Department of the Navy SBIR/STTR Transition Program

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Topic # N221-067
A Digital Twin Model for Robust 3D Woven PMC Pi Joints
Materials Research & Design

WHO

SYSCOM: ONR

Sponsoring Program: Air Platform, Materials/Processes

Transition Target: General Warfighting Requirements (GWR)

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Other Transition Opportunities: While the developed technology stems from a need to optimize the design and manufacture of woven airframe joints, MR&D's software tool can be used in a broader array of applications where a prediction of the quality and structural performance of a composite part is needed. Designers and material manufacturers from many industries beyond defense and aerospace could benefit from using MR&D's tool.

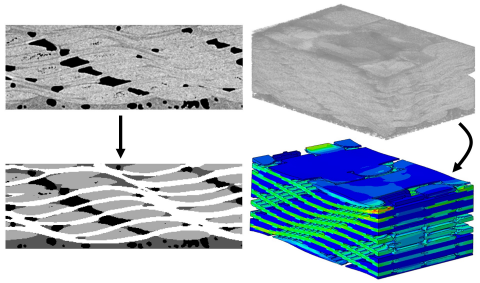

Image courtesy of Materials Research & Design, Inc.

Notes: On the top left is a slice of raw computed tomography (CT) data isolated from the volume on the top right. On the bottom left is the CT slice segmented into individual material phases using the deep learning tool, which is used to inform the finite element model that generated the stress contour plot on the bottom right.

WHAT

Operational Need and Improvement: The presence of manufacturing flaws, voids, and unexpected irregularities in woven composite parts necessitates the usage of overly conservative designs and costly structural testing to verify their usage in the airframe. Manufacturers need a more cost and time-effective way to accurately predict the strength and stiffness of their parts so they can use this data to increase confidence, improve performance, and reduce conservatism in their designs.

Specifications Required: An innovative method to efficiently create a digital twin of airframe components in the as-built condition using input CT data can be used to develop high-fidelity models to predict failure causes, probabilities, and locations. This would improve reliability, reduce uncertainty and scatter in performance, and thus enhance the user communities' confidence in the use of pi-preform-based primary bonded composite structures.

Technology Developed: MR&D is currently developing a deep learning-based image segmentation software that uses a convolutional neural network architecture to automate the task of segmenting individual material phases and predicting fiber orientation from input computed tomography (CT) data of composite woven parts. Following segmentation, the software executes small-scale finite element (FE) models to predict the CT volume's stiffnesses and strengths, which can be used to inform a larger-scale FE models of the entire woven part. The calculated stiffnesses and strengths of key regions can help manufacturers identify unexpected flaws, weak points, or areas where the part can be optimized from a design and/or manufacturing perspective.

Warfighter Value: The value proposition for developing a deep learning-based image segmentation software is increased confidence in the structural performance of as-manufactured woven composite parts. The software provides deeper insight into flaws and uncertainties in existing parts, and also helps flesh out areas for improvement while reducing reliance on long-term and costly structural tests.

WHEN

Contract Number: N68335-23-C-0609 **Ending on:** Jul 31, 2025

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Deep Learning Segmentation Software Development	Low	Segmentation algorithm generates results that match or exceed the quality of those from commercial software.	4	4th QTR FY24
Deep Learning Segmentation Software Optimization	Low	Finite element solver generates stiffness and strength results using CT data that match those of real-world coupon tests.	4	2nd QTR FY25
Deep Learning Segmentation Software Packaging and Completion	Low	Segmentation and finite element solver are properly integrated, software is packaged with documentation for use by customer.	4	3rd QTR FY25

HOW

Projected Business Model: By the nature of this project, the Navy will have full access to MR&D's developed software for its own research and design purposes. However, MR&D is also working with a vehicle prime as a subcontractor to which the software could be licensed for future system integration. Given the wide applicability of the software in analyzing the quality and performance of woven composite parts, MR&D will likely also be able to license it to other vehicle prime contractors in the defense and aerospace industries. Separate from licensing the software for others to use, MR&D's engineers will be able to use it for other contracts/projects that require the sort of in-depth composite analysis facilitated by the tool. Other forms of business stemming from the usage of the software include deep learning network preparation or image processing for a client to use as well as software training, documentation, and fixes/updates.

Company Objectives: MR&D is looking to discover new opportunities and customers who could benefit from the developed deep learning software in the design of woven composite parts. They aim to find new applications where MR&D's engineers could use the software as a foundational design tool or where the software may be licensed to another client (government or otherwise) for use.

Potential Commercial Applications: The focus of MR&D's technology is to optimize the performance and reliability associated with the design and manufacture of complex 3D woven composite joints. The software tool caters to a broad array of applications where the prediction of quality and structural performance of composite parts is needed. Designers and material manufacturers in both aerospace and defense industries require such expertise, but other composite integrators will benefit from the tool as well.

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