**WHEN**

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<td>Implement Modular Software Architecture</td>
<td>Med</td>
<td>ABAQUS coupled cure kinetics, Tg, void evolution mechanism models (Phase I models)</td>
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<td>Design and Development of Graphical User Interface</td>
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<td>GUI for process/defect model setup in ABAQUS for Flat Laminate geometries only</td>
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<td>Experimental Validation: Planar geometry void evolution; Single curvature experiments</td>
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<td>Demonstrate void maps and other state variable visualization in ABAQUS</td>
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**WHAT**

**Operational Need and Improvement**: OEM's have experienced fabrication issues, i.e. development of voids and delaminations, with autoclave processing of certain carbon/epoxy structural components. These defects cause part rejection which is both costly and effects program schedule. The M&S tool being developed in this STTR will predict manufacturing defects, including voids, ply waviness, delaminations, fiber wrinkling, resin rich/poor areas, and warpage caused from tool-part interaction using important processing parameters in an autoclave process, such as component internal temperature, resin kinetics and resin rheology, autoclave pressure and vacuum pressure, to model autoclave composite manufacturing.

**Specifications Required**: M&S tools that enable the prediction/characterization of manufacturing defects including voids, ply waviness, delaminations, fiber wrinkling, resin starvation/rich areas, and warpage caused from tool-part interaction in autoclave processing of thermoset composite materials. This tool identifies important processing parameters in an autoclave process, such as component internal temperature, resin kinetics, and resin rheology, autoclave pressure and vacuum pressure, then accounts explicitly for them to appropriately model autoclave composite manufacturing.

**Technology Developed**: An analytical model that describes void formation and evolution in the autoclave processing of thermoset composites has been developed. This model takes into account the material characteristics including state of cure, and various temperature dependent properties such as Tg, resin viscosity, heat generation, solubility, etc. The material properties are populated in SMARTee and integrated into ABAQUS, to take advantage of the inherent solvers (temperature, diffusion, pressure etc.) to efficiently develop the void dynamics.

**Warfighter Value**: This analysis tool will allow the NAVAIR engineer to evaluate the autoclave process for composite structures to assess if areas exist within the structure where defects may occur. Modifications to the manufacturing process can then be analytically performed to optimize the process conditions to eliminate these defects. This can also be done by the OEM's so that all parts can be produced without defects, on the first try. This should reduce or eliminate part scrap.

**HOW**

**Projected Business Model**: It is fully anticipated that at the end of the Phase II Option, a Modeling and Simulation (M&S) tool that accurately models the thermoset prepreg manufacturing process will be developed, encompassing all process options including autoclave and out-of-autoclave methods. This tool will allow engineers to import complex 3D part geometries, establish process conditions and locally interrogate for potential defect formation at specific zones of interest and visualize defect formation over time during the process cycle. After the Phase II Option Phases, CA anticipates interactions with software developers to implement these defect models with existing solvers for composite process modeling. This will lead to the licensing of a stand-alone GUI for thermoset prepreg processing and USERMAT subroutines. CA will also set up arrangements for consulting services for companies requiring assistance with this software for their specific components.

**Company Objectives**: The technical success on the proposed program would result in the creation of a relevant patent portfolio to protect the IP and is anticipated to generate at least two different commercialization opportunities, including 1) to provide analytical services to analyze the thermoset composite processing procedures of OEM's and composite manufactures to identify regions where defects may occur and assist in the modification to ensure defect free process methods; and 2) license the technology to existing composite analysis developers.

**Potential Commercial Applications**: The developed software has use in both Navy/DoD structures being fabricated using prepreg material as well as commercial applications such as large on- and offshore wind blade structures. The potential to reduce or eliminate manufacturing defects from these applications will reduce scrap and will potentially enable more efficient optimized fabrication which could reduce manufacturing costs. This may also allow the OEM's to consider composite manufacturing of other components that were thought to be too difficult to produce with the quality required for the application.

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