NASA Wiring Program

Wiring System Technology

OBJECTIVE

To address safety and reliability issues of complete wiring systems.

PLANS

• Determine Wiring System Design Factors
• Investigate Circuit Protection Technologies
• Address Manufacturing and Maintenance Procedures
NASA Wiring Program

Wiring System Failure Survey

PURPOSE
Form a comprehensive view of wiring safety, not only including the insulation, but also taking into account the wiring system factors.

JUSTIFICATION
For failures such as arc tracking and others to happen, insulation degradation of some degree must have occurred. The wiring system factors can often lead to degradation.

Overview of Space Missions with Wiring System Failures

<table>
<thead>
<tr>
<th>Mission</th>
<th>Cause</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemini 8</td>
<td>Electrical Wiring Short</td>
<td>Shortened Mission - Near Loss of Crew</td>
</tr>
<tr>
<td>Apollo 204</td>
<td>Damaged Insulation, Electrical Spark, 100% O₂</td>
<td>Fire, 3 Astronauts Lost</td>
</tr>
<tr>
<td>Apollo 13</td>
<td>Damaged Insulation/Short Circuit/Flawed Design</td>
<td>Oxygen Tank Explosion, Mission Incomplete</td>
</tr>
<tr>
<td>STS - 6</td>
<td>Abrasion of Insulation/Arc Tracking</td>
<td>Wire insulation Pyrolysis 6 Conductors Melted</td>
</tr>
<tr>
<td>STS - 28</td>
<td>Damaged Insulation/Arc Tracking</td>
<td>Teleprinter Cable Insulation Pyrolysis</td>
</tr>
<tr>
<td>Magellan</td>
<td>Wrong Connection, Wiring Short</td>
<td>Wiring insulation Pyrolysis - Ground Processing</td>
</tr>
<tr>
<td>Spacelab</td>
<td>Damaged Insulation/Arc Tracking</td>
<td>Wiring insulation Pyrolysis During Maintenance</td>
</tr>
<tr>
<td>Delta 178/GOES-G</td>
<td>Mechanical or Electrochemical Insulation Damage</td>
<td>Loss of Vehicle</td>
</tr>
<tr>
<td>ESA - Olympus</td>
<td>Electrical Wiring Short</td>
<td>Loss of Solar Array</td>
</tr>
</tbody>
</table>
Electrical Wiring System Failures

Influenced by a Combination of Factors

Wiring System Design
Circuit Protection Technology
Manufacturing/Maintenance Procedures
Insulation Construction/Material

Electrical Wiring System Failures

EXAMPLES
Wiring System Design

Space Shuttle (STS-28)

Original Teleprinter Cable

- Wire makes 180° bend.
- Repeated bending damaged insulation.

Redesigned Teleprinter Cable

- 90° Strain relief added.
- More flexible insulation used.

Wiring System Design

Command and Service Module (Apollo 13)

Oxygen Tank Failure

- Tanks contained ignition sources, combustible materials, and oxygen.
- Electrical wiring conduit constrictive.
- Wiring in close proximity to heaters.
- Pressure against sharp edges could lead to "Cold Flow".
- Failure modes were not detectable by normal post assembly testing.
Maintenance Procedures

**Space Shuttle Orbiters**

- During 1984 and 1985 there were 532 cable and connector problems reported.
- Problems resulted due to maintenance procedures.

---

**Circuit Protection Technology**

**Space Shuttle (STS-28)**

- Circuit breakers based on the thermal energy in the fault, may be ineffective in detecting arc-tracking.

---

- NASA Johnson Space Center Test Program - arc propagation limited to lengths of less than 1" up to 6".
- New technologies may improve detection.
Electrical Wiring System Improvements

EXAMPLES

Wiring System Design Improvements

- Awareness of designers to fault mechanisms.
- Specify new insulation constructions and materials for use in NASA spacecraft.

Manufacturing/Maintenance Procedure Improvements

- Improved training of personnel in "Wiring Awareness" techniques
- Routing/Protecting of wiring to avoid physical damage
- Improved quality control, including non-intrusive inspections
- Application of methods such as dynamic system engineering and total quality management.
Wiring Protection Measures

Space Shuttle Orbiters

Advanced Protection Technology

"Instantaneous Trip" Circuit Breakers

- Commercially Available Solid State Power Controllers (SSPC)
- Air Force 270 VDC SSPC Program
Advanced Protection Technology
"Smart" Fuses

Dual-element Time-delay Fuse

- Provide protection against low-level overload current or a short circuit current.
DIFFERENTIAL PROTECTION OF DCSU USING FIBER OPTIC CURRENT SENSING

POLARIZER
LASER
FAULT DETECTOR
RESOLVER

FAULT SIGNAL $\propto I_{SSU} + I_{BCDU1} + I_{BCDU2} + I_{BCDU3} + I_{DDCU} + I_{MB} + I_{FAULT}$

$\bigcirc$ = FIBER OPTIC COIL
Advanced Protection Technology

"Intelligent" Fault Detection Methods

• Incipient fault detection via "footprint" or "signature"

• Knowledge based expert systems

• Neural network methods

• Fuzzy logic methods

Summary

• The wiring system is an important consideration in designing a spacecraft power system.

• Arc-tracking has recently been identified as a failure mode which may not be completely eliminated through the use of new wiring constructions/materials

• The total wiring system including insulation, system design, handling procedures, and circuit protection need to be considered further.