Overview of Acoustics Research at Langley Research Center

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NASA Langley at a Glance (2012)

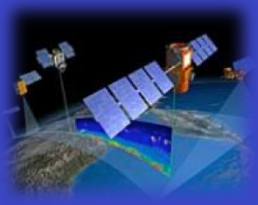
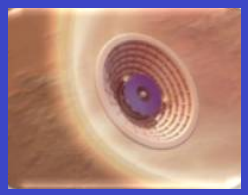
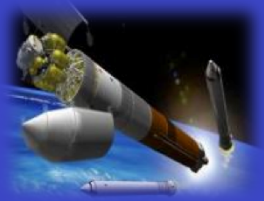
Founded in 1917 as the first civil aeronautical research lab

~$853M PY2012 Budget
~$823M NASA Langley budget
~$30M External business

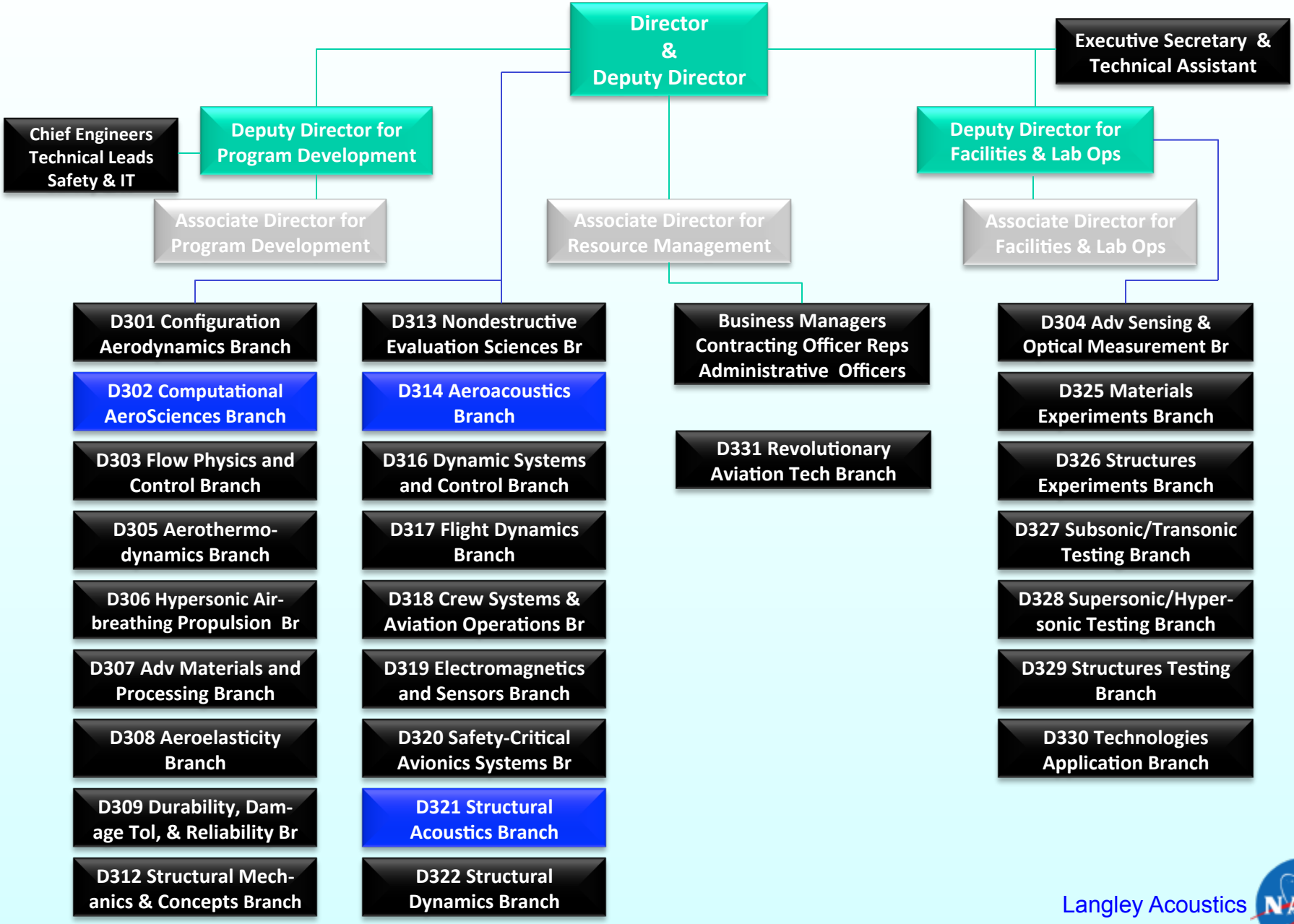
~3,600 Workforce
~1,900 Civil Servants
~1,700 Contractors (on/near-site)

Infrastructure/Facilities
788 acres, 169 Buildings
~$3.3B replacement value

Langley's Economic Impact (2011)
National economic output of ~ $2B and generates over 17,000 high-tech jobs
Virginia economic output of ~ $1B and generates over 9,000 high-tech jobs

Aeronautics 44%	Science 28%	Space Tech 15%	Human Exploration 12%	Education 1%
				

RESEARCH DIRECTORATE – D3



Research Directorate Areas of Expertise

- **Structures** (integrated multifunctional design, damage mechanics, nonlinear mechanics, radiation physics, loads and dynamics)
- **Materials** (lightweight materials, multifunctional materials, computational design, environmental interactions, innovative processing)
- **Measurement Sciences** (noninvasive measurement techniques and physics-based models of measurement methodologies)
- **Acoustics** (source noise, system noise, structural acoustics, and psychoacoustics)
- **Aerodynamics** (subsonic/transonic/supersonic aerodynamics, aeroelasticity & controls, fluid physics & modeling, flow control, computational methods, uncertainty)
- **Hypersonics** (physics & chemistry modeling, aerothermodynamics, air-breathing propulsion)
- **Flight Dynamics and Controls** (flight dynamics, control theory, systems identification, guidance & trajectory optimization, flying qualities)
- **Crew Systems & Aviation Operations** (air traffic operations, flight deck interface, human automation integration, atmospheric hazards and wake turbulence)
- **Safety-Critical Avionics Systems** (high confidence software-intensive systems)
- **Test Technologies (**methods and advanced tools to improve experimental facility data quality and fidelity; and operational processes and automation to improve experimental facility productivity and reduce operation costs**)**

Program/Project Structure

NASA Aeronautics Programs

and where the Green Aviation emphasis is



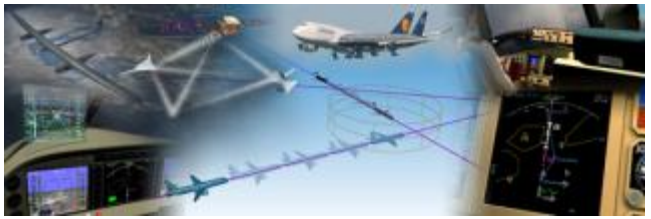

Fundamental Aeronautics Program

Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment



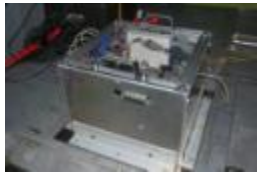


Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.


Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.

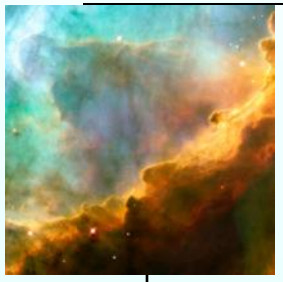




Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.


NASA Mission Directorate Organization



- Office of the Administrator
  - Science Mission Directorate (SMD)
  - Aeronautics Research Mission Directorate (ARMD)
    - Fundamental Aeronautics Program (FAP)
      - Fixed Wing
      - Rotary Wing
      - High Speed
      - Aeronautical Sciences
    - Airspace Systems Program (ASP)
    - Integrated Systems Research Program (ISRP)
      - Environmentally Responsible Aviation
      - UAS in the NAS
    - Aviation Safety Program (AvSafe)
    - Aeronautics Test Program (ATP)
    - Mission Support Office (MSO)
  - Human Exploration & Operations Mission Directorate (HEOMD)

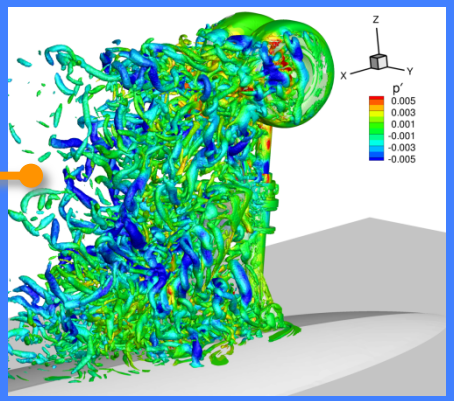
Acoustics @ Langley

Acoustics Workforce

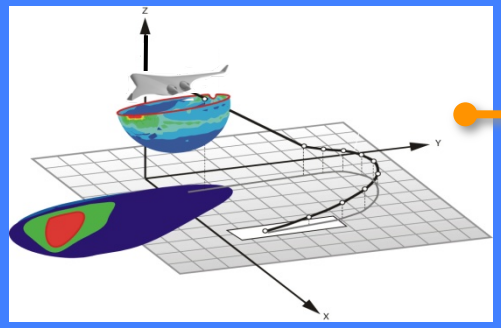
- **Aeroacoustics Branch**
  - 19 CS (11 PhD) 16 Contractors
- **Structural Acoustics Branch**
  - 15 CS (8 PhD) 7 Contractors
- **Computational AeroSciences Branch**
  - Total
    - 26 CS (20 PhD) 11.5 Contractors
  - Computational Aeroacoustics
    - 6 CS (5 PhD) 0.5 Contractors
- **Other research collaborations @ LaRC**
  - Configuration Aerodynamics Branch
  - Flow Physics & Controls Branch
  - Advanced Sensing & Optical measurement Branch
  - Advanced Materials & Polymers Branch

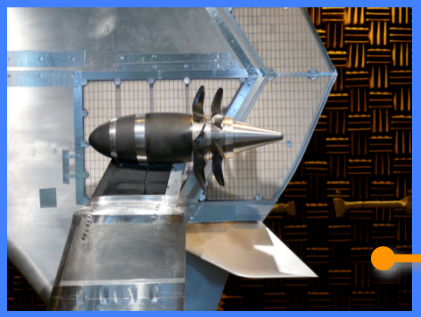
Areas of Expertise in Acoustics

Computational Aeroacoustics



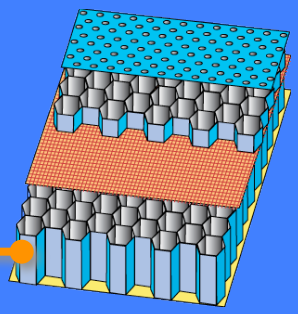
System Noise Prediction



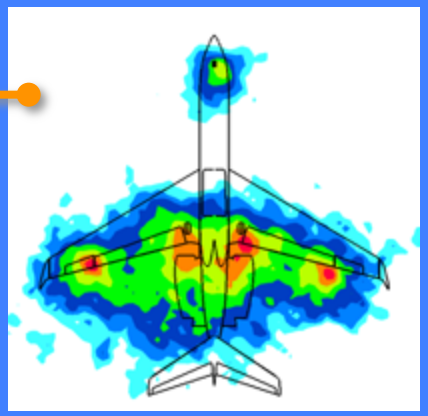


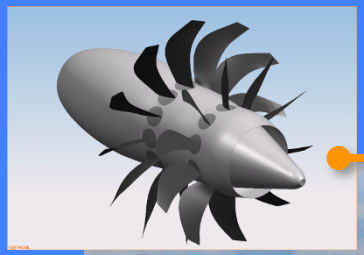
Propulsion-Airframe Aeroacoustics

Aircraft Liners

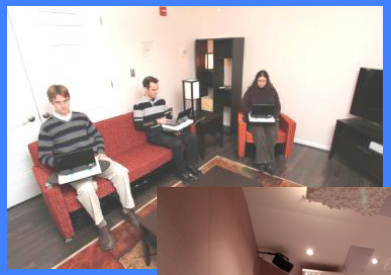


Airframe Noise





Rotor Noise



Human Response to Noise

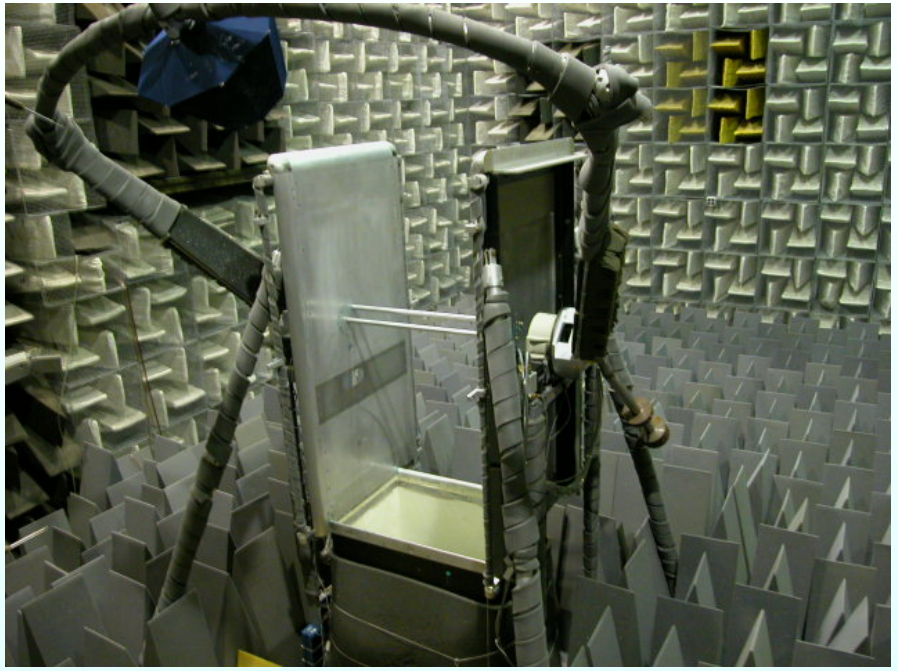
Cabin Noise/ Vibro-acoustics

Aeroacoustics Branch Facilities

Quiet Flow Facility (QFF)

Facility Characteristics

- 30’ deep x 20’w x 25’h anechoic test chamber
- Open jet from 2’x3’ nozzle (flow speeds up to Mach=0.17)
- Flow circuit employs baffles, turbulence screens and turning vanes to ensure low turbulence quiet flow from open jet.
- Chamber isolated from outside noise and vibrations.



Types of Testing

- Airframe, noise scattering and turbomachinery noise characterization and reduction studies.
- Development of acoustic measurement tools and processing techniques (for example, DAMAS).
- Benchmark aero/acoustic data for development and validation of noise prediction methods.

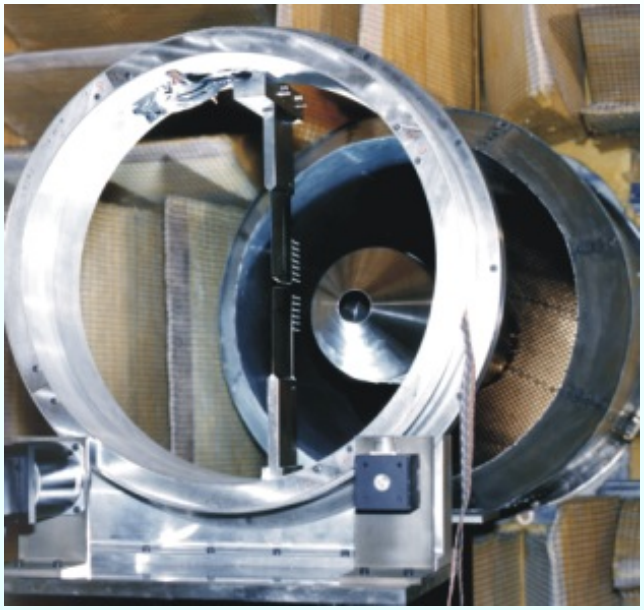
Other Facility Features

- Acoustic measurements (both single microphone and phased microphone arrays)
- Steady state and dynamic surface pressures
- Hot wire anemometry
- Particle image velocimetry

Small Anechoic Jet Facility (SAJF)

Facility Characteristics

- Static Test Facility
  - Anechoic Cutoff Frequency 200 Hz
  - Chamber Size 10’ w • 12’ l • 8’ h
- Single Flow Propulsion system
  - Nozzle Pressure Ratio up to 8
  - Total Pressure (nozzle) up to 120 psia
  - Total Temperature 50^{o} to 350^{o} F
  - Mass Flow Rates 0 to 2 lb/s



Types of Testing

- Prototyping for LSAWT
- Jet Plume Flow Field Measurements
- Acoustic Screening of Nozzle Noise Suppression Concepts
- Development of Measurement Methods for Jet Engine Simulator in the LSAWT

Other Facility Features

- Linear Acoustic Array
- Steady State and Dynamic Pressures
- Hot Wire Anemometry
- Particle Image Velocimetry
- Flow Visualization Data
  - Laser Light Sheet
  - Schlieren, Sharp-focused Schlieren
  - Imaging Radiometry

Langley Acoustics

Low Speed Aeroacoustic Wind Tunnel (LSAWT)

Jet Engine Simulator reproduces the dual-stream flow out of the back end of a typical jet engine. This jet exhaust is then surrounded by a low-speed flow to simulate takeoff/landing flight effects.

Facility Characteristics

- Dual Flow Jet Engine Simulator
  - Nozzle Pressure Ratio up to ~ 12
  - Total Pressure (nozzle) up to ~ 150 psia
  - Total Temperature 100° to 2000°F
  - Mass Flow to 20 lb/s per stream
  - Axial Thrust to 2000 lbf
- Continuous Flow 4.7' Free Jet Tunnel
  - Mach No. 0.1 to .32
- 17x17x34' Anechoic Chamber
  - Cutoff Frequency 200 Hz

Types of Testing

- Acoustic Characteristics of Nozzles
- Propulsion/Airframe Aeroacoustics
- Internal Performance of Nozzles
  - Uniform Flow Simulation
  - Mixed Flow Turbofan Simulation
- Aerodynamic Measurements of Plume
- CFD Code Validation Data

Other Facility Features

- Both Linear and Phased Acoustic Arrays
- Steady State and Dynamic Pressures
- Mass Flow for Air and Fuel Streams
- Particle Image Velocimetry
- Flow Visualization Data
  - Laser Light Sheet
  - Schlieren, Sharp-focused Schlieren
  - Imaging Radiometry

Mobile Acoustic Facility (MAF)

Facility Characteristics

- Wireless Acoustic Measurement System (WAMS)
- Signals digitized at microphone location
- Data stored on compact flash card
- 36 WAMS microphone systems
- WAMS RF link up to 50 miles LOS
- GPS time stamped
- 80 kHz maximum sample rate
- 96 dB dynamic range
- Battery operation w/solar power aug.
- Weather data at each mic location

Types of Testing

- Vehicle source noise characterization
- Assessment of low noise flight procedures and environmental impact
- Long range acoustic propagation studies
- Validation of acoustic detection models

Other Facility Features

- Self contained command and control trailer
- Tethered weather profiling system
- DGPS tracking and guidance system
- Inertial measurement unit for body attitude and rates
- Optical rotor tip-path-plane measurement system

Structural Acoustics Branch Overview
NASA Langley Research Center

Dr. Kevin Shepherd, Head
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Dr. Randolph Cabell, Assistant Head
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What we do

Structural Acoustics

- cabin noise
- sonic boom transmission
- sonic fatigue

Engine Nacelle and Liner Acoustics

- characterization & design of acoustical materials
- noise reduction technology
- duct propagation

Human Response to Noise

- prediction, synthesis and playback of aircraft flyover noise
- human response to sonic booms

Structural Acoustics – Interior Noise

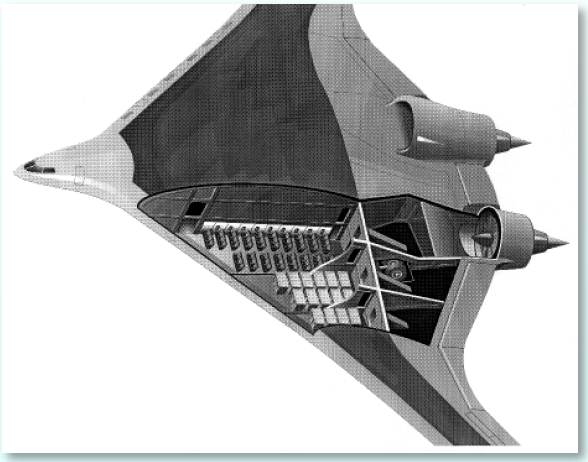
Understand and develop the technologies needed to create quiet aerospace vehicles

A blend of disciplines:

- acoustics
- structural dynamics
- aerodynamics

Research approach:

- characterize excitations
- model & predict structural response and corresponding interior noise
- develop and apply noise control strategies



Langley Acoustics

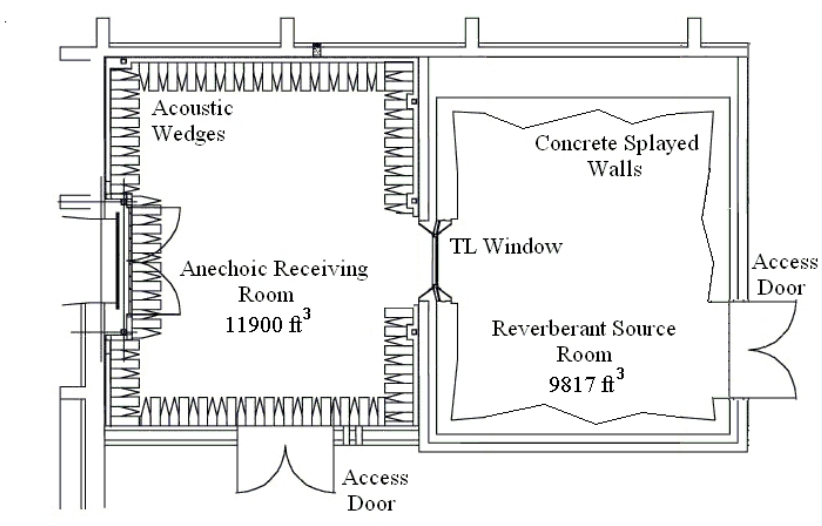
Long-term Vision – Interior Noise

- **Validated tools to design quiet vehicles**
  - computationally efficient models for early vehicle design
  - predict system performance of noise treatment concepts
  - characterize relevant sources (TBL, jet exhaust)

- **Noise control treatments**
  - metamaterials; functionally graded materials
  - carbon nanotube foams
  - active control

Enable quiet by design

Facilities: Structural Acoustics Loads and Transmission Facility

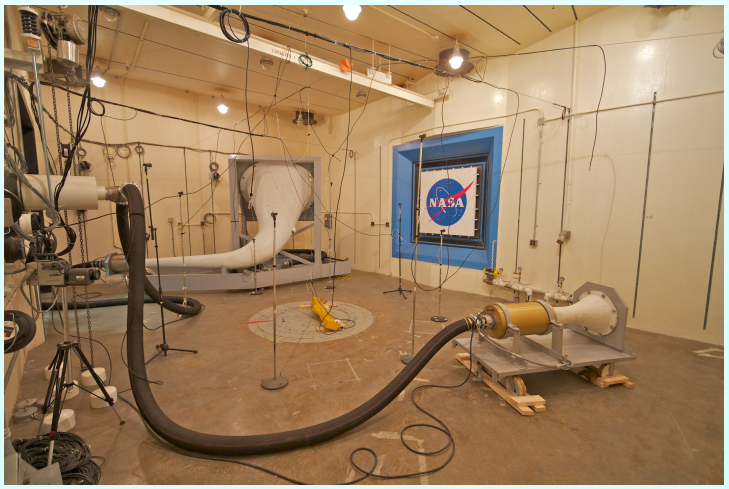


Conventional TL suite

- reverberant source room
- anechoic receiving room
- up to 58”x58” test window
- 110 dB typical SPL (80 Hz-10 kHz)

Qualification testing in source room:

- 156 dB SPL (25 Hz-2.5 kHz)



Langley Acoustics

Liner Technology Facility (LTF)

Facility Characteristics

- Small Flow Duct Acoustics – GFIT
  - Duct Size 2.0” w • 2.5” h
  - Frequency Range 0.4 to 3.0 kHz
  - Sound Pressure Levels up to 150 dB
  - Flow Mach 0 to 0.6
- Large Flow Duct Acoustics – CDTR
  - Duct Size 6” w • 15” h
  - Frequency Range 0.4 to 2.4 kHz
  - Sound Pressure Levels up to 140 dB
  - Flow Mach 0 to 0.5

Types of Testing

- Grazing Flow Impedance Tube — GFIT
  - Measure acoustic liner impedance
  - Evaluate flow profile effects
- Curved Duct Test Rig — CDTR
  - Generate selected higher-order modes
  - Evaluate duct curvature effects
- GFIT & CDTR
  - Evaluate inlet and aft-duct configurations

Other Facility Features

- Raylometer: automated test rig for evaluation of DC flow resistance
- Normal Incidence Tube: no-flow test rig for measurement of liner acoustic impedance
- Waveguide Calibrator: test rig for calibration of sensors at frequencies up to 90 kHz

Thermal Acoustic Fatigue Apparatus (TAFA)

Facility Characteristics

Progressive wave tube with radiant heating

- Test Articles to 6 ft. x 6 ft.
- OASPL: 125-172 dB
- Base Frequency Range: 40-500 Hz
- Extended Frequency Range: 40-1600 Hz
- Max Heat Flux: 48 BTU/ft^2-sec for > 2000°F
- SOA Control and Data Acquisition system

Types of Testing

- Nonlinear structural dynamic response prediction validation
- High cycle fatigue of high performance aircraft and spacecraft structures
- Combined thermal and acoustic loads

Other Facility Features

- Narrow band acoustic control
- 10 zone closed-loop thermal control
- Extensive Measurements capability
  - pressure - strain - acceleration
  - velocity - temperature - heat flux
- Damage detection using
  - thermography - radiography
  - ultrasonics

Human Response Testing – Exterior Effects Room (EER)

Capabilities:

- 31 channel 3-D audio (Vectsonic) system
  - 27 K&H O300 satellite speakers
  - 4 K&H O900 subwoofers
- 16 Hz – 20 kHz compensated frequency range
- Human-rated facility
- Active/passive stereo projection system
- Seating capacity: 39

Human response studies:

- Annoyance studies of current A/C fleet
  - Recording-based
  - Synthesized from predicted component noise
- Simulation of future A/C configurations
  - Rotorcraft
  - Conventional fixed wing
  - Revolutionary configurations
  - Operations & weather
- Detection and identification

Human Response Testing – Interior Effects Room (IER)

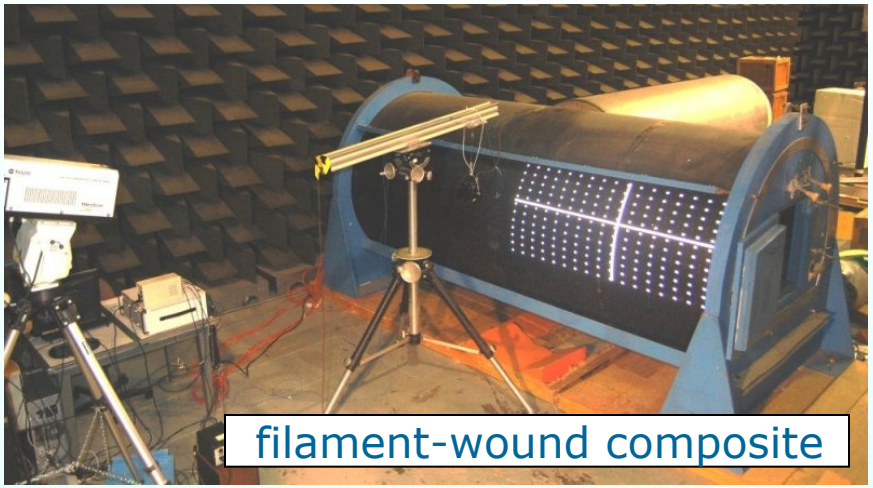
Facility Characteristics

- Single room psychoacoustic facility
- Configured as a residential living room
- Controllable indoor listening environment
- Exterior sound reproduction system
  - Simulates outdoor environmental noises that transmit indoors
  - Two speaker arrays outside two walls
  - 52 subwoofer and 52 mid-range speakers
  - Frequency range: 3 Hz to 5,000 Hz
  - Capable of reproducing sonic booms
- Interior satellite speakers
  - Simulate rattle, squeak and creak
  - Frequency range: 50 Hz to 20,000 Hz

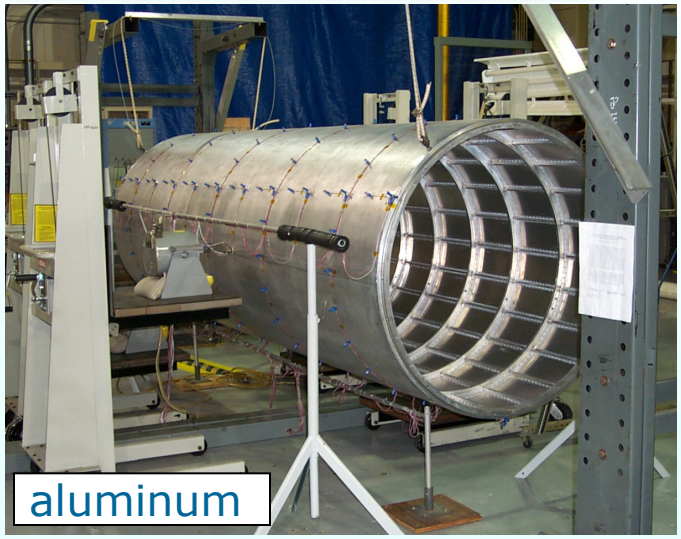
Types of Testing

- Subjective reaction to indoor noise
- Structural response to low frequency noise
- Applications
  - En route sonic boom (current research focus)
  - Airport noise: fixed wing and rotorcraft

Supporting Test Hardware



stiffened cylinders



custom components

Misc. Instrumentation

- laser vibrometer
- > 200 accelerometers
- > 200 microphones
- ~ 300 channels high speed data acquisition
- inertial actuators