

Application of LS-DYNA MAT 213 to NASA Problems of Interest

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LS-DYNA Aerospace Working Group

Engine Related Impact and Failure (ERIF) Subgroup Annual Meeting

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Overall Features of NASA Glenn Work

- NASA work transitioned from a “development” mode to a “production” mode
- Primary focus on how to best use model to make structural level predictions
- Aligning modeling efforts with NASA and industry established best practices (former NASA Advanced Composites Project)
- Numerous testing/analysis efforts underway for a variety of applications
- Substantial interactions with academia
- Developing methods and processes for improving characterization methods

NASA Impact Dynamics Team

- NASA Glenn Civil Servants: Rob Goldberg, Mike Pereira (retired), Duane Revilock, Trent Ricks, Chuck Ruggeri
- NASA Langley Civil Servants: Justin Littell, Matlock Mennu, Jacob Putnam
- NASA Contractor: Javier Buenrostro
- Academic Collaborators (EPSCoR): Iowa State University, Mississippi State University, University of Alabama-Huntsville, University of South Carolina, Wichita State University

Hi-Rate Composite Aircraft Manufacturing (HiCAM) Project

Goal: Demonstrate manufacturing approaches and associated technologies for large composite primary airframe structures that enable high-rate production (up to 80 aircraft per month) with reduced cost and no weight penalty versus 2020 technology for composite structures for early 2030s single-aisle aircraft production

Production Rate per Month

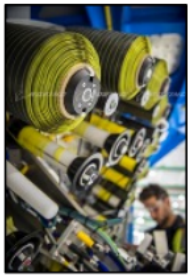
- Metals SOA: 60
- Composites SOA: 10-14
- Requirements: 80



Objectives:

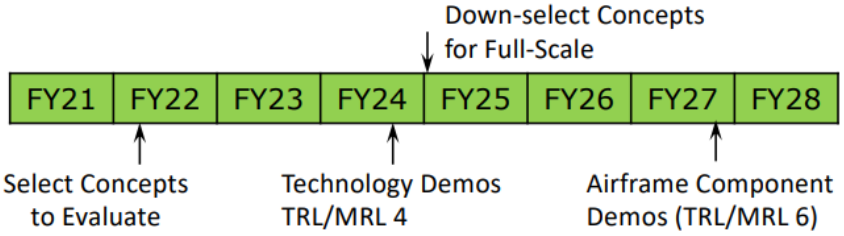
- Mature affordable, high-rate composite manufacturing technologies, with reduced labor, equipment, and tooling costs
- Develop model-based engineering tools for high-rate concepts





Approach:

- Baseline: scaled B787/777x composite aircraft production system
- Compete thermosets, thermoplastics, resin transfer molding
- System assessment of production cost and component weight
- Demonstrate capability for full-scale airframe component(s)

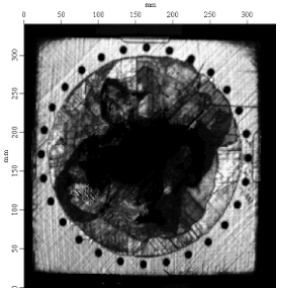
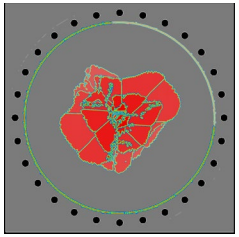


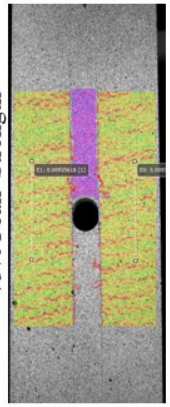
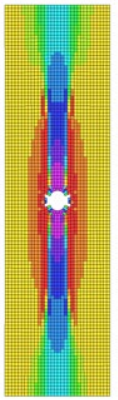
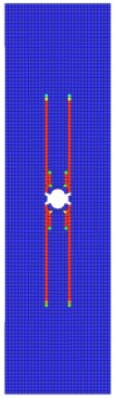
Addresses industry needs for rate, cost, and weight

Young, R. Hi-Rate Composite Aircraft Manufacturing (HiCAM) Overview April 2023. https://ntrs.nasa.gov/api/citations/20230006156/downloads/HiCAM%20Overview%20April_2023.pdf

MAT 213 Activities Under HiCAM

- Completed initial development of high-energy dynamic impact model for AS4D-PEKK-FC thermoplastic composite
- Identified gap in ability to predict delamination in thermoplastic composites
- Attempting to make model more predictive by calibrating to coupon level results
  - Leveraging previous project results for a similar thermoplastic material
  - Harmonizing modeling best-practices across multiple different progressive damage and failure material models
- Plans to investigate rate-dependent interlaminar fracture and ply behavior
- Utilizing MAT 213 to investigate limitations of other material models

LVG1520: 147 m/s	
Experiment	Simulation
	

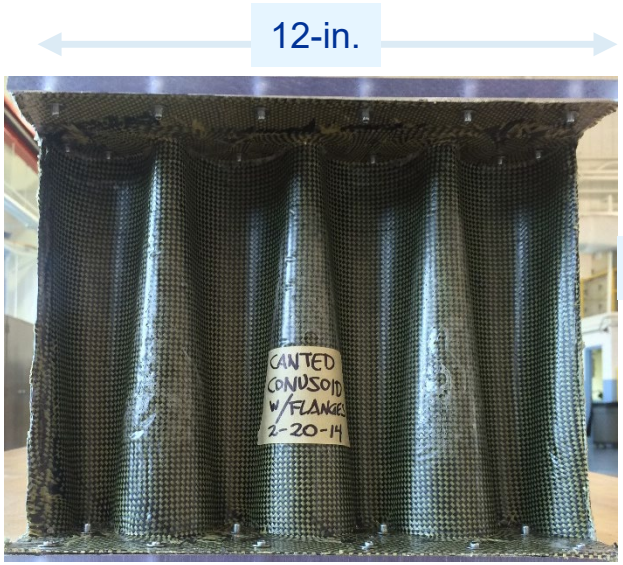
$[0]_{16}$		
Experimental Strain	Simulation Strain	Simulation HV#18
		

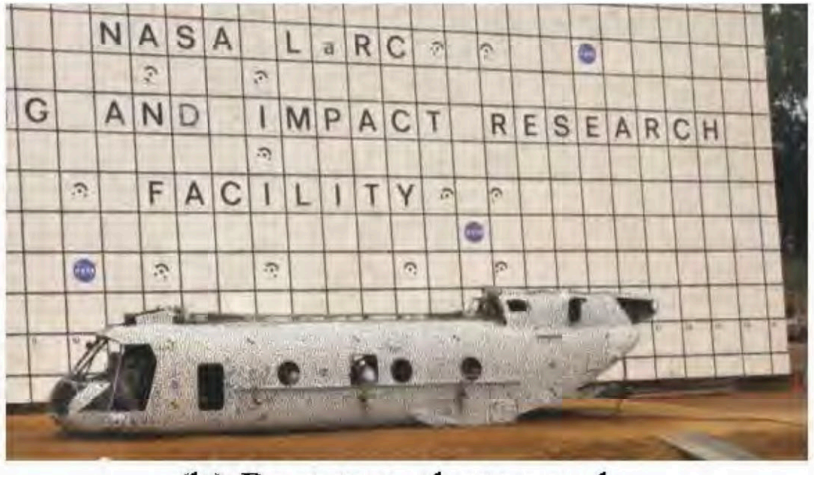
75% Peak Strength

*Buenrostro, J. et al. 2024. “Simulating High Energy Dynamic Impact of IM7/PEKK Continuous Fiber Laminated Thermoplastic Composite using Open Hole Coupon Experiments”, presented at the 39th Annual American Society for Composites Technical Conference, San Diego, CA.

Revolutionary Vertical Lift Project (RVLT) Project

- Concentrating on crashworthiness applications for rotorcraft structures, particularly eVTOL and Urban Air Mobility (UAM)
- Analyzing materials for deployable energy absorbers and fuselage structures
- Work not continuing in FY26 due to changing agency priorities



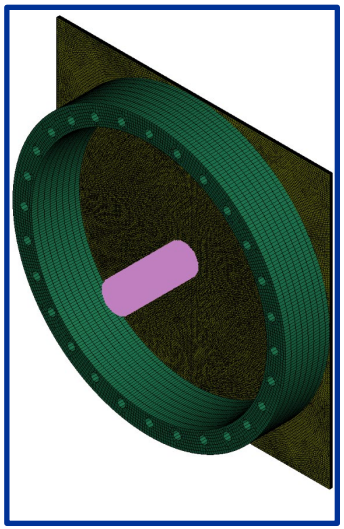


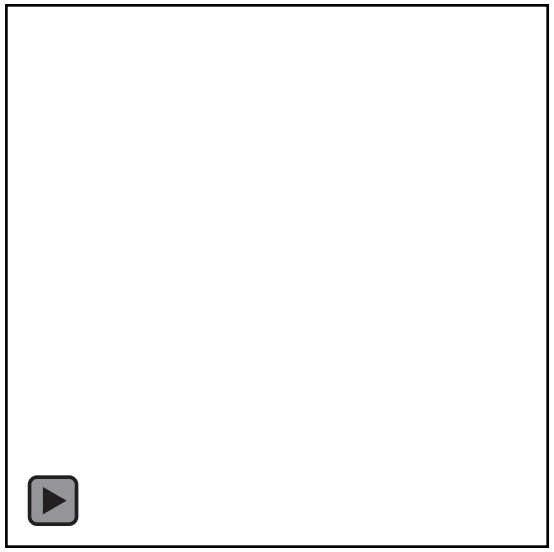
Bird Strike Impacts to UAM Materials

- Bird surrogate testing completed to characterize penetration threshold velocity (187 m/s, 615 fps)
- Initial bird and MAT 213 composite model developed for a woven carbon fiber composite
- Further refinement on pause due to loss of key personnel and changing project demands

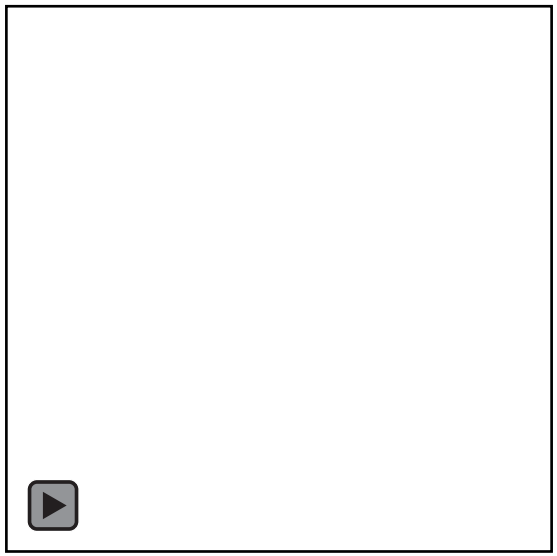


Nominal cross section of the bird surrogate (~57 g)

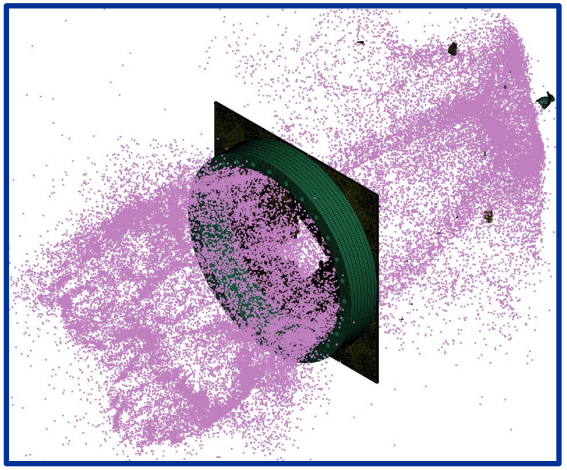




192 m/s (631 fps) Impact Velocity



241 m/s (790 fps) Impact Velocity



Case with initial velocity 260 m/s (851.6 fps)

NASA EPSCoR Program Overview

- The NASA EPSCoR program (Established Program to Stimulate Competitive Research) is designed to provide a pathway for universities in select states to have the opportunity to obtain NASA funding and to work with NASA researchers.
- Current funded efforts are:
  - Conducting tests on specified materials suitable for characterizing shell element version of MAT 213
  - Identifying and developing tests/methods to characterize flow rule parameters and post-peak stress response using coupon tests

NASA EPSCoR Efforts

Iowa State University

- Characterized woven carbon/Kevlar composite
- Conducting detailed off-axis and V-Notch shear tests to gain improved understanding of characterization of flow rule coefficients

Mississippi State University

- Characterized representative thermoplastic matrix composite (including high strain rate)
- Developing MAT 213 cards and conducting relevant simulations

University of Alabama-Huntsville

- Conducting high strain rate characterization of woven carbon fiber composite

NASA EPSCoR Efforts

University of South Carolina

- Characterized representative thermoplastic composite
- Developing method to determine post-peak stress response from coupon level tests
- Performing high strain rate characterization testing (including mode I fracture)

Wichita State University

- Characterized quasi-static response of woven carbon fiber composite and developed MAT 213 cards
- Developed and utilized an optimization approach to characterize flow rule coefficients
- Developed potential approach for characterizing post-peak behavior from coupon level tests

Conclusions

- MAT 213 being applied to multiple practical applications directly related to NASA projects.
- Reasonable levels of success in using MAT 213 to simulate impact and crush problems
- Areas of future work identified:
  - Improved methods to simulate interlaminar fracture for use with composite material models
  - Leveraging unique features of MAT 213 to investigate influence other material model assumptions
  - Moving towards utilizing seldom-used MAT 213 features (e.g., coupled damage, rate-dependence, viscoelasticity)