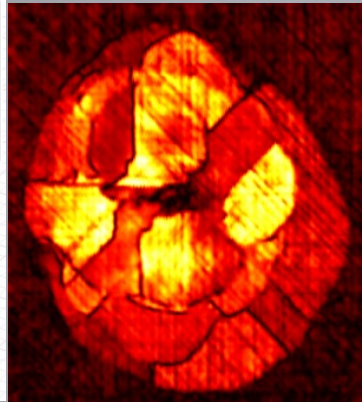
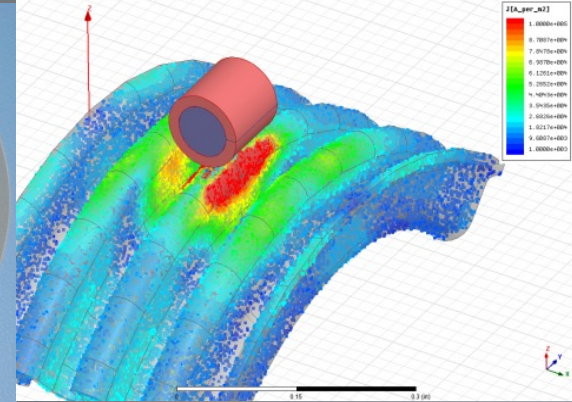
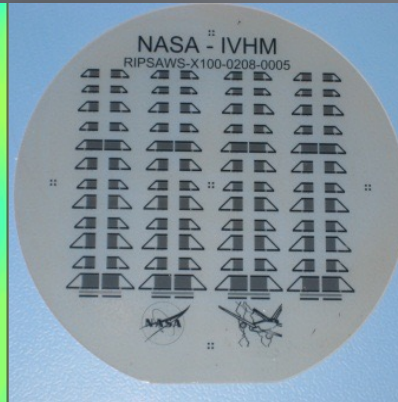
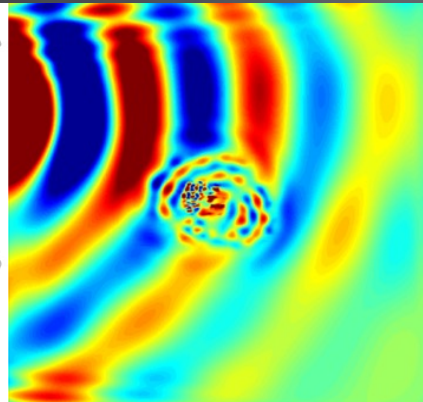
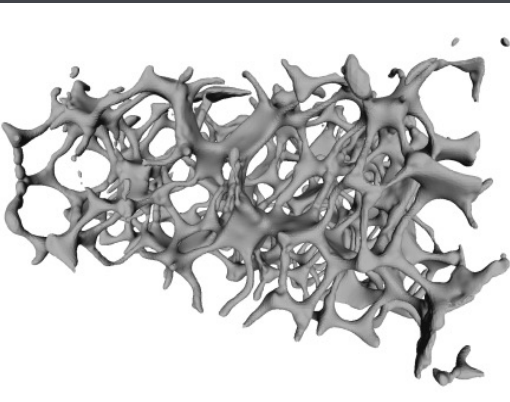


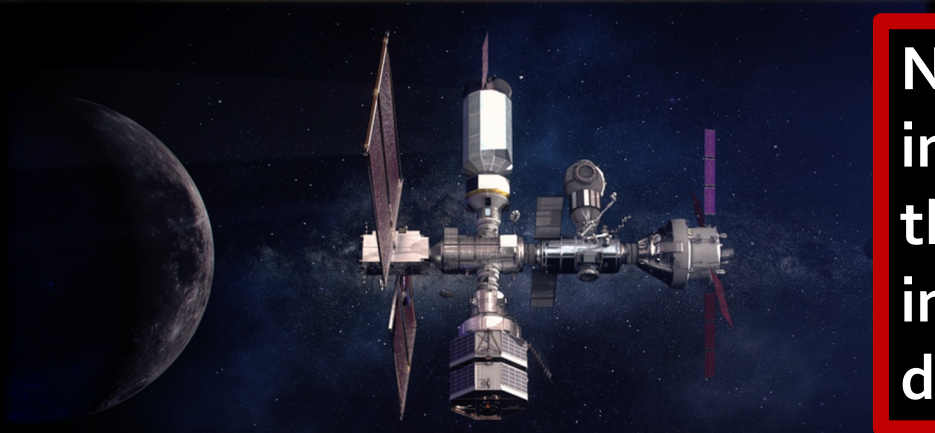
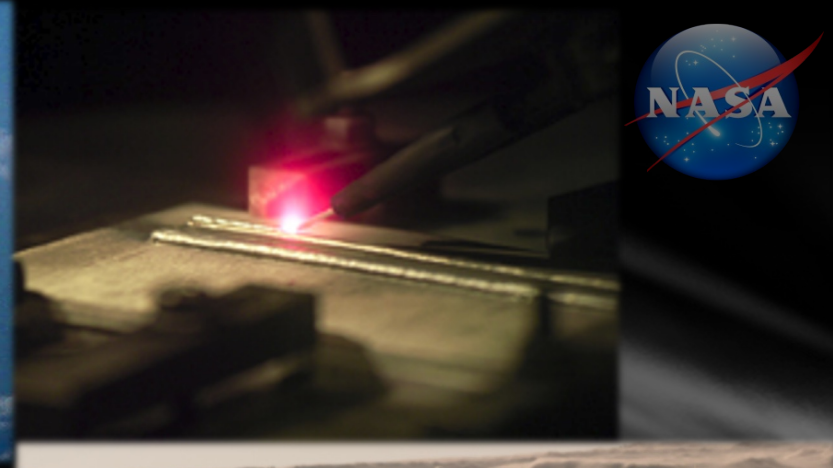
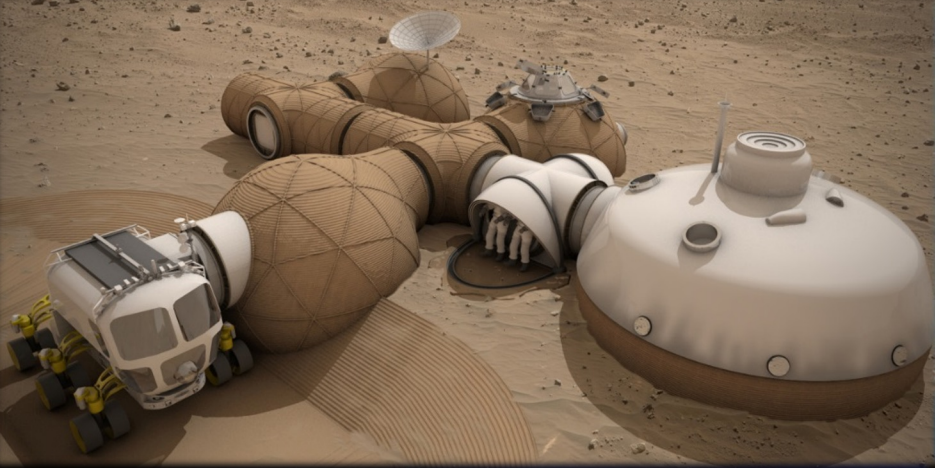
Artificial Intelligence & Machine Learning for Aerospace Nondesctructive Evaluation

Dr. Cara Leckey, Dr. Elizabeth Gregory, Dr. Peter Spaeth

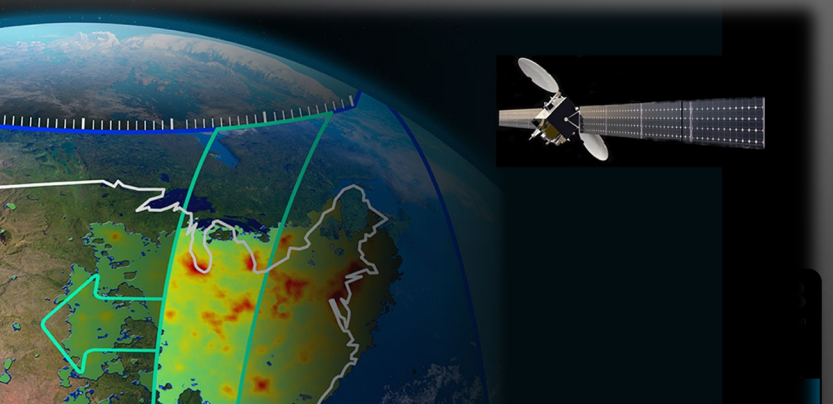
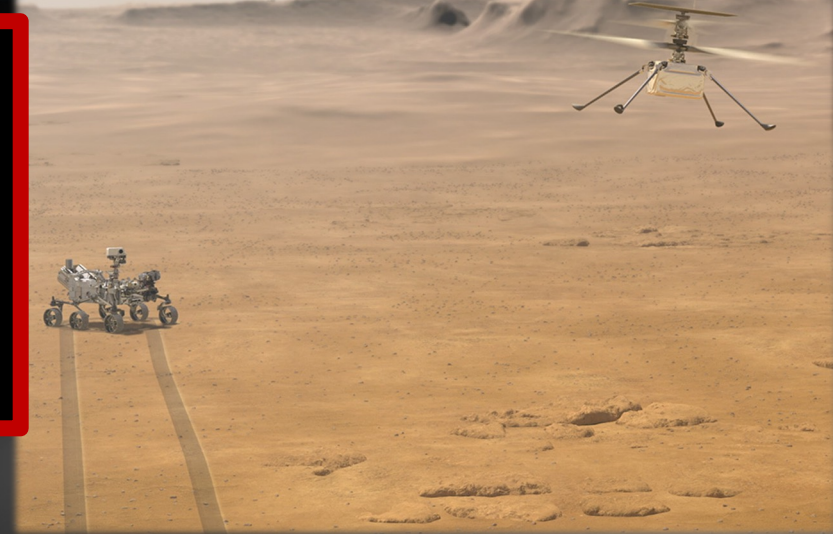
Nondesctructive Evaluation Sciences Branch

Research Directorate, NASA Langley Research Center





NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.



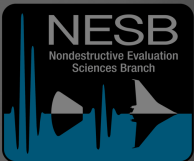


Nondestructive Evaluation Sciences Branch

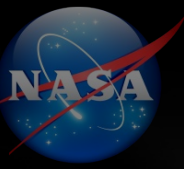
- NASA's primary nondestructive evaluation (NDE) Research organization



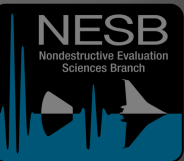
- NDE Research Laboratory
 - Thermal Imaging
 - Ultrasonic Scanning
 - Phased-Array Ultrasound
 - Eddy Current
 - Terahertz Imaging
 - Computed X-Ray Tomography
 - Fiber Optic Sensors Fabrication
 - Nano and Mems Sensor Fabrication
 - Photo and Thermal Elasticity
 - Scanning Electron Microscopy
 - Raman Spectroscopy

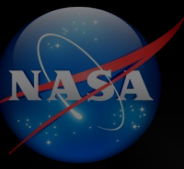


Artificial Intelligence (AI) & Machine Learning (ML) for Aerospace



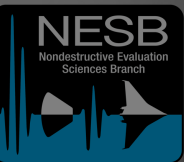
- ML NDE examples
- Beyond NDE data – Large Language Models (LLM)
- Challenges / Opportunities





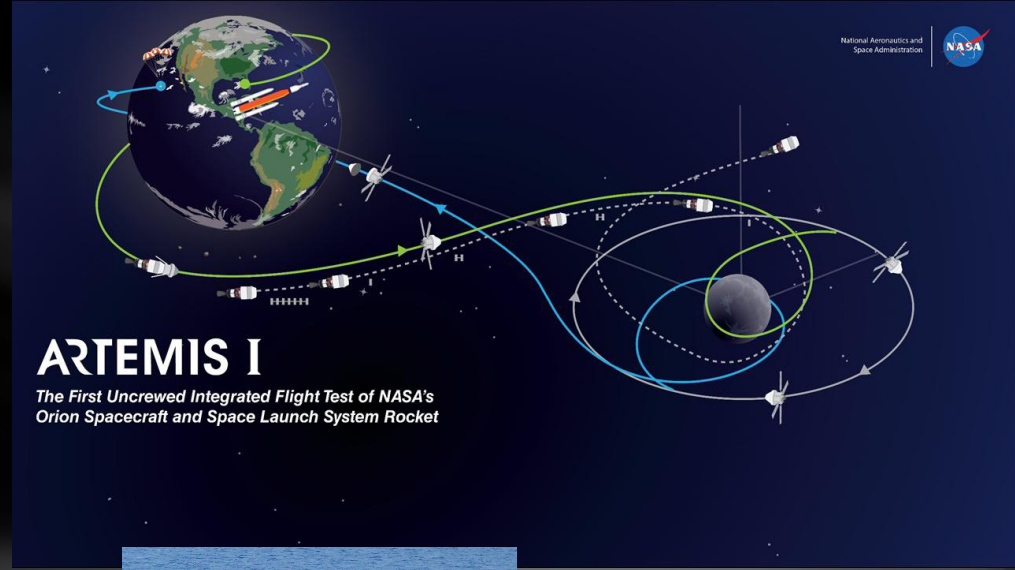
Machine Learning to Analyze NDE Data:

Examples

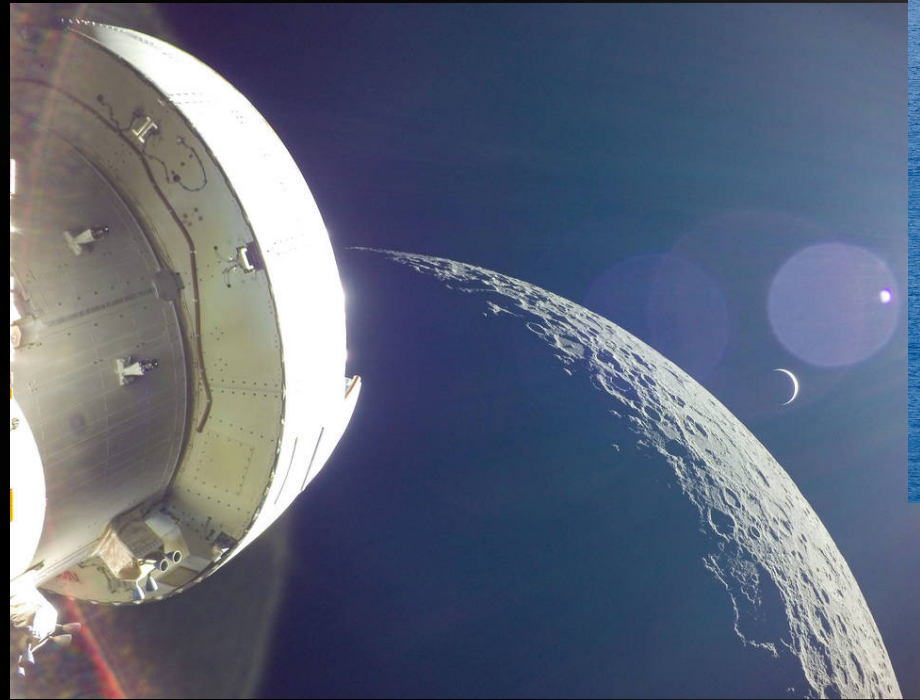


Artemis-1
(formerly EM-1)

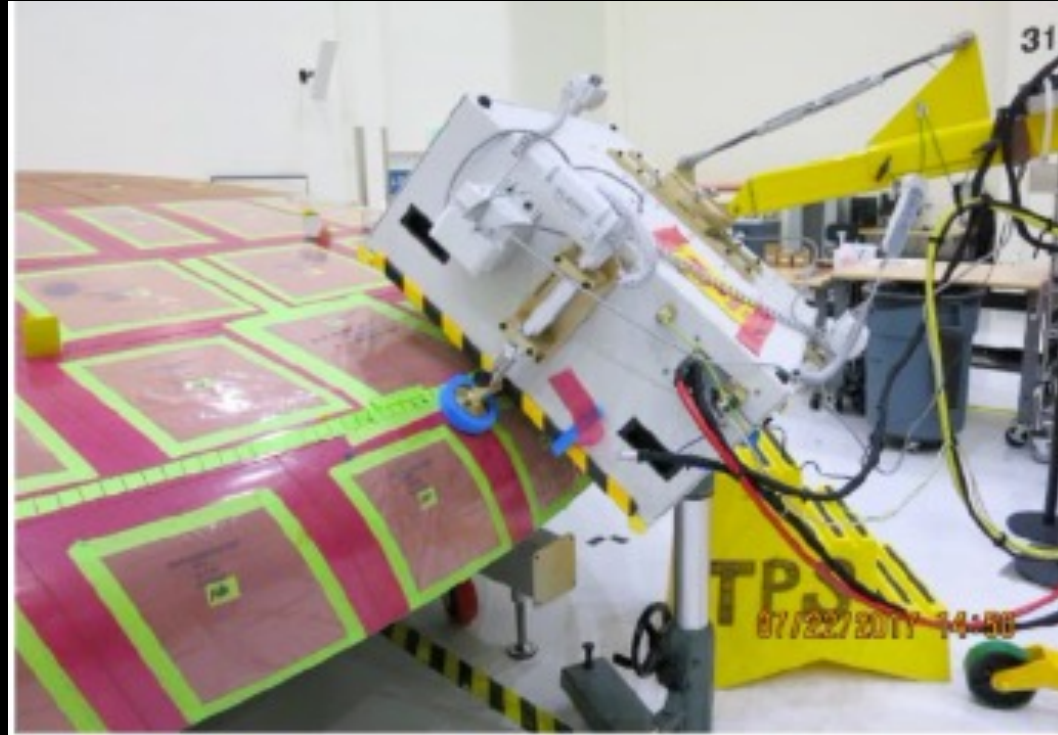
Launch:
11/2022



ARTEMIS I
The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket



Orion Heat Shield Inspection

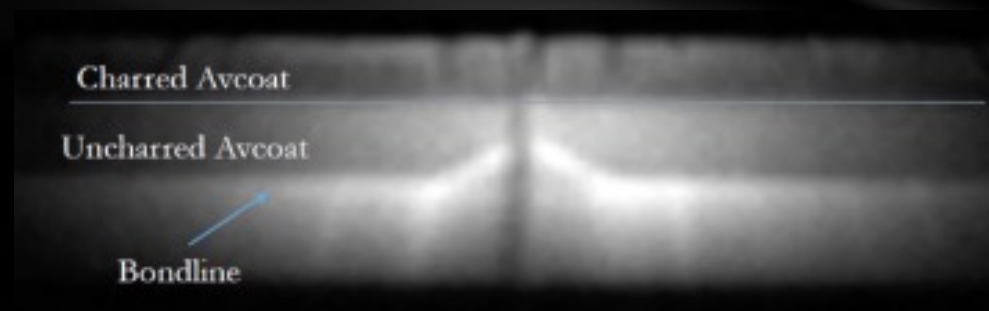


Backscatter x-ray (BSX) imaging

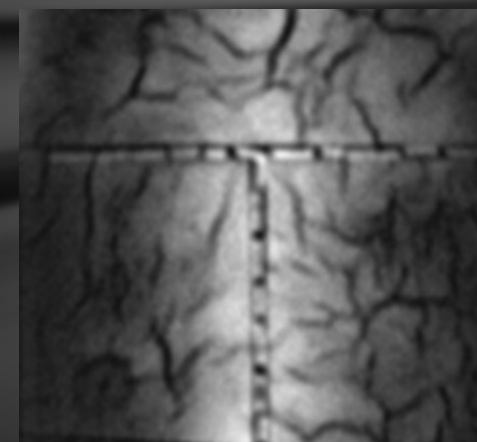
3D BSX Measurements



Test Block



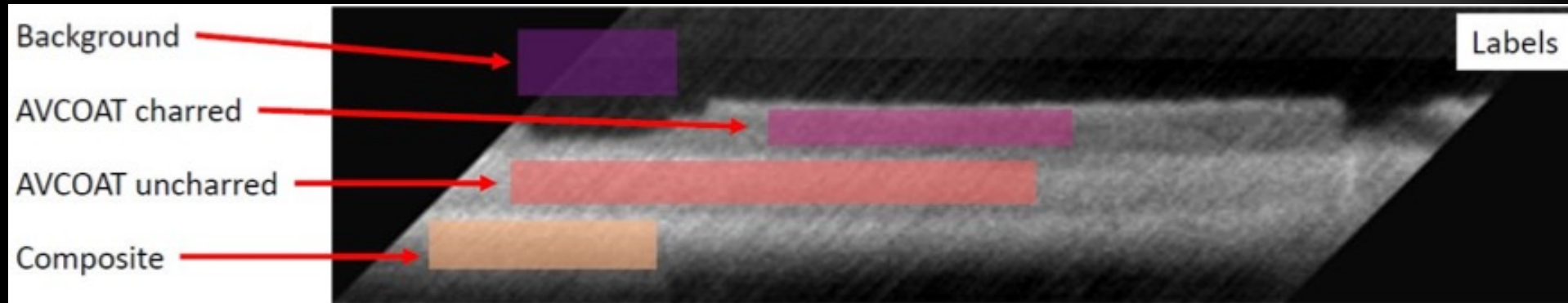
BSX side slice



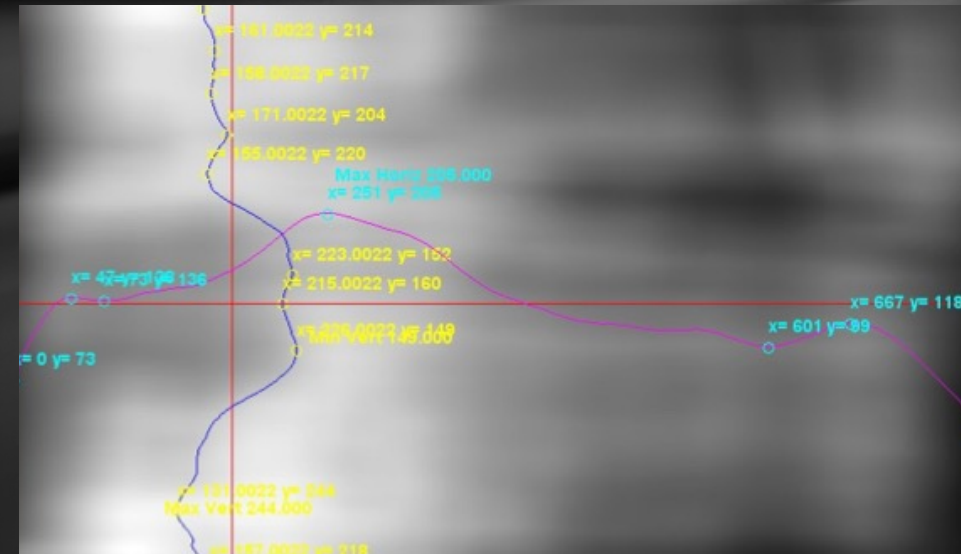
BSX top slice

- NASA has been investigating how to perform NDE on charred AVCOAT.
- The proof of concept could be used on flown Artemis-1 heat shield.

Data Analysis



- BSX data contains four types of classification (see image)
- Using supervised learning techniques and segmentation hyperparameters (random forest classifier applied to segment the images)
- Depth of char automatically calculated within +/- 2mm.

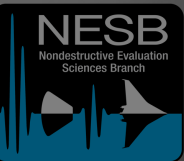


Gray-scale = estimate of char depth

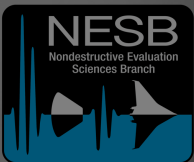
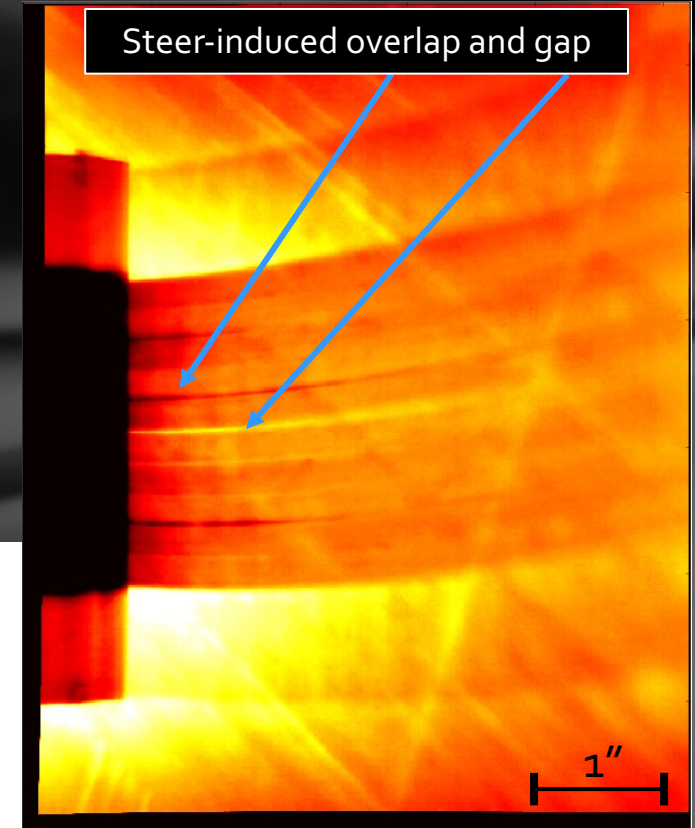
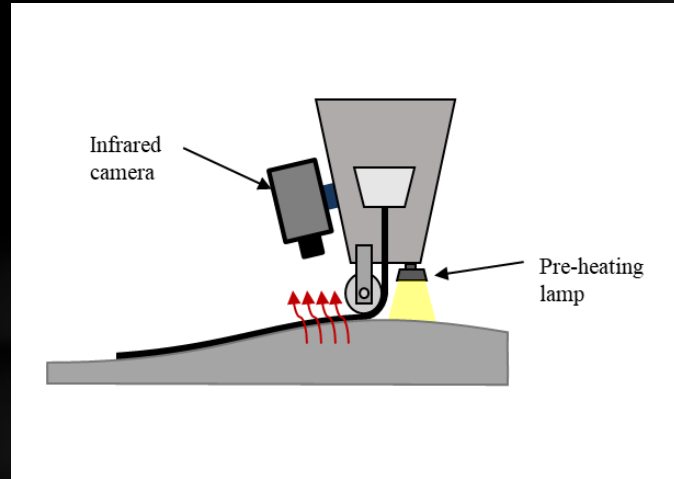


Why this approach to image classification?

- Random forest classifier applied to segment the images
 - Results are explainable for relatively shallow decision trees
 - Can be readily applied to the expectedly large set of BSX data that could be collected across the heat shield
 - Established open-source tools are available to carry out the analysis
 - Statistical tools are available to quantify the uncertainty in training the random forest



Inspection During Manufacturing for Automated Fiber Placement (AFP)





ML for Automatic Flaw Detection in AFP

Goals:

- Automated highlighting of areas where further inspection is required.

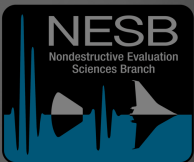
Challenges

- Other image analysis method performed poorly (e.g. edge detection, clustering).
- Thermal discontinuities are not uniform in size, shape, or any characteristic.
- Thermography is, by nature a diffusive process, meaning discontinuities lack defined edges.
- “Clean” data with clear flaws that can be used for training are difficult to come by.

ML Approach:

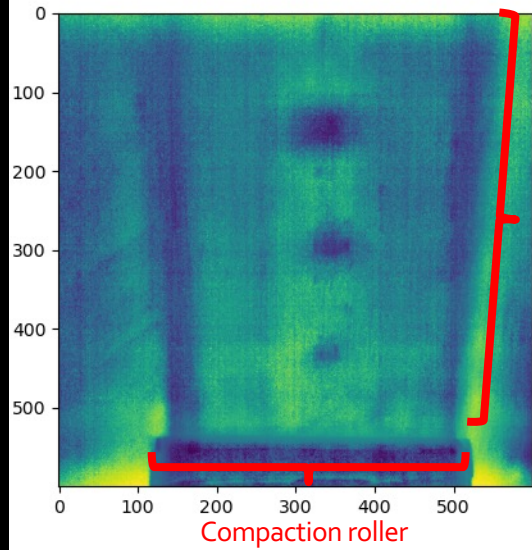
- Manually segmented images to make a training dataset.
- Trained a UNet to segment thermal images for manufacturing flaws.

POC: Dr. Elizabeth Gregory

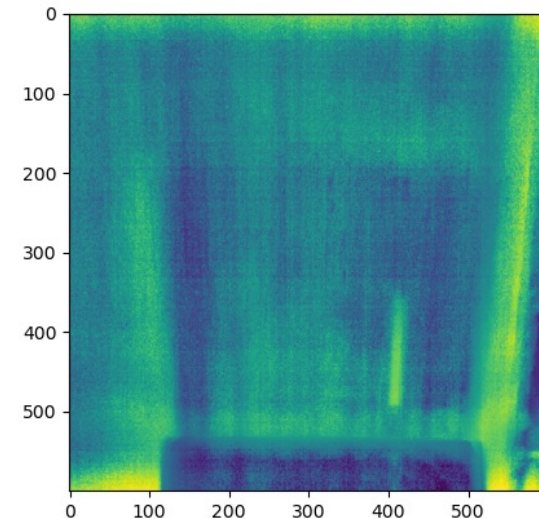
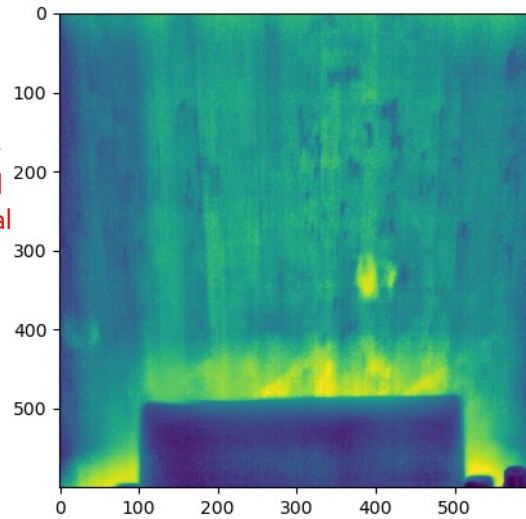


Labelled Data for ML Training

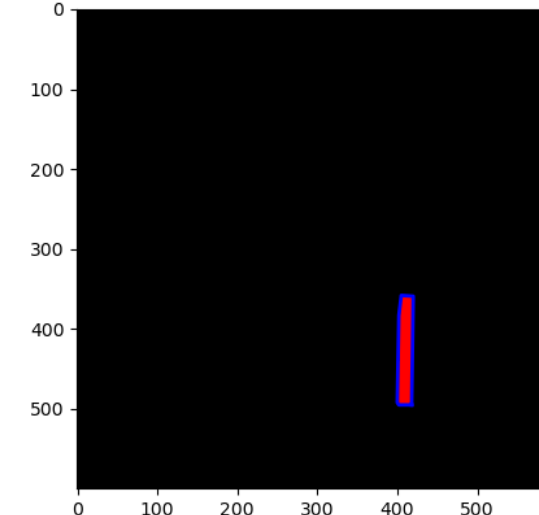
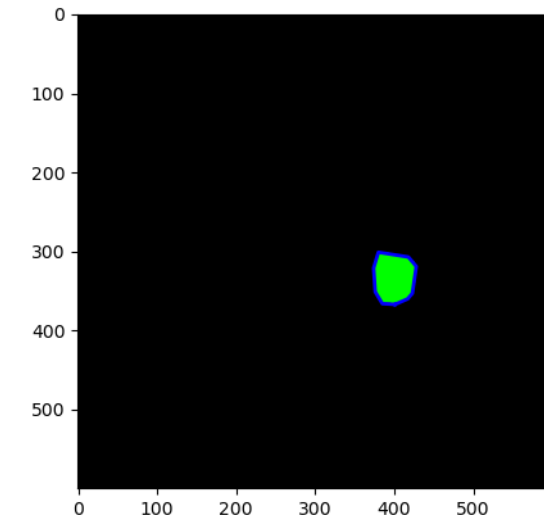
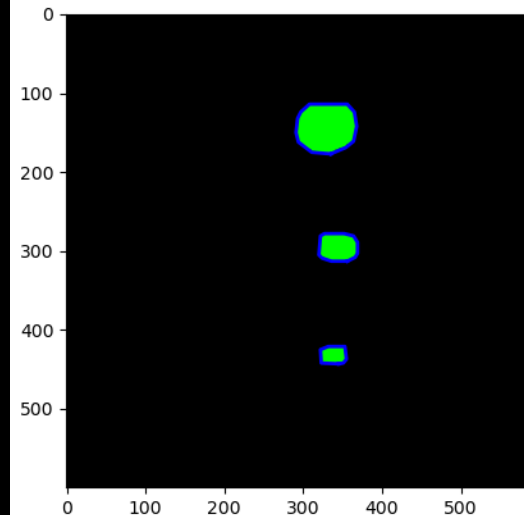
Original Data



Newly Placed Material



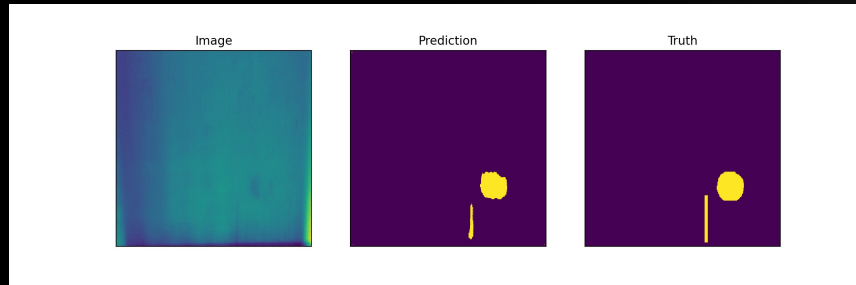
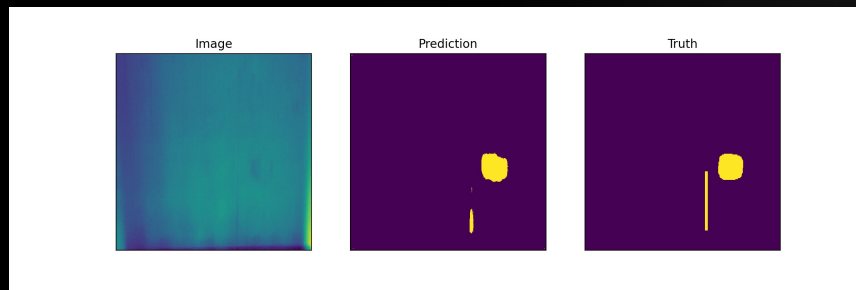
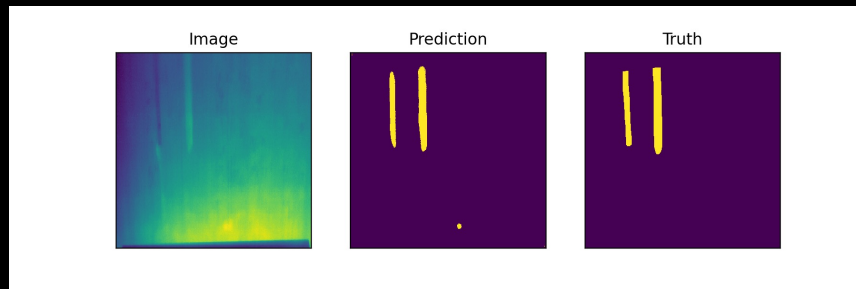
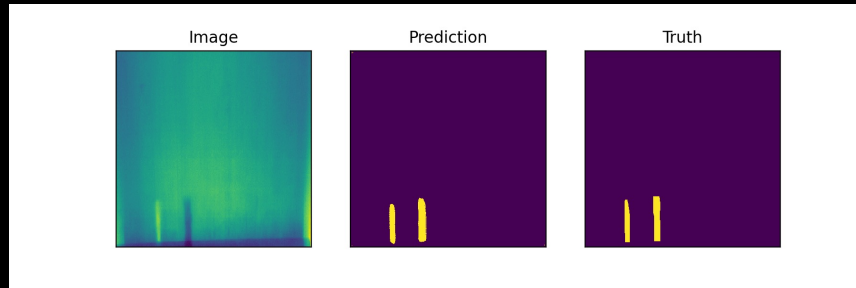
Labelled Data



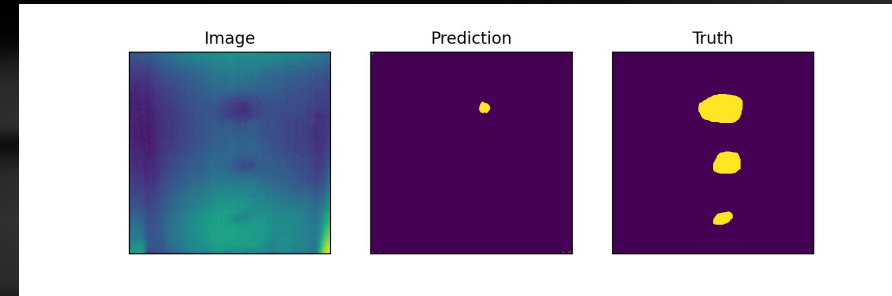
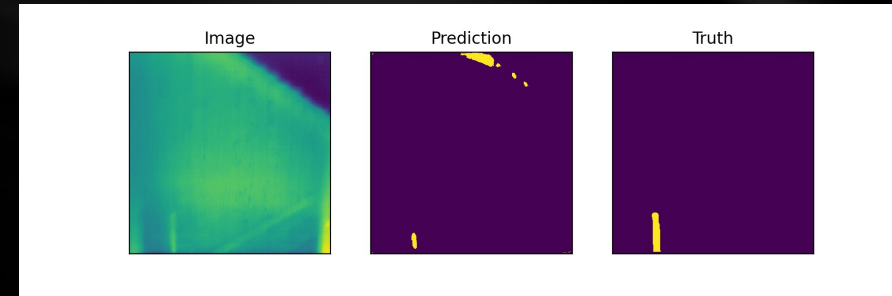
4229 images

50/50 flaw vs non-flaw

What it Does Well



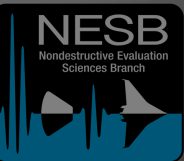
What it Does Poorly

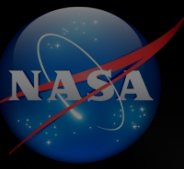


Near edge of part, and areas without as much definition.



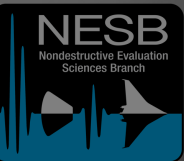
Beyond NDE Data Analysis





Large Language Model (LLM) tools

- Trained to take in text input and predict the most likely next word
- Opportunity: knowledge growth & knowledge management
- “ChatGPT sometimes makes things up. Is AI’s hallucination problem fixable?” by Matt O’Brien, TechXplore
 - "It's inherent in the mismatch between the technology and the proposed use cases."
 - "I think we will get the hallucination problem to a much, much better place...I think it will take us a year and a half, two years..."
 - Source: https://techxplore.com/news/2023-08-chatbots-ai-hallucination-problem-fixable.html?utm_source=nwletter&utm_medium=email&utm_campaign=daily-nwletter





RELEASE
IMMEDIATE RELEASE

DOD Announces Establishment of Generative AI Task Force

Aug. 10, 2023 | [f](#) [t](#) [r](#)

Today, the Department of Defense (DoD) announced the establishment of a generative artificial intelligence (AI) task force, an initiative that reflects the DoD's commitment to harnessing the power of artificial intelligence in a responsible and strategic manner.

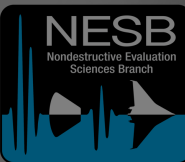
Deputy Secretary of Defense Dr. Kathleen Hicks directed the organization of Task Force Lima; it will play a pivotal role in analyzing and integrating generative AI tools, such as large language models (LLMs), across the DoD.

"The establishment of Task Force Lima underlines the Department of Defense's unwavering commitment to leading the charge in AI innovation," Hicks said. "As we navigate the transformative power of generative AI, our focus remains steadfast on ensuring national security, minimizing risks, and responsibly integrating these technologies. The future of

The future of defense is not just about adopting cutting-edge technologies, but doing so with foresight, responsibility, and a deep understanding of the broader implications for our nation."

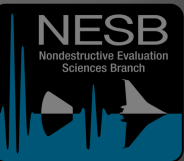
Source:

<https://www.defense.gov/News/Releases/Release/Article/3489803/dod-announces-establishment-of-generative-ai-task-force/>





Note: The following examples are based on AI tools currently under testing at NASA and are not intended to endorse or oppose any specific AI toolset





Opportunities – beyond NDE data processing

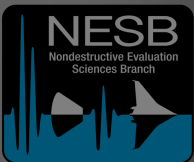
Currently testing LLM AI tool capabilities/limitations through a variety of test cases.

AI Research assistant

- Focus the AI tool on a specified data set.
- Summarization, understanding trends across multiple papers, compare papers, identify relevant search terminology, querying content of papers, identify gaps areas, identify key author .
- Citation of what results are based on.

The screenshot shows the DrivenData website for a competition titled "Research Rovers: AI Research Assistants for NASA". The page includes a navigation bar with "DRIVEN DATA", "Competitions", "How it works", and "Partner with us". On the right, there are links for "DrivenData^{LABS}", "Blog", "Log in", and "Sign up". The main content area features a "SCIENCE" category and the competition title. Below the title, it states "Help NASA assess emerging capabilities for AI-based research assistants. Competition hosted by NASA Tournament Lab." and provides statistics: "\$30,000 in prizes", "3 weeks left", and "210 joined". A "Join competition" button is visible. The "Overview" section contains a "Navigation" menu with "Home", "Problem description", "About", "Official rules", and "Participants". The main text under "Overview" reads: "In this challenge, you will prototype and demo an AI-based research assistant solution for the NASA workforce. Like many of us who depend on technical and scientific literature in our own work, NASA researchers need to understand the state of research in a particular domain or multiple domains. They are also often faced with the daunting task of becoming familiar with a body of literature that they don't have prior experience with. Whether you are an academic doing your own research, a data scientist exploring new machine learning techniques, or anyone else delving into a field of study that's new to them, this problem may feel very familiar. With the AI Assistants challenge, NASA is seeking innovative approaches to help assess emerging capabilities in". On the right side, there is a "On this page" section with links for "Get started" and "Prizes and Timeline".

<https://www.drivendata.org/competition/s/252/ai-research-assistants/>





Lebedev Scheme for Ultrasound Simulation in Composites

Francisco Hernando Quintanilla^a, Cara A.C. Leckey^{a,*}

^aNASA Langley Research Center, Hampton, VA, USA

Abstract

The growing use of composite materials for aerospace applications has resulted in a need for quantitative nondestructive evaluation (NDE) methods appropriate for characterizing damage in composite components. NDE simulation tools, such as ultrasound models, can aid in enabling optimized inspection methods and establishing confidence in inspection capabilities. In this paper a mathematical approach using the Lebedev Finite Difference (LFD) method is presented for ultrasonic wave simulation in composites. Boundary condition equations for implementing stress-free boundaries (necessary for simulation of NDE scenarios) are also presented. Quantitative comparisons between LFD guided wave ultrasound simulation results, experimental guided wave data, and dispersion curves are described. Additionally, stability tests are performed to establish the LFD code behavior in the presence of stress-free boundaries and low-symmetry anisotropy. Results show that LFD is an appropriate approach for simulating ultrasound in anisotropic composite materials and that the method is stable in the presence of low-symmetry anisotropy and stress-free boundaries. Studies presented in this paper include guided wave simulation in hexagonal, monoclinic, triclinic and layered composite laminates.

Keywords: Guided wave, Lebedev method, Simulation, Composite

Welcome to the Lebedev Scheme for Ultrasound Simulation in Composites PDF file! This paper presents a mathematical approach using the Lebedev Finite Difference method for ultrasonic wave simulation in composites, along with boundary condition equations for implementing stress-free boundaries. The results show that LFD is an appropriate approach for simulating ultrasound in anisotropic composite materials and that the method is stable in the presence of low-symmetry anisotropy and stress-free boundaries.

Example questions:

- What are the benefits of using ultrasound simulation tools for nondestructive evaluation in composite materials?
- How does the Lebedev Finite Difference method compare to other methods for simulating ultrasound in composites?
- Can the LFD code be used to simulate guided wave ultrasound in other types of composite laminates besides hexagonal, monoclinic, triclinic, and layered?



ChatwithPdf.com

4. Conclusion

The results presented in this paper demonstrate that the LFD approach is appropriate for simulation of ultrasonic wave propagation in composites. LFD was successfully implemented for hexagonal, monoclinic, triclinic, and multi-layer laminates. The wavenumber results from the Lebedev method matched well with experiment and dispersion curves. As discussed in [6], some differences from experiment are expected due to uncertainty in the actual as-manufactured material properties of the composite specimens. The LFD wavenumbers were between 1 to 13 % different from experiment, and overall it is noted that experiment consistently led to lower wavenumbers than LFD simulation. This trend was not consistently observed when comparing LFD to dispersion curves (i.e., dispersion curves sometimes led to a larger value than LFD). Recall that LFD and dispersion curves are both based on the material properties in Table 1, which were taken from the literature. The observed trend in experimental wavenumbers may be a clue that there is indeed a consistent difference between the material properties in experiment versus simulation. Recent work by Reed et. al also points to this possibility [29].

Additionally, it was shown that LFD is stable for low-symmetry anisotropic media and in the presence of stress-free boundaries. Stability for low-symmetry anisotropic cases is critical for simulating ultrasonic NDE in complex geometry composites (geometries requiring multiple stiffness matrix rotations, such as hat-stiffeners and complex curvature parts). The observed stability in the presence of stress-free boundaries is also of key importance for simulating NDE scenarios since they often involve ultrasonic wave scattering from part surfaces, edges, and corners. Furthermore, defects such as microcracking and delaminations can be simulated using stress-free boundaries [7, 28].

Future areas of work include optimization of the LFD code for more rapid simulations on MIC computing hardware. The initial code version used for the studies in this paper took multiple days to run a single simulation case on 30 CPU cores. Based on prior work with finite difference code optimization, it is expected that significant simulation speed increases can be achieved by optimizing the code parallelization and memory access patterns [1]. Future work will also entail the use of the LFD code to simulate ultrasound in complex geometry aerospace composites and adapting the code to include material based attenuation.

5. Acknowledgements

The authors thank NASA interns Christina Cole and Ashley Frank for assistance collecting experimental data. The authors also thank Dr. Vadim Lisitsa, Dr. Paul

with boundary condition equations for implementing stress-free boundaries. The results show that LFD is an appropriate approach for simulating ultrasound in anisotropic composite materials and that the method is stable in the presence of low-symmetry anisotropy and stress-free boundaries.

Example questions:

- ▶ What are the benefits of using ultrasound simulation tools for nondestructive evaluation in composite materials?
- ▶ How does the Lebedev Finite Difference method compare to other methods for simulating ultrasound in composites?
- ▶ Can the LFD code be used to simulate guided wave ultrasound in other types of composite laminates besides hexagonal, monoclinic, triclinic, and layered?

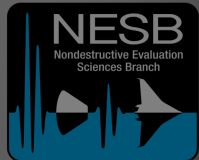
What are the primary conclusions of the paper?

The primary conclusion of the paper is that the Lebedev Finite Difference (LFD) method is an appropriate approach for simulating ultrasonic wave propagation in composites, and that the method is stable in the presence of low-symmetry anisotropy and stress-free boundaries. The paper also demonstrates that the LFD approach was successfully implemented for hexagonal, monoclinic, triclinic, and multi-layer laminates, and that the wavenumber results from the Lebedev method matched well with experiment and dispersion curves. 26

When is it not appropriate to use Lebedev method?

The paper does not provide specific information on when it is not appropriate to use the Lebedev method. However, it does mention that the LFD approach is appropriate for simulating ultrasonic wave propagation in composites, and that it is stable in the presence of low-symmetry anisotropy and stress-free boundaries. 26

Ask any question...





Opportunities – beyond NDE data processing

Currently testing LLM AI tool capabilities/limitations through a variety of test cases.

- Shareable codes:
Python License V 2.0

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2. Subject to the terms and conditions of this License Agreement, PSF hereby grants Licensee a nonexclusive, royalty-free, world-wide license to reproduce, analyze, test, perform and/or display publicly, prepare derivative works, distribute, and otherwise use Python alone or in any derivative version, provided, however, that PSF’s License Agreement and PSF’s notice of copyright, i.e., “Copyright (c) 2001, 2002, 2003, 2004, 2005, 2006 Python Software Foundation; All Rights Reserved” are retained in Python alone or in any derivative version prepared by Licensee.
3. In the event Licensee prepares a derivative work that is based on or incorporates Python or any part thereof, and wants to make the derivative work available to others as provided herein, then Licensee hereby agrees to include in any such work a brief summary of the changes made to Python.
4. PSF is making Python available to Licensee on an “AS IS”

The screenshot shows the Azure AI Studio interface. The left sidebar contains navigation options: Azure OpenAI, Playground, Chat, Completions (selected), DALL-E (Preview), Management, Deployments, Models, Data files, Quotas, and Content filters (Preview). The main chat area displays a conversation about the Python License V 2.0. The user asks: "Can this package be used in software that is released open source and why?". The AI responds: "Yes. The PSF and BeOpen licenses both allow for Python to be used in derivative works that are released open source as long as the original PSF or BeOpen license is retained and the changes made to Python are indicated." The user asks: "Is this license copyleft or permissive?". The AI responds: "This license is permissive, meaning it allows for the software to be used and modified without having to release the source code or derivative works." The user asks: "How am I permitted to use this license under open source software?". The AI responds: "You are permitted to use this license under open source software by reproducing, analyzing, testing, performing and/or displaying publicly, preparing derivative works, distributing, and otherwise using Python alone or in any derivative version, provided that the PSF or BeOpen license is retained in the software, alone or in any derivative version prepared by you." The interface also shows a "Generate" button, "Undo", "Regenerate", and "Tokens: 2414" at the bottom.


Can this package be used in software that is released open source and why?





Opportunities – beyond data processing

- Policy compliance:

**NASA**
Procedural Requirements
COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES

NPR 2210.1E
Effective Date: June 14, 2023
Expiration Date: June 14, 2028

Subject: Release of NASA Software

Responsible Office: Space Technology Mission Directorate

[View all pages in PDF](#)

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P.1 Purpose
P.2 Applicability
P.3 Authority
P.4 Applicable Documents and Forms
P.5 Measurement/Verification
P.6 Cancellation

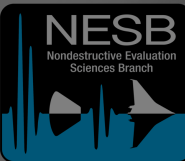
Chapter 1. Responsibilities

1.1 Technology Transfer Program Executive
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1.5 NASA Inspector General
1.6 NASA Chief Information Security Officer (CISO)
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1.10 Centralized Software Usage Agreement Processing Team
1.11 Responsible Center Offices or Projects

Chapter 2. Reporting, Review, and Assessment of Software

2.1 Center Awareness and Orientation Activities
2.2 Software Reporting
2.3 Review and Assessment Coordination
2.4 Intellectual Property and Releasability Rights Assessment
2.5 Technology Transfer Assessment
2.6 Export Control Assessment
2.7 Information Technology (IT) Security Assessment
2.8 SRA Release Determination

Establishes procedures and responsibilities for the reporting, review, assessment, and release of software created by, or for, NASA.





Completions playground

Looking for GPT-4? Go to Chat Playground to try it out.

Deployments

text-davinci-003

Examples

Summarize an article (abstractive)

Go to Chat Playground.

View code

Provide a brief summary of the text
at a 10 year old reading level.

Provide a brief summary of the text below at a 10 year old reading level.

NPR 2110 section 2.8

- 2.8.1 The SRA shall ensure that the release of applicable software is accomplished in accordance with this NPR and metrics will be captured to monitor the efficient flow of the software packages through the release process.
- 2.8.2 When a release of NASA software is requested, the SRA shall consult with the Office or Project responsible for the software to determine a recommended release category.
- 2.8.3 In establishing release restrictions for specified software, the SRA shall consider Agency technology transfer objectives along with the recommendations and determinations resulting from the release assessments.
- 2.8.4 The SRA shall then identify, consistent with the established release restrictions, the approved option(s) for releasing specified software as implemented.
- 2.8.5 Finally, the SRA shall consult with the Patent or IP Attorney to determine the proper SUA for a release of NASA software. Model SUAs have been prepared and adopted for use by the SRAs. Model SUAs may be revised for a particular release only after consultation with the Center Patent or IP Counsel.
- 2.8.6 Except in the case of an Open-Source Release (see 3.2.2.2), an SUA will be signed, or otherwise agreed to, or acknowledged by the recipient before the requested software may be released to the recipient.
- 2.8.6.1 In the case of software where NASA seeks to expedite broad dissemination such as with a Public Release or an Open-Source Release, a recipient's agreement may be, for example, by click-wrap agreement or terms of use under the agreement. The SRA shall consult with the Patent or IP Attorney and the Office or Project to assess whether a proposed Public Release or Open-Source Release of NASA software raises sensitivities or potential liability given the breadth of access and the unrestricted distribution of the NASA software.
- 2.8.6.2 In the case of a Project Release under a Government contract, software may be released by NASA to U.S. Federal Government support service contractors as Government-Furnished Computer Software (GFCS) under the NASA FAR Supplement 1852.227-88 Government-Furnished Computer Software and Related Technical Data Clause included in their support service contract. In this instance, the contract clause and any additional Contracting Officer direction serve as the SUA. If software is to be released as GFCS, the SRA shall work with the applicable Contracting Officer and obtain sufficient information to document the release.
- 2.8.6.3 An SUA issued for any purpose other than an Open-Source Release will, at a minimum, include a Software Release Record described in section 3.5.1, the disclaimer and indemnification provisions, unless the latter is removed per guidance provided by Center Patent or IP Counsel, as required in section 3.3 and the notices of section 3.4 as required in this NPR and may also include provisions for nondisclosure and export control as required.
- 2.8.6.4 An SUA will also specify any restrictions on use and disclosure of said software imposed by NASA on the recipient.
- 2.8.6.5 For all releases other than an Intra-NASA Release, Open-Source Release or Public Release via click wrap agreement, an SUA will be issued by the SRA.
- 2.8.7 An SUA is a Government record and will be maintained in NTTS for disposition per guidance provided in NPD 1440.6, NASA Records Management, and NPR 1441.1.

The SRA (Software Release Authority) must make sure software is released in the right way and measure how well it is done. They will talk to the Office or Project responsible for the software to decide what kind of release it should be. They will also consider technology transfer objectives and the results of the release assessments. The SRA will then decide how the software should be

Parameters

Temperature 0.3

Max length (tokens) 250

Stop sequences

Stop sequences

Top probabilities 1

Frequency penalty 0

Presence penalty 0

Best of 1

Pre-response text

Enter text

Post-response text

Enter text

Learn more

The SRA (Software Release Authority) must make sure software is released in the right way and measure how well it is done. They will talk to the Office or Project responsible for the software to decide what kind of release it should be. They will also consider technology transfer objectives and the results of the release assessments. The SRA will then decide how the software should be released. They will also talk to the Patent or IP Attorney to decide what kind of agreement should be used. For most releases, the recipient will have to sign or agree to an agreement, which will include a Software Release Record, a disclaimer, and notices. The agreement will also have restrictions on how the software can be used and disclosed. The agreement will be kept as a Government record.



Provide a brief summary of the following at a 10 year old reading level:

NPR 2110 section 2.8

Provide a brief summary for the following policy at a 10 year old reading level:

2.8 SRA Release Determination

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- 2.8.6.1 In the case of software where NASA seeks to expedite broad dissemination such as with a Public Release or an Open-Source Release, a recipient's agreement may be, for example, by click-wrap agreement or terms of use under the agreement. The SRA shall consult with the Patent or IP Attorney and the Office

Response

Markdown

The Software Release Authority (SRA) is responsible for ensuring that NASA software is released in accordance with this policy. The SRA will consult with the Office or Project responsible for the software to determine the recommended release category. The SRA will then identify the approved option(s) for releasing the software. The SRA will consult with the Patent or IP Attorney to determine the proper Software Use Agreement (SUA) for the release. An SUA will be signed by the recipient before the software can be released. In the case of a Public Release or Open-Source Release, the recipient's agreement may be by click-wrap agreement or terms of use. In the case of a Project Release under a Government contract, the software may be released as Government-Furnished Computer Software (GFCS) under the NASA FAR Supplement 1852.227-88 Government-Furnished Computer Software and Related Technical Data Clause included in their support service contract. An SUA issued for any purpose other than an Open-Source Release will include a Software Release Record, the disclaimer and indemnification provisions, the notices, and may also include provisions for nondisclosure and export control. An SUA will also specify any restrictions on use and disclosure of the software imposed by NASA on the recipient. For all releases other than an Intra-NASA Release, Open-Source Release or Public Release via click wrap agreement, an SUA will be issued by the SRA. An SUA is a Government record and will be maintained in NTTS for disposition per guidance provided in NPD 1440.6, NASA Records Management, and NPR 1441.1.

We want your [feedback](#).

Model
text-bison@001

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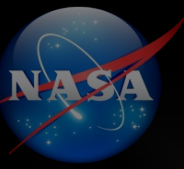
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Top-P 0.8

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Block few

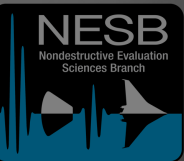
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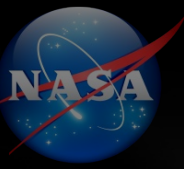
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Challenges / Opportunities (not specific to aerospace)

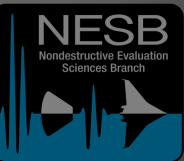
- Unable to use some techniques due to lack of training data.
 - Data from validated models?
- Lack of standard data set(s) for NDE
 - A consortium could enable this
 - Example: Round robin testing NASA and partners did under ACP, [link to that TM](#).
- 'Explainable': when is this needed? Can it aid in understanding when a model is not applicable



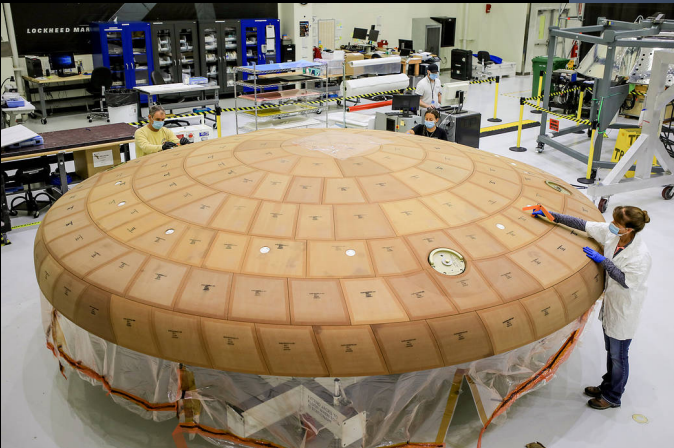


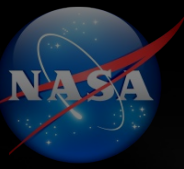
Challenges/Opportunities (not specific to aerospace)

- Cultural – Need partnerships to include experts (.e.g pair with computer science). Tool accessibility may be outpacing the understanding.
- Security.
- Understanding a specific AI/ML tool can be used for. When should it NOT be used. (true for both ML and LLMs!)

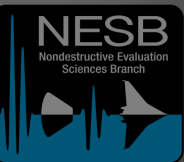


Specific to aerospace:





Questions?



Hyperparameter Tuning

Hyperparameters:

- Number of convolutional layers in each block.
- Number of blocks.
- Size of the filters.
- Activation scheme.

Challenge: Interaction of Hyperparameters is not intuitive.

Typical Solution: Trial and Error

Our Solution: Genetic Algorithm

