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

- a) Design, Manufacturing, Assembly, Acquisition Systems
- b) Vehicle and Payload Processing Operations
- c) Integrated Vehicle and/or Payload Processing Operations
- d) Launch and Mission Control
- e) Landing and Recovery
- f) Maintenance, Repair, and/or Refurbishment

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
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.

- **vulnerable**
- **average**
- **resistant**

A poorly designed (vulnerable) system enables humans to make errors.
A well designed (robust or resistant) system enables humans to avoid errors.

"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.
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.

- Investigation of wire arcing on shuttle launch found to be result of collateral damage.
- Human error issues include: maintenance workplace, standardized visual inspection & practices
Flight System Example #2
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

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

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

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Questions?