CASR

FAA Center for Aviation Systems Reliability

Engineering Assessment of Fluorescent Penetrant Inspection Program Overview January 2003

Delivery Order IA052

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CASR Center for Aviation Systems Reliability

To provide the FAA with cost-effective, reliable inspection tools and comprehensive training materials that meet the specific needs of the aviation industry and lead to safety improvements through their implementation

- Airframe structural systems
- Components (landing gear, wheels, etc.)
- Propulsion systems
- Nonstructural systems (e.g., wiring)

FAA Center for Aviation Systems Reliability

POC:

FAA-TC:	**Dave Galella, Program Monitor** **609-485-5784** **Cu Nguyen, Program Monitor** **609-485-6649**
ISU:	**Lisa Brasche, Program Manager** **515-294-5227**

Engineering Assessment of FPI

Annual Meeting – West Palm Beach, Fl – January 16 -17, 2003

DAY 1 – Thursday, January 16, 2003		
8:00	Welcome and Intro	Broz, Nguyen, Smith, Brasche
8:15	Overview of Year 1	Brasche
8:30 – 10:30	Developer Study Planning	Brasche
11 - 12	Stress study and surface treatments	Brasche, Lopez
	LUNCH	
1 – 4	Cleaning Study	Brasche
4 – 5	Light level studies	Brasche
5:00	ADJOURN – Group Dinner	

DAY 2 – Friday, January 17, 2003		
8 – 9	Prewash and emulsification parameters	
9 – 10	Penetrant application studies	Brasche
10 – 11	Part geometry and thickness studies	Brasche
11 - 12	Assessment tools for cleanliness and dryness	Brasche
	LUNCH	
1 – 2	Detectability studies	Brasche
	Sample fabrication status	Lopez
2 – 3	Summation – action Items	Brasche
3:30	ADJOURN	

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Objectives

- To identify the most relevant factors for which existing engineering data is insufficient, assess the parameter ranges that provide acceptable performance for typical aircraft and engine components, and document the results of these studies for use in revision of industry specifications
- To develop a self–assessment tool and protocol for use by airline and overhaul shops for performance verification compared against industry–accepted performance
- To complete an assessment of existing process control/monitoring tools and provide needed improvements
- To develop/validate FPI guidance materials for use by the airlines and OEMS that incorporate “lessons learned” in this program and incorporate other recently developed data and information

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Engineering Assessment of FPI

- Provide engineering data to support decisions regarding the safe application and relevant use of FPI
- Includes data to support changes in specifications
- Generate tools for use by airlines and OEMS that improve FPI processes
- Strong industry team with extensive experience

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Delta
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Consulting Services

General Electric Company

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Pratt & Whitney
A United Technologies Company

Rolls-Royce

SHERWIN
INCORPORATED

UNITED

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Program Structure

Engineering Studies

- Twelve studies identified
- Results to be published as FAA documents and on CASR website

Baseline Program

- Industrial Advisory Board functions including limited data analysis and interpretation
- Generation of guidance materials
- Fabrication of samples
- General ISU laboratory and measurement support

Engineering Tools

- Performance checks and standards
- Fluorometry study
- Performance verification kit
- Guidance materials
- Technology transfer workshops

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Approach

Baseline Program

- Industrial Advisory Board functions including limited data analysis and interpretation
- Generation of guidance materials
- Fabrication of samples
- General ISU laboratory and measurement support

Cooperative university/industry program which brings together aircraft and engine OEMs, airlines, vendors, as well as technical expertise from the NDE community.

Industrial Advisory Panel

Boeing - Long Beach
Dwight Wilson
Boeing - Seattle
Clint Surber, Steve Younker
Delta Airlines - Atlanta
Lee Clements
United Airlines - Indianapolis
Tom Dreher
Pratt & Whitney - EH and WPB
Kevin Smith, John Lively, Pete Ozga
Rolls Royce - Indianapolis and Darby
Pramod Khandelwal, Keith Griffiths, Bill Griffiths
GE Aircraft Engines
Terry Kessler, Thadd Patton
Sherwin - Cincinnati
Sam Robinson
D&W Enterprises - Denver
Ward Rummel

Approach

Baseline Program

- **Industrial Advisory Board functions including limited data analysis and interpretation**
- **Generation of guidance materials**
- **Fabrication of samples**
- **General ISU laboratory and measurement support**

Government Participants

FAA

Al Broz, Cu Nguyen, Dave Galella

Information routinely shared with USAF and Army

Vendor Participation

Sherwin will serve coordination function with other penetrant suppliers.

NDE Community

Updates to be provided at ASNT, ASTM and SAE Committee K meetings.

Utilize existing committees for publication of revised standards and specifications.

Technical Approach

- Define factors for which engineering data is deficient
  - Change in process, e.g., environmental changes
  - Change in applications
  - Data not available in the public domain
- Design engineering study that provides quantitative assessment of performance
  - Brightness measurements
  - Digital recording of UVA indication
  - Probability of Detection
- Complete study using either lab or shop facilities as appropriate
- Distribute results through use of web
- Support changes to industry specifications as warranted
- Utilize results to update/create guidance materials
- Transition process to airlines for internal, self-assessment

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Engineering Studies

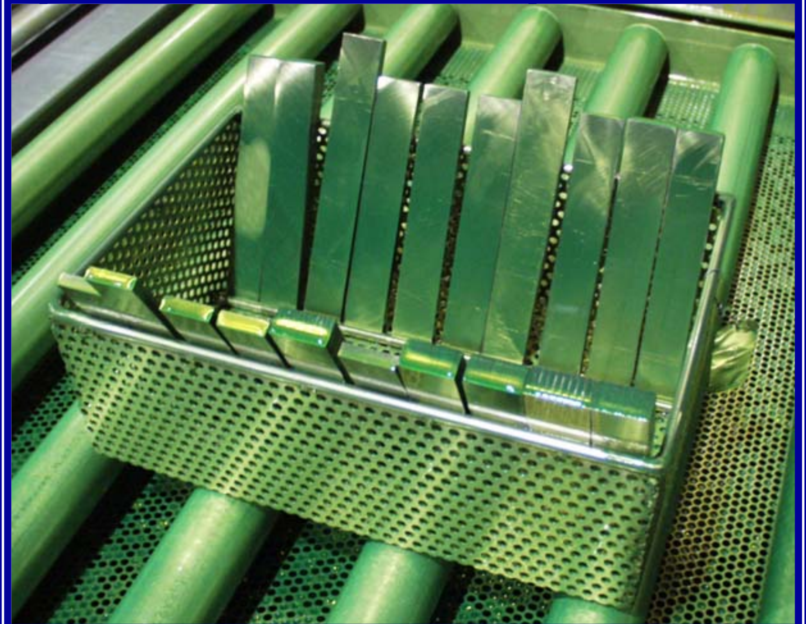
- Topics for engineering studies selected and prioritized by team
- Subteams developed for experimental design with review by the full team
- Experimental efforts to take place at various industry locations
- Definition currently underway

- ES – 1 – Developer Studies
- ES – 2 – Cleaning Studies for Ti, Ni and Al
- ES – 3 – Stress Studies
- ES – 4 – Assessment tool for dryness and cleanliness
- ES – 5 – Effect of surface treatments on detectability
- ES – 6 – Light level Studies
- ES – 7 – Detectability Studies
- ES – 8 – Study of Prewash and Emulsification Parameters
- ES – 9 – Evaluation of Drying Temperatures
- ES – 10 – Part geometry effects
- ES – 11 – Penetrant Application Studies
- ES – 12 – Relationship of part thickness to drying method

Baseline Program

Baseline Program

- Industrial Advisory Board functions including limited data analysis and interpretation
- Generation of guidance materials
- Fabrication of samples
- General ISU laboratory and measurement support



Fabrication of samples

- Alloys to be considered in both cast and forged/wrought product form
- Aluminum, titanium, and nickel
- Approximately 100 samples will be fabricated in each of the materials for a total of 300 samples

Baseline Program

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Baseline Program

- Industrial Advisory Board functions including limited data analysis and interpretation
- Generation of guidance materials
- Fabrication of samples
- General ISU laboratory and measurement support

Use of ISU laboratory and measurement support includes:

- FPI line
- Mechanical testing facilities
- Optical and analytical microscopy

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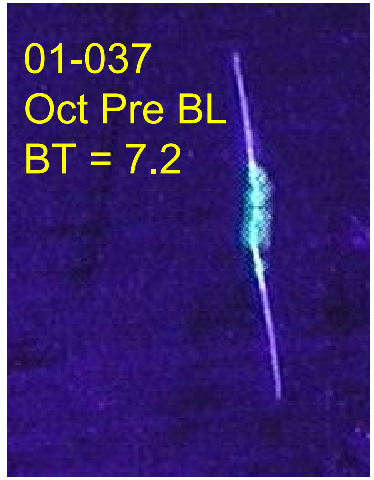
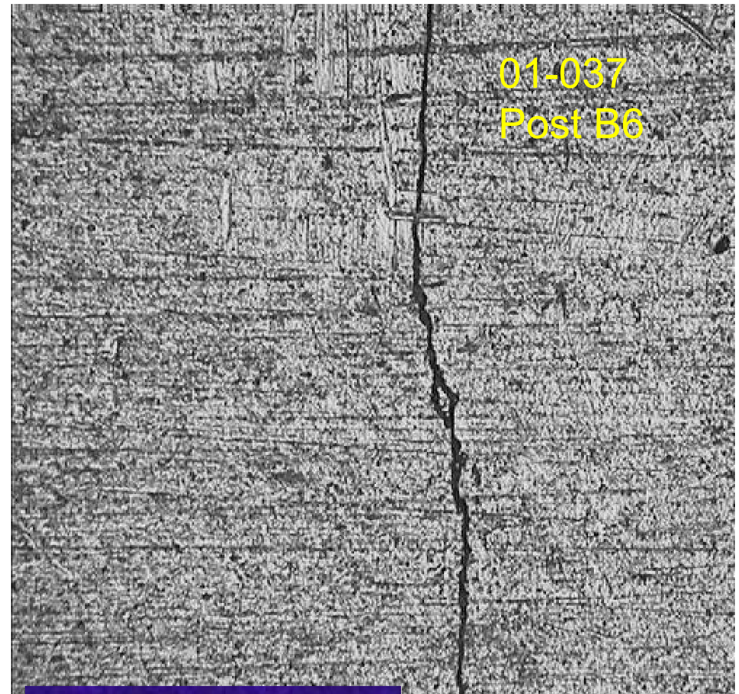
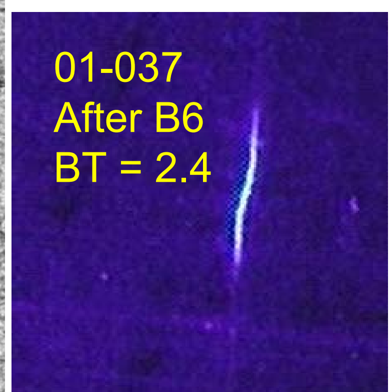
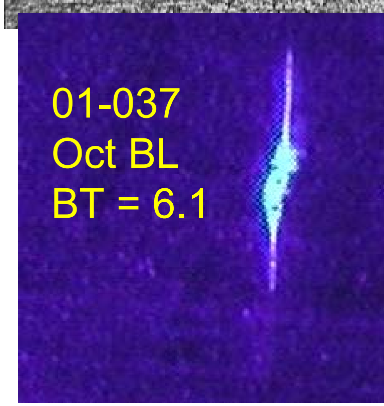
Engineering Studies









Engineering Tools

Engineering Tools

- Performance checks and standards
- Fluorometry devices
- Performance verification kit
- Guidance materials
- Technology transfer workshops

Technology transfer:

- Industry workshops held at annual intervals in conjunction with existing meetings to present status and continue broad industry and FAA input to program direction
  - Potential candidates include ATA NDT Forum or meetings of SAE Committee K
  - FAA personnel to participate in workshop or individual workshops held with FAA personnel to keep fully informed of progress and results
  - Full documentation and publication of results is planned in such resources as ASNT, the Aging Aircraft Conferences, and the Review of Progress in Quantitative NDE
- Website established at http://www.cnde.iastate.edu/faa-casr/fpi to distribute results including SAE Committee K activities

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Engineering Tools

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Guidance materials:

- Design panel comprised of FAA and industry members to assist in definition of the content, format, and delivery of guidance tools.
- Review of available public domain materials will be performed and provided at the end of sixteen months.
- Guidance tools developed at CASR, nominally 500 to 1000 copies, freely distributed to industry and to various FAA field offices. Use of FAA advisory circulars will be consider to convey the information as well.
- Development/validation of guidance materials is planned in the later half of the program with results of the engineering studies guiding the content and emphasis of the materials.
- Detailed program plan will be provided at eighteen months which describes the proposed guidance and instructional materials development. Materials will be generated for final review at month 48.

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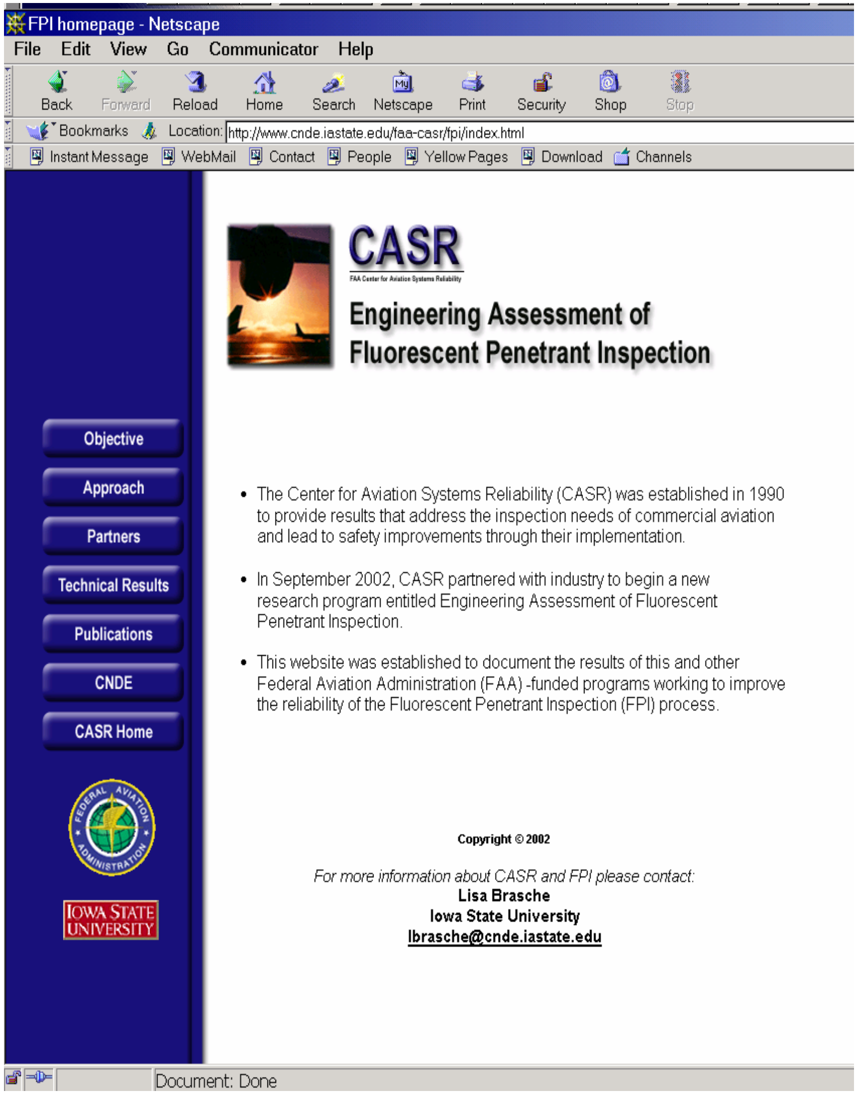
Outputs

- Engineering data for selected factors which affect sensitivity of FPI, including the presence and effect of silicates on detectability. This will include quantitative measurements of relevant penetrant system properties using analytical chemistry techniques as necessary
- Quantitative assessment of inspection technique parameters and process control effects for range of alloys using low cycle fatigue crack sample sets
- Feasibility study of the need and potential for development of new fluorometry devices
- Comparative study of daily performance checks including recommendations for improved approaches
- Guidance materials for use by industry and FAA. Initial distribution of materials will be primarily accomplished through the ATA NDT Forum
- Development of a self assessment tool and protocol
- Regular updates to industry through open meetings and internal working groups

CASR How are results transferred to industry?

- Intermediate workshops and public domain presentations
  - QNDE session – July 2002
  - ATA NDT Forum – ½ day workshop – Sept 2002
  - Future ATA and ASNT events
- Website to provide background info and publish technical results



http://www.cnde.iastate.edu/faa-casr/fpi

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Year 1 Accomplishments

- Established contracts with 8 (soon to be 9) organizations
- Established industry prioritization that identified twelve engineering studies
- Completed drying study using samples provided by Rolls Royce
- Established sample fabrication process and initiated sample generation for Ni and Ti
- Organized FPI workshop in cooperation with FAA in conjunction with ATA NDT Forum
- Established FPI website with over 75,000 visitors in the first year
- Initiated planning of engineering studies with subteam participants
- Completed survey of developer, cleaning and light level issues

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Engineering Studies

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ES – 1- Developer Studies

- ES – 1a – Compare different developer methods
- ES – 1b – Effect of stacking on detectability
- ES – 1c – Suggested design study for optimal distribution of particles in a chamber
- ES – 1d – Potential developer issues

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ES – 2 – Cleaning Study Plan

- ES – 2a - Evaluate multiple step process for cleaning Ti similar to that used for Ni and non-rotating Ti parts
- ES – 2b – Oil removal study for Al, Ni and Ti
- ES – 2c – Contamination study for Al (graphite, corrosion, conversion coating, anodic coating, paint removal, skydrol)
- ES – 2d – Quantify effect of alkaline cleaner residue on penetrant response for Al, Ni and Ti including buildup
- ES – 2e – Quantify benefit of rinse after media blasting

CASR ES 3 – Stress and ES – 5 Surface Finish

- ES 3a – Quantify the effect of stress on detectability for each of the alloys (Al, Ni, Ti)
- ES 3b – Understand the stress induced from various processes and correlate to the effect on detectability (i.e., crack closure). Processes will be selected from among the following:
    - Laser peening
    - Roller burnishing
    - Shot peening
    - High pressure water stripping
    - Flap peening – roto-peening
    - Blasting methods (plastic, Al203, walnut shell)
    - Ultrasonic cleaning
    - Welding
    - Barreling – vibratory tumbling
    - Thermal cycling
- Literature review of existing stress data to determine which processes require additional data

ES – 4 – Assessment tool for dryness and cleanliness

- ES 4 a – Evaluation of Sherwin KC Q-pon in conjunction with cleaning studies.
  - Process control specimens but not a guarantee of cleanliness
- Evaluation of CASR cleaning data at the close of the program to determine if other process control samples are evident

ES – 6 - Light Level Studies

- ES – 6a - Use spotmeter to document relationship between UV level and crack brightness
  - Function of crack size
  - Distance from surface
  - Real part geometry (curvature)
  - Penetrant type
  - White light level
  - Developer dwell time
- ES – 6b - Dark adaptation study
  - Review other literature (medical, human factors, etc.) for recommended parameters.
  - Perform POD study with interrupted light/dark exposure and compare to POD for “recommended” dark exposure.

CASR ES – 7 - Detectability Studies

- ES – 7a - Effect on re-bleed for range of crack sizes (closure) leading to a protocol

ES 8 – Emulsification/Prewash Studies

- ES 8 a – Emulsification Parameter Study to quantify the effects of concentration, agitation and surface finish on FPI response
- ES 8 b – Prewash Parameter Study to quantify the prewash parameters on FPI response

ES – 10 – Part geometry effects

- ES 10 a – Determine part volume effects on drying effectiveness

ES – 11 – Penetrant Studies

- ES – 11a - Document the effect of prior use of red dye on FPI brightness
- ES – 11b - Document the detrimental effect of the use of scotch brite
- ES – 11c – Document the relationship between min/max penetrant dwell times on detectability
- ES – 11d – Effects of re- FPI over penetrant from another manufacturer or other type/sensitivity.