Risk and Ambition:

The Columbia Shuttle Tragedy

Dr. G. Scott Hubbard,
Department of Aeronautics and Astronautics
Stanford University

The Board

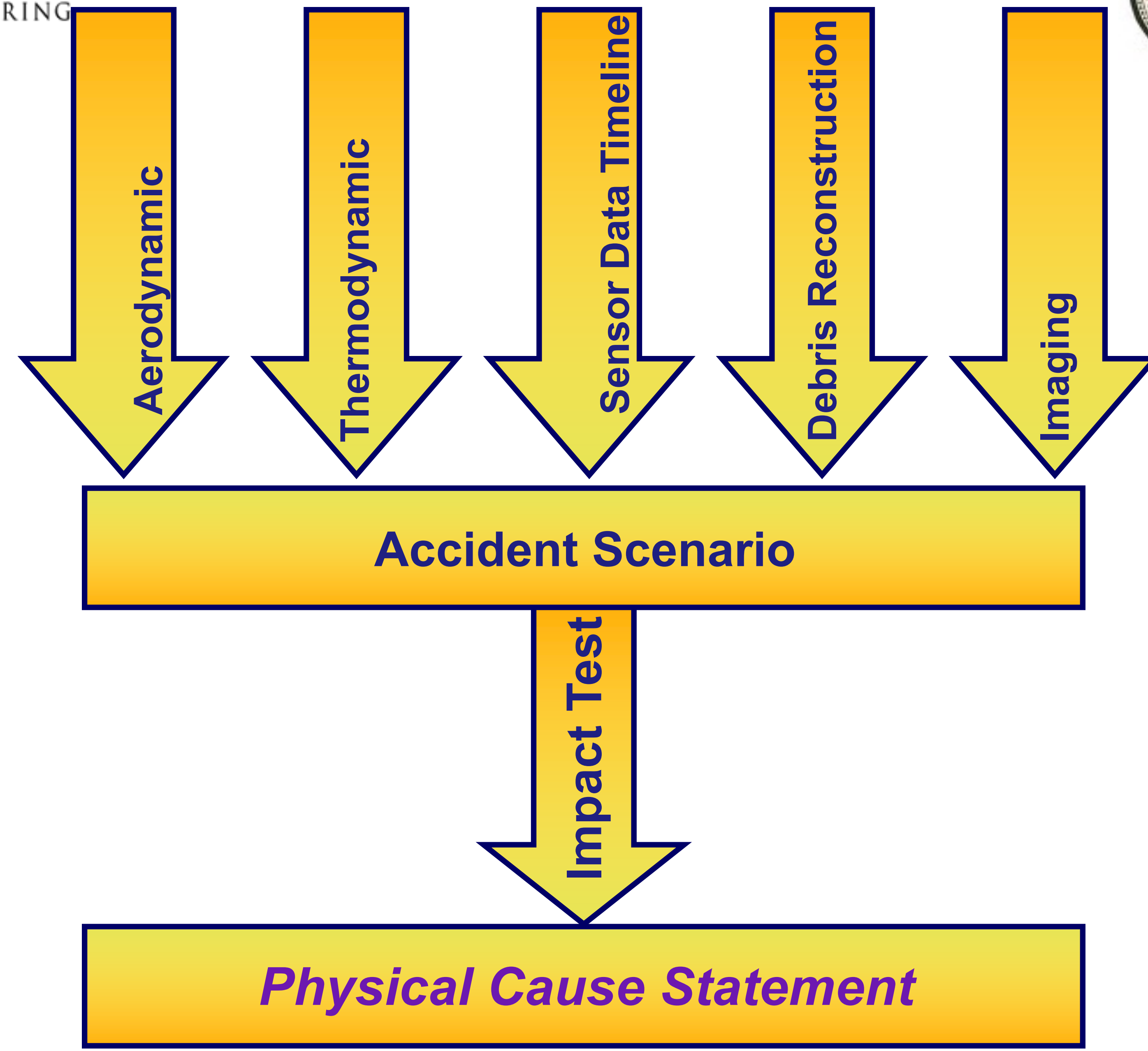
Back Row (from Left)

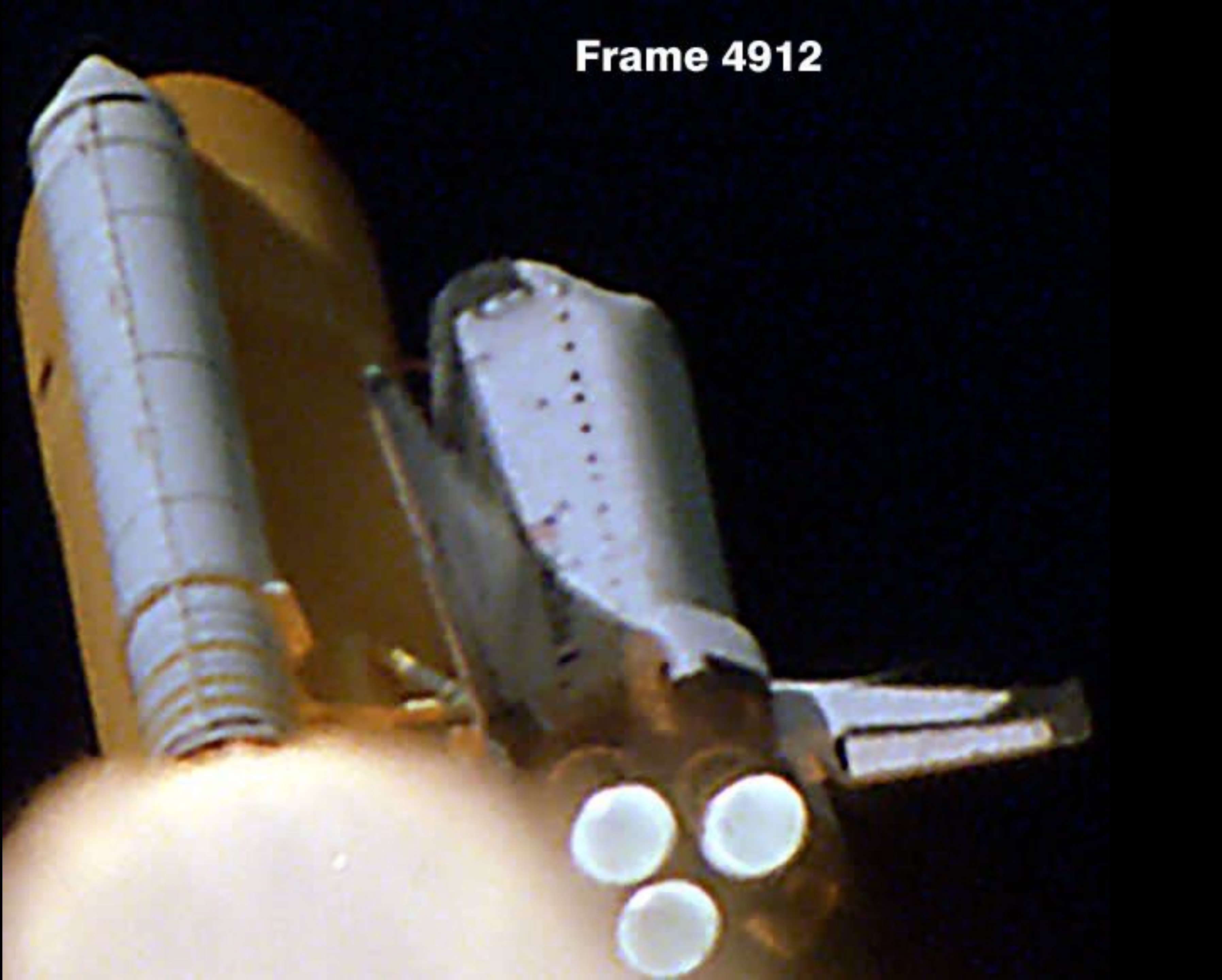
Dr. Douglas D. Osheroff, Professor of Physics and Applied Physics, Stanford University
Maj. General John Barry, Director, Plans and Programs, Headquarters Air Force Materiel Command
Rear Admiral Stephen Turcotte, Commander, Naval Safety Center
Brig. General Duane Deal, Commander, 21st Space Wing, USAF
Maj. General Kenneth W. Hess, Commander, Air Force Safety Center
Mr. Roger E. Tetrault, Retired Chairman, McDermott International, Inc.

Front Row (from Left)

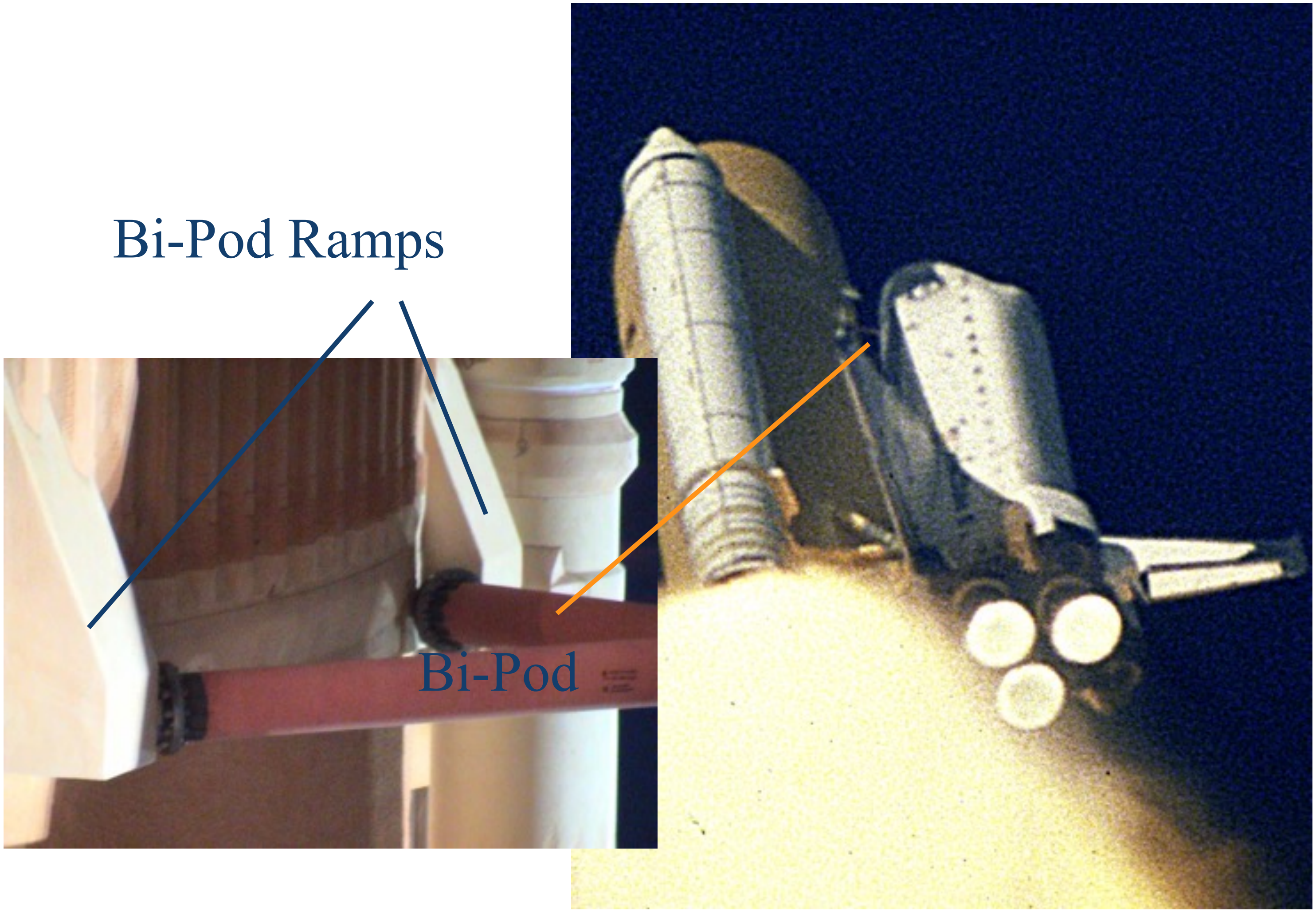
Mr. Scott Hubbard, Director, NASA Ames Research Center
Dr. James N. Hallock, Chief, Aviation Safety Division, Department of Transportation, Volpe Center
Dr. Sally Ride, Professor of Space Science, University of California at San Diego
Admiral Harold Gehman, Admiral, US Navy (retired) - Chairman
Mr. Steven B. Wallace, Director of Accident Investigation, Federal Aviation Administration
Dr. John Logsdon, Director of the Space Policy Institute, George Washington University
Dr. Sheila Widnall, Professor of Aeronautics and Astronautics and Engineering Systems, MIT

Physical Cause

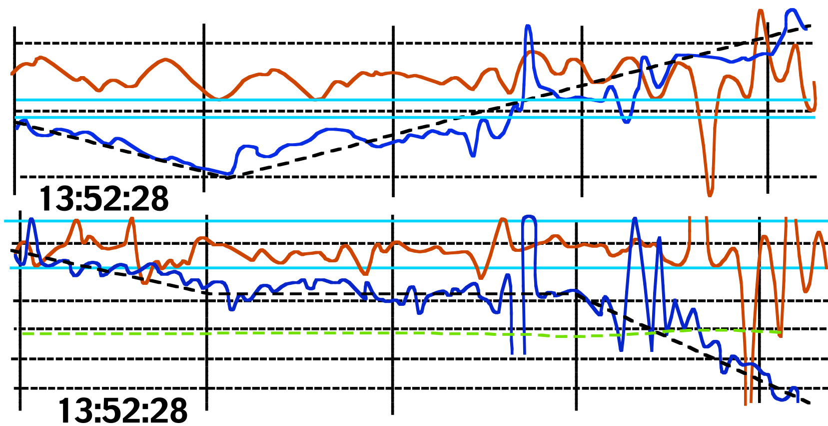



Frame 4912

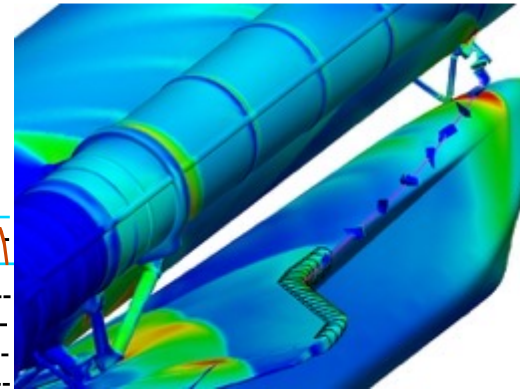
STS-107



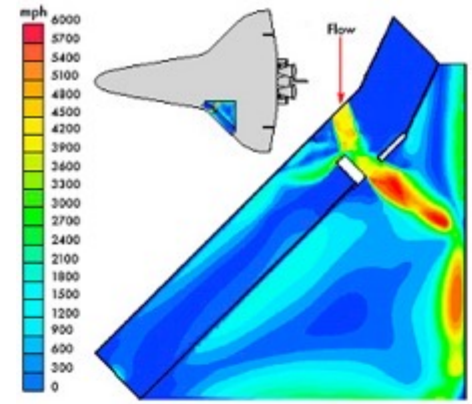
Board Analysis of Physical Cause: 5 threads



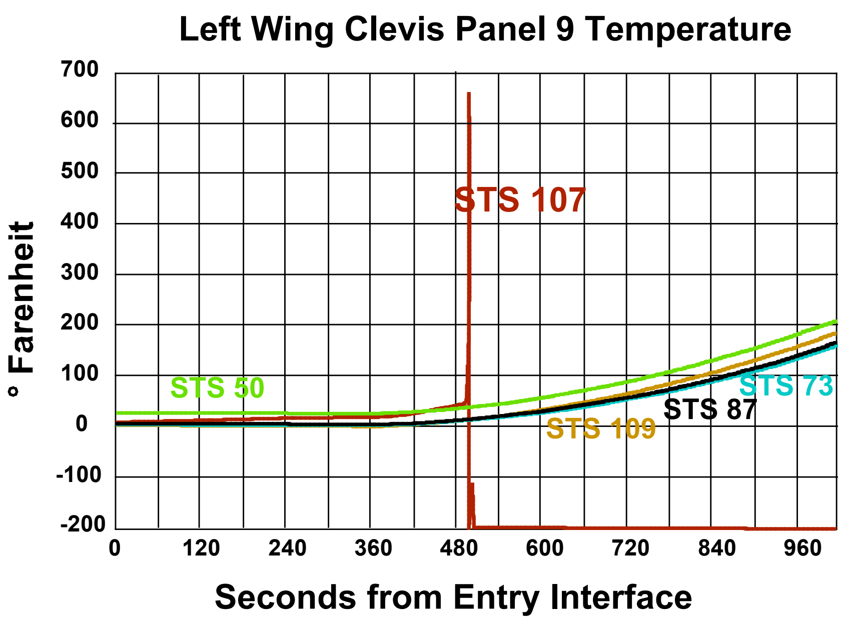
Aerodynamic:Yaw/Roll



Imagery: Impact images and debris trajectory



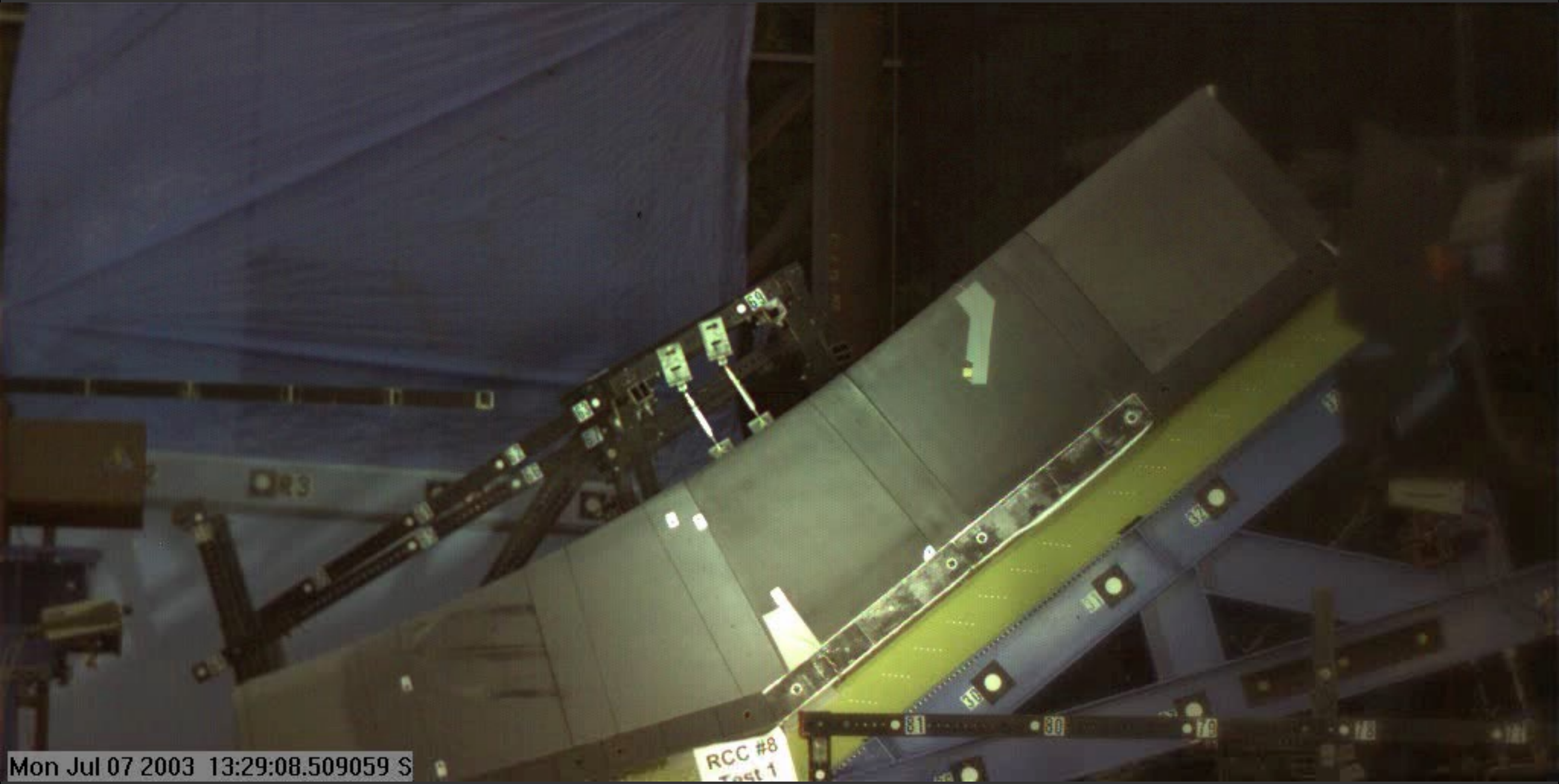
Thermodynamic:Heat flow through left wing



Sensor data matched and enhanced timeline

Debris:
25,000 searchers
~40% recovered
84,000 pieces

Wing Leading Edge Test Set Up


Mon Jul 07 2003 13:29:08.509059 S
RCC #8
Test 1

Physical Cause

- **The physical cause of the loss of Columbia and its crew was a breach in the Thermal Protection System on the leading edge of the left wing.**
- **The breach was initiated by a piece of insulating foam that separated from the left bipod ramp of the External Tank and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon panel 8 at 81.9 seconds after launch. During re-entry, this breach in the Thermal Protection System allowed superheated air to penetrate the leading-edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and breakup of the Orbiter.**

Organizational Cause

- **The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle Program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterizations of the Shuttle as operational rather than developmental, and lack of an agreed national vision.**
- **Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.**

These findings may have application to other Agencies and companies

Accident Theory

- **High Reliability vs Normal Accident**
  - **High-Reliability Theory**
    - >Organizations operating high-risk technologies, if properly designed and managed, can compensate for inevitable human shortcomings, and thus avoid mistakes that under other circumstances would lead to catastrophic failures.
    - >Works from the bottom up—if each component is highly reliable then the system will be highly reliable and safe.
  - **Normal Accident Theory,**
    - >Organizational and technological complexity contributes to failures.
    - >Organizations that aspire to failure-free performance are doomed to inevitably fail because of the inherent risks in the technology they operate.
    - >Emphasizes systems approaches and systems thinking

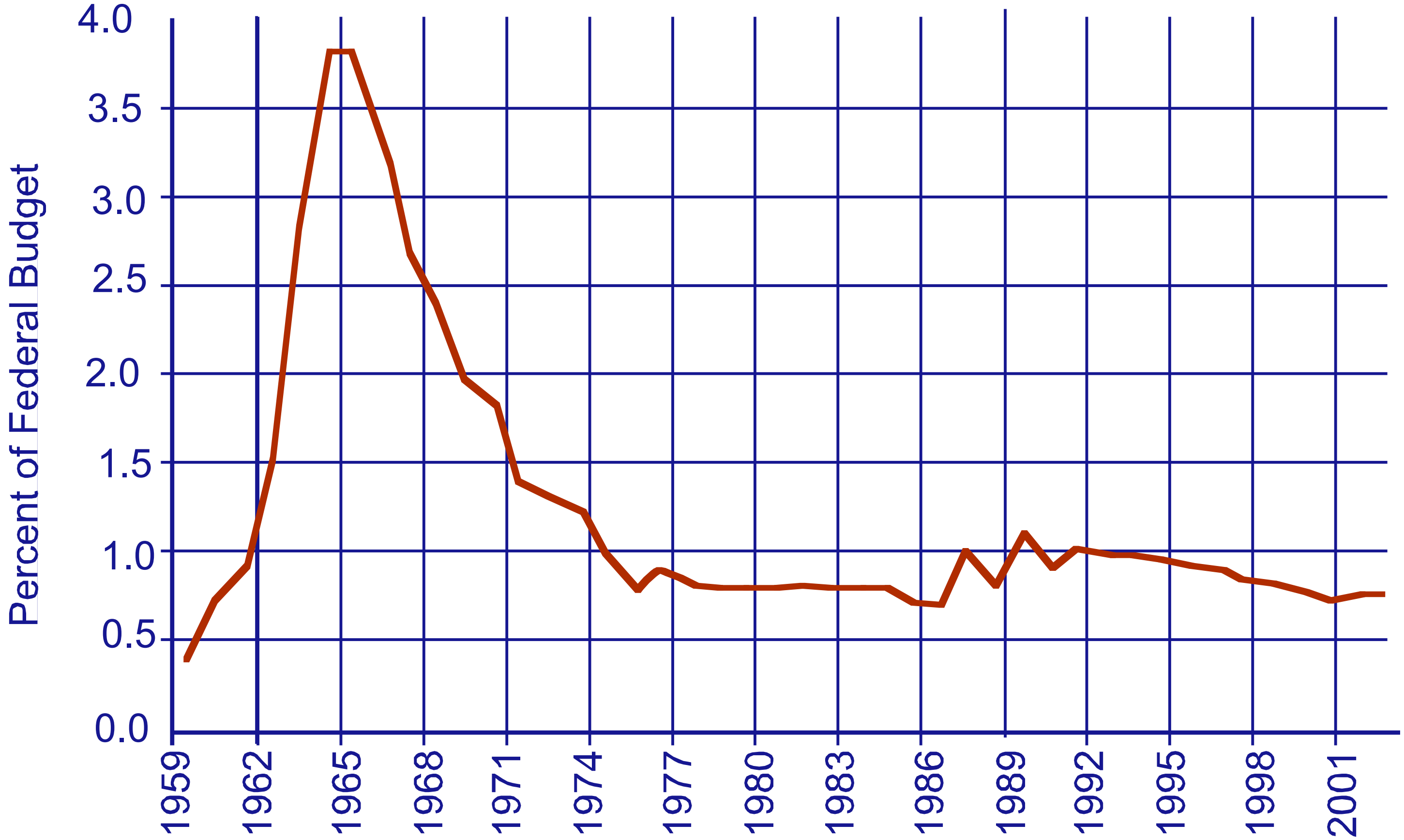
  - **Though neither High Reliability Theory nor Normal Accident Theory is entirely appropriate for understanding the Columbia accident, insights from each figured prominently in the Board's deliberation. Fundamental to each theory is the importance of strong organizational culture and commitment to safety in building successful safety strategies.**

CAIB Report Organizational Issues

- **Selected causes with broad applications:**
  - **Engineering and safety compromises in the face of programmatic (schedule or budget) pressures or constraints**
    - **>Need for an independent technical authority**
  - **How “mischaracterization” of unexpected performance shapes decision making**
  - **Relying on past success instead of sound engineering**
  - **Organizational barriers to effective communication**
  - **Lack of opportunity to express minority opinions**
  - **Lack of integrated management across program elements**

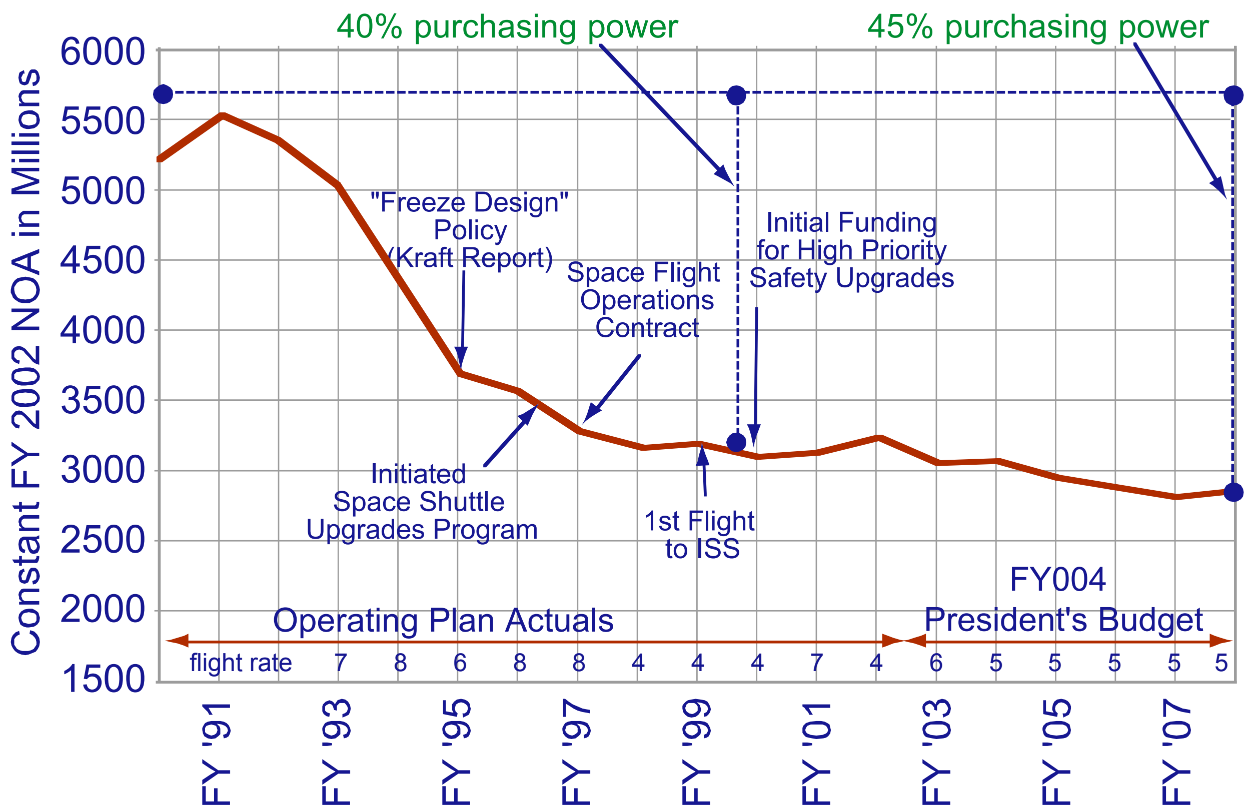
NASA's Budget History

- **Since the early 1970's, NASA has received 20% or less of the funding available to it during the Apollo Program**



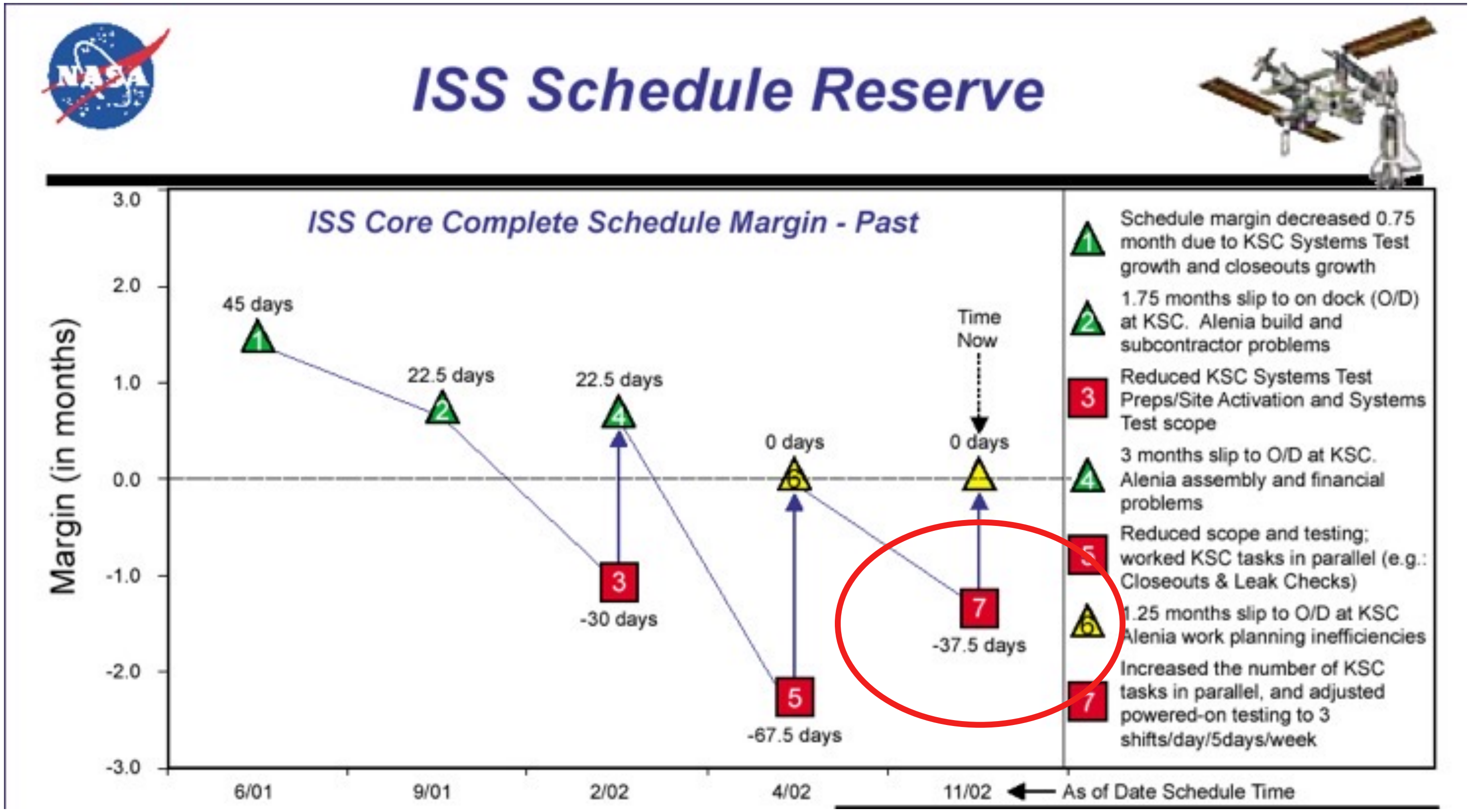
Shuttle Program Budget History

- NASA continued to pursue an ambitious agenda on a level budget; adopted a "faster, better, cheaper" approach, various managerial changes, and budget and workforce cuts to finance this agenda
- As largest single NASA program, Space Shuttle bore more than its share of these cuts



Engineering and Safety Compromises

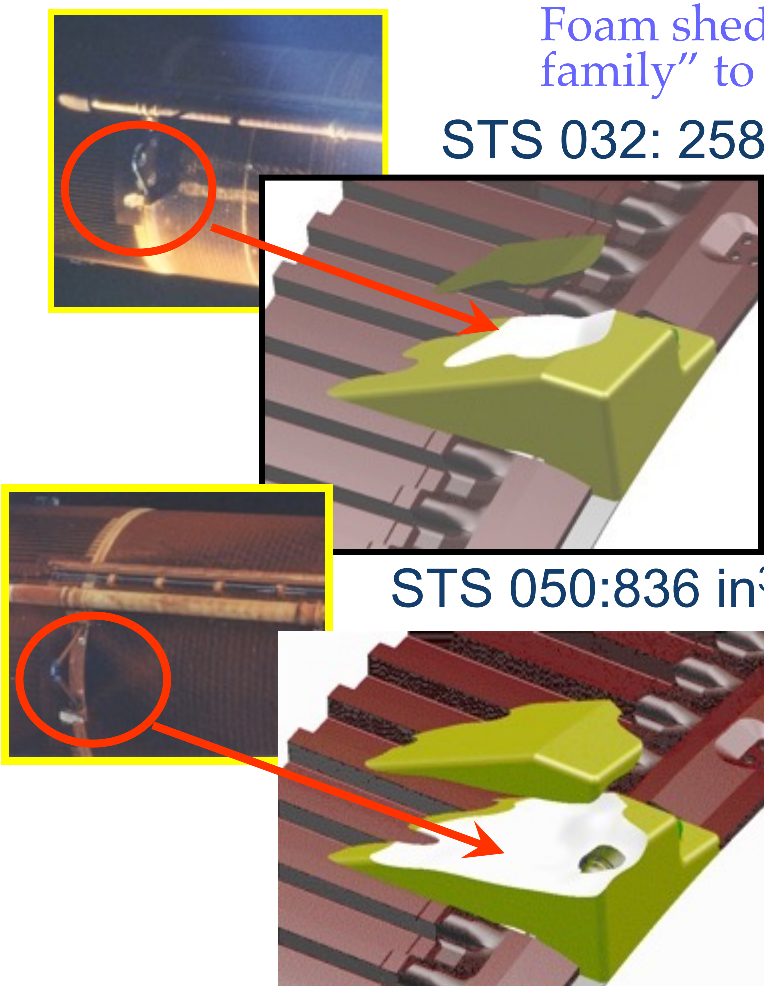
"Organizations that successfully deal with high-risk technologies create and sustain a disciplined safety system capable of identifying, analyzing, and controlling hazards throughout a technology's life cycle."

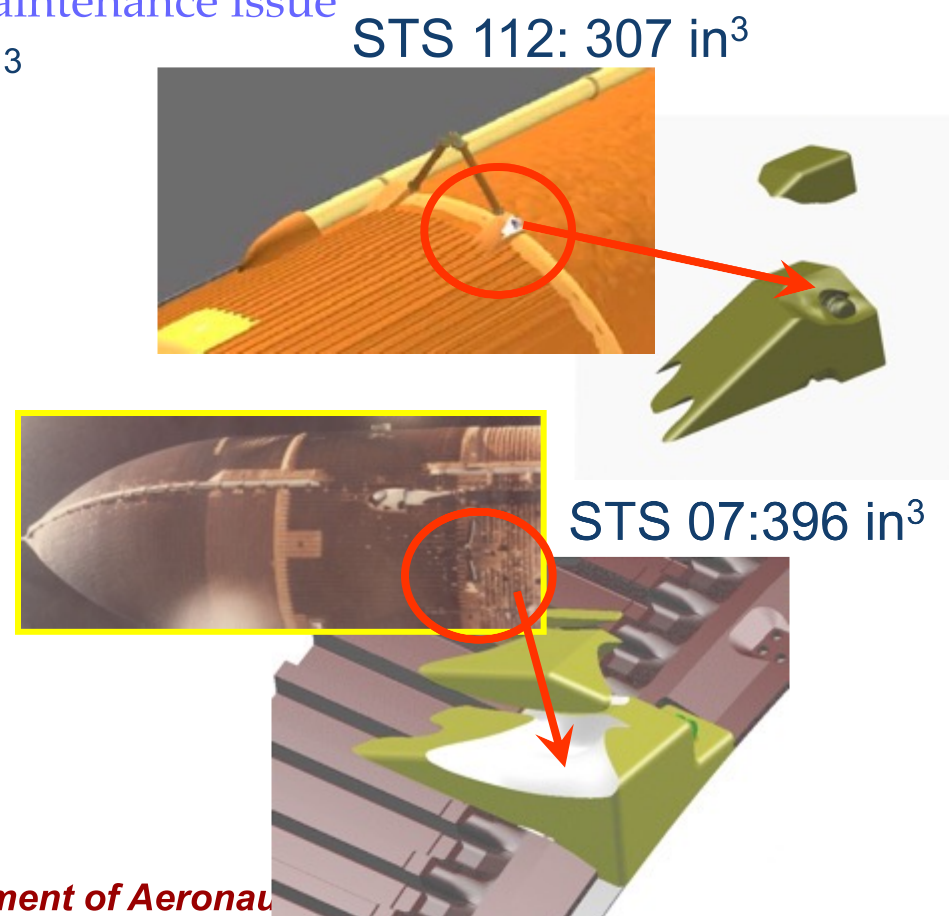


"Mischaracterizations" and Decision Making

"…learned attitudes about foam diminished management's wariness of the danger of debris hits. The Shuttle Program turned "the experience of failure into the memory of success.""

Foam shedding moved from inflight anomaly to "in family" to maintenance issue





Past Success vs Sound Engineering

"The stockpile stewardship program is designed to enable LLNL scientists and engineers to make…critical decisions based on complete, accurate scientific knowledge."

STS 112 landing at KSC

Successful mission despite significant foam shedding event.

Effective Communication

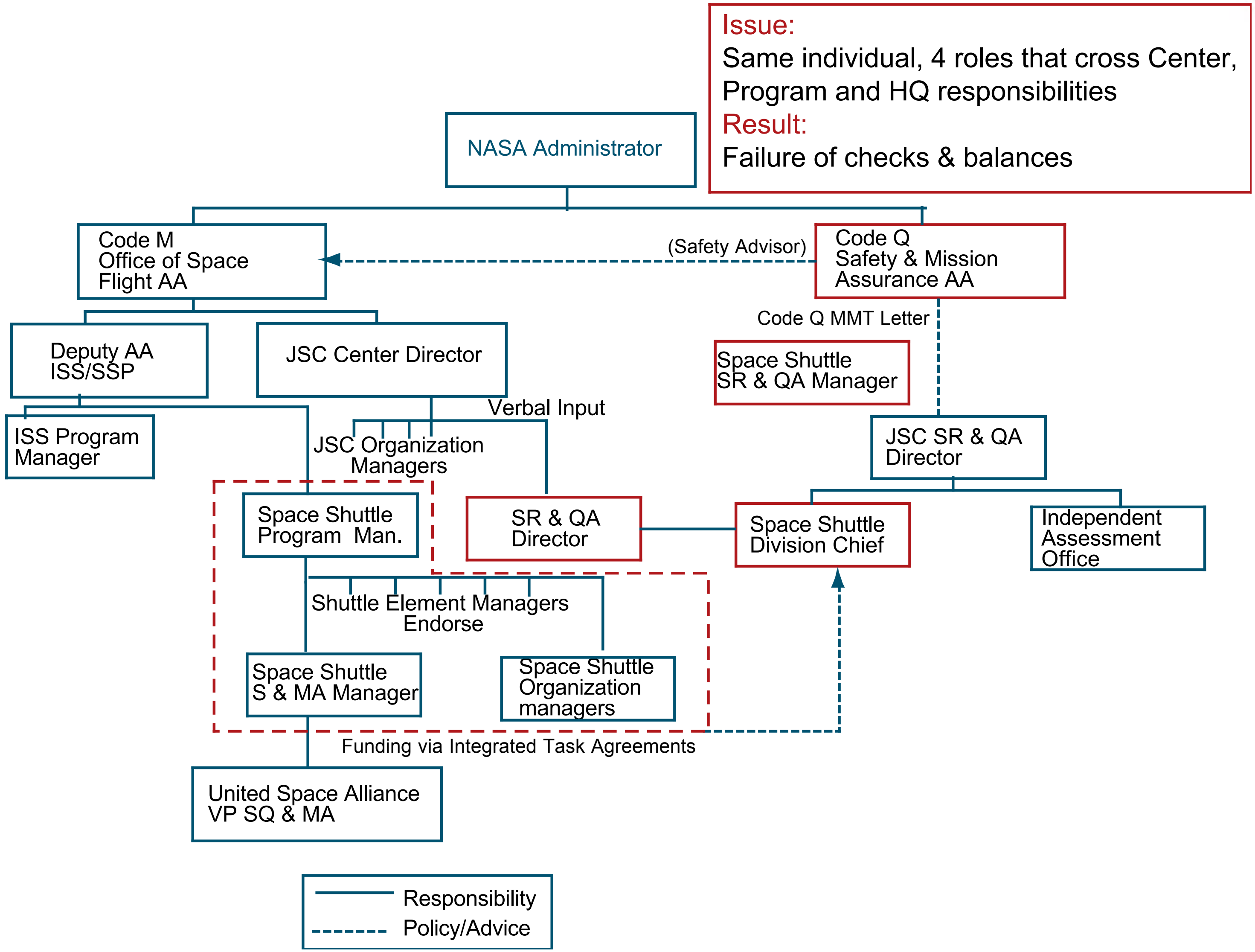
Johnson Space Center

"During the flight of Columbia….program leaders spent at least as much time making sure hierarchical rules and processes were followed as they did trying to establish why anyone would want a picture of the Orbiter. These attitudes are incompatible with an organization that deals with high-risk technology."

Expression of Minority Opinions

"Leaders continually emphasize that when no minority opinions are present, the responsibility of a thorough critical examination falls to management. Alternative perspectives and critical questions are always encouraged."

Integrated Management Problems



Independent Technical Authority

CAIB Recommendation 7.5-1: Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System... The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

The Navy's SUBSAFE Program was benchmarked by the CAIB as a successful response to the Thresher disaster

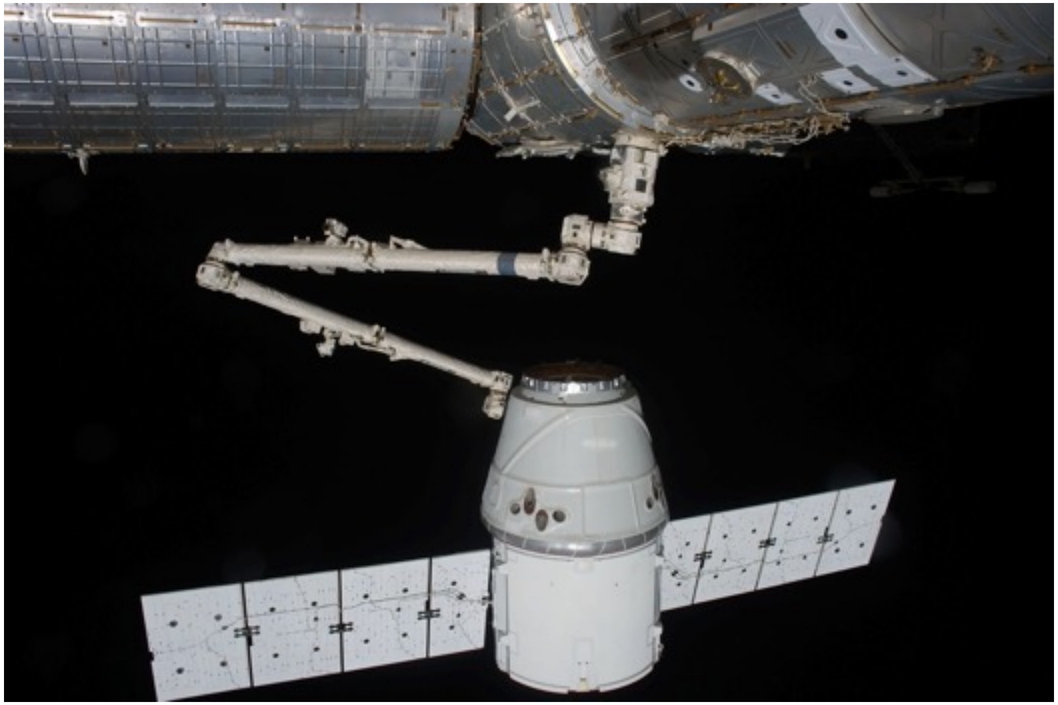
Postscript:
What Happened Since Columbia?

- Administrator of NASA Accepted all CAIB recommendations
- A major "Return to Flight" effort was launched to address all technical issues
- Independent Technical Authority Established
- New safety oversight personnel appointments made
- Agency wide "safety culture" training initiated
- Shuttle flights safely completed to the end of the Program: July 21, 2011

Final Shuttle landing: STS-135

STANFORD ENGINEERING

Today’s Relevance: Commercial Resupply to ISS Begun



Orbital Sciences

Cygnus berths with ISS

One mishap

- July 2014 – failure of refurbished Soviet engine in Antares ELV

SpaceX Dragon returns to flight

Two mishaps

- June 2015 – strut failure; poor materials screening
- Sept 2016 – tank failure in new environment

Commercial Crew selection:
Boeing, SpaceX


BROWN
CLARK
CHAWLA
ANDERSON
HUSBAND
MCCOOL
STS