Novel Wiring Technologies for Aerospace Applications

Dr. Tracy L. Gibson, ESC/KSC
Lewis Parrish, ESC/KSC

NASA Techbriefs Webinar
May 15, 2014
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:

Lewis Parrish, Technology Transfer, NASA/KSC
Lewis.M.Parrish@nasa.gov
321-867-5033
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
Overview

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

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

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

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

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

• Martha Williams
• Luke Roberson
• Mark Lewis
• Lanetra Tate
• Trent Smith
• Anne Caraccio
• Pedro Medelius
• Scott Jolley
• Lilliana Fitzpatrick
• Sarah Snyder
• Gary Bastin
• Rubiela Vinje
• Steven Parks
• Clyde Parrish
• Mike Walz
• George Slenski
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
• 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