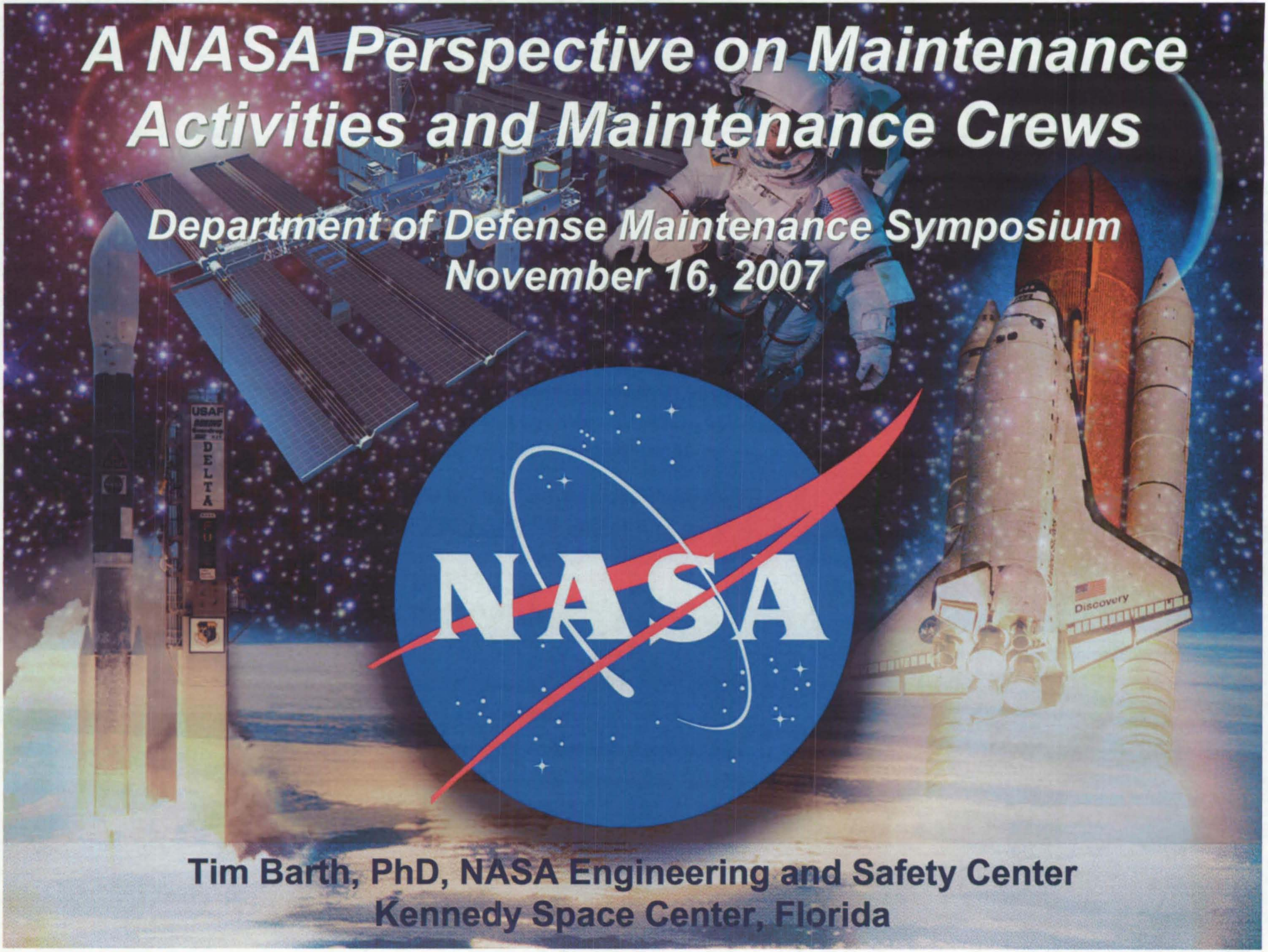
A NASA Perspective on Maintenance Activities and Maintenance Crews

Department of Defense Maintenance Symposium
November 16, 2007



Tim Barth, PhD, NASA Engineering and Safety Center
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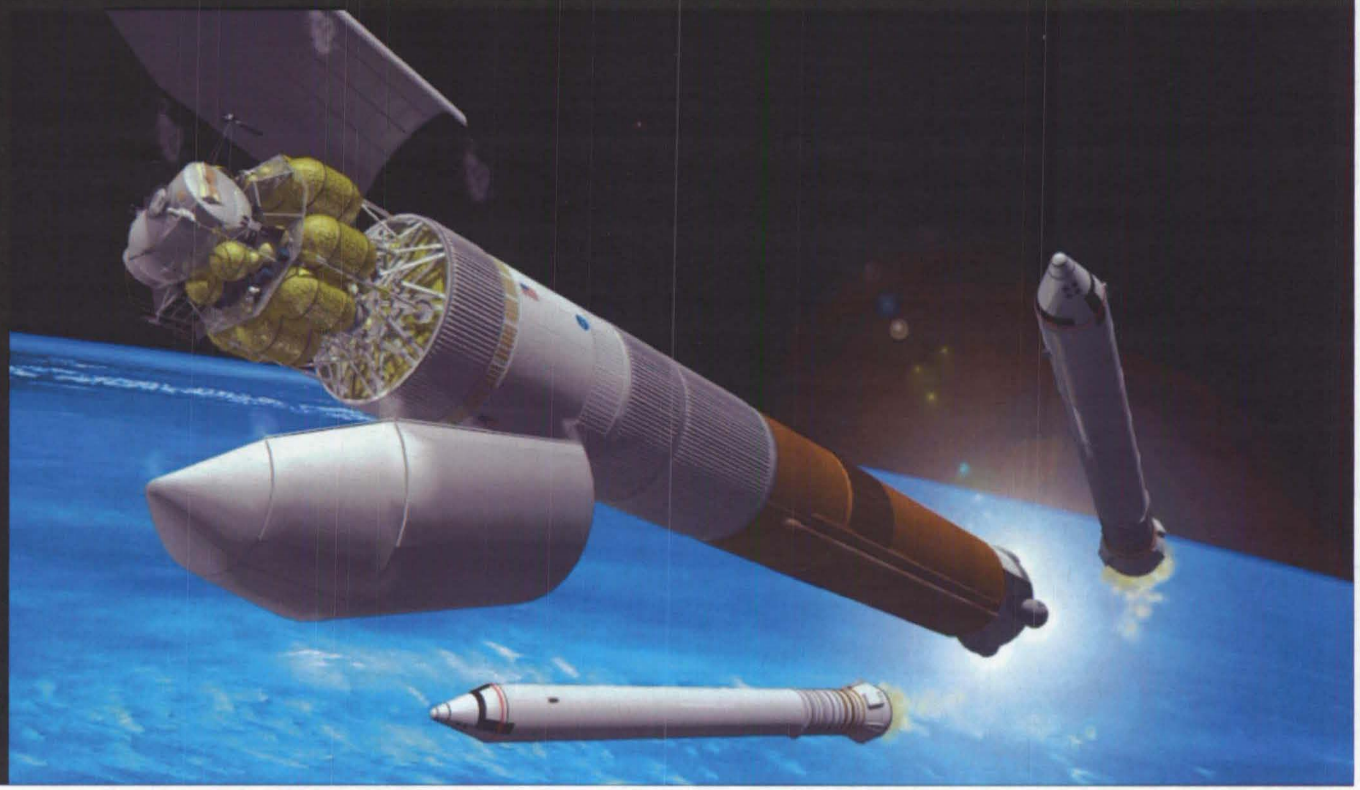
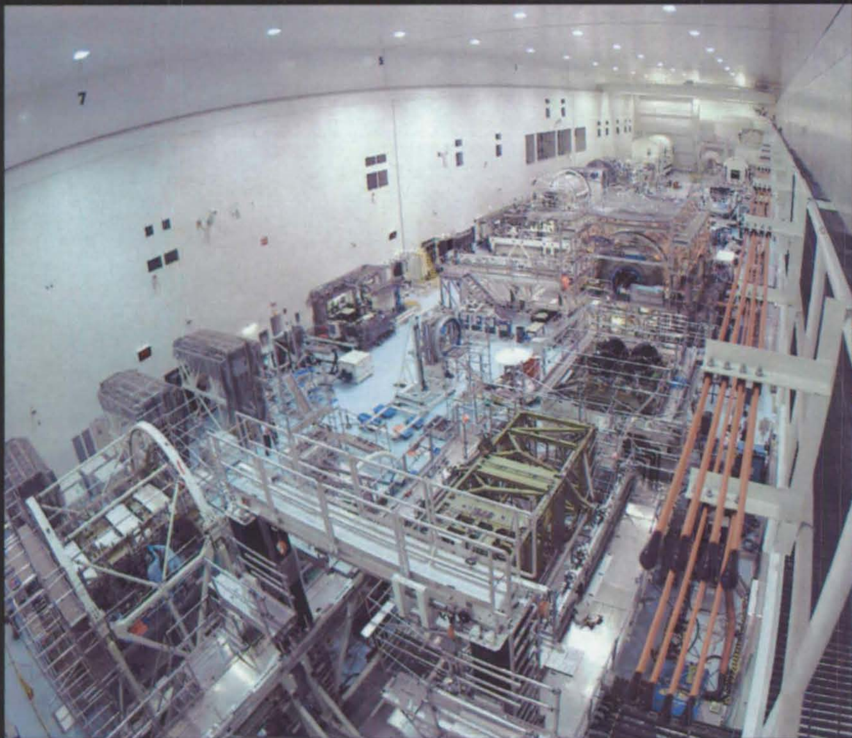
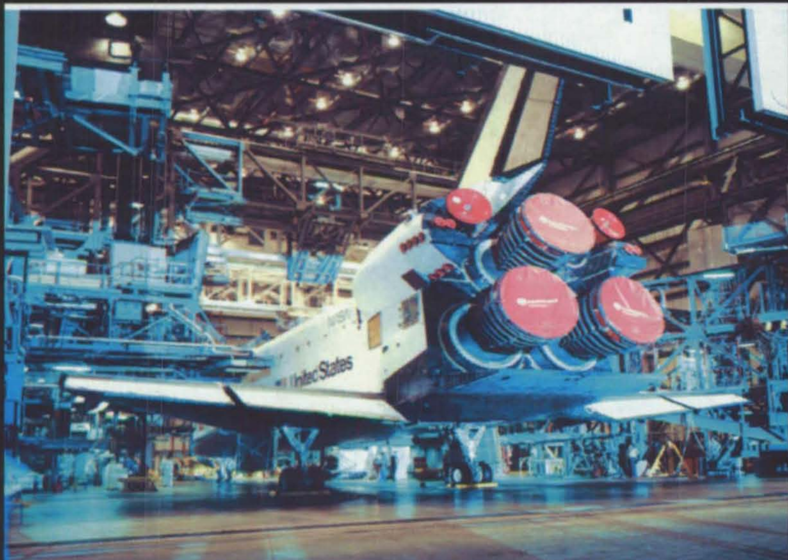
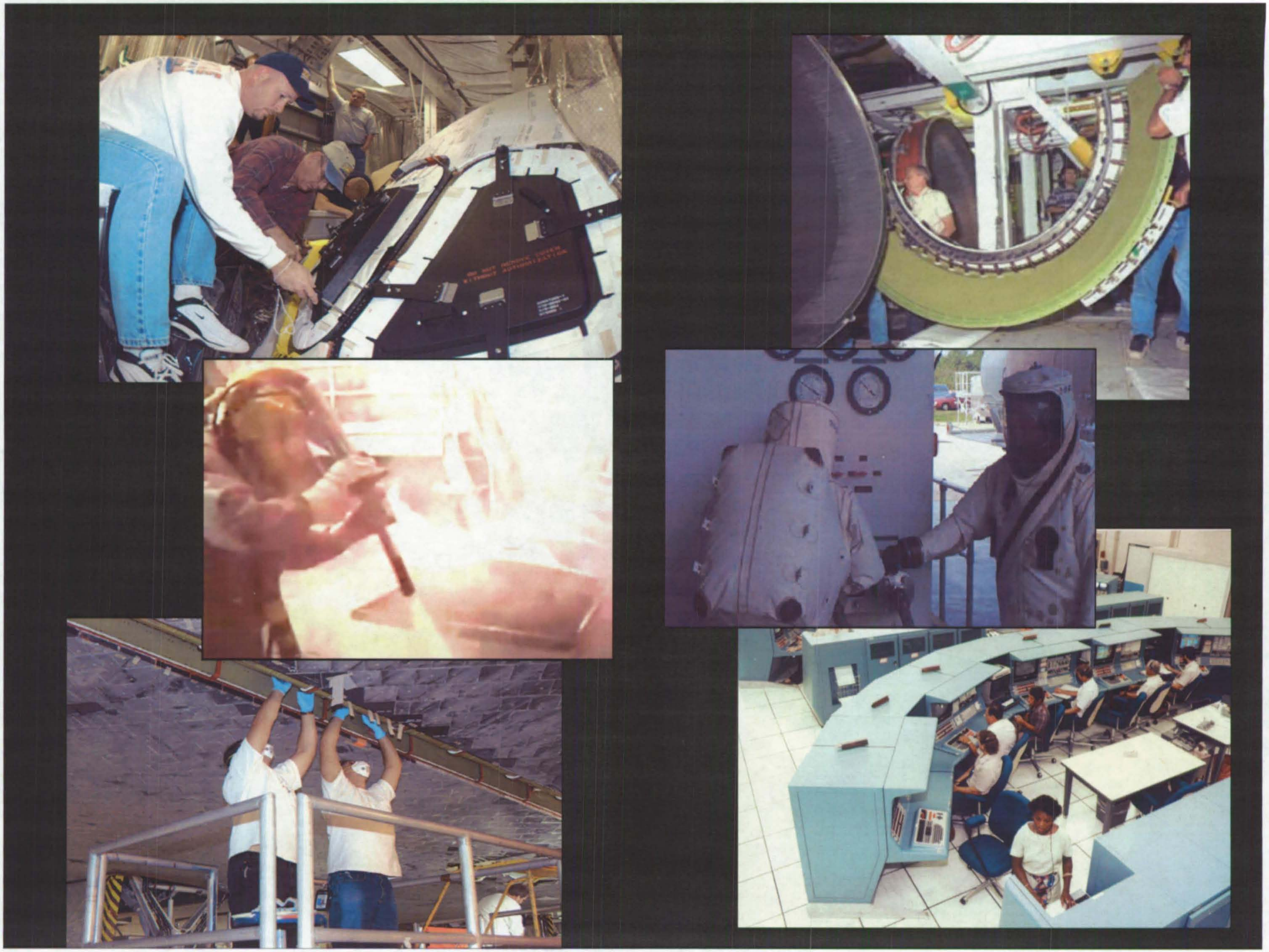
Outline

- Ground Crews and Space Vehicle Safety
- Flight/Ground System Interfaces
- Ground Systems
- Summary

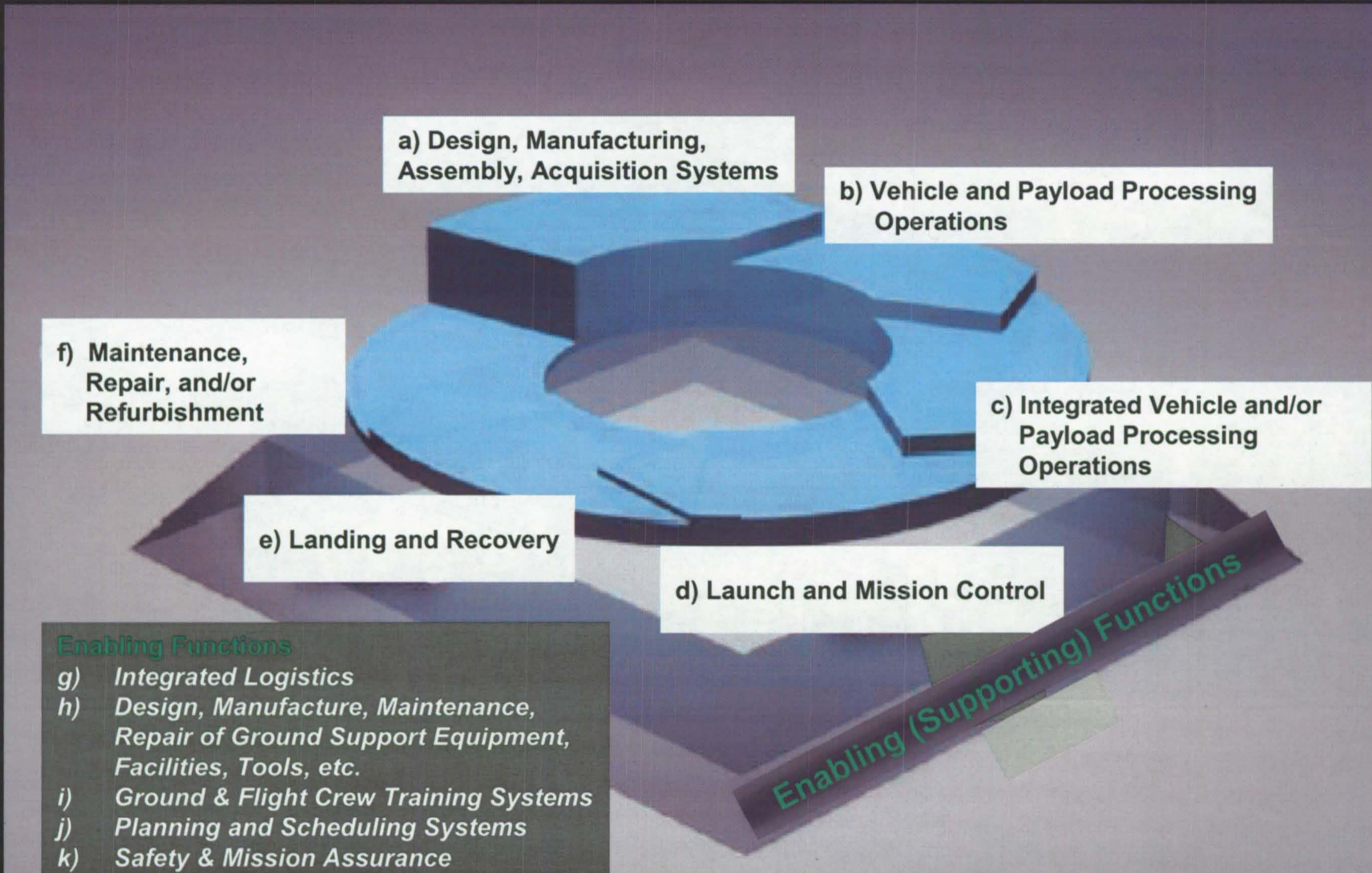






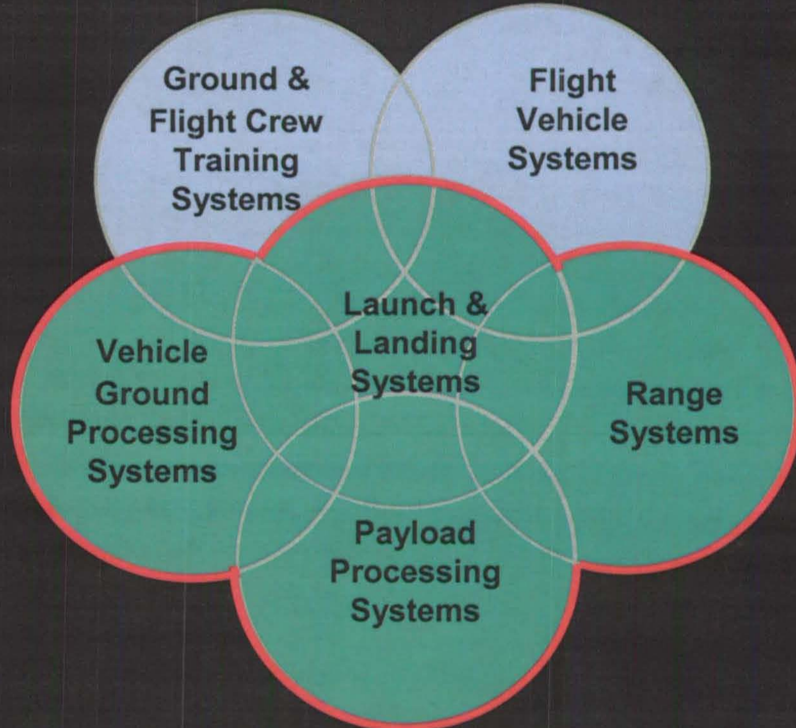


Ground Crew Functions



Why are Ground Crew Factors Important?

- Space transportation systems involve many ground and flight systems. A concurrent engineering, "system of systems" development approach is required to optimize life-cycle performance.
  - Apollo and Shuttle lessons learned



- Exploration systems must be *safe, sustainable, and affordable*
  - NASA safety stakeholders: public, flight crews, workforce (including ground crews), and high-value capital assets (including spacecraft)
  - Majority of life-cycle cost is historically in operations, including ground crew operations

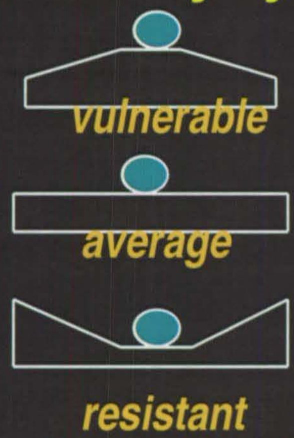
People are the critical elements of the system of Exploration systems: flight crews, ground crews, and surface crews

Constellation Human System Integration Challenges

- Design and development phases - requirements, standards, guidelines, design reviews.
  - Flight systems
    - Vehicles, payloads
  - Flight/ground system interfaces
    - Umbilicals, mechanical and electrical connectors, flex hoses
  - Ground systems
    - Ground support equipment, ground crew training systems, launch and mission control workstations, facility systems, personnel protective equipment (PPE), ground crew work instruction systems, line replaceable unit (LRU) repair/refurbishment workstations, and more.
- Operations and maintenance phases
  - Changing workforce
  - Mixed fleet: Shuttle phase-out and Constellation phase-in

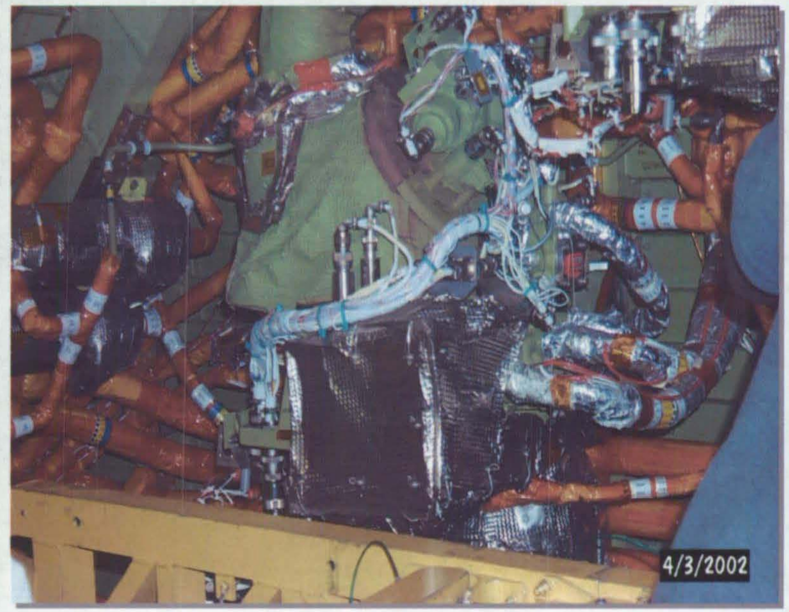
Human Errors in Ground Processing

Human errors occur in the design, development, operation, and maintenance of any system



A poorly designed (vulnerable) system enables humans to make errors

A well designed (robust or resistant) system enables humans to avoid errors



Example:
Space Shuttle Auxiliary Power Unit

"*Complex systems* sometimes fail in complex ways. Sometimes you have to work pretty hard to pin down those complex failure mechanisms. But if you can do that, you will have done the *system* a great service."

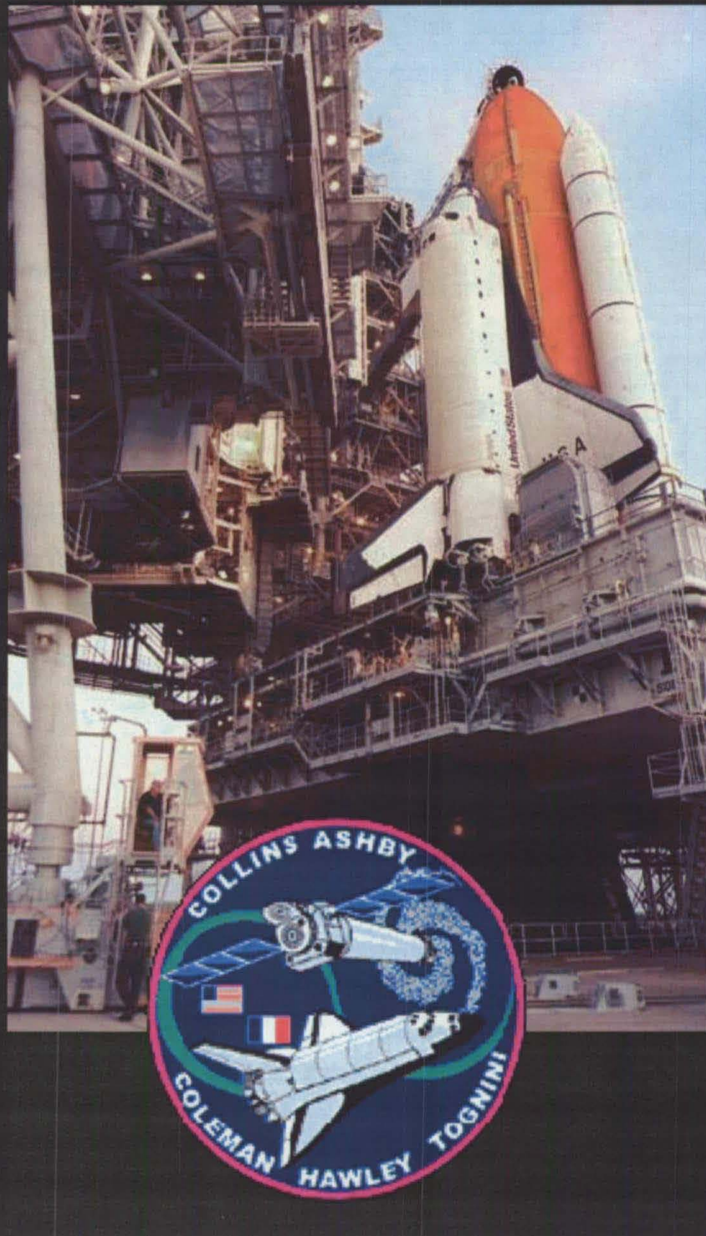
Admiral Harold Gehman, Chair of the Columbia Accident Investigation Board

Flight System Example

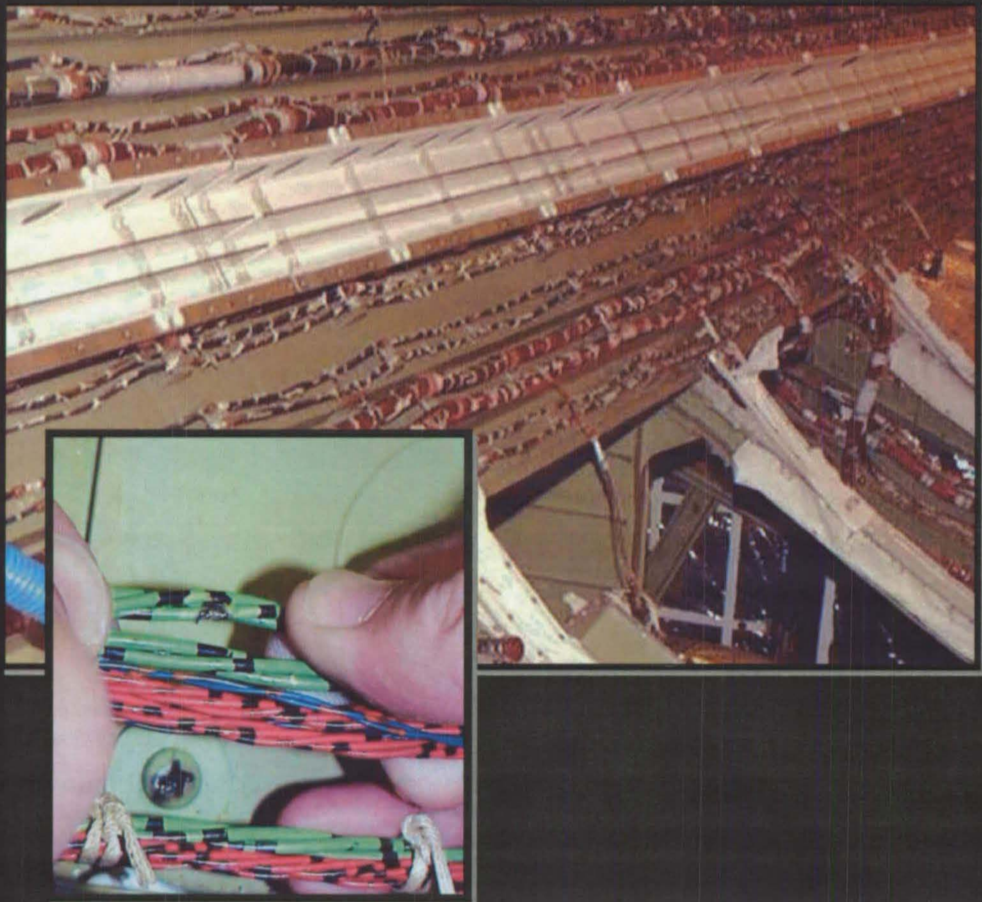
STS-93 JULY 23, 1999

- **Five seconds after lift-off, one of two redundant main engine controllers on two of the three engines shut down due to power fluctuation (later found to be due to wire arcing). The redundant controllers on those two engines -- center and right main engines -- functioned normally allowing them to fully support Columbia's climb to orbit**

- **Orbit attained was 7 miles short due to premature main engine cutoff an instant before the scheduled cutoff; eventually traced to a hydrogen leak in the No. 3 main engine nozzle**



Flight System Example



- Investigation of wire arcing on shuttle launch found to be result of collateral damage.
- Human error issues include: maintenance workplace, standardized visual inspection & practices

An orbiter has more than 300 miles of wires such as these shown in the cable tray inside Columbia's payload bay. A wire damaged by abrasion from the head of a screw was found during electrical wiring inspections in Columbia's payload bay following STS-93, when a damaged wire caused a short circuit in two separate main engine controllers on launch.

System Risk Management

- Ground processing errors that compromise vehicle safety
  - Design risks vs. maintenance risks
  - Assumption of "perfect" human reliability
- Visible vs. invisible risks
  - Over-reliance on small numbers of "big" events, lack of lower level data
  - Over-reactive vs. proactive

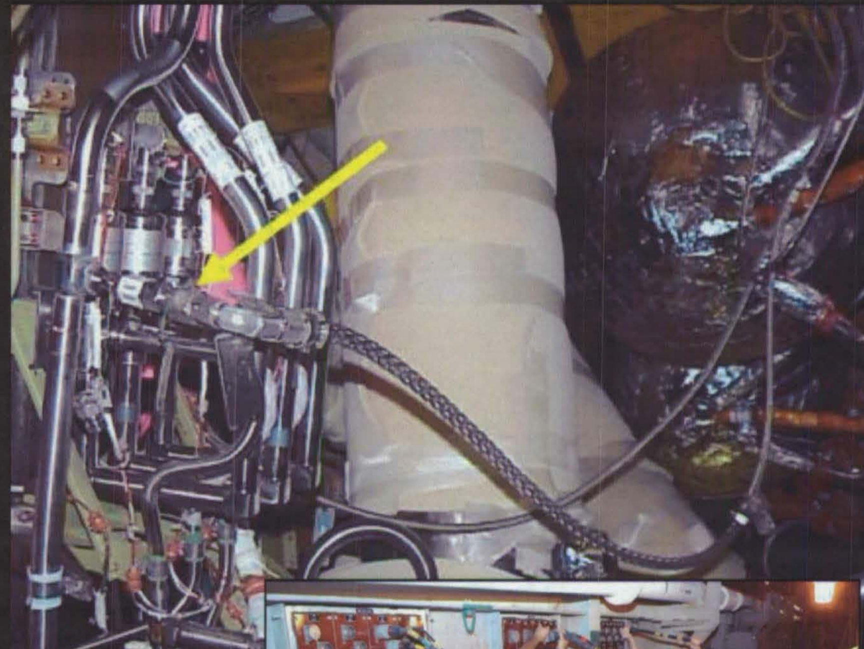
"accident scenarios…are…often a combination of the precipitant technical failure and the handling of the technical failure by the flight crew."
International Air Transport Association Safety Report (2003)

Flight/Ground System Interface Examples

Quick Disconnects (QDs), Fluid and Electrical Umbilicals:

- Flexhose connections inside the spacecraft introduce risk of collateral damage, additional work content
- Human error potential (QD mismates)

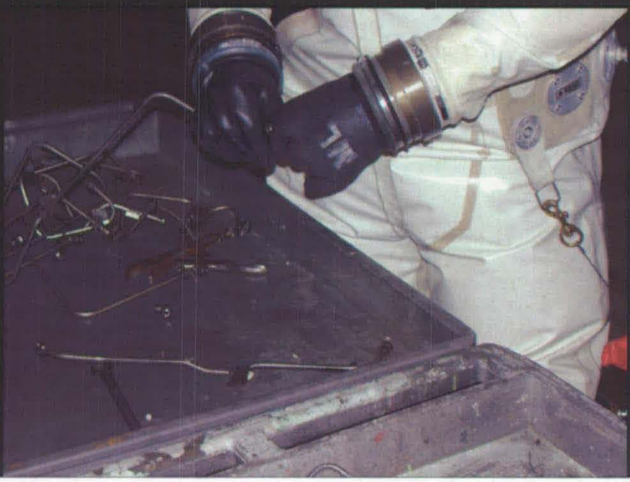
Spacecraft Handling Mechanisms



Ground System Example #1

Self-Contained Atmosphere Protective Ensemble (SCAPE) Suit HSI Challenges:

- Dexterity/agility/flexibility
- Weight/bulkiness
- Heat stress/fatigue
- Negative pressure relief valve
- Electrostatic discharge
- Sizing/suit dimensions
- Visibility
- Communication



Ground System Example #2

APPROVED

DATE: 04-16-1997 TIME: 1258

JC V80-95963
REVISION: S CHANGE: 2

10-19
[1-19]

OK To Install: Qw______ N______

CSR-242

Install (1) V070-395966-003 carrier panel (F/N 10) by using attaching hardware from Table (Ref Figure). Install threaded fasteners per MA0101-301.Torque screws to 20 to 30 in-lbs. .

PN V070-395966-003 CMID:______________________

TW 20 to 30 in-lbs Cal No.__________ Due Date__________

Not Performed ________________

T______ Qw______ N______

10-20
[1-20]

OK To Install: Qw______ N______

CSR-242

Install (1) V070-395974-005 carrier panel (F/N 15) and (1) V070-398888-018 flow restrictor (F/N 15) by tightening captive bolts and screws from Table (Ref Figure).
Perform corrosion protection for screws only per MA0608-301 code 08-AA-23-XX by using MB0120-083 TYPE II sealant .
Install captive fasteners per MA0101-308. Install threaded fasteners per MA0101-301. Torque -4 captive bolts to 20 to 30 in-lbs. . Torque -3 screws to 20-30 in-lbs.

PN V070-395974-005 CMID:______________________

PN V070-398888-018 CMID:______________________

TW 20 to 30 in-lbs Cal No.__________ Due Date__________

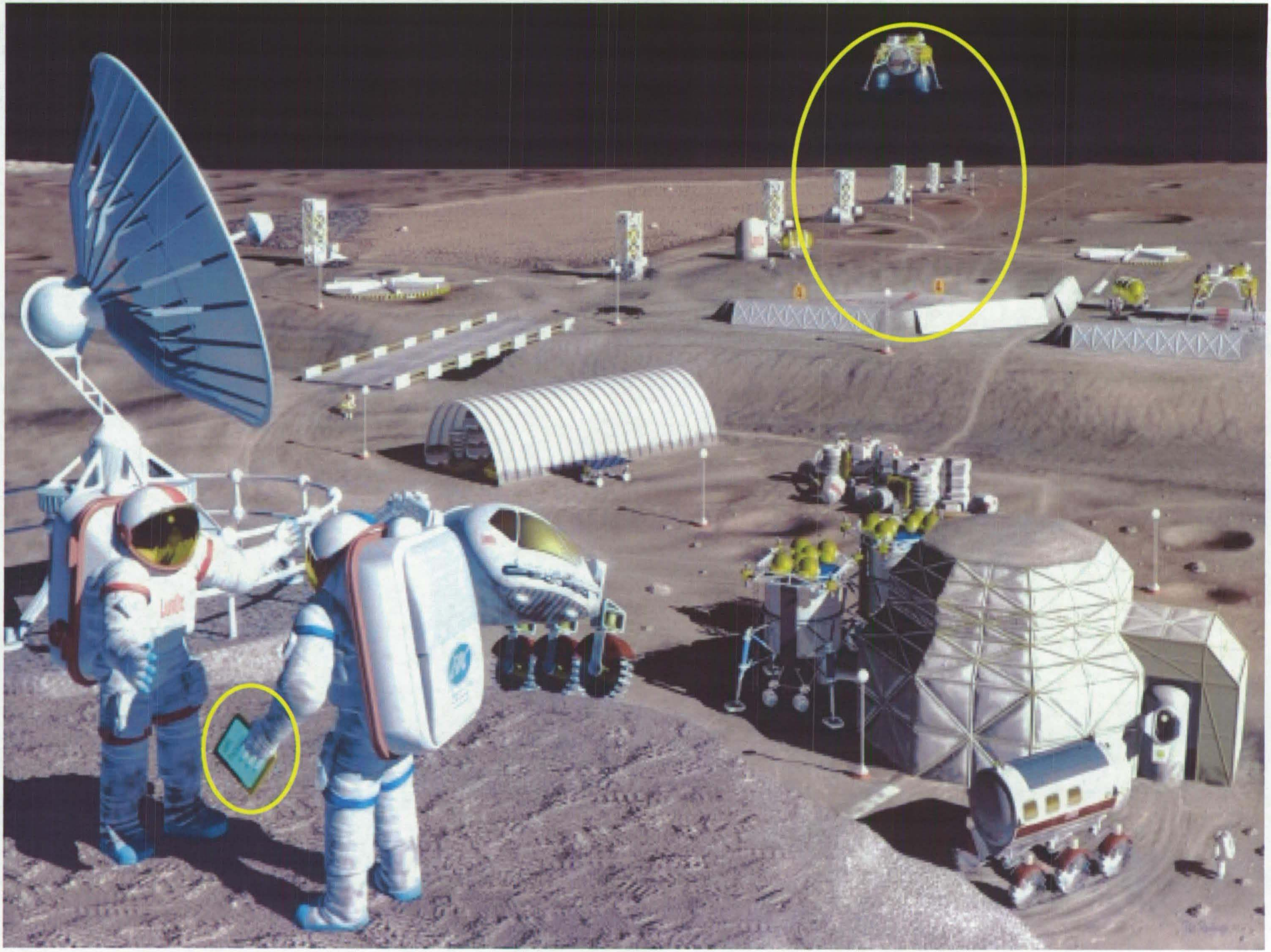
Not Performed ________________

T______ Qw______ N______

NON-HAZARDOUS
10-21
APPROVED

Work Instruction Systems: many HSI challenges associated with transition from centralized production & paper-based delivery to decentralized production & electronic delivery

- Requirement tracking
- Embedded reference information, photos, videos, drawings, training
- Automated deviations and updates
- Interfaces to other systems: scheduling, logistics, problem & mishap reporting



Summary

- Proactive consideration of ground crew factors enhances the designs of space vehicles and vehicle safety by:
  - Reducing the risk of undetected ground crew errors and collateral damage that compromise vehicle reliability and flight safety
  - Ensuring compatibility of specific vehicle to ground system interfaces
  - Optimizing ground systems
- During ground processing and launch operations, public safety, flight crew safety, ground crew safety, and the safety of high-value spacecraft are inter-related
- For extended Exploration missions, surface crews perform functions that merge traditional flight and ground operations