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: ≈150°F/sec max
  Heating Rate: ≈100 Btu/ft²-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
<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>