# Challenger and Columbia Lessons Learned

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The Space Shuttle Challenger and Columbia accidents resulted in tragic loss of life and national assets, and investigations into both accidents produced important lessons to prevent future accidents.

# Challenger and Columbia Lessons Learned

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Lessons Learned Session

TCC-ACIT EHS Seminar

"Those who cannot remember the past are condemned to repeat it."

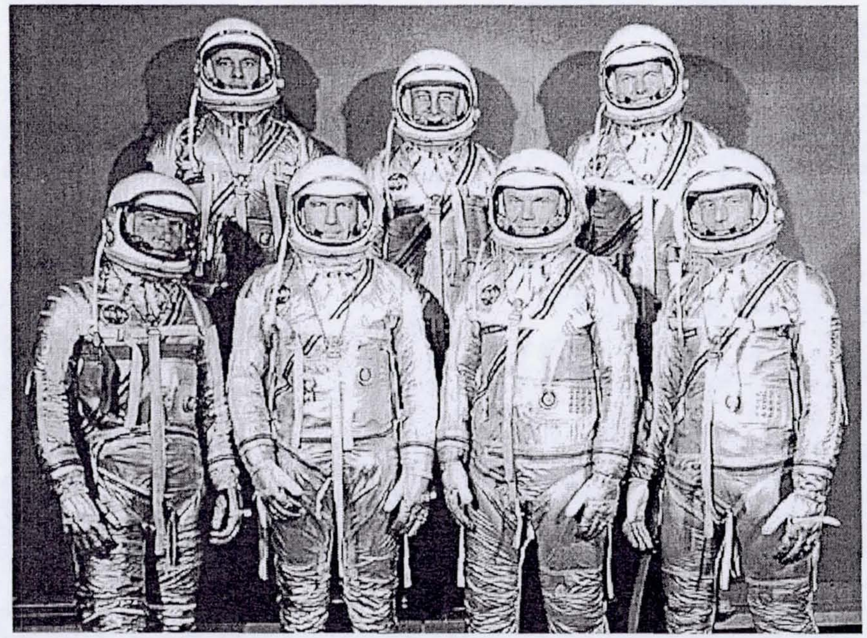
George Santayana,
The Life of Reason Vol. 1, 1905

"Insanity is doing the same thing and expecting different results."

Albert Einstein

# NASA's Legacy Prior to Challenger

- Mercury
  - 1st American in Space
  - 1st American in Earth Orbit
  - 6 missions
  - 34 hours longest mission duration



# Challenger and Columbia Lessons Learned

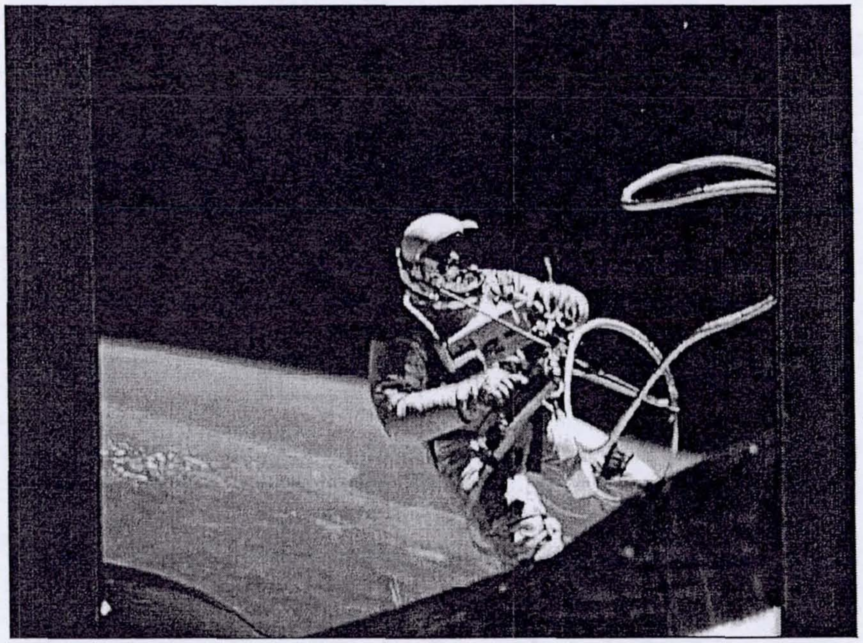
Agenda

- Legacy of NASA Prior to Challenger
- Challenger Accident
- Challenger Findings
- NASA Response to Challenger
- Columbia Accident
- Columbia Findings
- NASA Response to Columbia
- Common Lessons Learned

The Future

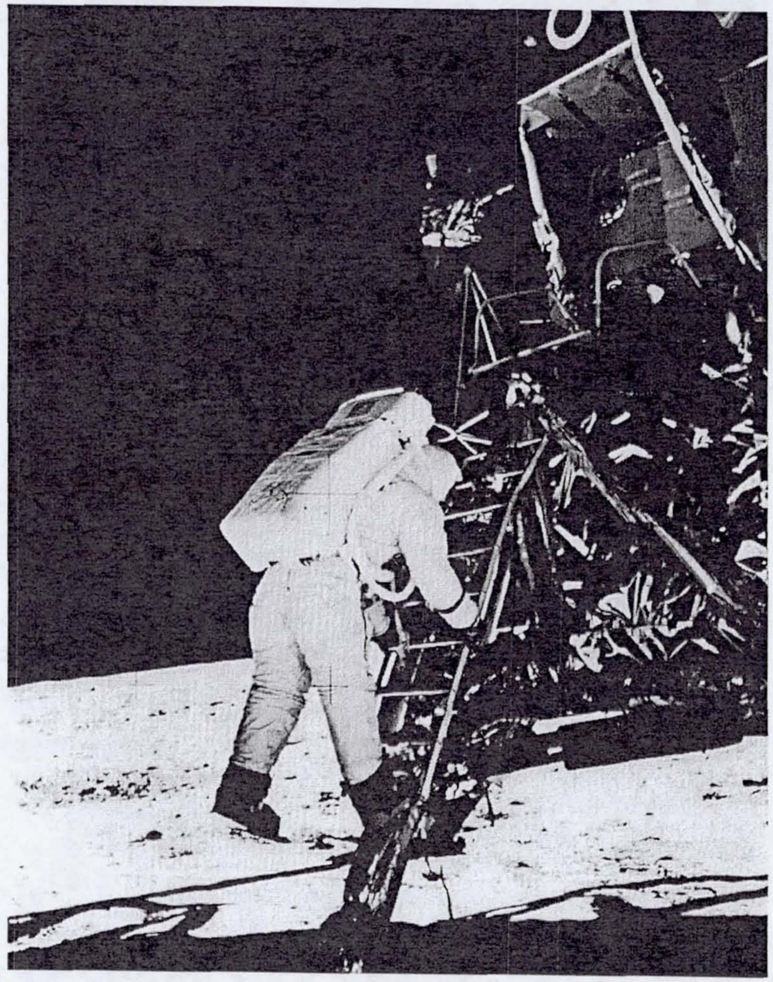
# NASA's Legacy Prior to Challenger

- Gemini
  - Two crew members in space for up to 2-weeks
  - 1st Space walks
  - Orbital docking and maneuvering
  - 10 manned flights

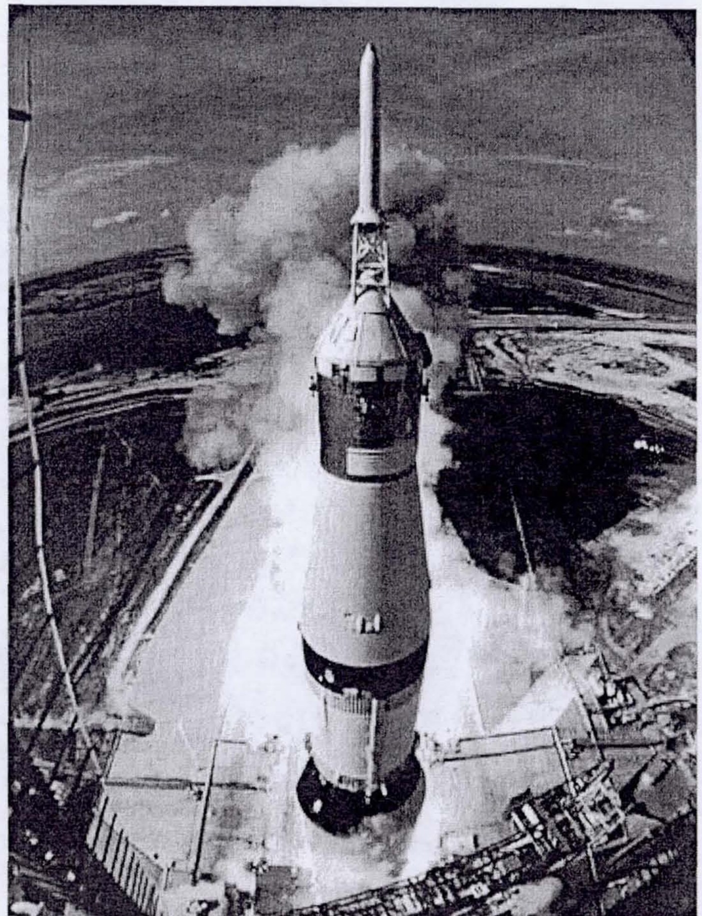


# NASA's Legacy Prior to Challenger

- Apollo
  - Lunar landing and return to Earth
  - 11 crewed missions
    - 2 earth orbit
    - 2 lunar orbit
    - Lunar swingby
    - 6 lunar landings



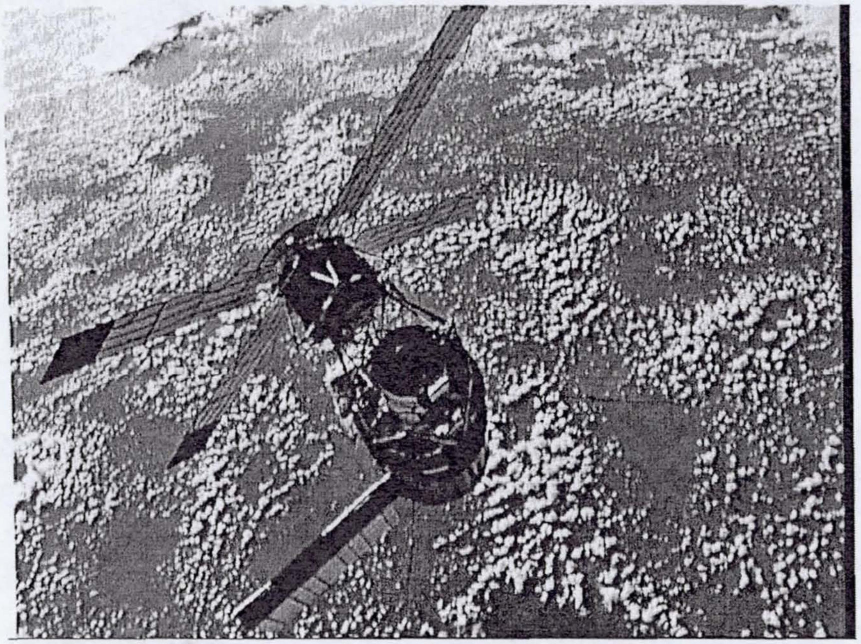
# NASA's Legacy Prior to Challenger

Apollo 11 (launch, on moon, in orbit)
NASA Langley Research Center 6/16/1989 Image # EL-2001-00482

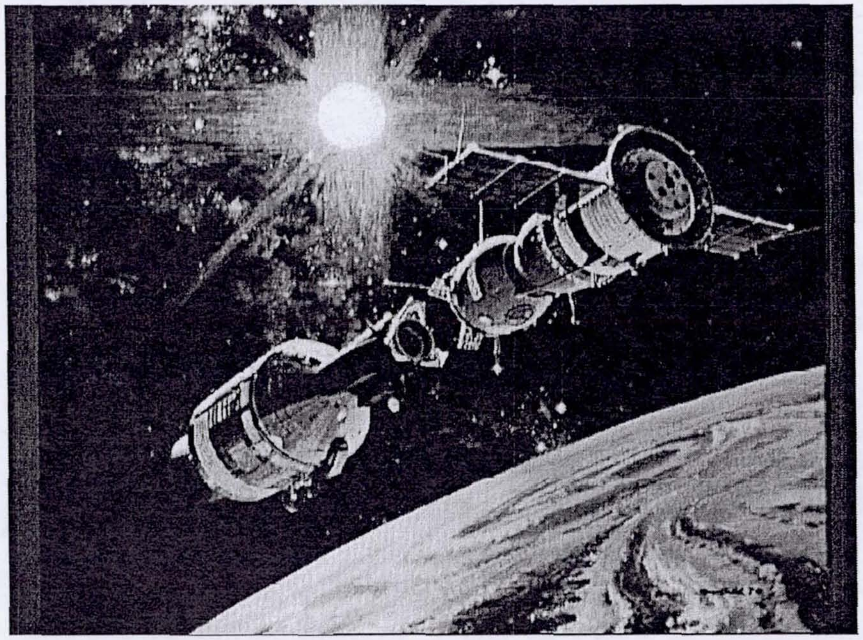
# NASA's Legacy Prior to Challenger

- Skylab
  - 1st US space station
  - 3 crew members
  - 3 missions, 29, 59, and 84 days
  - Experimental and observational platform



# NASA's Legacy Prior to Challenger

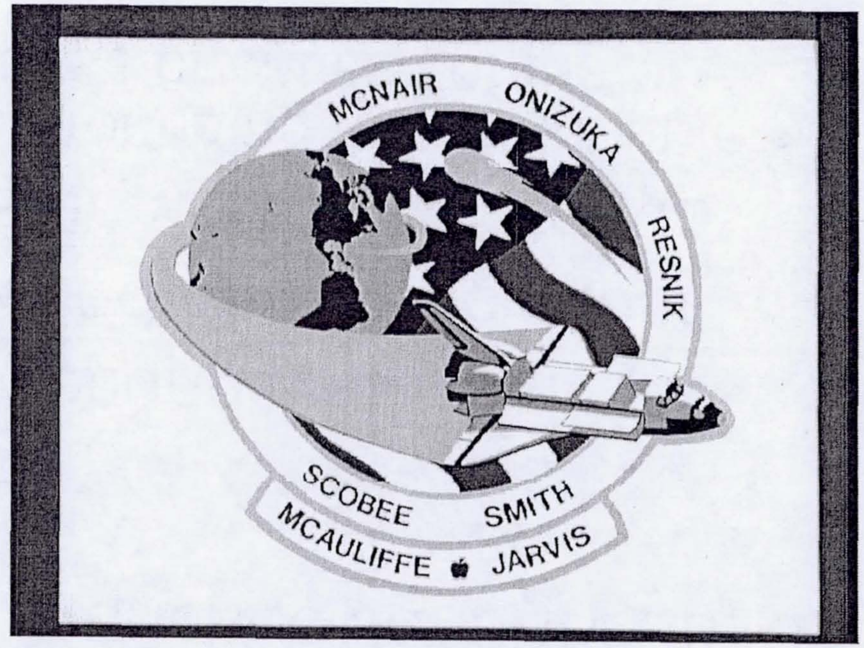
- Apollo-Soyuz
  - 1st international manned spaceflight
  - Test rendezvous and docking system compatibility
  - Opening for future manned spaceflights
  - 1975



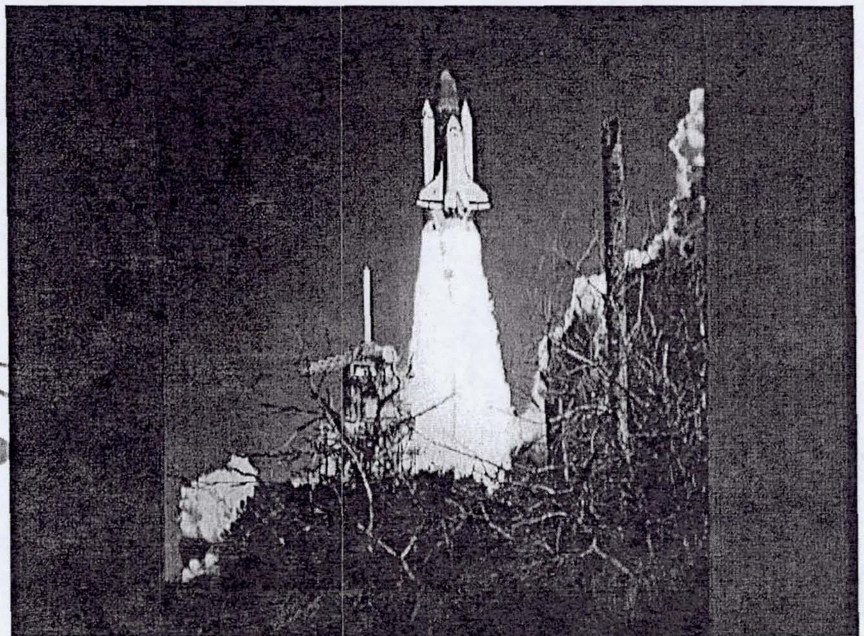
# The Challenger Accident

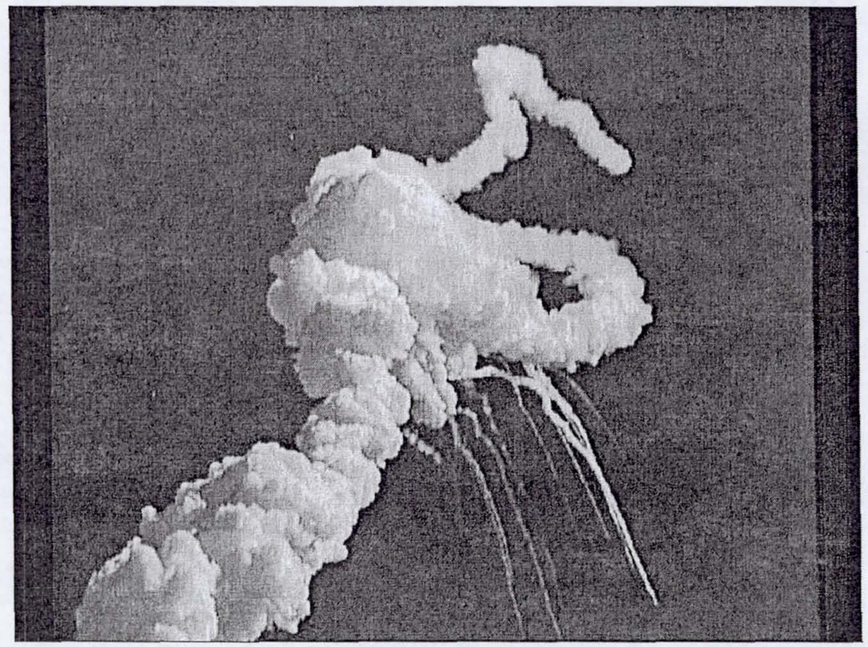
- Challenger mission 51L launched January 28, 1986
  - $25^{th}$ Space Shuttle Mission
- Challenger was lost 73 seconds into its flight
- 7 crew members were killed, the vehicle lost
- A Presidential Commission was appointed to
  - Review circumstances surrounding the accident to establish the probable cause or causes of the accident; and
  - Develop recommendations for corrective or other action based upon the Commission's findings and determinations.

# Challenger Accident



# Challenger Accident

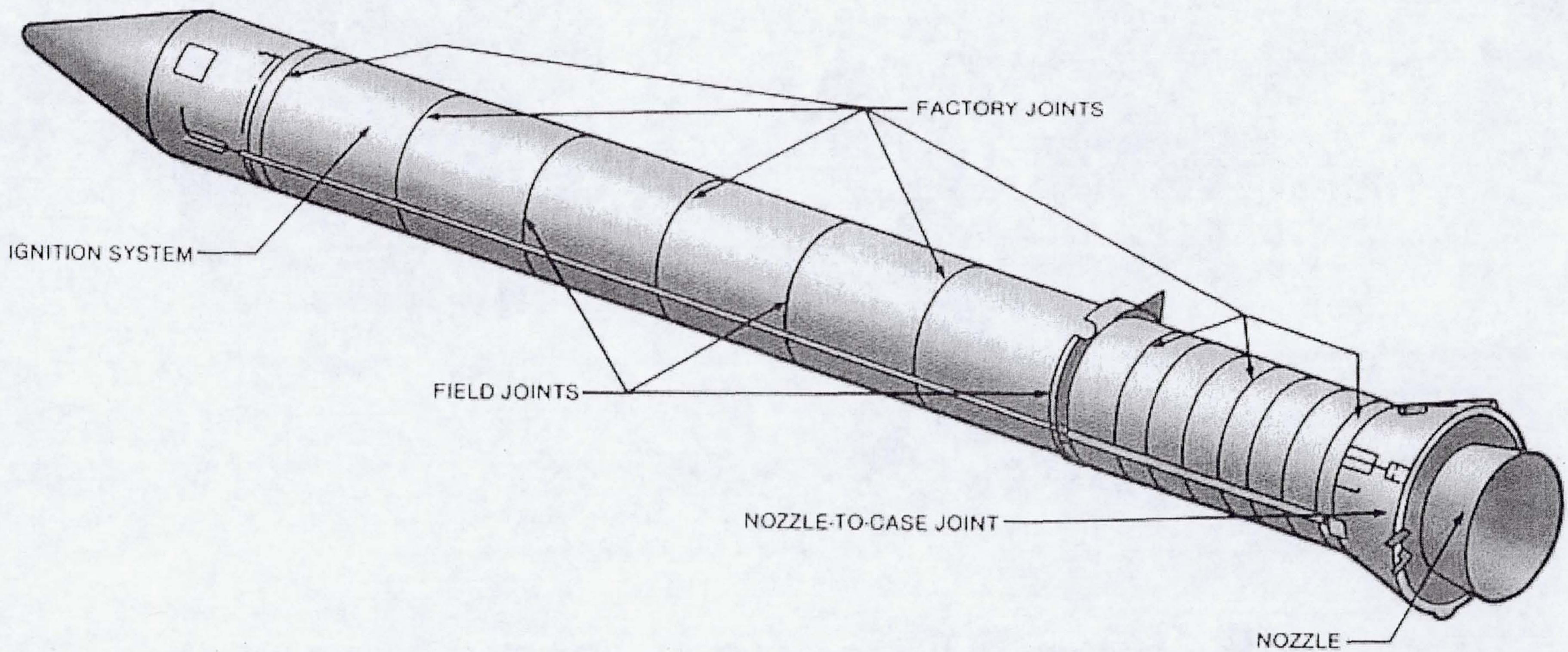




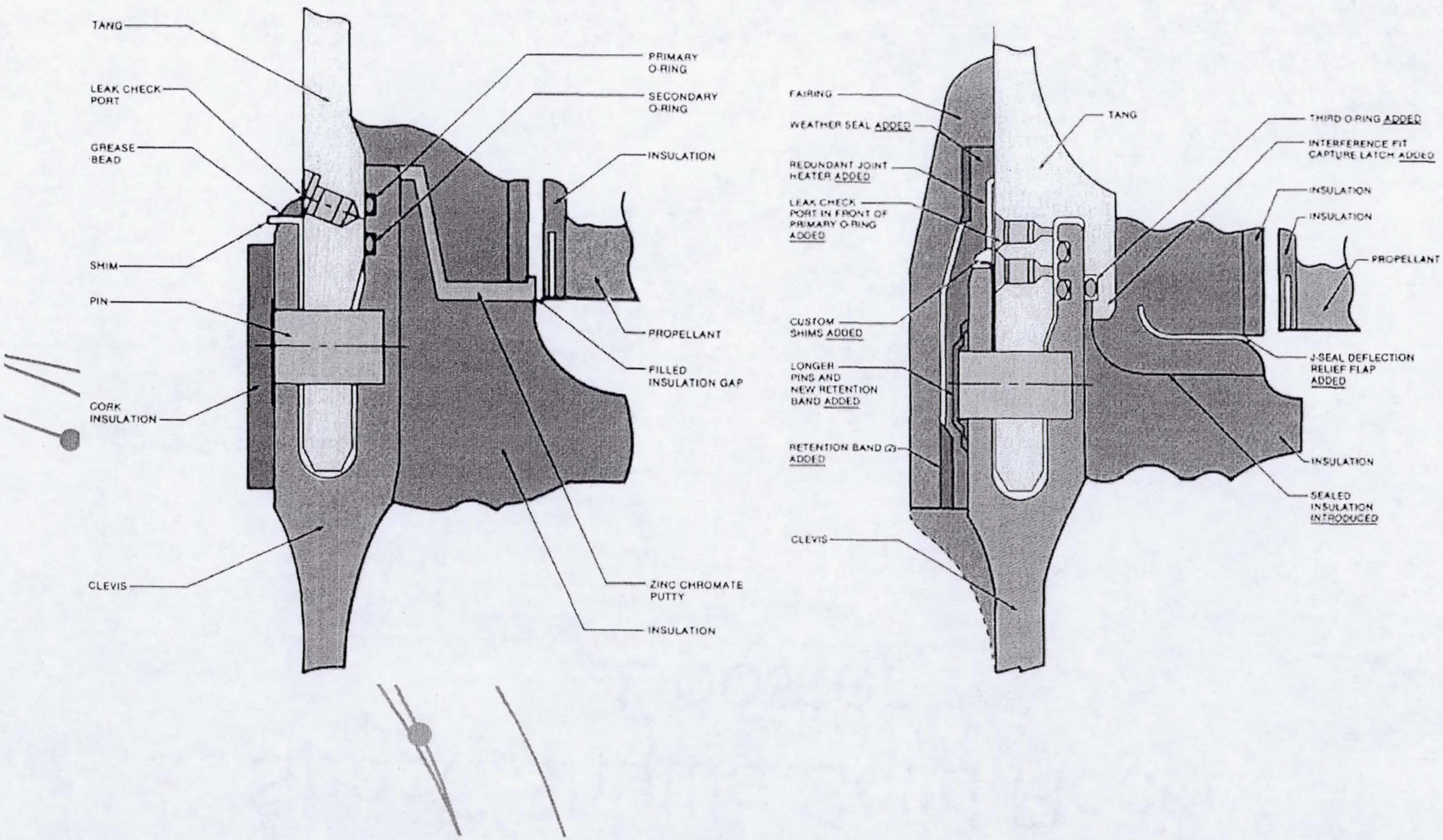
# Challenger Commission Findings

- The cause of the Challenger accident was the failure of the pressure seal in the aft field joint of the right Solid Rocket Motor.

# Space Shuttle Solid Rocket Booster



# SRB Field Joint Redesign



# Challenger Commission Findings

- Faulty design unacceptably sensitive to a number of factors
- Factors were effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing, and the reaction of the joint to dynamic loading

# Challenger Commission Contributing Cause Findings

- Decision making process seriously flawed leading up to launch of Challenger
- Waiving of launch constraints appeared to be at expense of flight safety and was not reviewed by all levels of management
- Marshall management appears to hold potentially serious problems internally

# Challenger Commission Contributing Cause Findings

- Rockwell recommendation regarding ice-on-the-pad was ambiguous
- NASA's response did not indicate appropriate consideration of Rockwell's input
- Freeze protection on the pad was inadequate

# Challenger Commission Findings
# Accident Rooted in History

- SRM joint test and certification program inadequate
- Neither NASA nor Thiokol understood join sealing mechanisms
- NASA and Thiokol accepted escalating risk because they " got away with it last time"

# Challenger Commission Findings
# Accident Rooted in History

- Tracking of anomalies for Flight Readiness Reviews failed in not identifying joint seal failures on previous flights
- O-ring failure history presented to NASA Level I August 1985 was sufficient to require corrective action before next flight
- A careful flight history analysis would have revealed the correlation of O-ring damage with low temperatures

# Challenger Commission Findings
# Silent Safety Program

- Reductions in Marshall safety, reliability, and quality assurance work force limited capability in those functions
- Organization structures at Kennedy and Marshall place safety, reliability, and quality assurance offices under the offices whose activities they are to check
- Problem reporting requirements are not concise and fail to communicate to proper management

# Challenger Commission Findings
# Silent Safety Program

- Little or no trend analysis on O-ring problems
- As flight rate increased, safety, reliability, and quality assurance workforce at Marshall was decreasing, adversely affecting safety
- Five weeks after the Challenger accident, the criticality of the SRM field joint was not properly documented in the Marshall problem reporting system

# Challenger Commission Findings
# Pressures on the System

- Shuttle flight processing and training system capabilities were stretched to limit due to flight rate
- Spare parts were in critically short supply
- When flights occur in rapid succession, no system in place to ensure anomalies are addressed before next flight

# Challenger Commission Recommendations

I. Redesign SRB with Independent Oversight

II. Place more authority with Program Management

Assign Astronauts to Management

Establish a Shuttle Safety Panel

III. Review critical items and hazards analysis

IV. Establish an Office of Safety Reliability and Quality Assurance at Headquarters

# Challenger Commission Recommendations (continued)

V. Improve Communications
   I. Constraints
   II. FRR records and attendees
VI. Landing Safety
VII. Launch Abort and Crew Escape
   I. Provide a crew escape system for gliding flight

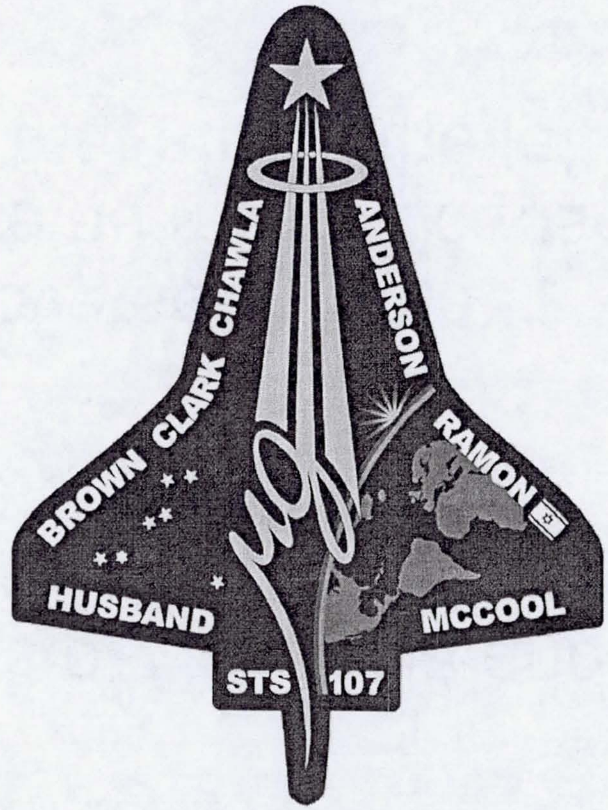
# NASA Response to Challenger

- Redesigned SRM with Independent Oversight of Design Activities
- Reorganized Shuttle Management to Report to Headquarters
- Appointed Astronauts to Management Positions (Associate Administrator for Space Flight)
- Established Shuttle Safety Panel

# The Columbia Accident

- Columbia's mission STS-107 launched on January 16, 2003
  - 113th Space Shuttle Mission
- Columbia was lost during atmospheric reentry February 1, 2003
- 7 crew members were killed
- NASA Administrator Appointed Investigation Team
- Determine the facts, as well as the actual or probable causes of the Shuttle mishap in terms of dominant and contributing root causes and significant observations and, recommend preventive and other appropriate actions to preclude recurrence of a similar mishap.

# Columbia Accident

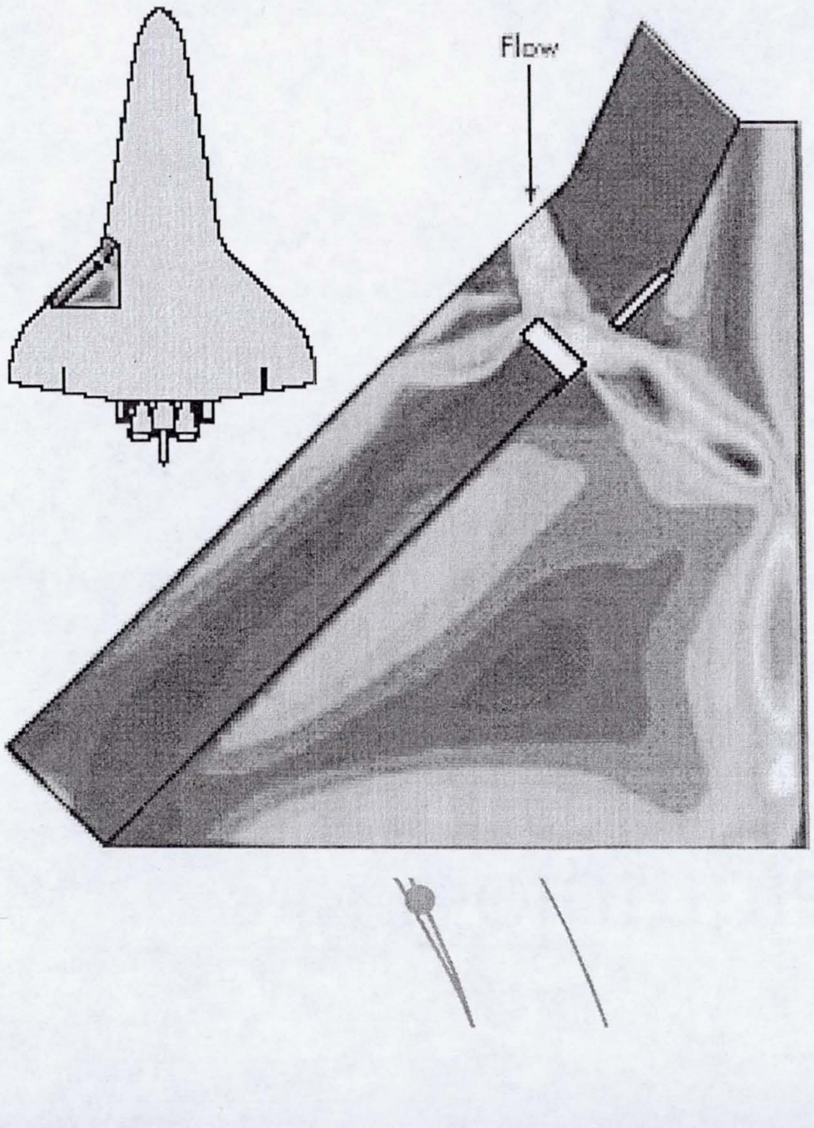


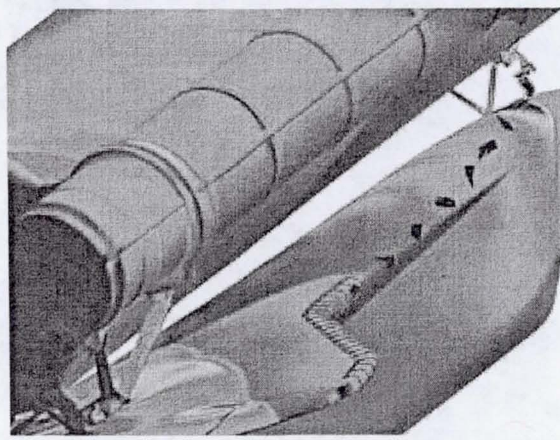
# Columbia Accident Investigation Board Findings

"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 management practices overseeing the Space Shuttle Program were as much a cause of the accident as the foam that struck the left wing."

# Columbia Accident



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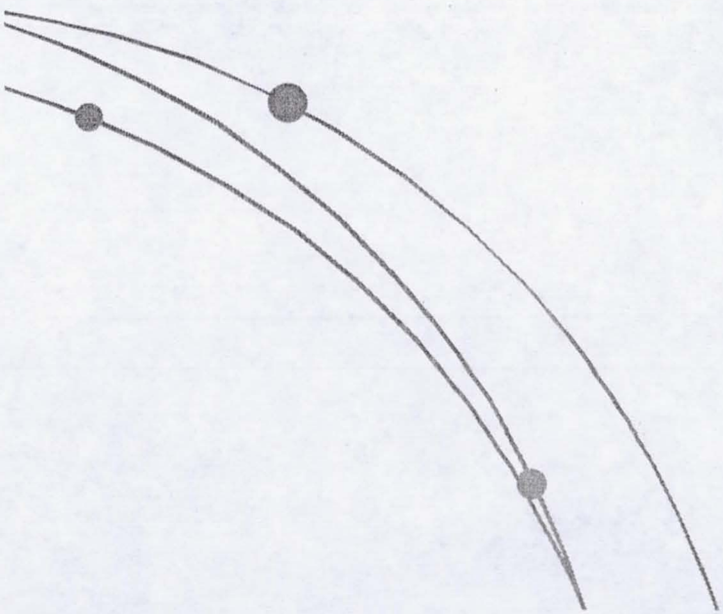
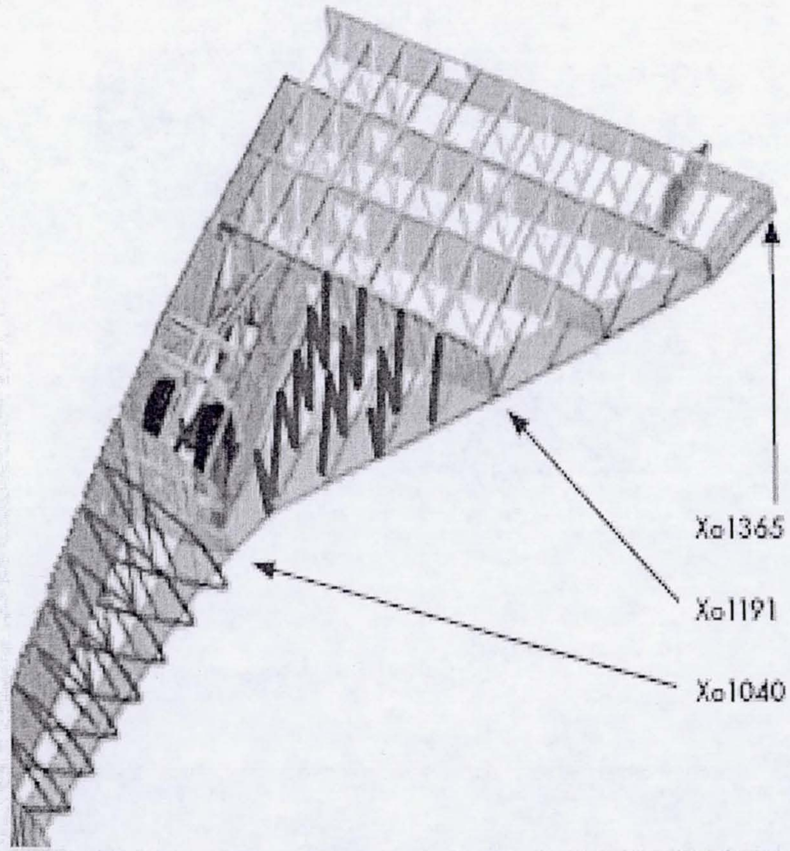




# Columbia Findings

Technical

- NASA does not fully understand External Tank (ET) foam loss mechanisms
- 80% of 79 missions with imagery have had ET foam loss
- Reinforced Carbon-Carbon (RCC) not required to have impact resistance
- Inspection techniques inadequate for RCC
- Two foam closeout processes on ET able to be performed by one-person

# CAIB Findings

Technical

- Photographic evidence indicated foam projectile impacted leading edge of left wing in area of RCC panels 6 through 9
- Data on foam was adequate to determine its effect on both thermal tiles and RCC
- Columbia entered atmosphere with preexisting breach in left wing
- NASA debris impact analysis tools inadequate

# NASA Response to Columbia

Technical

- SRB bolt catcher certification done by analysis
- Quality assurance on bolt catchers not adequate to assure product acceptability
- Unknown metal object seen separating from Shuttle during SRB separation on 6 missions

# CAIB Findings

Organization

- By Columbia, many institutional practices in place at Challenger had returned
  - Silent Safety Program
  - Acceptance of deviations from expected performance
  - Schedule pressure
- Space Flight Operations Contract

# CAIB Findings

Organization

- Shuttle budget reduced 40% over last decade
- Shuttle workforce reduced by 42% between 1993 and 2002

# CAIB Findings

Organization

- NASA did not follow its rules on foam shedding
- Foam shedding evolved from serious safety concern to in-family or no safety of flight risk or accepted risk
- Lack of feedback among projects on in-flight anomalies

# CAIB Findings

Organization

- Resolution of STS-112 foam loss in-flight not due until after Columbia mission
- No trend analysis performed on foam loss
- NASA headquarters focus on ISS schedules
- System capabilities stretched to support schedule

# CAIB Findings

Organization

- NASA safety system historically deficient
- Administrator for SR&QA not responsible for execution but instead policy
- Little progress in integrated Shuttle hazards analysis
- Shuttle Systems Integration office handles all systems except Orbiter
- Lessons learned are not part of process

# CAIB Findings

Decision Making

- Foam strike identified during photo review on flight day 2 larger than any seen before
- Outside imagery of Orbiter for damage assessment requested by Chair of photo working group on flight day 2
- Debris team model used outside calibrated database
- Uncertainties in analysis not communicated to management
- RCC damage not mentioned in management briefings

# CAIB Findings

Leadership

- Management not engaged in foam analysis
- Management had belief that foam strike not a safety of flight issue
- Management required engineers to prove debris strike was unsafe instead of safe
- Management did not challenge presentations

# CAIB Recommendations

29 Recommendations

- Eliminate ET foam shedding
- Toughen Orbiter TPS
- Improve inspection of RCC
- Develop on-orbit inspection and repair of TPS and RCC
- Develop validated analysis models for debris assessment

# CAIB Recommendations

- Provide sensors on Orbiter for vehicle health and monitoring
- Develop wiring inspection techniques
- Require at least 2-employees attend all ET foam closeouts
- Develop flight schedule that is resource driven

# CAIB Recommendations

- Conduct mission management team training
- Establish independent technical authority responsible for requirements and waivers
- Establish Safety and Mission Assurance with line authority over program
- Update drawings and verify configuration accuracy with closeout photos

# NASA's Response to CAIB

- NASA is addressing technical and organizational causes of accidents
- Formed NASA Engineering and Safety Center for technical oversight of programs
- NASA Implementation Plan for Space Shuttle Return to Flight and Beyond
  - Addressing all CAIB recommendations and observations
- Return to Flight Oversight Committee
- Addressing cultural issues through management structural changes, assessment, and training

# Challenger and Columbia Common Lessons Learned

- *Provide continual, independent, program oversight and program review functions that emphasize safety.*
- *Ensure quality program and safety management that have clear definition of authority and responsibility and have resources commensurate with requirements.*
- *Maintain comprehensive and effective program processes and systems that support the safety risk management function.*

# Challenger and Columbia Common Lessons Learned

- *Maintain realistic plans that have provisions for flexibility, minimize outside pressures and stress flight and ground safety.*
- *Control effectively the development of critical items with respect to performance environments, tolerances, margins, manufacturing processes, testing and safety.*

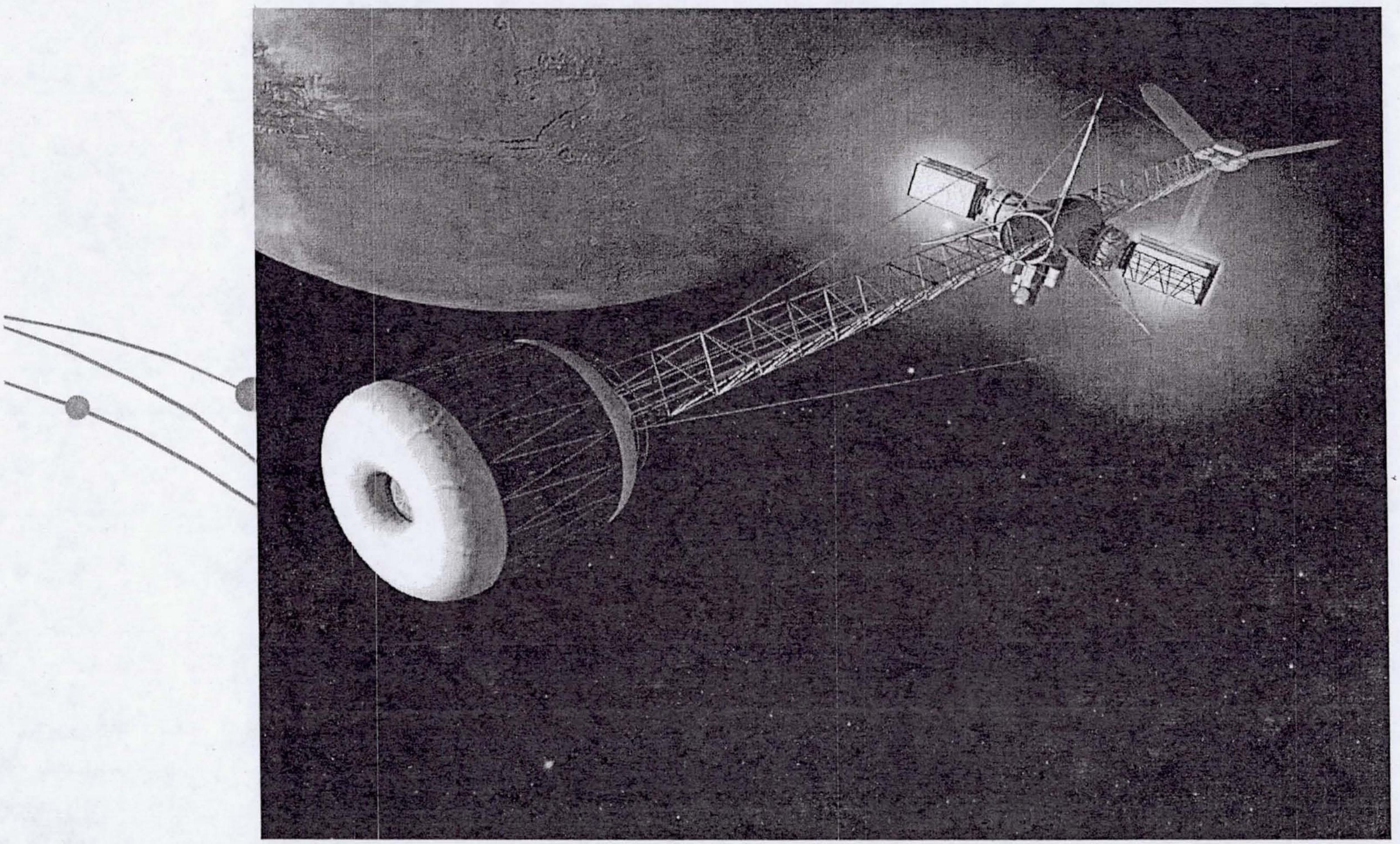
# Challenger and Columbia Common Lessons Learned

- *Ensure quality performance of work force involved in safety critical operations including adherence to required procedures and constraints.*
- *Provide cultural climate conducive to expression of differing opinions and open dialog*

# The Future

- Vision for Space Exploration issued by President Bush January 14, 2004
- Fly Shuttle until 2010
- Complete Space Station Assembly
- Focus Station research on space exploration goals
- Begin robotic missions to moon by 2008, human missions to moon by 2020
- Continue Mars robotic exploration
- Conduct human missions to Mars after capability exists
- Develop a Crew Exploration Vehicle to support exploration

“This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart”
President George W. Bush



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