



Fracture Critical POD Process Validation

Active Project (2015 - 2017)

Charles Nichols, NASA JSC WSTF

Edward Generazio, NASA LaRC

Background

- Flaw detection capability is established for inspection systems and inspectors 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 0.90 probability of detection with 95% confidence (90/95 POD).
- A number of issues with current processes exist and will be addressed:
 1. The existing OSMA POD data set, including flaw standard specimens, have been consolidated at WSTF. Specimens are available upon demand. A variety of materials, geometries, defects, and NDE methods are included spanning about 860 specimens.
 - ✓ Specimen storage procedures are inline with proposed best practices appendix.*
 2. In FY17 a centralized, searchable, and robust online database will be created to log and track POD specimens and results using agency mandated security and backup measures in line with ISO requirements.
 3. In FY18 a web-based service will be developed to enable analyses to be performed consistently across centers.

* Reference: Proposed NASA-STD-5009 Appendix, TEST SPECIMENS AND THEIR IDENTIFICATION, HANDLING, CLEANING, ETCHING AND REFURBISHMENT.

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 cataloging POD data.

- If we know *a priori* that a data set is inadequate for providing acceptable multi-parameter Maximum Likelihood Estimate (MLE) of POD, then what direction is need to be given and satisfied to make the data set a viable data set for multi-parameter MLE.
- It's better to know this before, rather than after the analyses is done and you are trying validate a POD estimate that cannot be validated.

Approach

- Phase 0: Best practices appendices for POD and specimen storage (FY15)
 - First steps for the team's education in POD.
- Phase 1: Analyze the OSMA NDE POD Data Set (FY16)
 - Second step. Three studies completed, aided by Floyd Spencer. Reports in review.
- Phase 2: Create a centralized repository for POD specimens/ NDE capabilities essentially providing a living, backed-up, and encrypted table for NASA-STD-5009 via MAPTIS (FY17)
 - Phase 0 and 1 efforts informed team of database field and organization requirements.
- Phase 3: Develop and validate a web-based **analysis tool** standardizing analyses using the four common analysis algorithms:
 1. Multi-Parameter MLE
 - a. Logistic Regression models (e.g. Logit and Probit) from MIL-HDBK-1823, NASA/TM-2014-218183 (April 2014).
 - b. Add internal and external validation test for MLE estimates (draft coded into DOEPOD, but not released).
 2. Simple Binomial
 - a. Method used by DOEPOD, and NASA Shuttle and Space Station Program estimate of POD.
 - b. DOEPOD and DOEPOD's validation was critically reviewed by statistician Bill Meeker/ Iowa State.¹
 - c. NASA/TM-2014-218183 was critically reviewed, over a two year period by statisticians, Dr. William Q. Meeker of Iowa State University and Dr. Floyd W. Spencer of Sfhire, and Dr. William Vesely for NASA.
 3. Bayes Rule
 4. Receiver/Relative Operating Characteristics (ROC)
 - a. ROC is a display technology that may be based on Binomial, MLE, or Bayes rule, etc.

Accomplishments

- Team assisted in review of NASA-STD-5009, proposing appendices for POD Best Practices (Appendix B) and an appendix governing sample storage (Appendix C). Language requiring method validation added to -5009.
- Publication of DOEPOD methodology. Version 1.2 and manual available. The software was licensed under non-disclosure to organization directly supporting DOT and to a business venture for other applications.
- **Phase 1:** About 70% of the specimens have been tested. All non-Adobe Version 9 files have been converted to MS Excel. Software glitch only allows Adobe 9 access to some inspector reports. Analysis and reports drafted for eddy current (ET), Level 3 (L3) Penetrant Testing (PT), and Level 4 (L4) PT.
- **Phase 2:** POD specimen database inclusion into MAPTIS via MSFC agreement began in FY17. Will poll Center POC's for specimens and studies to import.
 - Worked in parallel: OSMA flaw specimens relocated to WSTF, being checked for cleanliness, cataloged, and secured for agency distribution.
- **Phase 3:** Not started. MLE and DOEPOD methods will be included (proposed work for FY18 & FY19). Sets precedent as the first complex calculation modules added to MAPTIS. FY16 presentation to national NDE council drew interest in application independent and standardized calculator.



POD Studies

Phase 1: Progress in Analyzing the OSMA NDE POD Data Set

Specimen Sets

- About 860 metallic specimens were produced before 2011 with a selection of fatigue cracks, fastener hole cracks, lack of weld fusion, and electrical discharge machined (EDM) flaws at a cost of about \$630,913. The metals used in this study are common throughout aerospace and include aluminum, titanium, nickel-chromium alloy, and stainless steel.
- NDE was performed on these specimens to augment the NASA NDE Data Book, which feeds into Table 1, NASA-STD-5009. Specimens were examined with x-ray radiographic testing (RT) under differing film densities, digital radiography (DR), ultrasonic testing (UT) (including phased array UT), ET (including automated methods), fluorescent PT (L3 & L4), magnetic particle testing (MT), and visual testing (VT). Three of about 60 POD analysis have been completed.



Specimen Sets – maintained by WSTF, available for PODs / recerts

Aluminum Plates with Fatigue Cracks

Box #1: AIA-1 to -16

Box #2: AIA-19 to -46

Box #3: AIA-47 to -74

Box #4: AIA-75 to -102

Titanium Plates with Fatigue Cracks

Box #5: AIT-1 to -16

Box #6: AIT-18 to -38

Box #7: AIT-39 to -59

Box #8: AIT-60 to -80

Box #9: AIT-81 to -101

Inconel Plates with Fatigue Cracks

Box #10: All-1 to -16

Box #11: All-18 to -33

Box #12: All-34 to -50

Box #13: All-51 to -68

Box #14: All-69 to -85

Box #15: All-86 to -101



Aluminum Flat Plate w/ LOF Welds

Box #16: BIA-1 to -6

Box #17: BIA-18L to 39L

Box #18: BIA-40L to 61L



Titanium Flat Plate w/ LOF Welds

Box #19: BIT-1 to 16

Box #20: BIT-18 to 38(7)

Box #21: BIT-40 to 61

Inconel Welds w/ EDM Notches

Box #22: BII-18 to 22, 24-25, & 27-37

Welds w/ EDM Notches (SS, Al, Ti)

Box #23: BIS-18 to 27, 29-30, & 32-37

Box #24: BIA-18 to -37

Box #25: BIT-18 to -37

Inconel Tubes with Fatigue Cracks

Box #26: CII1-1 to 16

Box #27: CII1-17 to 33



Stainless Tubes with Fatigue Cracks

Box #28: CIS1-1 to 3, 9-16, & 18-20

Box #29: CIS1-21 to 39

Stainless Tubes with LOF Welds

Box #30: CIS2-1 to 17

Box #31: CIS2-18 to 33

Inconel Tubes with Fatigue Cracks

Box #32: CI1-1L to 16L

Box #33: CI1-18L to 39L

Box #34: CI1-40L to 61L

Inconel Tubes with LOF Welds

Box #35: CIS1-18L to 33L

Box #36: CIS1-40L to 61L

Box #37: CIS1-62L to 83L

Stainless Tubes with LOF Welds

Box #38: CIS2-18L to 33L

Box #39: CIS2-40L to 61L

Box #40: CIS2-62L to 83L

Cracked Fastener Holes, Aluminum

Box #41: DIA-1 to 16

Box #42: DIA-18 to 31

Box #43: DIA-32 to 46

Box #44: DIA-47 to 61



Cracked Fastener Holes, Titanium

Box #45: DIT-2 to 17

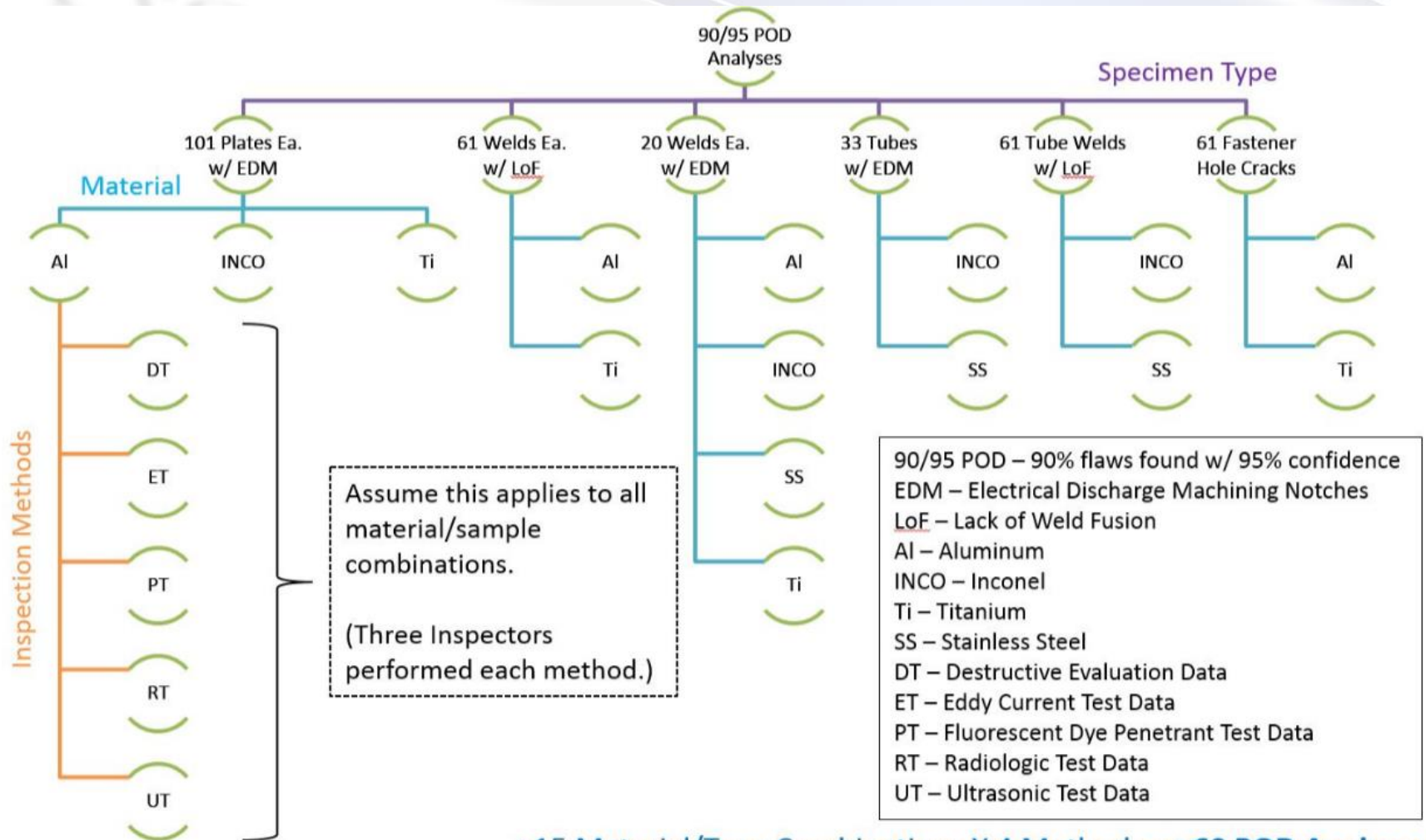
Box #46: DIT-18 to 31

Box #47: DIT-32 to 46

Box #48: DIT-47 to 61

Box1 and Box2 are radiographs

Inspection Data Produced



>15 Material/Type Combinations X 4 Methods = >60 POD Analyses



MAPTIS


MATERIALS AND PROCESSES TECHNICAL INFORMATION SYSTEM

NDE POD Standards Library



Phase 2: Creates a centralized repository for POD specimens/ NDE capabilities essentially providing a living, backed-up, and encrypted table for NASA-STD-5009 via MAPTIS.



Also logs Phase 1 specimens for agency support and dissemination.

NDE Probability Standards Library (NPSL) Database – Main Menu

MENU search here... searches all records and documents. 

Welcome to NDE Probability of Detection Standards Library (NPSL)

Probability of Detection Calculator (In Work) Capability Demonstration Specimens Completed Capability Demonstration Studies  New Record 

 home  help

Completed Capability Demonstration Studies

Probability of Detection Study How-To Guides

Capability Demonstration Specimens

Probability of Detection Calculator (In Work)

NDE Probability of Detection Standards Library

Purpose

The library provides a living accounting of the capability demonstration *studies* and *specimens* used to establish nondestructive evaluation (NDE) method detection limits for fracture critical hardware across the agency.

Applicable Standards

Per **NASA-STD-5009**: Special NDE consists of nondestructive inspections that must be capable of detecting crack-like flaws smaller than those detectable by Standard NDE (table 1 or table 2) or those that do not conform to the requirements for Standard NDE given in section 4.2, Standard NDE. All deviations from standard NDE shall be approved by the responsible NDE engineering organization, the RFCB, and Technical Authority.

Demonstration of Capability

A 90/95 percent flaw detection capability shall be demonstrated before a Special NDE inspection can be implemented. The demonstration of the Special NDE inspection at a given crack size qualifies the Special NDE for implementation for the detection of cracks at the demonstrated size and larger. Once established and accepted, Special NDE qualification is generally limited to the equipment, procedure, and inspectors involved in the capability demonstration study unless approved by the responsible NDE engineering organization, the RFCB, and Technical Authority.

Acknowledgements

The library is maintained by Marshall Space Flight Center and managed by Johnson Space Center via White Sands Test Facility. Support for the library is provided by the NASA Office of Safety and Mission Assurance **NDE Program**.

Points of Contact


Project Manager: Charles Nichols, 575.524.5389, charles.nichols@nasa.gov
 Technical Lead: Rick Serwecki, 256.544.3977, rick.serwecki@nasa.gov

Under Construction. Likely to go live in June:

<https://maptis.ndc.nasa.gov/Athena/ViewRecords.aspx?pk=32>



NPSL Database – How-To Guides (Draft)

MENU search here.. searches all records and documents.  Welcome to NDE Probability of Detection Standards Library (NPSL)

[Probability of Detection Calculator \(In Work\)](#) [Capability Demonstration Specimens](#) [Completed Capability Demonstration Studies](#) [more...](#) [New Record](#) [home](#) [help](#)

PROBABILITY OF DETECTION STUDY HOW-TO GUIDES

starts with: [Select All](#) [Generate Report](#)

Filter By ▾

- ASTM E 2862, Standard Practice for Probability of Detection Analysis for Hit/Miss Data
- Ed Generazio - DOEPOD NDE Capabilities Data Book
- EN-SB-08-012, USAF In-Service Inspection Flaw Assumptions for Metallic Structures
- Floyd Spencer - Nonparametric POD Estimation for Hit/Miss Data Model Comparisons
- Jennifer Brown - It takes more than a Statistician to do POD
- MIL-HDBK-1823A (2009), DoD Handbook for NDE System Reliability Assessments
- MIL-HDBK-5J, DoD Handbook for Metallic Materials and Elements for Aerospace Vehicle Structures
- NASA-STD-5009 Draft Appendix, Best Practices for POD Testing - Specimen Storage Best Practices
- NASA-STD-5009, Nondestructive Evaluation Requirements for Fracture-Critical Metallic Components
- Ward Rummell - Recommended Practices

page 1 of 2 (11 Records) [<< first](#) [< prev](#) [1](#) [2](#) [next >](#) [last >>](#)

NPSL Database – POD Specimens (Draft)

New Record X

Save

Record Name * :

Notify Me

Specimens Flaws Delete Me Owner Location

General Characteristics of Each Box of Specimens

Representative Images * : Browse...
Click "Browse..." and select one or more files (hold CTRL to select more than one) or drag and drop files here to upload.

Specimen type: in

Material * : Select

Alloy * : Select

Specimen Type * : Select

Flaw Type * : Select

Specimen Width: in

Specimen Length: in

Specimen Thickness: in

Specimen Outer Diameter: in

Specimen Inner Diameter: in

Detailed Inventory: Browse...
Click "Browse..." and select one or more files (hold CTRL to select more than one) or drag and drop files here to upload.

Specimen Thickness: in

Specimen Outer Diameter: in

Specimen Inner Diameter: in

Detailed Inventory: Browse...
Click "Browse..." and select one or more files (hold CTRL to select more than one) or drag and drop files here to upload.

Date of Inventory * :

Inventory Conducted By * : Select

Range of Specimen Serial Numbers * :

Delete, likely available in one month on 1/22: Select

Container Number * :

* Indicates required attribute

CAPABILITY DEMONSTRATION SPECIMENS

NPSL Database – POD Studies

(Draft)

New Record X

Record Name * :

Notify Me

Capability... **Certified ...**

NDE Capability Demonstration Study

Location:

NDE Method:

Material * :

Alloy * :

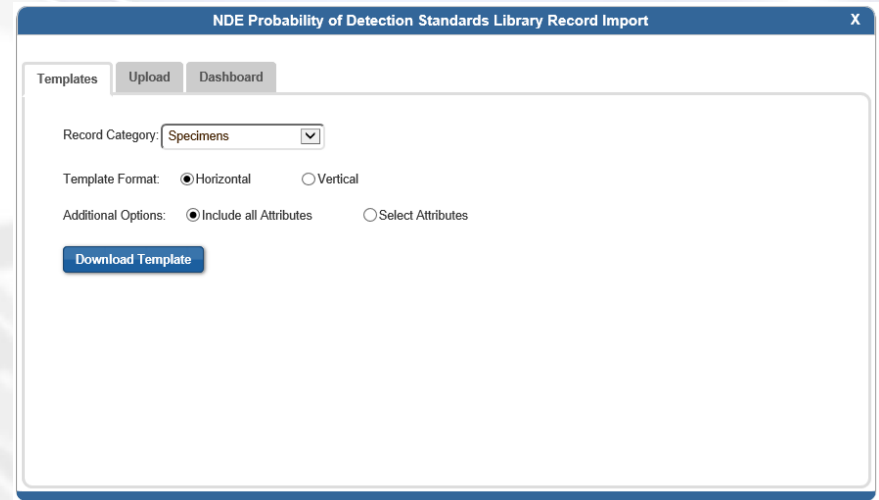
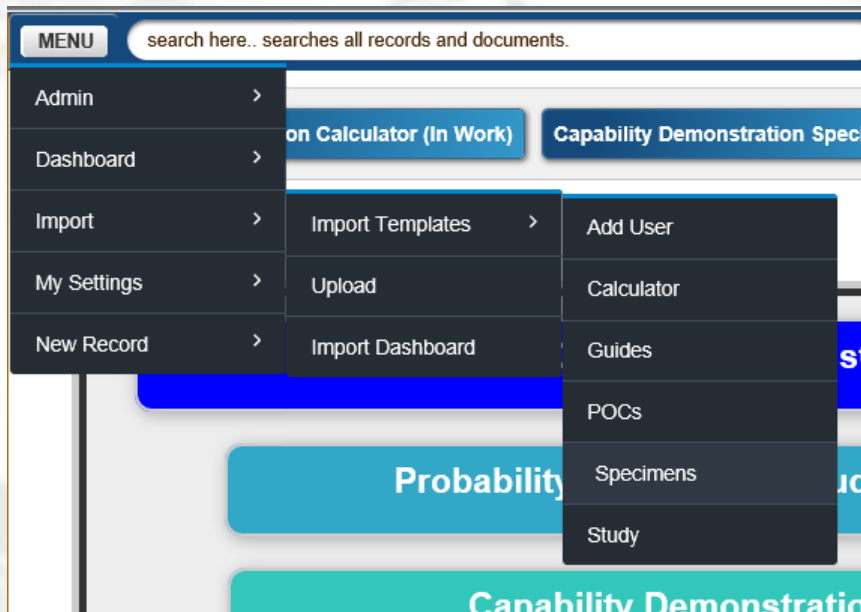
Files & Report * :

Click "Browse..." and select one or more files (hold CTRL to select more than one) or drag and drop files here to upload.

* Indicates required attribute

COMPLETED CAPABILITY DEMONSTRATION STUDIES

NPSL Database – Upload Templates



Results in a MS Excel spreadsheet laid out to enable rapid, batched uploads.

Users can just copy > paste into the appropriate column from existing tables.

NPSL Database – Search & Reporting Features

Material Selection List

[maptis home](#) | [search](#) | [help](#) | [Tutorial](#)

inconel [Classic Search](#)

Material Record Count: 1

✕ inconel
✕ Pneu Impact: Pressure 5000 to 10000

Filter Results By

Metal Non-Metal

Mech Impact where Pressure (psia) 5000 to 10000

Results

1 Material matched your search

Mtrl Code	Mtrl Name (Designation)	Use Temp Min	Use Type Max	Composition	Specification
10129	INCONEL™ 718 BAR ST 1750F	-423	1120	50-55NI 17-21CR 17FE .2-.8AL .006B .08C 1CO .3CU .35MN 2.8-3.3MO 4.75-5.5NB .015P .015S .35SI .65-1.15TI	MB0170-075

Example: Material Selection Database, Link: <https://maptis.ndc.nasa.gov/matsel/>

NPSL Database – Access Controls

NDE Probability of Detection Standards Library Project Admin

Project Data Map User Rights Access Control

Enter Name, User ID or Email Address:

LAST NAME	FIRST NAME	E-MAIL	
Burke	Eric	eric.r.burke@nasa.gov	Select

User ID: erburke
Name: Eric R Burke
Email: eric.r.burke@nasa.gov

User Rights:

- Project Admin
- Edit Records
- Delete Records
- Modify Access Controls
- View All Records
- User Admin
- Import Module
- Bulk Delete
- Dashboard Module

Schedules/Milestones

- ✓ FY15: Inventory all data; identify and fill gaps, should they exist. Provide a Best Practices appendix to NASA-STD-5009. Include recommendations for long-term sample storage.
- ✓ FY16-17: Analyze and log the following NNWG POD standards –*NDE Methods: UT, RT, ET, & PT*. Not practical to accomplish in one year under given resources.
 - About 60 studies would need to be performed. Three studies were wrapped up.
 - ~101 flat plates with fatigue cracks (Al, INCO, & Ti)
 - 61 plate weld specimens with lack of fusion (Al & Ti)
 - 20 plates welded with an EDM notch specimens (Al, INCO, SS & Ti)
 - ~33 1" or 2" tubes welded with an EDM notch (INCO, SS)
 - ~61 1" or 2" tubes welded with lack of fusion (INCO & SS) and
 - 61 fastener hole crack specimens (Al & Ti)
- ☐ FY17+: Alpha test/approve NPSL entry and query capabilities. Create a platform-independent POD analysis tool Extract, interpret, and integrate macros from DOEPOD into NPSL.
 - Code in MLE as presented in NASA/TM–2014-218183, April 2014.
 - Add internal and external validation test for MLE estimates (these have been draft coded into DOEPOD, but not released).
- ☐ Proposed for FY18-19: Test and approve NPSL entry and query capabilities. Create a platform-independent POD analysis tool
 - Code in MLE as presented in NASA/TM–2014-218183, April 2014.
 - Add internal and external validation test for MLE estimates (these have been draft coded into DOEPOD, but not released).

Customers

NASA Infusion

1. Having a central catalog of POD studies provides a number of benefits: tracking POD study values across a wide variety of parameters to establish precedence via a living database, auditable sources for POD studies and inspector certs, alerting Center reps to looming inspector recertification expiration (2-year certs per NASA-STD-5009), the ability to learn how other Centers qualify NDE, etc.
2. Once Center surveys are completed, the database will serve as a centralized NASA library for locating the specimens and resources needed to perform capability demonstration studies. As these specimens can be very expensive to produce, collaboratively sharing resources and reducing duplicated efforts has the potential for saving programs and agency NDE practitioners thousands of dollars each year.
3. Later, addition of a POD calculator to the database will reduce the practice of using multiple tools across NASA to run estimations.

U.S. Air Force

- Though the necessary validation, security protocols, and database population will take some time, the project team wishes to make NPSL accessible by agency partners across the country. This is unprecedented. There is some USAF interest in an updated database based on Berens and Hovey POD v3 implementing MIL-HDBK-1823, but this has not yet come to pass.

U.S. Navy

- NASA collaboration through NAVSEA/NUWC is a possibility on some submarine work, however the USAF remains the most prolific user of POD throughout the U.S. military.

Products

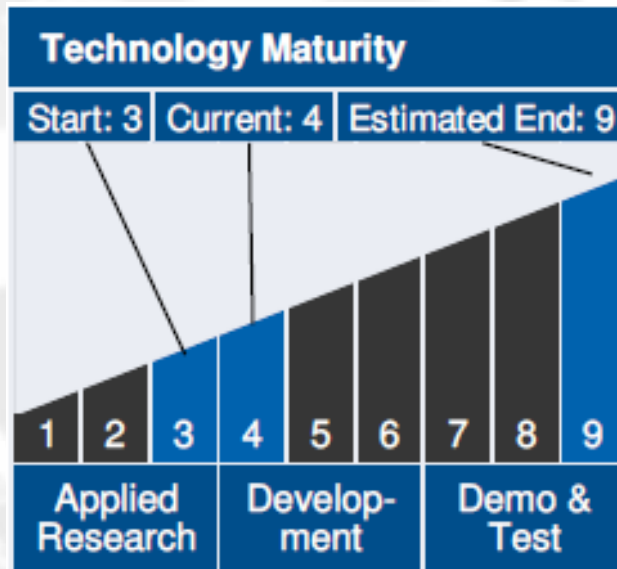
Publications

1. Binomial Test Method for Determining Probability of Detection Capability for Fracture Critical Applications (<http://ntrs.nasa.gov/search.jsp?R=20110015149>)
2. 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>)
3. Interrelationships Between Probability of Detection Methodologies, NASA/TM–2014-218183 (<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140005337.pdf>)
4. NASA DOEPOD NDE Capabilities Data Book, NASA TM 2015-218770 (<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013943.pdf>)
5. OSMA's NDE Program Published Capabilities Data Book, [OSMA Website](#)

Patents

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

Metrics



Technology Areas

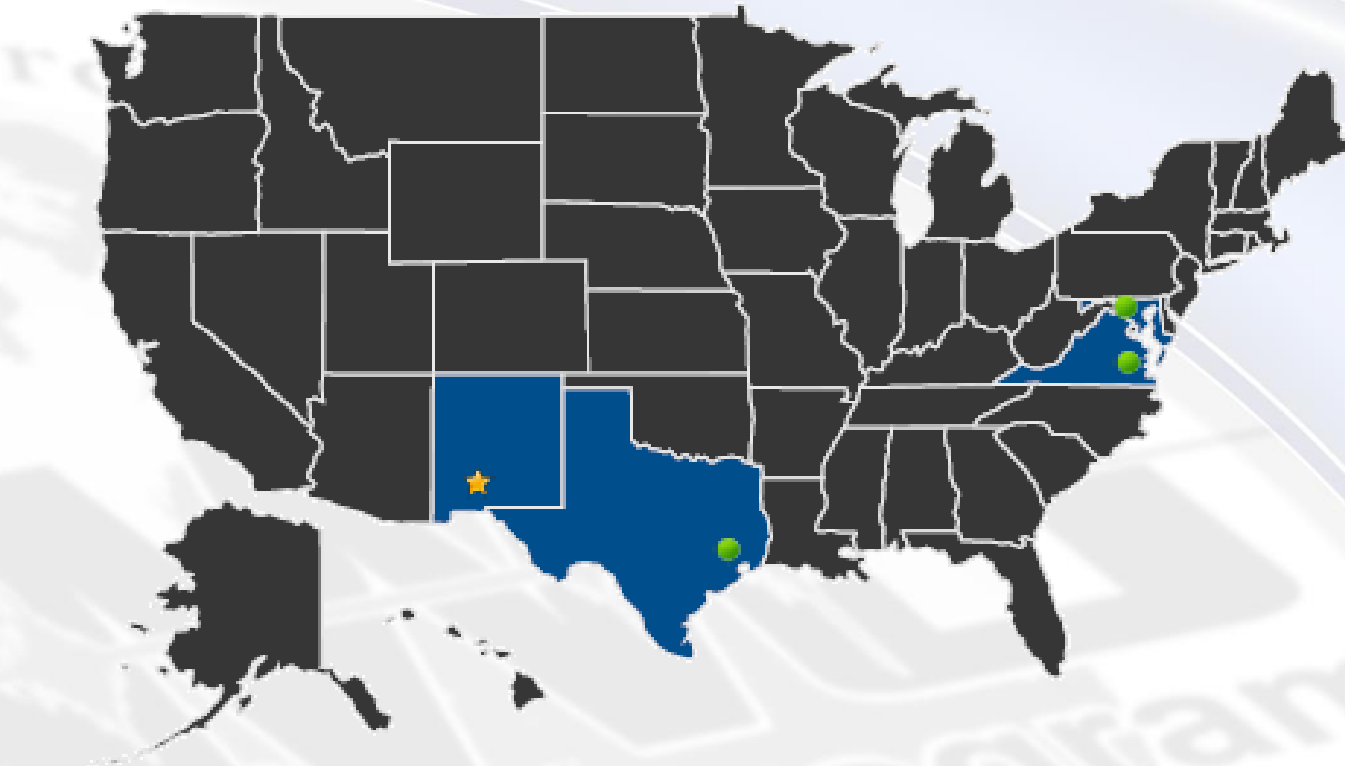
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

└ Nondestructive Evaluation Sensor and Method (TA 12.4.5.1)

Cross-Cutting (no content) (TA 12.5)

Fracture Critical POD Process Validation

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

Acknowledgements

- Ed Generazio: DOEPOD
- Bill Prosser: training
- Ajay Koshti: training
- Ward Rummel: POD methods
- Floyd Spencer: POD analyses
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- Mika Myers: reporting & consolidation
- Laura Cerecerez
- Sandy Montoya
- Jess Waller: best practices
- Jill George
- Justin Jones: archiving
- Brad Parker
- Judy Corbett: NPSL
- Ken Hodges: -5009
- Jennifer Petry
- Eric Burke
- John Aldrin
- Jennifer Brown: POD statistical methods
- Mike Suits: -5009
- Ben Henrie & Teresa Miller: MAPTIS

Q & A

- For further information, refer to the following report:

Link: <https://techport.nasa.gov/view/32921>

- Point of Contact:

Charles Nichols, PM

NASA JSC White Sands Test Facility

Telephone: (575) 524-5389

charles.nichols@nasa.gov