



Managing Electrical Connections Systems and Wire Integrity on Legacy Aerospace Vehicles

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NASA Langley Research Center



Managing Electrical Connections Systems and Wire Integrity on Legacy Aerospace Vehicles

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Kennedy Space Center
NASA
and
George Slenski
Materials Directorate
Air Force Research Laboratory



Outline

- **Introduction**
- **Aging Wiring Issues**
- **Shuttle Wiring Failure**
- **Shuttle Wiring Inspections**
- **Conclusions**

Aging Wiring

Wiring is just one part of the electrical Interconnection system

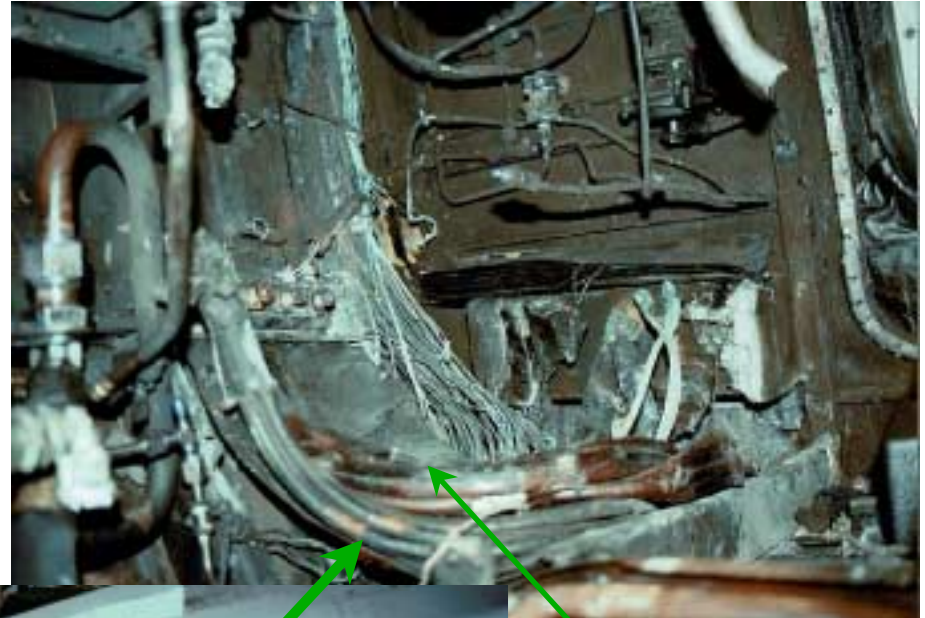
- Wiring, connectors, relays, circuit breakers, power distribution panels, and generators makeup the system**

Aging wiring can be understood as degraded performance due to accumulated damage from long-term exposure.

- Damage is from chemical, thermal, electrical, and mechanical stresses**
- Stresses are often induced by the operational environment and installation and maintenance practices**
- Wiring failures often appear as broken conductors and damaged insulation which can disrupt electrical signals and/or lead to arcing.**



Wiring System Failures

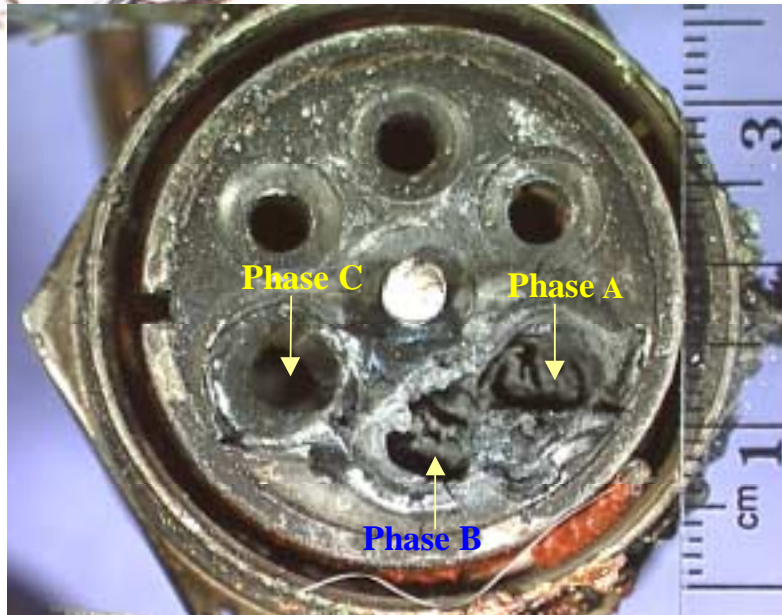


In-Flight Electrical Fire

Initiation Site



Chafed Wire Failure



Failure Initiated by Degraded Bearings and Wire Chafing



Wiring Failure Mechanisms



Electrical



Mechanical



Thermal



Chemical



Arc Tracking Wire Failures

Field Failure



Dry Arc Tracking



Polyimide Insulation
(Mil-W-81381)



Aging Aircraft Wiring Systems

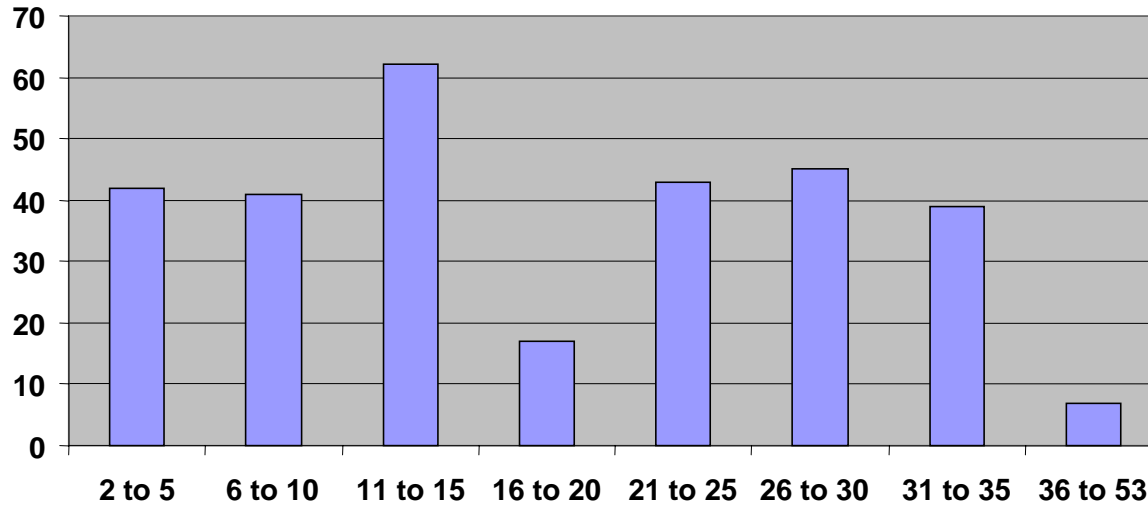
Wiring Failure Data for a Typical Fighter

- 46% Broken Wires**
- 30 % Insulation Chafing Damage**
- 14% Outer Layer Chafing**
- 10% Failure in Contractor Connector**

AF Mishap Data For Electronic Related Failures

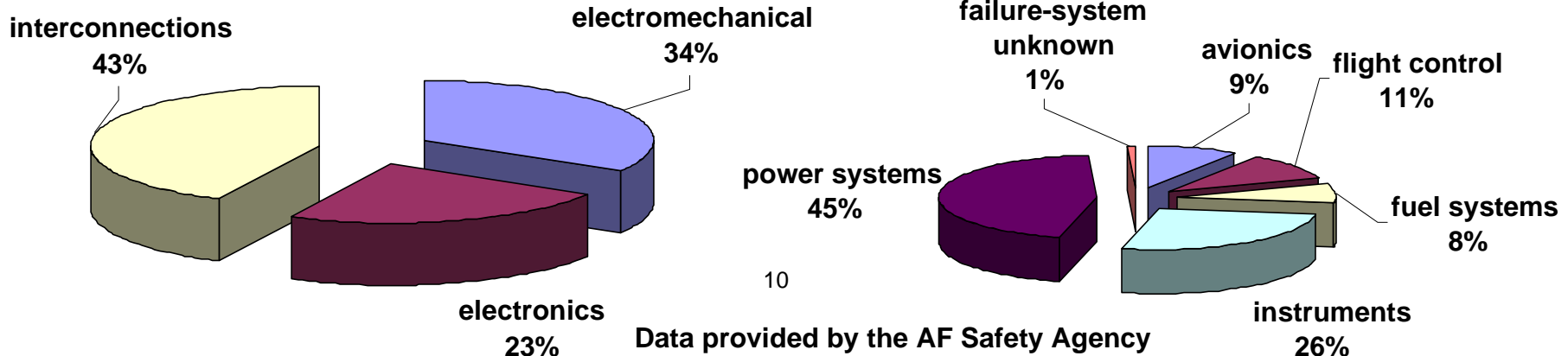
(1989-99)

Age Groups of Mishap Aircraft



Function

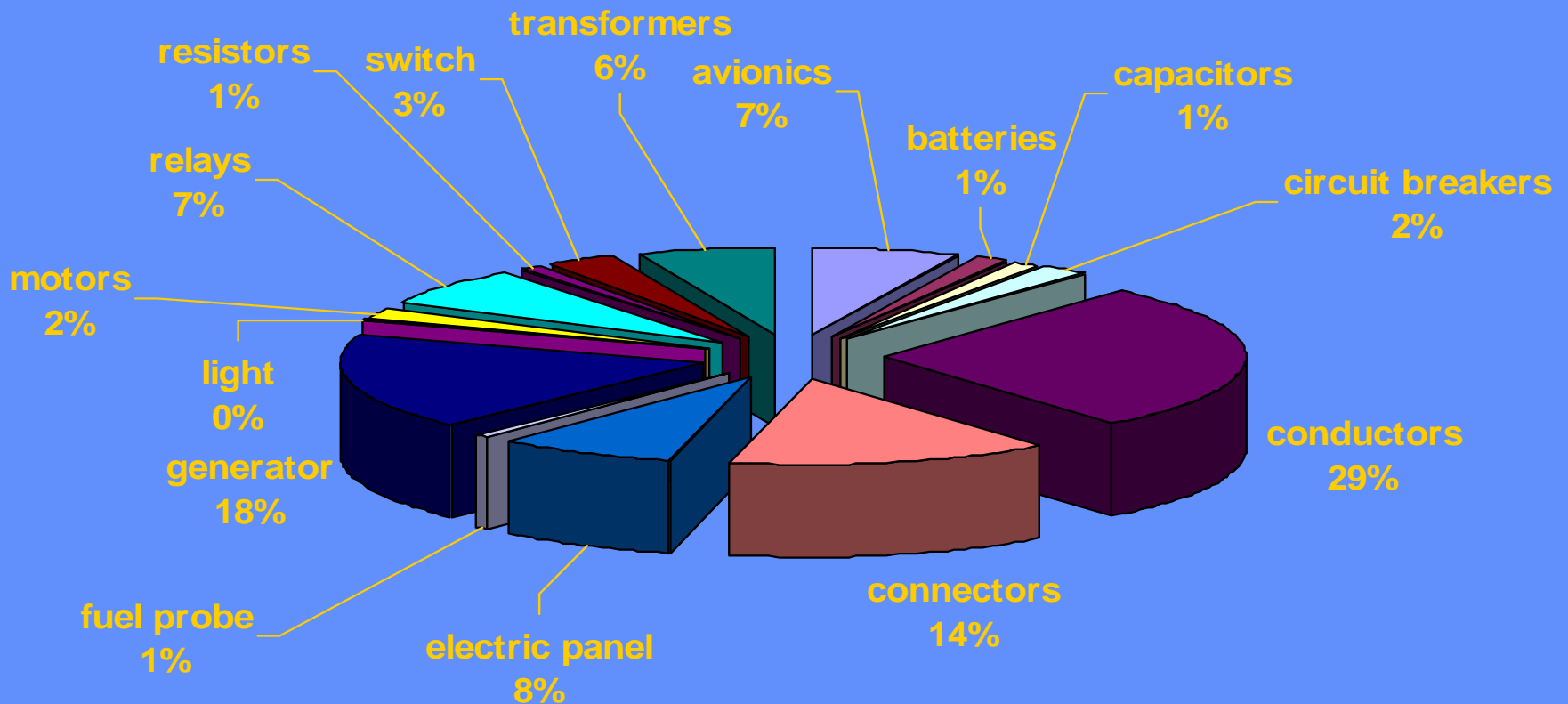
System



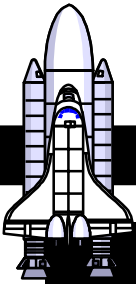
Data provided by the AF Safety Agency

AF Mishap Data Related to Electronic Failures (1989-99)

Components Contributing to AF Mishaps

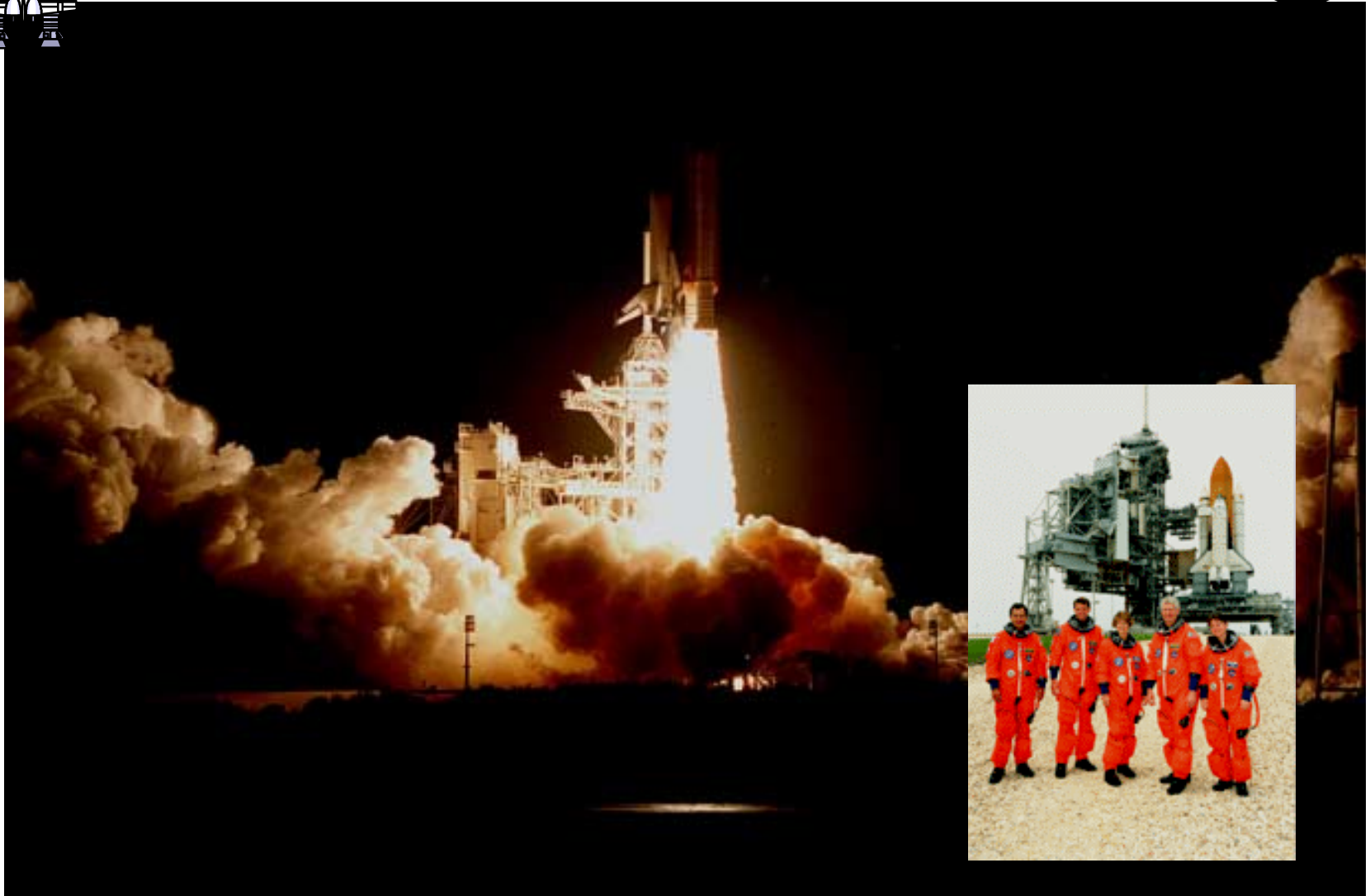


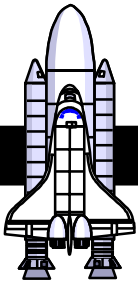
Data provided by the AF Safety Agency



OV102 Launch STS-93

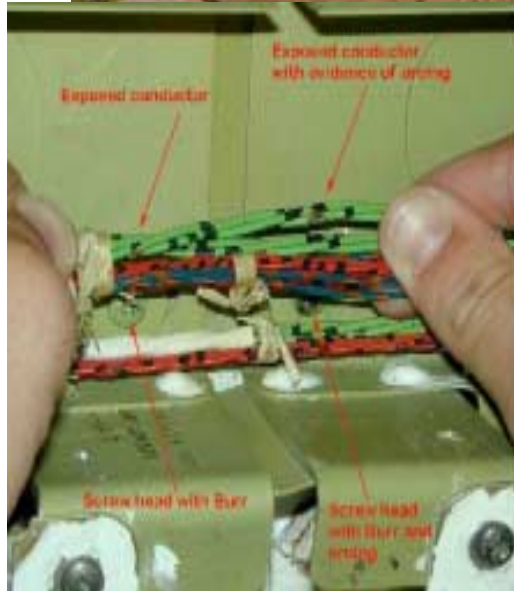
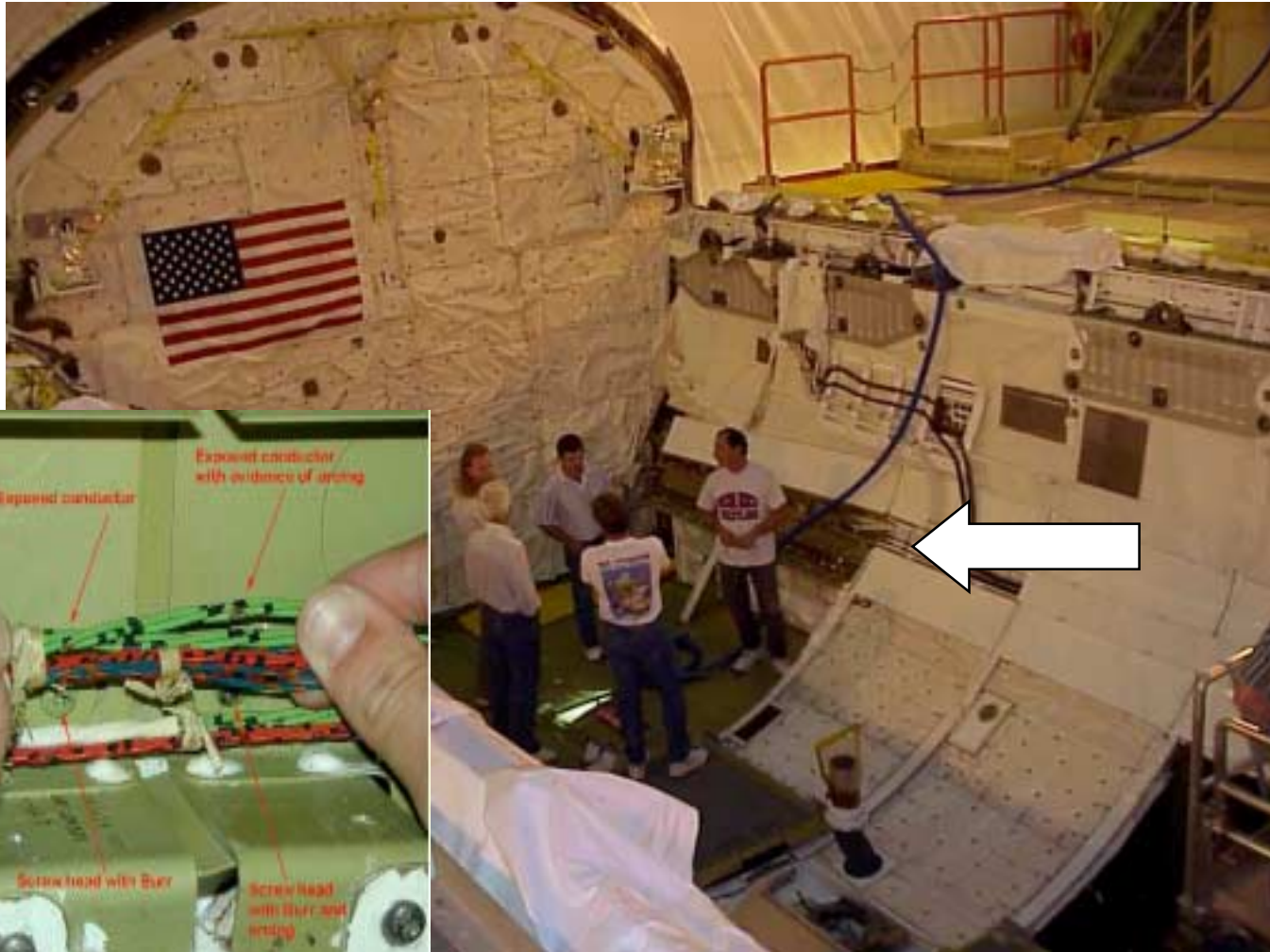
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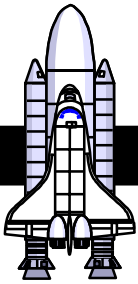




OV102 Electrical Short- Midbody

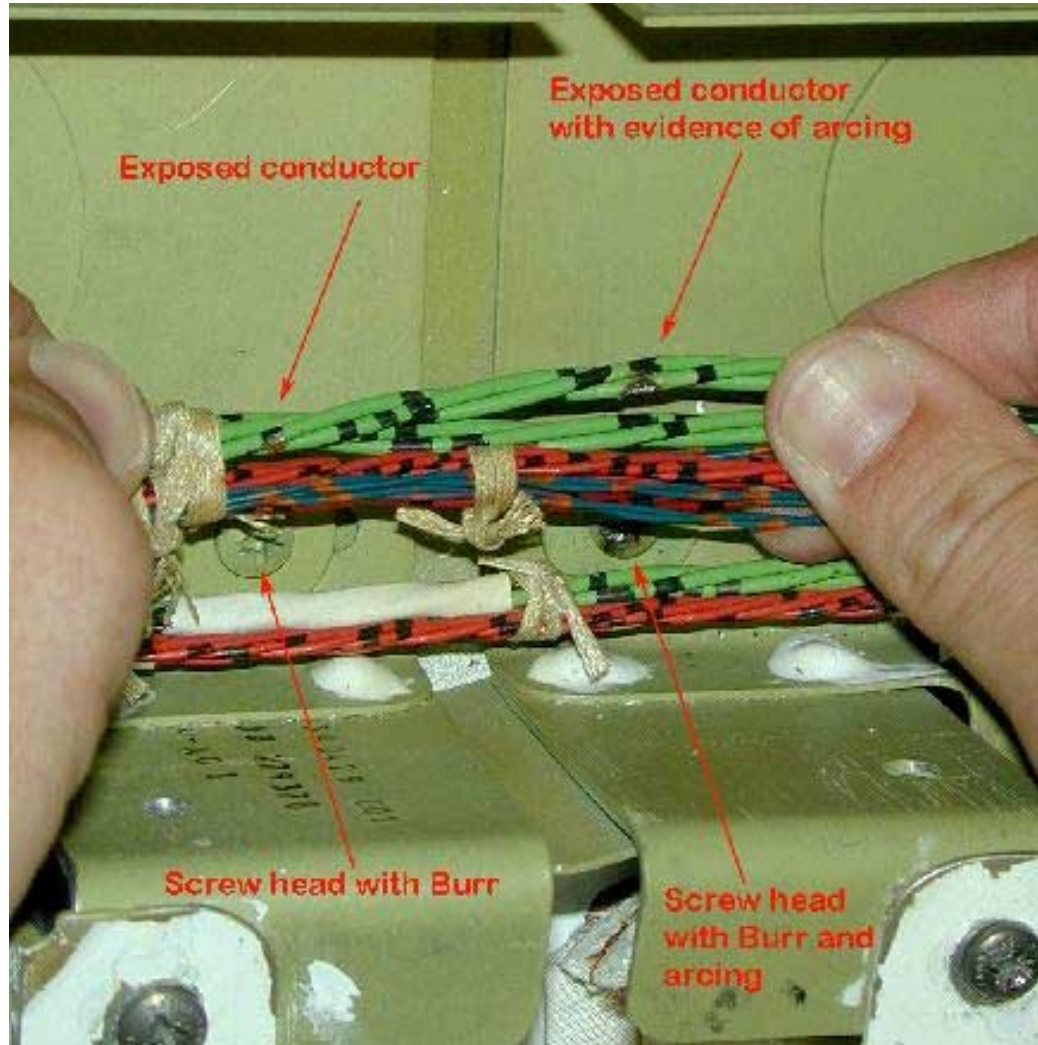
PROCESS ENGINEERING

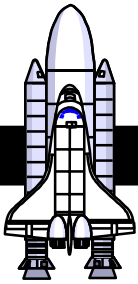




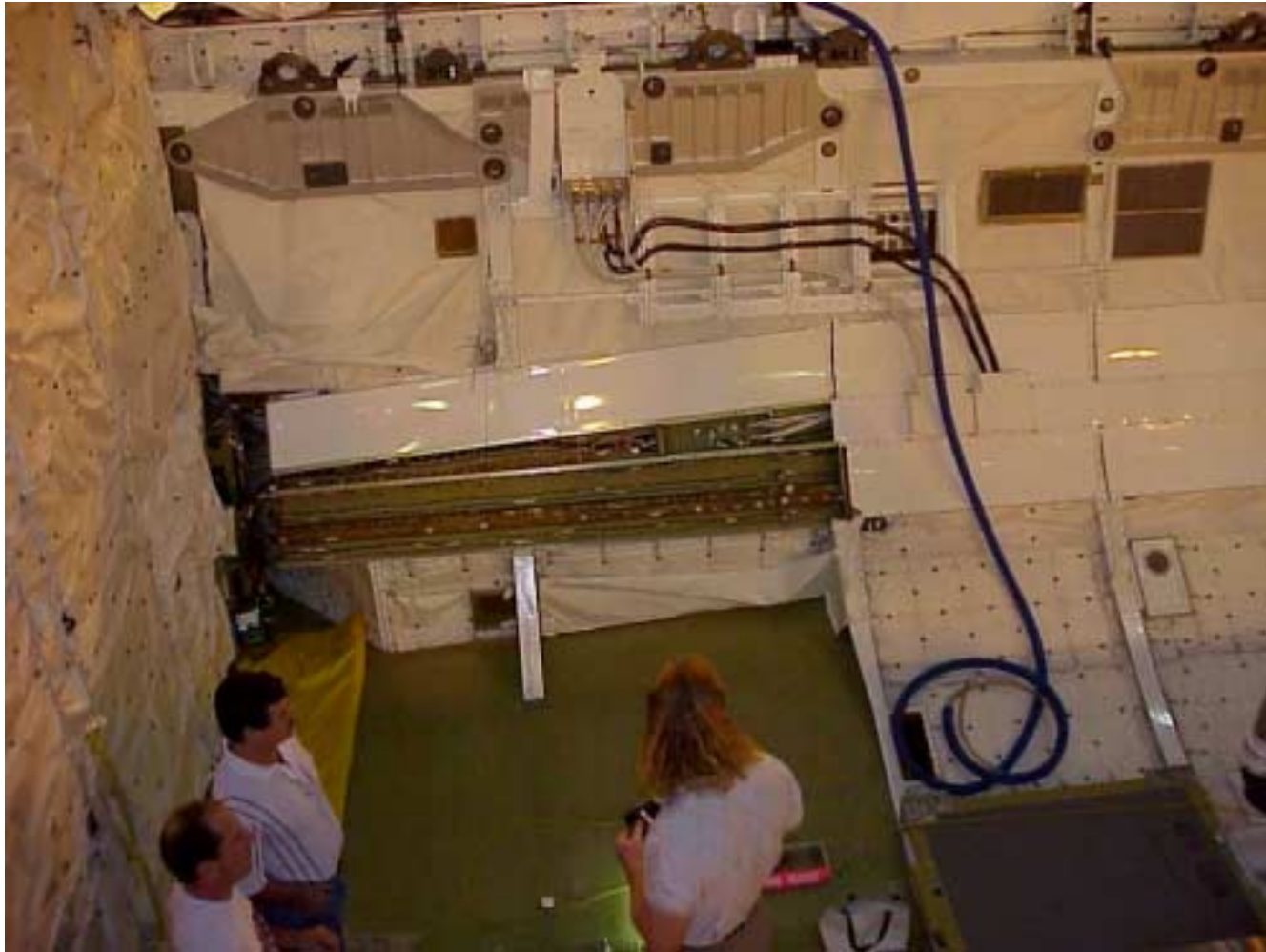
OV102 Electrical Short

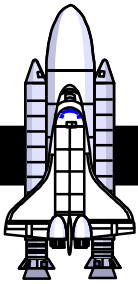
PROCESS ENGINEERING





PROCESS ENGINEERING

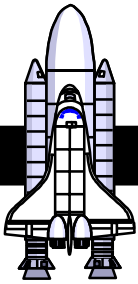




Closeup of Burred Screw

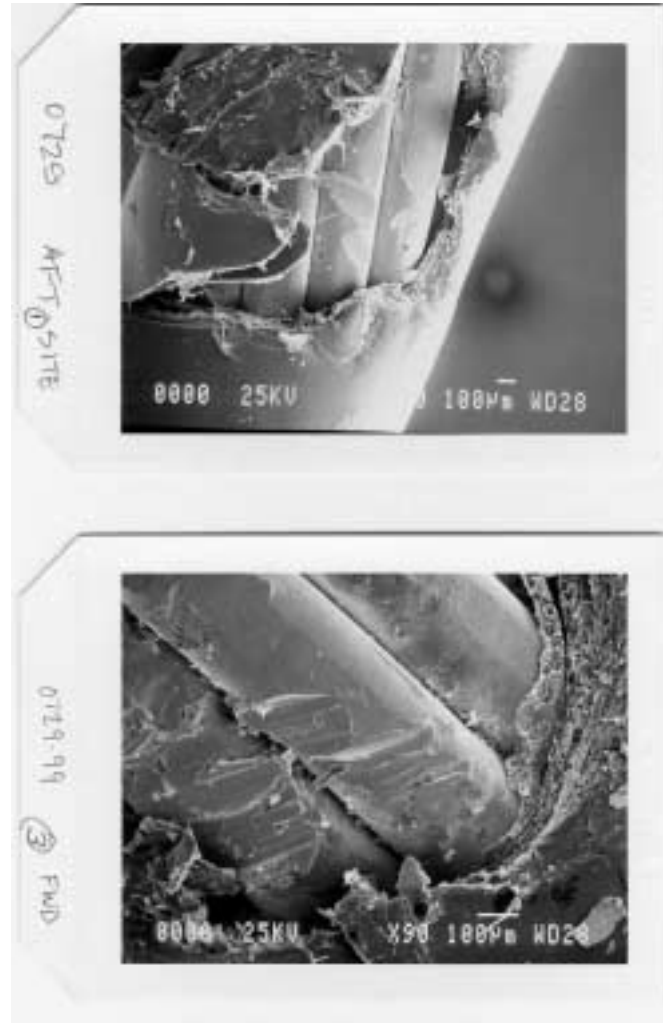
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Electron Microscope Picture of Fault

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No evidence of vibration induced damage

(3 Independent Labs and AFRL Mal Lab)

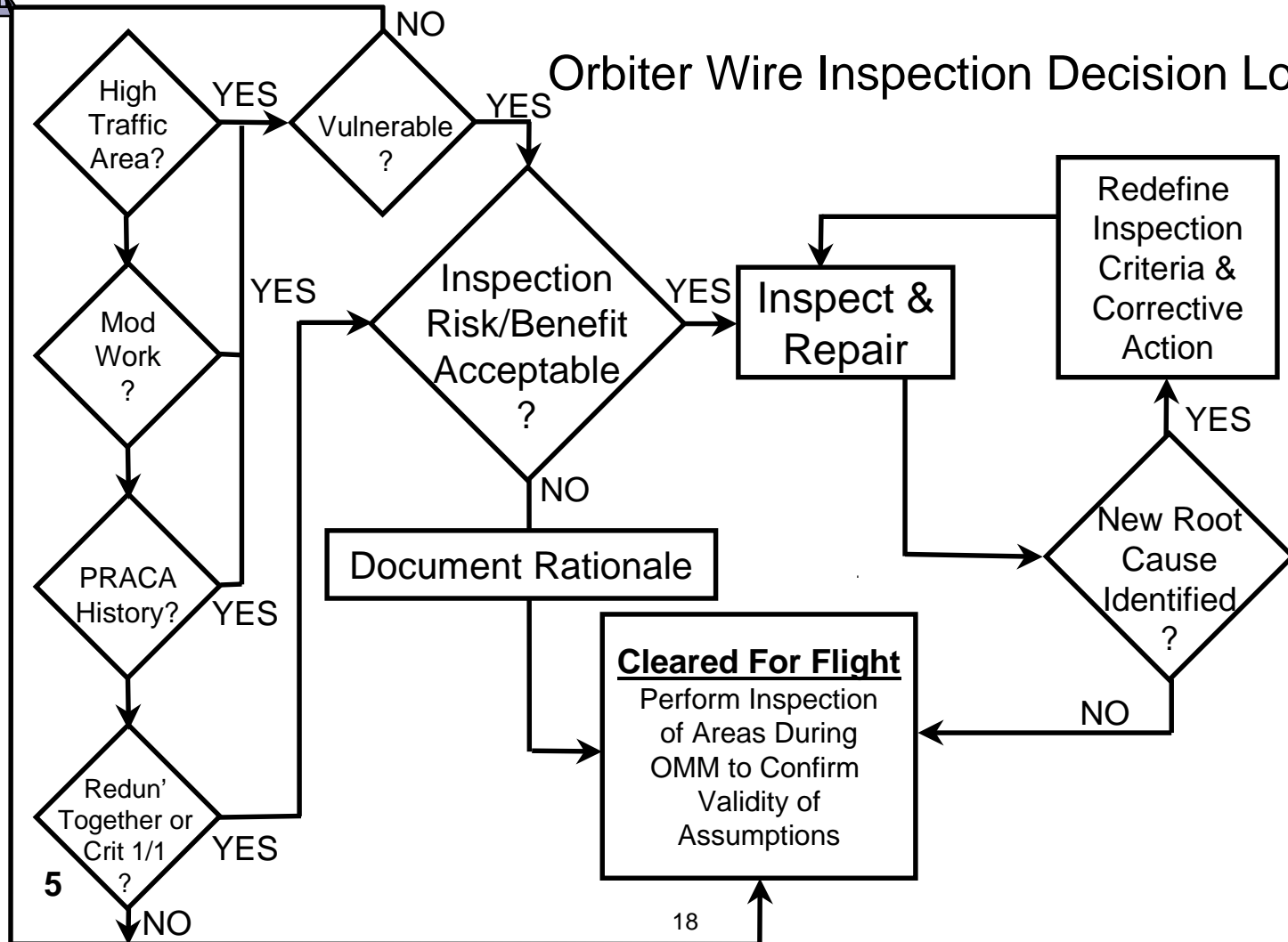
Damage was caused by significant impact to cable

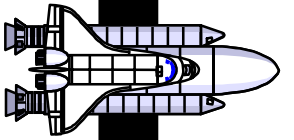
Oxide growth revealed that damaged wire had flown several times

What To Inspect?? “A learning process”



Orbiter Wire Inspection Decision Logic

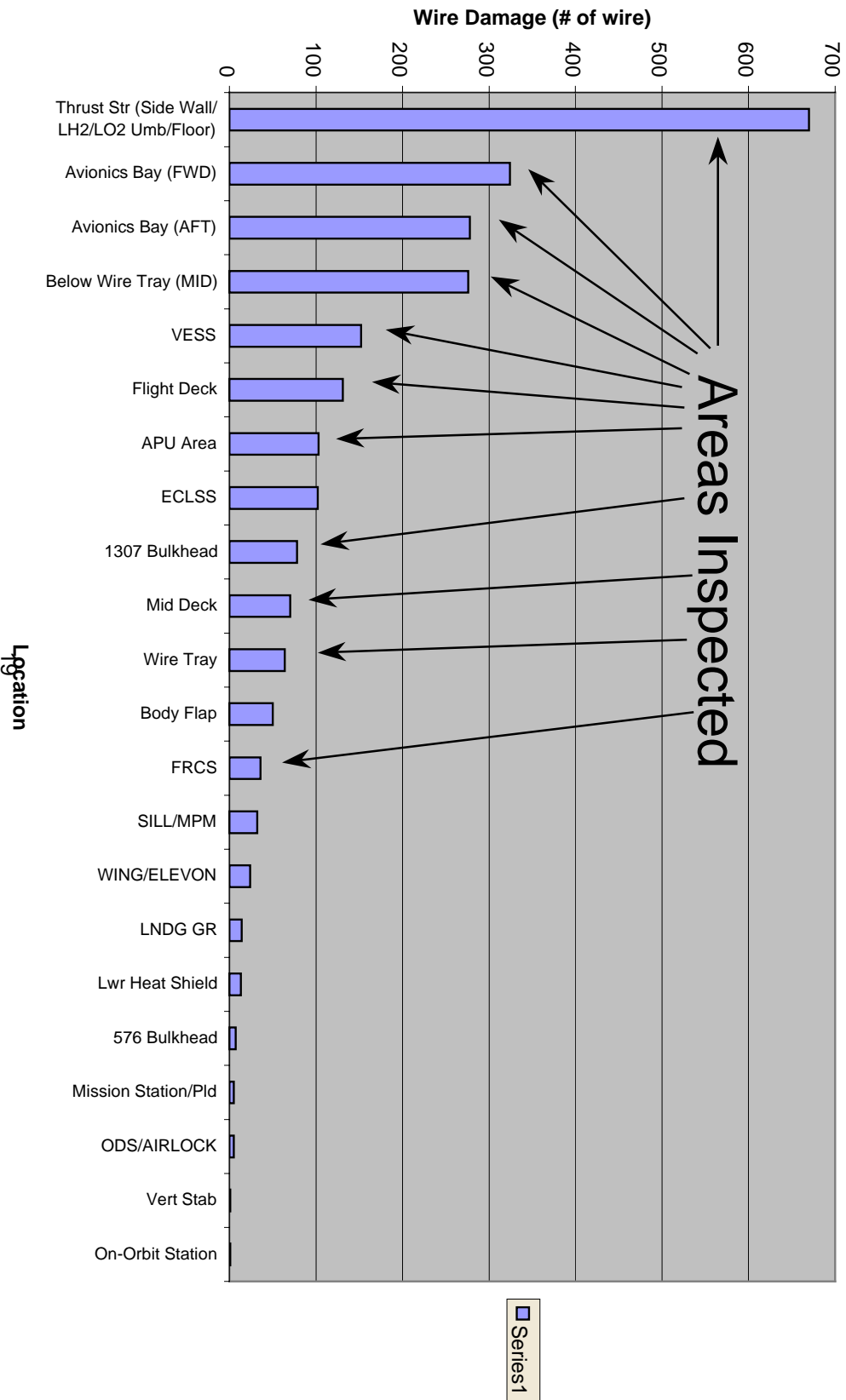


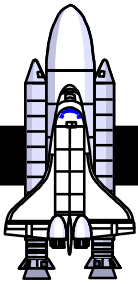


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Analysis of Wiring Damage History

PRACA SUMMARY (FWD/MID/AFT)



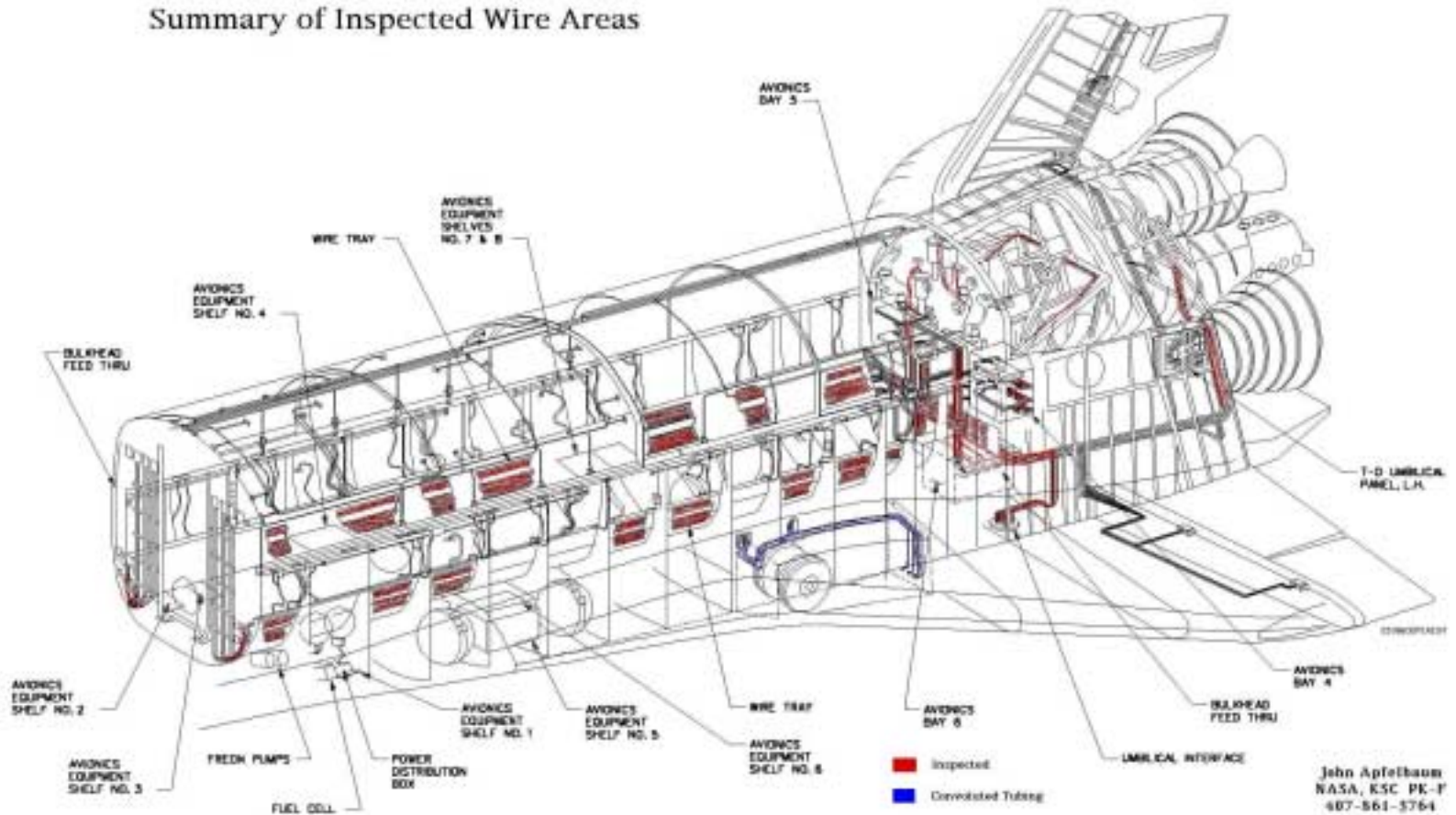


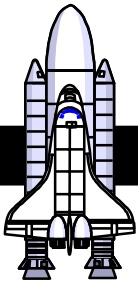
Wire Harness Inspection

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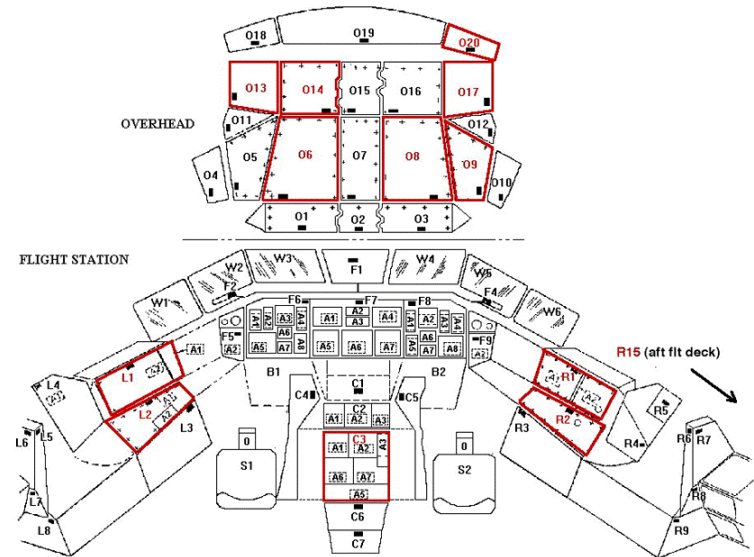
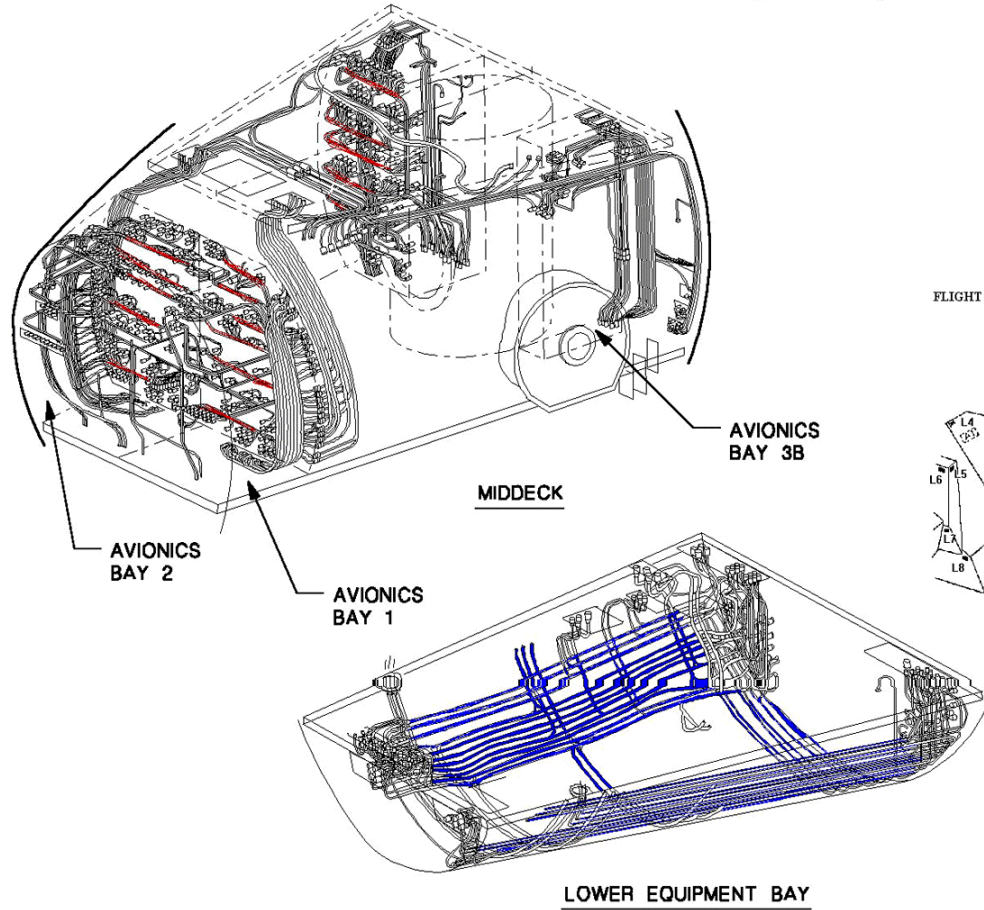
Summary of Inspected Wire Areas





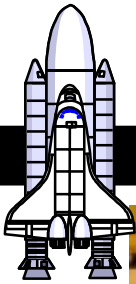
Wire Harness Inspection

Summary of Inspected Wire Areas



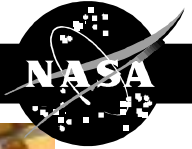
- Inspected
- Convoluted Tubing

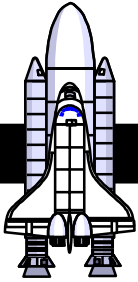
John Apfelbaum
 NASA, KSC PK-F
 407-861-3764



Orbiter Midbody Wire Harness Inspection

PROCESS ENGINEERING

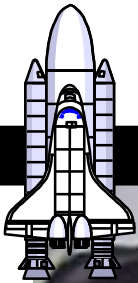




Wire Harness Inspection

PROCESS ENGINEERING



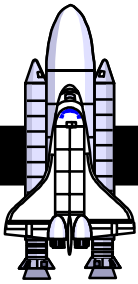


1500 VDC DWV Testing

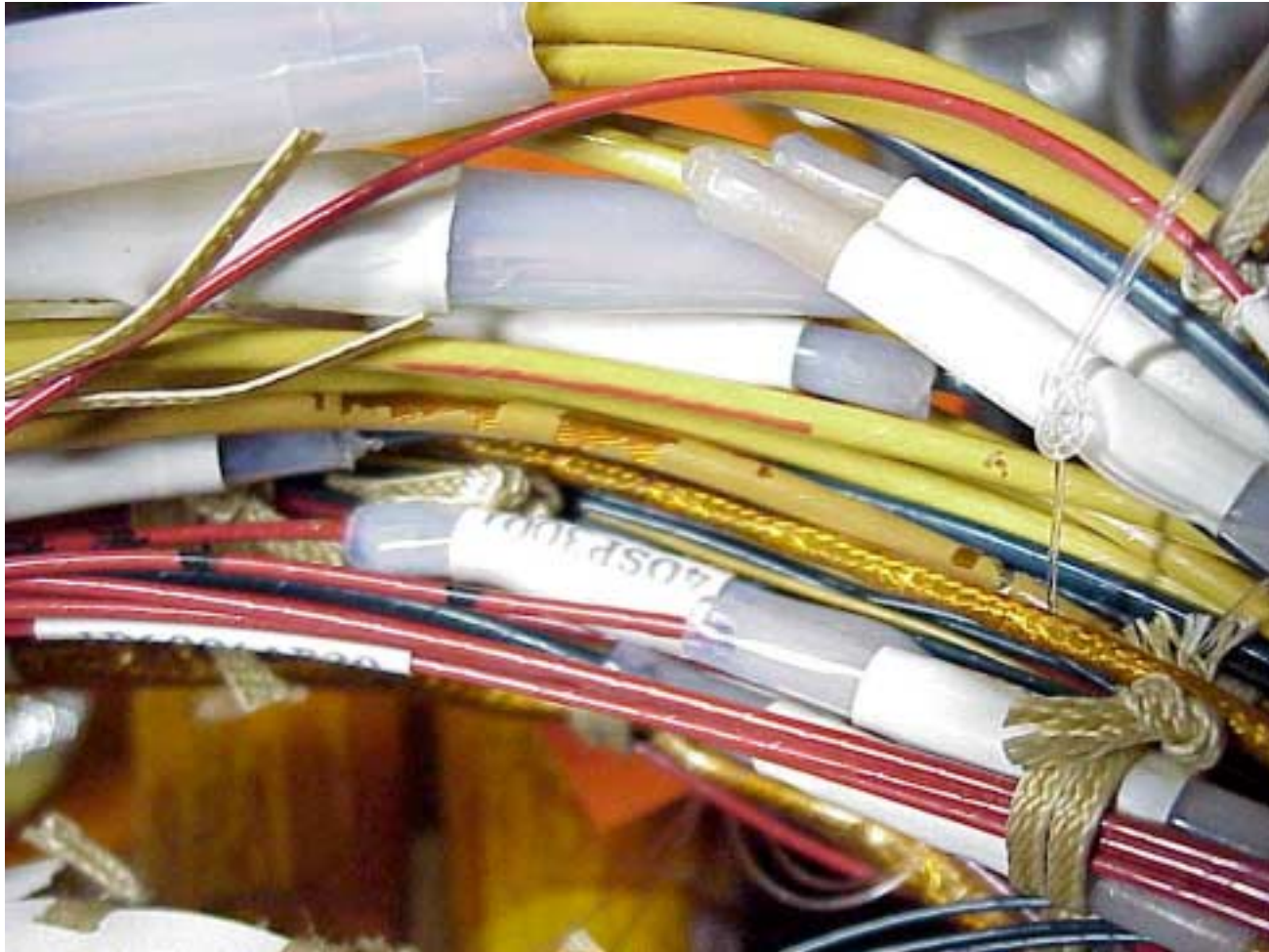
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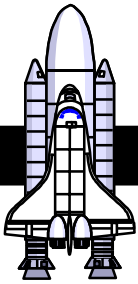


HOW GOOD IS A DWV TEST (HIPOT)????



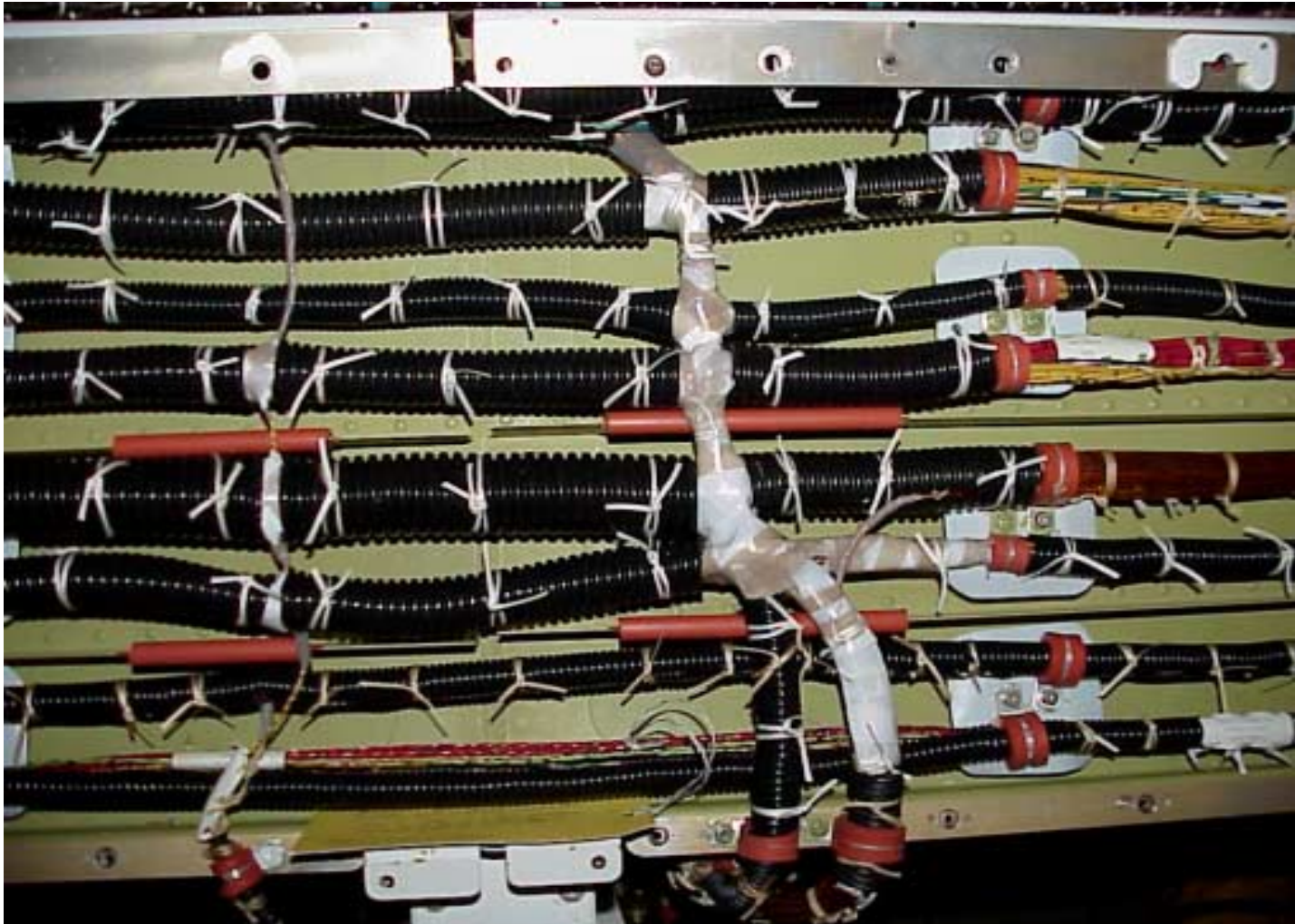
Types of Damage

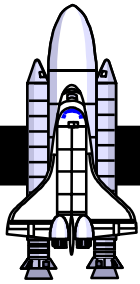




Convoluting Tubing

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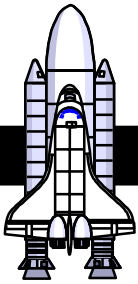




Glass Cockpit Modifications – MEDS

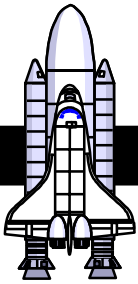
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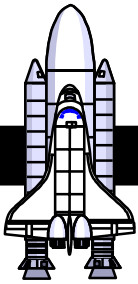




When you think you have seen everything??

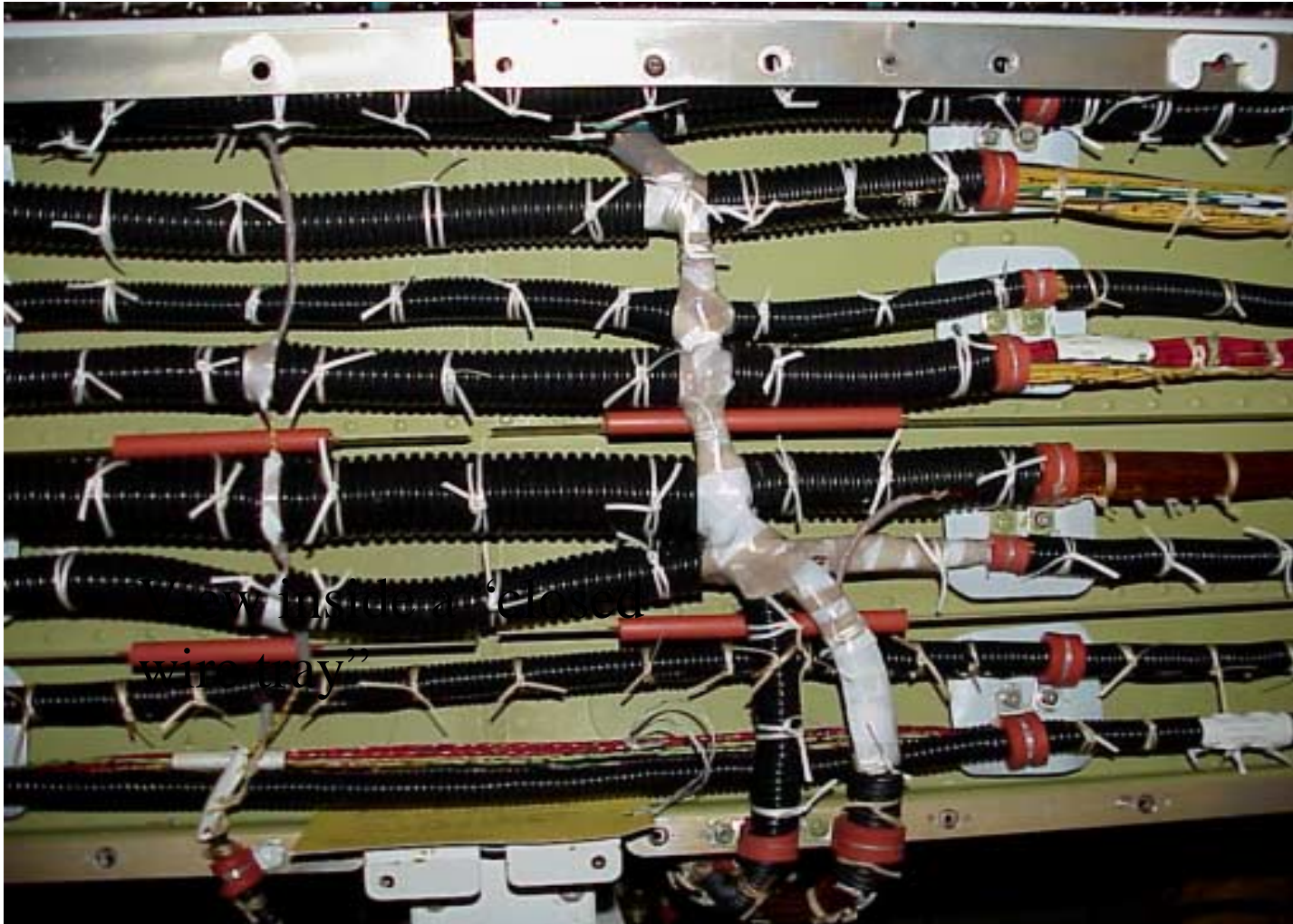
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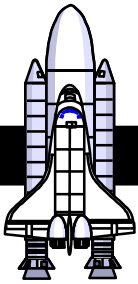




Wire Harness Separation Modification

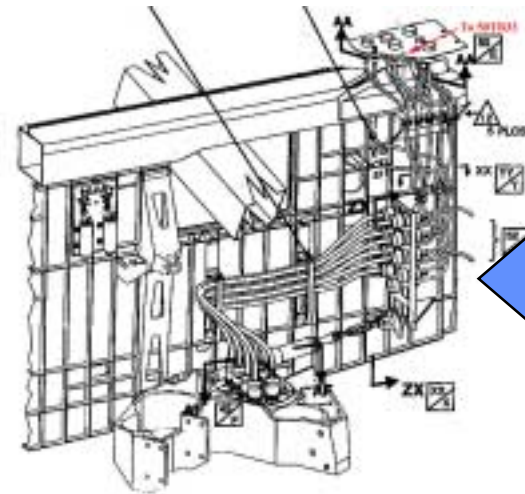
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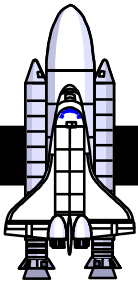




Orbiter/ External Tank Electrical Monoball Production Break

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“Inspect & Protect” Awareness Campaign

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INSPECT & PROTECT!

Prevent In-Flight Anomalies!

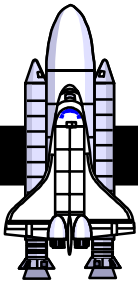
ST5-6
Humbly Separator Wiring Pin

ST5-93
Screw Head Short

QUALITY CONTROL

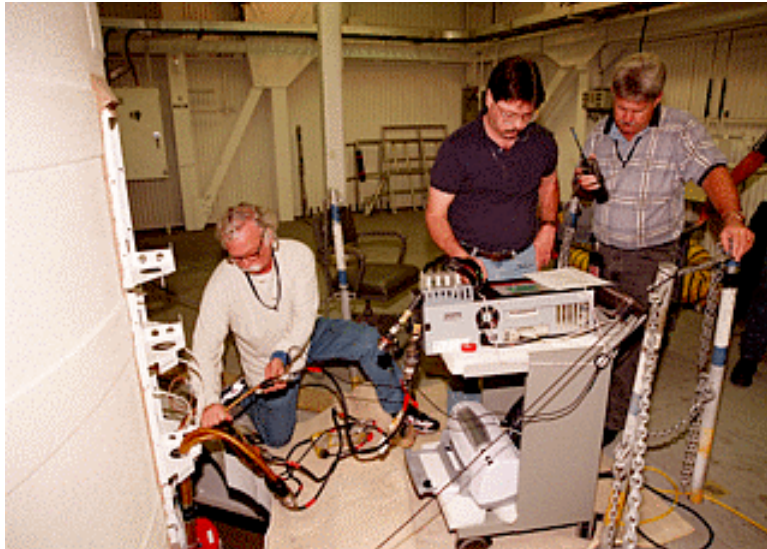
Bill Crawford at 714-372-5803 or Bill Dean at 714-372-5815

The poster features a yellow background with the title "INSPECT & PROTECT!" in large, bold, red letters. Below the title are four photographs showing various inspection and repair work on spacecraft components. The top-left photo shows a person working on a large, curved structure. The top-right photo shows a close-up of a component with a screw. The bottom-left photo shows a bundle of wires. The bottom-right photo shows a close-up of a screw head. The text "Prevent In-Flight Anomalies!" is written in red. At the bottom, there is a NASA logo, the words "QUALITY CONTROL" in a stylized font, and contact information for Bill Crawford and Bill Dean.



Repetitive Dielectric Withstanding Voltage (DWV) Study (Planned)

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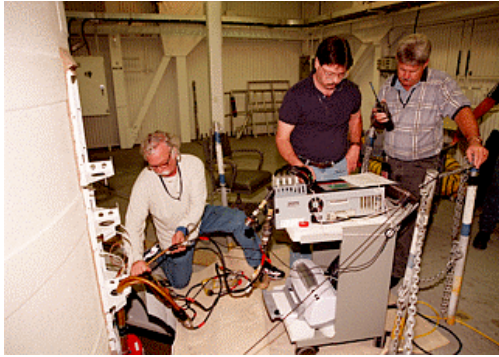


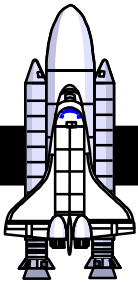
- **Effects of Repetitive DWV**

Larry Ludwig – NASA KSC Mal Lab (321)-867-7049



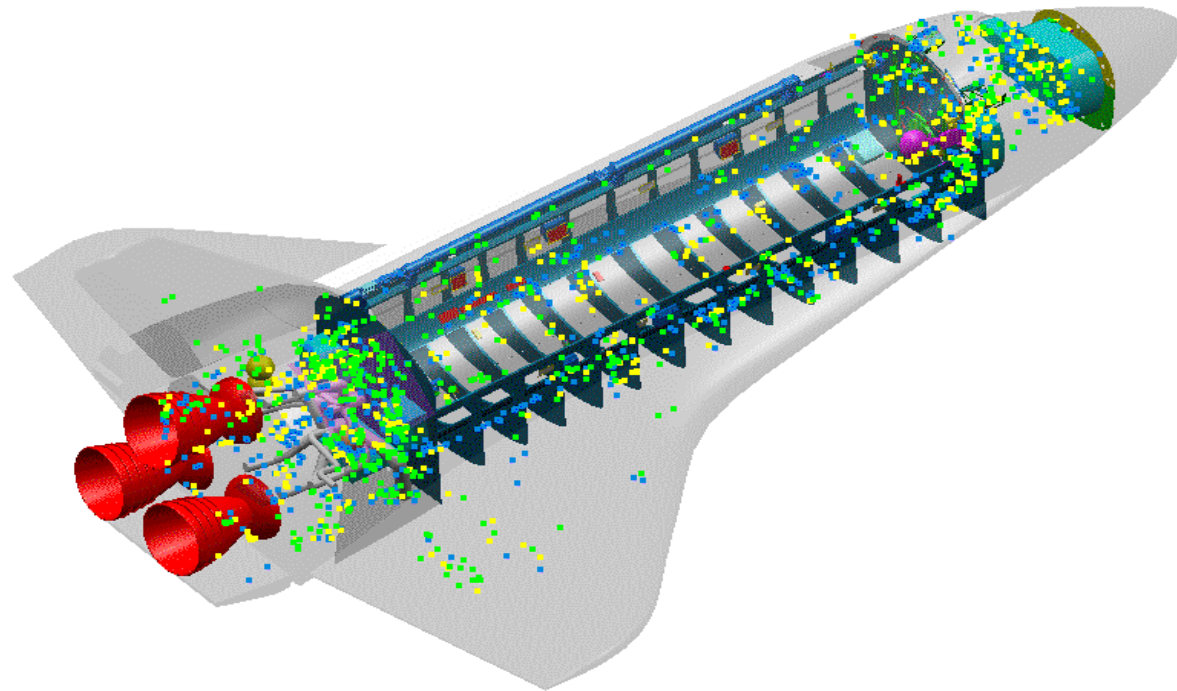
Solid Rocket Booster Cabling

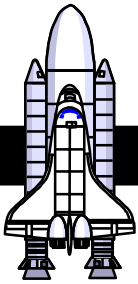




Wire Damage Mapping

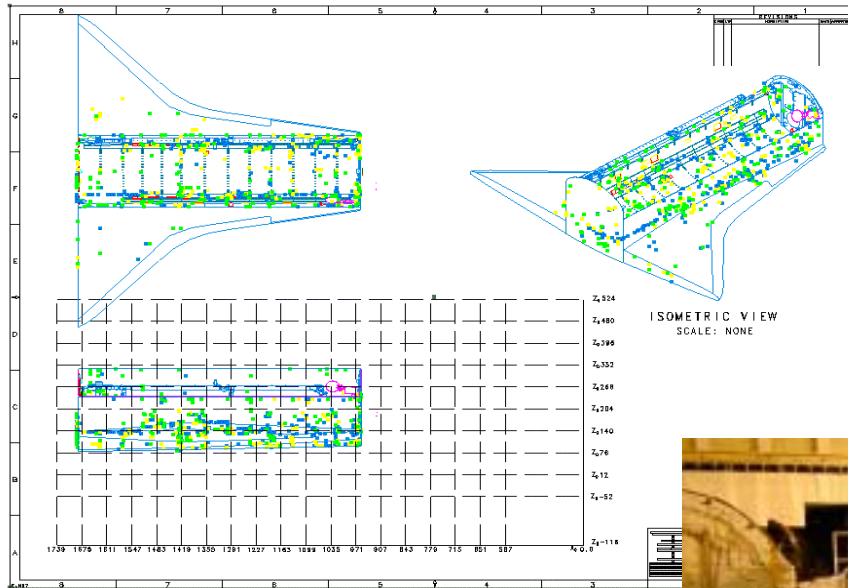
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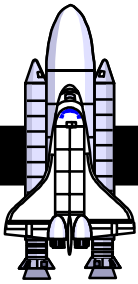




Wire Damage Mapping - Midbody

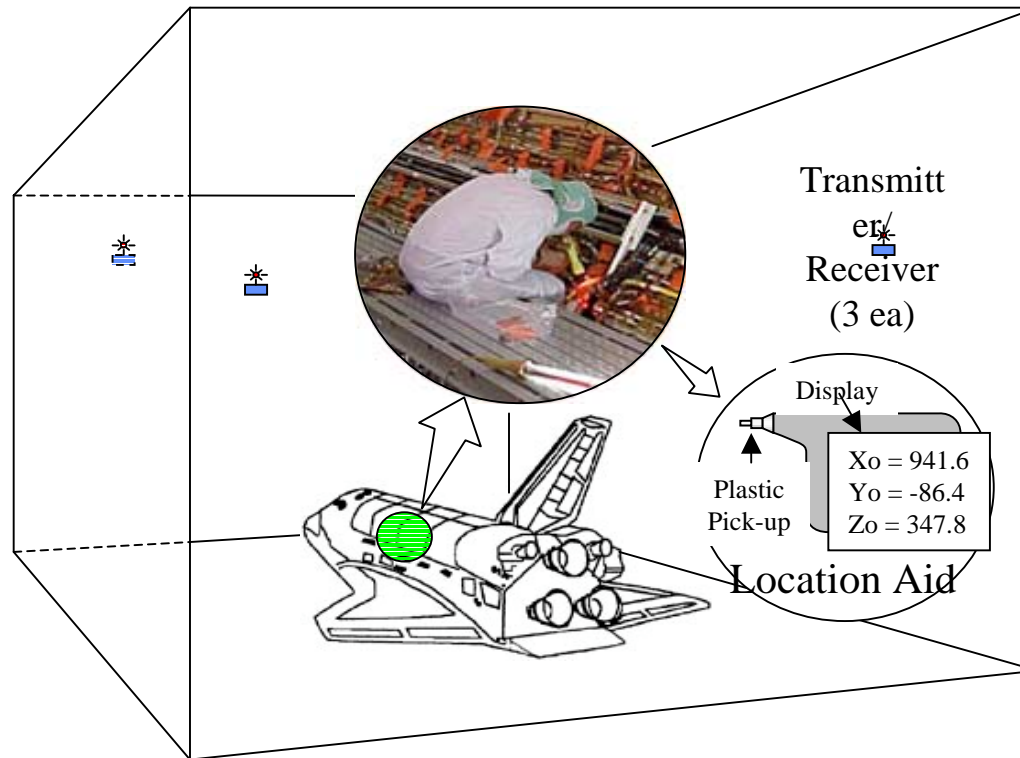
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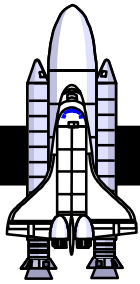


Wire Damage Mapping – x y z coordinate locator (Study Phase)

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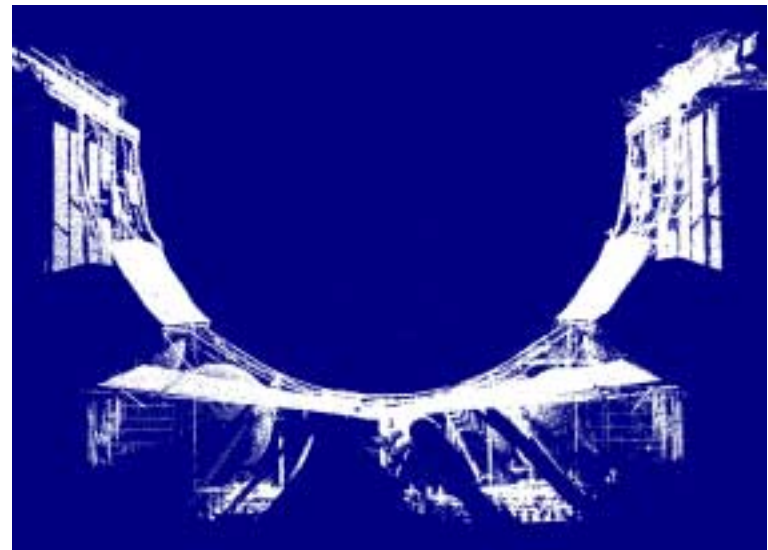
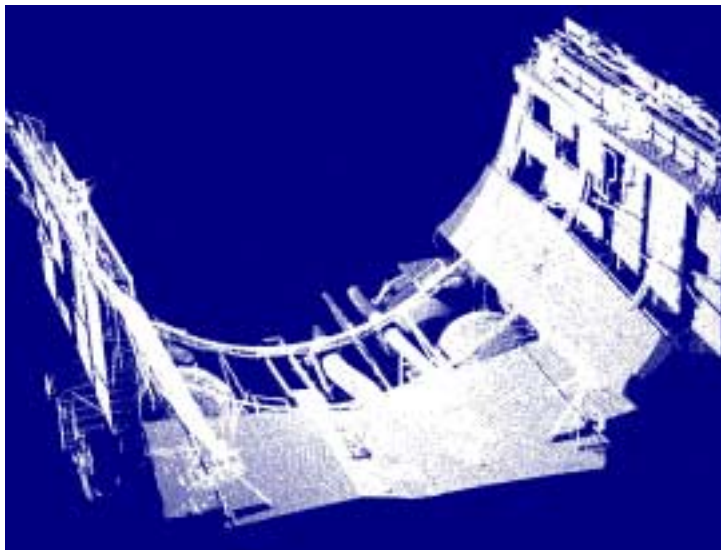


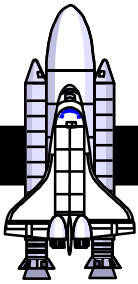
*Note: Latest concept does not use transmitters



LASER 3-D Scanning Study Phase

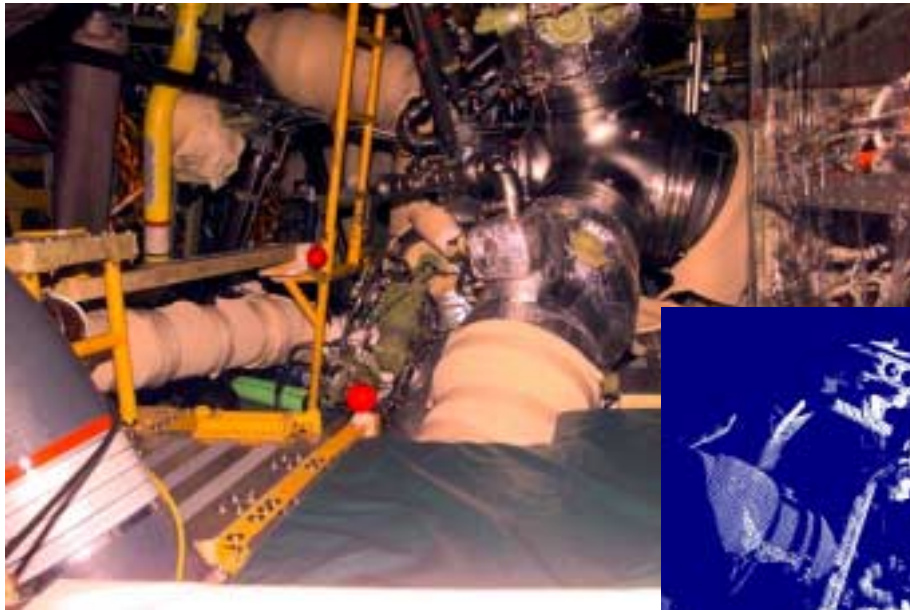
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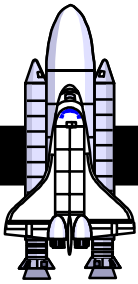


LASER 3-D Scanning Study Phase

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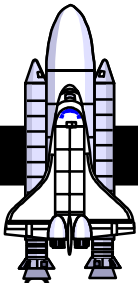
Standing Wave Reflectometry



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Summary



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Summary:

- Scheduled wire inspections at major modification (Performed by two independent inspectors NASA quality and USA quality)
- Inspector and technician training and certification on wire damage assessment
 - “Hands on Trainer” developed and class
- Wiring specifications tightened and clarified for assessing cable damage
- Maintenance requirements added that when cable clamps removed technician and quality will fan wire harness out for inspection
- Platforms and area protection on work platforms
- Convoluted tubing installed in “high traffic” areas (>150lbs per orbiter)
- Aging polyamide wire study with Boeing and Lectromec (800 page report)
- Orbiter wire separation study to assess any areas that there may have been a violation of critical circuits routed together