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Human Factors Throughout the Life Cycle: Lessons Learned from the Shuttle Program

Human Factors in Ground Processing

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Agenda

Human Factors in Ground Processing

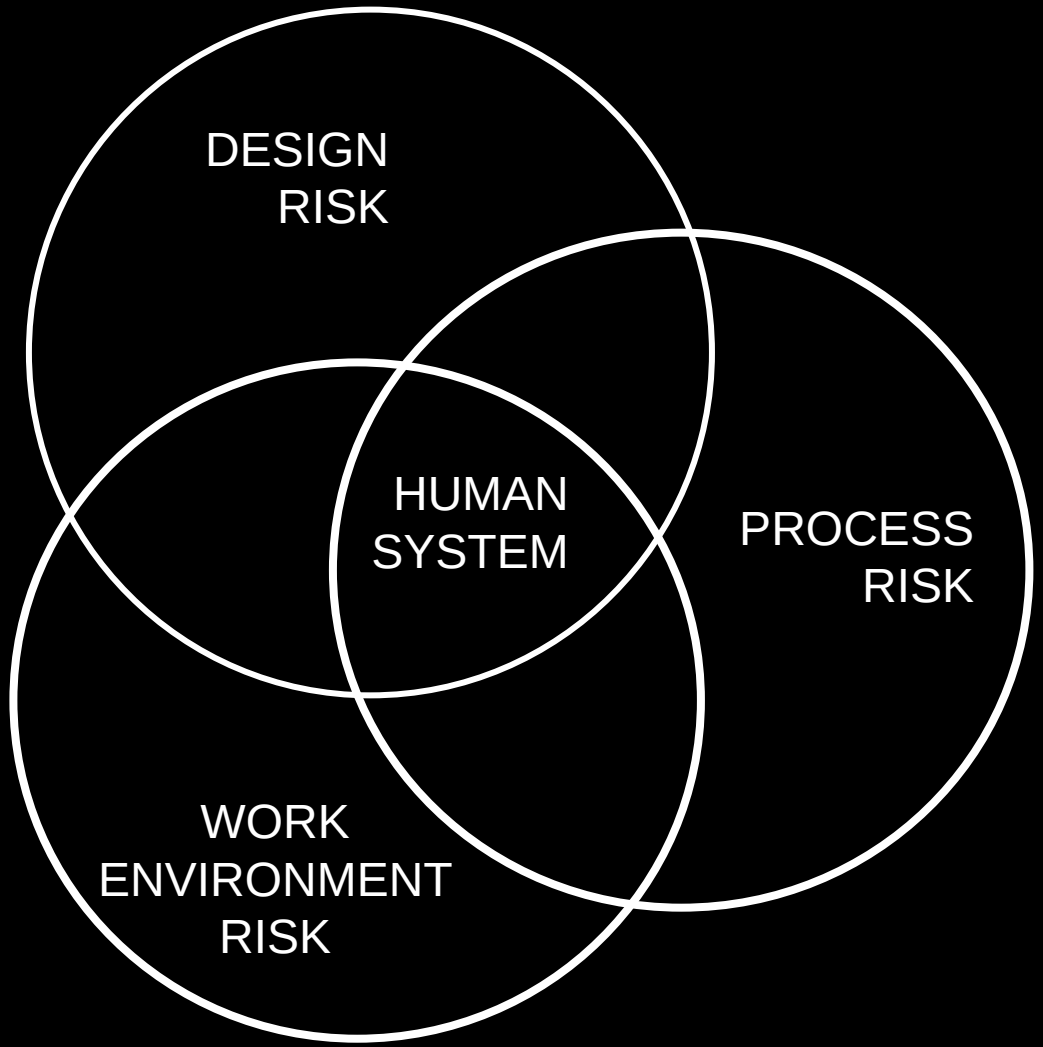
- Introduction
  - Managing risk in human systems
  - Contributing risks: design, environment, process
- Example: STS-93 wire anomaly
  - Design risks
  - Environment risks
  - Process risks
  - Human systems issues
- Summary

Managing Risk in Human Systems

- HUMAN SYSTEMS
  - Individual / Teams
    - Skills & knowledge
    - Leadership
    - Team complement
    - Work practices
  - Organizations
    - Training
    - Controls
    - Resources
    - Workforce
- DESIGN RISK
  - Hardware / Software
- ENVIRONMENT RISK
  - Workplace / Conditions / Hazards
- PROCESS RISK
  - Procedures / Policies / Resources

Focus on the human interfaces

Managing Risk in Human Systems

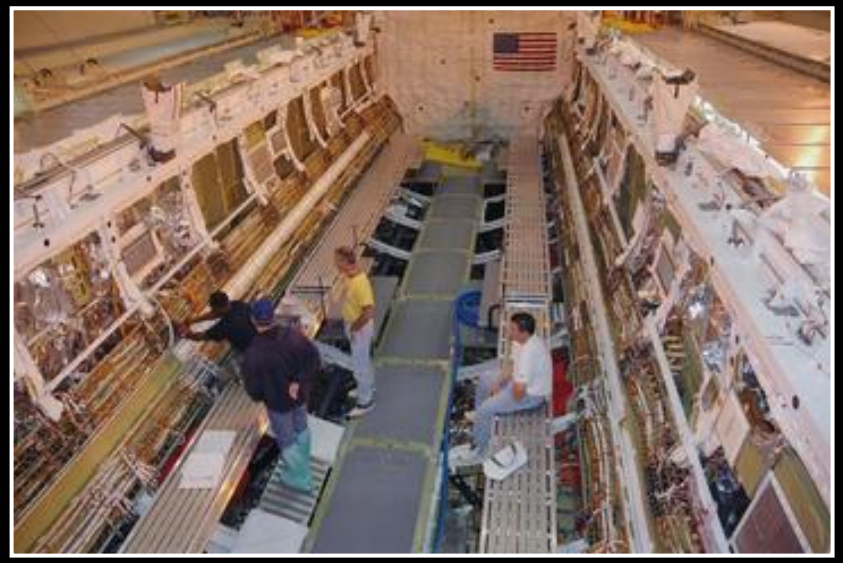


- DESIGN
  - Is damage visible?
  - Is there access to the work area?
- ENVIRONMENT
  - Is there adequate space, lighting?
  - Is PPE required?
- PROCESS
  - Are resources, controls adequate?
  - Are work procedures usable, up-to-date?
  - Do teams communicate/ coordinate appropriately?

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).
- OUTCOME: The redundant controllers on those two engines -- center and right main engines -- functioned normally allowing them to fully support Columbia's climb to orbit

An orbiter has more than 300 miles of wires such as these shown in the cable tray.



A damaged wire found during wiring inspections in Columbia's payload bay following STS-93, caused a short circuit in two separate main engine controllers on launch.

Wiring In-Flight Anomaly:
Basic Findings

- Inspection revealed a single 14 ga. polyimide wire had arced to a burred screw head; located in the aft left-hand mid-body bay #11 lower wire tray.
- Wiring in the mid-body payload bay normally covered; records indicate covers last removed during Orbiter Maintenance Down Period (OMDP) 4 years earlier in the Palmdale depot facility.

Wiring In-Flight Anomaly: Root Cause

- Root cause
  - Work-induced collateral damage
  - No evidence of generic chafing exists (not simply fair wear-and-tear)
  - Wire protection specification applied inconsistently
- Therefore, assessments focused on maintenance practices.

Wiring In-Flight Anomaly: Assessments

- Review the Space Shuttle systems and maintenance practices… look at NASA practices, Shuttle anomalies, and civilian and military experience. (NASA)
- Identify strengths and weaknesses in shuttle processing, compare shuttle processing to commercial aviation best practices, make suggestions to reduce Ground-Processing-Induced In-Flight Anomaly (GPI-IFA) risk (USA)

http://www.hq.nasa.gov/osf/shuttle_assess.html

HUMAN SYSTEM Issues

- INDIVIDUAL RISKS: Ground personnel expected to perform “error-free” and in compliance with procedures
  - Not aware of the in-fight consequences of ground-processing-induced “errors”
  - Downsized workforce under strain
- TEAM-LEVEL RISKS: KSC team and Palmdale processing teams have different standards
  - Wire inspection criteria need redefinition

TECHNICAL Issues: Wiring System

- DESIGN RISKS
  - Maximum feasible separation of redundant systems (e.g., redundancy of circuits compromised by placement in same wire bundle)
  - Identification of single point failures
  - Over time and modifications, additional wire protection for critical systems (e.g., wire tray covers become hard to close)

TECHNICAL Issues: Wiring System

- WORK ENVIRONMENT RISKS
  - Extensive wiring inspection, repair
  - High traffic area?
  - Access to work area?
  - Damage visible?

TECHNICAL Issues: Wiring System

- PROCESS RISKS
  - Managed through certification, skill, procedural control, inspection, teaming and continuous reinforcement of safety awareness
  - Little emphasis on error reporting, management, and understanding of why workmanship errors occur
  - Line employees should be aware of relationship between workmanship/test errors and GPI-IFAs

Summary

- Risk Management in Human Systems applies to:
  - Individuals
  - Teams
  - Organizations
- Risk Contributors to Human Systems are:
  - Design risks
  - Work Environment risks
  - Process risks

Summary

- Apply Lessons Learned to future programs
  - Maintain a realistic attitude toward risky operations
  - Develop a better understanding of the risk of Ground-Processing-Induced In-Flight Anomalies
  - Expand corrective actions beyond specific, technical fixes
  - Fit solutions to the risks: design risks are not well-solved by process solutions

Thank You