

Advanced Composite Tow-Steered Structures Research At NASA Langley

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Purdue cdmHUB Visit to NASA
Hampton, Virginia
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Presentation Outline

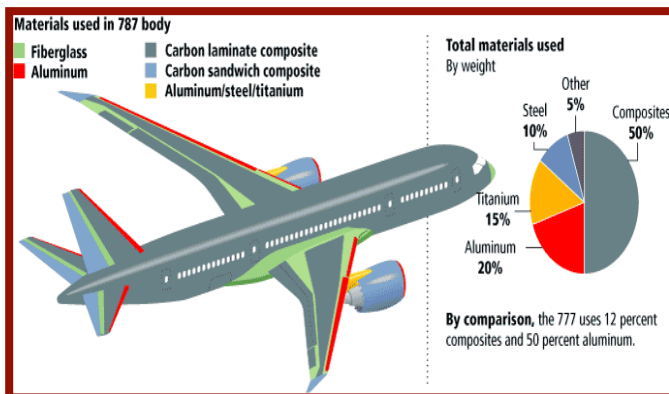


- **Motivating factors**
 - National, NASA, LaRC
- **Composite Cryotank**
- **ISAAC description and capabilities**
- **Operational timeline**
- **Tow-steered composite structures**
- **Concluding remarks**



Composites Manufacturing Supports Agency and National Needs

- Supports all Mission Directorates: Aeronautics Research, Science, Human Exploration and Operations, Space Technology
- Supports Advanced Manufacturing National Initiative, and National Network for Manufacturing Innovation
- Other Government Agencies: DOD, DARPA, DOE
- Identified in NASA's Space Technology roadmap TA12 (lightweight materials and structures among the highest priorities identified by NRC)
- Spans multiple Centers and disciplines
- Industry and Research community



Composite Cryotank

- **Point design built by Boeing**
- **Large, mostly unexplored, trade space of design and process variables**
 - Laminate optimization
 - Mechanical joints
 - Material out-life studies
 - Material development, selection & evaluation
 - Out-of-autoclave materials
 - Thin-ply materials
 - Access points
 - Tank penetrations
 - Bonding
 - Softening strip development
- **Need better understanding of entire trade space**
- **Be a smarter buyer and a more effective, more relevant partner to the entire Aerospace Industry – not just Boeing**
- **Make smarter investments in advanced composite systems – leverage knowledge for future projects**



Scope: Material Process Development, Coupon & Joint Testing

- ARES I: > \$5M
- CCTD Phase I: > \$3 M
- CCTD Phase II:
 - Boeing: > \$2.4M
 - CS FTE: 3
 - NASA WYE: 1



Integrated Structural Assembly Of Advanced Composites

A Multi-Center Plan

“A Pending Explosion of Composites Use”



- **The Fiber Placement Robot is a key platform to achieve goals and meet challenges in composites technology**
- **Multiple Center participation – Centers contribute what they do really well**
- **Equipment at both LARC and MSFC**
 - Low- to mid-TRL Materials and Structures at LARC
 - Mid- to high-TRL Manufacturing Development at MSFC
 - GRC and others supplement with materials capability
 - Cost is comparable with other capabilities – SEM/TEM's, additive manufacturing, large mechanical test frames
- **Also allows improved collaboration with Industry and Academia to advance technology**
- **Performs advanced composite work that spans the entire TRL/MRL range**
- **Brings an advanced composite collaborative R&D hub to Agency**
- **Fosters closer ties between researchers, engineers, and manufacturing personnel**

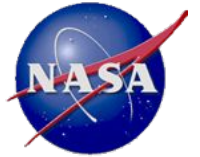
Enables a revolutionary science-based, digitally integrated approach to design, manufacturing, and certification



Integrated Structural Assembly Of Advanced Composites

NASA Capability

“Extraordinary Platform for Composites Manufacturing”



- Mature, highly flexible, automated composites manufacturing capability
- Appropriate scale for research activities and support of NASA missions
- Great opportunity to establish NASA leadership role in composites
- Opportunity for Government and Industry stronger collaboration
- Top training ground for young talent
 - hands-on exposure/experience
- Goals: innovation, leadership, collaboration, competitiveness



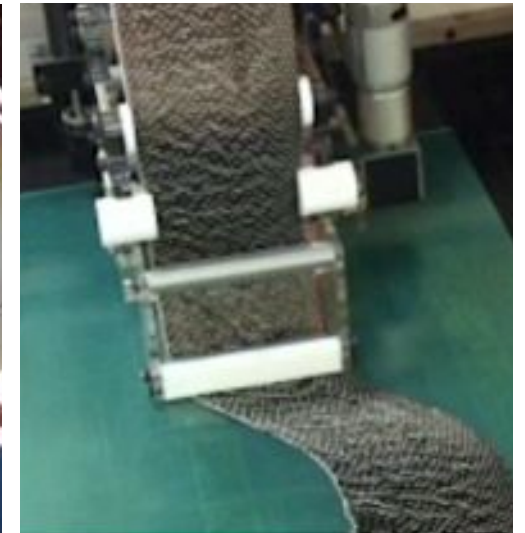
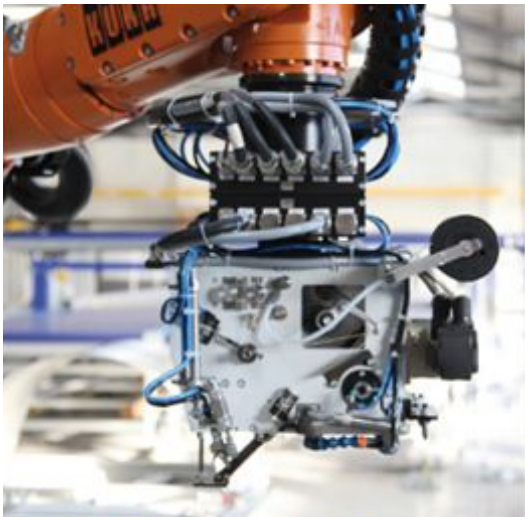
*To greatly increase our understanding
of composites*



Integrated Structural Assembly Of Advanced Composites

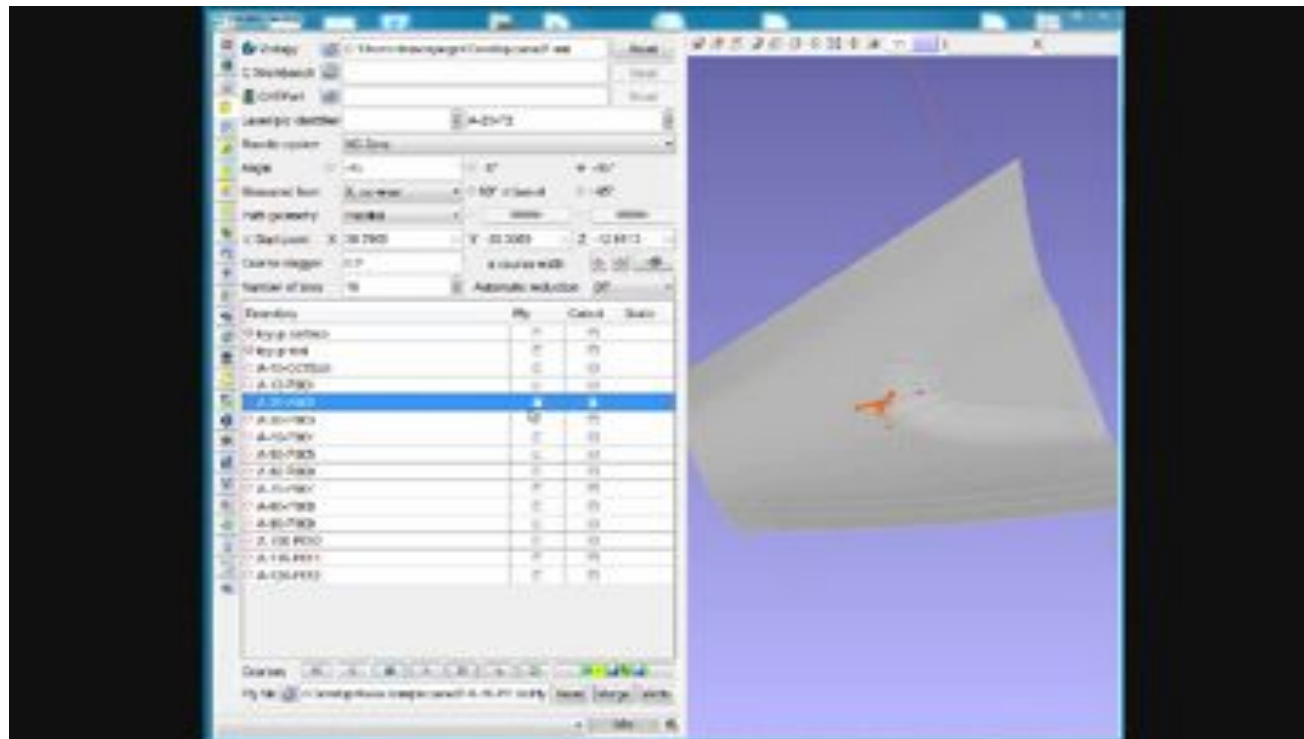
LaRC Vision for Advanced Manufacturing

Integrated Structural Assembly of Advanced Composites (ISAAC)



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

- Parametric, feature-based modeling with bidirectional associativity
 - No commitment until tooling is fabricated
 - More relevant trade studies
 - Faster design-analysis-DFM cycles





Integrated Structural Assembly Of Advanced Composites

Integrated Research Across TRL Spectrum



TRL 1-3

Develop
New Resins
and Fibers

Pre-Pregging of
Composite Tows

Develop Advanced
Manufacturing and
and NDE Processes



(Baseline ISAAC shown)

TRL 4-6

Design and Manufacture of
Composite Structures

Fabrication of
Flight Vehicle
Structures

TRL 7+

Testing and Analyses of
Composite Structures

Post-Cure, In-Situ NDE
of Composite Structures



Integrated Structural Assembly Of Advanced Composites

Operational Timeline



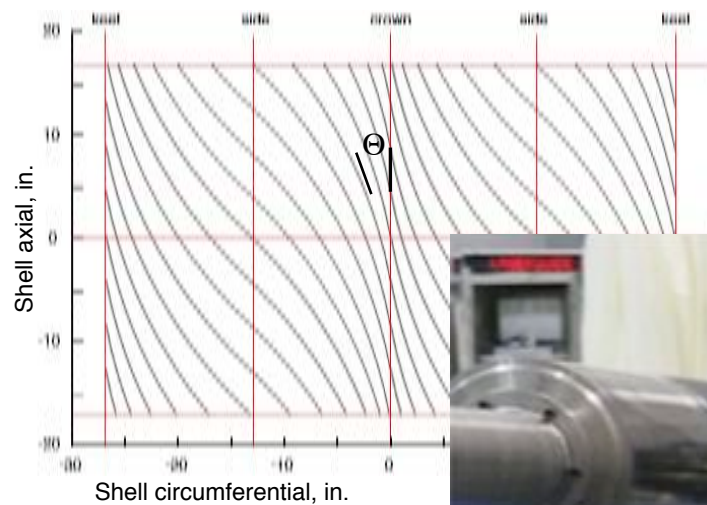
- **Facility Mods: May-August 2014**
- **Robot AFP System Verification: August 2014**
- **Delivery to LaRC: September 2014**
- **On-Site Install/Integration: Sept-Dec 2014**
- **Integrated System Review (ISR): Dec. 2014**
- **Begin project work: Feb. 2015**



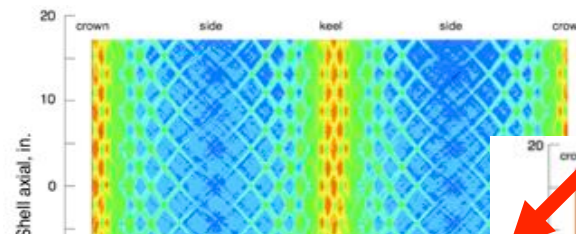
Tow-Steered Composites Overview

- In conventional laminates, all fibers in a given ply are straight and parallel with a given orientation; structural tailoring achieved by varying the number of plies and orientations (typically fixed to 0, ± 45 and 90 deg.)
- In tow-steered (a.k.a. *variable stiffness*) composites, the fiber orientation *within each ply* can vary continuously over the structure's planform
- Provide new opportunities for optimized designs by tailoring structural load paths, thermal and mechanical properties, and damage tolerance
- Fiber placement systems that can precisely and accurately steer composite tows during manufacture are enabling technology for cost-effective fabrication of highly tailored structures

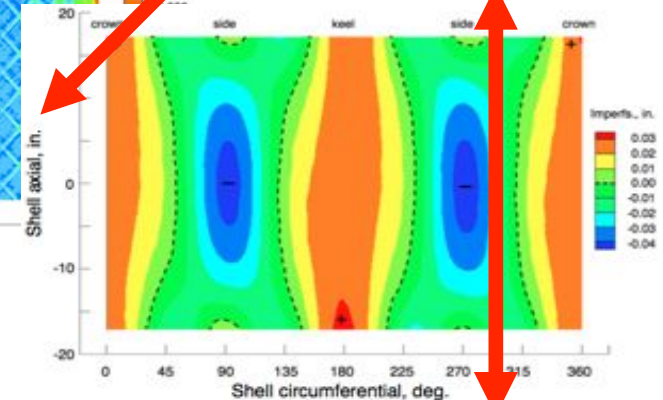
ACTSS Design-Build-Analysis-Test



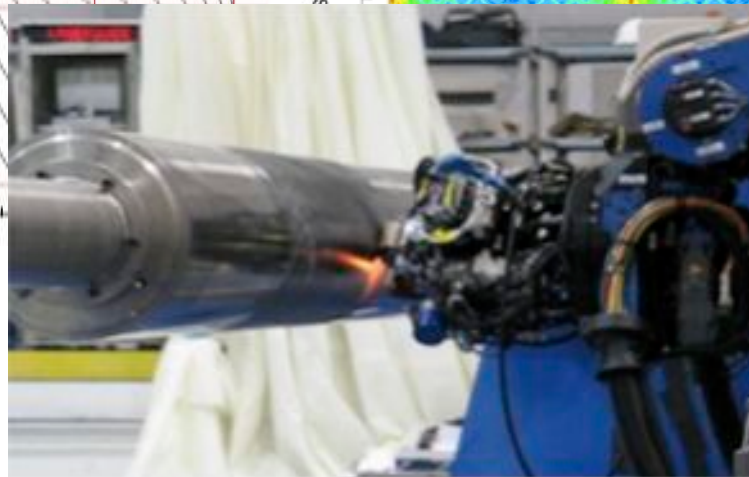
**Structural Concepts,
Design and
Analyses**



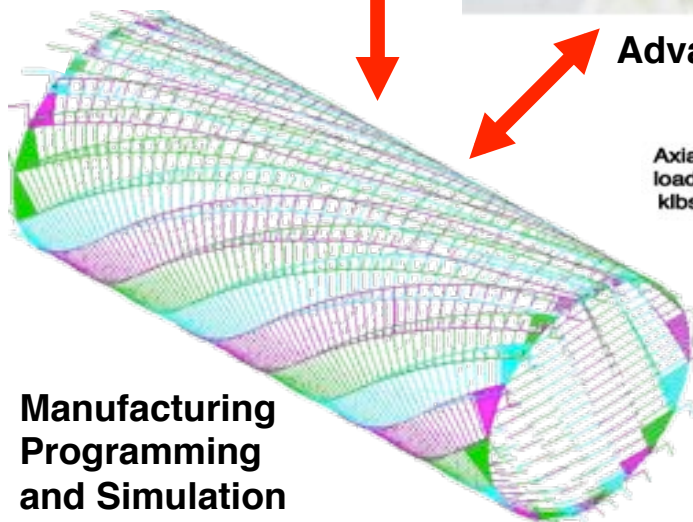
**Characterization of
As-Built Structures**



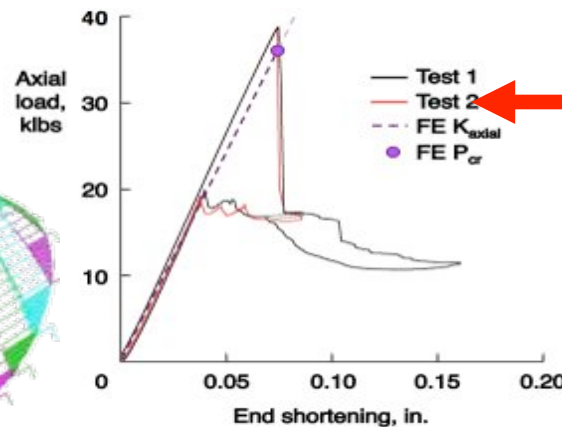
**Structural Analyses
with Nonlinearities**



Advanced Manufacturing



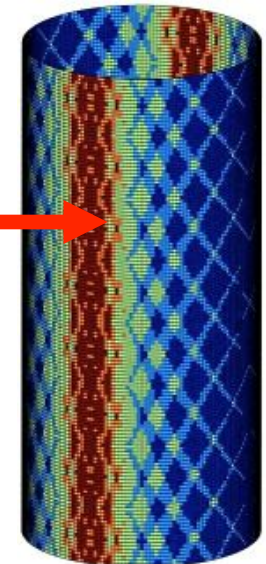
**Manufacturing
Programming
and Simulation**



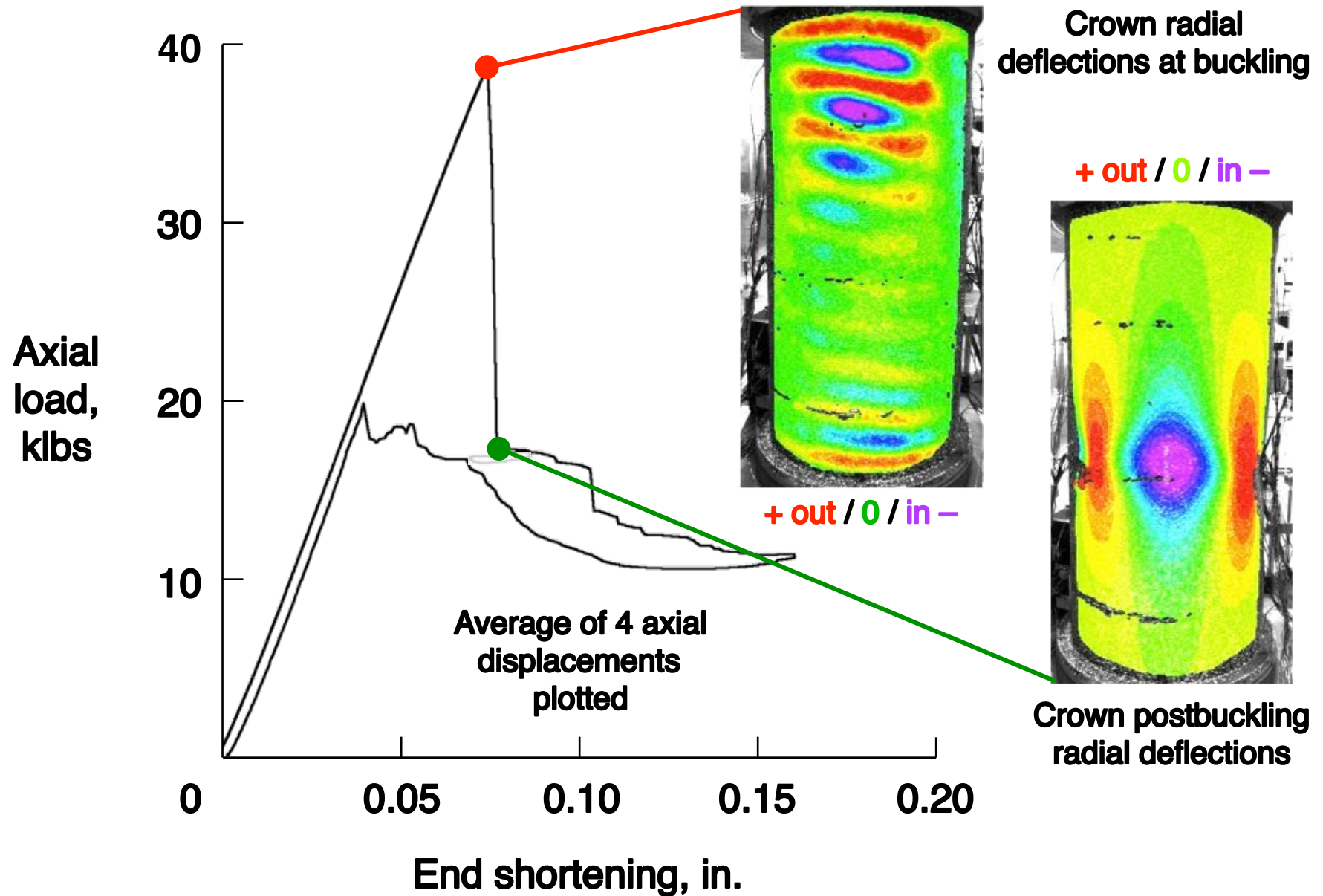
Test-Analysis Correlation



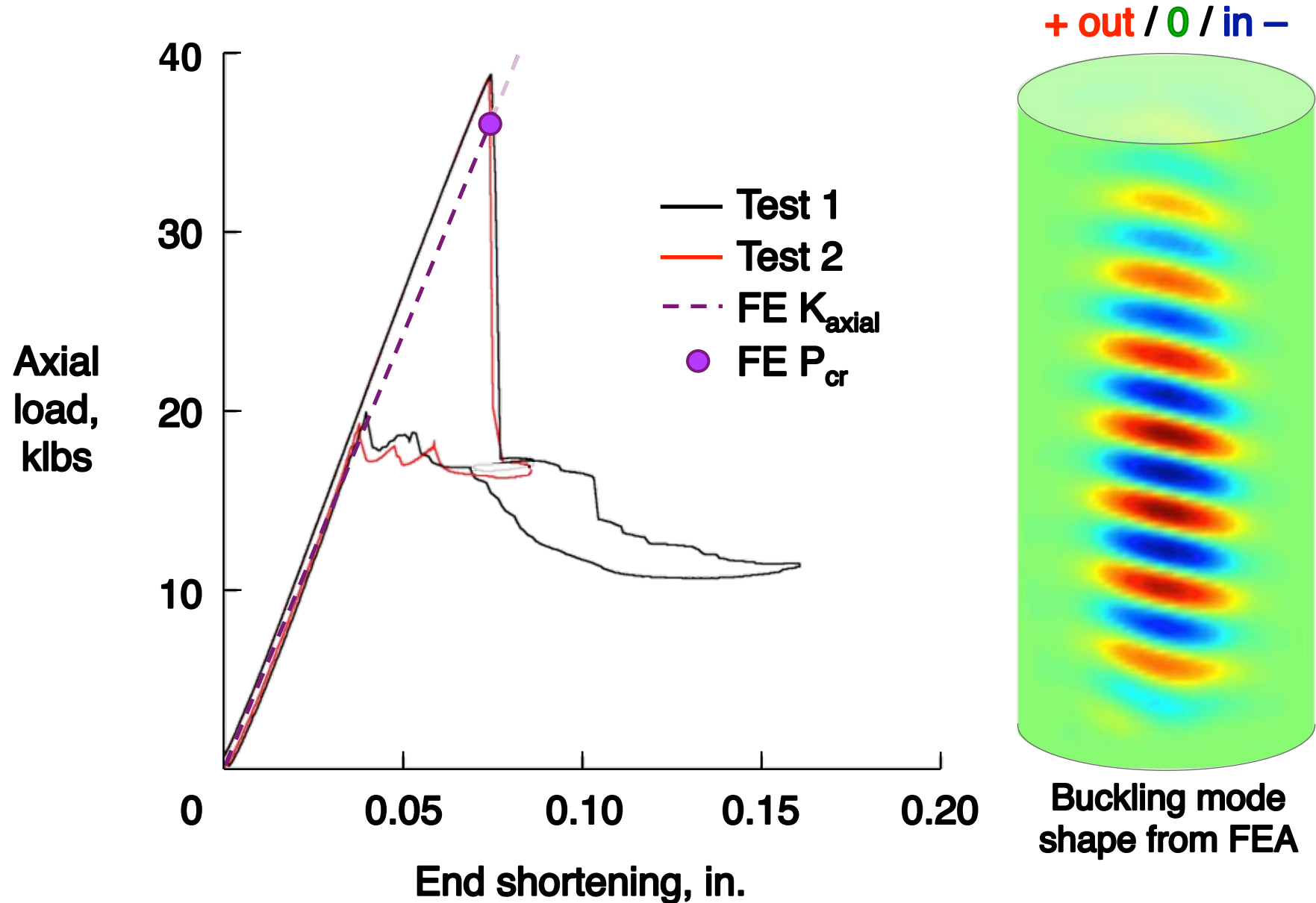
Testing



Shell With Overlaps Test Results

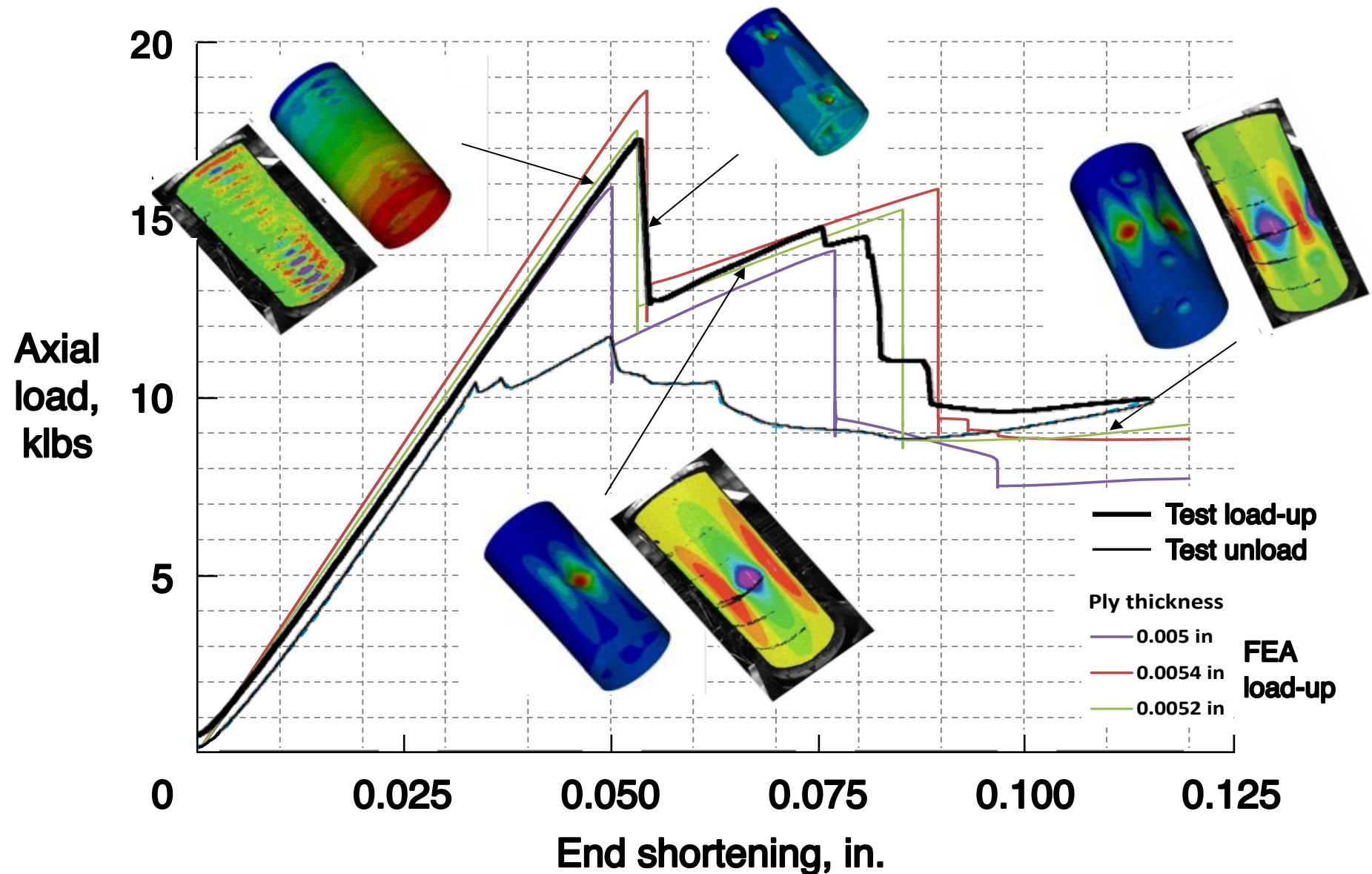


Shell With Overlaps Test And FEA

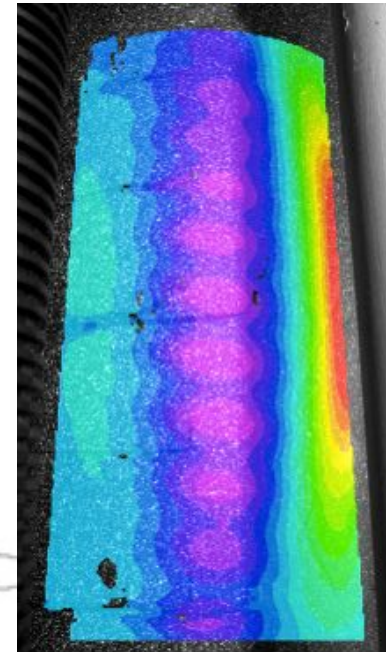
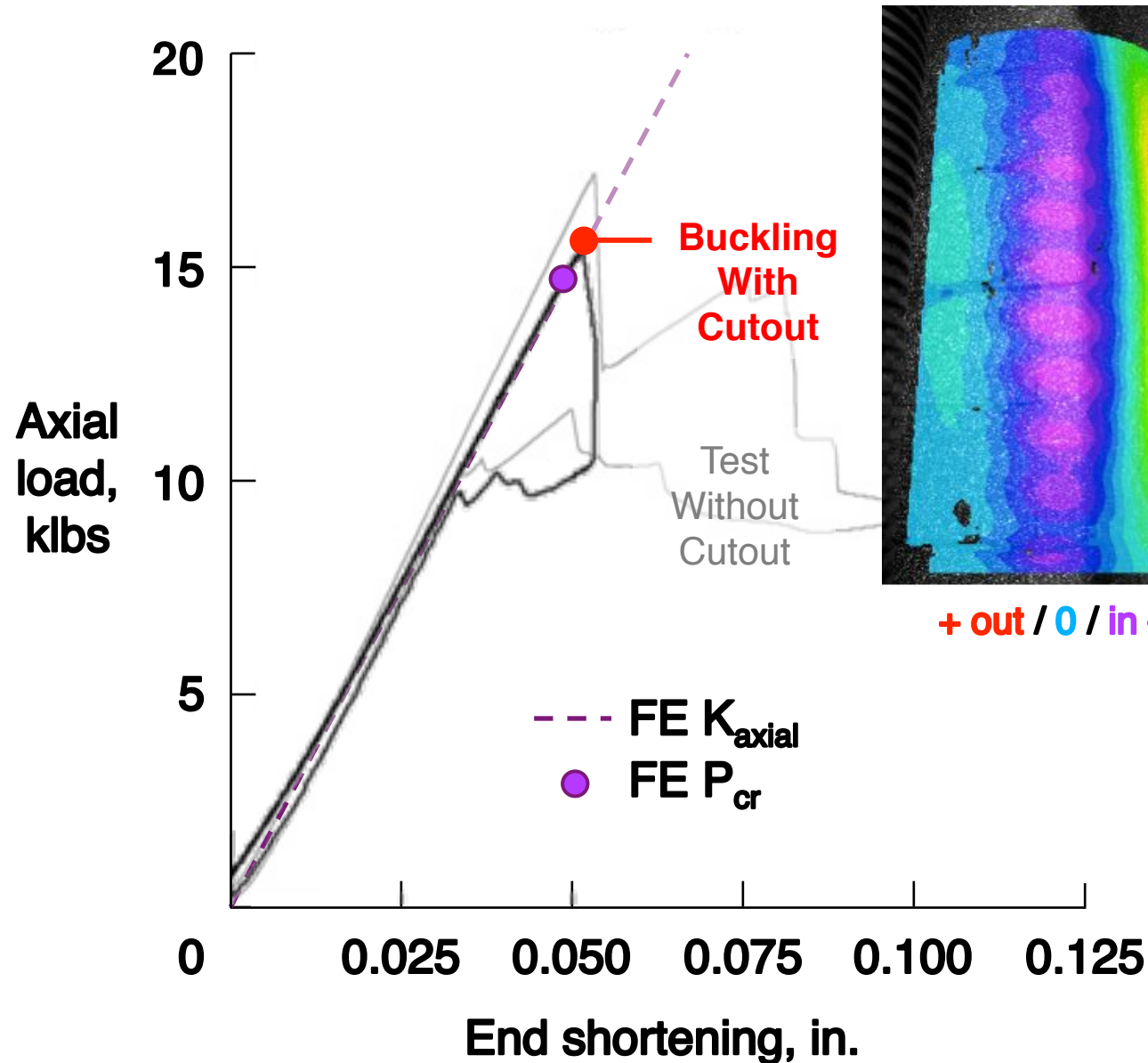


Shell w/o Overlaps Test And Geom. NL FEA

Simon White and Paul Weaver, University of Bristol

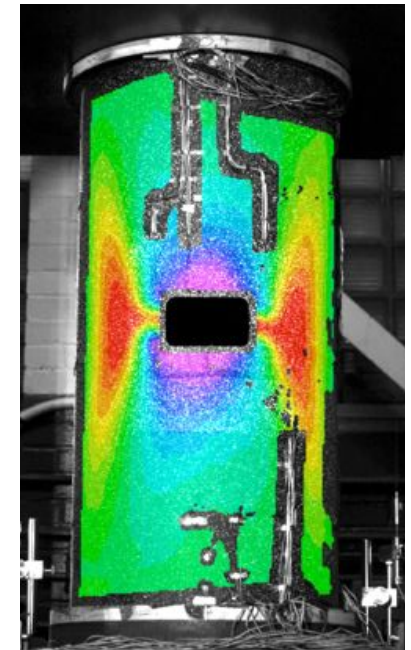


Shell w/o Overlaps w/ Cutout Test And FEA



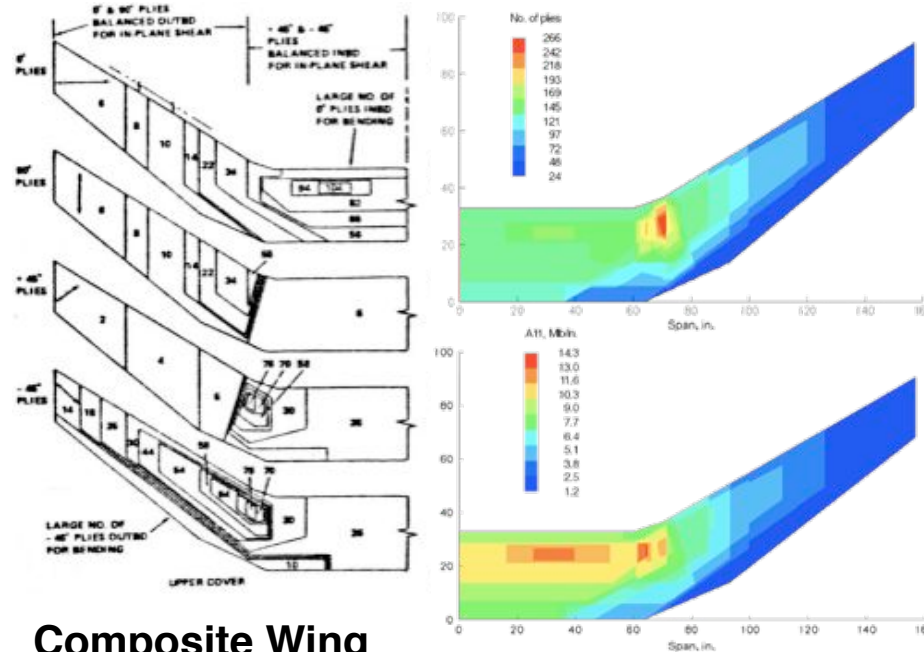
Prebuckling crown radial deflections

+ out / 0 / in -



Prebuckling side radial deflections

Proposed Tow-Steered Aerostructures



Composite Wing

Aeroelastically Tailored Wind Tunnel Model



Composite Wind Tunnel Blade

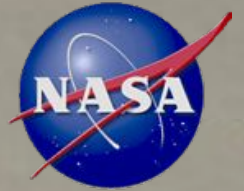




Concluding Remarks

- Tow-steered composite structures show significant performance improvements over conventional, straight-fiber composites, offering potential for major weight savings on primary structures
- Efficient design techniques for tow-steered composites are still a fertile research area. However, industry acceptance of tow-steered composites is still an open issue (e.g., FAA certification)
- The ISAAC system will enable the full TRL spectrum of advanced composites research at NASA Langley, from materials to flight structures

An Advanced Composites Capability For NASA



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of Advanced Composites**
NASA Langley Research Center

