FAA Aging Electrical Systems Research Program

Prepared for:
Aging Transport Systems Rulemaking Advisory Committee
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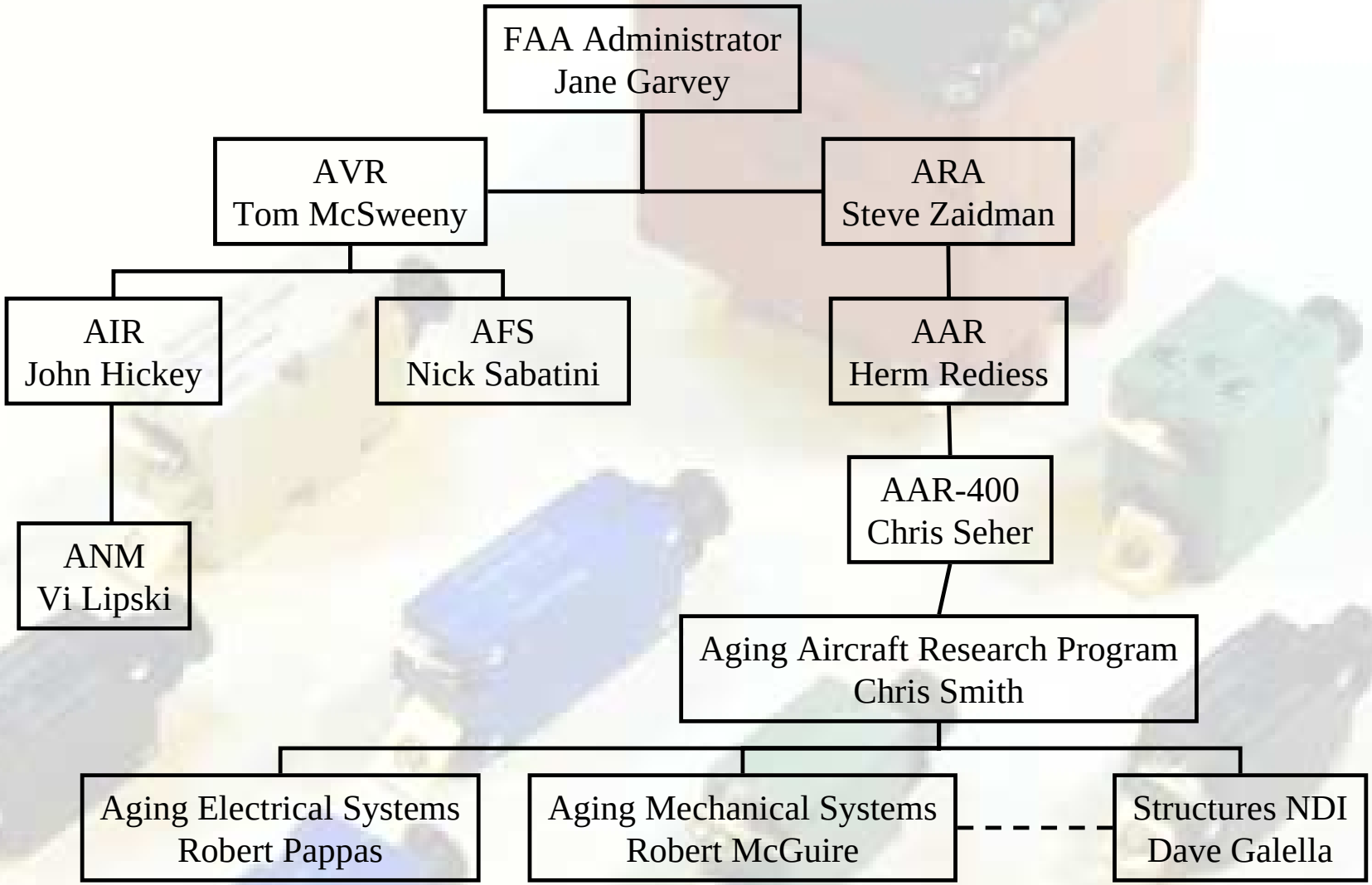
Briefing Topics

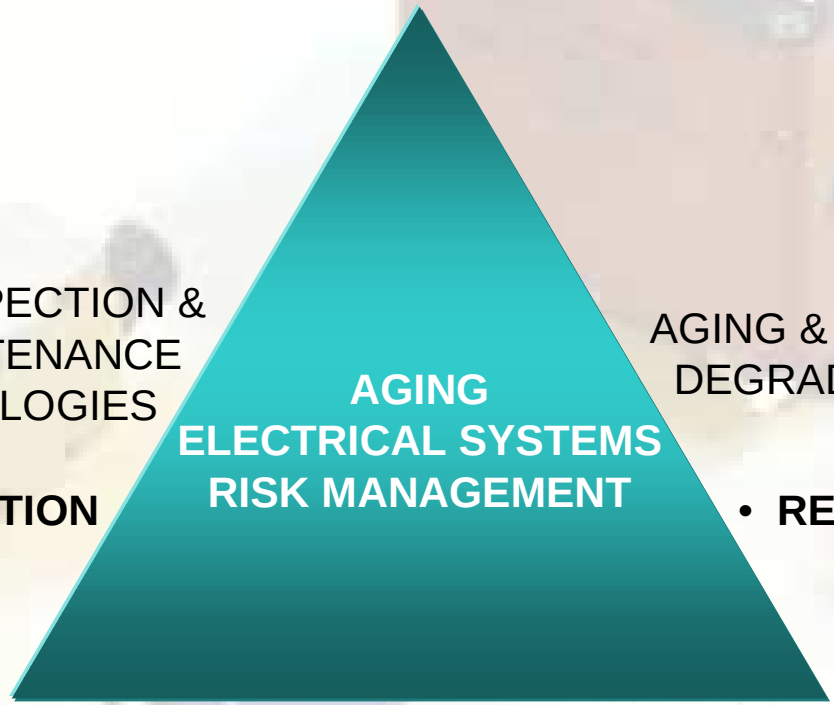
- Introduction
- Arc Fault Circuit Breaker
- Wire Degradation Research
- Wire Performance Specification
- Wrap-up / Q&A

Introduction

Organization



Approach



INSPECTION & MAINTENANCE TECHNOLOGIES

- **HAZARD PREVENTION**

AGING & DEGRADATION

- **RESEARCH & ANALYSIS**

PROTECTIVE DEVICES

- **HAZARD MITIGATION**

FY00 Projects

PROJECT NAME	PERFORMING ORG.	RESEARCH AREA	SPONSORING ORG.
Intrusive Inspection	FAA, DOD, Industry	Hazard Analysis	ATSRAC
Arc Fault Circuit Breaker	Eaton Corp., Hendry/TI	Hazard Mitigation	NAVAIR, ONR, FAA
Aging Circuit Breakers	Sandia Labs	Hazard Analysis	FAA
Excited Dielectric Test System	CM Technologies	Hazard Prevention	FAA/AFRL
Aging Characterization of Polymeric Insulation	Northwestern University	Hazard Analysis	FAA

FY01 Projects

PROJECT NAME	PERFORMING ORG.	RESEARCH AREA	SPONSORING ORG.
Intrusive Inspection	FAA, DOD, Industry	Research	ATSRAC
Arc Fault Circuit Breaker	Eaton Corp., Hendry/TI	Haz. Mitigation	NAVAIR, ONR, FAA
Aging Circuit Breakers	Raytheon	Haz. Analysis	FAA
Broadband Impedance Monitoring	Boeing/RSC/Eclypse	Haz. Prevention	FAA/AFRL
New BAA/SBIR Projects	Seven Awards Pending	Haz. Prevention	FAA
Risk Assessment Methods/Electrical Sys.	RFP Issued	Haz. Analysis	FAA
Aircraft Wire Degradation Research	Raytheon	Haz. Analysis	FAA
Excited Dielectric Test System	CM Technologies	Hazard Prevention	FAA/AFRL
Aging Characterization of Polymeric Insulation	Northwestern University	Hazard Analysis	FAA

FY02 & Beyond

- Effects of maintenance and support operations on aircraft wiring
- Aging Electrical Components
  - RCCBs, Relays, etc.
- AFCB's
- Advanced circuit protection devices
  - RCCBs, Relays, Loads
  - Built in diagnostic capabilities

FY02 & Beyond

- Effects of mixed wire types
- Validation of test and inspection systems
- Wire separation/segregation
- Performance requirements, test criteria and procedures, for aircraft wire
- Environmental Monitoring of In-Service Wiring
- Supplemental R&D
  - ATSRAC
  - Pop-ups
- AANC Aging Systems Infrastructure Improvements

Arc Fault Circuit Breaker

AFCB Purpose

Mitigate the effects of electrical arcing on aircraft wiring.

Joint Program:

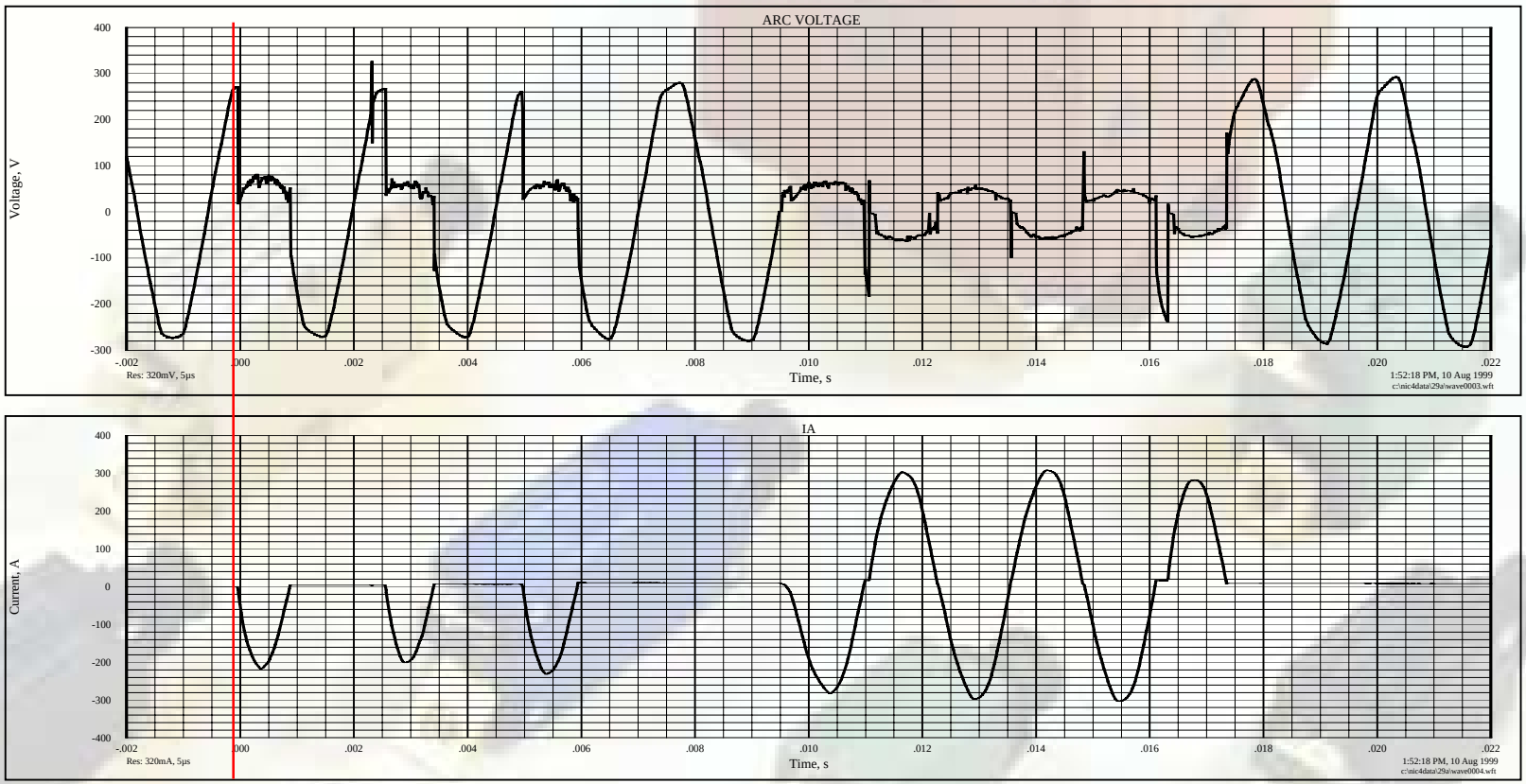
Background:
Current Inspection Technology

- Current inspection and surveillance methods for aircraft wiring are limited in effectiveness and periodic in frequency.
- Arc Fault Circuit Breakers provide continuous protection.

Background:
Arc Faults

- Present aircraft circuit breakers are designed to protect against over loads and short circuits.
- Arcing faults draw less current than hard faults and are intermittent in duration.
- Arcing faults can cause systems failures and fires.

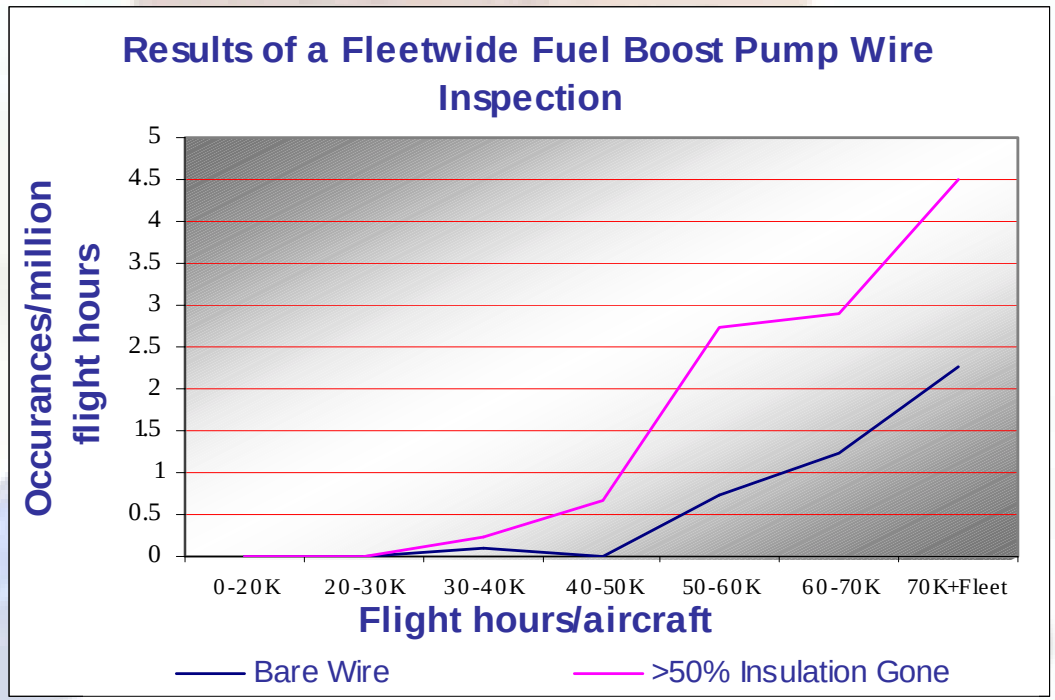
Background:
Typical Arcing Fault



Arc Voltage and Current Waveform of Arcing Fault at 10,000 Feet

Background: Wire Degradation

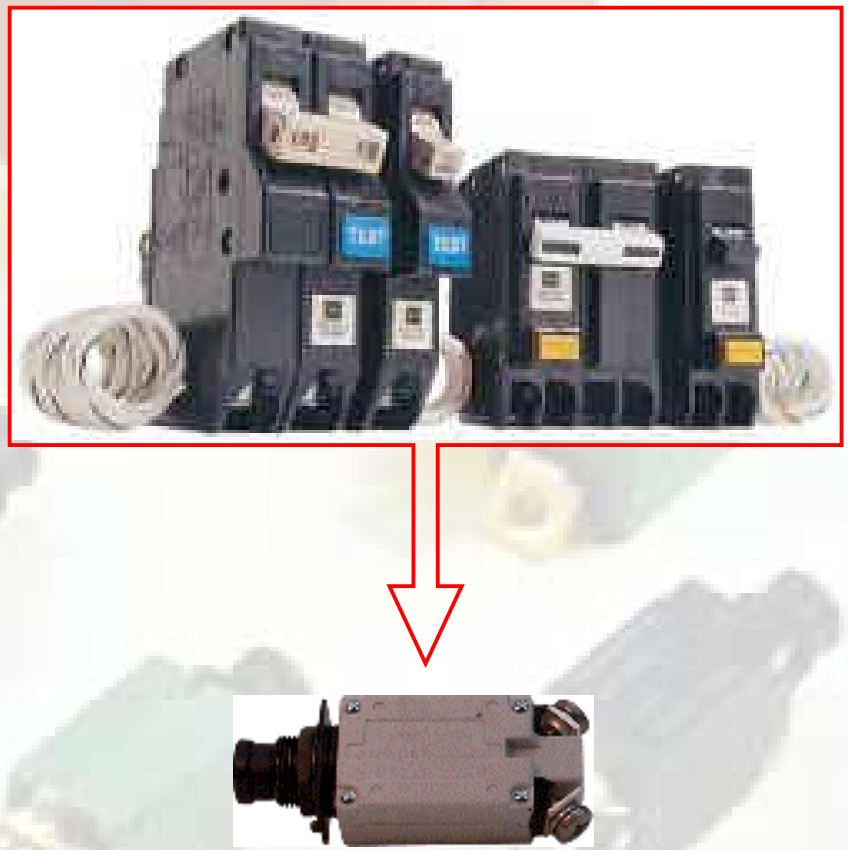
- Wiring insulation degradation increases with time do to a variety of reasons such as:
  - Chaffing
  - Environmental stresses
  - Maintenance.



- Degradation varies due to design, maintenance, and operational differences

Background:
Commercial AFCI

- 60 Hz AFCB's are commercially available.
- Aircraft AFCB's must:
  - Be at least 50% smaller in size.
  - Operate in an aircraft environment.
  - Work in an aircraft electrical system.



Photos courtesy Eaton Corp. and Texas Instruments

Background:
Commercial AFCB

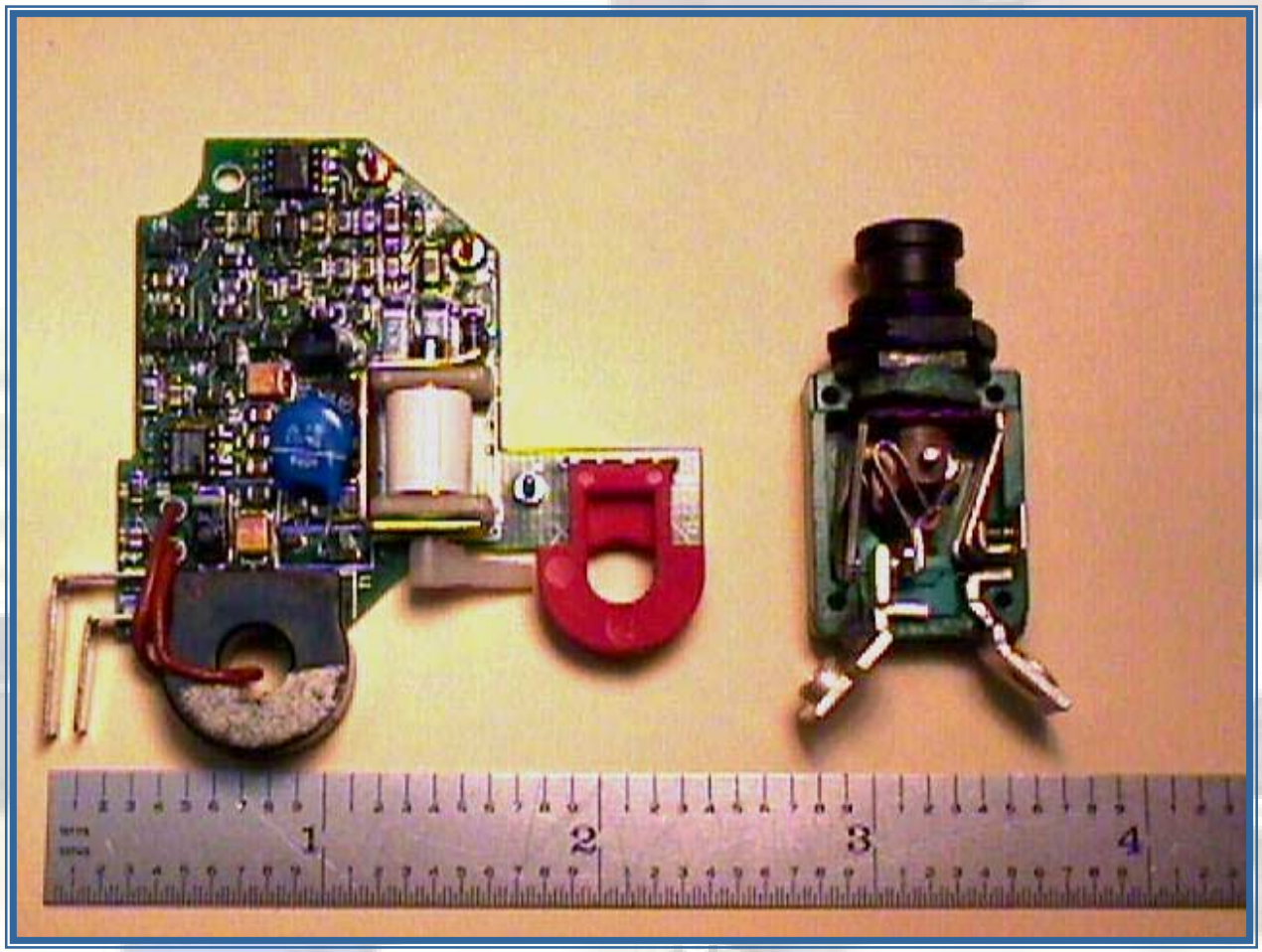


Photo courtesy Eaton Corp.

AFCB Progress

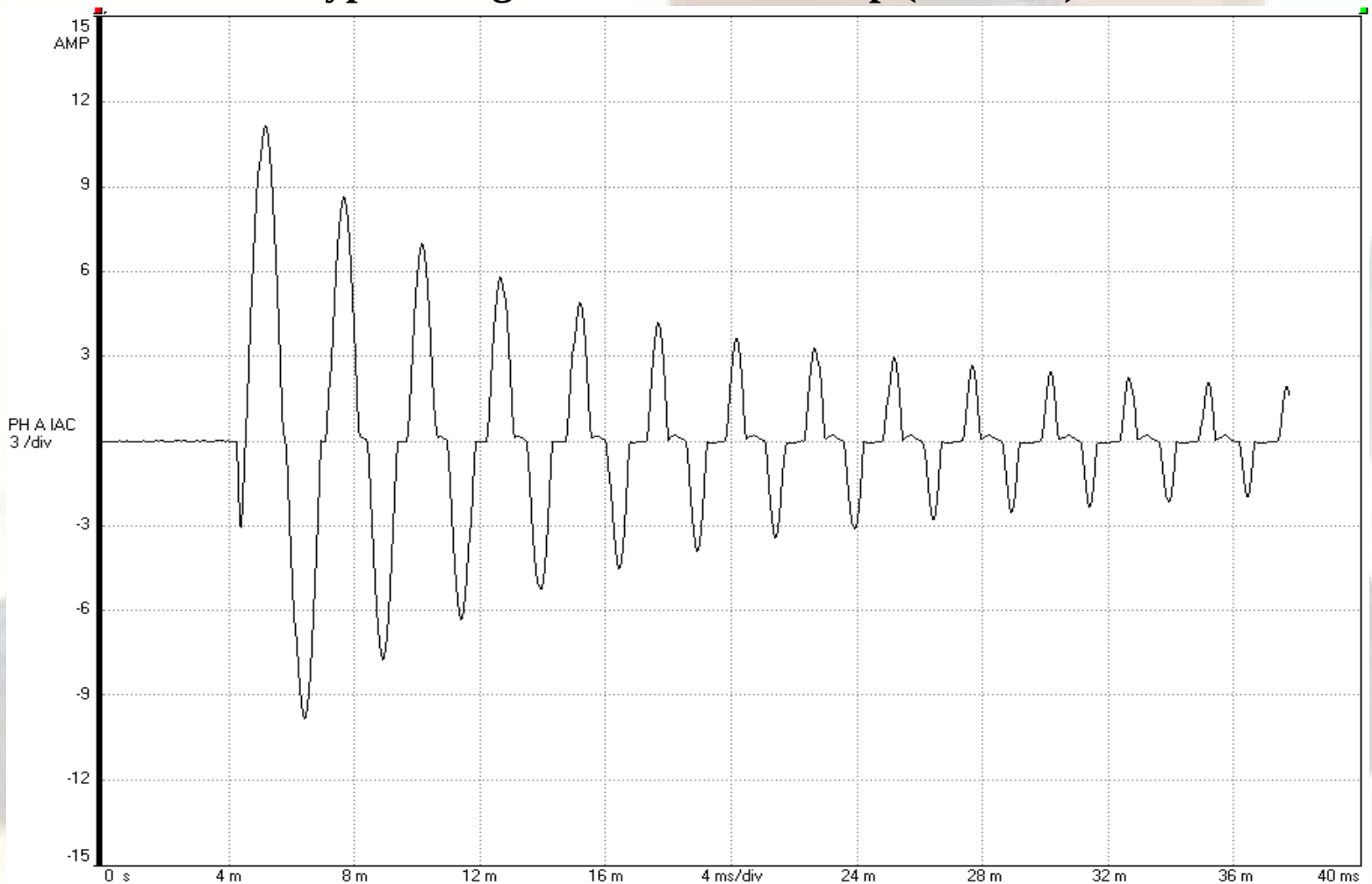
- Two R&D contracts awarded in December 1999
  - Eaton Aerospace Controls
  - Hendry Telephone Products
- Each company will deliver:
  - 20 prototype AFCBs
  - 400 Hz Only
  - MS-24571 Package or smaller

AFCB Progress

- Load and Power Characterization
  - Extensive load characterization
    - FAA B727 (N40)
    - Navy C-9
    - Boeing Power Lab
  - Extensive power characterization
    - FAA B727 (N40)
    - Boeing Power Lab
    - Navy C-9
  - Nuisance trip testing
    - FAA B727 (N40)
    - Boeing Power Lab

AFCB Progress

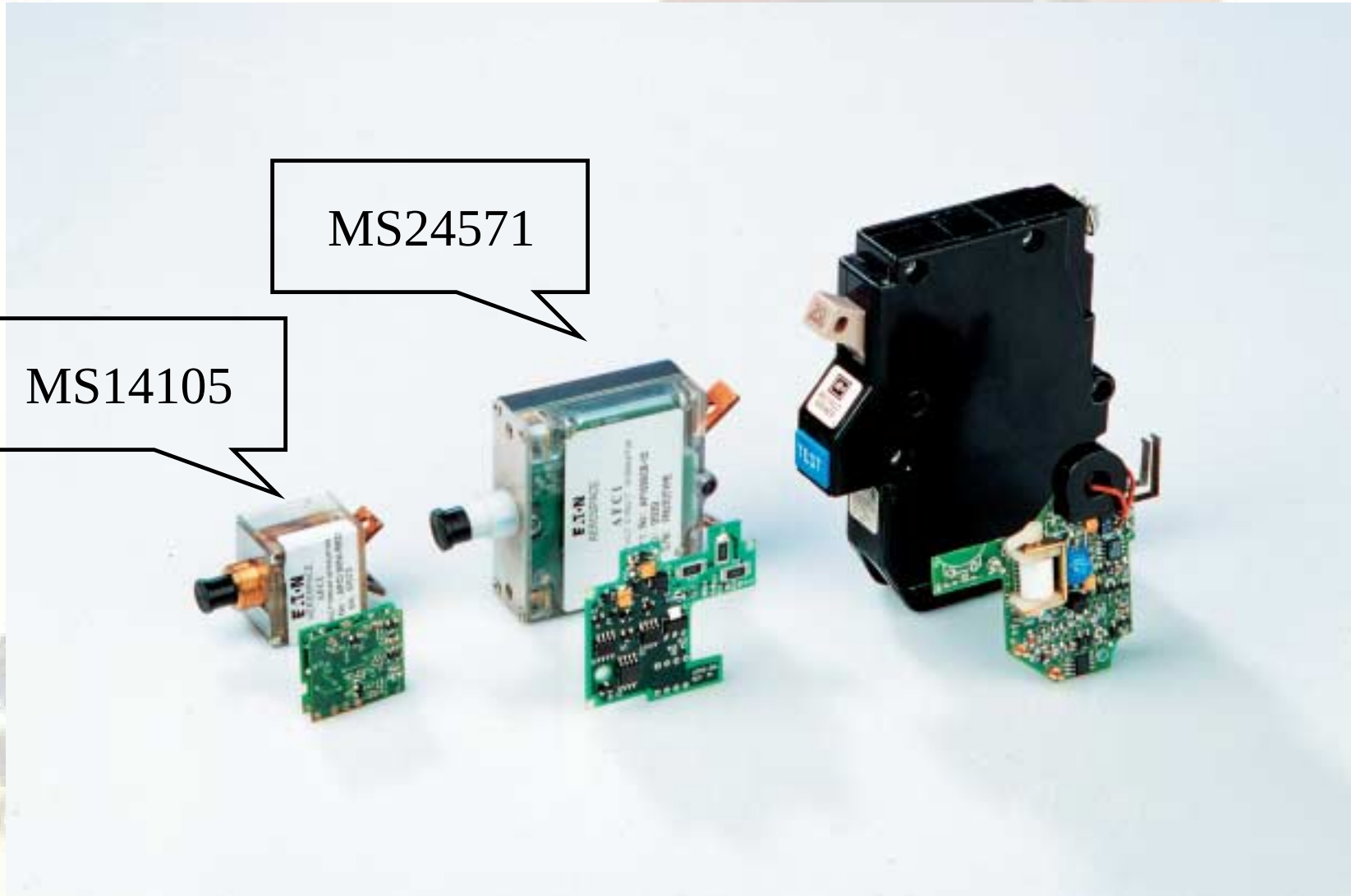
Typical Flight Recorder Start-up (Current)



AFCB Progress

- Current status
  - Laboratory demonstrations of AFCB prototypes successfully completed.
  - Safety of Flight (Environmental) testing of Eaton AFCB prototypes: Apr-May 2001. Successfully completed.
  - B747 Characterization (August) and ground testing of Eaton breakers.
  - FAA and Navy flight testing of Eaton breakers scheduled for August through Feb 2002.
  - Boeing flight test (737-900) of Hendry & Eaton prototype AFCB's underway.

Eaton Prototypes



Hendry Telephone/Texas Instruments Prototype

AFCB Operational Issues

- Post-trip Troubleshooting
  - Testing AFCB Device
  - Nuisance Trip vs. Arc Fault
  - Location of arc fault
  - Release for flight
- Development of AFCB diagnostics
- AFCB surveillance

SAE AFCB Committee Overview

SAE AFCB Specification: Development

- SAE Committee is developing an industry standard for “minimum operating specification for AFCBs.”
- FAA is developing associated TSO and advisory circular in parallel with the SAE activity.
- Completion of the draft AFCB specification expected by October 2001. The TSO and AC to follow.
- Performance requirements are being established by the committee.

SAE AFCB Specification: Development

SAE AE8B-1, Protective Devices Subcommittee

- Three AFCB Sub-Groups
  - Mil-C-5809 sections 1, 2, 5, and 6 (definition of boiler plate content)
  - Mil-C-5809 and MIL-PRF-83383 Integration (ground integrity, sensing life, electronic reliability, etc.)
  - Mil-C-5809 arc fault definition and test team
  - Thermal requirements will remain identical to requirements in Mil-C-5809

SAE AFCB Specification: Status

- Meetings held in 11/00, 02/01, 06/01.
- Interim meeting held 07/01.
- Next meeting 09/01 (Mon & Tue preceding the Aging Aircraft Conference – Orlando)
- Planned submission of Final Draft Specification to SAE for approval and publication, October 2001.
- Approval & Publication – ASAP.

SAE AFCB Specification: Issues

- Specification of Arc Detection Thresholds
- Parallel tests only. Sufficient data on series ‘faults’ still being developed.
- Arc fault qualification test methods
  - Guillotine
  - Wet Arc Test (Similar to Mil-Std-2223, method 3006)
- Arc fault tests closely simulate ‘real world’ arc fault failure mode characteristics.

SAE AFCB Specification: Issues

- Nuisance Tripping
  - Loads
- Cross Talk
- Feedback
- Masking

SAE AFCB Specification: Issues

- Power/ground requirements for AFCB: slash sheet
- Coordination between AFCB's
  - No requirement in first generation devices
- Arc Fault Indication will not be specified
- Intermix capabilities between manufacturers and technologies

FAA

AFCB Issue Paper

AFCB Issue Paper

- AFCB Installation, Means of Compliance for
- Draft only, under review by FAA
- Drafted in the absence of:
  - Industry Standards
  - FAA TSO
- FAA POC: Brett Portwood, Long Beach ACO

AFCB Issue Paper

- Three installation categories:
  - Approval of AFCBs in non-essential circuits for the purposes of gathering in-service data for a limited duration
  - For full approval of AFCBs in non-essential circuits
  - Approval of AFCBs in essential and critical circuits

AFCB R&D Flight Test Program

R&D Flight Test: Objective

Fly AFCB's on a variety of aircraft and electrical loads to show it is ready for qualification and introduction into civilian and military transport aircraft.

R&D Flight Test: FAA

- B727
- Tiered Approach
  - 25 to 50 hours experimental flight
    - Monitoring and recording of voltage/current characteristics
    - Pre-test characterization of circuits under test
  - 6 month R&D evaluation
    - One only STC – N40
    - Limited Duration

R&D Flight Test: FAA

- B727 Flight Test Loads

NAME	RATING
Oscillating Navigation Light	5A
DME-2	3A
Window Lights	10A
Landing Lights Left Inboard	7A
Passenger Cabin Ceiling Lights - Left Side	15A
PROJECT POWER (60 hz converter)	15A
AUX. PITOT HEAT	5A
WINDOW HEAT, R4,5	5A

R&D Flight Test: Navy & Boeing

Navy Testing

- C-9
- Fly seven AFCB's for six months on five different electrical loads
- AFCBs installed inside CB panels

Boeing Testing

- B737-900 (not affiliated with Government flight test program)
- Fly six AFCB's for approximately 12 months

Future AFCB R&D

Future AFCB R&D

- Three-phase
- 28vDC
- AFCB Component Miniaturization
  - MS-3320 size
  - Additional features fitted into existing AFCB sizes
    - BIT, data storage, post-trip diagnostics, databus communication, etc.

Future AFCB R&D

- AFCB Qualification Test Equipment
  - Record and reproduce arc and load characteristics
  - Standard library of load characteristics
- AFCB diagnostic test equipment

AFCB Conclusions

AFCB Conclusions

- Present aircraft circuit breakers are not designed to mitigate the effects of arcing faults.
- AFCB development is proceeding rapidly.
- Select mitigation/prevention technology appropriate to the hazard.

AFCB Conclusions

- There are installation and operational issues to be resolved.
- Tools for testing AFCB’s and determining location of electrical arcs are necessary.
- Certification applicants must demonstrate to the FAA that AFCB’s perform their intended functions in a safe and reliable manner.
- New features can greatly enhance functionality of future AFCB’s.

AFCB Conclusions

Arc Fault Circuit Breaker technology is a viable and promising solution

Wire Degradation Research
Phase II

Wire Degradation Research

Purpose:

Subject wire types found on transport aircraft to accelerated degradation to determine the degeneration process as a function of the operational environment, including the effect of mixed wire types.

Wire Degradation Research

- ATSRAC Intrusive Inspection Project completed.
- Phase II research plan completed.
  - FAA research program.
- Raytheon Technical Services selected to conduct the program.
- Agreements with NAVAIRSYSCOM completed.
- Work will begin within the next several weeks.

Wire Degradation Research

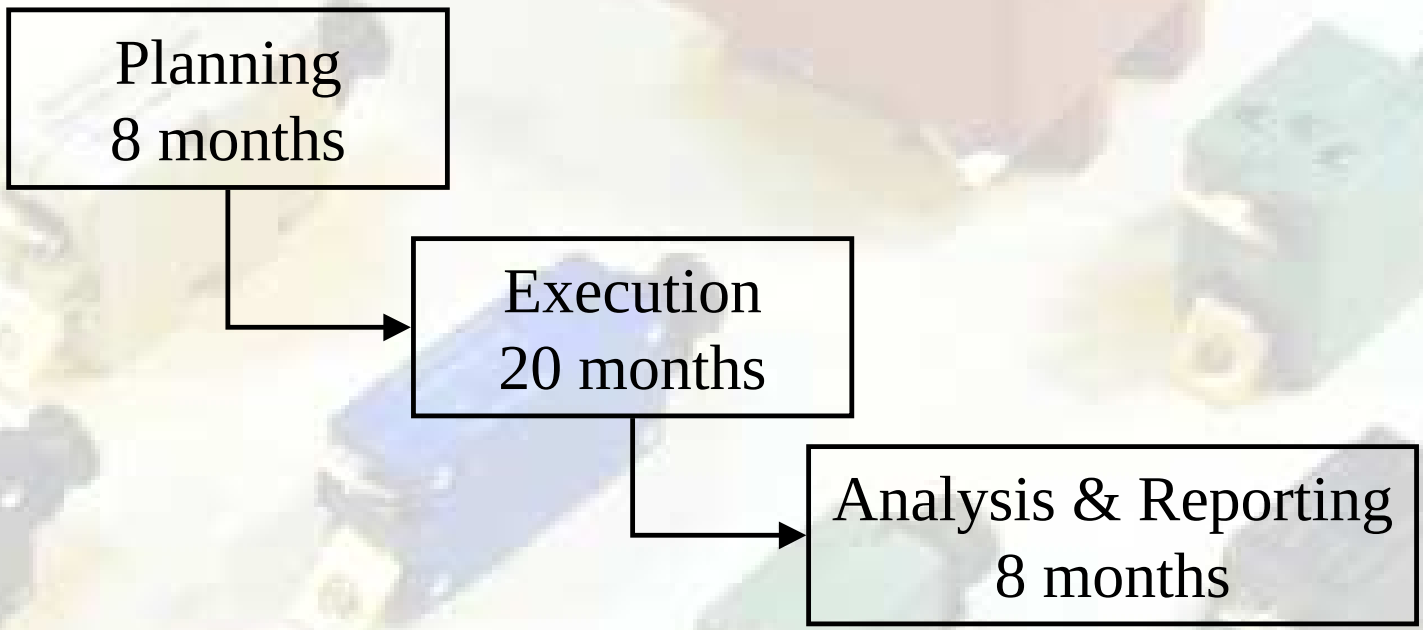
- Consultation with stakeholders a key part of planning process

Stakeholders

- FAA, DOD, other government agencies
  - Including foreign and international civil aviation authorities.
- Wire Manufacturers
- Aircraft manufacturers
- Operators

Wire Degradation Research

- Three-year, three-phase research project



Wire Degradation Research Planning

Define the applicable environmental exposure variables (aging factors) of the wire.

- Research all known existing aircraft wiring aging test reports for identification of environmental variables that have shown effect on degradation.

Wire Degradation Research Planning

Define the applicable environmental exposure variables (aging factors) of the wire.

- Survey stakeholders for inputs:
  - environmental variables and levels that affect wire life in the field
  - non-predictable "single event" (perturbations) in the field that can cause degradation including single event probability of occurrence and severity
  - design variables that affect wire life in the field. Examples would include mixing of wire types (in the same bundle and between adjacent bundles), clamping, hot stamping or other marking, etc.

Wire Degradation Research Planning

Define the applicable environmental exposure variables (aging factors) of the wire.

- Select the environmental variables
  - Environmental exposure: temp., humidity, u.v. exposure, fluids, temp. cycling, etc.
  - Mechancial: bending stress, repetitive flexing, vibration stress, abrasion or chaffing, notch propagation stress, tensile stress, etc.
  - Electrical: Voltage and current stress loads. Others for consideration include current overload, arcing, etc
- Establish quantitative test levels for each variable.

Wire Degradation Research Planning

Define the performance criteria to determine point of wire failure and degree of degradation.

- Insulation failure: dielectric breach of the insulation.
- Insulation degradation: Insulation tensile strength and elongation values on samples as they are aged.
- Conductor failure: Loss of electrical continuity.
- Conductor degradation: Increase in conductor resistance from unaged state.

Wire Degradation Research Planning

Determination of Test Samples

- Wire insulation type selection
  - Polyimide
  - PVC/Glass/Nylon
  - Crosslinked Ethylene Tetraflouroethylene (XLETFE)
  - Polyimide/Polytetraflouroethylene composite (PTFE)
  - Polyalkane-imide (Poly-X) – *availability**

Wire Degradation Research Planning

Determination of Test Samples

- Conductor materials selection
  - Tin coated copper
  - Silver coated copper
  - Nickel coated copper *(not applicable to PVC/G/N)*

Wire Degradation Research Planning

Determine Experimental Design: Primary experiment

- What is the best expected life quantitative equation for each of the 5 aircraft wire insulation types with the 3 conductor types when exposed to various levels of the environmental variables?
- Dependent variable: Time to failure, degradation vs. time
- Independent variables: defined in previous slides
- Sample Variables: wire and conductor types

Wire Degradation Research Planning

Determine Experimental Design: Secondary experiments

- Shorter term test methods tailored for specific insulation types
- Limited subset of environmental variables
- Examples:
  - Lectromech WIDAS process/polyimide
  - Dupont Inherent Viscosity/polyimide
  - Thermo-gravimetric analysis/all types
- Statistical correlation with primary experimental results

Wire Degradation Research Planning

Obtain Test Samples

- Dependent upon specific requirements established through the planning process.

Wire Degradation Research Execution

Execution of Planned Testing

- Multiple test laboratories
- Documented test procedures
  - Standard test procedures will be used where applicable
- Strict control of samples and experiment conditions.

Wire Degradation Research Analysis and Reporting

Analysis of Test Results

- Results of the long-term multi-variable life test program will be analyzed using multi-regressional analysis and other statistical techniques.
- Estimation of quantitative algorithms to correlate the aging factors with insulation and conductor failure and degradation.
- Duplicate and cross-lab results will assist the validation of the results.
- Results of the short-term test methods for specific wire types will be analyzed using applicable procedures for that technique.

Wire Degradation Research Analysis and Reporting

Analysis of Test Results

- Results will be analyzed for correlation with various prior commercial and military wiring investigations to crosscheck the validity of the results.
- Results will be analyzed for correlation with results of the FAA Intrusive Wiring Inspection Program and NTSB findings.
- Correlation to other laboratory aging studies where applicable.
- The contractor shall estimate whether the service life distribution is likely to be realized in practice or whether unpredictable or unknown characteristics of the aging process will dominate the degradation process

Wire Degradation Research Analysis and Reporting

Reporting

- Results of all testing, statistical analysis.
- Quantitative algorithms and equations.
- Qualitative assessment non-predictable “single-event” effects and the related effects to the overall degradation process.

Wire Performance Research

Wire Performance Research

- Purpose: Investigate and develop performance requirements, test criteria and procedures for aircraft wire.
- Review all existing requirements, standards, specifications, research and test data, etc.
  - FAA and other civil aviation authorities
  - Military
  - Wire Manufacturers
  - Aircraft Manufacturers
  - Standards bodies
- Baseline existing performance requirements
- In cooperation with all stakeholders, identify potential improvements in performance requirements.

Wire Performance Research

- For identified improvement areas…
  - Conduct research and/or testing to develop performance requirements and appropriate test methods.
  - Establish the framework and work with appropriate organizations to confirm new performance requirements.
  - Update FAR Part 25 as necessary, establish TSO’s.


The End