



Advanced Composite Structures At NASA Langley Research Center

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Langley Research Center, Hampton, Virginia, USA

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Overview

- Composites on NASA's Space Launch System (SLS)
 - Payload Fairing
 - Exploration Upper Stage (EUS)
- ISAAC composites manufacturing research tool
- Previous NASA Composites Projects
 - Advanced Composites Technology (ACT)
 - Composites for Exploration (CoEx)
- Advanced Composites Project (ACP)

NASA's Space Launch System (SLS)



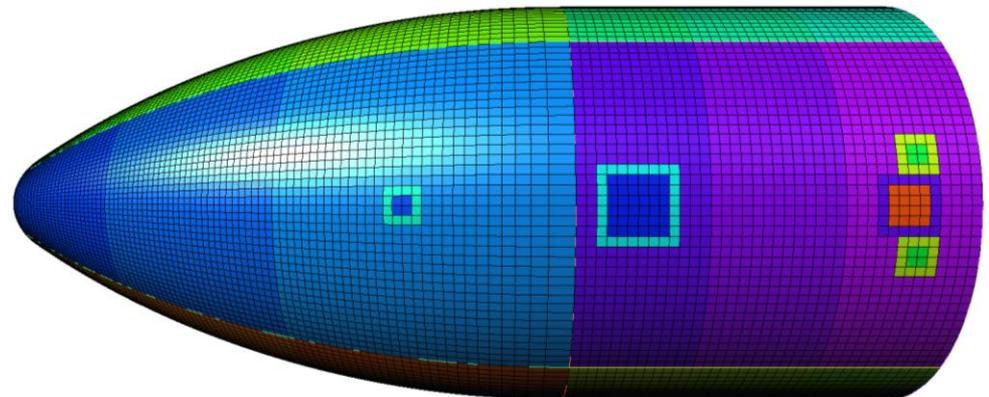
Payload Fairing

Exploration Upper Stage (EUS)

- Block 2 Evolved SLS Cargo Configuration
- 130 metric ton cargo capacity

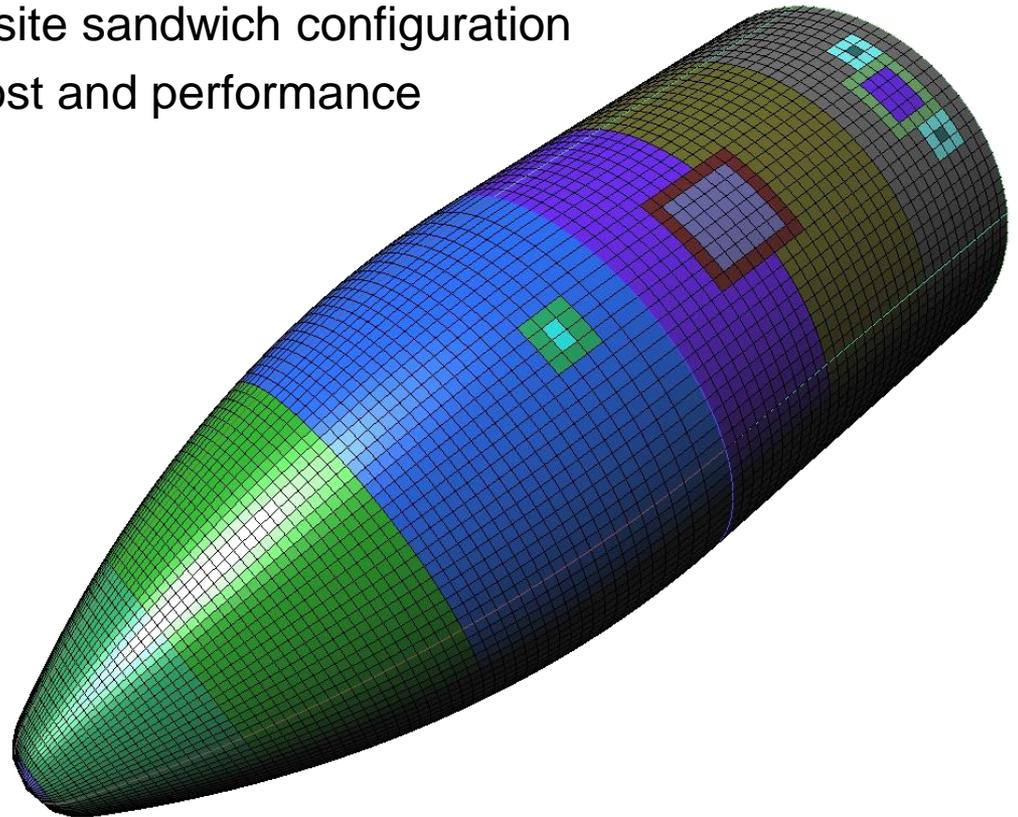
Composites on Ares V – Payload Fairings

- Fairing team led from Glenn Research Center stood up for the Ares V Constellation Program cargo rocket.
- Ares V fairing was 10m diameter to protect Altair lunar lander. (Ares V core was also 10m diameter.)
- Fairing system trades included material system, stiffening approach, nose shape, petal count, max operating temperature, acoustic treatments.
- Fairing structure is lightly loaded and is sized by buckling constraints rather than strength.
- Following end of Constellation, team supported SLS system architecture studies.



Composites on SLS – Payload Fairings

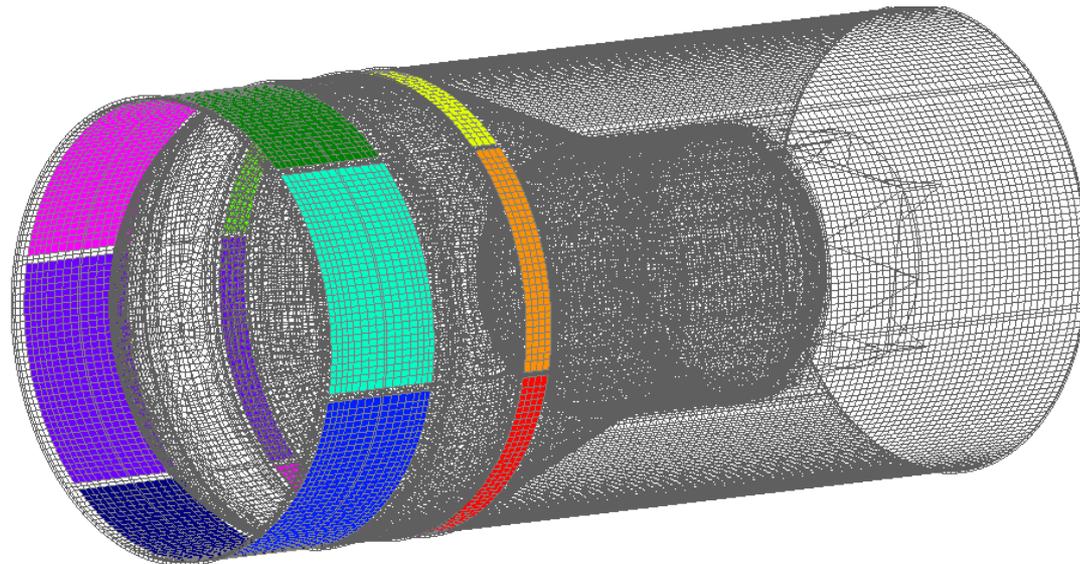
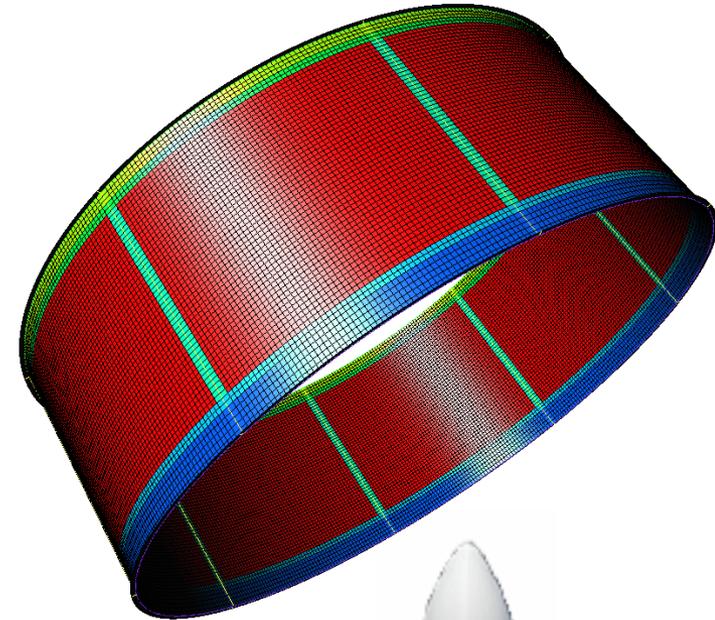
- SLS cargo configurations include 5.4m (COTS), 8.4m, and 10m diameter fairings on an 8.4m core.
- Initial Baseline SLS fairing design was metallic
- Composite trade study delivered October 2012 convinced the SLS program to change to composite sandwich configuration
- Trade study demonstrated both cost and performance advantages to composites.



Composites on SLS – Upper Stage



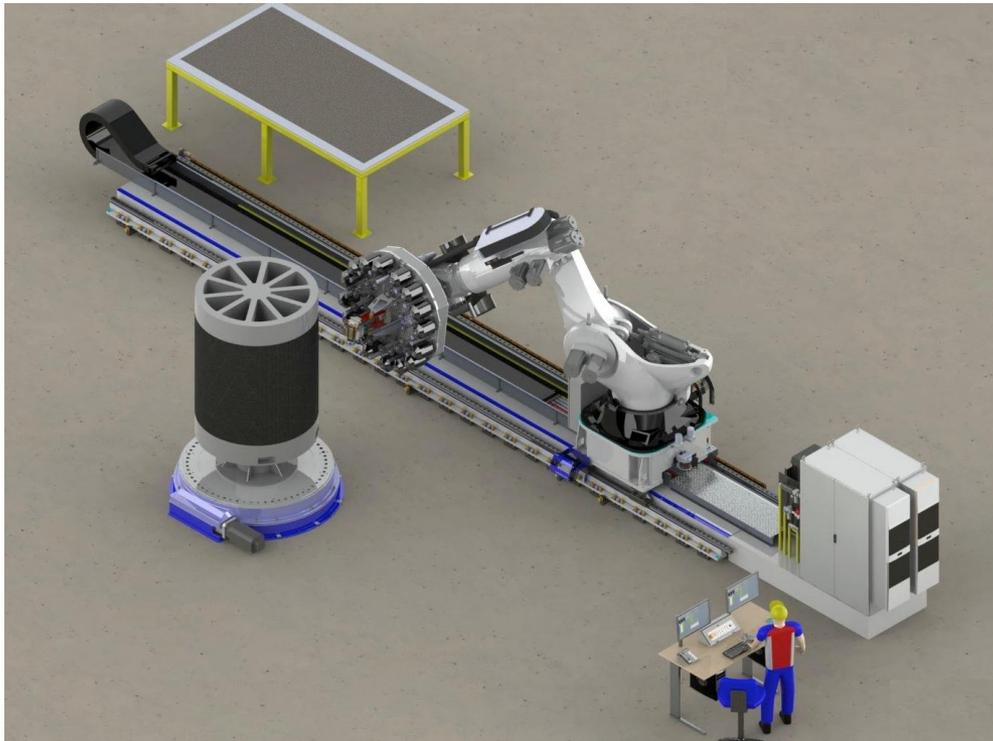
- Composite Exploration Upper Stage (C-EUS) effort examining approaches to utilize and **certify** composite structures on very highly loaded components.
- Upper skirt, lower skirt, and payload adaptor structures being studied
- Full scale prototypes will be designed, reviewed constructed, and tested.



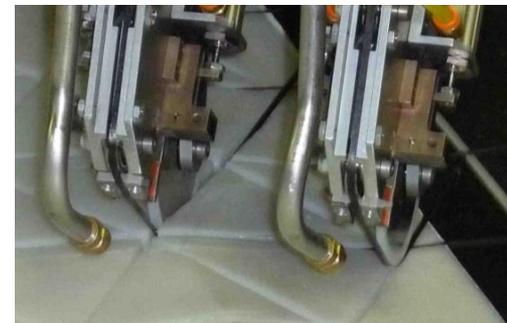
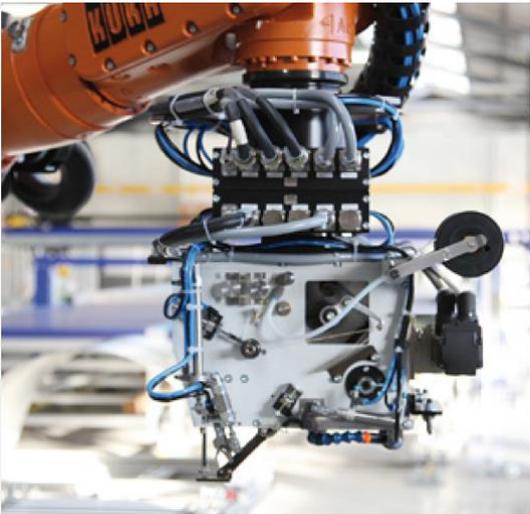
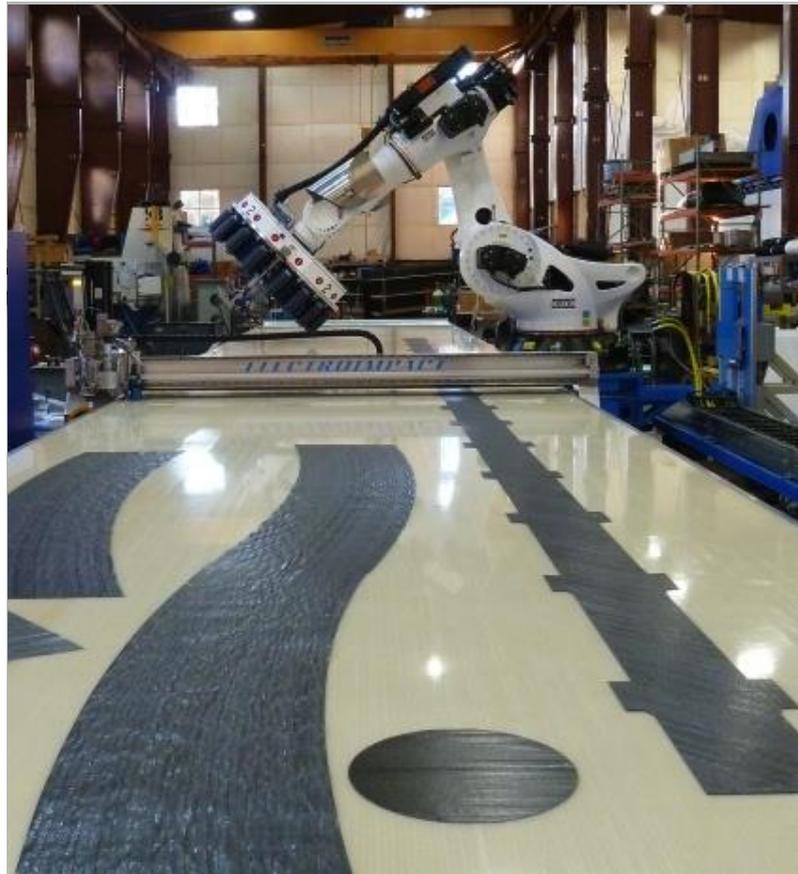
ISAAC – Robotic Composites Layup



**Integrated Structural Assembly
of Advanced Composites**
NASA Langley Research Center



ISAAC - LaRC Vision for Advanced Manufacturing



A robot-based system that utilizes multiple end effectors to develop and evaluate next generation composite materials, processes, structural concepts, manufacturing, and inspection techniques

Integrated Research Across TRL Spectrum



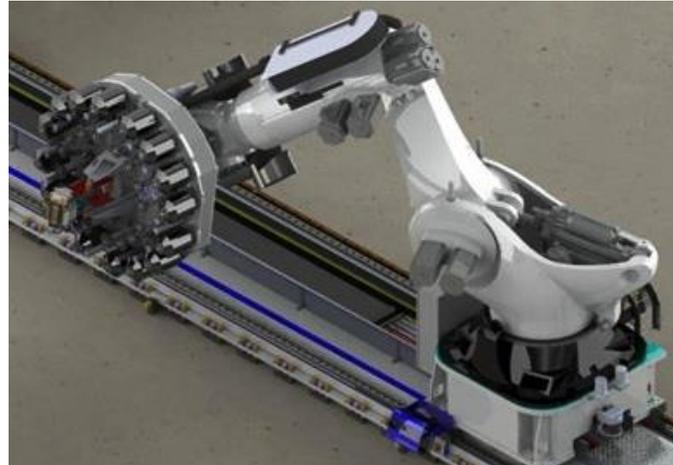
TRL 1-3

Develop
New Resins
and Fibers

Pre-Pregging of
Composite Tows

Develop Advanced In-Situ,
In-Process NDE and
Fabrication Technologies

TRL 4-6



Fabrication of
Flight Vehicle
Structures

TRL 7+

Testing and Analyses of
Composite Structures

Post-Cure Characterization
and NDE of Composites

Design and Manufacture of
Tow-Steered Composites

Recent NASA Composites Projects



- Advanced Composites Technology (ACT)
 - Focused on maturing composites technologies for application to NASA's Constellation program. Applications included Ares V payload fairing and intertank
- Composites for Exploration (CoEx)
 - Goal: to develop high payoff dry composite structures and materials technologies with direct application to enable NASA's future space exploration needs



Advanced Composites Project (ACP)



- Aeronautics focused research
- Goal: Infuse next-generation, physics-based tools and streamlined processes to accelerate the development and regulatory acceptance of advanced composite structures for aeronautics vehicles manufactured from qualified or industry standard composite (Target: 30% reduction)

Relevance to National Need



- **From FY14 President's Budget Request**
 - Focus on reducing the timeline for development and certification of innovative composite materials and structures, which will help American industry retain their global competitive advantage in aircraft manufacturing



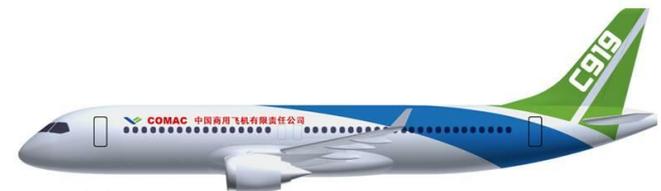
Lockheed Martin F-35



Northrop Grumman
Fire Scout



Airbus
A-350 XWB



Comac C919 (China)

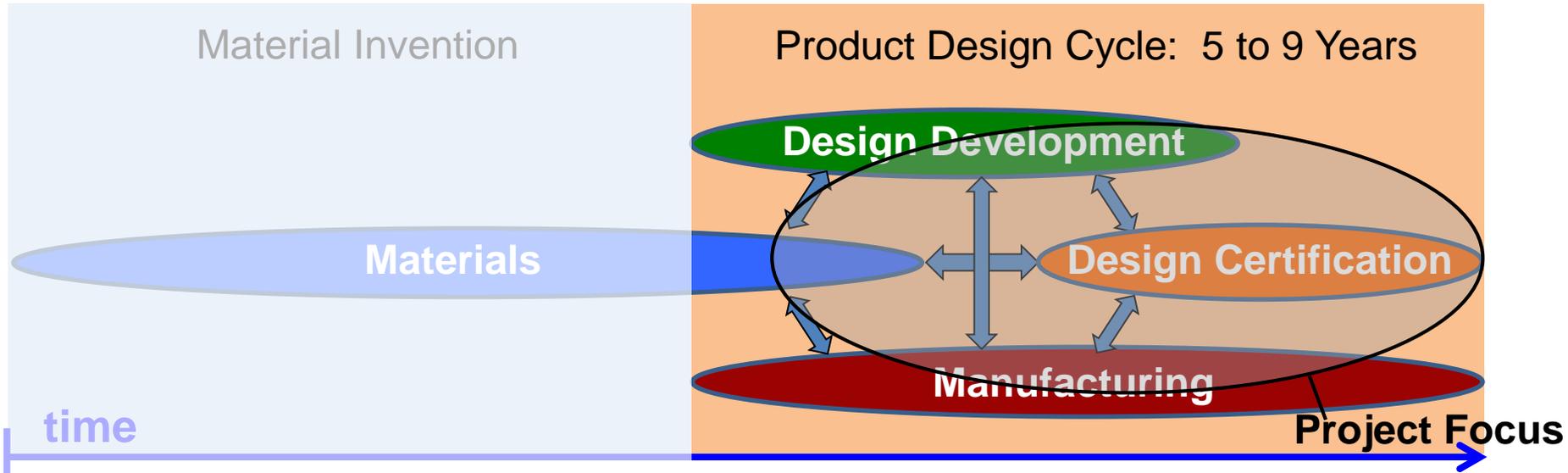


Bombardier
C-Series

Sukhoi Superjet 100
(Russia)



Project Goal



Goal: Reduce product development and certification timeline by 30%

NASA Project Planning with Partner Input



Portfolio Formulation

Community Needs

1. Material qualification databases
2. Progressive damage modeling
3. Design coupled to manufacturing
4. Bonding and bond qualification
5. Manufacturing tooling and molds
6. Accelerated certification approaches
7. Material durability and aging
8. Education of workforce
- Systems Engineering

Apply Filters



Tech Challenges (v1)

1. Efficient Design
2. Streamlined Certification
3. Progressive Damage Modeling
4. Enhanced Manufacturing
5. Systems Assessment

Vet & Refine



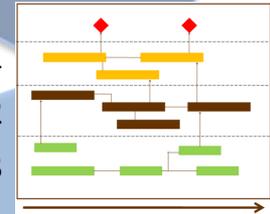
Tech Challenges (v2)

1. Predictive Capability
2. Rapid Inspection
3. Manufacturing Process & Simulation

Team Validation & Tech Roadmaps



Phase I Execution



- Content, ROM \$, time

Manage Portfolio

- Cost/Benefit/Risk Analysis
- Down-select



Execute & Evaluate

- Fabricate
- Test
- Analysis
- Timeline model

Team-Developed Detailed Technical Work Packages



Identify Community Needs



Portfolio Formulation

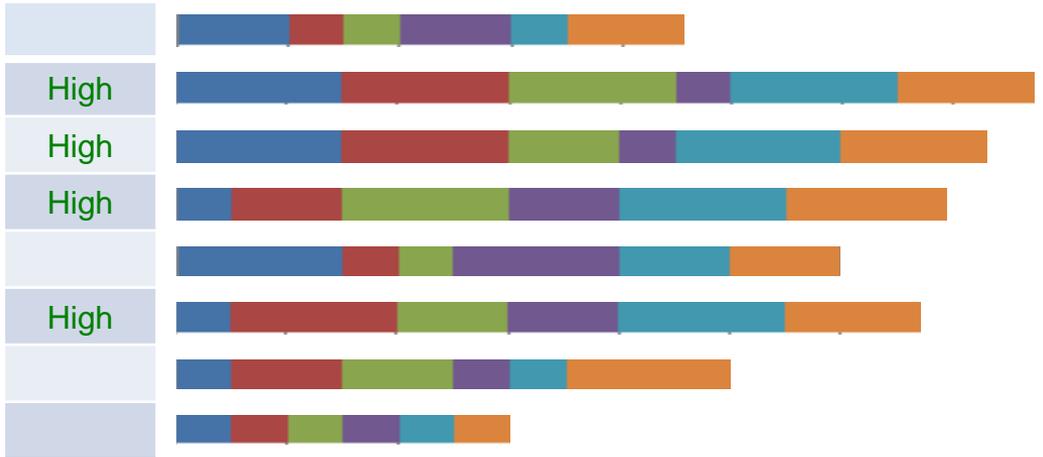
Advanced Composites Workshop (May 2012)

Community Needs

NASA SME: Impact	Industry: Impact
High, Med, Low	Impact

Industry Partner Survey

1. Material qualification databases
2. Progressive damage modeling
3. Design coupled to manufacturing
4. Bonding and bond qualification
5. Manufacturing tooling and molds
6. Accelerated certification approaches
7. Material durability and aging
8. Education of workforce



Vet and Refine (cont.)



Portfolio Formulation

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Vet & Refine



Tech Challenges (v1)

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NASA Advisory Council AND NRC-organized Meeting of Experts

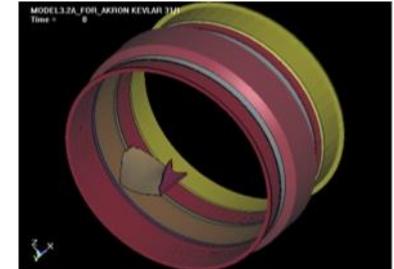
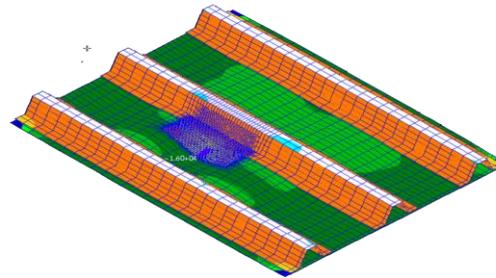
- Project is too broad
- End of program: usable efficient products
- Recommend Accelerated Validation – more than certification, and not omitting steps
- Suggested unifying theme - certification by integrated analysis and test; validated tools
- Tool integration through manufacturing physics is critical. Key part of certification and validation is to understand variability.

ACP Technical Challenges



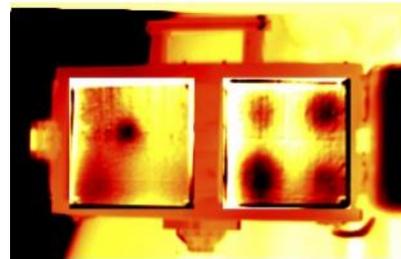
Predictive Capabilities

- Robust analysis reducing physical testing
- Better prelim design, fewer redesigns



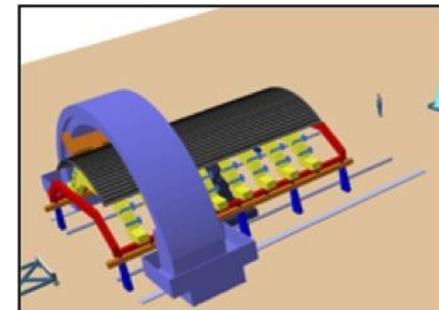
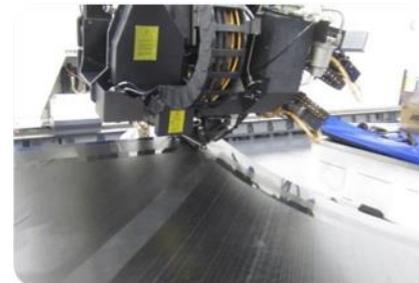
Rapid Inspection

- Increase inspection throughput
- Quantitative characterization of defects
- Automated inspection



Manufacturing Process & Simulation

- Reduce manufacture development time
- Improve quality control
- Fiber placement and cure process models



ACP Technical Challenges



State of Practice

Benefit

Predictive Capabilities

- Robust analysis reducing physical testing
- Better prelim design, fewer redesigns

- Analysis insufficient for strength or life with damage; must test
- Gaps prelim design and tests; redesign

- Reduced testing
- Expanded design space
- Less risk; fewer redesigns

Rapid Inspection

- Increase inspection throughput
- Quantitative characterization of defects
- Automated inspection

- NDI cannot quantify various defect types
- Skilled or subjective interpretation of data
- Manual disposition / transfer to analysis

- Rapid disposition
- Reliable data
- Improved input to damage models
- Better feedback to manufacturing

Manufacturing Process & Simulation

- Reduce manufacture development time
- Improve quality control
- Fiber placement and cure process models

- Unable to predict fiber placement & cure induced defects; trial and error iterations
- Part variability
- Rework / redesign

- Fewer iterations
- Fewer defects
- Less redesign
- Shorter time to develop

TC1- Predictive Capabilities

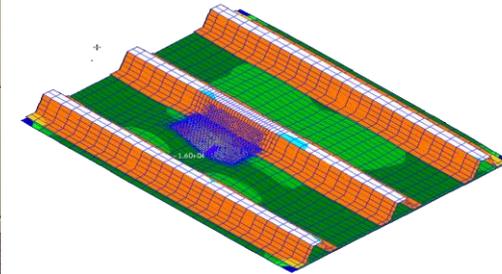


GOAL:

Develop new and improved analytical methods and rapid-design tools to reduce composite structural design cycle time and testing effort by 30% during the development and certification process

APPROACH:

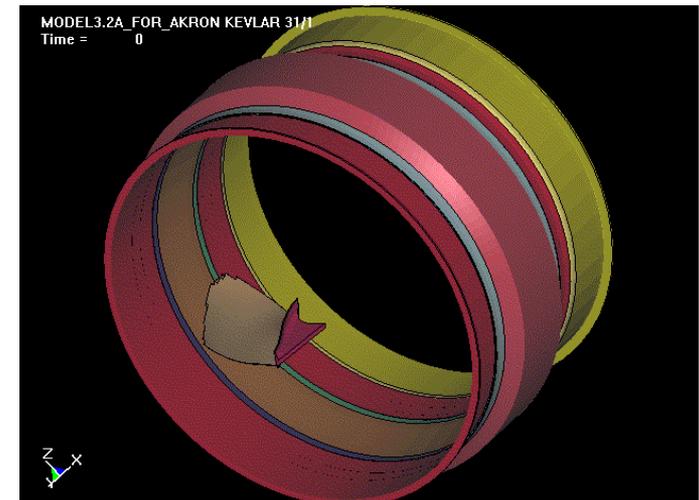
- High Fidelity Analysis Methods
 - Progressive failure analysis for residual static strength of airframe components
 - Transient dynamic failure analysis of engine components
 - Progressive fatigue failure analysis of airframe and dynamic components
- Rapid Design Tools
 - Assess state of the art and gaps
 - Develop new / improved methods



Experiments document damage progression



Validates new improved predictive models



TC2 - Rapid Inspection

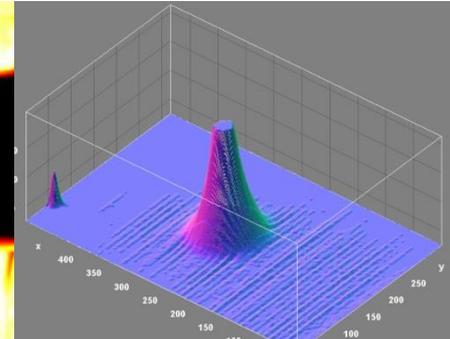
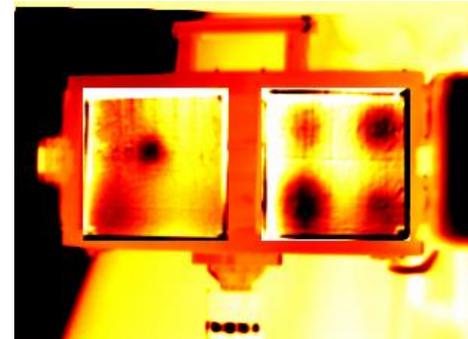
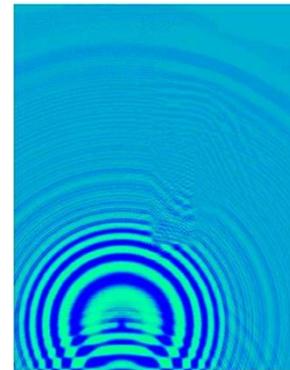
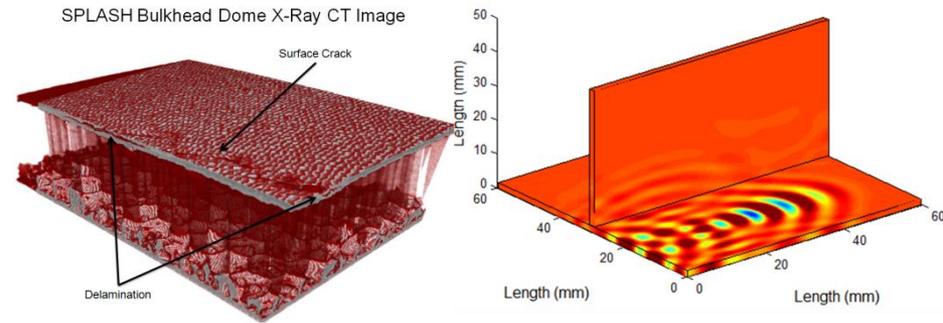


GOAL:

Increase inspection throughput in the major lifecycle phases by 30% through the development of quantitative and practical inspection methods, data managements methods, models, and tools

APPROACH:

- Rapid Quantitative Characterization of Defects
 - SoA assessment for inspection and data interchange
 - Determination of critical defects requiring quantitative characterization
 - Develop validated tools for quantitative characterization
 - Development of data transfer interfaces
- Development of Automated Inspection Techniques
 - Technique identification for automated processes
 - Establish baseline SoA for comparison of improvements
 - Identify and rank candidate tools and analysis methods for automation
 - Develop automated inspection hardware & software tools



TC3 - Enhanced Manufacturing

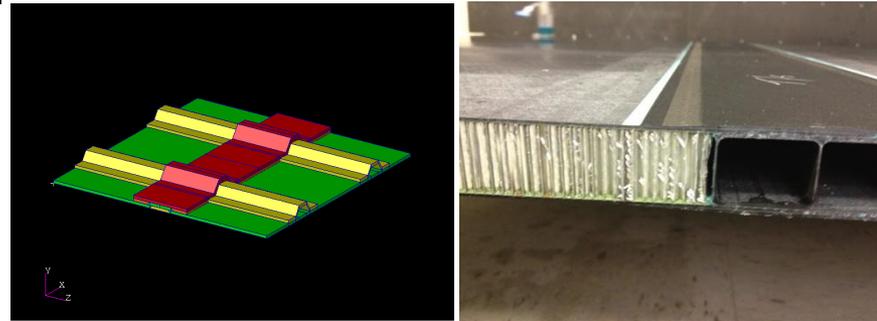
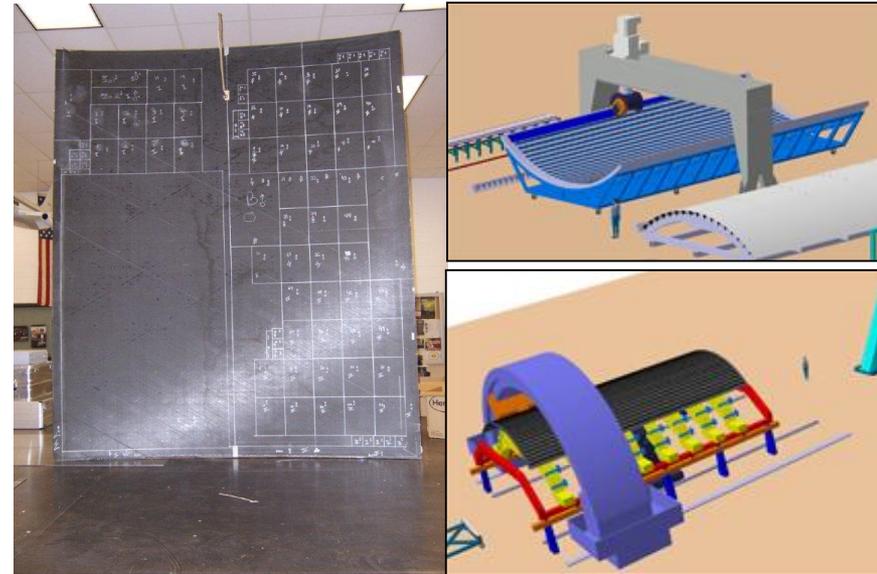


GOAL:

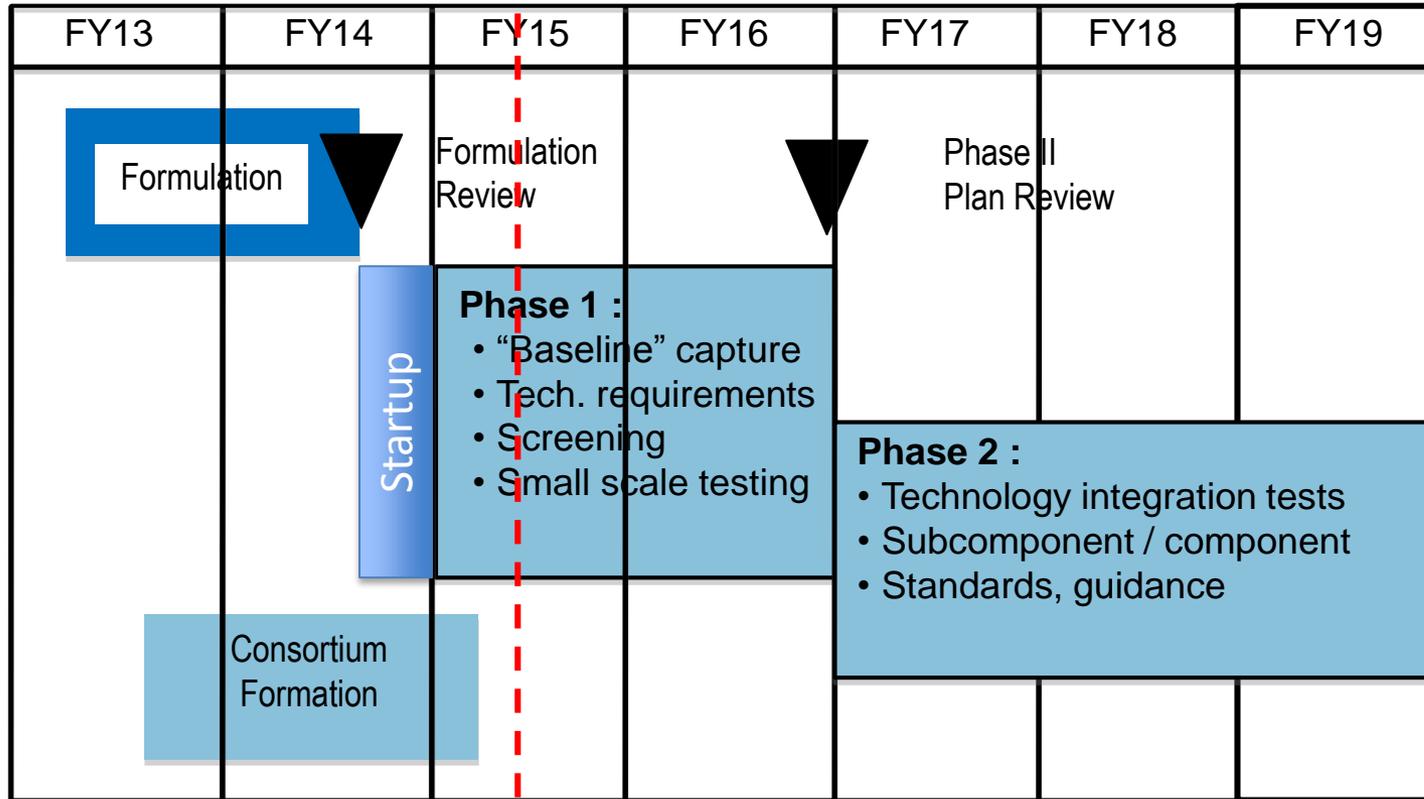
Enhance manufacturing through streamlined automated technologies, better quality control standards, and cure process simulations leading to reduced part changes and fewer design iterations

APPROACH:

- Streamlined Automated Manufacturing Technologies
 - Design for manufacturability (D4M) software
 - Physics-based automated fiber placement (AFP) process models
 - Effects of AFP defects
- Quality control standards for interfaces, joints, and discontinuities
 - Establish process parameters to improve joint reliability
- Cure process modeling
 - Develop physics-based cure process models
 - Determine sensitivity of raw material variation on laminate quality/performance
 - Integrate physics-based AFP and cure process models with D4M software framework to interface fabrication process with design



Advanced Composites Project Flow (Proposed)



ACP Budget	\$25 M	\$25 M	\$28 M	\$29 M	\$25 M	TBD
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Team Approach: NASA and Partners



- Fundamental understanding of the science and physics
- High fidelity analysis and experimental methods
- Independent validation of methods
- Coordination of Working Groups

NASA

- Understanding of requirements
- Design and manufacture; production quality test articles
- Applied research expertise
- Validation testing and data sets
- Development of standard practice

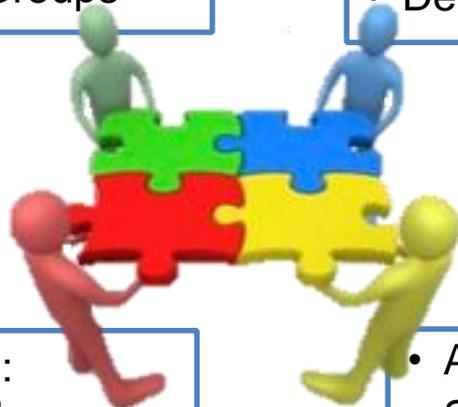
Industry

Academia

- Expertise in fundamentals: supporting damage models, process models, data processing

FAA

- Advice with certification aspects
- Safety implications and practicality in application



ACP Work Approaches

- Advanced Composite Consortium (ACC)
 - Large tier 1 OEM Partners
 - Smaller tier 2 partners
 - Analysis tool manufacturers, material suppliers
- NASA Research Announcements (NRA)
 - Academia
 - Small aerospace contractors
- In house research
 - NASA civil servants and contractors
 - ISAAC robotic manufacturing



Advanced Composites Consortium (ACC)



- ACC formation complete, Jan. 2015
- Founding members:
 - NASA, FAA, Boeing, GE Aviation, Lockheed Martin, United Technologies Corp., National Institute of Aerospace (Integrator)
- Other members to be added
- 50/50 cost sharing
- Collaborative research tasks with multiple partner teams

Executive Steering Committee



Technical Oversight Committee



Cooperative Research Teams



- Shared vision
- High gov't value
- Data / Inventions shared by performing members
- Leverage resources
- Real issues

Conclusions



- Improvements in use and application of composite structures are of significant interest to NASA
 - Exploration: SLS Fairing and EUS.
 - Aeronautics: ACP work on predictive capabilities, inspection, and manufacturing
- Certification processes are a major focus area
- A CEUS project goal is to improve NASA's procedures for certification of man-rated launch vehicle structures.
- ACP project goal is to improve tools and procedures to produce 30% improvement in time to certification for composites on commercial aircraft.

