NASA Dryden Flight Loads Laboratory

Tom Horn
Chief, Aerostructures Branch

NASA Dryden Flight Research Center
Edwards, CA
February 29, 2008
NASA Dryden’s Flight Loads Laboratory

- Proof Loading
- Loads Calibration
- Ground Vibration Testing
- Moment of Inertia
- Strain Gage Installation
- Aerodynamic Heating Simulation
- Thermostructural Testing
- High-Temp Instrumentation
Flight Loads Lab Capabilities and Research Interests
Experienced Engineering and Technical Workforce

- Structural, thermal, & dynamic analysis
  - Finite-element analysis (FEA)
  - Aerodynamic loads analysis (CFD)
  - Flutter analysis
  - Aeroservoelastic analysis (ASE)
  - Aeroheating / heat transfer analysis

- Structural, thermal, & dynamic ground-test techniques
  - Structural loads calibration and equation derivation
  - Proof loads testing
  - Ground vibration and structural mode interaction testing
  - Thermal / structural testing

- Advanced structural instrumentation
  - Strain, temperature, heat flux, deflection, etc.
  - Fiber-optic strain and temperature sensors

- Flight test support
  - Flight test planning
  - Structural and thermal flight data analysis
Flight Loads Lab Capabilities
Overview

- **General Description**
  - A unique laboratory for structural and thermal testing of aerospace structures
  - Large 164’ x 120’ high-bay test area

- **Structural Loading Capabilities**
  - Structural loading equipment including load frames, load cells, and hydraulic actuators
  - 84 channels of hydraulic load control
  - Aircraft ground vibration and structural mode interaction testing

- **Thermal Loading Capabilities**
  - Quartz lamp and graphite element heating
  - Vacuum furnaces, low and high temperature chambers, liquid and gaseous nitrogen supply systems
  - 4000 gal of liquid nitrogen storage for cryogenic testing

- **Structural Evaluation Systems**
  - Infrared Pulsed Thermography for NDE
  - Photogrammetry for Strain and 3D Deformation
  - Acoustic Emission Sensing for Damage Detection

- **Data Acquisition and Control System**
  - 1280 channels of data acquisition
  - 108 channels of thermal control (expandable to 512)
Flight Loads Lab Capabilities

Loads Calibration Testing

- Loads calibration testing of large aircraft and structures
- Application of realistic pressure load distributions
- Derive load equations for real-time determination of in-flight loads
Flight Loads Lab Capabilities
Ground Vibration Testing

- Ground vibration testing of flight vehicles and structures
- Determination of structural mode shapes, natural frequencies and damping
- Supports FEM validation and provides data to update FEM as required
- Soft-support system capable of testing structures up to 60k lbf structure
Flight Loads Lab Capabilities
Combined Thermal / Structural / Cryogenic Loading

- Flight environment can be simulated through cooling, heating and structural load application
- Hydraulic actuators and load cells with capacities up to 300,000 lbf
- Temperature Range: -320°F to >3000°F
  Temperature Rise Rate: $\approx 150^\circ F/sec$ max
  Heating Rate: $\approx 100$ Btu/ft$^2$-sec

Shuttle Elevon Seal Test

Hot Structures Testing

Thermal / Cryo Testing with Mechanical Loading
Flight Loads Lab Capabilities
“Virtual Flight Loads Lab”

• Real-time remote access to data, video and com system

• Customer control of data and video

• 128 bit data encryption

• Maximizes customer participation and reduces need to travel
Flight Loads Lab Capabilities
Photogrammetry for Measuring Strains and 3D Deformations

- Optical technique for measuring strains and spatial deformations
- High-speed cameras for dynamic testing
- Coupon specimens to large aircraft
Flight Loads Lab Capabilities
Non-Destructive Evaluation

- NDE of structural components using Infra-red Pulsed Thermography
- Locates and maps delaminations and porosity
- Locates precise depth of defect
Flight Loads Lab Capabilities
Advanced Structural Instrumentation

• Strain, temperature, heat flux measurements on advanced materials including:
  – Metallics, metal matrix composites, superalloy honeycomb, C/C and C/SiC

• Sensor evaluation and calibration systems
  – Strain sensors from -320°F to 3000°F
  – Temperature sensors from -320°F to 4000°F
  – Heat flux gages to 400 Btu/ft²·sec

• Attachment techniques
  – Epoxy based adhesives
  – Ceramic & graphite cements
  – Plasma and Rokide thermal spraying

• Advanced sensor application research
  – Fiber-optic strain and temperature
  – Ground and flight testing
Ikhana Fiber Optic Flight System

• Current flight system specifications
  – Fiber count 4
  – Max fiber length 40 ft
  – Max sensing length 20 ft
  – Max sensors / fiber 480
  – Total sensors / system 1920
  – Sample rate 2 fibers @ 36 sps
    4 fibers @ 22 sps
  – Power 28VDC @ 4 Amps
  – User Interface Ethernet
  – Weight 23 lbs
  – Size 7.5 x 13 x 13 in

• Environmental qualification specifications
  – Shock 8g
  – Vibration 1.1 g-peak sinusoidal curve
  – Altitude 60kft at -56C for 60 min
  – Temperature -56 < T < 40C
Flight Instrumentation

- Instrumentation
  - 2880 FBG strain sensors (1920 recorded at one time)
  - 1440 FBG sensors per wing
  - Select optimal number of FBG sensors for real-time wing shape sensing
  - 16 strain gages for FBG sensor validation
  - 8 thermocouples for strain sensor error corrections
## Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom Horn</td>
<td>Branch Chief, Aerostructures Branch</td>
<td>661-276-2232</td>
<td><a href="mailto:Thomas.J.Horn@nasa.gov">Thomas.J.Horn@nasa.gov</a></td>
</tr>
<tr>
<td>Larry Hudson</td>
<td>FLL Chief Test Engineer</td>
<td>661-276-3925</td>
<td><a href="mailto:Larry.D.Hudson@nasa.gov">Larry.D.Hudson@nasa.gov</a></td>
</tr>
<tr>
<td>Dr. W. Lance Richards</td>
<td>Group Lead, Advanced Structures &amp; Measurements</td>
<td>661-276-3562</td>
<td><a href="mailto:Lance.Richards@nasa.gov">Lance.Richards@nasa.gov</a></td>
</tr>
<tr>
<td>Larry Schuster</td>
<td>Group Lead, Aero / Structural Loads</td>
<td>661-276-3919</td>
<td><a href="mailto:Larry.Schuster@nasa.gov">Larry.Schuster@nasa.gov</a></td>
</tr>
<tr>
<td>Dr. Chan-Gi Pak</td>
<td>Group Lead, Structural Dynamics</td>
<td>661-276-5698</td>
<td><a href="mailto:Chan-Gi.Pak-1@nasa.gov">Chan-Gi.Pak-1@nasa.gov</a></td>
</tr>
</tbody>
</table>