Novel Wiring Technologies for Aerospace Applications

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Overview

- Technology Transfer Opportunities
- Background
- KSC Wiring Technologies
  - Damage Detection
  - Re-Routing
  - Self-Healing Wire Insulation
  - Manual Repair
  - In-Situ Wire Damage Detection
- Conclusions

Technology Transfer

For further information on the technology and licensing the patents contact:

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Background

- STS-93 (July 1999)
  - Short circuit in 14 AWG polyimide insulated wire
- TWA 800 (July 1996)
  - Frayed polyimide wire in center tank area
- SwissAir 111 (September 1998)
  - Damaged wire in plane’s entertainment system
- AS-204 (Apollo 1, January 1967)
  - Electrical wire short

Background

- KSC's objective – to develop a smart wiring system that contains:
  - A detection system that detects and locates an electrical compromise
  - A re-routing system that will re-direct electrical signals or power to spare conductors when damage is detected
  - A self-healing system that initiates self-healing of damaged wire insulation
  - A manual repair system that repairs damage to electrical wire insulation when the damage is too large to self-heal

- KSC scientists and engineers have been developing novel wiring technologies for more than a decade, focusing on advancing the technologies needed for the development of a truly smart wiring system, with diagnostic and prognostic capabilities

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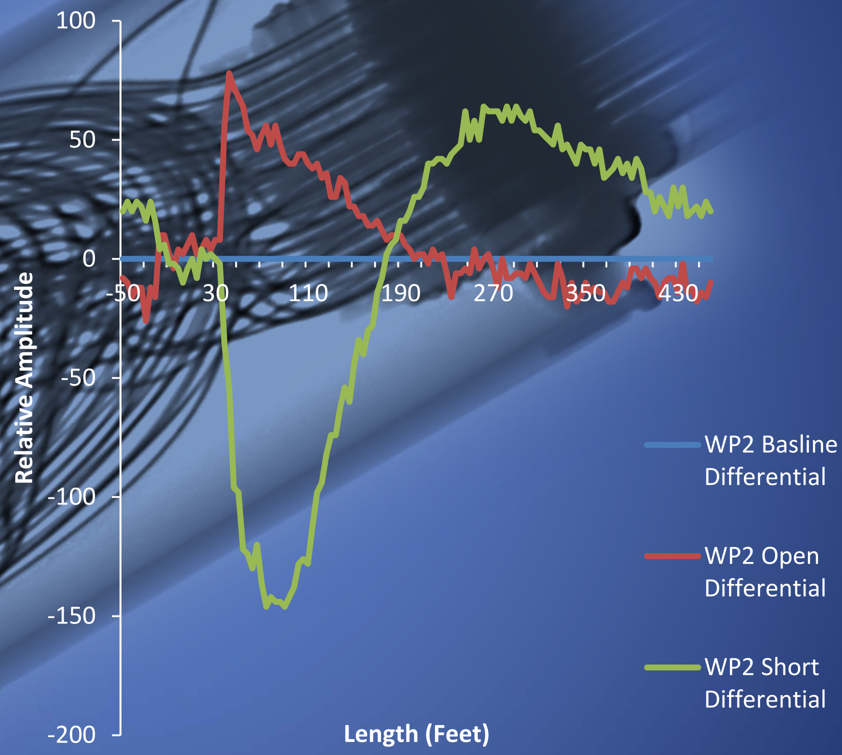
Damage Detection

- In-line time domain reflectometer (TDR) with the capability to detect open, short, and intermittent faults in either powered or unpowered cables
- Prototype unit – 6” X 1.5”, 200 grams (including connectors)
- Design incorporates over 8100 logical gates and was designed based on a field programmable gate array.
- Current prototype provides the capability to evaluate up to 16 wires in a cable bundle in a single scan, while acquiring failure information in real-time.

Damage Detection

- Online Mode
- Utilized custom test-box with a visual light emitting diode (LED) indicator
- LED was powered by a power source applied to the cable under test
- Breaks or shorts in the cable under test would cause a loss of power to LED
- Wire was damaged at 28 feet – collected data indicated damage at 30 feet
- POC – P. Medelius



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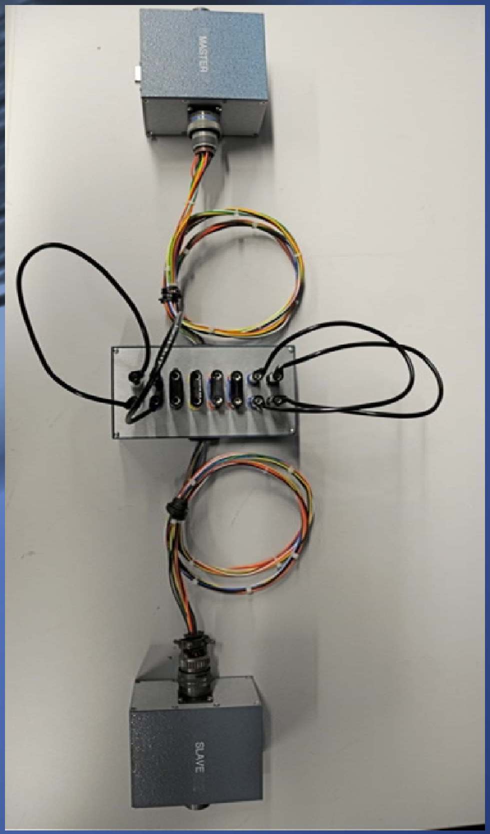
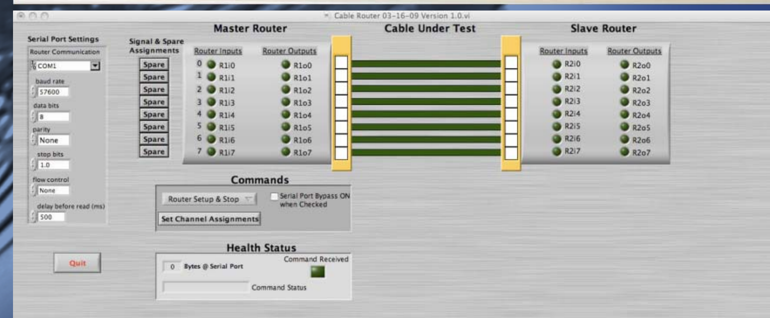
Re-Routing

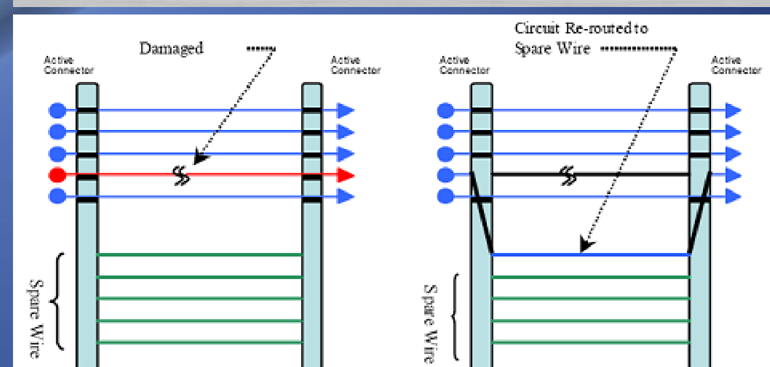
- Master and Slave Units
- Master unit consists of a pulse generator, a multiplexer, a switch matrix, and a detector circuit
- The slave unit monitors the wire and once it receives the signal, it routes it back to the master unit through a communication wire
- Pulse generator provides a step pulse to multiplexer, which then routes to one of 8 wires, followed by propagation of the signal through selected wire to slave circuit, which receives the signal and routes back to master unit
- Current implementation of the hardware can monitor up to 8 wires



Re-Routing

- Laboratory testing has demonstrated the capability of autonomously re-routing a faulty wire to an alternate path thus re-establishing the integrity of the failed circuit
- Laboratory testing also demonstrated that the circuitry was capable of reliably determining the onset of failure and quickly switching the failed circuit to spare conductors
- Future development efforts will focus on the use of MEMS switches for increased reliability, greater current capacity, wider voltage range, and reduced size
- POC – M. Lewis





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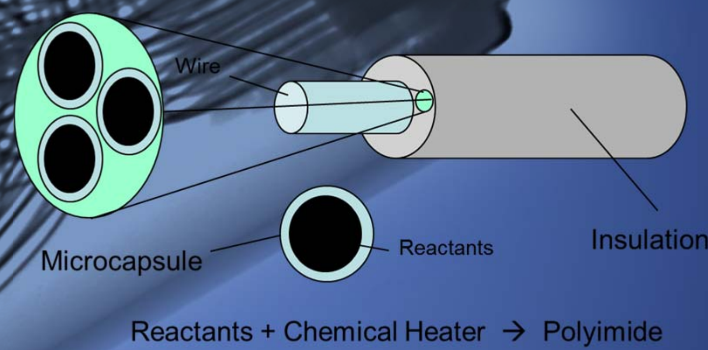
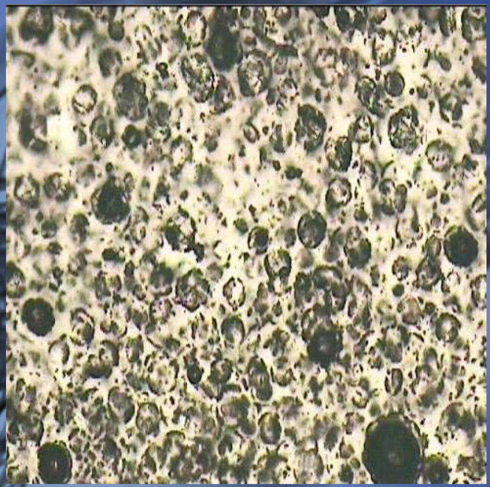
Self-Healing Wire Insulation

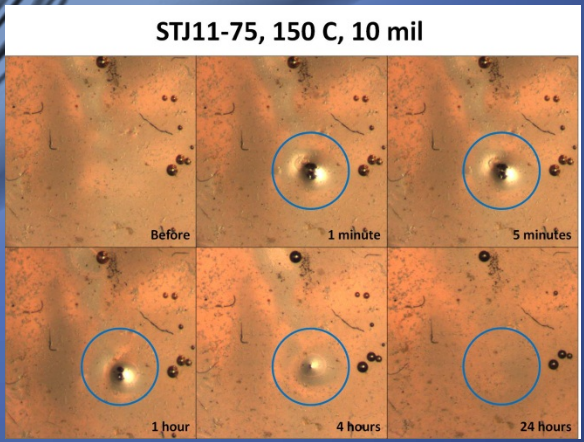
- Wiring failures are the #1 issue for aerospace vehicles and aircraft
- There are currently no commercially available self-healing wire insulation materials
- Can utilize microencapsulation technologies, flowable material systems, and combinations thereof
- Goal is to produce high-performance self-healing wire insulation with healed performance equivalent to undamaged wire
- Self-healing wire insulation is expected to reduce life-cycle costs, safety requirements, and increase mission reliability



Self-Healing Wire Insulation

- Microencapsulation of healants for self-healing damages – optimized for efficient delivery of healants, thermal, electrical, and chemical stability
- Self-sealing – utilizes novel low-melting polyimide chemistry developed at KSC
- Systems can be utilized individually or together – as stand-alone materials or laminates
- Self-healing has been demonstrated in a laboratory environment but has not been scaled-up to produce usable quantities for production
- POC – M. Williams





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Manual Repair

- One of the major limitations of current spacecraft wire insulation is that it tends to crack and fray as it ages
- Current repair methods used include a tape-wrap repair and a heat shrink repair
- These methods have several drawbacks, including susceptibility to vibration or other mechanical stresses
- KSC's goal was to produce a manual repair technology the provided a highly flexible, high performance repair that performed as well as the undamaged wire
- Supplements self-healing technology

Manual Repair

- Evaluation – Thermal, voltage withstand, electrical, flammability, mechanical slip testing, t-peel testing, solvent resistance, and life cycle evaluation
- Repair materials developed are low-melting siloxane-containing polyimides
- Optimized repair process to allow repairs to be performed using either a custom fabricated or DOD approved heating tool
- Repair process takes between 5-20 minutes
- POC – T. Gibson

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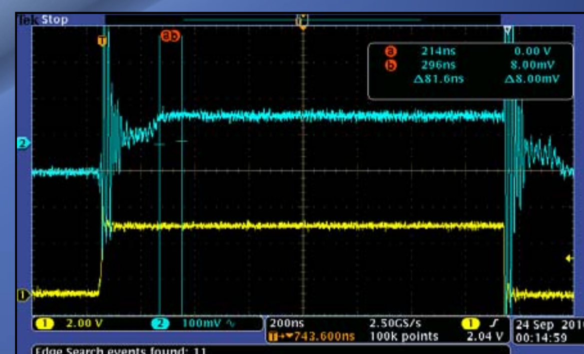
In-Situ Wire Damage Detection

- Integration of smart wiring technologies – damage detection, self-repair, re-routing, and manual repair
- Damage detection utilizes a new wire construction with a damage-detection layer and TDR
- Detection layer can be applied via spraying, sputtering, dip coating, or wrapping
- Multiple prototype wire constructions fabricated, utilizing a variety of conductive materials

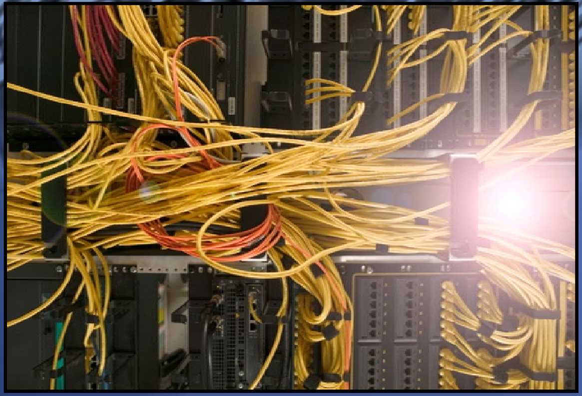
In-Situ Wire Damage Detection

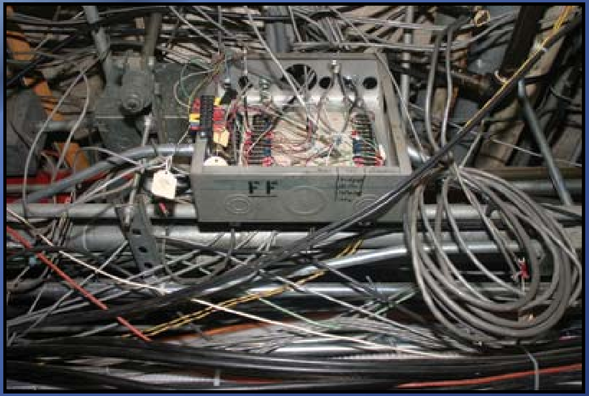
- Integrated damage detection (TDR) and re-routing system developed and evaluated as part of dust tolerant connector project (cable diagnostics system)
- Cable diagnostics systems evaluated under a wide variety of test conditions – open, short, pairs of opens and shorts, etc.
- New wire constructions evaluated using laboratory TDR and SWR
- Both reflectometry methods detected damage to detection layer – potential issues with connection to detection layer
- POC – M. Lewis & T. Gibson



Conclusions

- KSC has made significant progress in advancing technologies needed for development of a smart wiring system
- The technologies developed have been patented and are available for technology transfer
- KSC continues to advance the technologies and seek partners to continue development efforts





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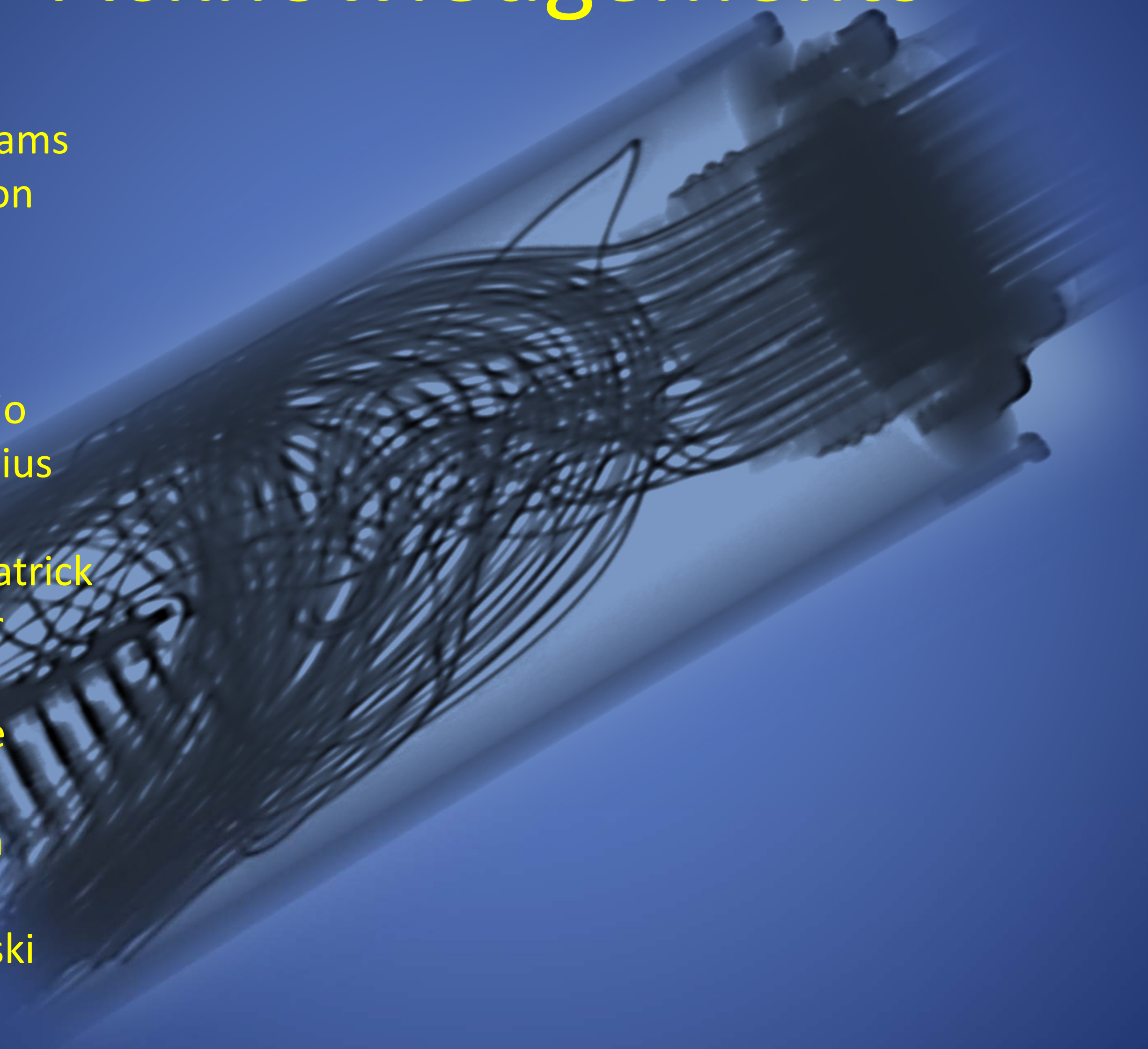

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Patents

- US 8,593,153 B2 – Method of Fault Detection and Rerouting
- US 8,623,253 B2 – Low-Melt Poly(amic acids) and Polyimides and Their Uses
- US 2011/0210749 A1 – In-Situ Wire Damage Detection System
- US 2012/0321828 A1 – Self-Healing Polymer Materials for Wire Insulation, Polyimides, Flat Surfaces, and Inflatable Structures
- 13/915,407 – Low-Melt Poly(amic acids) and Polyimides and Their Uses (Continuation in Part)
- 14/207,472 – Fluid/Electrical Connector Dust Mitigation Rotating Cap