Active Project (2014)

Consistent Practices for the Probability of Detection (POD) of Fracture Critical Metallic Components Project

Nondestructive Evaluation Program | Office Of Safety And Mission Assurance (OSMA)

ABSTRACT

NASA-STD-5009 requires that successful flaw detection by NDE methods be statistically qualified for use on fracture critical metallic components, but does not standardize practices. This task works towards standardizing calculations and record retention with a web-based tool, the NNWG POD Standards Library or NPSL. Test methods will also be standardized with an appropriately flexible appendix to -5009 identifying best practices. Additionally, this appendix will describe how specimens used to qualify NDE systems will be cataloged, stored and protected from corrosion, damage, or loss.

ANTICIPATED BENEFITS

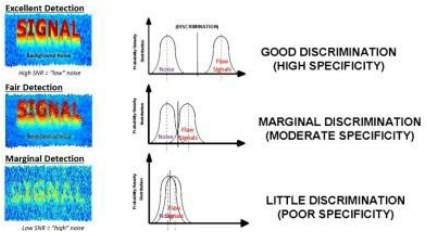
To NASA funded missions:

Although required and widely used to qualify inspection capabilities, the conduct of and tools for Probability of Detection (POD) analyses are not standardized for NASA and no system exists for cateloging POD data. This project reviews NASA's most common 90/95 POD methods and drafts an appendix to the current standard, titled *Best Practices for Performing POD Analyses and Storing NDT Test Standards* and provides standardized analysis and archiving tools.

DETAILED DESCRIPTION

Background

Flaw detection capability is established for inspection systems on the basis of Probability of Detection (POD). The commonly accepted metric for an adequate inspection system is as follows: for a minimum flaw size which is smaller than the critical defect being sought, there is 90% probability of detection with 95% confidence (90/95 POD). Inspection systems that are



Probability of Detection evaluates the effectiveness of inspection techniques and inspectors

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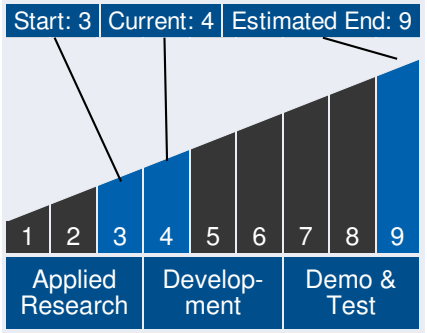
Technology Maturity



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incapable of meeting the 90/95 POD requirement at or below the critical defect level for fracture critical components are deemed unsuitable for that inspection.

To provide an efficient and accurate methodology that yields estimates of POD and confidence bounds for Hit-Miss or signal amplitude testing the directed design of experiments for probability of detection (DOEPOD) method has been developed. In DOEPOD, signal amplitudes are reduced to Hit-Miss data by defining a signal threshold. The directed DOEPOD method uses a nonparametric approach for the analysis of inspection data which, unlike other methods, does not rely on simlifying assumptions regarding the general form of a POD function. This differs with other methods that define a POD curve based on a curve fit and does not assume increasing detection with increasing flaw sizes that can often be proven untrue. For a given sample set, the DOEPOD procedure identifies whether the minimum requirement of 90% probability of detection with 95% confidence is demonstrated for a minimum flaw size and for all greater flaw sizes (90/95 POD). These procedures are sequentially executed to minimize the number of samples needed to demonstrate that there is a 90/95 POD lower confidence bound at a given flaw size and that the POD is monotonic for flaw sizes exceeding that 90/95 POD flaw size.

This work provides strong experimental and simulation evidence that a 90/95 POD flaw size will be identified by DOEPOD 95% of the time if it exists, and the procedures will yield a determination that the POD is non-monotonic 97% of the time when it is non-monotonic. Based on this evidence, the DOEPOD methodology may be used to reduce mission risk by quantifiably meeting the requirements of NASA-STD-5009, “Nondestructive Evaluation Requirements for Fracture Critical Metallic Components.”

Approach

1 Patent
5 Publications

Management Team

Program Executive:
- Brian Hughitt

Program Manager:
- Edward Generazio

Project Manager:
- Charles Nichols

Principal Investigators:
- Edward Generazio
- Mika Myers
- Floyd Spencer
- Jess Waller
- Jordan Wladyka

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A total of 860 metal specimens have been produced with a selection of fatigue cracks, fastener hole cracks, lack of weld fusion, and electrical discharge machined (EDM) flaws. The metals used in this study are common throughout aerospace, and include aluminum, titanium, nickel-chromium alloy, and stainless steel. Flat plates and tubes with programmed defects are being examined. These specimens are being examined with x-ray radiography with differing film densities, digital radiography, ultrasound (including phased array), eddy current (including automated methods), florescent penetrant testing (L3 & L4), magnetic particle testing, and visual testing.

Customers

All NASA centers and missions utilizing failure critical components.

Products

The data set generated by this study is vast. Specialized web-based software, termed the NNWG NDE Standards Library (NPSL), is being developed to archive and analyze all data and results. While this web application is being developed and validated to provide analytical support for this study, it will also be expanded upon to provide a centralized and living NDE capability database. Further, it will also provide NDE experts with a standard POD analysis tool for future studies.

Lessons learned as the result of this study will be published in guidance documents for designing statistically adequate POD tests as new standards or appendices to NASA-STD-5009. The Design of Experiments for Determining the Probability of Detection Capability of Inspection Systems and for Qualification of Inspectors (DOEPOD) will be used aggregation and quantification of the inspection results. A comparison with predictive POD methods will be made to identify validation gaps

Management Team *(cont.)*

Co-Investigators:

- John Aldrin
- Eric Burke
- Laura Cerecerez
- Judy Corbett
- Jill George
- Kenneth Hodges
- Justin Jones
- Bradford Parker
- Jennifer Petry

Technology Areas

Primary Technology Area:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)
- Manufacturing (TA 12.4)
  - Nondestructive Evaluation and Sensors (TA 12.4.5)
    - Nondestructive Evaluation Sensor and Method (TA 12.4.5.1)

Secondary Technology Area:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)
- Cross-Cutting (no content) (TA 12.5)

in POD methodologies used for failure critical inspections increasing overall mission success. Regardless of the model used, this estimate needs to be validated before implementation. (NASA/TM–2014-218183).

Project Manager

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Accomplishments

- 100 percent of the flawed samples have been manufactured and delivered for testing.
- Publication of DOEPOD methodology. 70% of the specimens have been tested.
- *DOEPOD v.1.2* and manual available.
- Familiarization training on LaRC/GSFC file structure and *DOEPOD* complete.
- Electronic/hard copy data consolidated
- NPSL software requirements agreed to including cataloging and searching capabilities.
- POD literature review and draft ‘Best Practices’ completed.
- Review outsourced to POD experts (Brown, Aldrin, Volovoi) and NESC NDE TDT statused.

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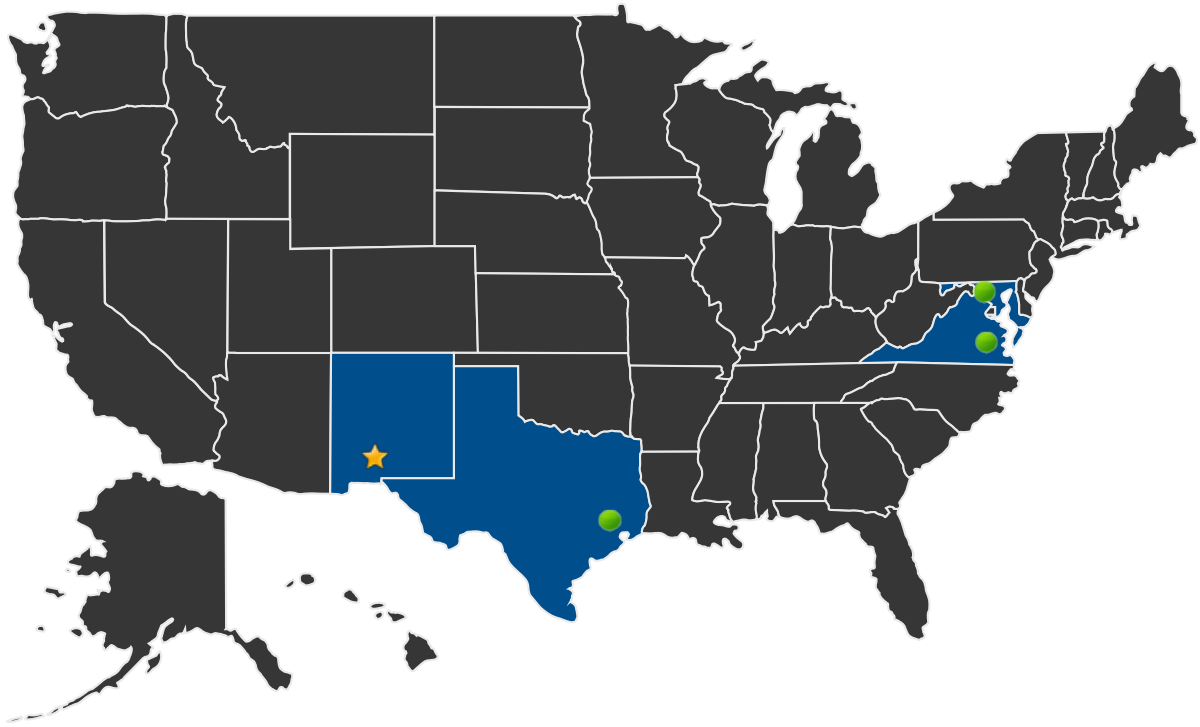
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
White Sands Test Facility

Supporting Centers:

- Goddard Space Flight Center
- Johnson Space Center
- Langley Research Center

Contributing Partners:

- AFRL

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PROJECT LIBRARY

Publications

- 2016 Presentation to the OSMA NDE Program at NASA Goddard
  - (https://techport.nasa.gov:443/file/20721)
- Binomial Test Method for Determining Probability of Detection Capability for Fracture Critical Applications
  - (http://ntrs.nasa.gov/search.jsp?R=20110015149)
- Directed Design of Experiments for Validating Probability of Detection Capability of NDE Systems (DOEPOD), NASA TM 2015-218696
  - (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013987.pdf)
- Interrelationships Between Probability of Detection Methodologies, NASA/TM–2014-218183
  - (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140005337.pdf)
- NASA DOEPOD NDE Capabilities Data Book, NASA TM 2015-218770
  - (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013943.pdf)

Patents

- US Patent 8108178, Directed Design of Experiments for Validating Probability of Detection Capability of a Testing System
  - (http://www.anypatents.com/patents/US8108178)

IMAGE GALLERY

NPSL
NNWG POD Standards Library

DETAILS FOR TECHNOLOGY 1

Technology Title

NNWG POD Standards Library

Technology Description

This technology is categorized as complex electronics software for engineering, design, modeling, or analysis

Although required and widely used to qualify inspection capabilities, the conduct of and tools for Probability of Detection (POD) analyses are not standardized and no system exists for cateloging POD data. This project reviews NASA's most common 90/95 POD methods and drafts an appendix to the current standard, titled *Best Practices for Performing POD Analyses and Storing NDT Test Standards*.

Capabilities Provided

The NNWG POD Standards Library, or NPSL, is a web-based analysis and archiving tool standardizing complex NASA-STD-5009 techniques using the four common analysis algorithms:

1.Multi-Parameter Maximum Likelihood Estimate (MLE)

2.Simple Binomial

3.Bayes Rule

4.Receiver/Relative Operating Characteristics (ROC)

Potential Applications

Unlike the medical community, NASA and the aerospace industry does not require and codify the validation of all POD curves prior to inspections. If 10% of POD data were removed at random, would the estimated POD curve fit be consistent? Validation of POD estimate curves must be addressed, and will be a requirement for the revised NASA standard.

NASA invented POD techniques in the 70's and is looked at as the model for inspection qualification along with the US Air Force. NASA is collaborating with the Air Force Research Laboratory, or AFRL, to produce a database logging POD studies, tracking samples, and performing analyses using a consistent and verified web-based platform. This has significant

impact on the safe inspection and qualification of fracture critical metallic parts within the Agency and Department of Defense, which is likely to carry over throughout industry.

Performance Metrics

Metric	Unit	Quantity
Tools and techniques required for qualifying fracture critical metallic inspections		