A NASA Perspective on Maintenance Activities and Maintenance Crews

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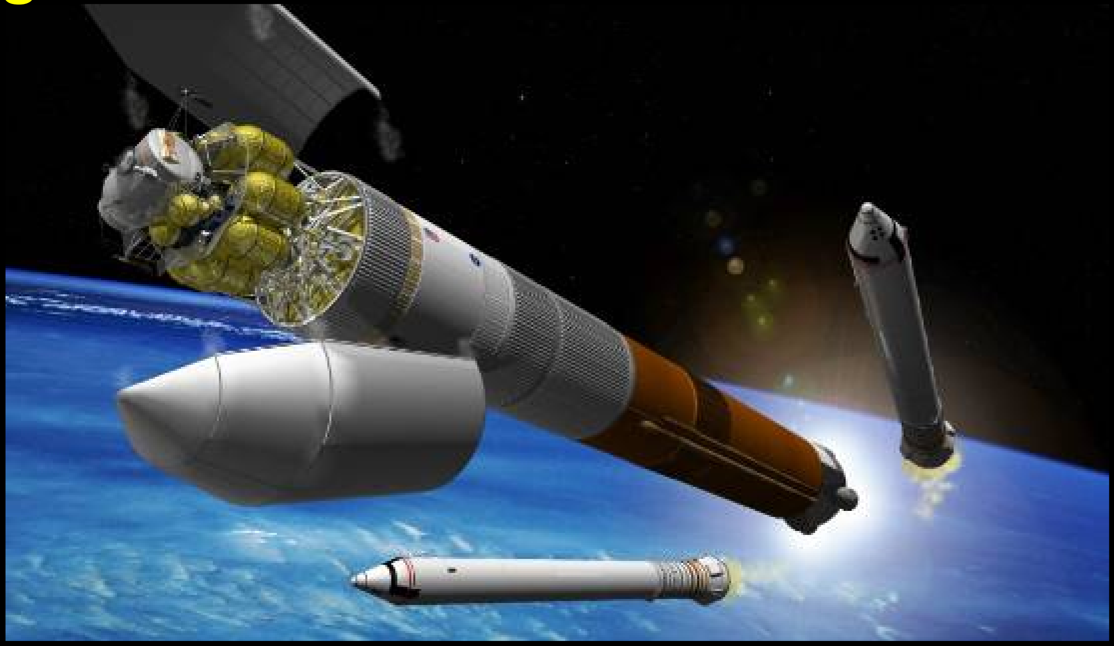
Outline

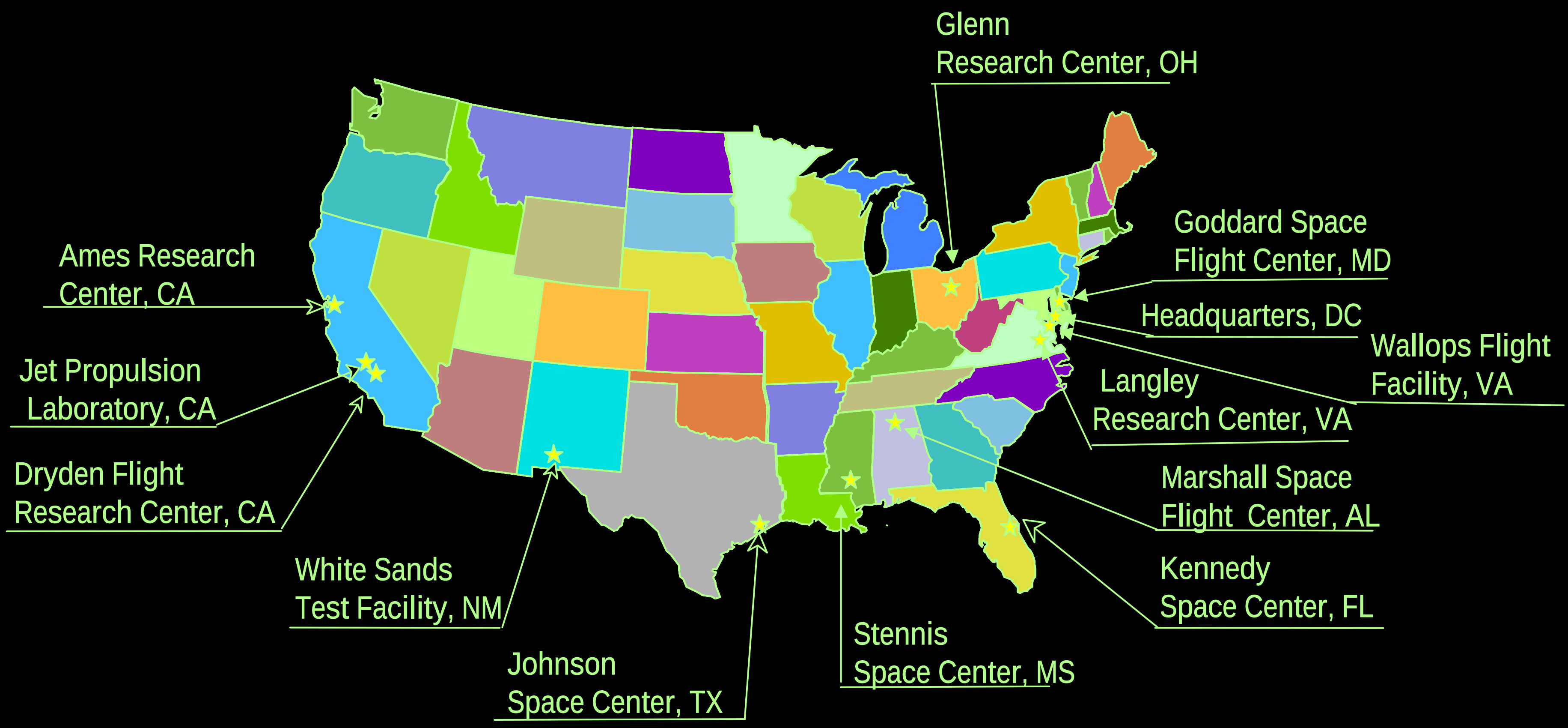
- Exploration Vision
- Evolution of Maintenance Concepts
- Ground Crew Factors
  - Flight Systems
  - Flight/Ground System Interfaces
  - Ground Systems
- Summary
- Q & A



National Space Exploration Vision

"This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart." – President Bush, 1/14/2004

One NASA,
Four Missions (Space Operations, Exploration Systems, Science, Aeronautics Research),
Many Centers and Competencies



Kennedy Space Center

- **140,000 acres**
- **≈ 13,000 people**
  - **Approx 1800 NASA Civil Servants**
  - **Approx 11,200 On/Near-Site Contractors & Tenants**


Spaceport of Today
Kennedy Space Center
LC-39

Spaceport of Tomorrow

Ground Operations

Enabling Functions

g) Integrated Logistics
h) Design, Manufacture, Maintenance, Repair of Ground Support Equipment, Facilities, Tools, etc.
i) Ground & Flight Crew Training Systems
j) Planning and Scheduling Systems
k) Safety & Mission Assurance

Evolution of Maintenance Activities in U.S. Human Space Flight

- **Mercury, Gemini, and Apollo**
  - **Flight and ground systems were generally not reusable – no need to design for maintainability, life-cycle cost, or spaceport safety**
  - **Major components of the Apollo launch site infrastructure have been refurbished and recycled for Shuttle and Constellation Programs**

- **Space Shuttle**
  - **First launch in 1981**
  - **First-generation reusable launch vehicle - airplane & airport-like operations originally envisioned**
  - **Scheduled for retirement in 2010**

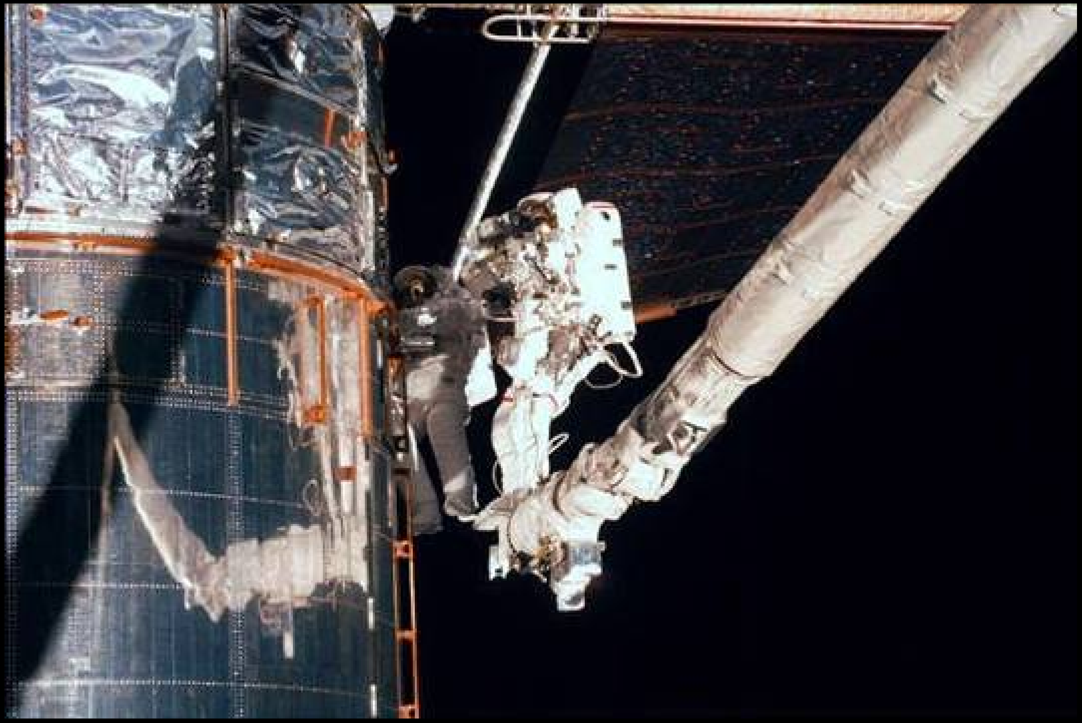
- **International Space Station**
  - **Flight system (on orbit) and ground system/infrastructure maintenance**
  - **Crew and equipment re-supply**

- **Exploration Systems**
  - **First Crew Exploration Vehicle launch in 201x**
  - **Must be *safe, sustainable, and affordable***
  - **Importance of maintainability and ground crew factors already recognized within Program management**

- **Commercial Operators**
  - **Emerging space tourism market**
  - **Systems must be safe, maintainable, reliable, and cost-effective**


United States

People are the CRITICAL elements of the Systems of Exploration Systems



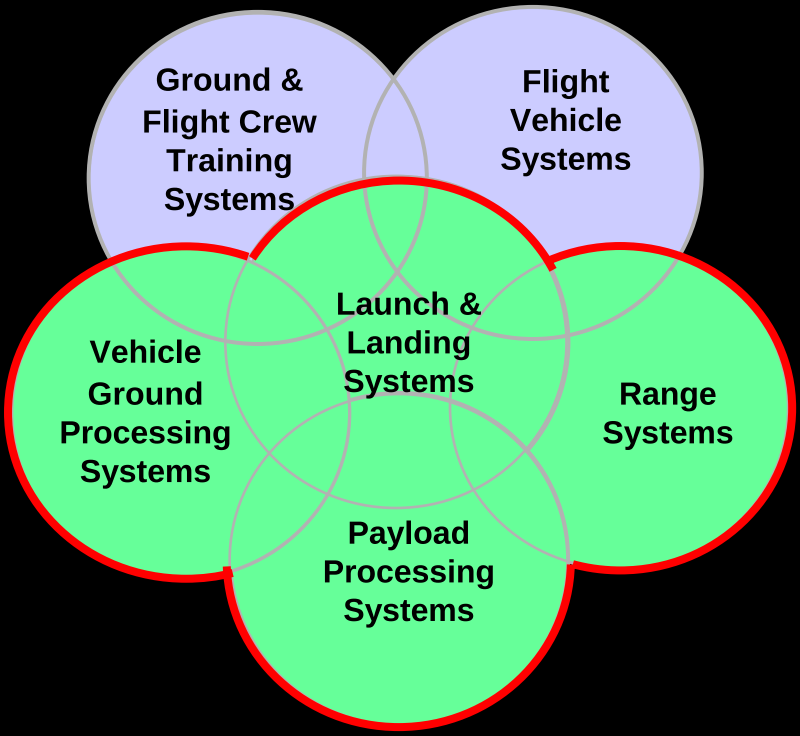





Why are Ground Crew Factors Important?

- **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**

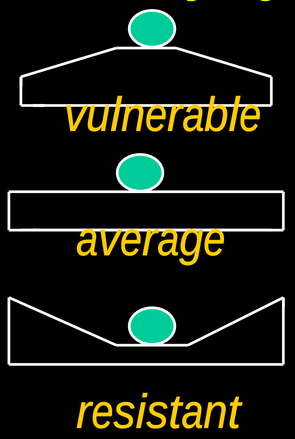


Constellation Human System Integration Challenges

- **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

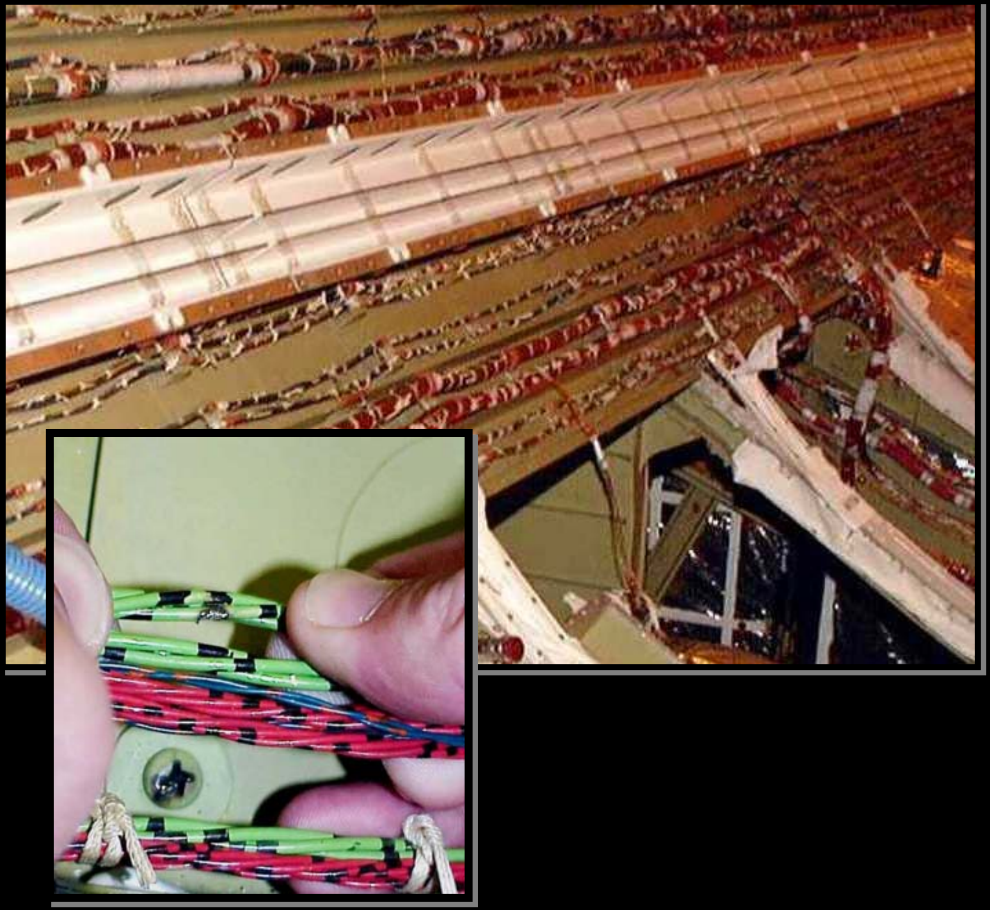
Flight System Example #1

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**

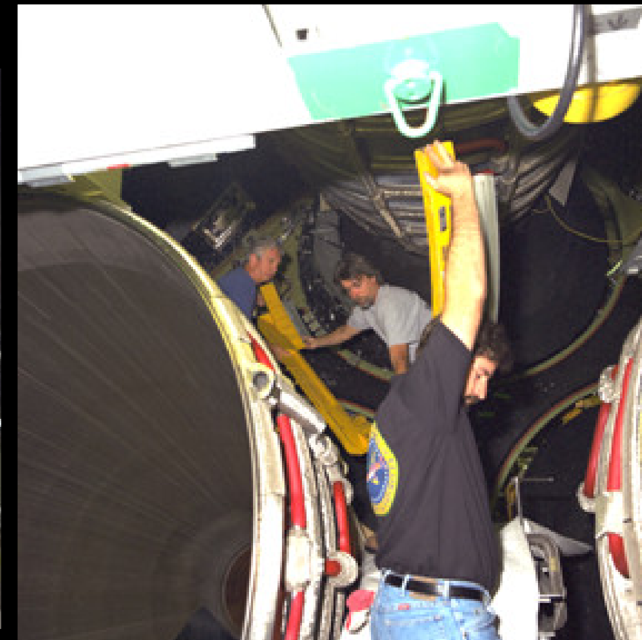
Flight System Example #1 - continued

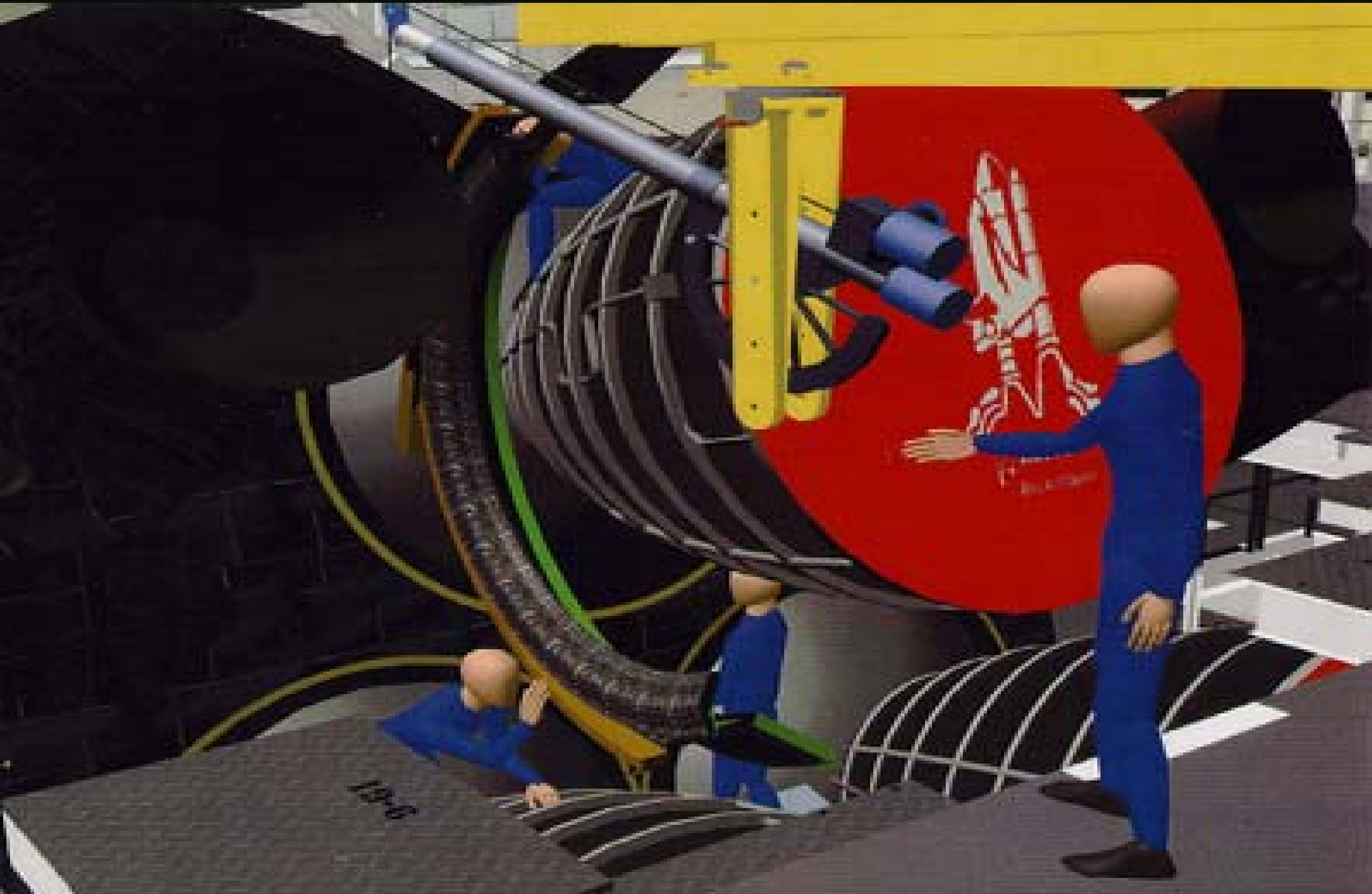


- **Investigation of wire arcing on shuttle launch found to be result of collateral damage.**
- **Human error issues include: maintenance workplace, standardized visual inspection & practices**

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.

Flight System Example #2



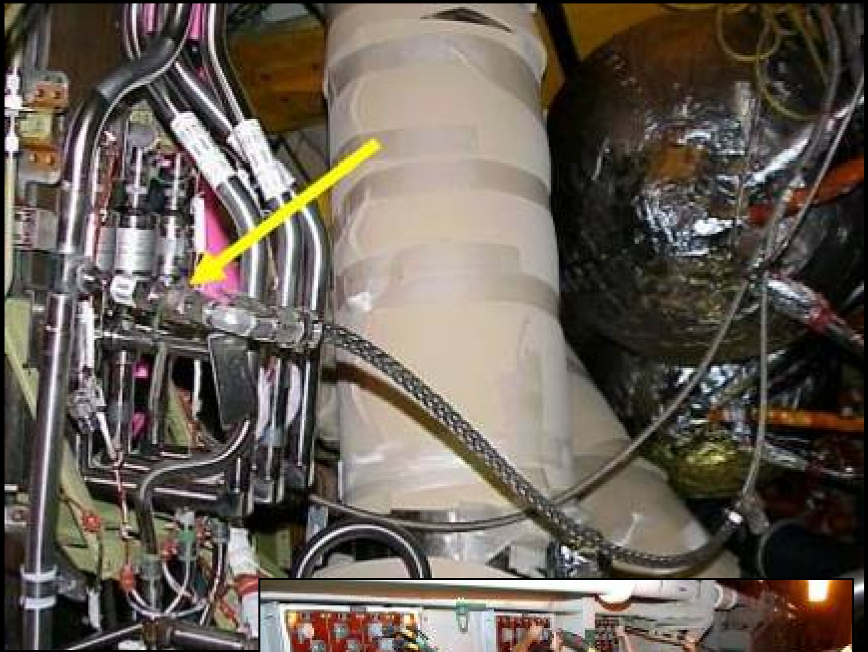


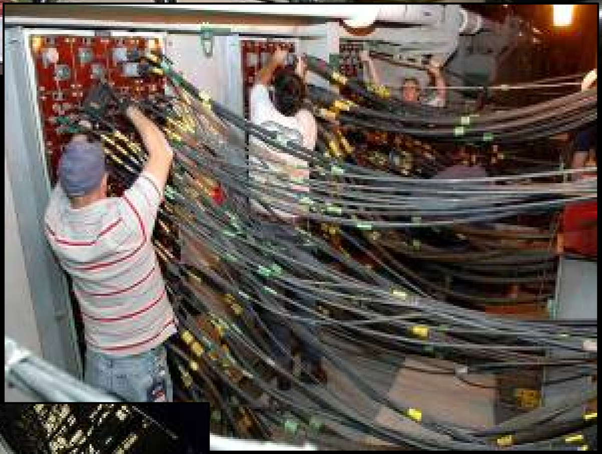
Flight/Ground System Interface Examples

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



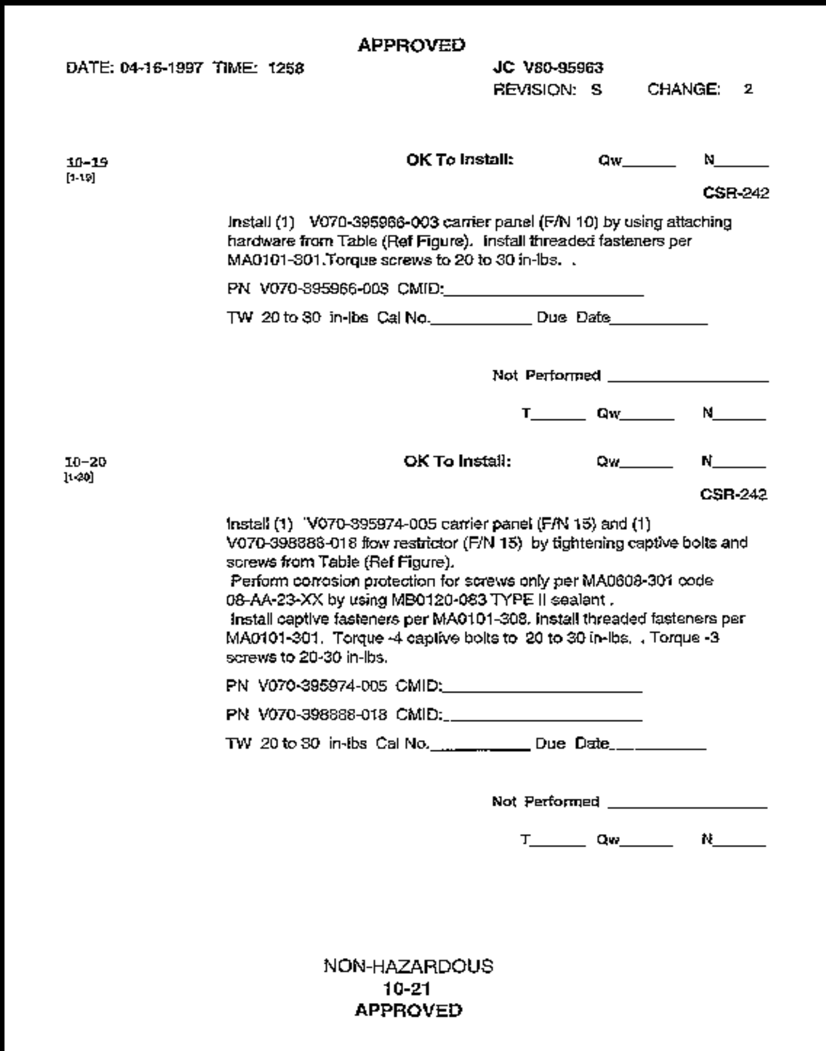


Ground System Example #1

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__________

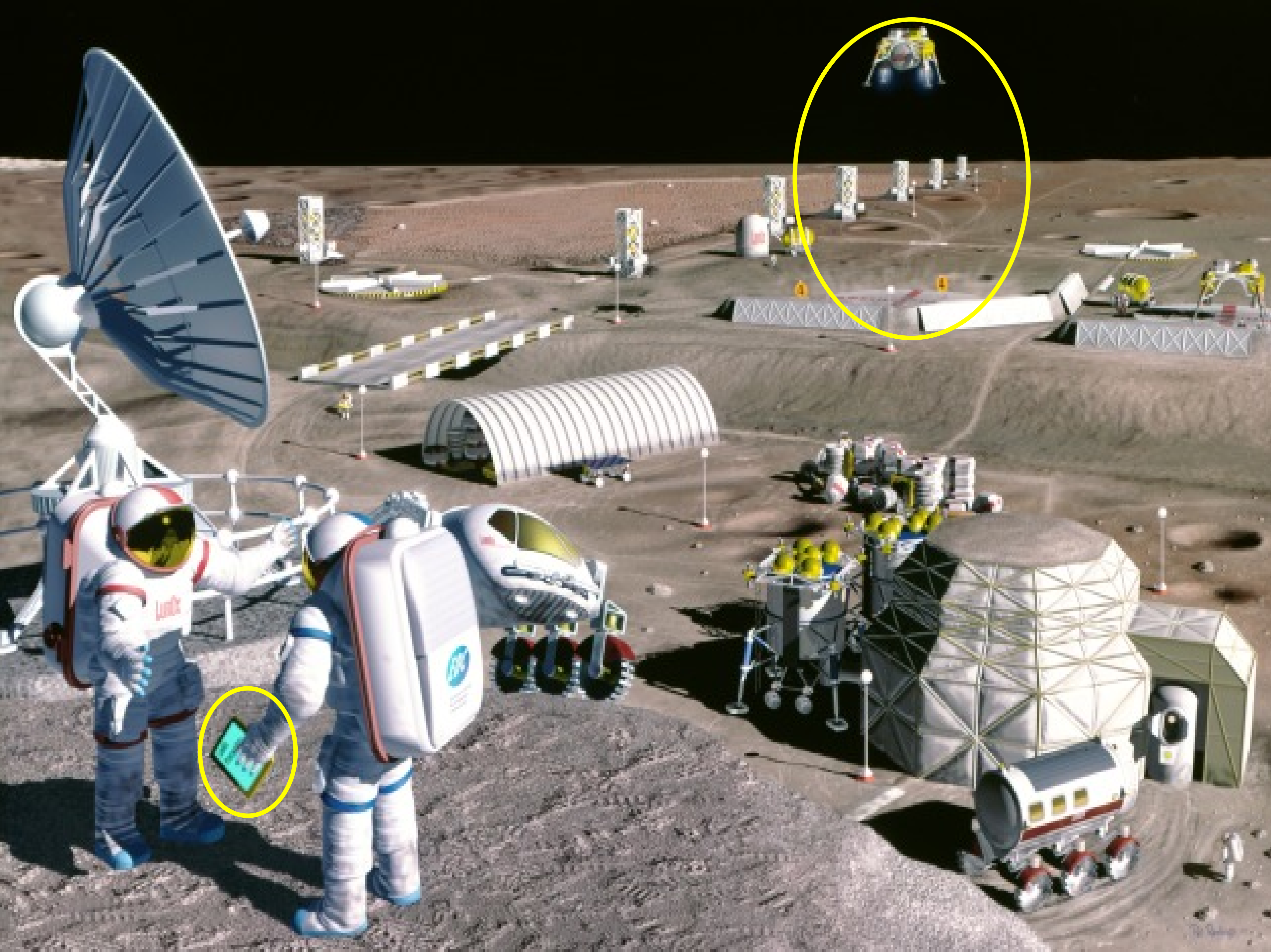
Not Performed ________________

T______ Qw______ N______

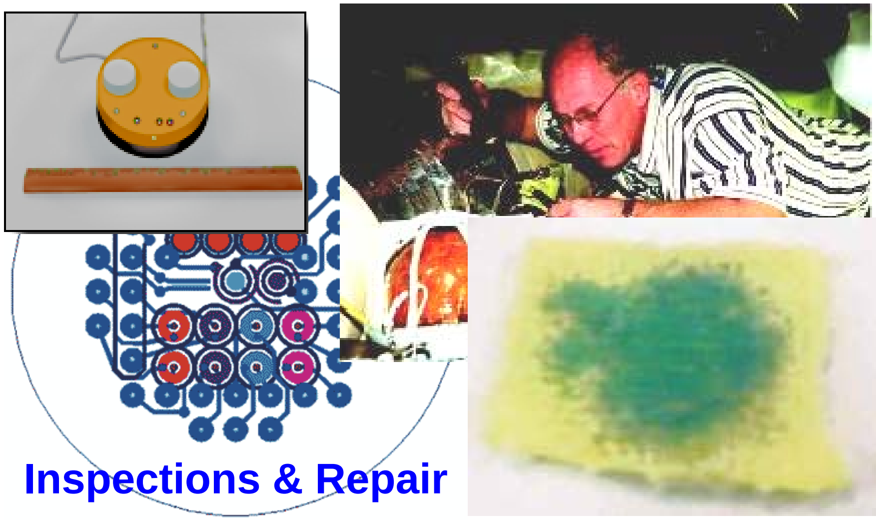
NON-HAZARDOUS
10-21
APPROVED

Work Instruction Systems: many 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



Supportability/Sustainability of Surface Systems



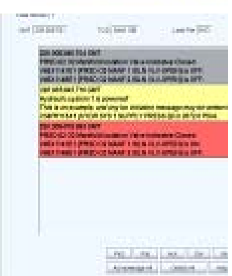
Inspections & Repair

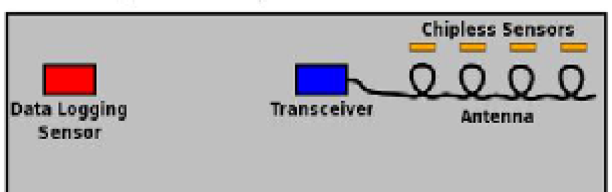
Tools & Equipment

Test & Checkout

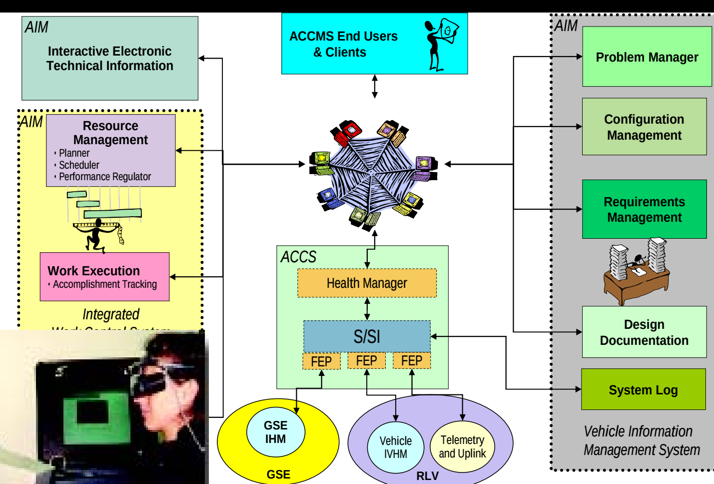
NESTA

NASA Engineering Shuttle Telemetry Age





Configuration Management & Inventory Control



Information Infrastructure & Electronic Processes

Saturn Dynamics

- Tennis Shoe Test
- Ground Winds

Summary

- Proactive consideration of ground crew activities and ground crew factors enhances the design and operation of aerospace systems (flight and ground systems)

- Crew safety and mission assurance are enhanced 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
  - Maintenance challenges on-Earth, in-flight, and on-other planetary surfaces

Additional Information

- NASA Home Page
  - http://www.nasa.gov/
- Kennedy Space Center Home Page
  - http://www.ksc.nasa.gov/
- NASA Technology Spinoffs
  - http://www.sti.nasa.gov/tto/index.html/
- Tim.Barth@nasa.gov

Questions?