



# **NASA Armstrong's Structural Dynamics Testing Capabilities & Testing Facility**

Presented to NASA Reflex User Group  
May 3<sup>rd</sup>, 2017

*Natalie Spivey, NASA AFRC  
Structural Dynamics Group*



# Outline



- NASA Armstrong Flight Research Center (AFRC)
- AeroStructures Branch
- Flight Loads Laboratory
- Structural Dynamics Capabilities
  - Ground Testing Capabilities
  - Analysis Capabilities
  - Flight Flutter Testing Capabilities

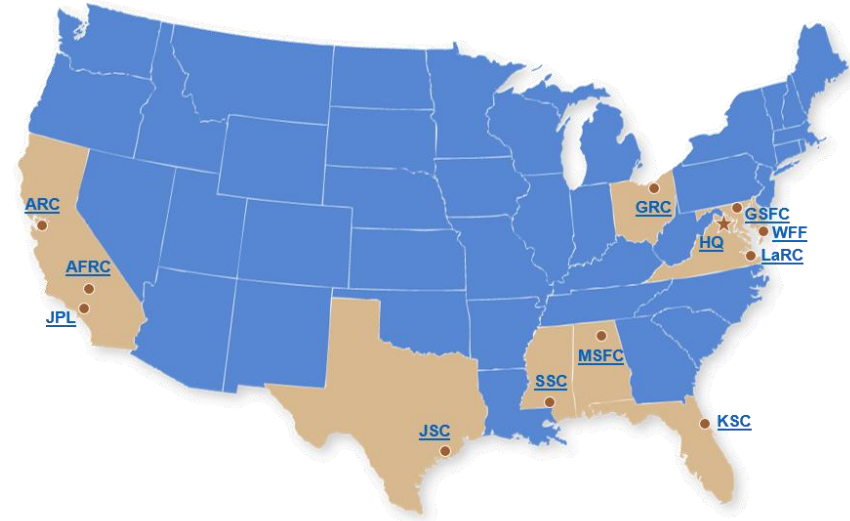


# NASA Centers - NASA Reflex User Group



- NASA Centers

- NASA Headquarters (HQ) - Washington, D.C.
- Ames Research Center (ARC) - Moffett Field, CA
- **Armstrong Flight Research Center (AFRC) - Edwards, CA**
- **Glenn Research Center (GRC) - Lewis Field, OH**
- Jet Propulsion Laboratory (JPL) - Pasadena, CA
- **Johnson Space Center (JSC) - Houston, TX**
- **Kennedy Space Center (KSC) - Cape Canaveral, FL**
- **Langley Research Center (LaRC) - Hampton, VA**
- **Marshall Space Flight Center (MSFC) - Huntsville, AL**
- Stennis Space Center (SSC) - Hancock County, MS



Brüel & Kjær LAN-XI DAQ

- NASA Field Facilities

- **Goddard Space Flight Center (GSFC) - Greenbelt, MD**
- Wallops Flight Facility (WFF) - Wallops Island, VA

5-slot Mainframe



LAN-XI 12-channel  
3053 Module

11-slot Mainframe

Note: **BOLD** text, locations participating in NASA Reflex User Group  
NASA Reflex User Group



# NASA Armstrong Flight Research Center (AFRC) Edwards Air Force Base



- Remote location
- Varied topography
- 350 testable days per year
- Extensive range airspace
- 29,000 ft of concrete runways
- 68 miles of lakebed runways
- 301,000 acres
- Supersonic corridor



# What Does AFRC Do?

- Pushes the boundaries of flight through research & testing

- Aviation: Perform flight research & technology integration to revolutionize aviation and pioneer aerospace technology
- Spaceflight: Validate space exploration concepts
- Earth science: Conduct airborne remote sensing & science observations

F/A-18



ER-2 Science Platform



F-15A/D

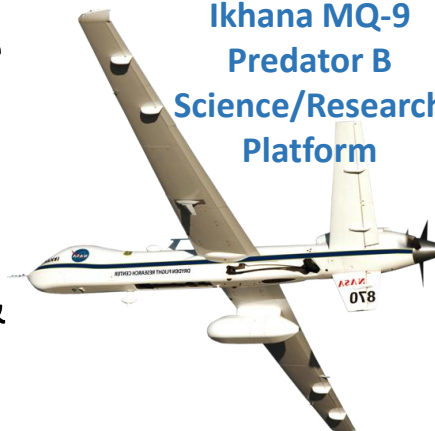


Stratospheric Observatory for Infrared Astronomy (SOFIA)



Ikhana MQ-9

Predator B Science/Research Platform



C-20A & GIII



DC-8 Science Platform

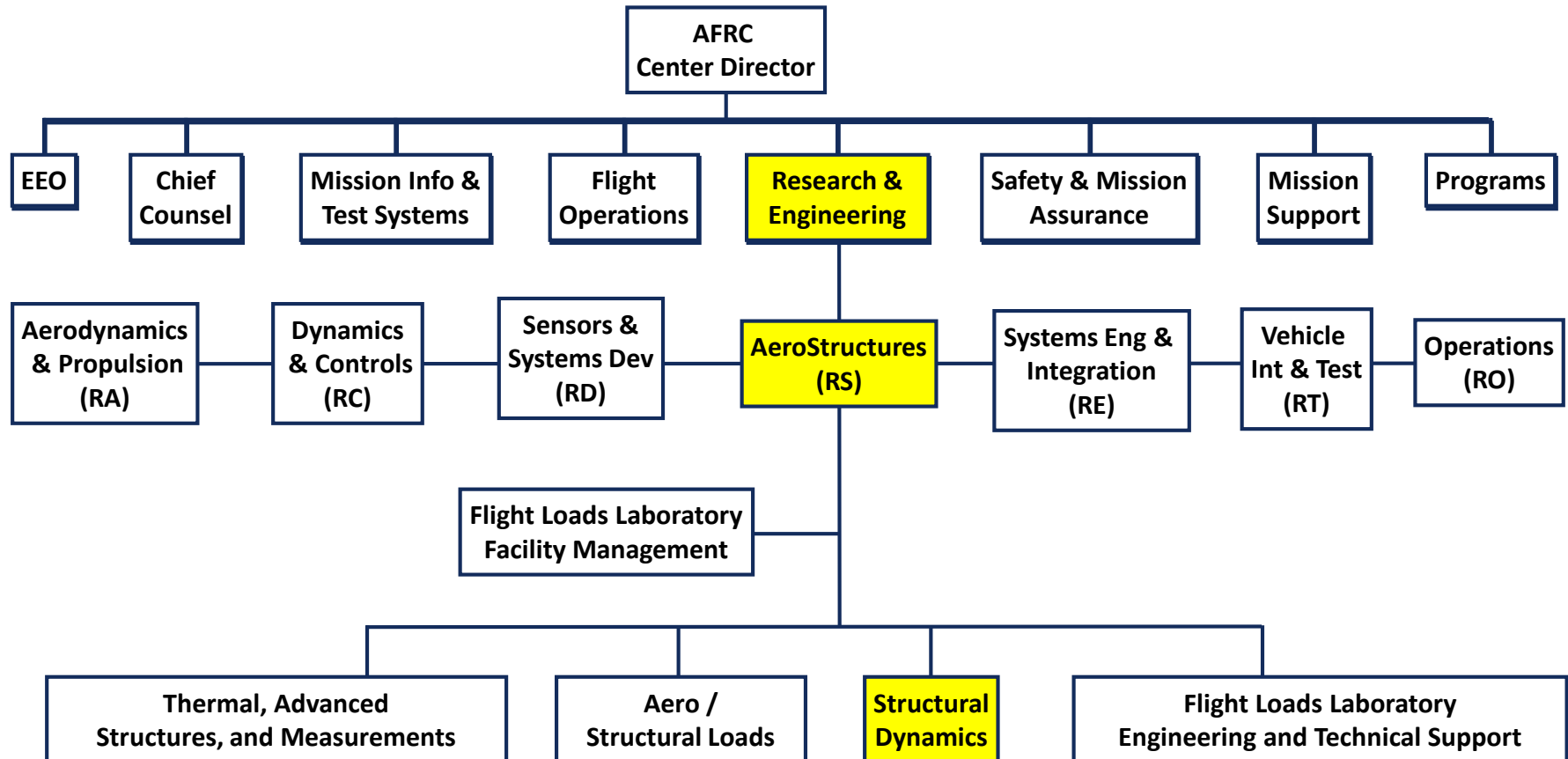


Global Hawk RQ-4 Science Platform





# NASA AFRC Organizational Chart





# AeroStructures Branch (RS)



- Primary efforts are Airworthiness & Research
- Airworthiness
  - Loads: External loads; Inertial loads; Store loads; Structural deflections; FEA; Stress analysis; Airframe modification evaluation; Structural design; Loads calibrations; Proof load testing; Functional testing under load; Thermal/mechanical instrumentation; Flight-test support; Envelope expansion
  - Dynamics: Modal analysis; Flutter analysis; Ground Vibration Testing (GVT); FEM model tuning; Mass property testing; Structural mode Interaction (SMI) or Structural Coupling Test (SCT); Dynamics flight-test support; Envelope expansion
  - Thermal, Advanced Structures, and Measurements: Heat transfer; Thermal stress; Thermal protection systems/methods; Instrumentation application/installation
  - FLL: Ground test execution; Test design; Non-Destructive Evaluation (NDE)
- Research
  - Loads: Loads calibration techniques; Fiber Optic Strain Sensing (FOSS) applications; Testing of advanced structural concepts; Aero-tow
  - Dynamics: GVT methods; mass property testing methods; Improved flutter flight-test techniques; Multidisciplinary Design, Analysis, and Optimization (MDAO) tool development; Passive/active control analysis/design of flexible structures (multi-discipline); Operational Modal Analysis (OMA); Aeroservoelastic (ASE) systems modeling, analyses, and tool development; Elevated-temperature modal test and analysis
  - Thermal, Advanced Structures, and Measurements: Hot structures test techniques; Hot structures design; Thermal coatings; Thermal protection system (TPS) development; Pyrometry; Shape memory alloys (SMAs) for aerospace applications; Elastomer aerospace applications; Frangible joint evaluations (NESC); Instrumentation application; FOSS applications; Non-contact strain and temperature measurement; High temperature instrumentation development; Composites M&P
  - FLL: Thermal/mechanical testing and analysis

- Structures, dynamics, and thermal component and airframe qualification (airworthiness) and research

## FLL Test Capabilities

- Proof loading, load calibrations, deflection tests, control surface proof of operations, loads flight test
- Modal test, flutter test, ASE test, freeplay test, mass properties tests
- Thermal and thermal-mechanical test, TPS development and test, pyrometry, SMAs, elastomer aerospace applications, frangible joint evaluations
- Conventional, high temperature, and advanced instrumentation (e.g. FOSS)



**Proof Loading**



**Loads Calibration**



**Ground Vibration Testing**



**Moment of Inertia**



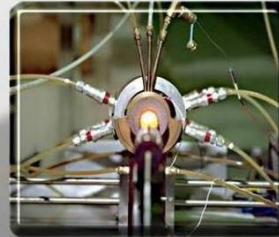
**Strain Gage Installation**



**Aerodynamic Heating Simulation**



**Thermostructural Testing**



**High-Temp Instrumentation**





# Structural Dynamics Capabilities



- Mission
  - Conduct aeroelastic research and demonstrate the flutter airworthiness of aircraft / flight test articles by verifying required margins for aeroelastic and aeroservoelastic instabilities
- How
  - By providing structural dynamics ground testing, analysis and flight monitoring experience and capabilities
- Capabilities
  - Ground Testing
    - Ground Vibration Test (GVT)
    - Mass Property Test
    - Structural Mode Interaction Test (SMI)
  - Analysis
    - Modal Analysis
    - Aeroelastic Modeling, Analyses, and Tool Development
    - Multidisciplinary Design, Analysis, and Optimization Tool Development
    - Active Flexible Motion Control and Aeroservoelastic Systems Modeling, Analyses & Tool Development
    - Unsteady CFD
  - Flight Flutter Testing
    - Flight Monitoring
    - Flight Test Planning, Data Analysis and Evaluation

- Ground Testing
  - Ground Vibration Test (GVT)
  - Mass Property Test
  - Structural Mode Interaction (SMI) Test
- Supporting Hardware
  - Test Support Stand/Fixtures
    - Swing Set, 20k-lbs capacity
    - Erector Set
    - Lifting Fixtures
    - Load Rated Floor Tracks
  - Instrumentation
    - Two GVT data acquisition systems (VXI & LAN-XI) ~340 channels each
    - Wide range of accels & force transducers
    - Wide range of load cells and position measurement sensors
    - Non-contact measurement systems
  - Excitation
    - Shakers, 7-500 lbs peak-to-peak
    - Impact hammers
  - Soft Supports
    - Overhead systems, from light to 14k lbs
    - System for aircraft jacks, 60k-lbs capacity Soft Support System (SSS)
    - Customized designs
  - Gain Control
    - Custom designs based on aircraft control laws

**Inertia Swing Set**



**Erector Setup**



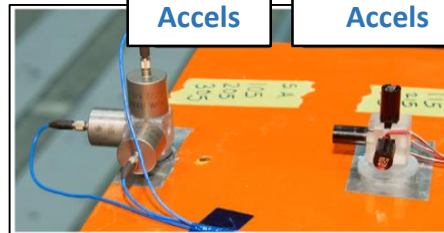
**3-DOF Transducer on 100-lbs Shaker**



**1-DOF Force Transducer**

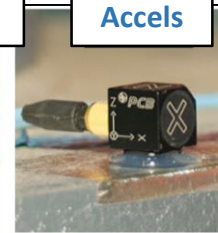


**Seismic Accels**



**Single Axis Accels**

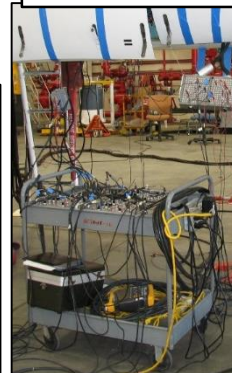
**Triaxial Accels**



**10k-lbs Overhead System**



**F-15B SMI Gain Box Setup**



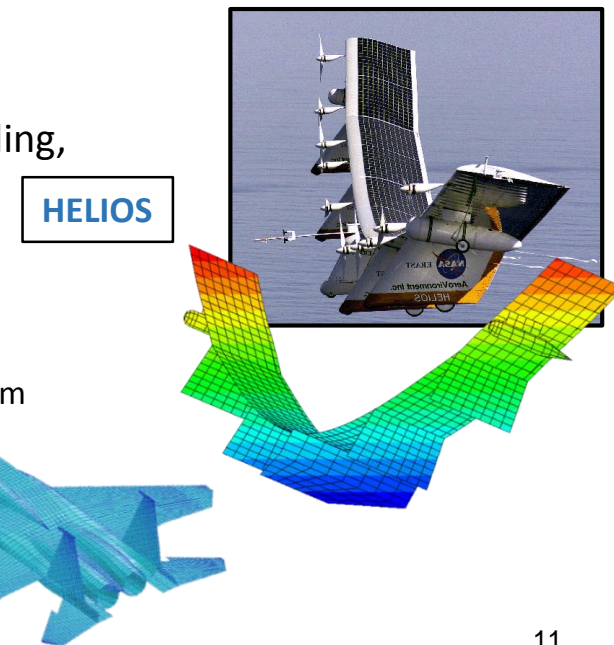
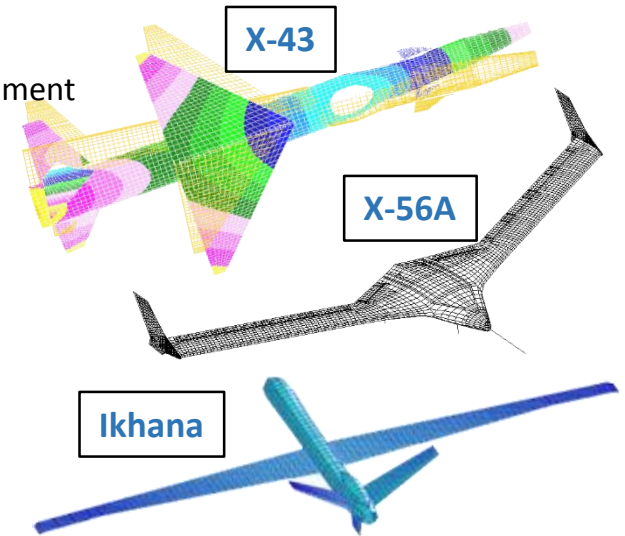
**SSS**



**GIII on SSS**



- Modal Analysis
  - Structural Dynamic Finite Element Modeling, Analyses & Tool Development
    - Use CAD & NASTRAN/PATRAN codes for Modeling & Analyses
  - Finite Element Model Tuning
- Aeroelastic Modeling, Analyses, and Tool Development
  - Flutter & Divergence Analyses
    - Subsonic & Supersonic Speed Regimes: Use Frequency Domain Approaches
    - Transonic Speed Regime: Use Time Domain Approaches
  - Unsteady Aerodynamic Model Tuning
- Multidisciplinary Design, Analysis, and Optimization (MDAO) Tool Development
- Active Flexible Motion Control & Aeroservoelastic Systems Modeling, Analyses & Tool Development
  - Aeroservoelastic (ASE) Analysis
    - Develop in-house ASE analysis tools (subsonic & supersonic)
    - Use CFD code CFL3D for transonic speed regime
  - Gust/Maneuver Load Alleviation, Flutter & Vibration Suppression, and Trim Shape Control
  - Actuator Model Tuning using SMI data
  - Aeroservoelastic Stability Analyses





# Flight Flutter Testing Capabilities

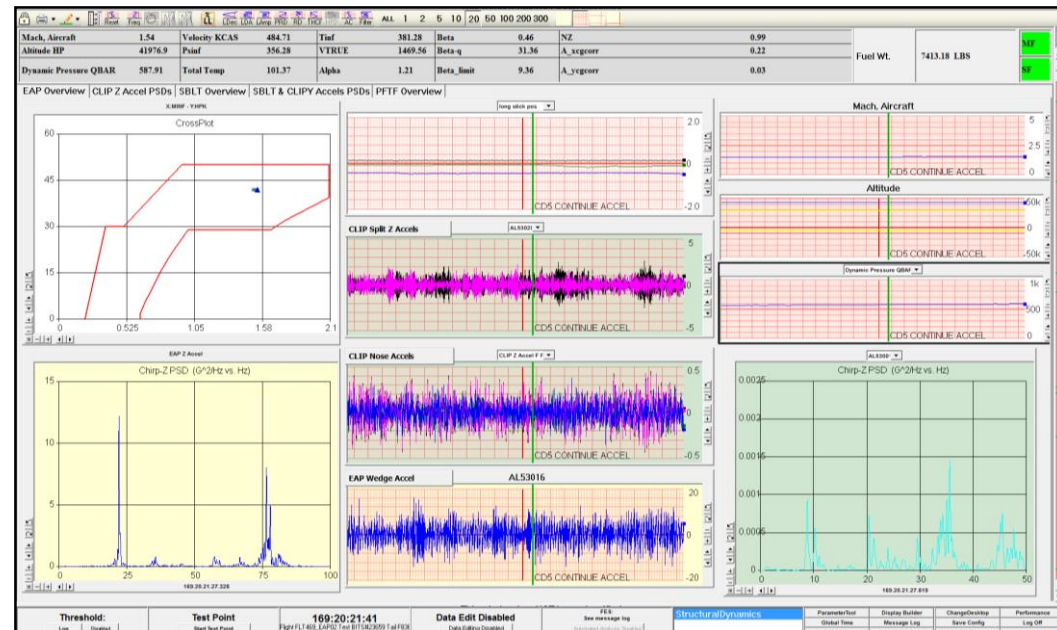


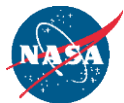
- Flight Flutter Planning
  - Develop flight instrumentation layout, test points and maneuvers using a build-up approach
  - Develop displays for safely monitoring and clearing test points
- Flight Monitoring & Data Analysis
  - RED phone access to pilot
  - Software: Symvionics Interactive Display System (IADS)
    - Monitoring real-time time-domain (stripchart) and frequency-domain (PSD) data
    - Calculate and log frequency and damping values
    - Ability to implement external Matlab-based algorithms
    - Post-flight analysis

Armstrong's Control Room



IADS Display





# Questions

---



?