National Aeronautics and Space Administration

Fluid Mechanics Laboratory (FML) Capabilities

Experimental Aero-Physics Branch
NASA Ames Research Center

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Experimental Aero-Physics Branch

Organizational Overview

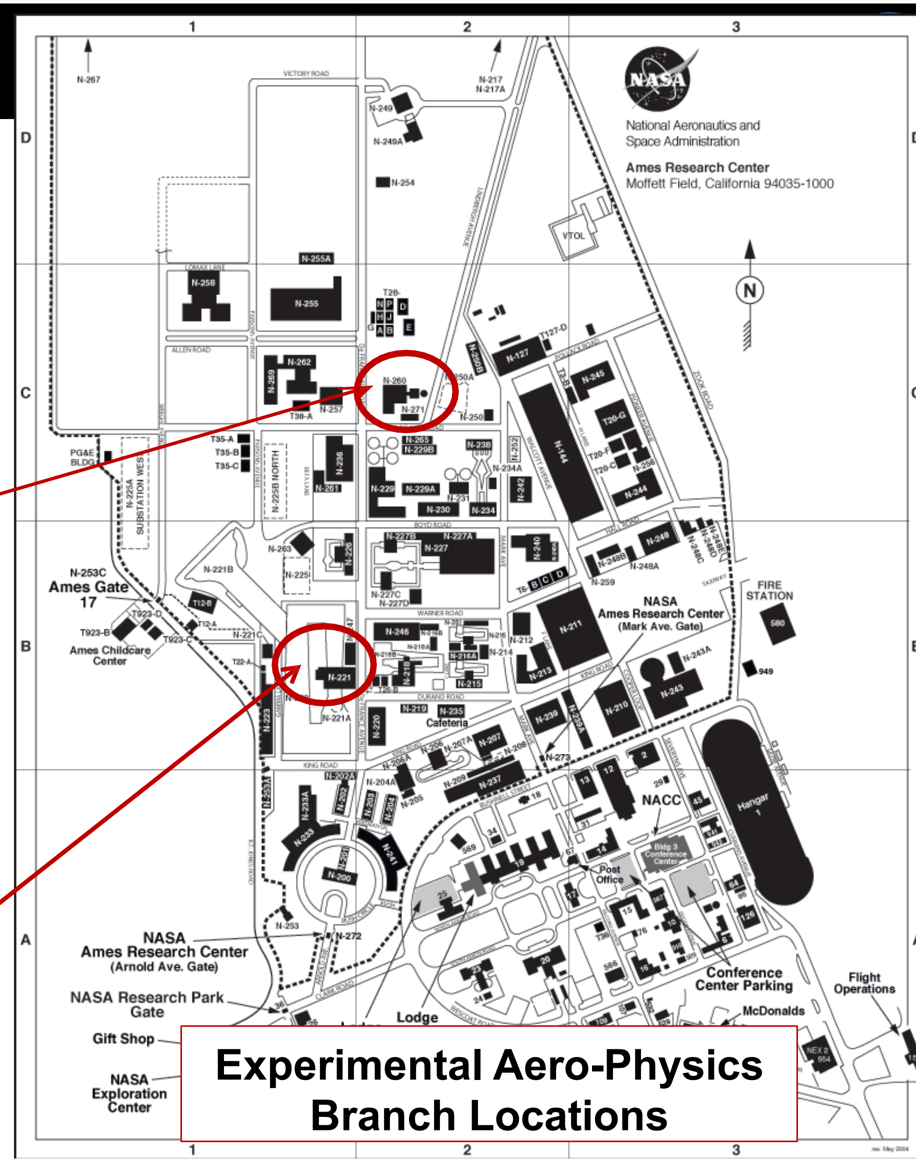
NASA Ames Research Center, Moffett Field, CA
Code AOX (Aeronautics/Wind Tunnel Ops/Experimental Aero-Physics)
22 FTEs & 5 WYE

Strategic Goals

- To be the source of small-scale, low-cost, high-availability, easy to operate facilities.
- To develop, optimize, and evaluate advanced flow instrumentation/techniques.
- To field those techniques and instrumentation at all NASA facilities.
- To perform preliminary testing before moving to the larger NASA wind tunnels.
- To develop, optimize, and evaluate advanced acoustic measurement techniques.
- To provide subject matter expertise in flow physics, aerodynamics, acoustics, and vehicle analysis supporting research, design, and evaluations.

Experimental Facilities

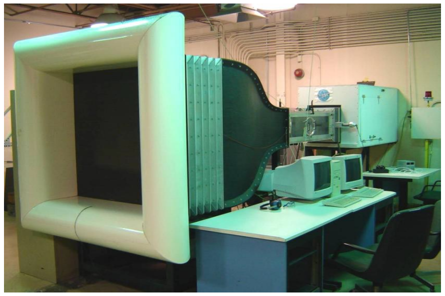
Five Wind Tunnels, Water Flow Facility, Anechoic Tunnel, Instrumentation Lab, Acoustics Lab, Electronics Lab, Machine Shop

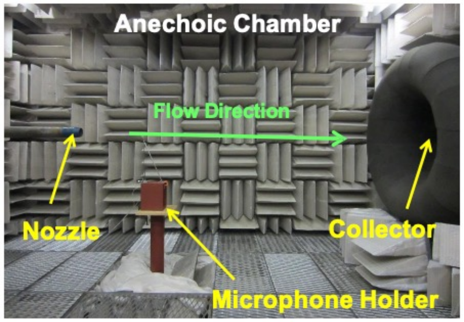


Experimental Flow Facilities Summary

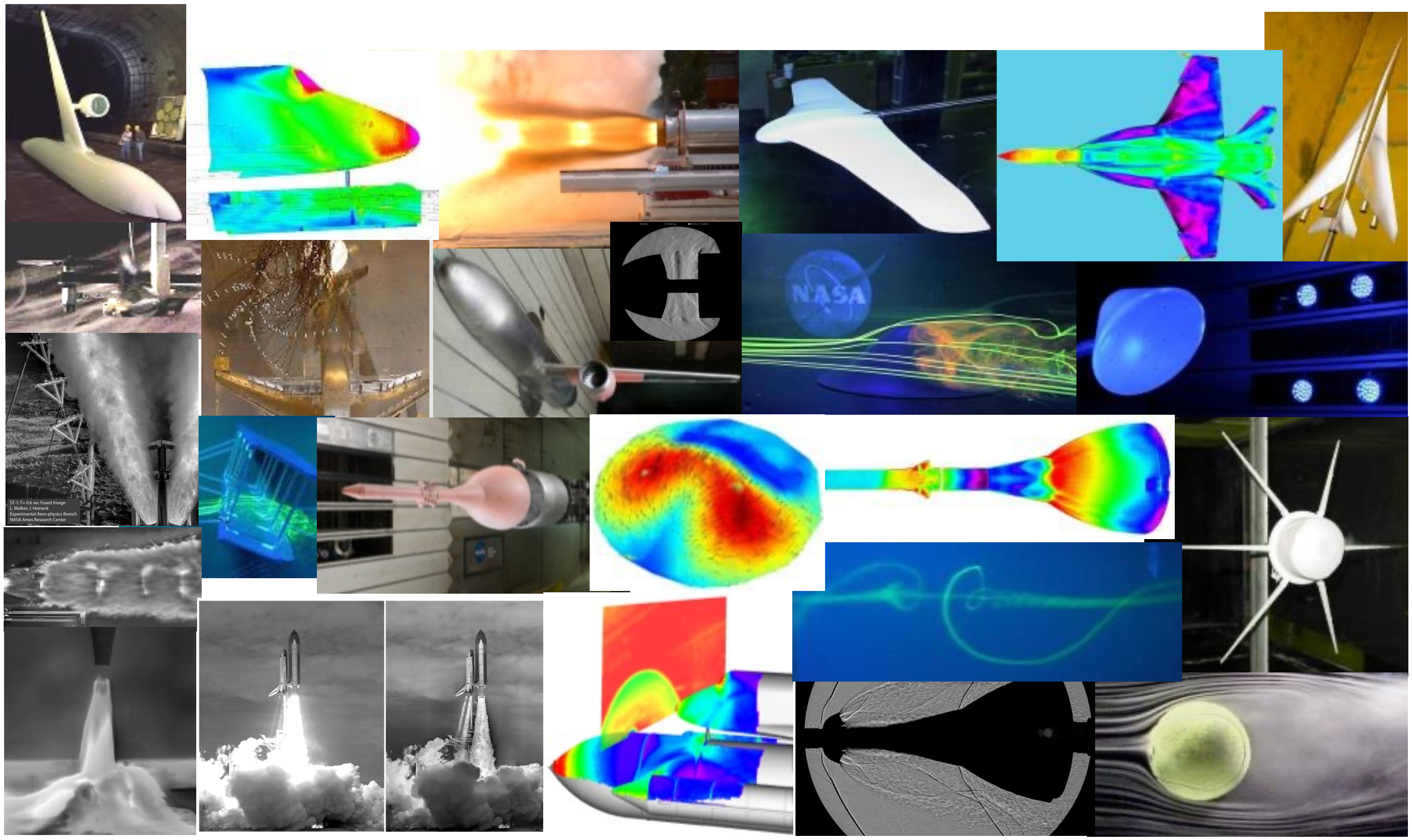
Facility	Test Section Dimensions	Max Speed	Types of Tests
Probe Calibration Facility	4” W x 4” H x 12” L	35 fps	Airspeed sensor calibrations
Black PSP Research Tunnel	12” W x 12” H x 24” L	400 fps	PSP Development
Test Cell #3 Indraft Tunnel	14.5” W x 14.5” H x 48” L	500 fps	High Speed Photogrammetry, PIV, Pressure Measurements
Blue Indraft Tunnel	15” W x 15” H x48” L	210 fps	Drag Measurements, Flow Visualization
Water Channel Facility	17” W x 10” H x 48” L	1 ips	Low Reynolds Number Flow Visualization
Lifesaver Tunnel	24” W x 24” H x 120” L	80 fps	Drag Measurements, Airspeed Sensor Tests
Lifesaver Extension	48” W x 24” H x 96” L	40 fps	Exhaust Flow Visualization and Measurement; Boundary Layer Tests
Test Cell #2 Indraft Tunnel	48” W x 32” H x 120” L	170 fps	Balance Tests, PIV, PSP, FISF, Flow Visualization
Anechoic Wind Tunnel	Open Jet; 4”- 8” nozzle	500 fps	Microphone calibrations Acoustic measurements

https://www.nasa.gov/ames-fluid-mechanics-lab/



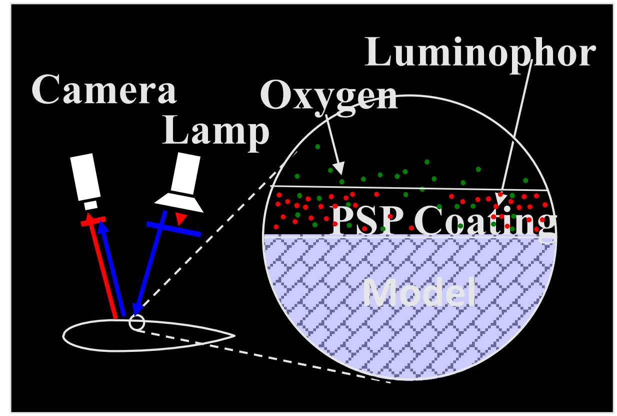


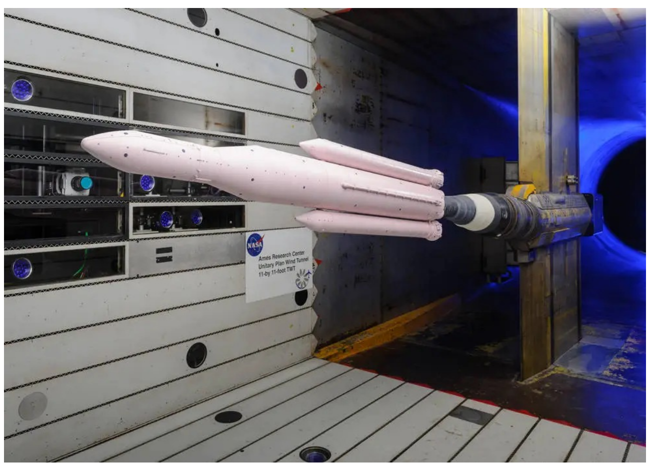
Advanced Instrumentation Systems Overview

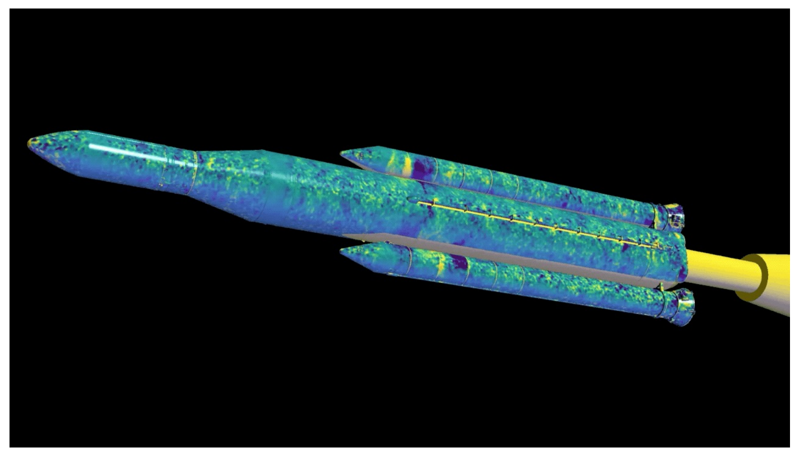


Unsteady Pressure Sensitive Paint (uPSP)

- Model Covered with Pressure Sensitive Paint
- PSP Excited with UV Light
- Excited PSP Molecules Return to Base State via Oxygen Quenching
- Higher Pressure (more oxygen) = More Quenching = Less Luminescence



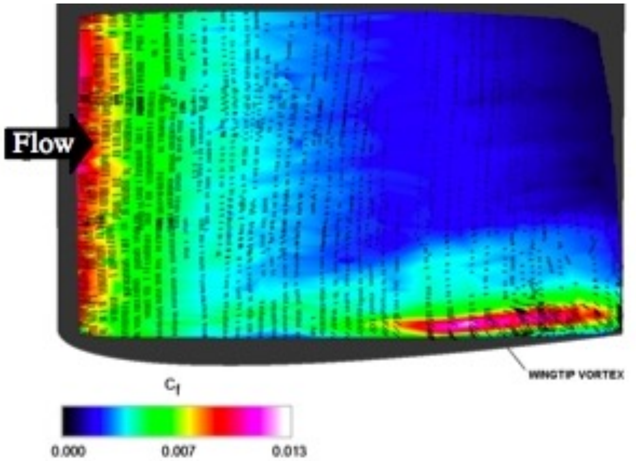




Skin Friction Measurement Technique (FISF)

FISF (Fringe Imaging Skin Friction)

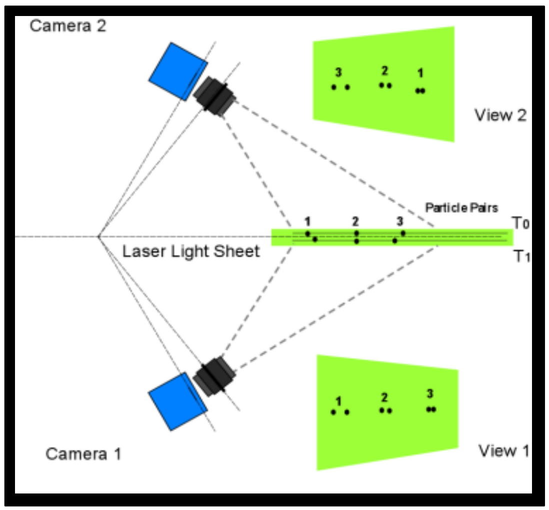
- Apply Oil (Drops/Lines) of Known Viscosity
- Run Wind Tunnel to Create Fringes
- Illuminate with Extended Monochromatic Light Source
- Measure Fringe Direction and Spacing to get Skin Friction Vector

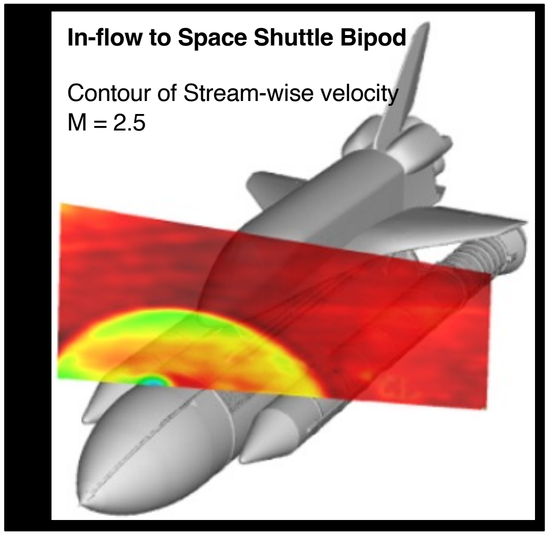


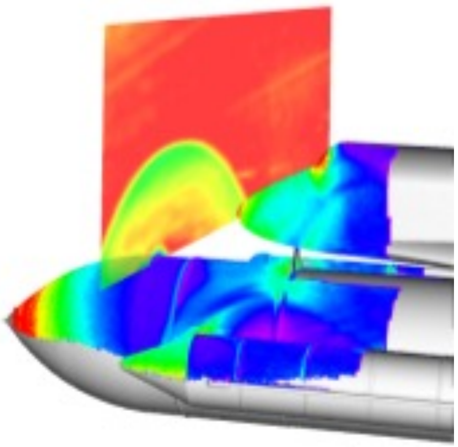
False-colored FIFS image of a wing tip model showing the skin friction coefficient distribution at Reynolds number = 4.5 million and angle-of-attack = 10°.

Particle Image Velocimetry (PIV)

- Non-intrusive flow field measurement using lasers, cameras and flow seeding
- Three components of velocity in a plane
- Commonly used for CFD validation and turbulence measurements
- Software used to overlay PIV with PSP for Return to Flight studies







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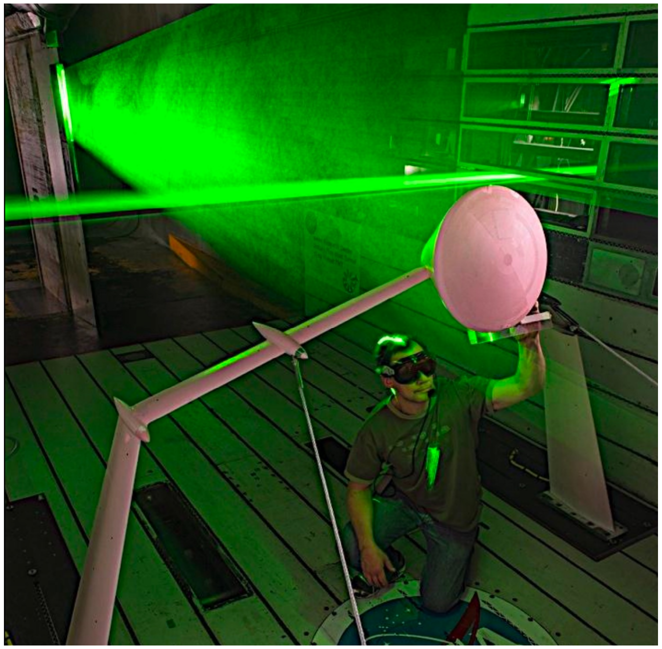
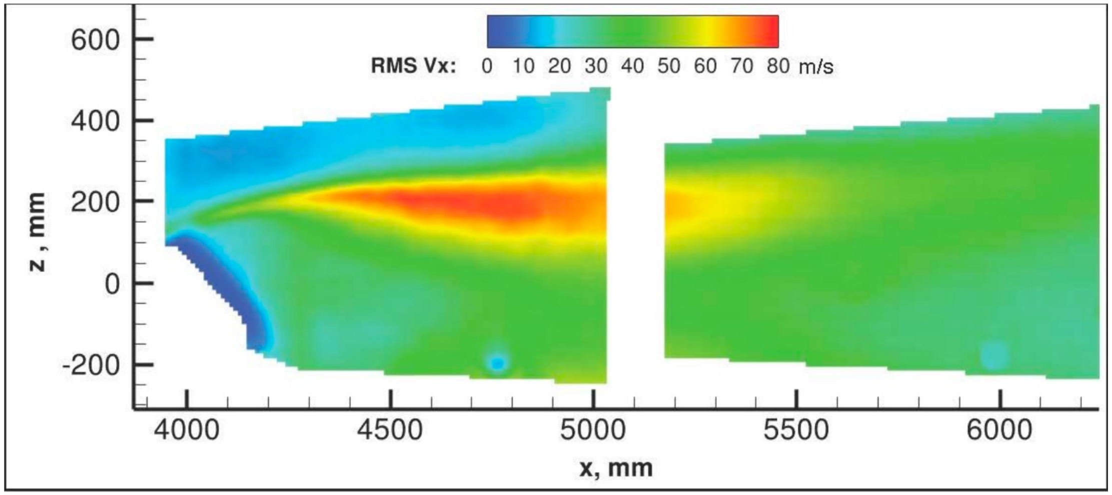
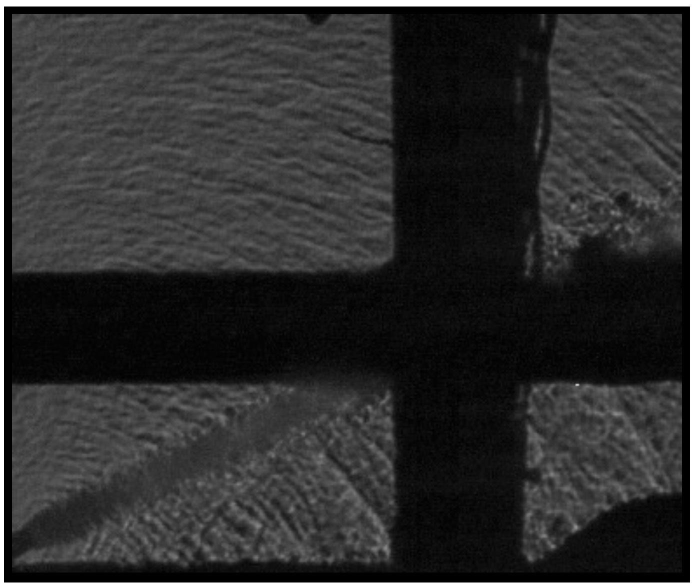




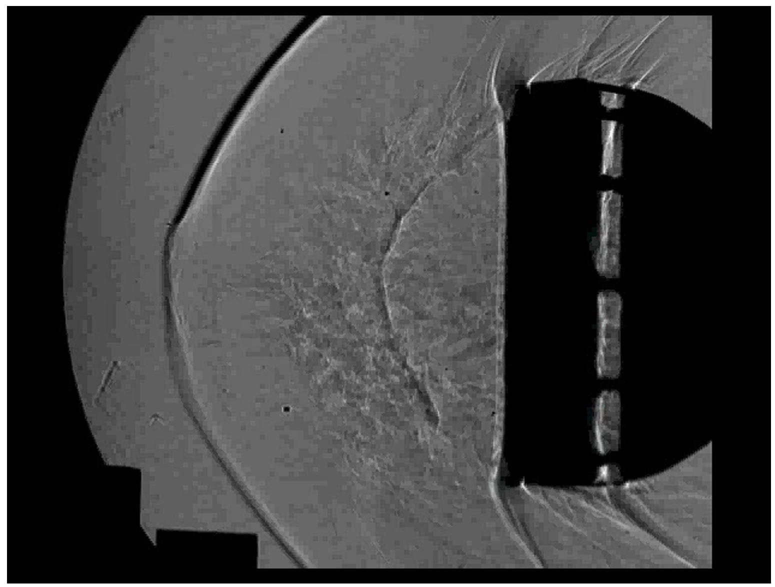
PIV for Orion Studies

High-Speed Imaging of Conventional Schlieren

- Efficient use of pulsed LED light source permits the use of high-speed cameras
- Fast downloads used for production testing in the Unitary Plan Tunnels gives a movie for each condition
- Cameras can record up to 600,000 fps
- Software developed to obtain feature fluctuation frequency



Mach wave radiation from supersonic jet, 20,000 fps



Rigid model of MSL parachute at M= 2.5, 10,000 fps

High-Speed Imaging of Conventional Schlieren

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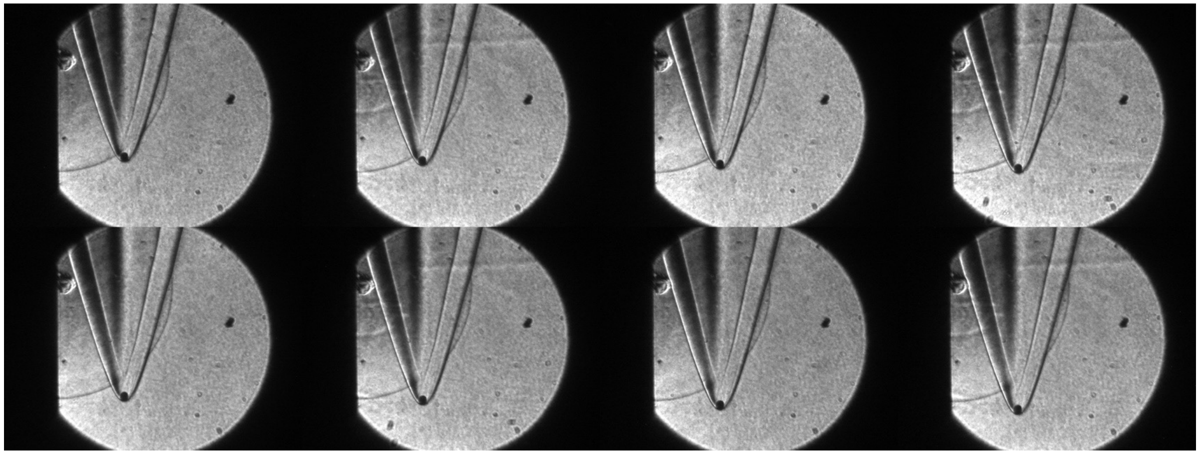
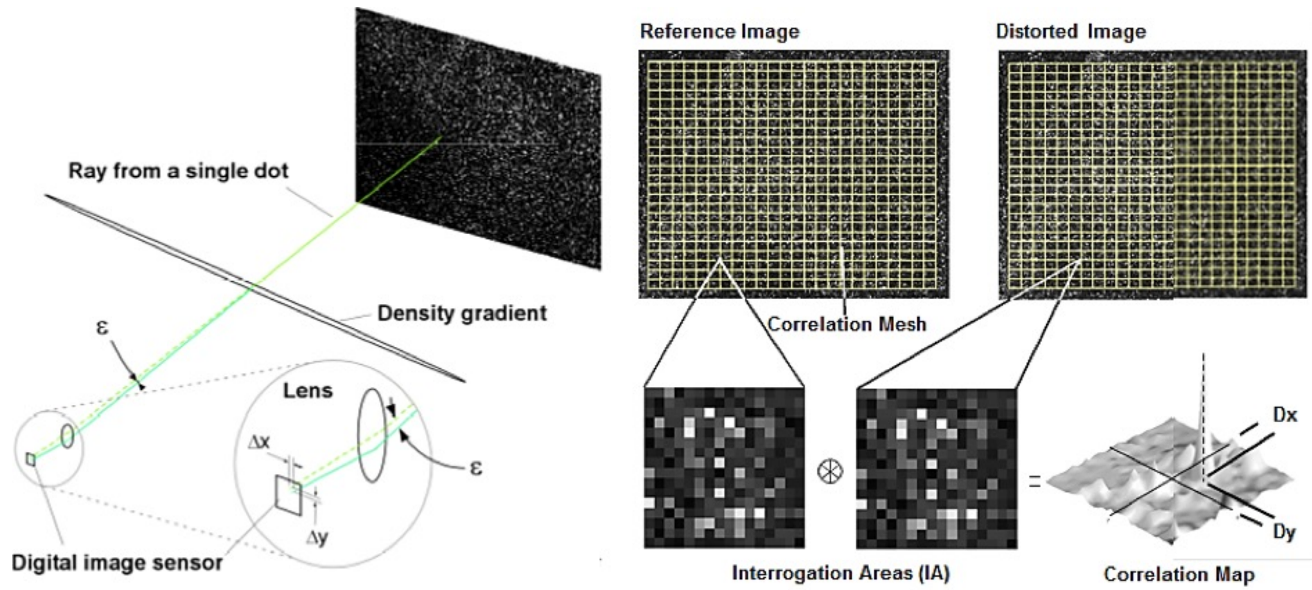


Density gradient imaging – hypersonic shock-shock interactions – fundamental aero (Ames Vertical Gun Range. Mach wave radiation from supersonic jet, 20,000 fps

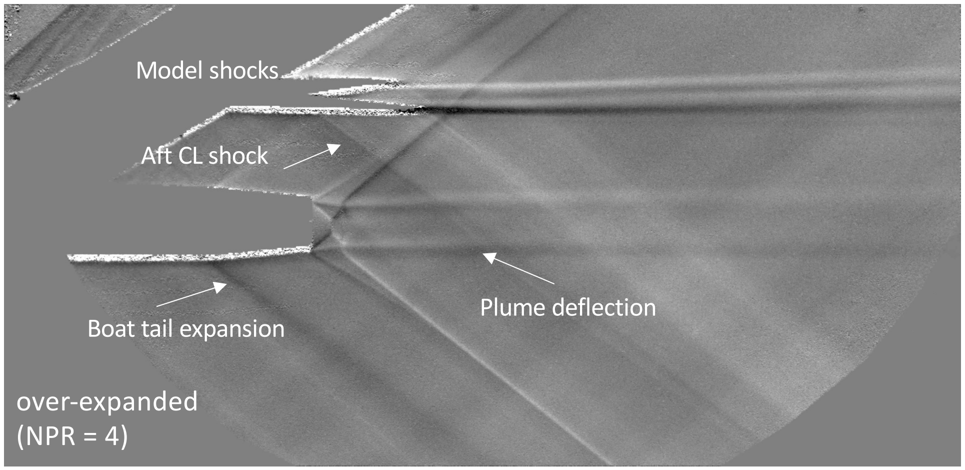
Retroreflective Background Oriented Schlieren (RBOS)

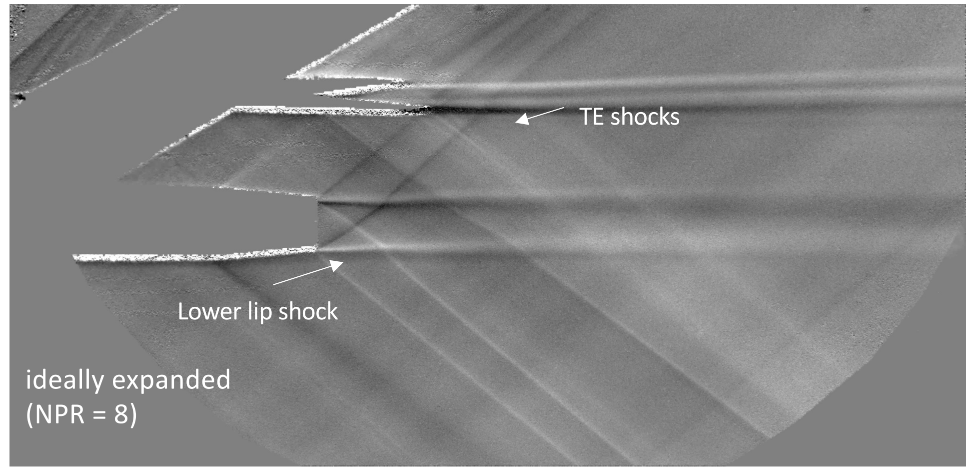
- Density gradient imaging without mirrors that requires only a digital camera and a randomized speckle pattern of paint dots on a contrasting background
- Cross-correlation software detects the local shift in the background pattern caused by density gradient
- Can provide quantitative measurements of density
- Retroreflective background material permits schlieren imaging in facilities with limited optical access



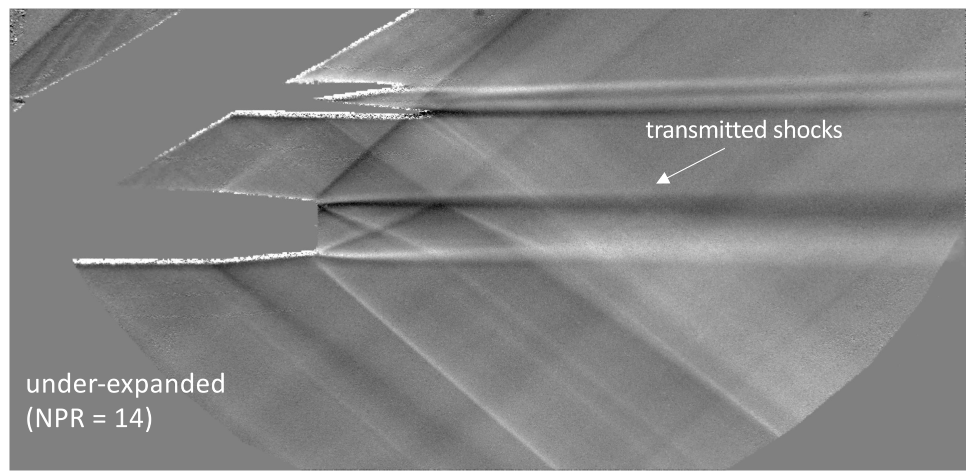
Retroreflective Background Oriented Schlieren (RBOS)

X-59: Ames Plume/Shock Interaction 25-D Tail M = 1.6



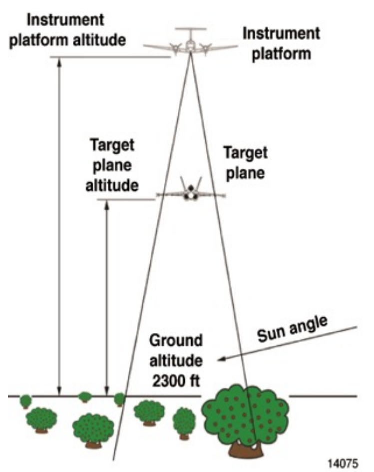


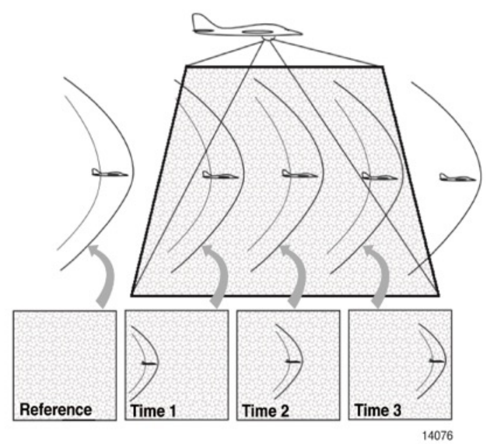
- Over, ideal and under-expansion
- Nozzle Shocks
  - Lower lip shock: upstream shift with decreased M
- Model Shocks
  - Increased angles with decreased M
- Interaction
  - Plume deflection less severe – weaker model shocks
  - Transmitted shocks steeper w/ larger Mach difference
  - Interaction length increase with decreased M

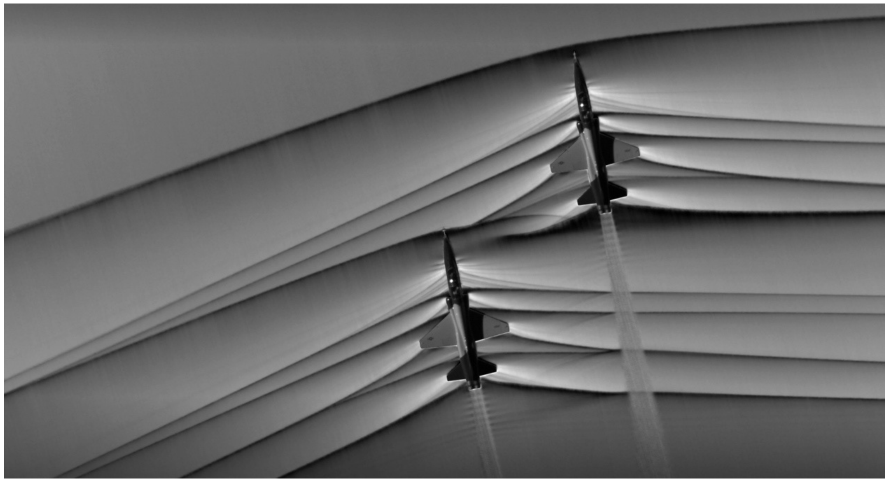


Air-to-Air Natural Background BOS

Use of natural features as retroreflective background







Density gradient imaging – AirBOS imaging of two T-33s in flight with interacting shocks and expansion.

Applications of Stereo Photogrammetry

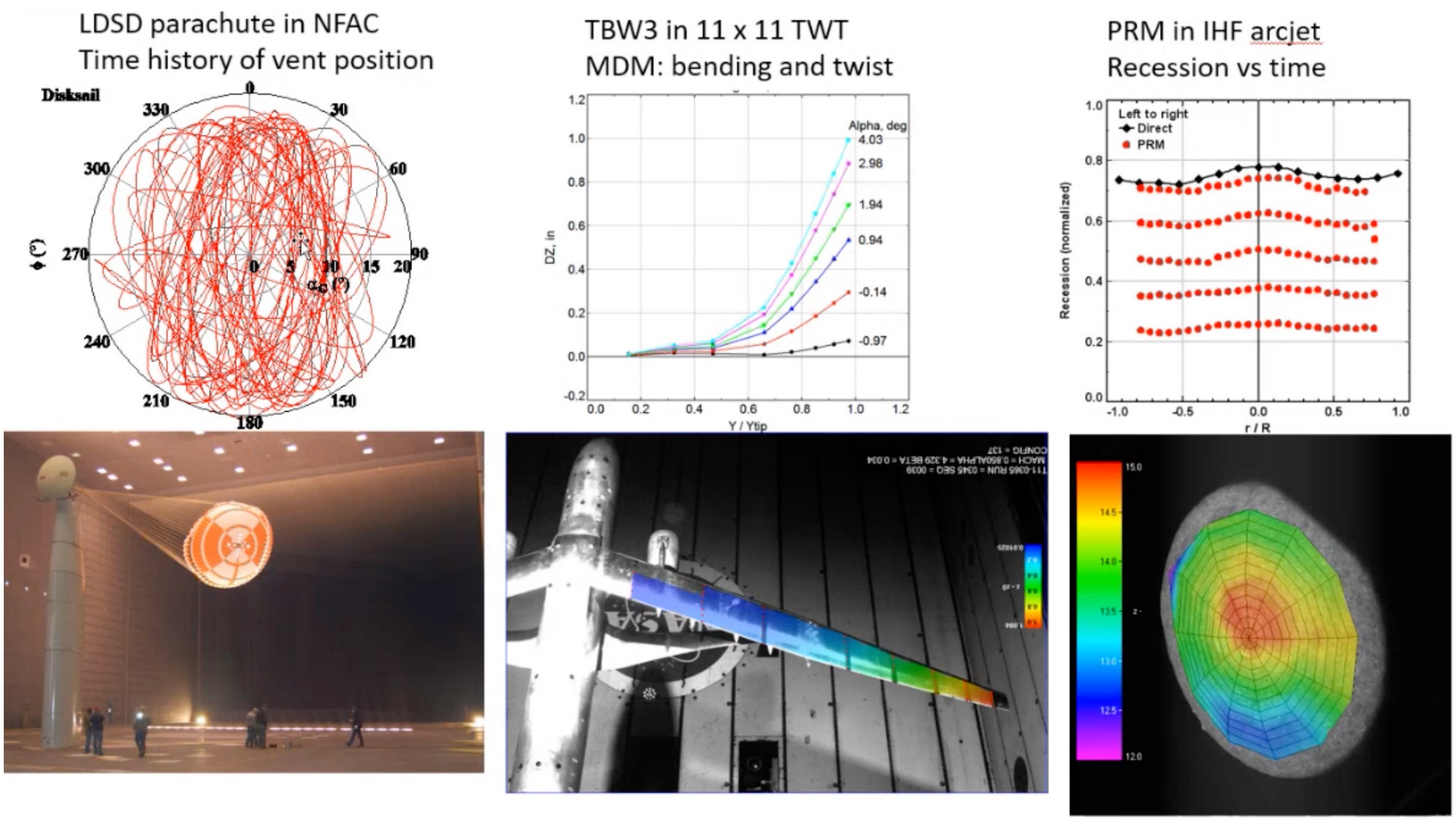


Image Fusion for Dynamic Intensity Flow Fields

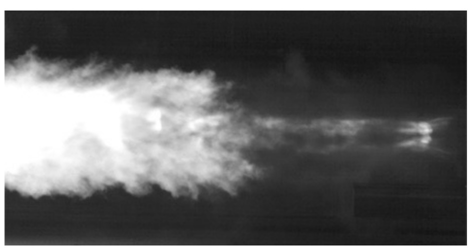
Normal Exposure

Fusion algorithm replaces saturated pixels with midtone pixels for full-detail imaging

25% Transmission

4-Camera Fused Image

12% Transmission



Fusion Applied To:

High Dynamic Range
Multispectral
Schlieren

3% Transmission

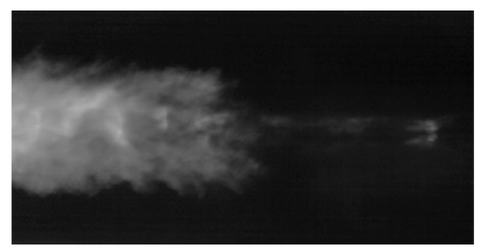
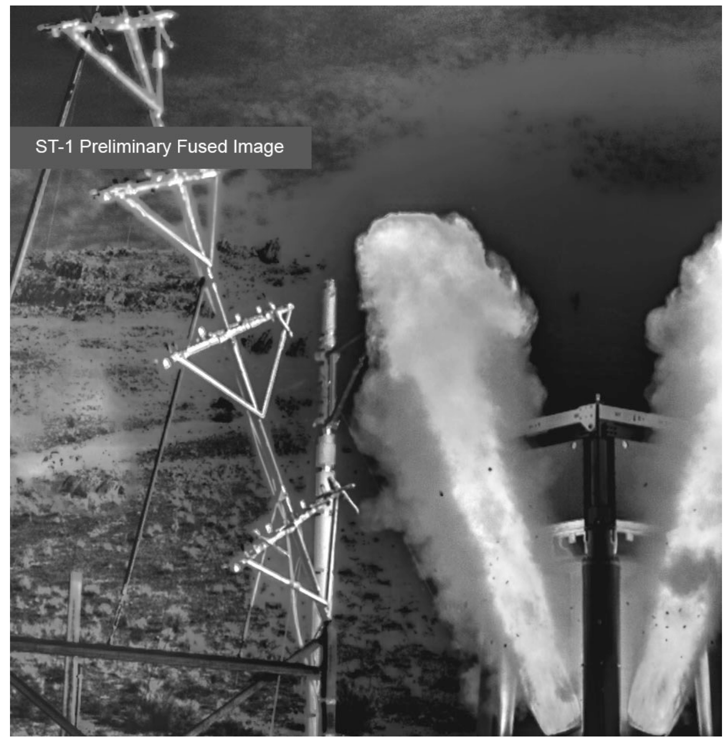


Image Fusion for Dynamic Intensity Flow Fields

Fused Original Images Re-Fused with Infrared (IR) image

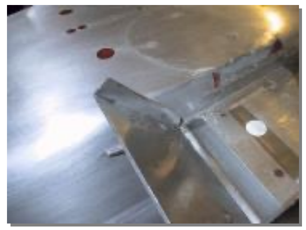


Aeroacoustics Research

Airframe Noise Measurements

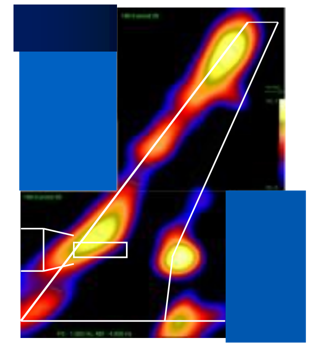
777 Landing Gear

1st large- scale gear noise data in U.S.



Flap Tip Fence

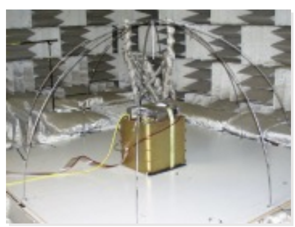
ARC patented noise control device for flap/slat tips



26%-Scale B-777

Large-scale application of microphone arrays in a wind tunnel

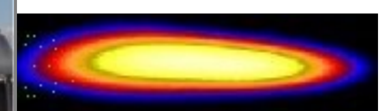
Space Station Noise Control



Anechoic Chamber Measurements

Enables flight qualification of ARC science experiments for ISS

Jet Noise Collaborative Study



Jet Noise Reduction Program

Investigation of jet noise reduction through micro-jet injection (in collaboration with Florida State University and ONR)

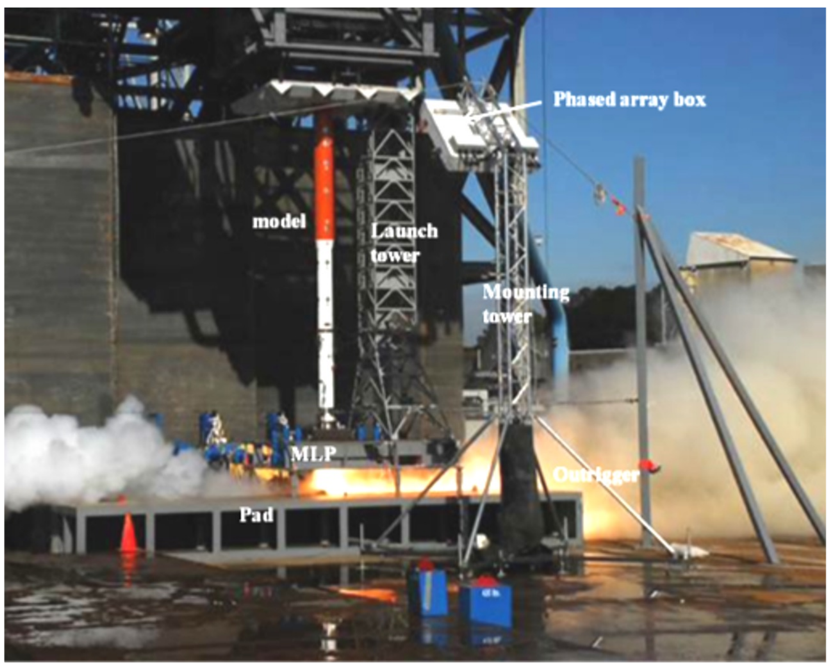
Acoustical Measurements in Rocket Motor Tests

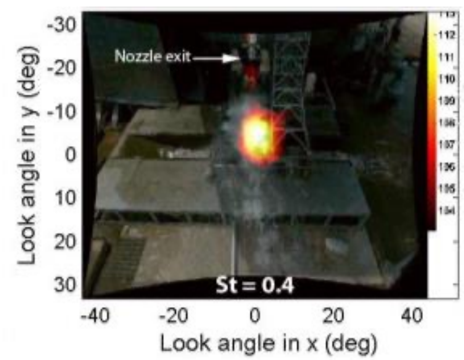
- Measurement of near- and far-field noise generated by rocket motors/engines
- Specialized application of microphone sensors in harsh, high-noise, outdoor test stands
- Easily portable systems

◄ ***Measurement of the plume-generated noise in the static test of MPCV launch abort motor.***

Direct Identification of Noise Sources

- Microphone arrays can pinpoint the sources of noise in wind tunnels and outdoors
- Applications include engine tests and rocket launches, in-tunnel measurements can isolate individual noise sources up to 8 dB below background levels
- Non-intrusive and deployable from a distance





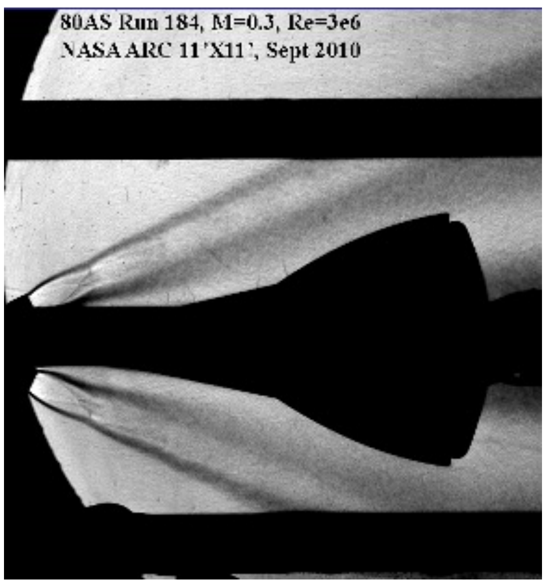
▲ ***Distribution of noise-sources on the test stand.***

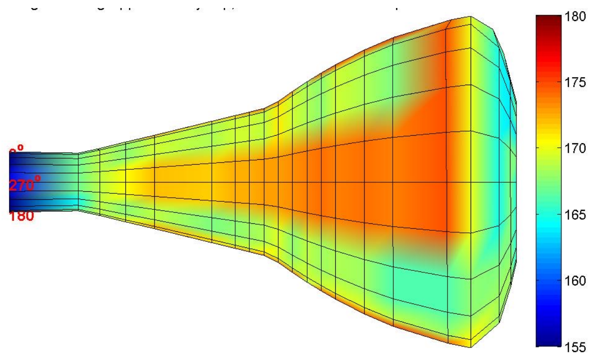
◄ ***Phased-array in Ares I scaled model acoustic test at MSFC***

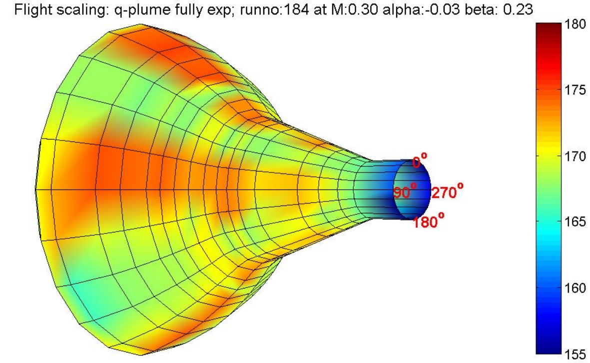
Subject Matter Expertise Supporting Hot Helium Orion Test (80-AS)

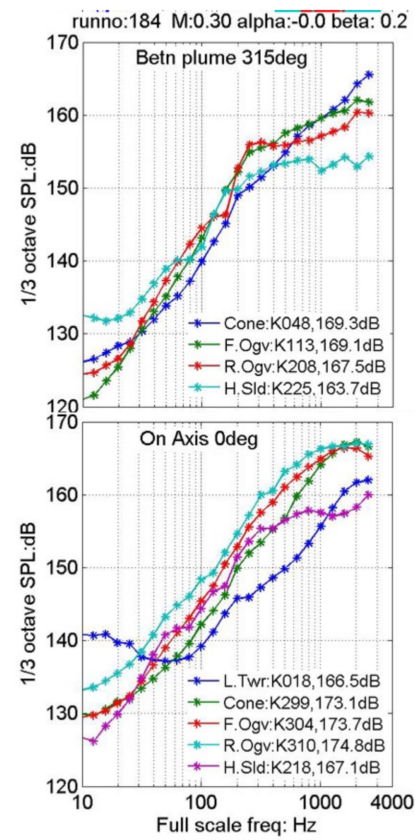
Mitigate Orion Risk: catastrophic failure of Orion during launch abort

- Use heated Helium to simulate the surface pressure fluctuations on Orion Launch Abort System created by the plumes of the abort motor
- Tested at UPWT 11 Foot Wind Tunnel





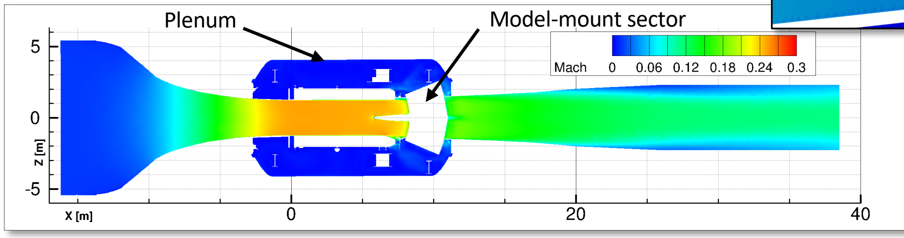


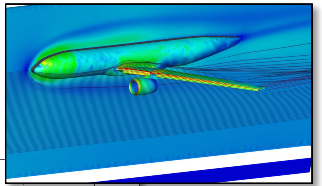


CFD/WT Test Integration Project

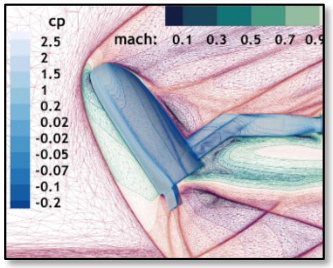
- Develop best practices for simulating all AETC wind tunnels (12 facilities, 17 test sections)
  - Use available work from other projects; NTF, 14x22, TDT, facility upgrades (9x15), new facility design (Flight Dynamics Research Facility)
  - Develop geometry and guidelines for simulations of remaining 12 tunnels/test sections
  - Archive the information in a way that enables NASA and reimbursable wind-tunnel customers to simulate their models in wind tunnels
    - Enable better understanding of the experimental results
    - Help customers improve their CFD tools and processes
- Use CFD simulations to better understand flow in AETC wind tunnels
  - Flow-quality and improvement opportunities
  - Process or measurement improvements
  - Improved data correction schemes
- Maintain understanding of the ability of CFD to simulate flow over models in all flight regimes simulated by AETC wind tunnels
  - Help customers with in-tunnel CFD (not doing it for them, yet)
  - Encourage sharing of CFD accuracy by NASA reimbursable and customer test teams
- AETC Project managed at Ames/FML
  - Employs 1.5 FTE in AOX, 0.25 FTE & 1 WYE in AA, .2 FTE in TSA in addition to LaRC and GRC researchers

Side View of NTF Tunnel High-Speed Leg
Center-Plane Mach Number

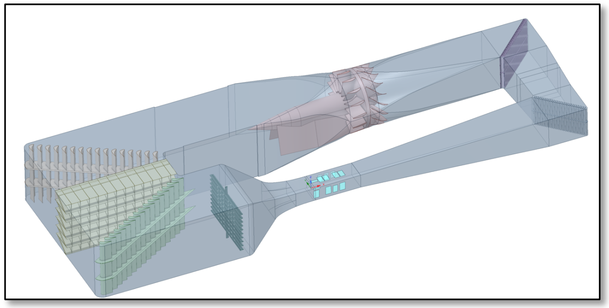




In-tunnel CRM simulation - Chris Yam



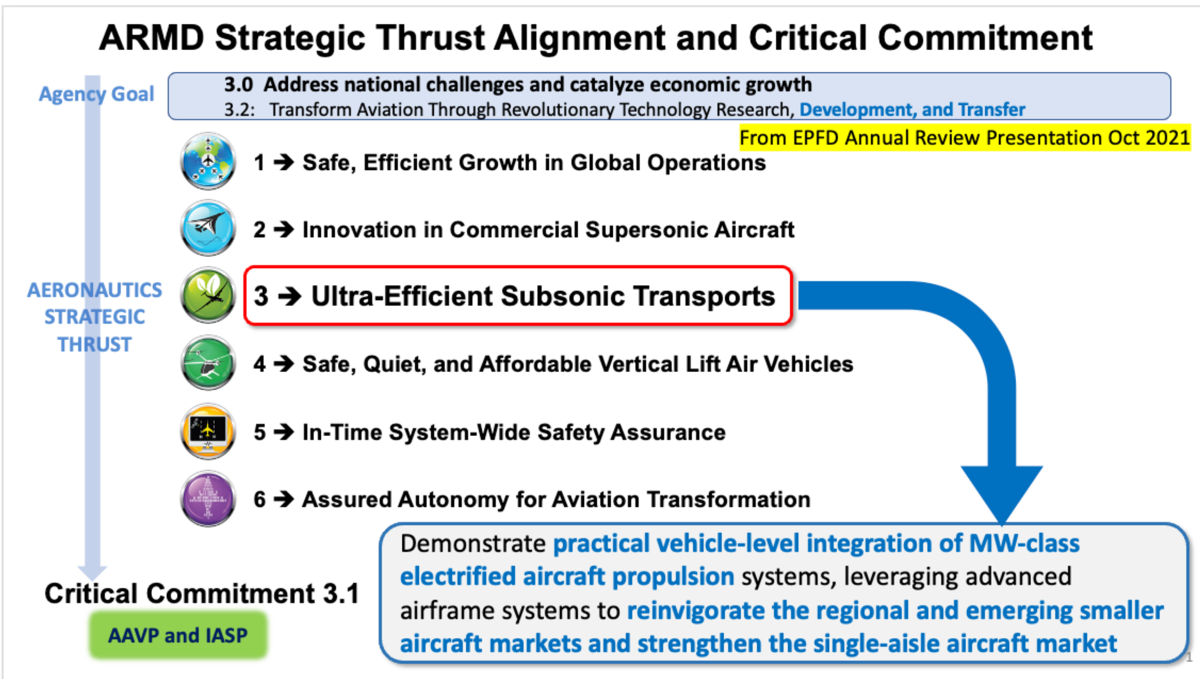
COBRA MRV model in 4' SSWT Bil Kleb – FUN3D



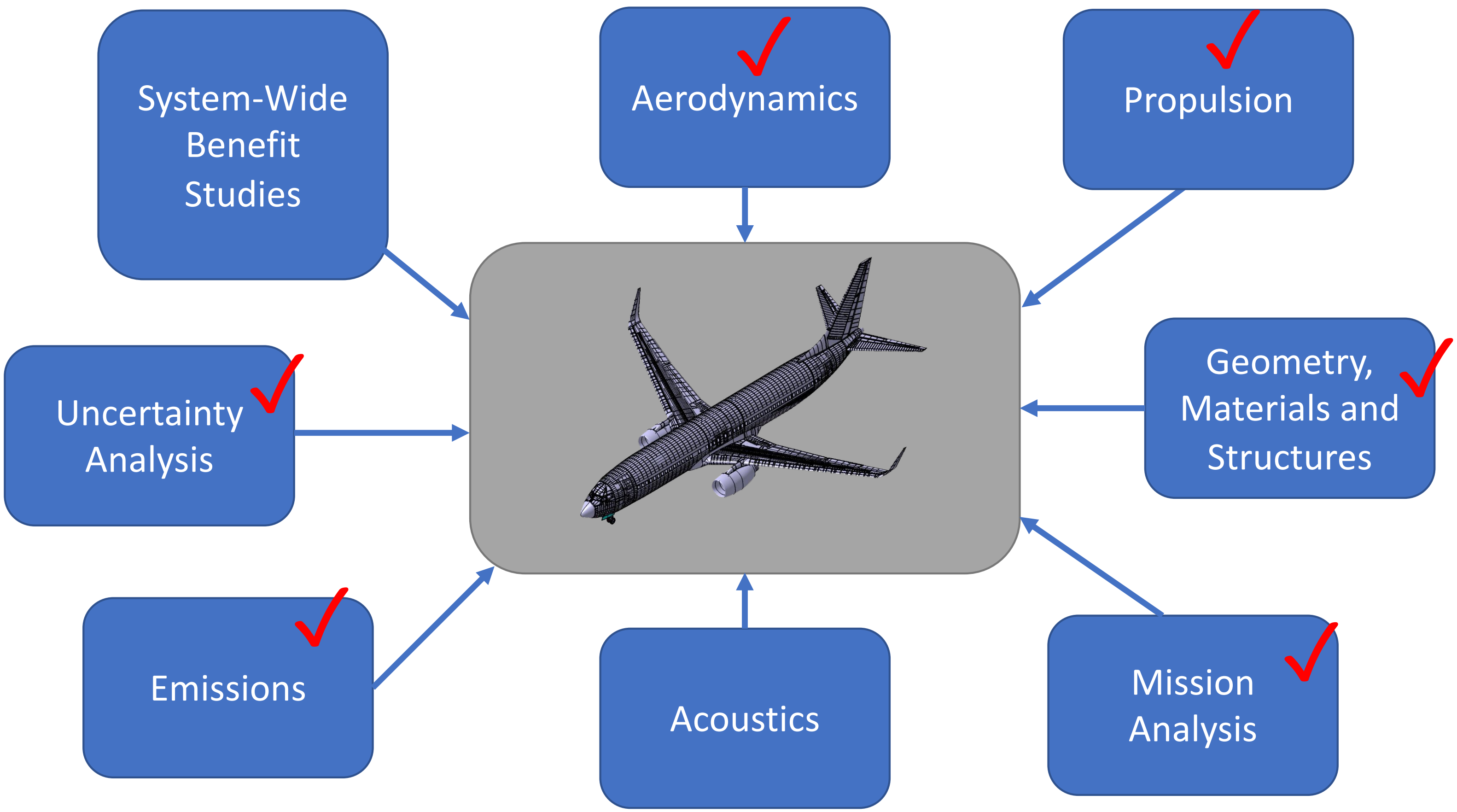
Icing Research Tunnel CAD model

Vehicle Assessment and System-wide Benefit Analysis

Collaborating closely with Code AA and Code AF in the independent assessment of flight demonstration vehicles and to better understand design trades and the uncertainties/risks in their proposed commercial systems.

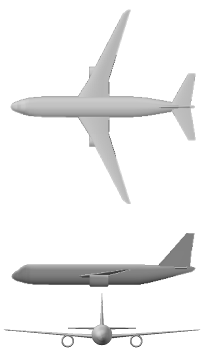


Vehicle Assessment and System-wide Benefit Analysis



Vehicle Assessment and System-wide Benefit Analysis

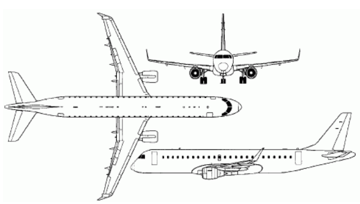
Recent Assessments (Code AA and AOX)



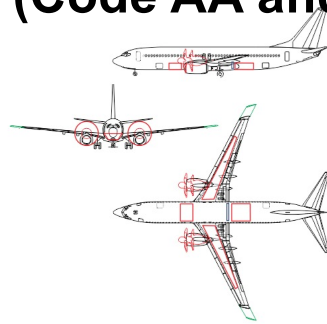
Advanced Tube and Wing
Span = 124.1 ft
GTOW = 146,399 lbs

Transonic Truss Braced Wing
Span = 172.4 ft
GTOW = 141,482 lbs

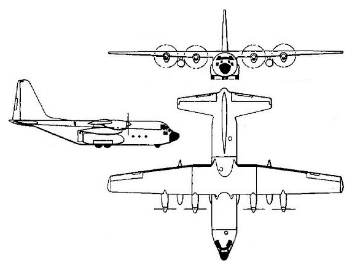
Hybrid Wing Body
Span = 168.5 ft
GTOW 160,396 lbs



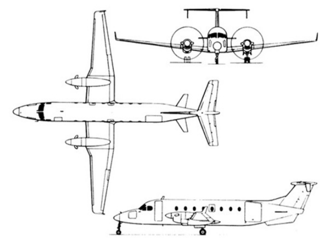
Embraer 190-E2
Span = 110.6 ft
GTOW 124,300 lbs



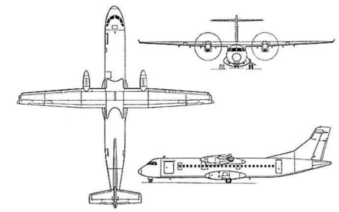
All-electric 150 pax
Span = 112.6 ft
GTOW 133,000 lbs



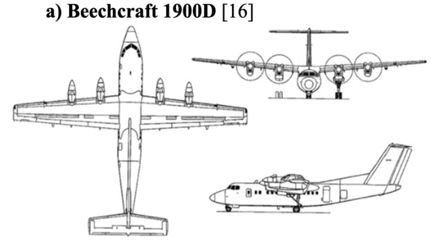
C130H (LM100-J)
Span = 132.6 ft
GTOW 155,000 lbs



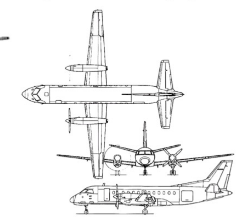
a) Beechcraft 1900D [16]



b) ATR 42-600 [16]



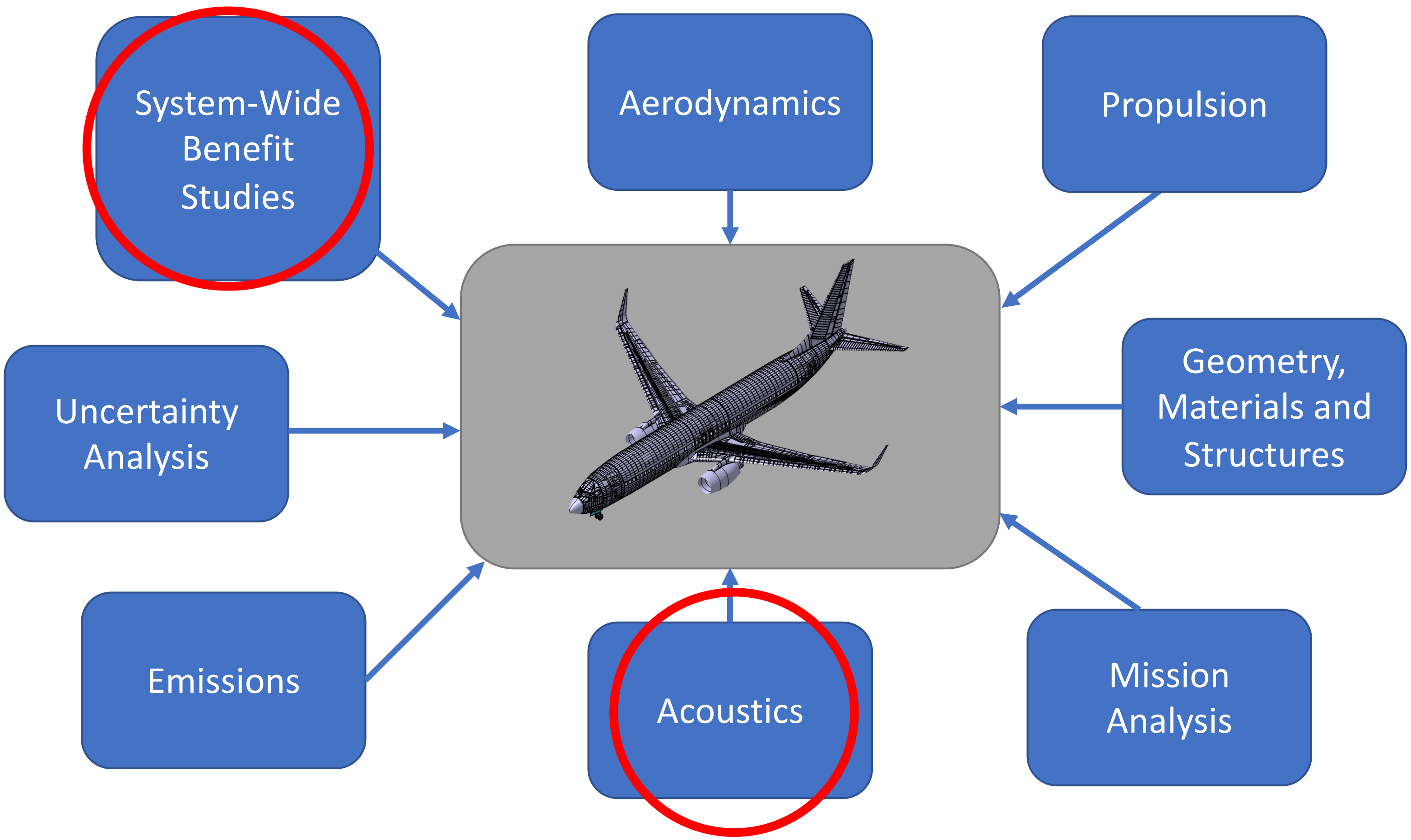
c) DHC-7-100 [16]



d) Saab 340B [16]

Physics-based vehicle library of "closed vehicles", baseline and conceptual vehicles, including single-aisle and regional aircraft, turbofan and turboprop, conventional and unconventional fuels

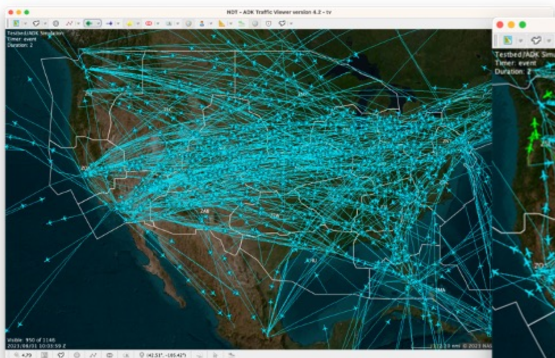
Vehicle Assessment and System-wide Benefit Analysis



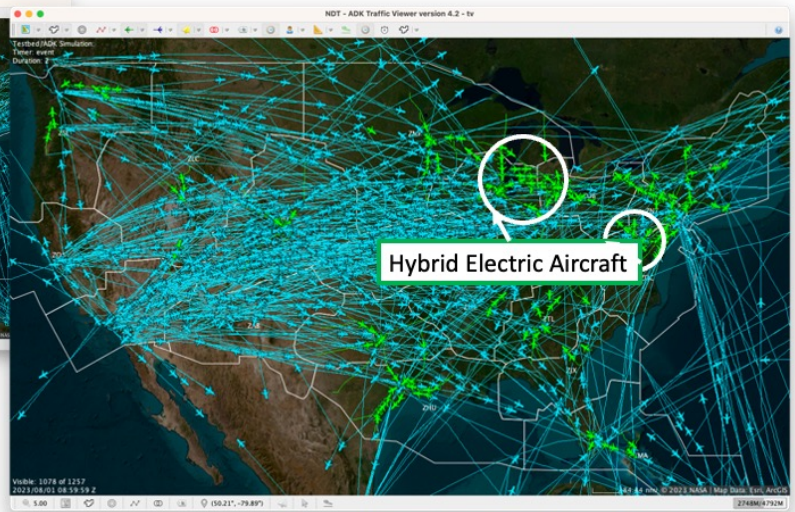
Vehicle Assessment and System-wide Benefit Analysis

Recent Progress

Code AF NAS Digital Twin

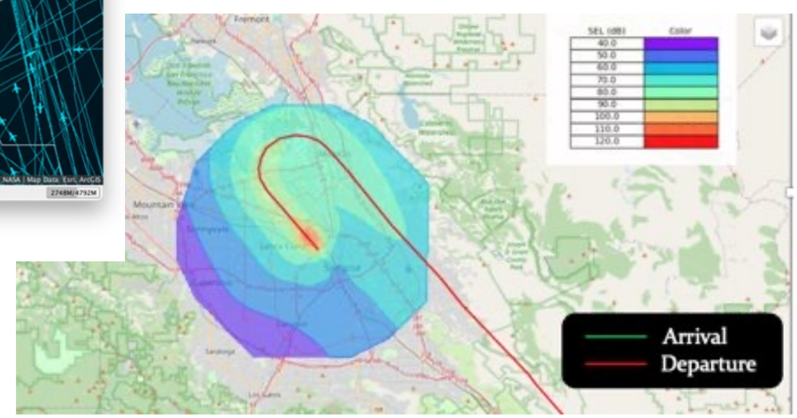


Baseline



Scenario 2

Code AOX Acoustic Prediction



Experimental Aero-Physics Branch

Collaborators

- ARMD Programs (AAVP, IASP, TACP) / Projects (CAS)
- NASA Mission Directorates (ARMD, STMD)
- Other government agencies (LLNL, DARPA)
- International research organizations (DLR)
- Airplane manufacturers
- Universities (GaTech, University of Michigan)

Competitors

- Private sector technology developers
- Universities for basic research and instrumentation development

Experimental Aero-Physics Branch

Recent Developments

- NASA Ames/Langley Unitary wind tunnel flow-quality-improvement study in Test Cell 3
- Development of a multi-hole probe for X-59 at GRC 8x6 wind tunnel
- Aeroacoustics Rotorcraft Measurements in the NFAC
- Development of unique measurement techniques (uPSP, LASEI, Rayleigh Scattering)
- uPSP demonstration test in the Ames Unitary (in progress)
- Aeroacoustic measurements of DAVINCI descent probe
- SFD/EPFD Vehicle Assessments combined with system-wide benefit analyses in tight collaboration with Codes AA and AF.
- Recent request from DARPA for AOX help in large scale stereo photogrammetry and thermal transition measurement techniques