Lessons Learned from Large-Scale Aerospace Structural Testing

Andrew E. Lovejoy, Dawn C. Jegley, Mark W. Hilburger and Adam Przekop

Structural Mechanics and Concepts Branch

NASA Langley Research Center, Hampton, VA

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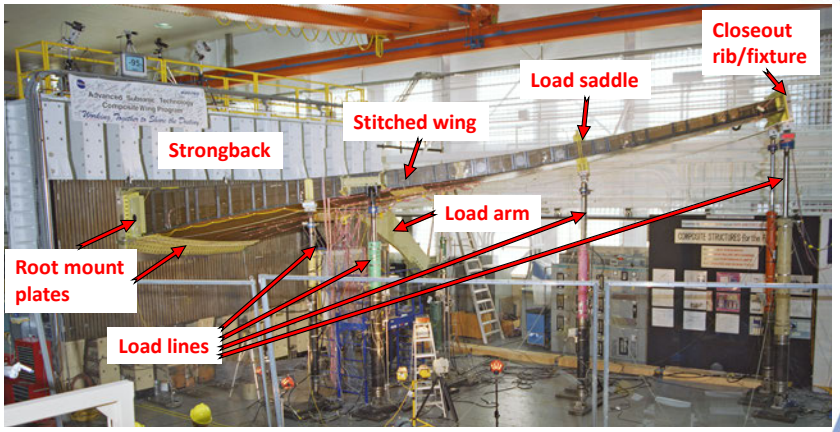
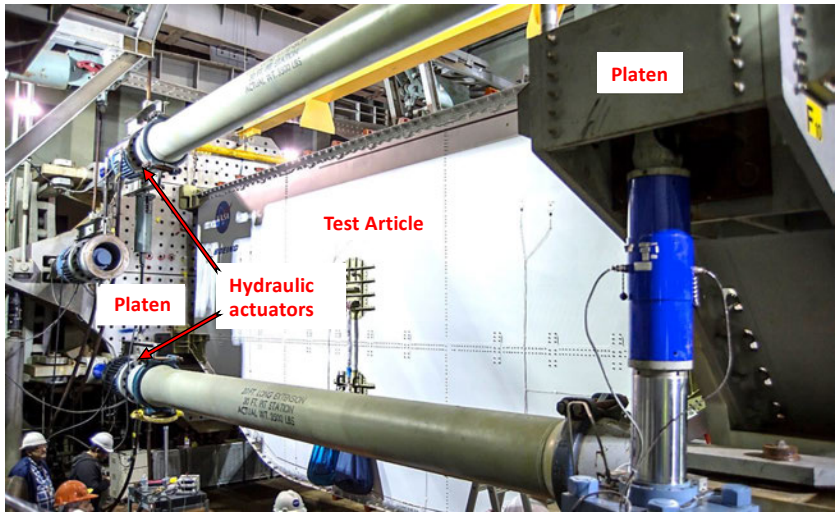
Introduction

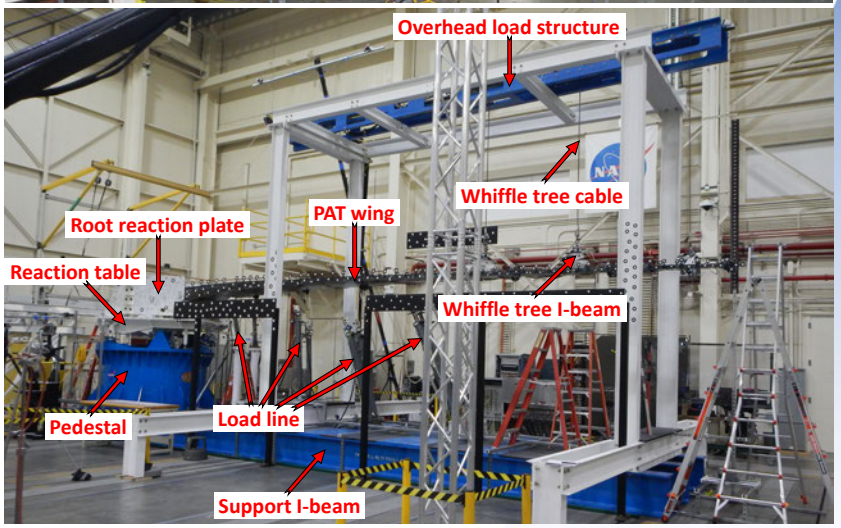
- **Large-scale testing of representative aerospace structures is used to validate performance**
  - A building-block approach is commonly used leading to the large-scale testing
  - Is the culmination of years of research and development
  - Is used when the proper full-scale response cannot easily be represented by smaller scale testing
    - Particularly true for composite structures where scaled testing is typically not easily accomplished
- **This presentation describes lessons learned from large-scale structural testing by researchers at the NASA Langley Research Center (LaRC), NASA Marshall Space Flight Center (MSFC), and NASA Armstrong Flight Research Center (AFRC)**

Large-scale Composite Tests

- Stitched Composite Wing
- Passive Aeroelastic Tailored Wing
- Blended Wing Body,
  Multi-bay Box

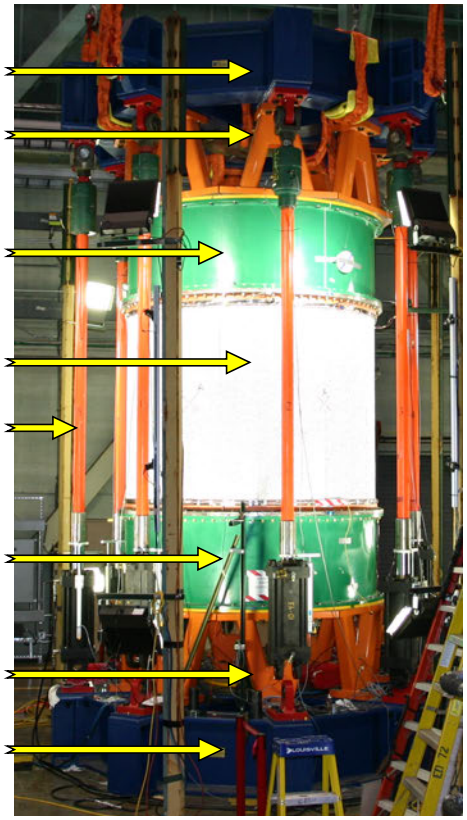




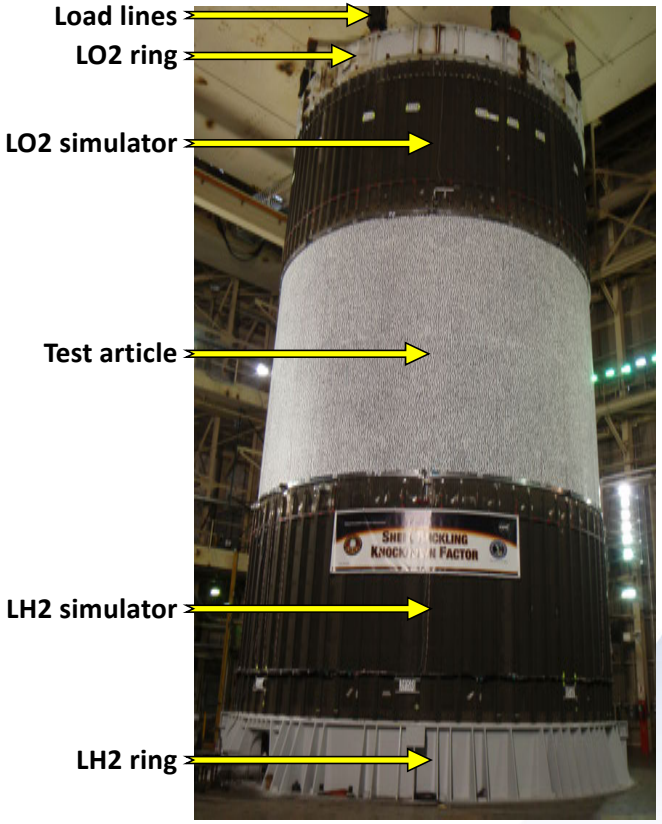


Large-scale Metallic Tests

8-ft Dia. Large-Scale Cylinders



27.5-ft Dia. Full-Scale Cylinders

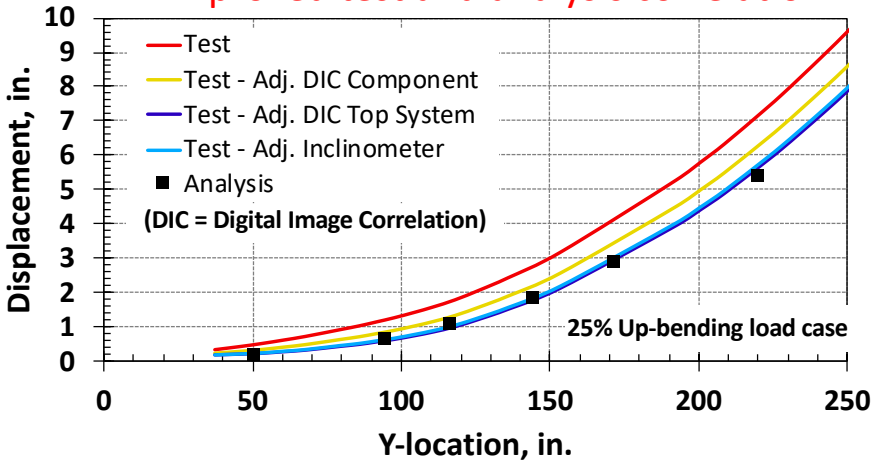


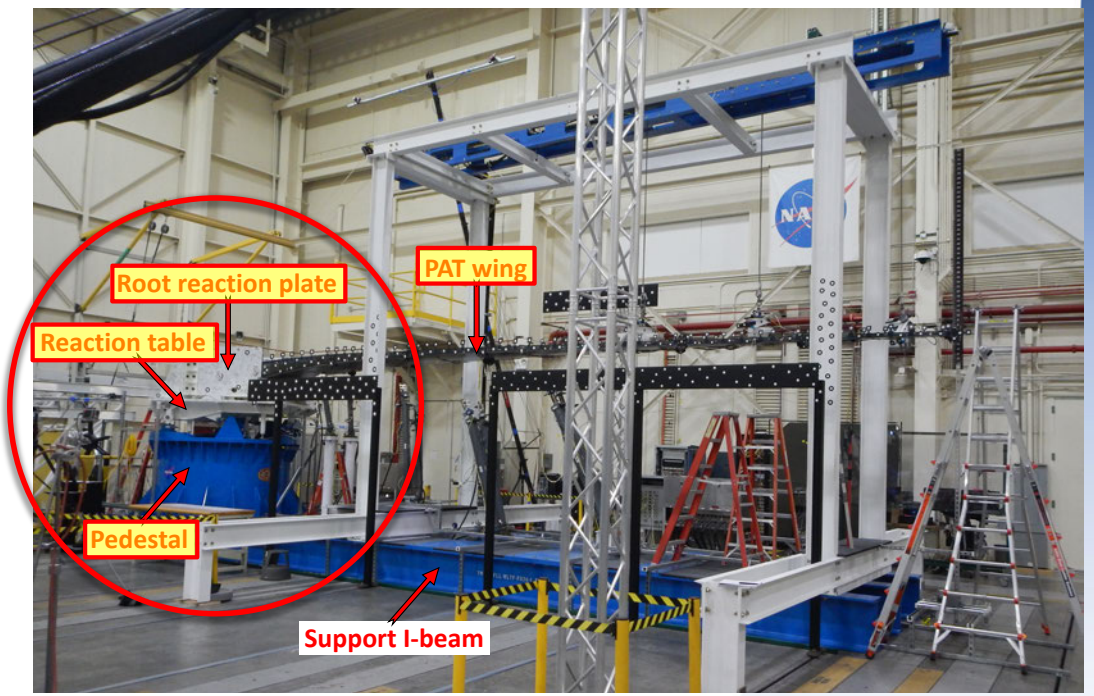
Lesson 1 – Test Analysis

- **Analyze the test configuration using appropriate analysis approaches**
- **Example: Stitched Composite Wing - Load orientation, nonlinear response**
  - Closeout rib/fixture
    - Normal loads developed
    - Introduced bending stresses
  - Load lines modeled
  - Stiffeners added to closeout rib/fixture
    - Relieved bending stresses
    - Ensures fixture does not fail

Lesson 2 – Load Introduction Structure Response

- **Characterization of load introduction structure response is critical to understanding test response**
- **Example: Passive Aeroelastic Tailored Wing**
  - Reaction structure response
    - Rigid body motion
    - Elastic deformation
  - Improved test and analysis correlation



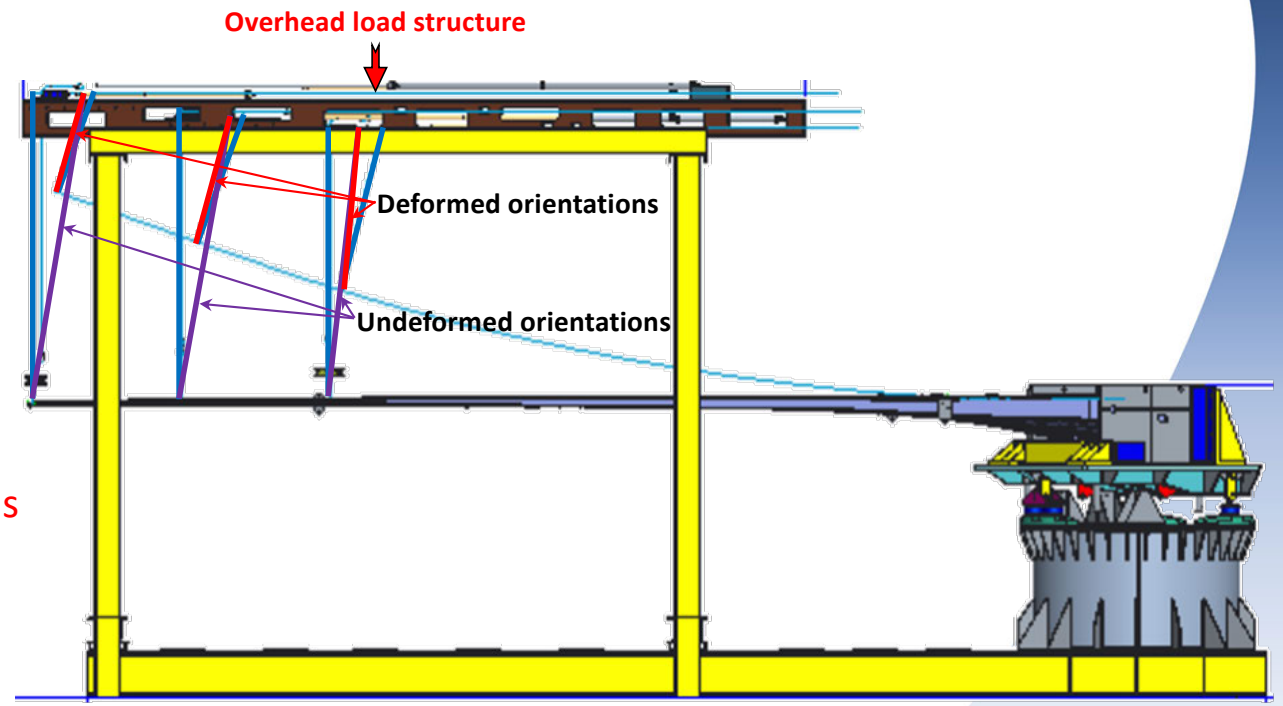


Lesson 3 – Load Application System

- **Design the load application structure with sufficient margin to account for variability in test article predicted response**
- **Example: Passive**

Aeroelastic Tailored Wing

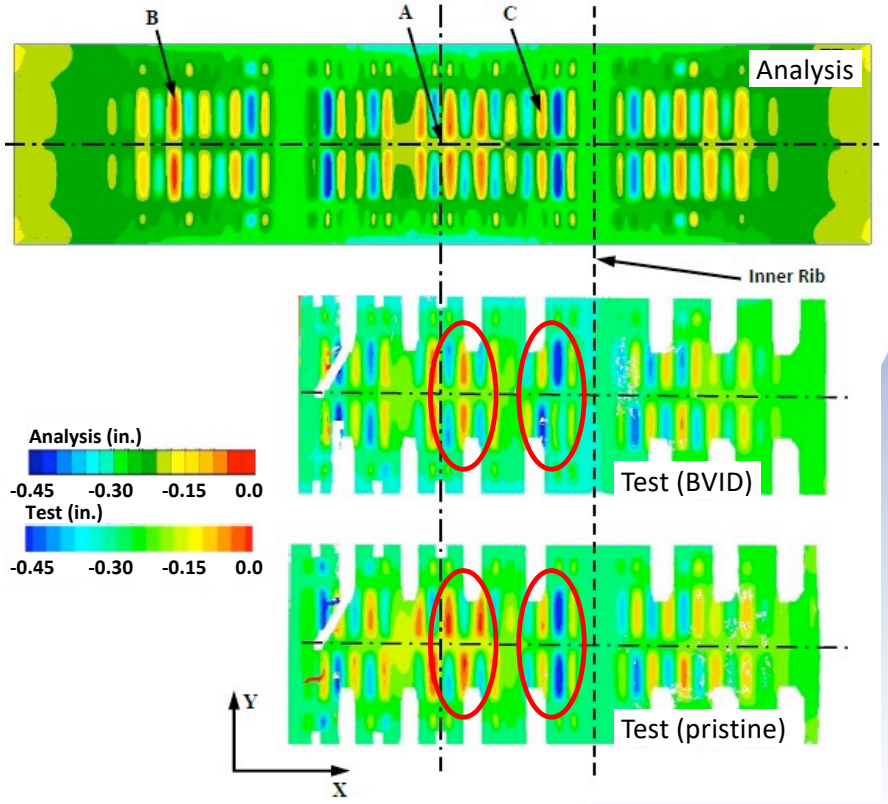
- Overhead load structure
- Designed early in project
  - Insufficient stroke
    - Pully actuator
    - Load actuator
- Unable to apply desired wing loads
  - Normal throughout loading
- Able to incorporate as-loaded orientation for test and analysis correlation



Lesson 4 – Full-Field Response Measurement

- **Full-field response measurements are crucial to understanding response when complex, and potentially nonunique, responses may occur**

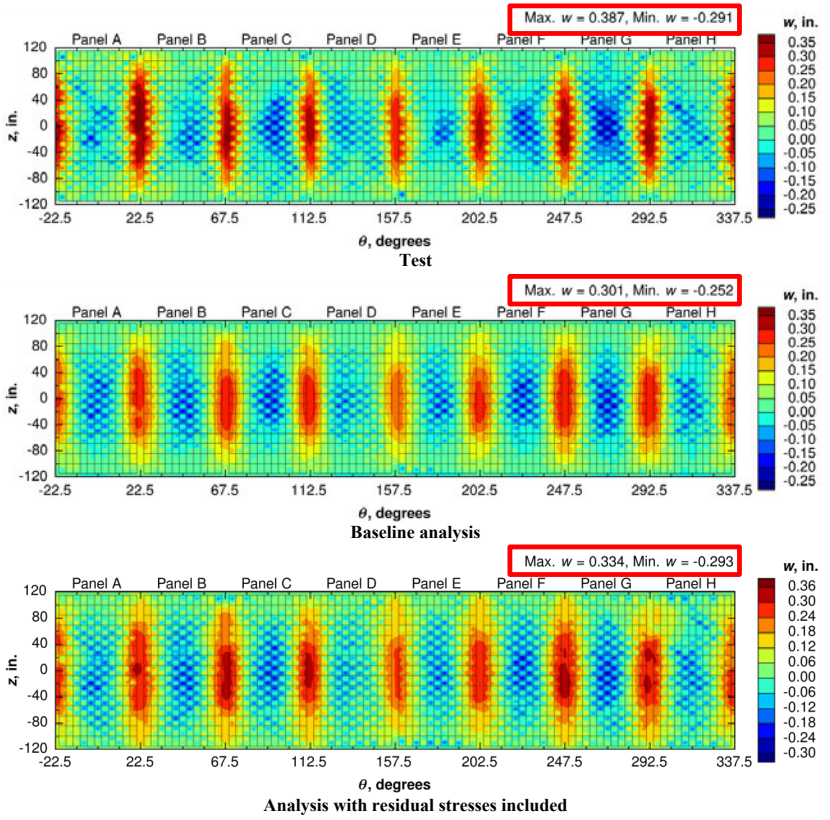
- **Example: Multi-Bay Box**
  - Full-field digital image correlation (DIC)
  - Upper cover multiple stable states
    - Difference between multiple test loadings
      - Pristine
      - Barely visible impact damage (BVID)
    - Multiple solutions with various nonlinear solver input parameters
      - Integration step increment
    - Improved knowledge of test response
      - Improved test and analysis correlation



Lesson 5 – Residual Stresses

- **Residual stresses can have an effect on test article response, and should be included in the analysis whenever possible**

- **Example: Full-scale 27.5-ft dia. metallic barrel**
  - Panel radius 168.0 inches
  - Barrel radius 165.5 inches
  - Residual stresses in forming process
    - Change in radius
      - Small tension in skin
      - Larger compression at top of circumferential stiffeners
    - Welding
  - Improved test and analysis correlation



Summary

- **Five lessons learned were presented**
- **These lessons may seem intuitive, but they can often be ignored when schedule and cost become crucial aspects of a project**
- **Application of these lessons results in successful testing outcomes**
  - Test design and execution
  - Test and analysis correlation
- **Failure to understand and apply these lessons may yield poor results**
  - A test that is unable to obtain the desired data or test results
  - Result in failure to meet project objectives
- **Engineers should always be on the lookout for uncertainties**
  - Effects of modeling assumptions
  - Lack of knowledge when designing and analyzing large-scale structural tests

QUESTIONS?