



Raytheon

AIRCRAFT WIRE DEGRADATION STUDY

6 November 2002

Joe Kurek

Multi-Disciplined Engineer
Design

(317) 306-7029

kurekj@indy.raytheon.com

Nick Kirincich

Section Manager, Wiring

(317) 306-7264

kirincichn@indy.raytheon.com

This work is being performed under contract to the FAA
Technical Center (Contract No. DTFA03-02-C-00040)

Goal

- **To study the degradation mechanisms of five wire types commonly used for commercial airframe wiring, in order to understand and model the “aging” mechanisms.**

- **WHY?**

To ensure safe long term operation of aircraft by fully understanding the reliability of electrical wire used in aircraft electrical interconnect systems.

Wire Issues

Exposed to Heat / Humidity



Other examples in previous presentation

Exposed to Heat, Flex



Specific Goals

- **To attempt to develop algorithms in an effort to predict the degradation of wire in aircraft.**
- **To determine degradation of wire relative to original performance specifications.**
- **To establish relationships between performance degradation and potential failure modes, and to determine the critical thresholds.**
- **To determine how thresholds can be used to eliminate or mitigate potential wiring hazards.**
- **To identify major model perturbations.**

Tasks

- **Phase I: Development of Test Program** **Aug 01 - May 02**
- **Phase II: Execution of Test Program** **Oct 02 - Aug 04**
- **Phase III: Analysis and Reporting** **Apr 04 - Dec 04**

The Team

- **Direct Team**

- Raytheon Technical Services (lead)
- Brookhaven National Laboratories
- Sandia National Laboratories
- Lectromechanical Design Company
- Qualstat Services

- **Indirect Team**

| | |
|----------------------------|--------------------|
| Airbus Industries | Boeing Company |
| Bombardier Aerospace | Dupont Company |
| NASA | QinetiQ |
| Barcel/CDT | Tensolite Company |
| Tyco Electronics (Raychem) | |
| Airtran | Northwest Airlines |
| SR Technics | United Airlines |

Phase I: Develop and Plan Study

- **Required Items for the study**
 - **Background study**
 - **Determine baseline data**
 - **Define Wire types to evaluate**
 - **Identify aging variables**
 - **Identify perturbations to the aging process**
 - **Develop a test plan**
 - **Develop a project plan**
 - **Develop a quality assurance plan**
 - **Draft test procedures**
 - **Define test protocols**
 - **Develop Statements of Work for subcontractors**
 - **Coordinate with industry stakeholders**
- **Complete**

Wire Types to Evaluate

- **Aromatic polyimide (PI) tape wrap (US & European versions)**
- **Aromatic polyimide tape wrap with fluorocarbon bonding layers and polytetrafluoroethylene outer wrap (PI/PTFE) composite**
- **Crosslinked aliphatic polyimide (XPI), extruded**
- **Crosslinked modified ethylene tetrafluoroethylene (XLETFE), extruded**
- **Polyvinyl chloride with extruded polyamide outer jacket (PVC/Nylon)**

Variables that may Affect Wire Aging

- **Time**
- **Thermal**
- **Electrical**
- **Mechanical**
 - Bend, static
 - Bend, dynamic (Flex)
 - Abrasion, Vibration
 - Thermal Expansion
- **Chemical**
 - Aircraft Fluids (cleaners, hydraulic fluid, lubricants, deicing fluids, etc.)
 - Humidity
 - Oxidizers (Ozone, NO_x, SO_x, etc.)
- **Radiation**
 - Heat
 - Ultraviolet
- **Biological Organisms**

Perturbations

- **Identify perturbations to the wire aging process**
- **Uncontrollable Stressors that can include**
 - **wiring design**
 - **wiring installation or installation deficiencies**
 - **maintenance (EIS or aircraft)**
 - **operational extremes outside of the design guidelines**
 - **exposure to various debris outside of the design guidelines**
 - **exposure to high temperature caused by unpredicted environmental conditions**
 - lightning
 - electrical shorts
 - component failure
- **Actual conditions any specific wire is exposed to during its life is unknown**

Evaluation Tests

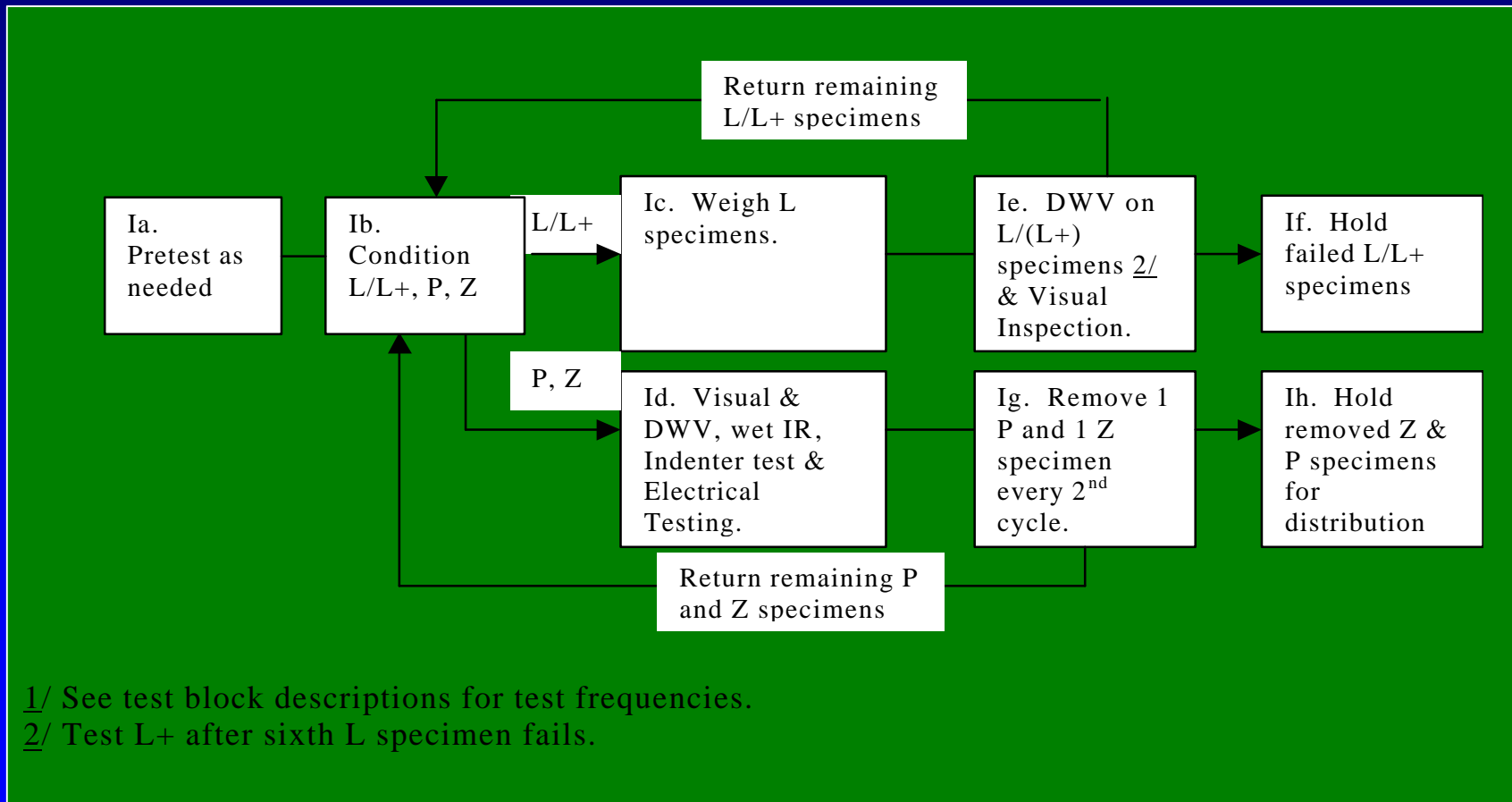
- **Tests that will be utilized**
 - **Some specific techniques currently used**
 - **Visual**
 - **IR/DWV**
 - **Tensile and Elongation**
 - **Flammability**
 - **Time Domain Reflectometry (TDR)**
 - **Some new techniques to evaluate**
 - **Terahertz**
 - **Insulation Modulus/Hardness**
 - **Inherent Viscosity**
 - **Weight Loss**
 - **Oxidation Induction Time**
 - **FTIR Spectroscopy**
 - **UV/VIS Spectroscopy**

Test Method & Failure Criteria

- Method based on the standard ASTM Method 3032 for wire.
- “Accelerated Aging” type conditioning of wire specimens
 - Using test variables
 - Stressors (Flex, Thermal Shock, Vibration, Fluid Exposure)
 - Conditions (Temperature, Humidity, Static Bend)
 - Not all variables can be examined
 - Each wire type has unique test protocol
 - Cycle specimens through conditioning and testing until failure
- Test specimens
 - Start with new wire
 - Test wire following periods of accelerated aging
- Wire specimens fail when...
 - Insulation Resistance cannot be held
 - Wire cannot hold dielectric voltage
 - Conductor cannot pass current

Test Protocol Example

- FIGURE 1: TEST PROTOCOL I – STRESSOR 1 & CONDITIONS A, A+, B, C, D, E, and J 1/



Phase II: Execution

- **Get subcontractors under contracts**
- **Procure all required materials**
- **Finalize test plan**
- **Finalize test protocol**
- **Finalize test procedures**
- **Disposition comments to test plan**
- **Finalize Schedule in a project plan**
- **Execution of test program**

Phase III: Analysis & Reporting

Raytheon

- Full Data analysis
- Draft Report
- Lab Reports
- Final Report
- Request Industry Comments
- Present to FAA

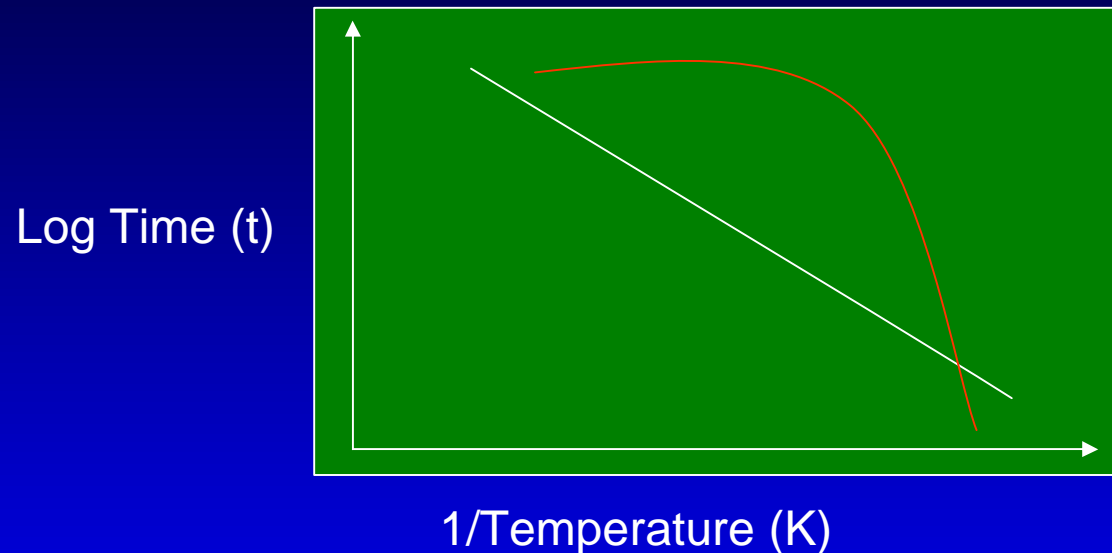
- Scheduled to begin April 2004, and to complete December 2004

Anticipated Results

- **Baseline standard for conditioned wire samples.**
- **Benchmark for correlation of novel aircraft wiring test techniques.**
- **Method for evaluation for future wire studies.**
- **Curves that represent the time to failure of the samples under specific environments.**
- **Curves that correlate the change of the “state of wire” to data obtained from other techniques.**
- **Thresholds that may be established to mitigate increased potential safety risks.**

Possible Correlation of Data

Raytheon



- **Modeling Degradation Times and Property Results**
 - Model: $\text{Log Time} = [a + b * (1 / \text{Temp}) + c * (\# \text{ Cycles stressed})] \text{ Log time}$
- **f (Property) = model of similar form? linear, quadratic, etc.**
- **Model developed for each combination of Dynamic Stressor Test and Aging Condition. Several models per wire type.**
- **Will also compare life estimates (e.g. temperature indexes) versus the design variables & interactions**