

Overview of Current Efforts within the OSMA NDE Development Program

Eric Burke

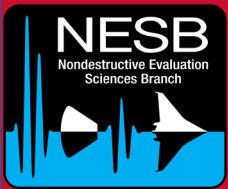
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[OSMA NDE Development Program Website](#)

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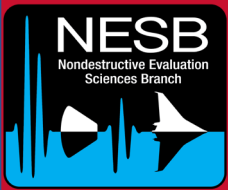


OSMA NDE Development Program

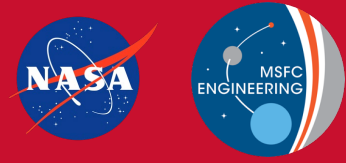


How the OMSA NDE Development Program Operates:

- At the beginning of the budgetary cycle, PM puts out a call to all Chief engineers and the NDE TDT at all centers to collect the NDE critical issues list ahead of the program proposal cycle.
- New starts will begin as a Phase 1. Phase 1's will have a budgetary cap of 150K per year full cost, per Center involved. Partnered Centers can aggregate funding, but Center funding distribution must be included in the proposal. Phase 1 timeframe will be only 1 year.
- Successful Phase 1's will be eligible for Phase 2. Phase 2's will have a budgetary cap of 300K per year and can also be aggregated across Centers. Phase 2 expected completion timeframe will be 1 to 2 years.
- All Phase 1 and Phase 2 proposal's will be presented at the annual review, voted on and graded with the guidance of the CLT. This review will be held in conjunction with first Face-to-Face TDT meeting of the calendar year.
- At the end of any Phase 1 or Phase 2, unused money will immediately be evaluated and reallocated where necessary at the discretion of the program manager.
- FY22 Had and updated and new equipment budget but was canceled due to FY23 budget constraints.



New Starts Evaluation Criteria



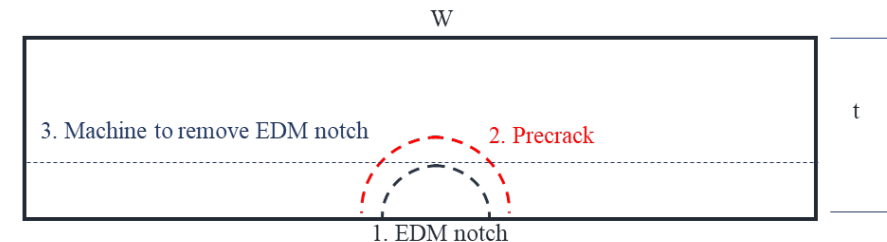
- Proposals addressing an ongoing NASA mission or activity are highly desired. Letters of support should be included and highlighted in the proposal.
- Similarly, proposals that address issues that are on the NDE critical issues list are highly desired. In future years, the **NDE critical issues list** will be initiated at end of the fiscal calendar and made available by the first week of December.
- Proposals that partner with other Centers to tackle larger issues are highly encouraged.
- Proposals should target longer term inspection goals.
- Proposals that support short term NESC activities and/or missions, but that have longer term goals will also be considered.
- Proposals that will increase the quality of inspection at NASA will be considered.
- Each Center is allowed up to 3 Phase 1 submittals and 1 Phase 2 submittal every cycle.
- **Indication of a publication or TM will be mandatory at the end of phase 1 or 2. Please include travel for conference where applicable.**
- It should be noted that for of FY22 center access was limited to mission critical work only. So some project moved slower than normal.

Past & Current Efforts 2022 & 2023

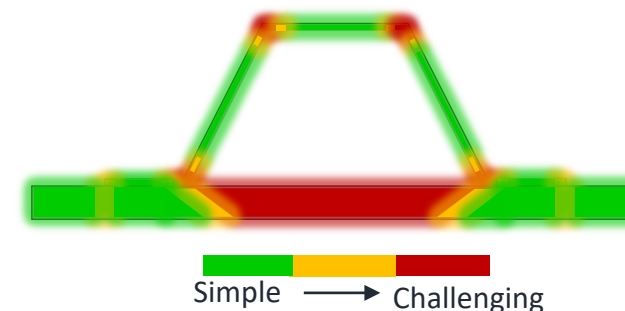
- Comparison of NDE Response of Fatigue Cracks, Notches and Holes including Issue #3 (Multi-Center & NESC)
 - Notches are used to demonstrate nondestructive evaluation (NDE) capability, but their NDE responses are dissimilar to those of cracks
 - An understanding of the response of cracks and EDM notches and the associated sensitivities will help inform an estimated transfer function.
 - This effort is being co-funded with the NESC. Additionally, we are running CIVA models along side the testing effort. OSMA and HPC Incubator have made CIVA available agency wide.
 - Outcome of the study and how it will affect the NASA-STD-5009 ongoing.
 - Continuing work in FY23, Related to the NESC Double Wall study
- It is noteworthy that providing simulation tools across the agency is having positive effects that were not planned.
 - (LaRC) Design for inspection simulation prototypes are starting to be developed. Where designs can be assessed before fabrication as to how inspectable they might be.



Pre-etch microscopy of an Inconel crack panel, after penetrant inspection



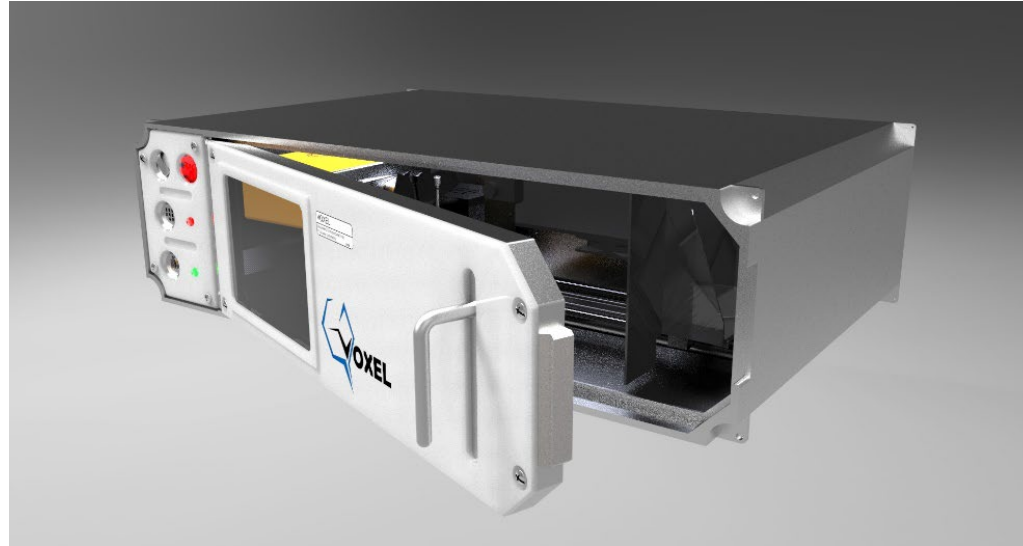
Cross Section of Test Sample



Design for Inspection - Simulation

Past & Current Efforts 2022 & 2023

- NASA Goddard Space Flight Center (GSFC) has led efforts to investigate In-Space X-ray Computed Tomography (CT) for multi-use applications, in collaboration with other centers
- Efforts include Concept Development and Trade Studies to assess feasibility for CT in different environments (ISS, lunar, Martian, crewed/non-crewed)
- Instrument Design Lab (IDL) study in late 2019 - early 2020 demonstrated core system feasibility and key requirements met for a pathfinder, prototype design, including deep dives into 12 major subsystems. Complete.
- Non-funded partnership agreement with North Star Imaging
- Continuing – FY23



One potential venue for CT in Space could be on an ISS Express Rack (or similar setup on NASA Gateway). Shown above are generic Mid-Deck Locker (MDL) dimensions, representative of the size of such a system (e.g., could be single or double, as shown). Lower image shows an exterior rendering of our VOXEL MDL design concept.

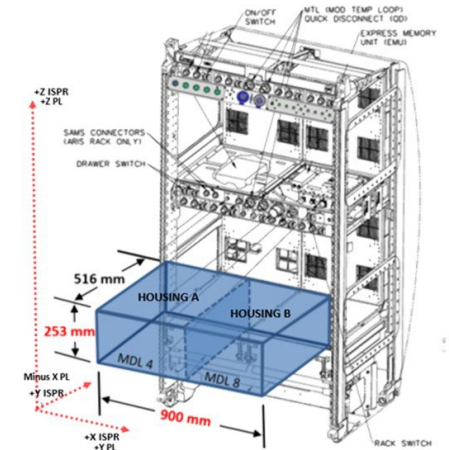
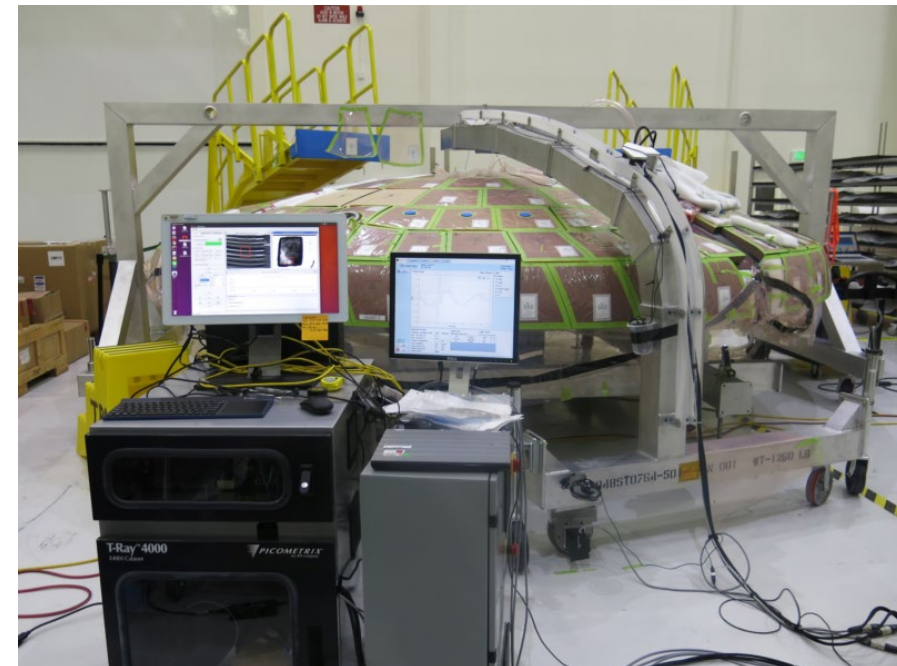
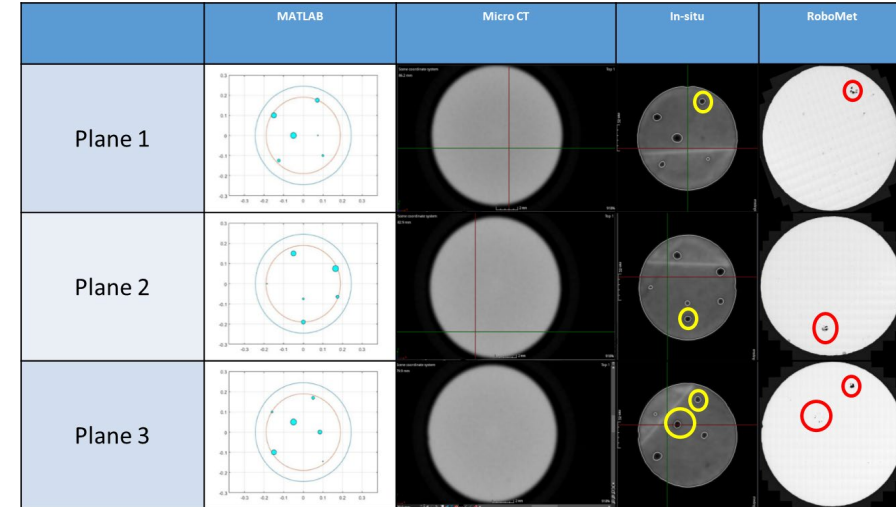


Image Credit: NASA

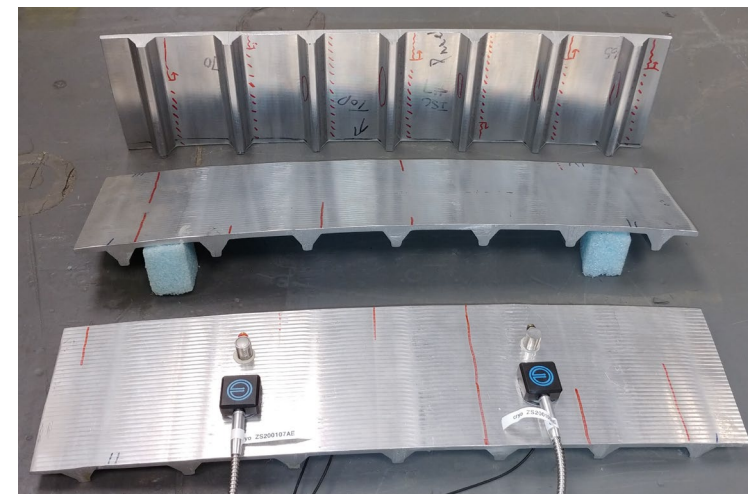
Past & Current Efforts 2022 & 2023

- In-Situ Monitoring for Defect Detection and Certification of Additive Manufacturing (MSFC)
 - Correlate in-situ monitoring indications with NDE and metallography
 - Develop methods for creating realistic seeded flaws
 - Inspect with CT, radiography (RT), other NDE
 - Analyze flaw state with RoboMet serial sectioning
 - More in upcoming presentation! Several national presentations given.
 - Work continuing in FY23.
- Advanced NDE for TPS Systems (LaRC)
 - Several more TPS systems are currently under investigation with Ames Research center. Mostly (3D Mid Density Carbon Phenolic) 3MDCP. Targeting a full scan of MSR development units.
 - Back Scatter 3D system (THRON) is being returned to LaRC after completion of use on Orion. Currently being used for Avcoat Char investigation (NESC)
 - Microwave camera installation complete and investigation on various TPS systems are underway.
 - SAA completed with Blue Origin has been established.
 - Work continuing in FY23.

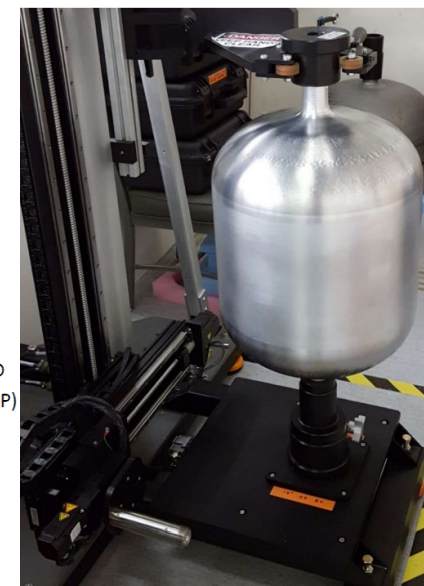
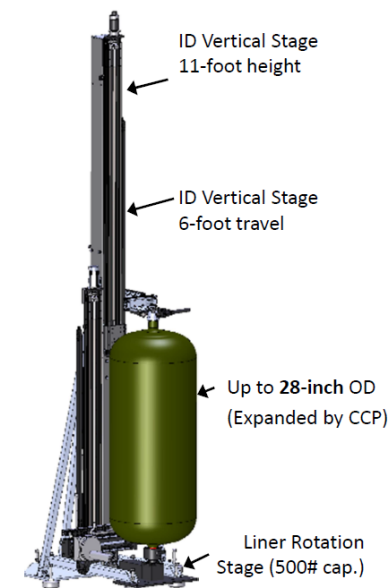


Past & Current Efforts 2022 & 2023

- High sensitivity, fiber optic (FO) based ultrasonic AE transducer (LaRC)
 - EMI Immune
 - Can work at high and low temperatures.
 - Acquisition and training where completed. But sensors needed to be redesigned for liquid oxygen cryo testing.
 - Successfully deployed on Hocker Drop test, LaRC.
 - Completed early FY23



- Crack ET POD for Inconel[®] 718 Pressure Vessels (Multi-Center)
 - Purpose: Share progress of robotic eddy current nondestructive testing (ET) for crack detection in Inconel[®] 718 Composite Overwrapped Pressure Vessel (COPV) liners, an alloy common to containers supplying spacecraft oxygen or propellant oxidizers. This effort results in the determination of the largest crack size likely to be missed by robotic inspections of COPV liners with a cylinder sidewall thickness of about 0.03 in.
 - Completed in Beginning FY23.



Past & Current Efforts 2022 & 2023

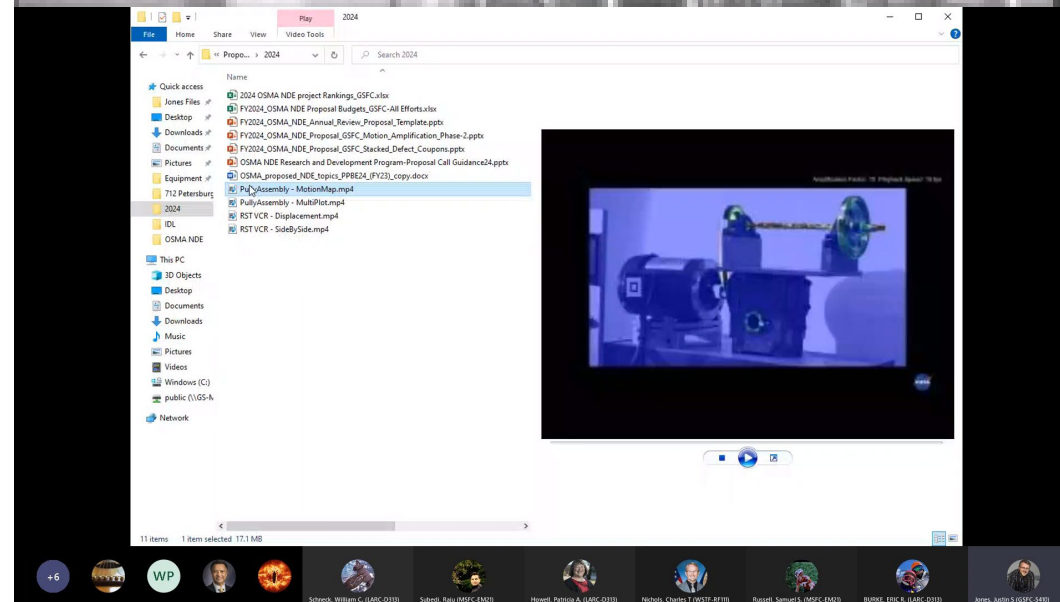
- NDE of Fasteners (Multi-Center)
 - Fracture critical fasteners are not currently addressed by NASA-STD-5009. Current inspection of fracture critical fasteners provides instructions for proof testing with no standard guidance for NDE inspection.
 - PCRT requires shorter inspection time (screening) and can produce historical record of fastener response for comparison in future inspections such as those of over-torque scenarios. Symmetrical nature of fasteners facilitates implementation of forward modeling or machine learning teaching sets for PCRT inspection. Identification of potential natural occurring defects to be used as acceptance/reject response for various standard NDE techniques (RQI)
 - Initial results showed good promise for bolt screening.
 - External collaborator for PCRT in academia (Penn State, PENSUL lab)
 - Additional testing was requested from MSFC.
 - Should complete in FY23.



541 Short Tensile
Setup

Past & Current Efforts 2022 & 2023

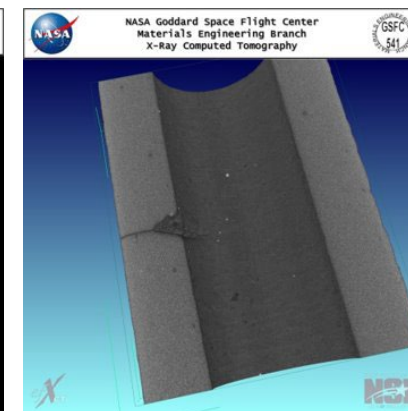
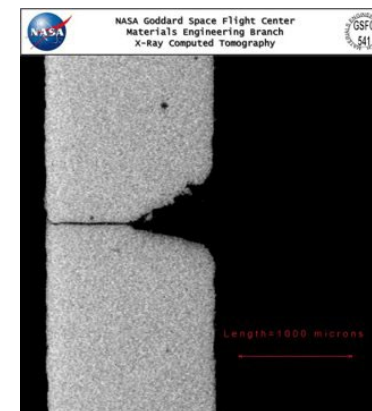
- Applications of Motion Amplification Imaging (GSFC)
 - A few years ago some new software tools were developed for industrial surveillance/inspection. This uses image motion amplification methods to identify and exaggerate very small amplitude changes in an image sequence.
 - Create simple test setups to learn what are the benefits and limitations of this approach from NDE perspective, plus what test conditions are required (magnification/resolution, excitation approaches, tilt angle, lighting, etc.).
 - Can this be used like digital image correlation?
 - The core benefit would be an alternative NDE tool, with potential use for composite inspection (delams, voids) or other instances where small deformation measurement is useful (perhaps crack growth in NDE flaw coupons).
 - If proven useful, the motion amplification test equipment would simply require a camera and some way to “activate” the part, such as heat gun, vacuum pressure, etc. Key benefit would be ease of collecting data with no initial setup/calibration and low cost, easily accessible tools.



Past & Current Efforts 2022 & 2023

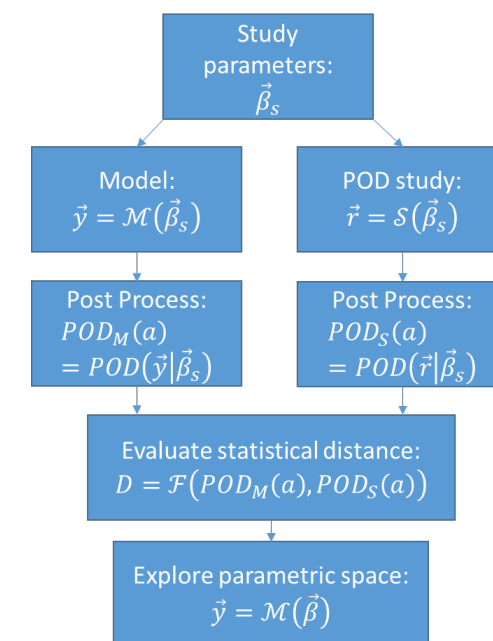
• Comparative Evaluation of Crack-like Defects in Additively Manufactured Parts versus Traditional Parts (GSFC)

- The goal of the study is to determine how the NDE response of various method (RT, CT, UT, ET, PT) varies on an additively manufactured part compared to a wrought part.
- Two parameters of interest:
 - Determine if NDE signal response is affected by AM surface roughness.
 - Determine if NDE signal response is affected by AM internal grain structure.
 - Study is on-going in FY23



• Model Assisted Probability of Detection (LaRC)

- Advanced material technologies are currently being developed for tougher and lighter aerospace systems. These sophisticated material technologies can have complex flaw states.
- Complex flaws have high parametric dimensionality and complicate the determination of Probability of Detection (POD). Characterization of POD is necessary to certify inspection processes for flight systems.
- MAPOD allows for cheaper, faster, more comprehensive POD studies. NASA requires POD studies on many mission and health critical structures. As these structures and the materials increase in complexity the cost and time required to complete them in a traditional manner becomes prohibitively expensive and long.

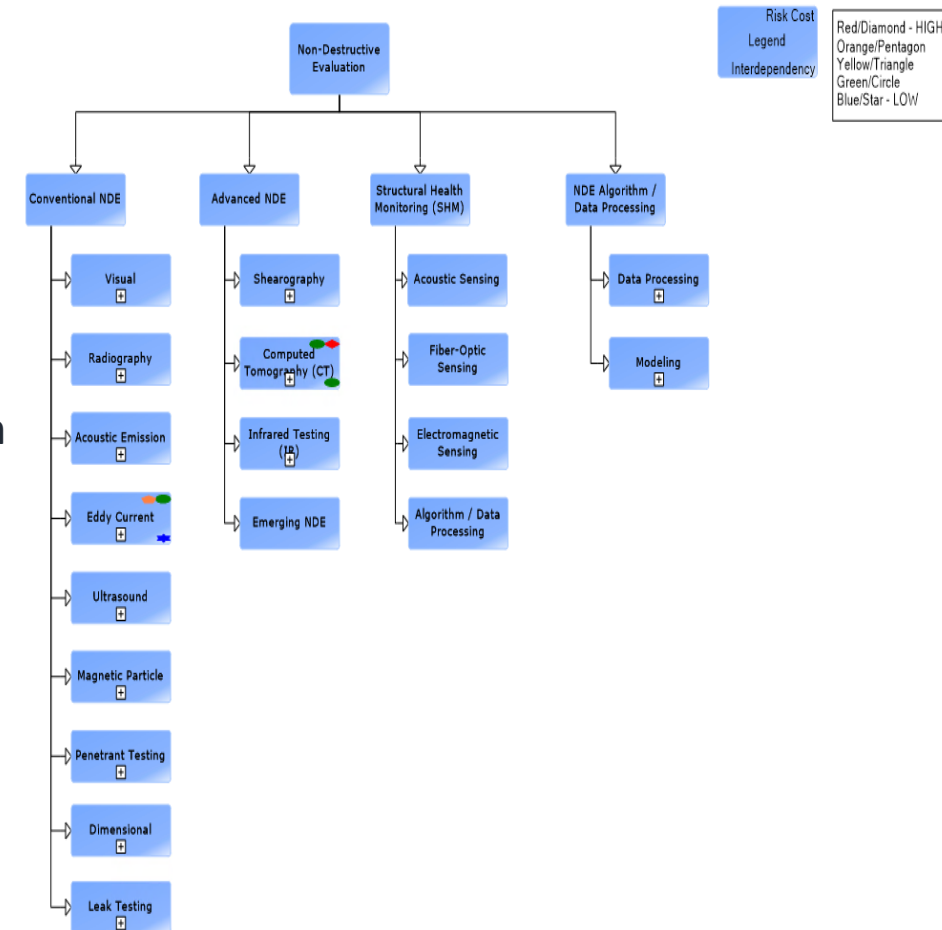


Past & Current Efforts 2022 & 2023

- Digital Twin (Multi-Center)

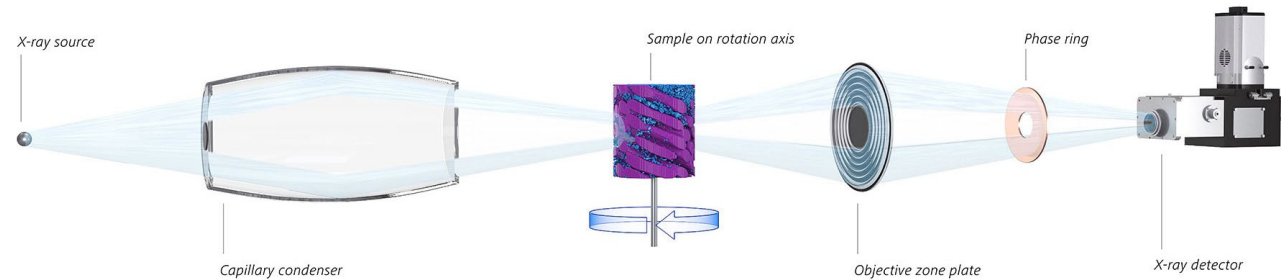
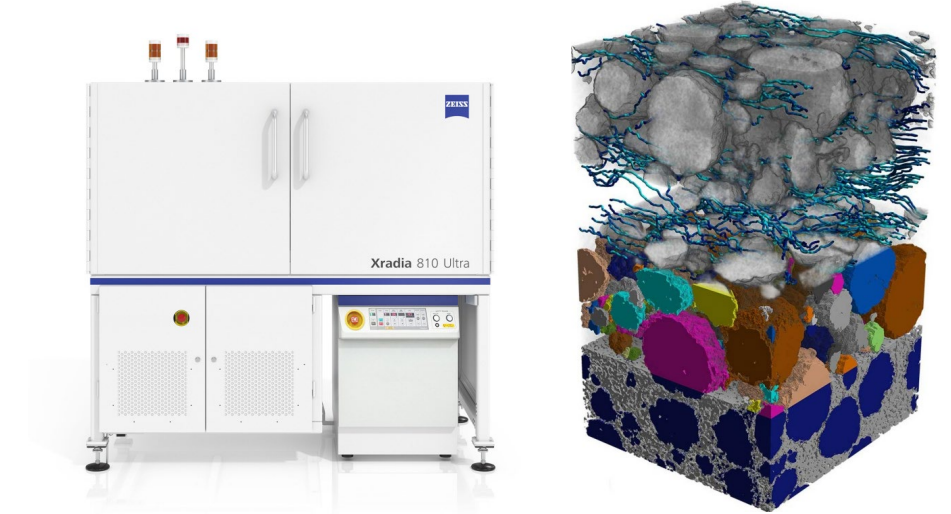
- Plans for a phase 2 (5 year out model) were developed but halted. The NASA COPV working group has asked for a NDE data catalogue and those efforts are in work.
- The Problem: Technical Discipline insight/integration within and across centers:
 - Current efforts are document based (i.e. PPT, Excel, Email), w/manual updates and SME based access to inventory rather than a digital catalogue that allows agency to leverage digital data.
 - Strategic decisions across disciplines may lack insight into interfaces or interdependencies with other disciplines.
 - Enables strategic interest in trend analyses for health assessments (workforce, tools, facilities, technical challenges) but little patience for data calls and integration.
 - Current implementation uses agency available Casewise enterprise architecture (EA) modeling software.
 - Final conclusion was that the real power of the model cant be realized without models from other disciplines.

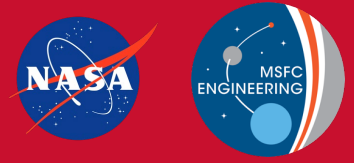
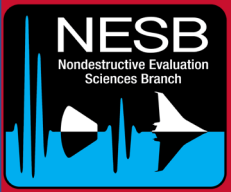
NASA Non Destructive Evaluation Capabilities



Past & Current Efforts 2022 & 2023

- Investigation of AM using Nano Computed Tomography (LaRC & GSFC)
 - OMSA is currently looking at which nano-computed tomographic system would fit NASA's needs best.
 - Current state of the art uses x-ray optics to achieve nanoscale spatial resolution down to 50 nm and 16 nm voxel sizes. Current limit is approximately 1 micron.
 - Currently Microphotronics (Bruker), Rigaku and Ziess have been contacted.
 - Currently looking to setup demonstration on additive manufacturing demo sample.
- Training and Certification – Generally minimum of 1-2 trainings per center.
 - Total trainings provided across NASA 20.
 - Total trainings provided across NASA 22.

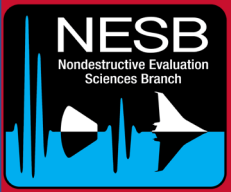




Thank you for your Attention.

Eric Burke

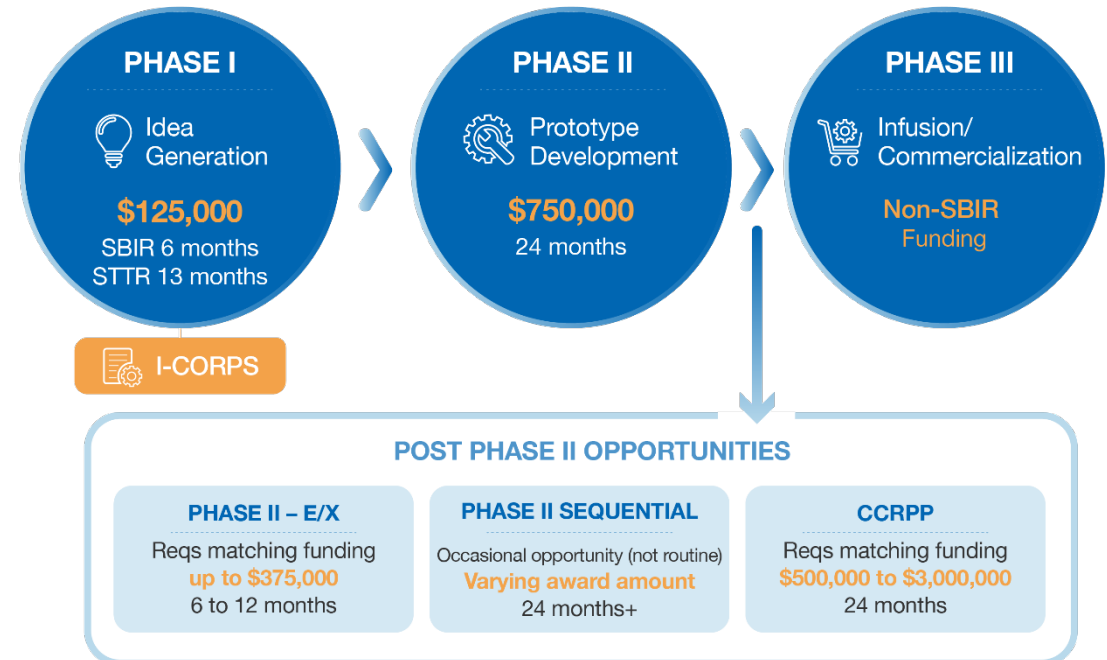
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Backup

- The NASA SBIR and STTR programs fund the research, development, and demonstration of innovative technologies that fulfill NASA needs as described in the annual Solicitations and have significant potential for successful commercialization. If you are a small business concern (SBC) with 500 or fewer employees or a non-profit RI such as a university or a research laboratory with ties to an SBC, then NASA encourages you to learn more about the SBIR and STTR programs.
- NASA has selected 409 technology proposals for the first phase of funding from the agency's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program. The contracts will provide approximately \$51 million to 312 small businesses in 44 states and Washington, D.C.

NASA SBIR/STTR PHASES



20-002

<https://sbir.nasa.gov/content/nasa-sbirsttr-basics>

SBIR Space Launch System (SLS) Core Stage Deployment

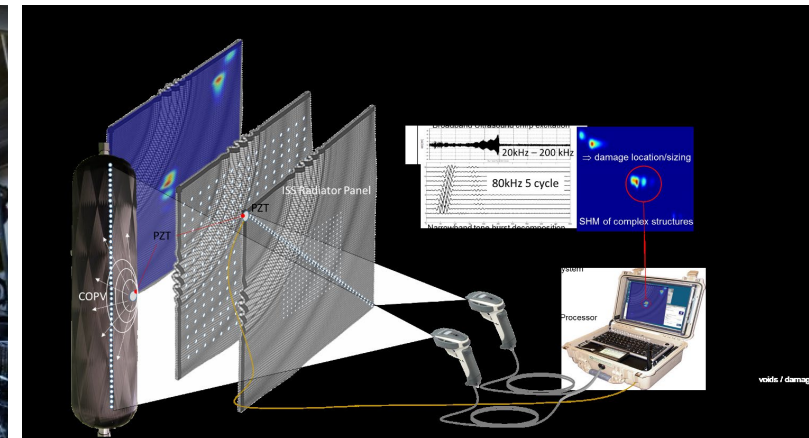
- Artemis Block 1 integrated SLS and Orion: 322' tall, 5.75 million pounds, will produce 8.8 million pounds thrust (15 percent more than Saturn V).
- Artemis 1 will be an uncrewed flight test that will provide a foundation for human deep space exploration, and demonstrate our commitment and capability to extend human existence to the Moon and beyond.
- This is currently on-going at Kennedy Space Center in preparation for flight.



SLS Block 1

Nondestructive Evaluation SBIR Overview Highlights

- NASA NDE community has been very active in the NASA Small Business Innovation Research (SBIR) Program for the past decade.
- Since 2010 NDE has had over 68 phase 1 and phase 2 awards and we have participated in an additional 37 from other subtopics. For a total of 105 Phase 1&2's
- Several of these prototypes are currently deployed to help the Artemis program achieve its goals.
- The SBIR Topic, Subtopic, Contracting Officer Representative (COR'S) and reviewers come from 7 of the major NASA centers.
- NASA technical experts for the are the reviewers for all the proposals and generally take 2-3 months to complete the review process.
- Several of these have been in-situ monitoring systems and studies on POD for CT.
- Not covered here but there are also several impact monitoring systems that are in work and currently deployed.



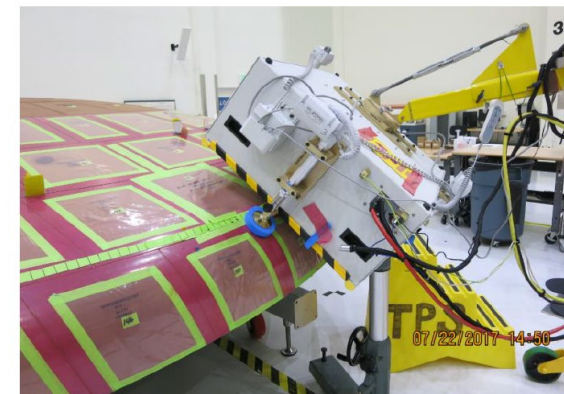
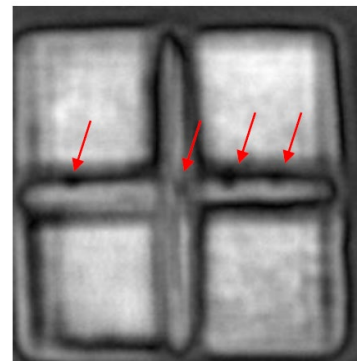
Opportunities for Investment and Collaboration

- The NASA NDE community has been very active in the NASA (SBIR) Program for the past decade.
 - Since 2010, NDE has had over 73 phase I and II awards.
 - NASA technical experts are the reviewers for all the proposals and generally take 2-3 months to complete the review process.
 - Several awards have funded prototypes that are currently deployed to help Artemis and other programs achieve their goals.
- **SBIR/STTR call for proposals is a great place to learn what “NDE Tools” are needed by NASA, as well as what sort of materials challenges are currently relevant**

Recent Award:

UES and PSU-ARL won SBIR Phase 2 for “Probability of Detection and Validation for Computed Tomography Processes for Additive Manufacturing”. Using Robo-Met as ground truth for CT qualification.

Past Highlight:



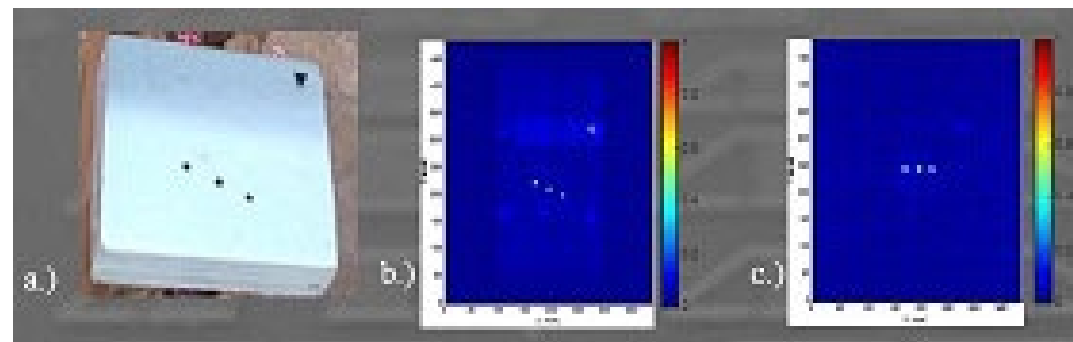
Physical Optics Corp (POC), 3D backscatter unit (single-sided CT) deployed to KSC to preform thermal protection system gap inspection.

3D Microwave Imager for Damage Detection



TRI and ISU's multi-static imaging array developed in the Phase II SBIR effort consisting of 8 linear arrays, each with 64 antennas (width is ~16").

- In a Phase II SBIR effort, TRI and ISU produced a Millimeter wave SAR imaging system.
- Provides high-resolution three-dimensional (3D) images.
- The system has 8 linear arrays, each containing 32 transmitting and 32 receiving antennas (512 total) and performs multi-static measurements.
- Operation frequency range of 26.5–40 GHz. Cross-range resolution (lateral directions) of ~2.5 mm and an along-range resolution of ~9.4 mm (depth direction).
- Resolution figures are calculated for vacuum (or air) and the resolution increases inside dielectrics.
- Sample image-set shown of a foam calibration block with embedded rubber targets.
- Using the SAR algorithm, 2D image slices were generated from the 3D data.
- Was recently awarded a phase 2E



(a) Foam calibration block with embedded rubber targets and 2D slices of the Ka-band (26.5-40 GHz) 3D SAR image at two depths; (b) surface of tile and (c) 25 mm deep.