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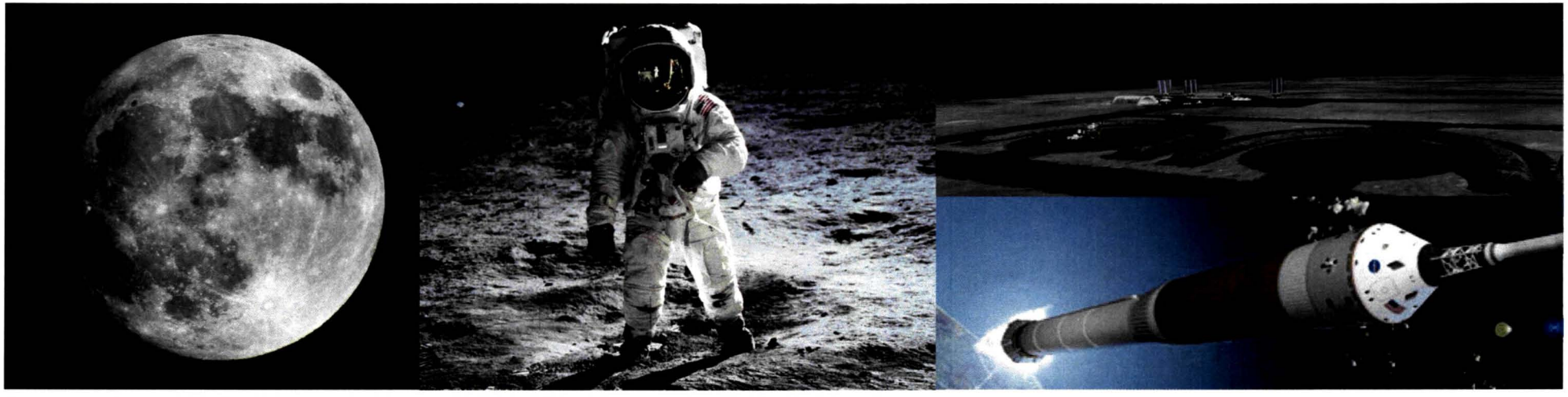

New Wire Constructions for Active Damage Detection

Materials Science Division
Engineering Directorate
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4/21/2011

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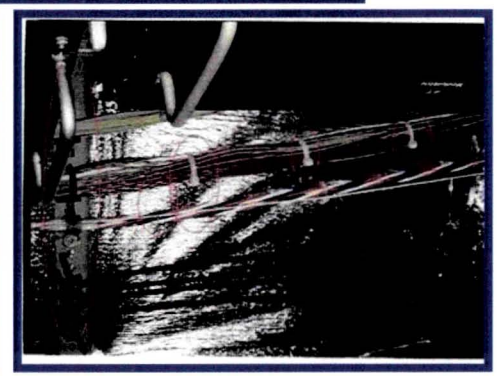
Long History of Wire Failures



TWA 800 (July 1996)

Frayed Kapton® wire in center tank area led to midair explosion of 747 (230 killed)

3 other 747s were found with same fraying issue and grounded*

SwissAir 111 (September 1998)

Damaged wire in plane's entertainment system led to MD-11 crash in Atlantic Ocean (229 killed)

STS-93 (July 1999)

Short circuit in 14 AWG Kapton® insulated wire

Dreamliner 787 Test Flight ZA002 (October 2010)

Electrical fault in P100 panel caused fire forcing emergency landing in Laredo, Texas

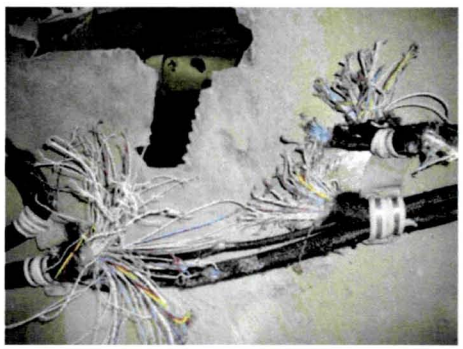
* Flight Safety Foundation, Aviation Mechanics Bulletin, July 1998, page 6.

Types of Aircraft Wire Failures

Investigations of those accidents and later examinations of other airplanes showed a collection of common problems. Deteriorated wiring, corrosion, improper wire installation and repairs, and contamination of wire bundles with metal shavings, dust, and fluids (which would provide fuel for fire) were common conditions in representative examples of the "aging fleet of transport airplanes."

FAA Regulations on the certification and maintenance of aircraft wiring systems (FAA-2004-18379)

Electrical wire failure on Airbus A380



Thermal

Mechanical

Chemical

Wire Failures Modes

INSTALLATION FAILURE

The wire or cable was not installed correctly.
Poor connector choice or incorrect connector installation.

ENVIRONMENTAL FAILURE

The wire or cable is not intended for the place it is installed.
Examples: Indoor-Outdoor cables; cable installed in interference areas; temperature variations.

OPERATIONAL FAILURE

Improperly designed or purchased for operation. Example: cable length - cable can be run too far or a poorly-manufactured version may be substituted for one of higher quality. This is commonly known as the "just as good" syndrome.

MANUFACTURING FAILURE

The wire or cable was incorrectly manufactured, incorrectly labeled, or incorrectly tested. Cable failures of this kind may or may not be apparent to the designer, purchaser or installer.

Courtesy of Thermax/Belden

NASA's Approach

Goal: Develop a next generation wire where insulation and/or core damage can be detected on a powered wire.

- NASA has developed a fault detection wire technology that is ready to be shared with prospective users.
- Thermax, as part of Space Act Agreement KCA-4247 revA, is a manufacturing partner with the goal of commercializing the technology.

Status: Multiple samples have been developed and evaluated. The technology is now at a point that end user involvement is needed to continue development and commercialization.

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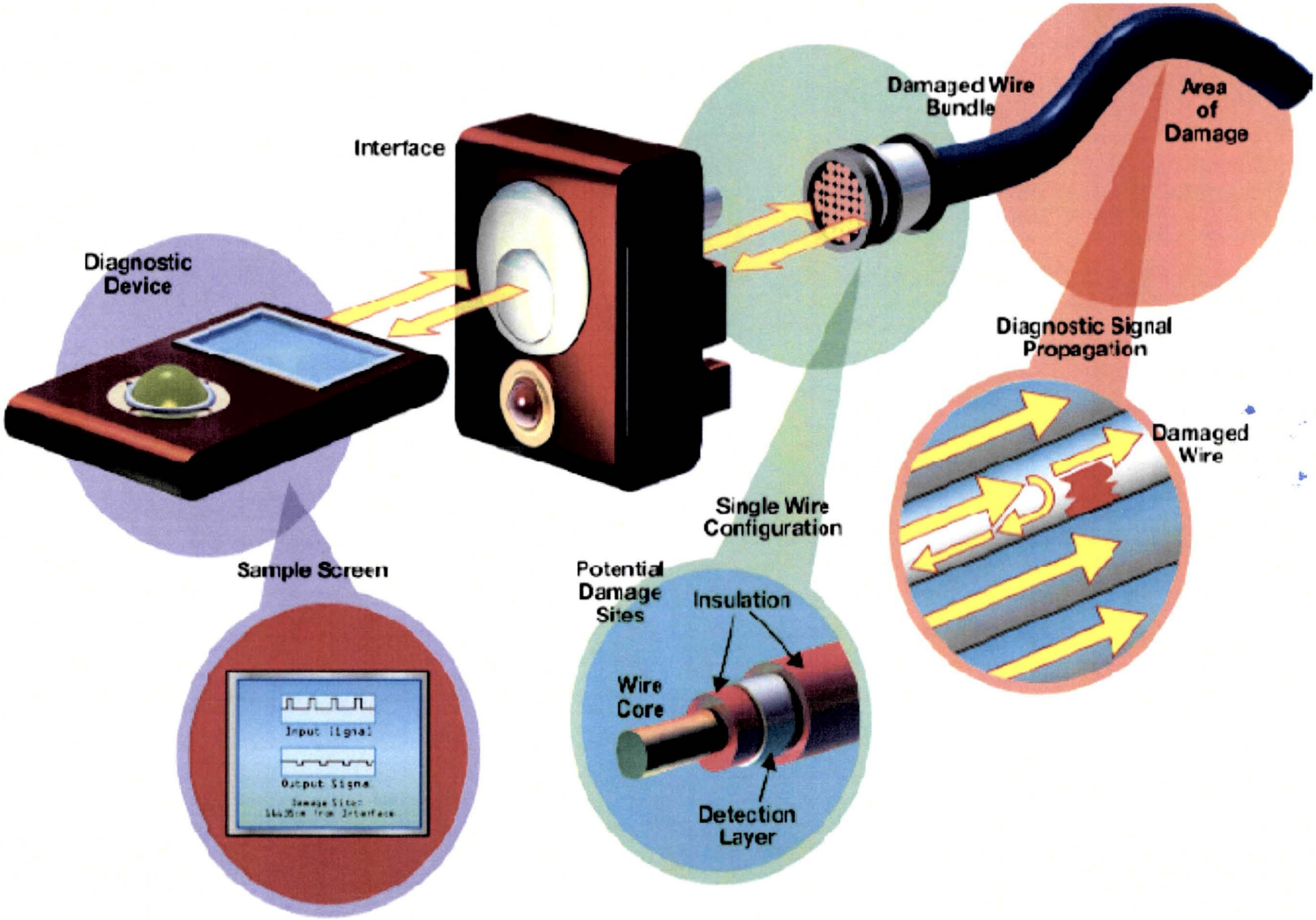
Wire Detection Systems & Integration



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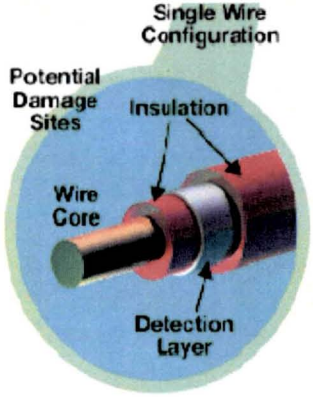
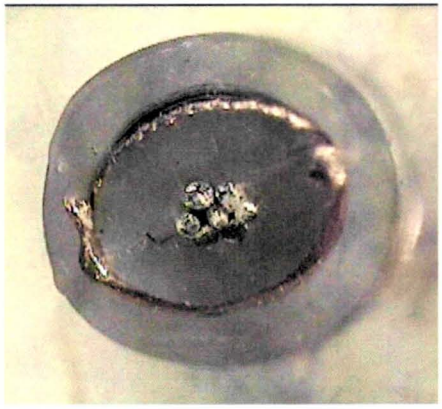
Wire Construction

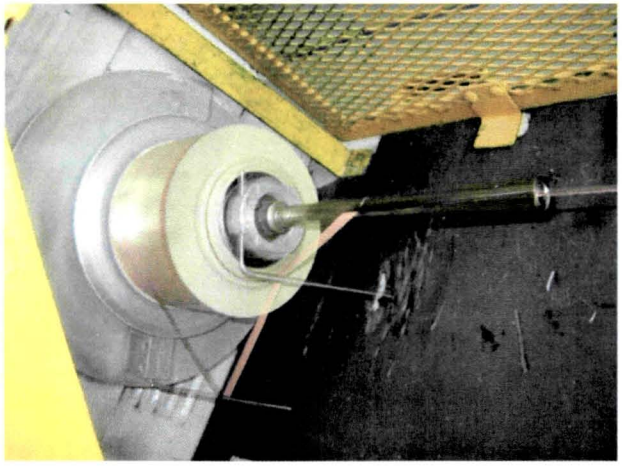
Materials examined during development of detection layer

- Metal foils
- Nickel coated carbon fiber
- Conductive carbon cloth
- Metallized mylar tapes
- Sputter coated metals
- Electroplated metals
- Printed-on conductive inks
- Inherently conductive polymers

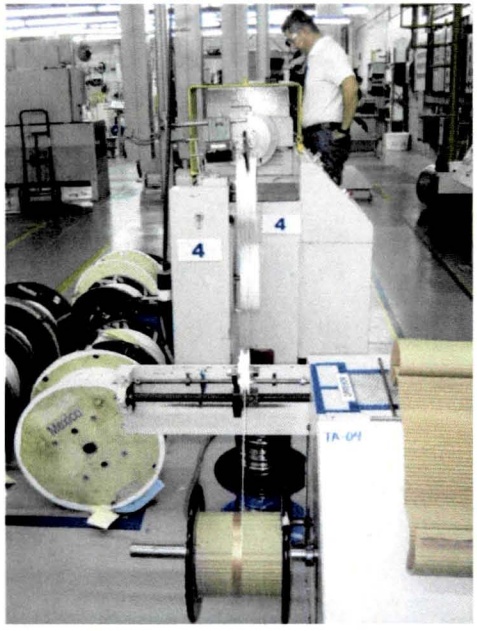


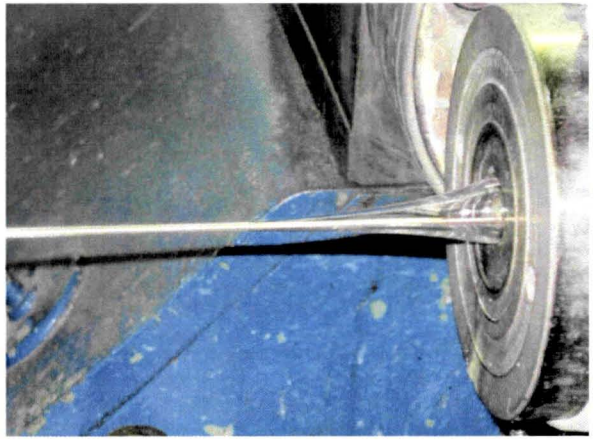


Cross section of RG316 wire with Cu foil and PTFE jacket



Tape wrapped Cu/Mylar foil on RG316





Extruded FEP on Cu foil

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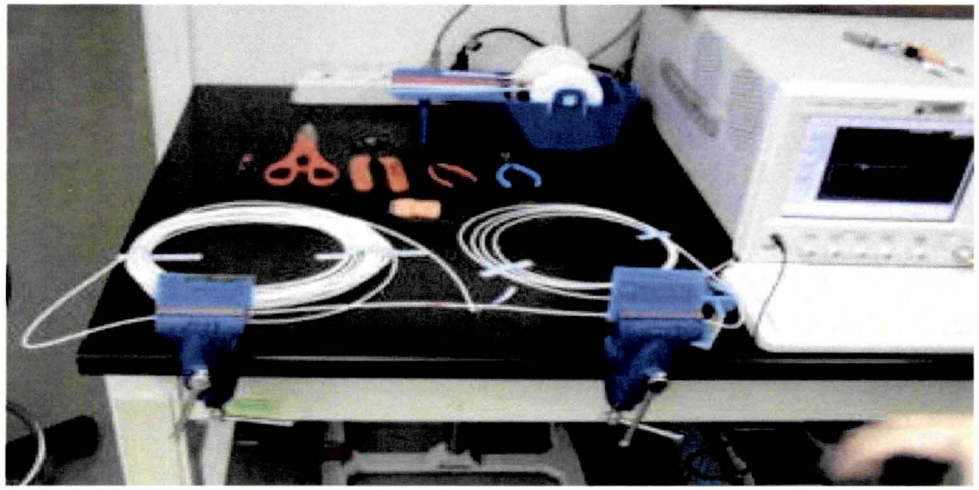
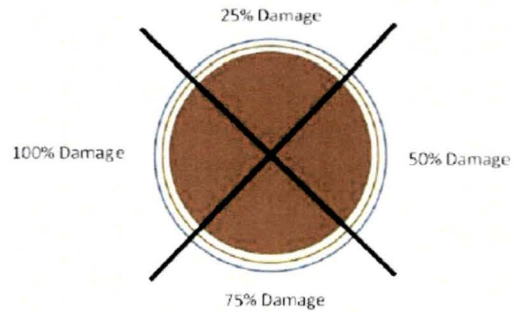
Wire Analysis

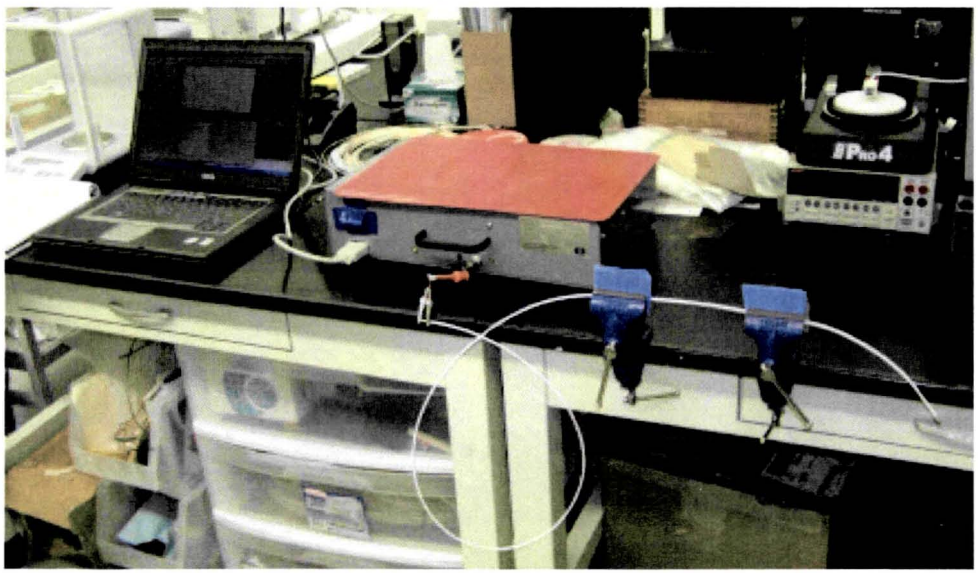
TDR Desktop Testing Setup

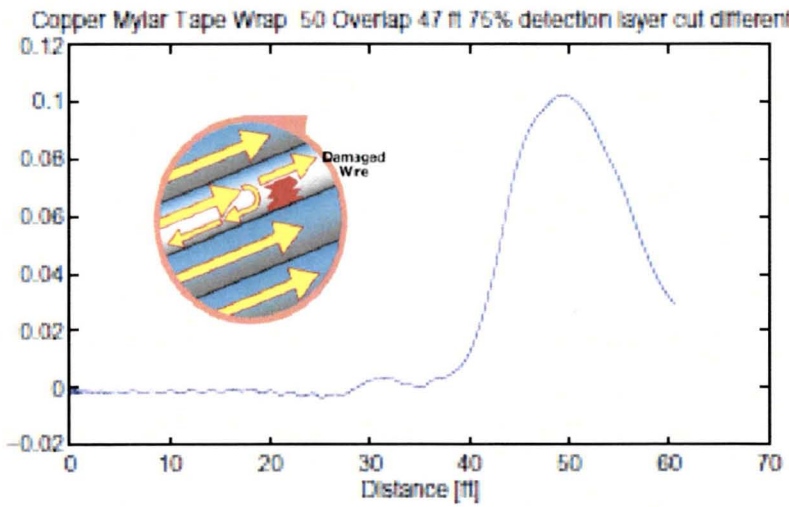




Damage profile for TDR testing

SWR Desktop Testing Setup





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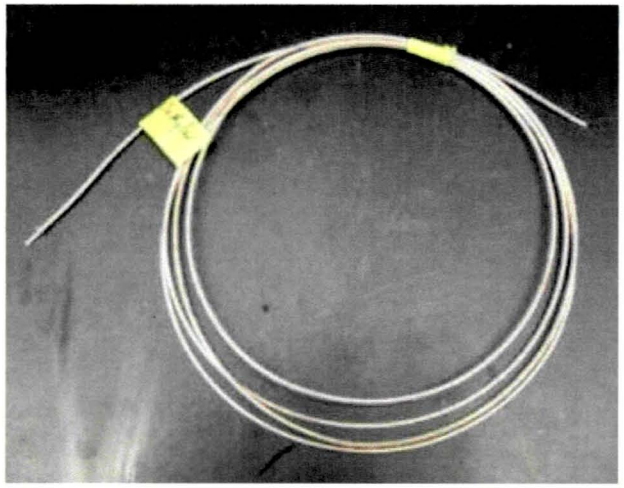
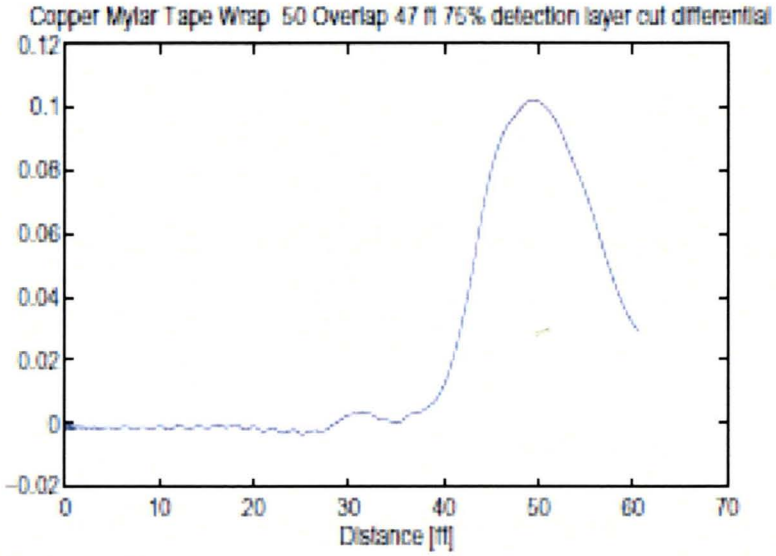
Cu/Mylar Construction Results





Wire Construction	Results
Copper/Mylar® Core: RG316 Hookup Wire Conductive Layer: Copper/Mylar® Tape Outer Insulation: Extruded FEP Conductive Layer Overlap: ~50% Resistance of Detection Layer: 0.11 Ω/Ft	Two different lengths of this construction were evaluated: 37 feet and 8 feet. 75% damage to the detection layer was observable at both lengths. Damage less than 75% was not observable for the lengths evaluated.

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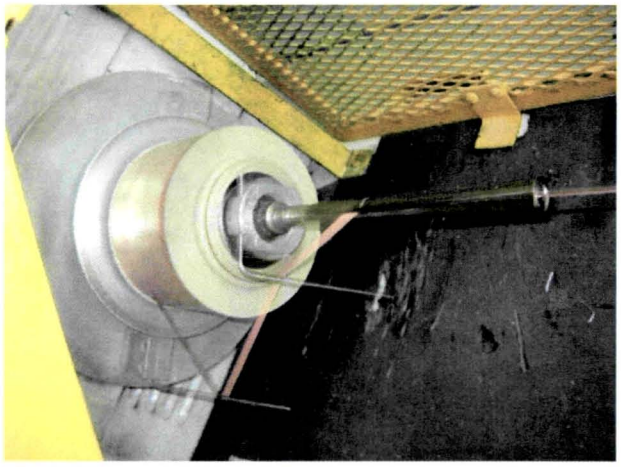
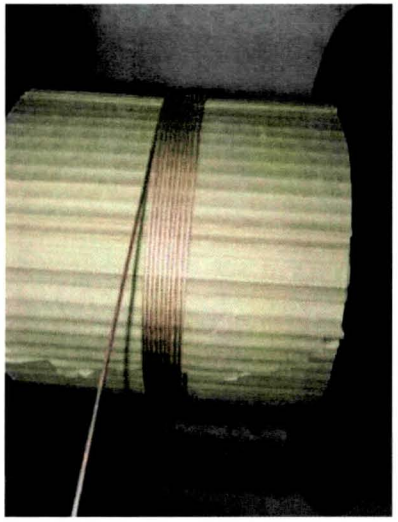
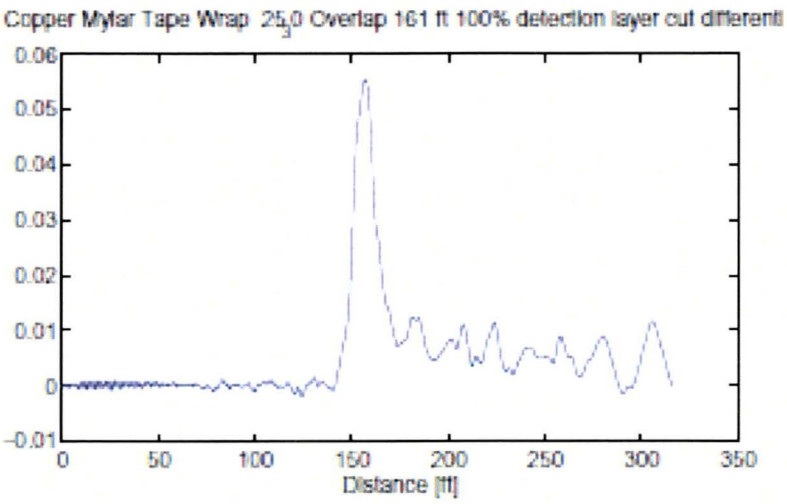
Cu/Mylar Construction Results







Wire Construction	Results
Copper/Mylar® Core: RG316 Hookup Wire Conductive Layer: Copper/Mylar® Tape Outer Insulation: Extruded FEP Conductive Layer Overlap: ~25% Resistance of Detection Layer: 0.09 Ω/Ft	Two different lengths of this construction were evaluated: 151 feet and 8 feet. 100% damage to the detection layer was observable for both lengths evaluated. Damage less than 100% was not observable for the lengths evaluated.

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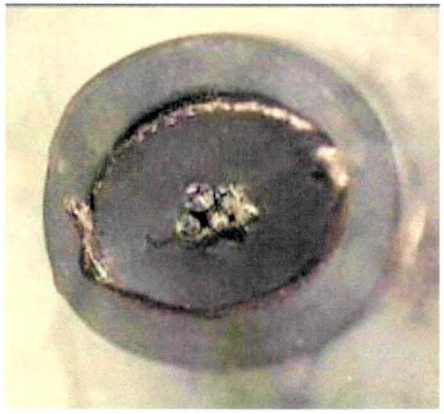
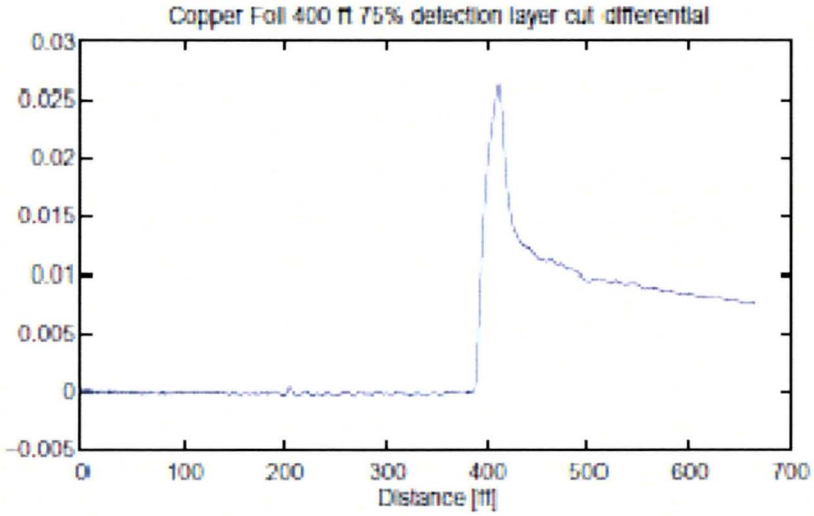
Cu Foil Wire Construction Results





Wire Construction	Results
Copper Foil Core: RG316 Hookup Wire Conductive Layer: Copper Foil Outer Insulation: Extruded FEP Conductive Layer Overlap: ~25% Resistance of Detection Layer: 0.04 Ω/Ft	Four different lengths of this construction were evaluated: 400 feet, 190 feet, 100 feet, and 20 feet. 100% damage to the detection layer was observable at 190 feet, 100 feet, and 20 feet. 75% damage to the detection layer was observable at 400 feet. Damage less than 75% was not observable for the lengths evaluated.

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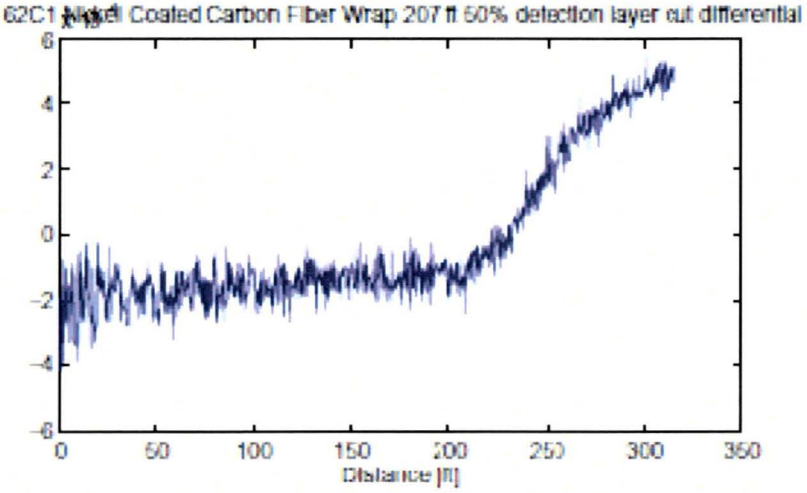
Ni-C Fiber Results



Wire Construction	Results
62% Nickel-Coated Carbon Fiber Core: RG316 Hookup Wire Conductive Layer: 62% Nickel-Coated Carbon Fiber Outer Insulation: PTFE Tape, Sintered Conductive Layer Overlap: ~0% Resistance of Detection Layer: 0.30 Ω/Ft	Two different lengths of this construction were evaluated: 197 feet and 8 feet. 50% damage to the detection layer was observable for both lengths evaluated. Damage less than 50% was not observable for the lengths evaluated.

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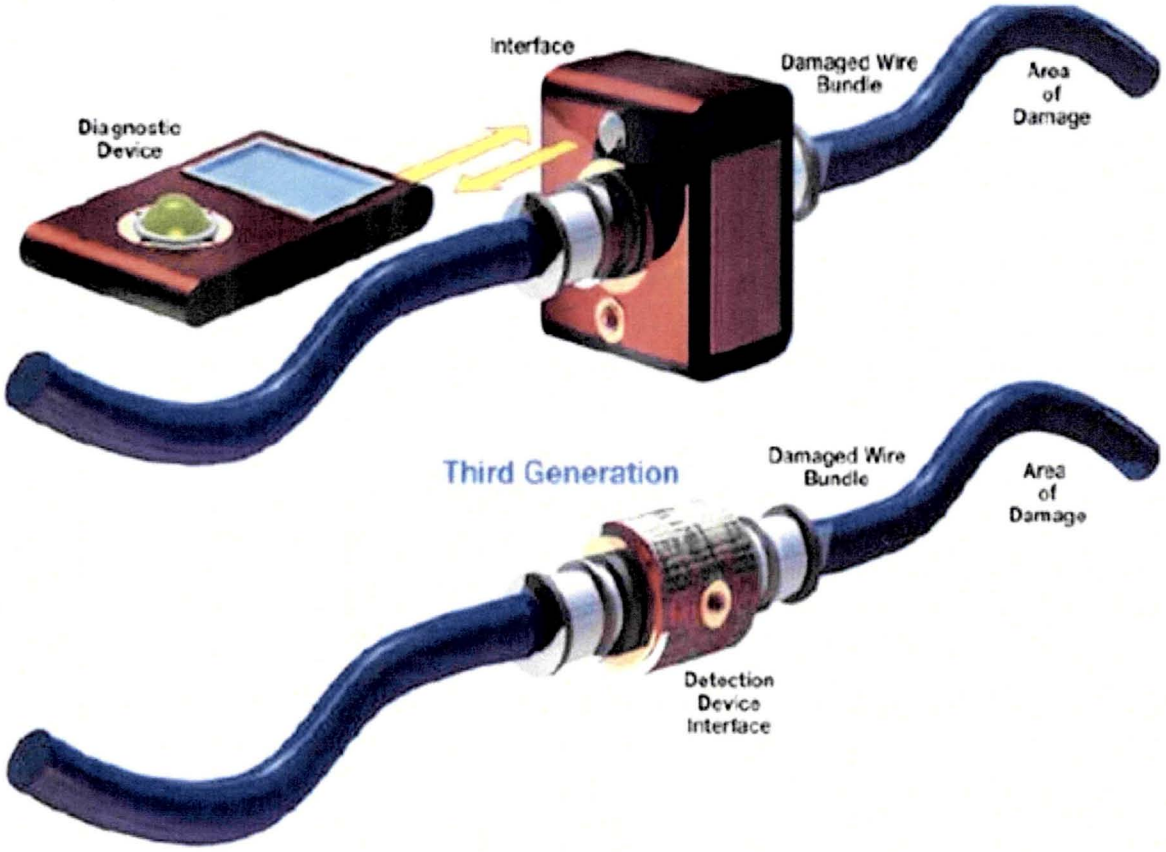
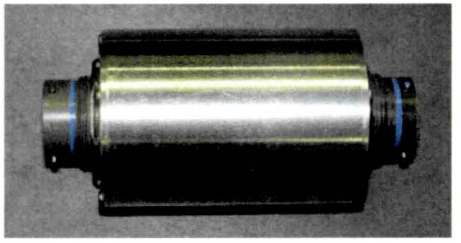
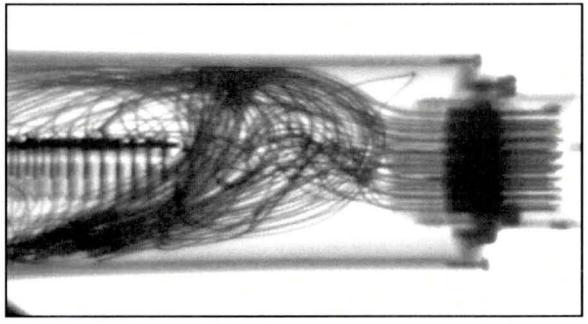
In-line Connectors







X-ray image of miniaturized 2nd generation TDR connector

2nd and 3rd generation designs provide in-line vehicle health monitoring

Patent Application #s 12/843353, 12/843382, 12/843487

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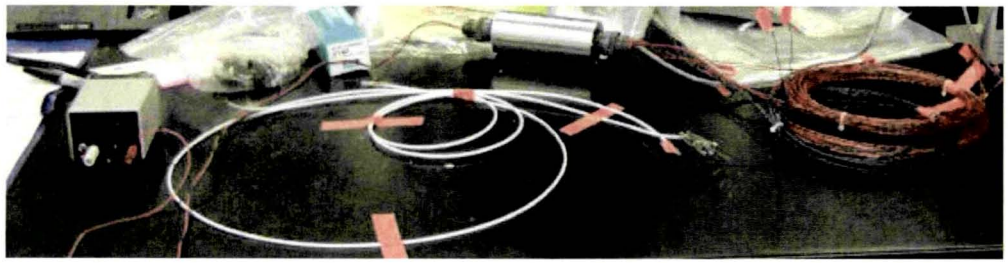
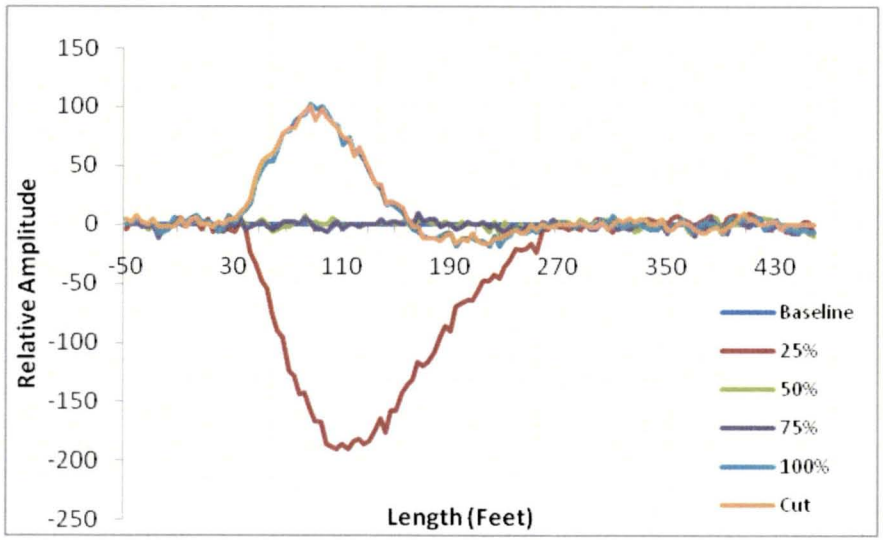
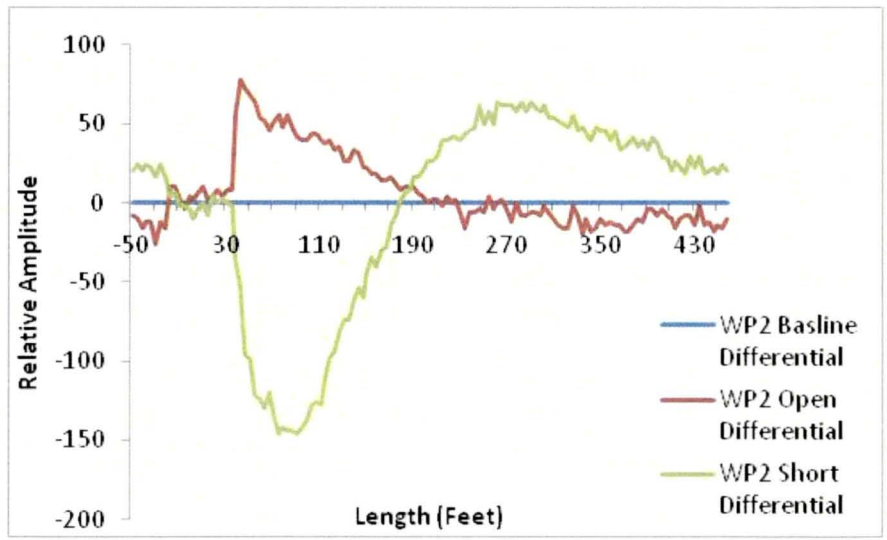
In-line Connector Results



Testing of new wire construction using in-line TDR.



Off-line mode



On-line, powered mode

Differential data for in-line TDR testing of new wire construction.

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Technology Transfer to Industry

NASA is seeking collaborators, vehicle designers, and end users for specific application needs.

Thermax can manufacture tailored wire constructions for end-user applications.

End-users can test damage detection systems in real-time applications.

NASA is seeking connector companies to license and build in-line TDR connector technology. NASA proposed funding in FY12-14 may help subsidize technology transfer costs.

SENSITIVE BUT UNCLASSIFIED (SBU)

KSC Wire Diagnostics System Technology Transfer and Partnership Strategic Plan

Prepared By
Lew Parrish
Technology Transfer Specialist
ASRC Aerospace Corporation

February 10, 2011

SENSITIVE BUT UNCLASSIFIED (SBU)

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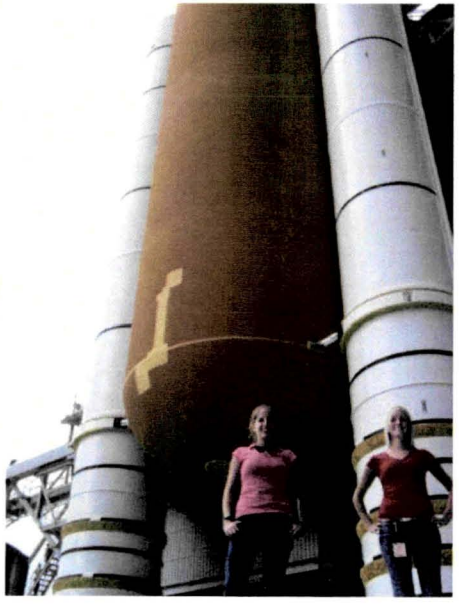
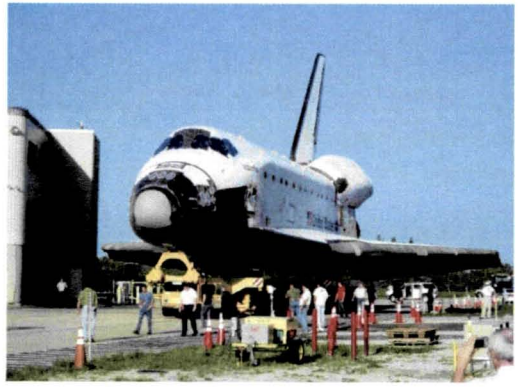
Pasquale Ferrari

Thermax CDT

Don Slutz
John Dunn
Ray Lopez
Craig Fischer

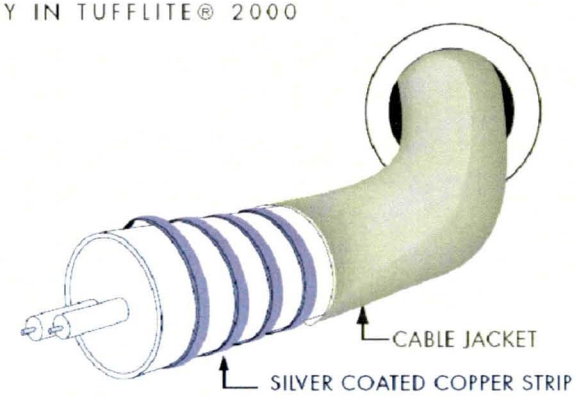




Wire Systems Integration

SHORTWATCH

'PREDICTIVE WIRE-FAILURE' TECHNOLOGY IN TUFFLITE® 2000



- Silver-coated copper strips didn't provide uniform coverage across entire area.
- Thickness and weight of strips+insulation increased volume and weight above design requirements
- New construction provides detection for multiple damages.