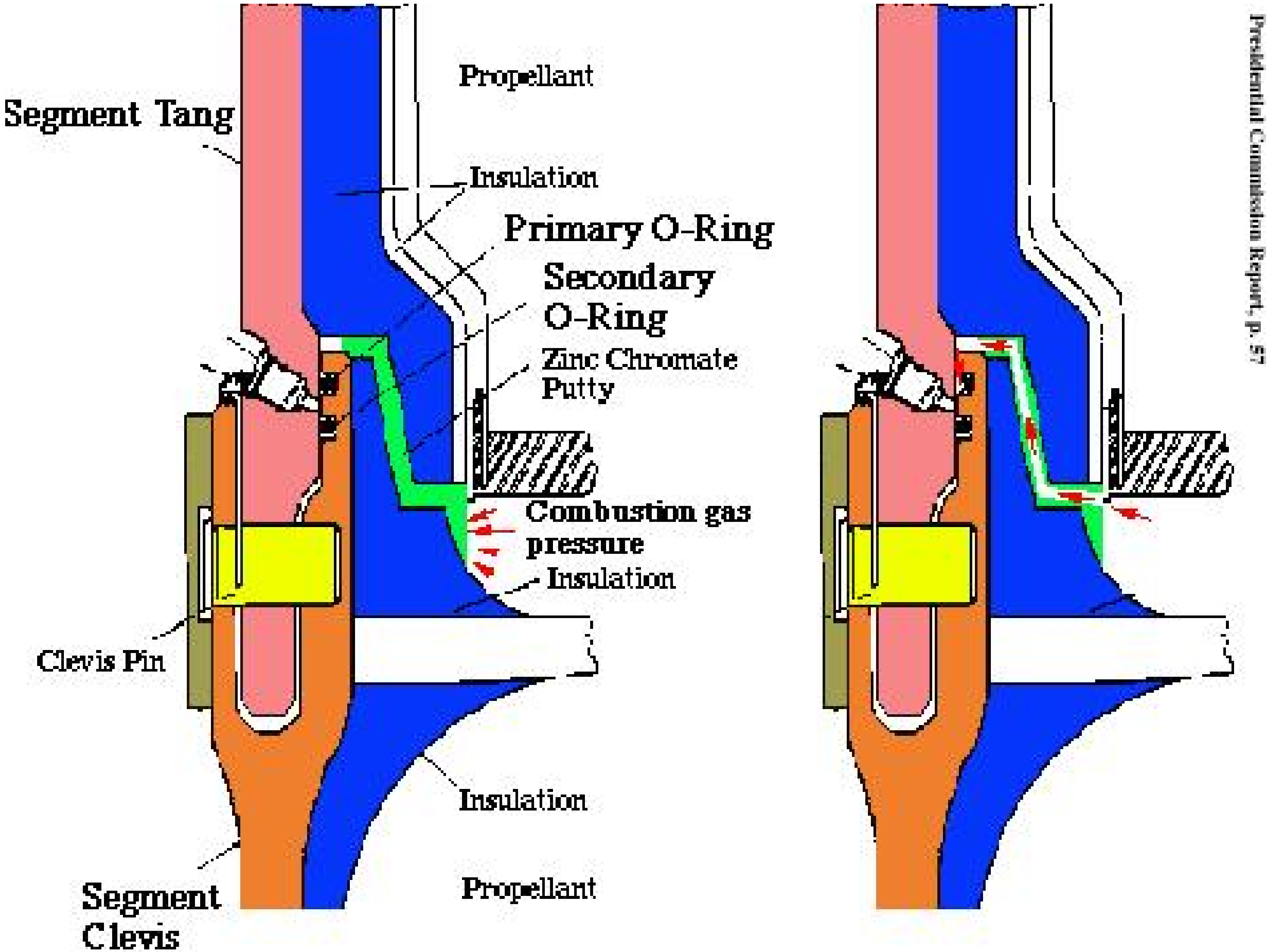
Ice on the Launchpad.

Lowest temperature: 8^o F



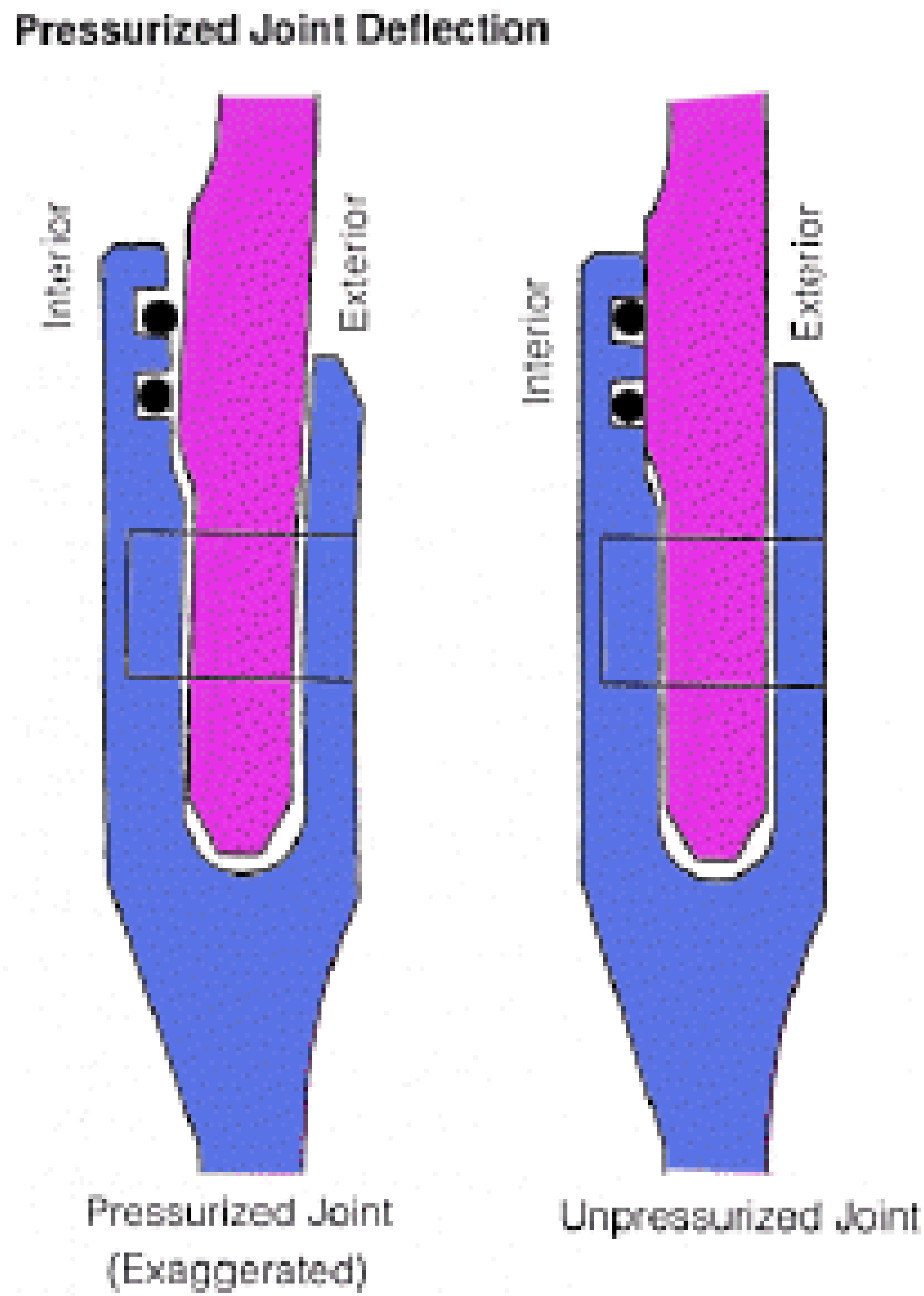
Presidential Commission Report, p. 52





O-ring Design

O-ring Failure Mechanism



The O-ring contraction was by no means a shocking new phenomenon. A post-flight examination of a previous challenger mission indicates that the O-ring had shrunk ('eroded‘) as a result of temperature. As the heated gas came in contact with the contracted O-ring, the integrity of the ring was compromised. Smoke did not appear until 58 seconds after ignition because the putty, filling the space between the rubber pieces of lining, flowed into the gap of the ring and sealed it.

An engineer familiar with the O-ring stated, "The O-ring was having to perform beyond what we had initially intended, but the question was, is this a serious problem?"(5) The uncertainty of this question demonstrates how those involved in the decision making process could have acted so differently.

The Challenger Disaster

Engineering Issues
(Professionalism)

Management Issues
(Ethics and Whistleblowing)

Memo from Roger Boisjoly on O-Ring Erosion

Morton Thiokol, Inc
Wasatch Division

Interoffice Memo

31 July 1985 2870:FY86:073 TO: R. K. Lund Vice President, Engineering CC: B. C. Brinton, A. J. McDonald, L. H. Sayer, J. R. Kapp FROM: R. M. Boisjoly Applied Mechanics - Ext. 3525 SUBJECT: SRM O-Ring Erosion/Potential Failure Criticality This letter is written to insure that management is fully aware of the seriousness of the current O-ring erosion problem in the SRM joints from an engineering standpoint.

Memo from Roger Boisjoly on O-Ring Erosion, continued

"The mistakenly accepted position on the joint problem was to fly without fear of failure and to run a series of design evaluations which would ultimately lead to a solution or at least a significant reduction of the erosion problem. This position is now drastically changed as a result of the SRM 16A nozzle joint erosion which eroded a secondary O-ring with the primary O-ring never sealing. "

Memo from Roger Boisjoly on O-Ring Erosion, continued

"If the same scenario should occur in a field joint (and it could), then it is a jump ball as to the success or failure of the joint because the secondary O-ring cannot respond to the clevis opening rate and may not be capable of pressurization. The result would be a catastrophe of the highest order - loss of human life. "

Memo from Roger Boisjoly on O-Ring Erosion, continued

"It is my honest and very real fear that if we do not take immediate action to dedicate a team to solve the problem with the field joint having the number one priority, then we stand in jeopardy of losing a flight along with all the launch pad facilities."

R. M. Boisjoly

Concurred by: J. R. Kapp, Manager

Applied Mechanics

A Deadly Mentality

Throughout the space program, NASA was under political pressure to *“beat Russia to everything.”* NASA promised two missions a month by the late '80's. The Challenger mission had already been delayed several times because the turn around for the previous Columbia mission had taken longer than expected. With this pressure on their reputation, NASA was determined to launch the Challenger on that cold January morning.

NASA officials were aware of the dangers involved in a cold weather launch, which included the possibility of ice damaging the heat shield, but proceeded to launch the shuttle anyway.

NASA boasted that the O-rings were "fail-safe".

The Night Before the Launch

Temperatures were predicted to be in the low 20°s. This prompted Alan McDonald (Director of the Solid Rocket Motors Project) to ask his engineers at Thiokol to prepare a presentation on the effects of cold temperature on booster performance.A teleconference was held between engineers and management from Kennedy Space Center, Marshall Space Flight Center in Alabama, and Morton-Thiokol in Utah.

The Night Before the Launch, cont’d

Thiokol's engineers gave an hour-long presentation, presenting a convincing argument that the cold weather would exaggerate the problems of joint rotation and delayed O-ring seating. The lowest temperature experienced by the O-rings in any previous mission was 53°F in 1985. With a predicted ambient temperature of 26°F at launch, the O-rings were estimated to be at 29°F.

The Night Before the Launch, cont'd

After the technical presentation, Thiokol's Engineering VP Bob Lund concluded that 53°F was the only low temperature data point Thiokol had. The boosters had experienced O-ring erosion at this temperature. **Since his engineers had no data below 53°F, they could not prove that it was unsafe to launch at lower temperatures.** The predicted temperatures for the morning's launch were outside the data base and NASA should delay the launch

The Night Before the Launch, cont'd

This confused NASA managers because the booster design specifications called for booster operation as low as 31°F. *(Thiokol understood that the 31°F limit temperature was for storage of the booster)*

Marshall's Solid Rocket Booster Project Manager, Larry Mulloy, commented that the data were inconclusive and challenged the engineers' logic. Mulloy bypassed Lund and asked Manager Joe Kilminster for his opinion.

The Night Before the Launch, cont'd

Kilminster was in management,although he had an extensive engineering background,but Kilminster stood by his engineers. Kilminster asked for a meeting off of the net, so Thiokol could review its data. Boisjoly and Thompson tried to convince their senior managers to stay with their original decision not to launch. A senior executive at Thiokol, Jerald Mason, commented that a management decision was required.

The Night Before the Launch, cont'd

The managers seemed to believe the O-rings could be eroded up to one third of their diameter and still seat properly, regardless of the temperature. The data presented to them showed no correlation between temperature and the blow by gasses which eroded the O-rings in previous missions. According to testimony by Kilminster and Boisjoly, Mason (*a Sr. Thiokol executive)* finally turned to Bob Lund and said, **"Take off your engineering hat and put on your management hat."**

The Night Before the Launch, cont’d

Alan McDonald, who was present with NASA management in Florida,was surprised to see the recommendation to launch and appealed to NASA management not to launch. NASA managers decided to approve the boosters for launch despite the fact that the predicted launch temperature was outside of their operational specifications.

The Launch

During the night, temperatures dropped to as low as 8°F. In order to keep the water pipes in the launch platform from freezing, safety showers and fire hoses had been turned on. Ice had formed all over the platform. There was some concern that the ice would fall off of the platform during launch and might damage the heat resistant tiles on the shuttle. The ice inspection team thought the situation was of great concern, but the launch director decided to go ahead with the countdown.

The Challenger Disaster

Effects on Personnel

Roger Boisjoly lost his job at Morton-Thiokol. He is now retired in Mesquite, NV

According to Roger Boisjoly, no NASA manager was ever disciplined or sanctioned in connection with the Challenger disaster.

Issues Relevant to Engineers

What is the proper role for engineers in management positions?

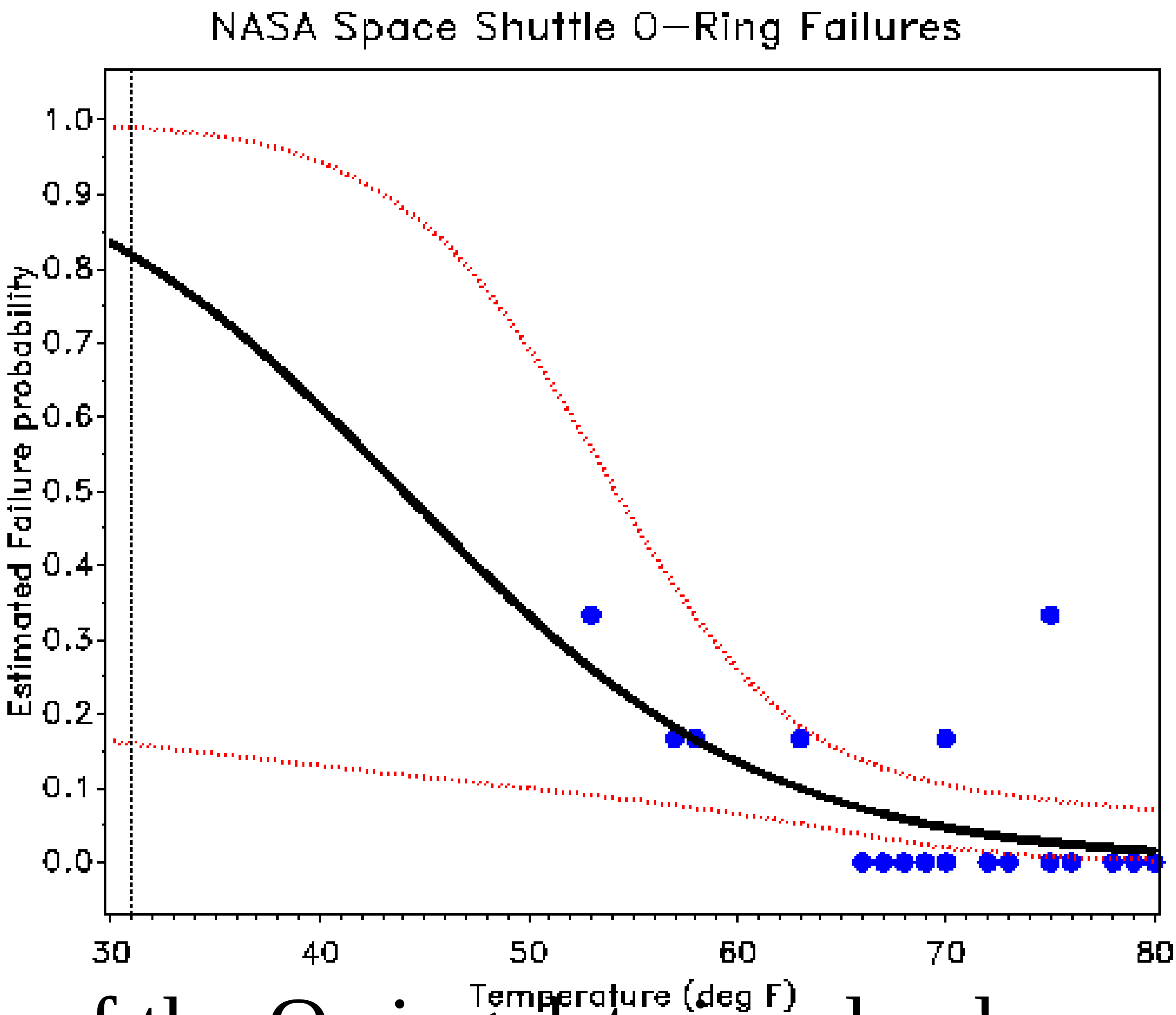
Insufficient data. A reason to proceed?

Does might make right? Of course not. So what should you do?

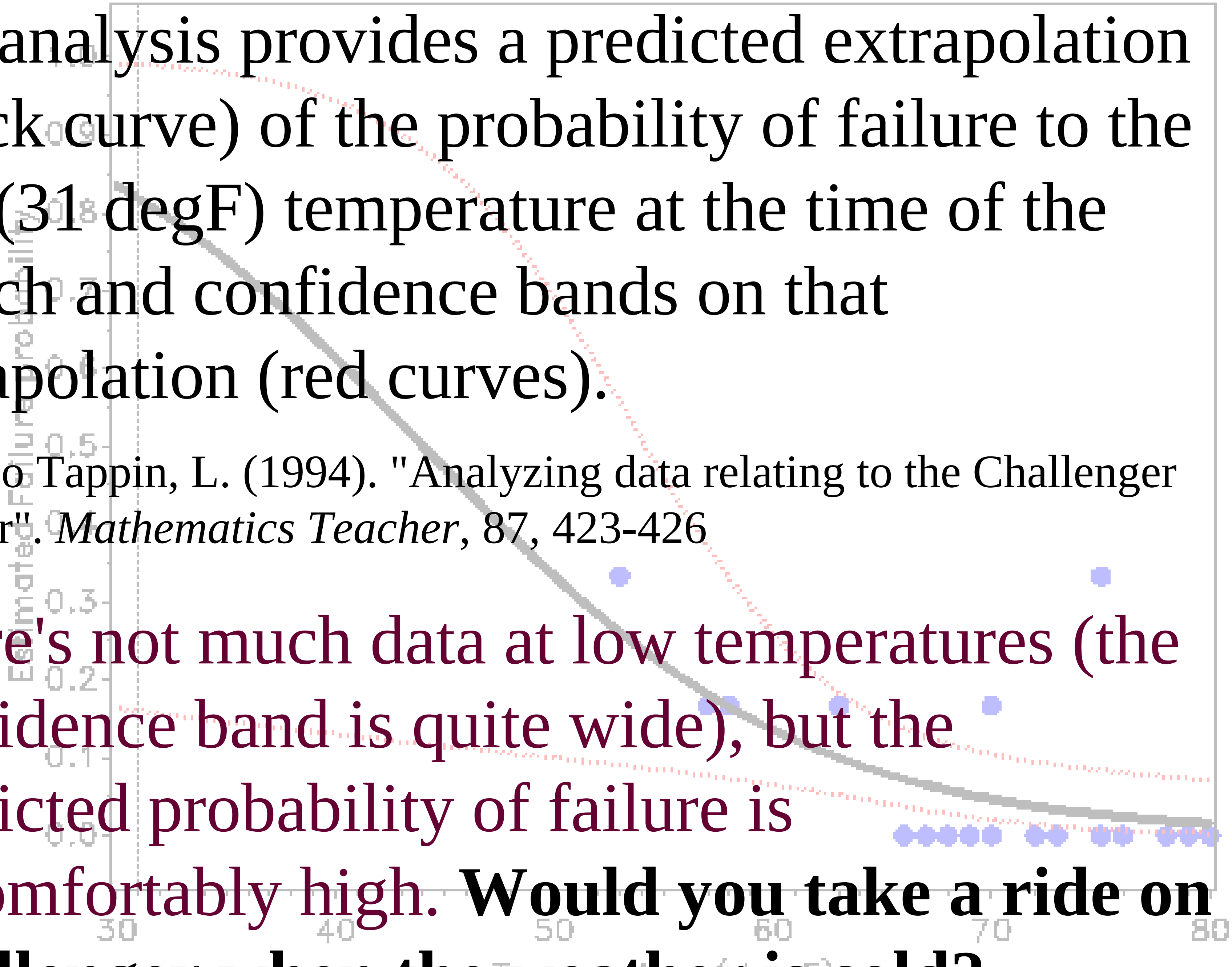
The Need for Clear Communication

Missed Opportunities

One virtue of a good graphical display is to allow us to see patterns, trends, or other structures which would otherwise be concealed in another form of display. It may be heartbreaking to find out that some important information was there, but the graph maker missed it. The story behind the *Challenger Disaster* is perhaps the most poignant missed opportunity in the history of statistical graphics.



Reanalysis of the O-ring data involved fitting a logistic regression model.

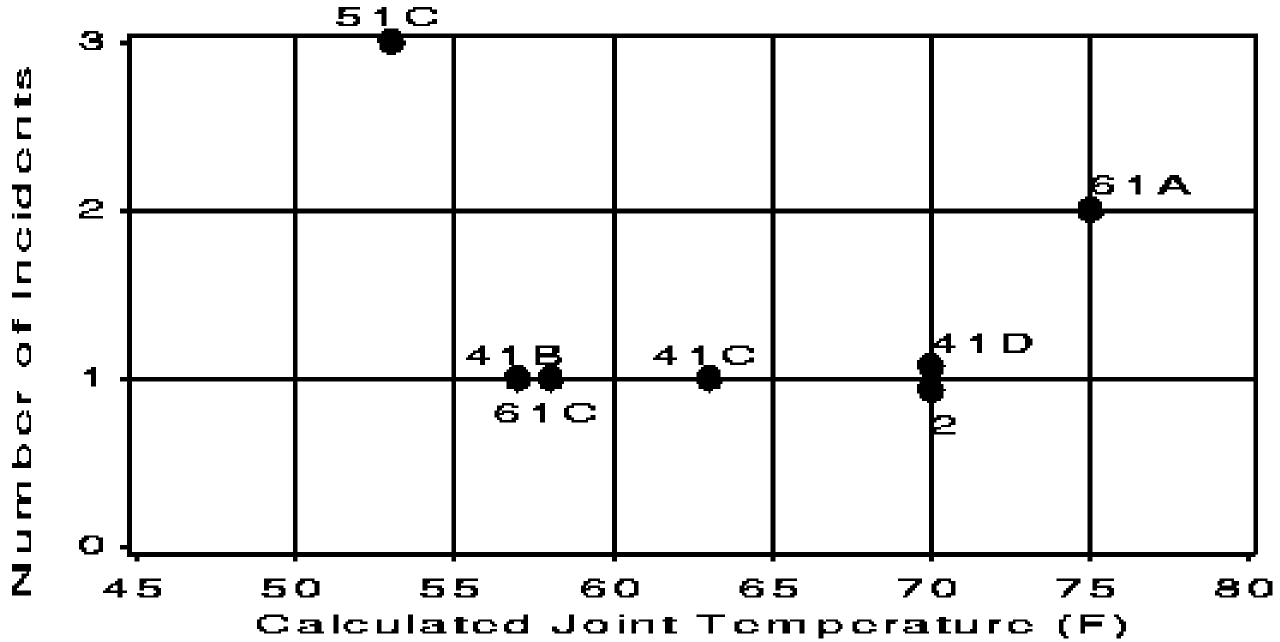


The analysis provides a predicted extrapolation (black curve) of the probability of failure to the low (31 degF) temperature at the time of the launch and confidence bands on that extrapolation (red curves).

See also Tappin, L. (1994). "Analyzing data relating to the Challenger disaster". *Mathematics Teacher*, 87, 423-426

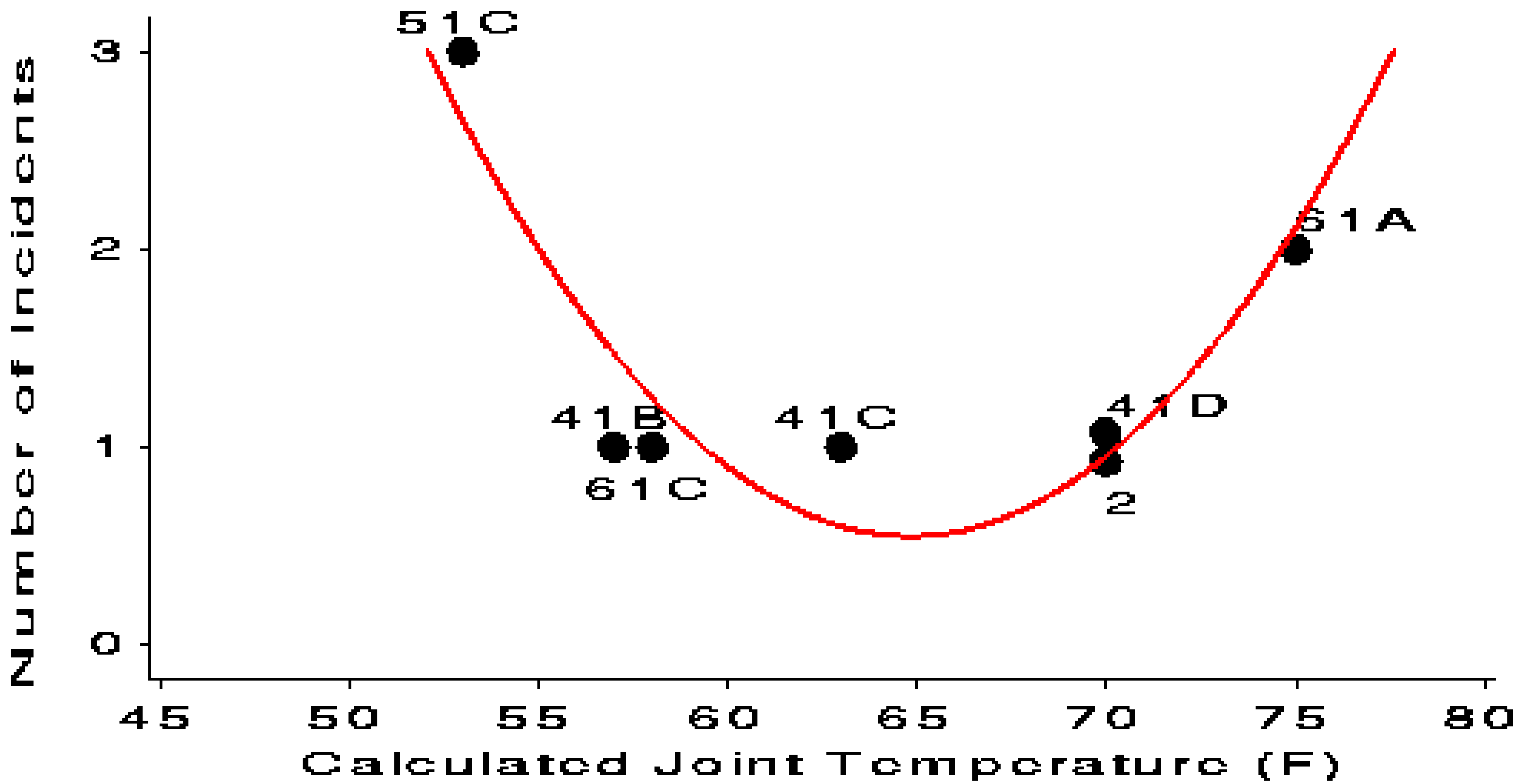
There's not much data at low temperatures (the confidence band is quite wide), but the predicted probability of failure is uncomfortably high. **Would you take a ride on Challenger when the weather is cold?**

What if they had made a better graph?



This original graph was prepared by engineers from the contractor, Morton Thiokol. It is perhaps unreasonable to expect a sophisticated statistical analysis, given the time pressure for a launch / no-launch decision.

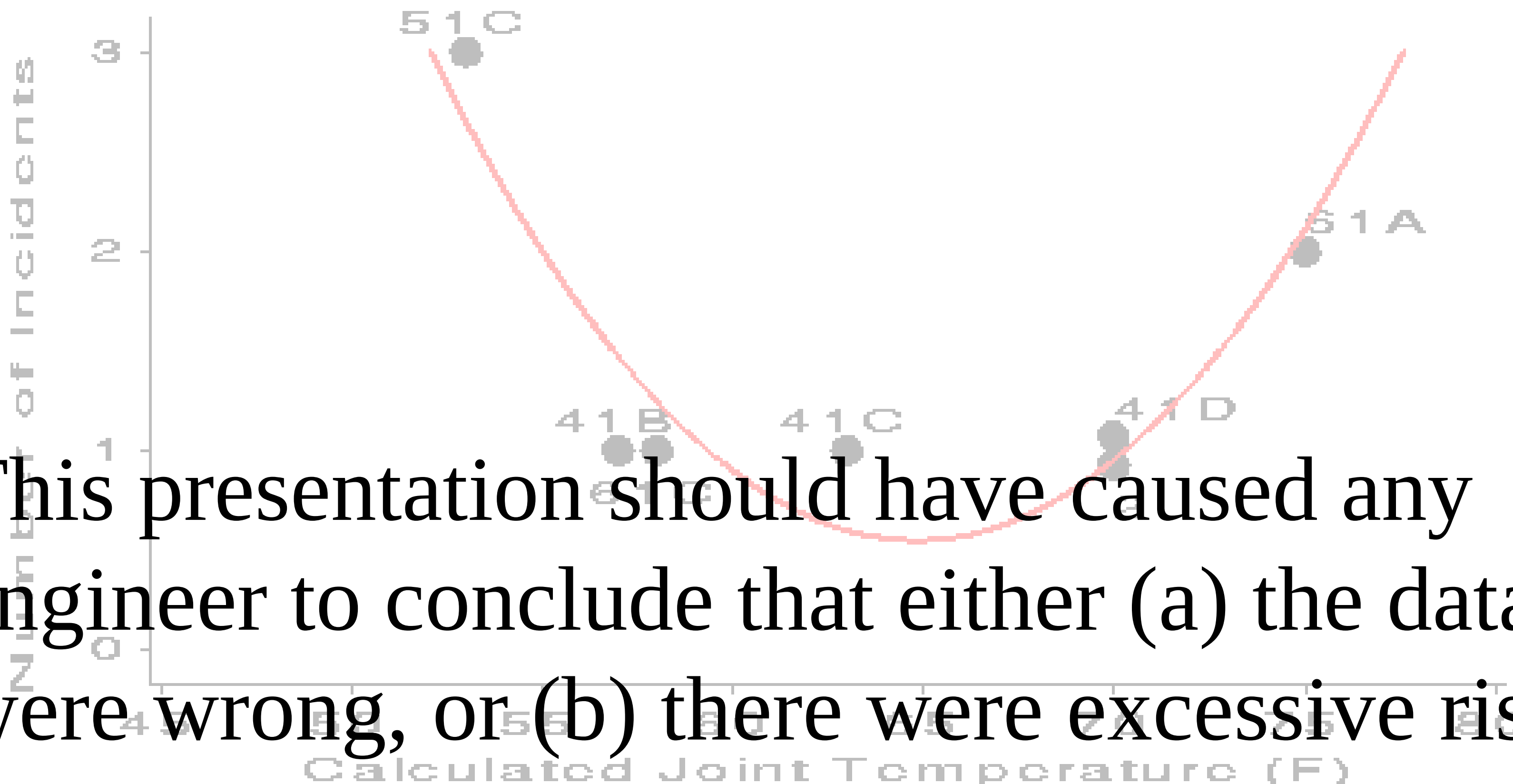
What if they had made a better graph?



Same data set.

What's different?

What if they had made a better graph?



This presentation should have caused any engineer to conclude that either (a) the data were wrong, or (b) there were excessive risks associated with both high and low temperatures. [We know that brittleness of the rubber used in the O-rings is inversely proportional to $(temp)^3$.]

Space Shuttle Columbia
2003

Some remarks concerning the Columbia Space Shuttle Disaster

Source: NY Times, 2/03/03

We know : A section of the left wing was damaged on Liftoff. (see illustration)

Columbia Liftoff.

Source: Der Spiegel, 2/03/03

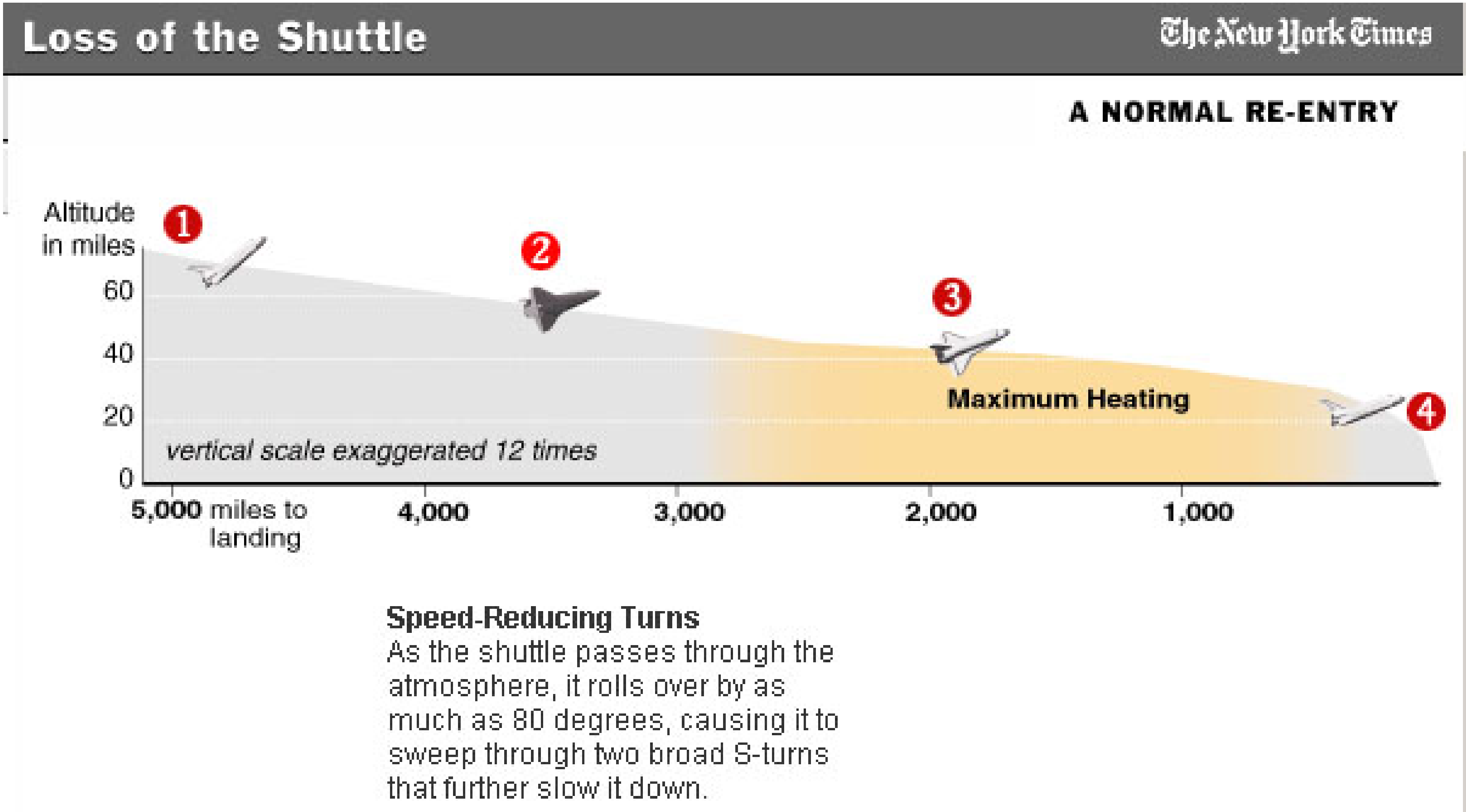
Ron D. Dittemore, NASA's shuttle program manager, said there were several indications of an unusual increase in temperatures on the shuttle's exterior near the left wheel well. He also said that two minutes before the craft broke up computers detected an increase in drag on the left side, suggesting a rough or missing tile on the shuttle's protective surface.

Source: NY Times, 2/03/03

Mr. Dittemore, the program manager, said the hit from the broken-off insulation was not discovered until a day after the Columbia's ascent, when engineers reviewed liftoff tapes. He said that there had been a "thorough discussion" of the event and that NASA experts had concluded that the incident was "inconsequential."

Source: NY Times, 2/03/03

The Planned Descent



Source: NY Times, 2/03/03

Normal Re-entry:

At the point of maximum heating, the thermal tiles can reach temperatures of about 3,000 degrees Fahrenheit.
The air around the shuttle is ionized, usually preventing radio contact for about 13 minutes.

Speed
15,045 m.p.h.

Source: NY Times, 2/03/03

The Sequence of Events

1. 8:53 A.M.
Over California
Hydraulic and braking measurements are lost to flight control. Temperature readings in the left wing wheel well rise 20 to 30 degrees in five minutes.

2. 8:54 A.M.
Over eastern California and Nevada
Temperature readings above left wing rise 60 degrees in five minutes.

3. 8:58 A.M.
Over Arizona
Drag on the left wing of the orbiter causes it to roll left, possibly a result of missing tiles. The shuttle's flight control system attempts to counteract the roll.

4. 8:59 A.M.
Over western Texas
Drag on the left wing again causes the shuttle to bank left. The computer system again attempts to counteract the roll. Eight tire and temperature readings are lost.

Source: NY Times, 2/03/03

Re-entry on Feb. 2:

1. 8:53 A.M. Over California

Hydraulic and braking measurements are lost to flight control. Temperature readings in the left wing wheel well rise 20 to 30 degrees in five minutes.

Source: NY Times, 2/03/03

Re-entry on Feb. 2:

2. 8:54 A.M.
Over eastern California and Nevada
Temperature readings above left wing rise 60 degrees in five minutes.

Source: NY Times, 2/03/03

Re-entry on Feb. 2:

3. 8:58 A.M.

Over New Mexico Drag on the left wing of the orbiter causes it to roll left, possibly a result of missing tiles. The shuttle's flight control system attempts to counteract the roll.

Source: NY Times, 2/03/03

Re-entry on Feb. 2:

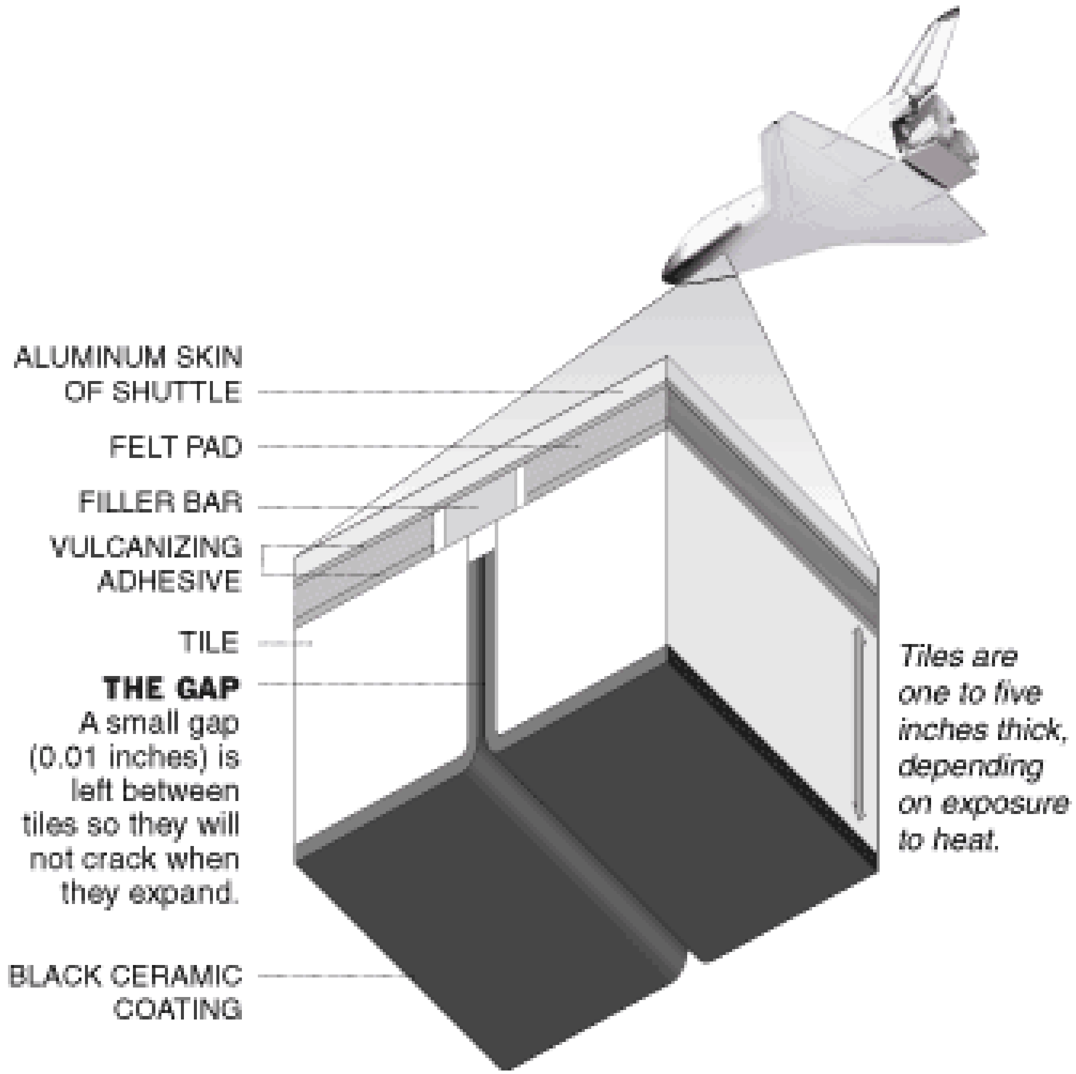
4. 8:59 A.M.

Over western Texas

Drag on the left wing again causes the shuttle to bank left. The computer system again attempts to counteract the roll. Eight tire and temperature readings are lost.

Source: NY Times, 2/03/03

The Tiles



Source: NY Times, 2/03/03

Space Shuttle Columbia: Emerging Issues

NASA Dismissed Advisers Who Warned About Safety

When an expert NASA panel warned last year that safety troubles loomed for the fleet of shuttles if the agency's budget was not increased, NASA removed five of the panel's nine members and two of its consultants. Some of them now say the agency was trying to suppress their criticisms.

Source: NY Times, 2/03/03

A sixth member, a retired three-star admiral, Bernard M. Kauderer, was so upset at the firings that he quit NASA's Aerospace Safety Advisory Panel.

"I have never been as worried for space shuttle safety as I am right now," Dr. Richard D. Blomberg, the panel's chairman, told Congress in April. "All of my instincts suggest that the current approach is planting the seeds for future danger."

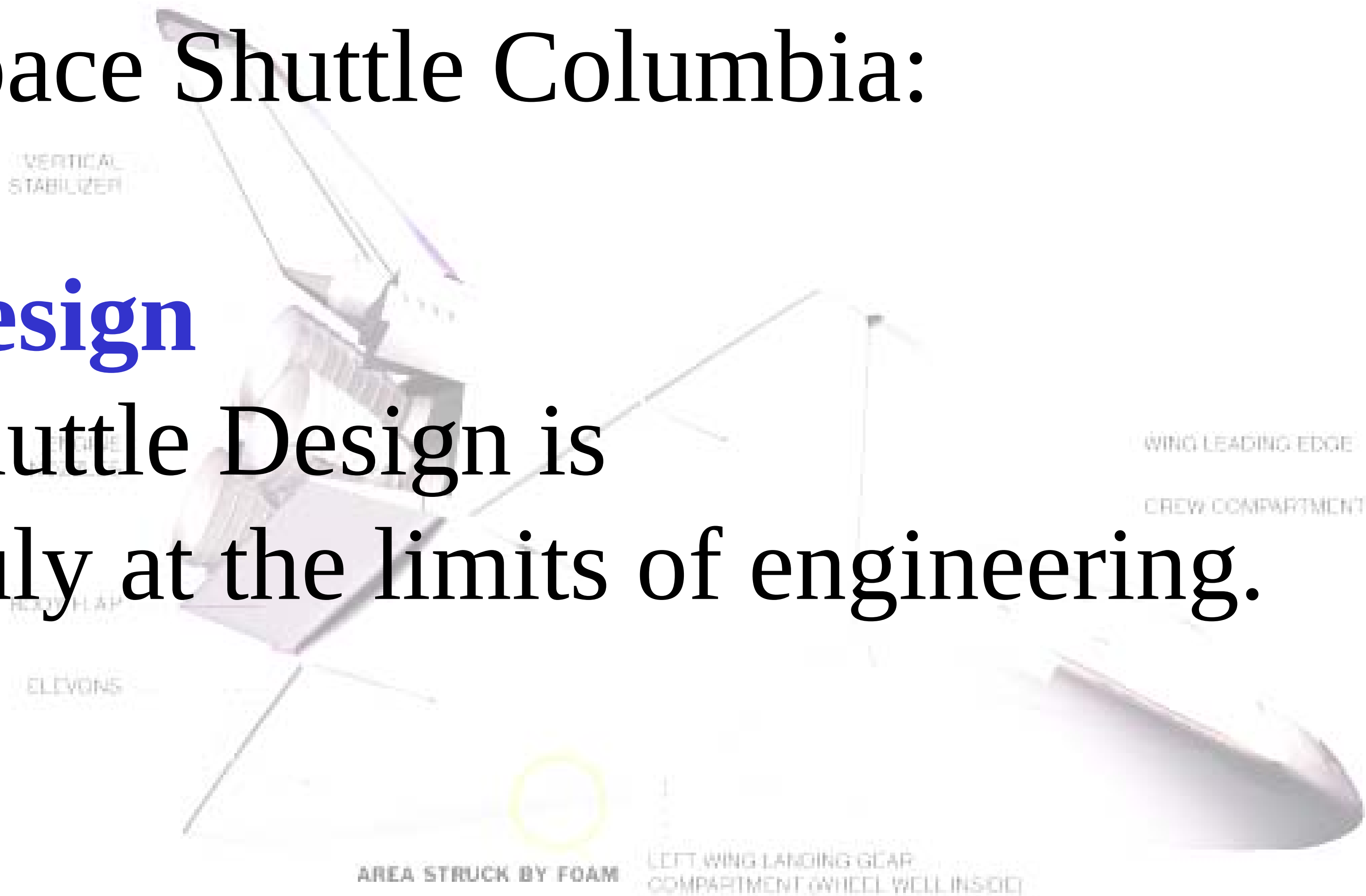
Source: NY Times, 2/03/03

Space Shuttle Columbia: What can we learn?

Space Shuttle Columbia:

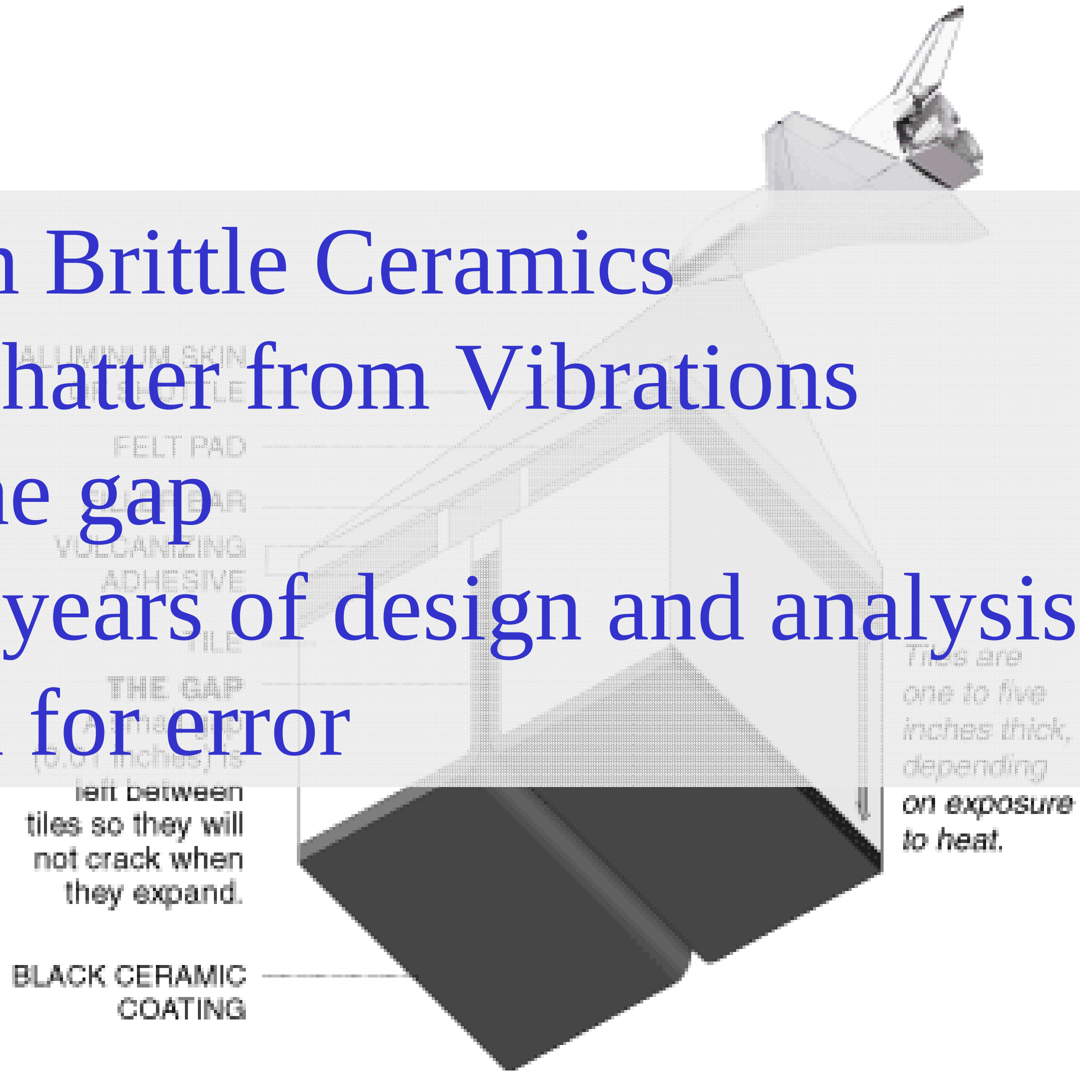
Design

Shuttle Design is
truly at the limits of engineering.



The Tiles revisited

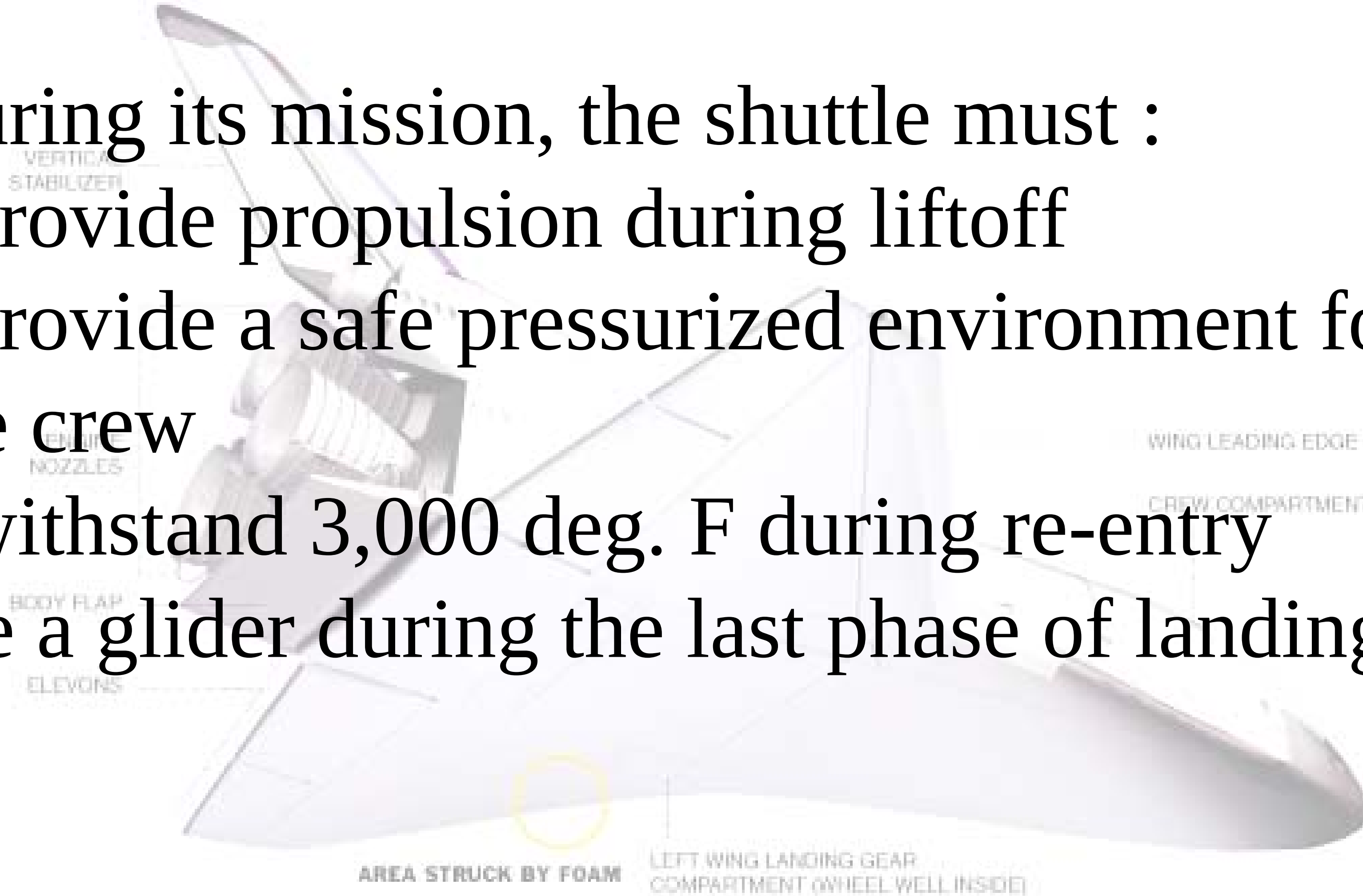
- Made from Brittle Ceramics
- Tiles can shatter from Vibrations
- Look at the gap
- Tiles took years of design and analysis
- No margin for error



Source: NY Times, 2/03/03

During its mission, the shuttle must :

- provide propulsion during liftoff
- provide a safe pressurized environment for the crew
- withstand 3,000 deg. F during re-entry
- be a glider during the last phase of landing



Primary Causes of Engineering Disasters

The primary causes of engineering disasters are usually considered to be (I) human factors (including both 'ethical' failure and accidents), (ii) design flaws (many of which are also the result of unethical practices), (iii) materials failures, (iv) extreme conditions or environments, and, most commonly and importantly, (v) combinations of these reasons.

Source:http://www.matscieng.sunysb.edu/disaster/

A recent study conducted at the Swiss federal Institute of technology in Zurich analyzed 800 cases of structural failure in which 504 people were killed, 592 people injured, and millions of dollars of damage incurred. When engineers were at fault, the researchers classified the causes of failure as follows:

Primary Causes of Engineering Disasters

Insufficient knowledge 36%
Underestimation of influence 16%
Ignorence, carelessness, Negligence... 14%
Forgetfulness, error 13%
Relying upon others without sufficient control 9%
Objectively unknown situation 7%
Unprecise definition of responsibilities .. 1%
Choice of bad quality 1%
Other 3%