NASA's Low-Boom Flight Demonstration Mission

Concept of Operations and Research Plans

AIAA Aviation 2019

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www.nasa.gov

Agenda

- LBFD Mission Overview
  - Thrust 2: Supersonics Strategy
  - Timeline
- Background
  - Sonic Boom Basics
  - Key Assumptions
- Concept of Operations
  - Test & Validation Research Objectives
  - Phase 1 Functional Checkout and Envelope Expansion
  - Phase 2 Acoustic Validation
  - Phase 3 Community Response Testing
- Summary

Overcoming the Barrier to Overland Supersonic Flight

Standards to Replace Current Prohibitions

NASA's Low-Boom Flight Demonstration is specifically planned to generate key data to validate design approaches and support development of en route certification standards based on acceptable sound levels

- **New Environmental Standards are needed to open the market to supersonic flight**
- **An En Route Noise Standard is the biggest challenge**
  - Requires proof of new design approaches, test procedures and response metrics
  - No relevant data exists to define limits
    - Community data from large, diverse population is a requirement
  - Standard must be accepted internationally

Strategic Thrust 2: Supersonics Strategy

STRATEGIC THRUST, OUTCOME, and CRITICAL COMMITMENT

Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft

Outcome (2015 – 2025): Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise

Critical Commitment: Deliver to ICAO a database of community response to quiet supersonic aircraft flight over land

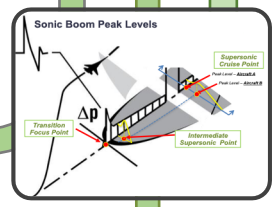
Integrated Design Solutions for Revolutionary High Speed Aircraft
Research & development of validated analysis tools and technologies that enable the low-sonic boom design of supersonic aircraft

Design & Build Low Boom Demonstrator Aircraft (X-59)
Design and build a first-ever low-boom demonstrator aircraft that can be utilized to generate the necessary boom data

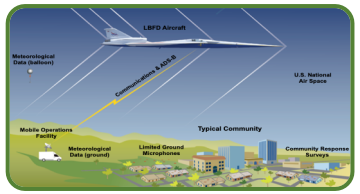
Understanding & Measuring Community Response to Sonic Booms
Research, development, application of validated methodologies for a field study of community response to enable development of overland sonic boom standards

Critical Commitment: Deliver Database

Low boom design tools
Prediction validation



Sonic boom community response metric & methodologies



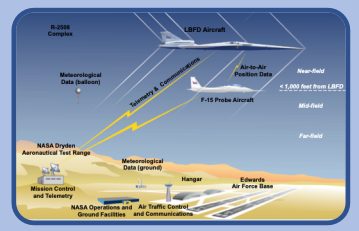
Community test planning
Community testing

Airborne measurements & range operations
Acoustic validation test prep & execution

Design Tools
Validated Hardware
Test Tools & Methods
Response Data

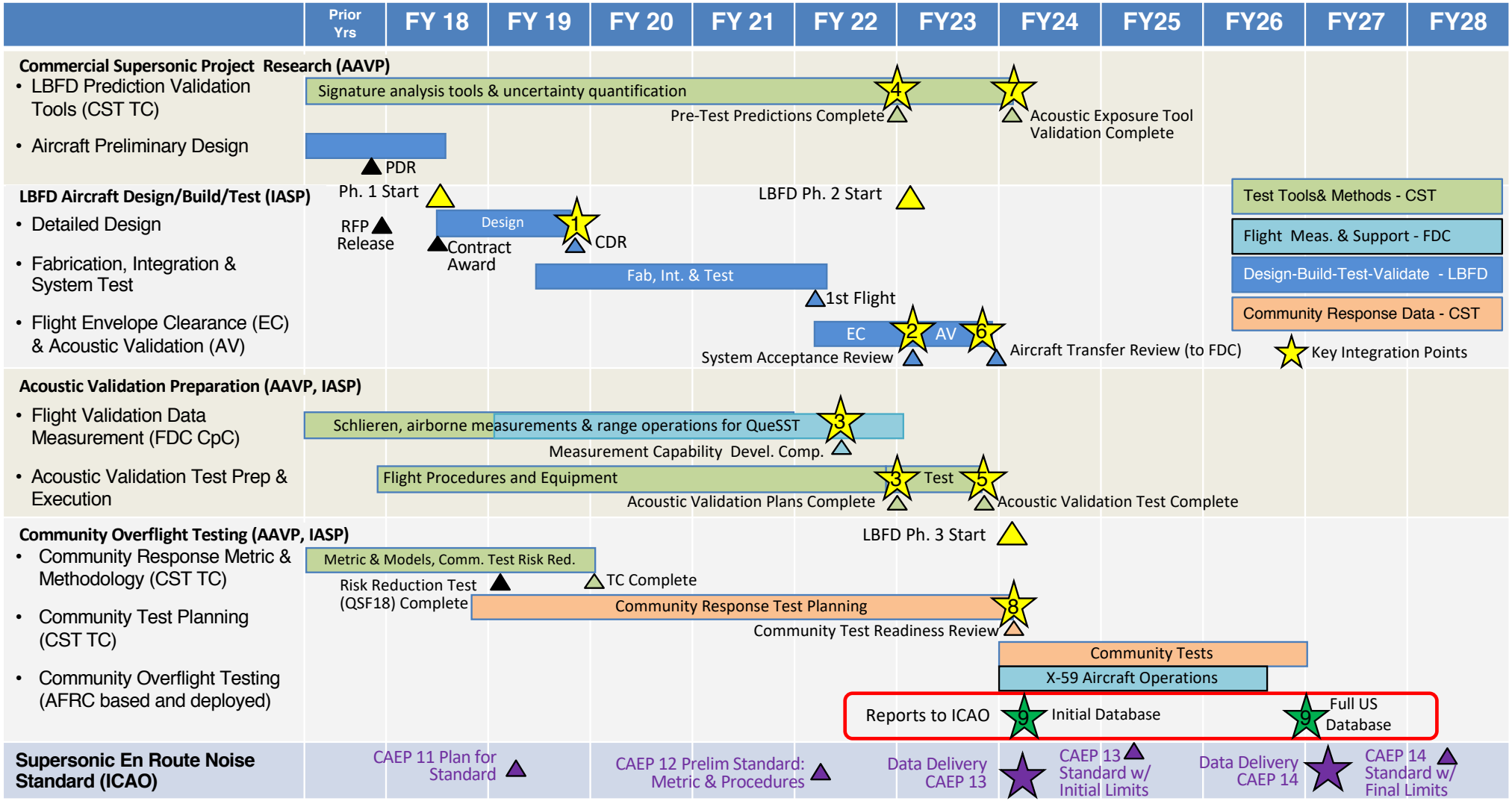
LBFD Project

Design & build aircraft with low-noise sonic boom signature characteristics



Verify aircraft low-boom acoustic signature

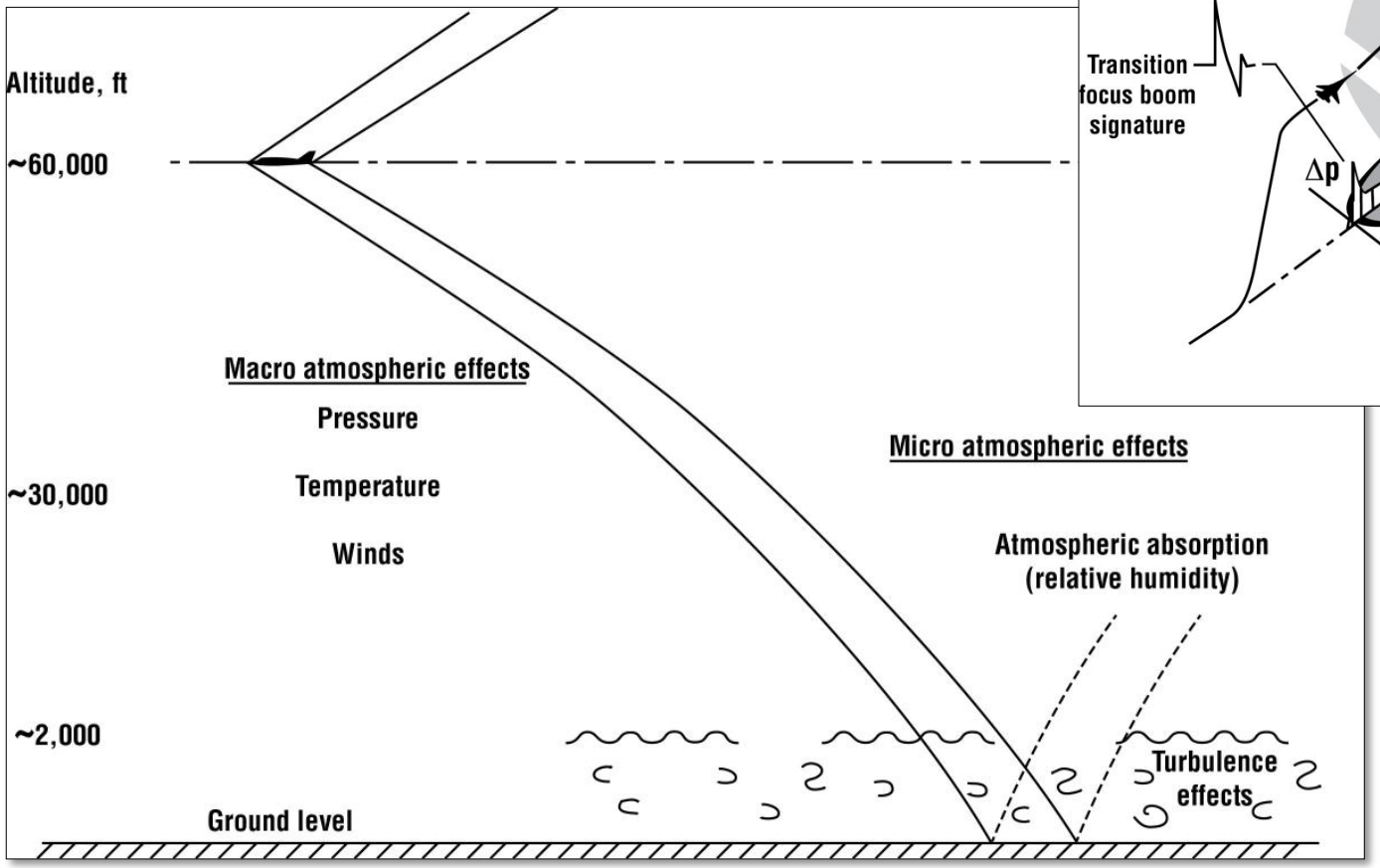
Low-Boom Flight Demonstration Mission Timeline

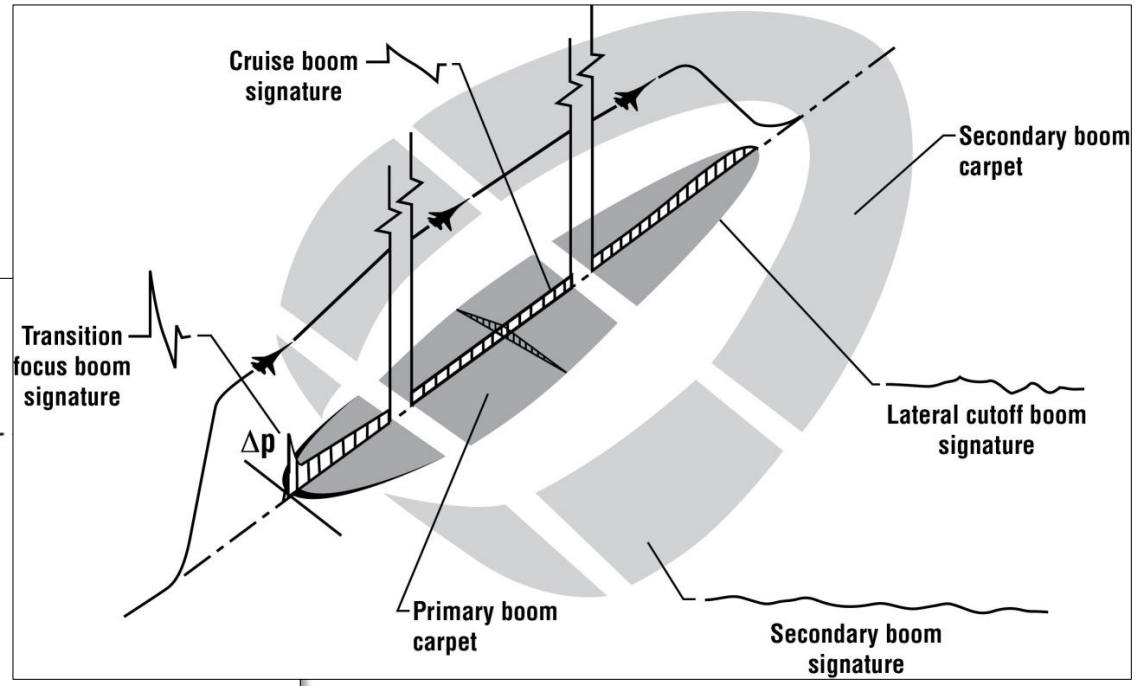


Timeline shown above aligned with LBFD management agreement dates

Sonic Boom Basics

Sonic boom With Atmospheric Effects





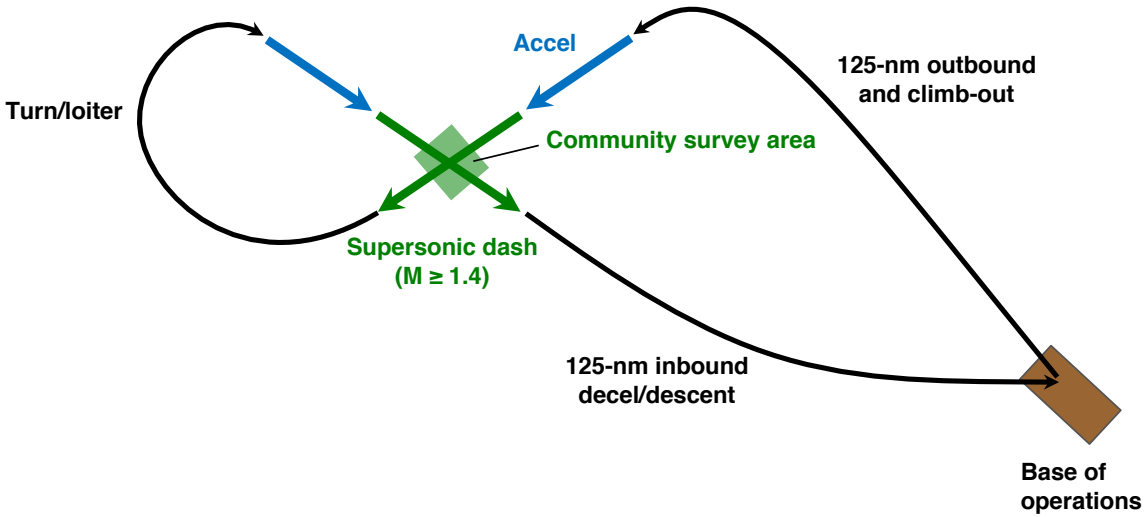
Boom Signature Carpet

Early Mission, Test and Aircraft Assumptions

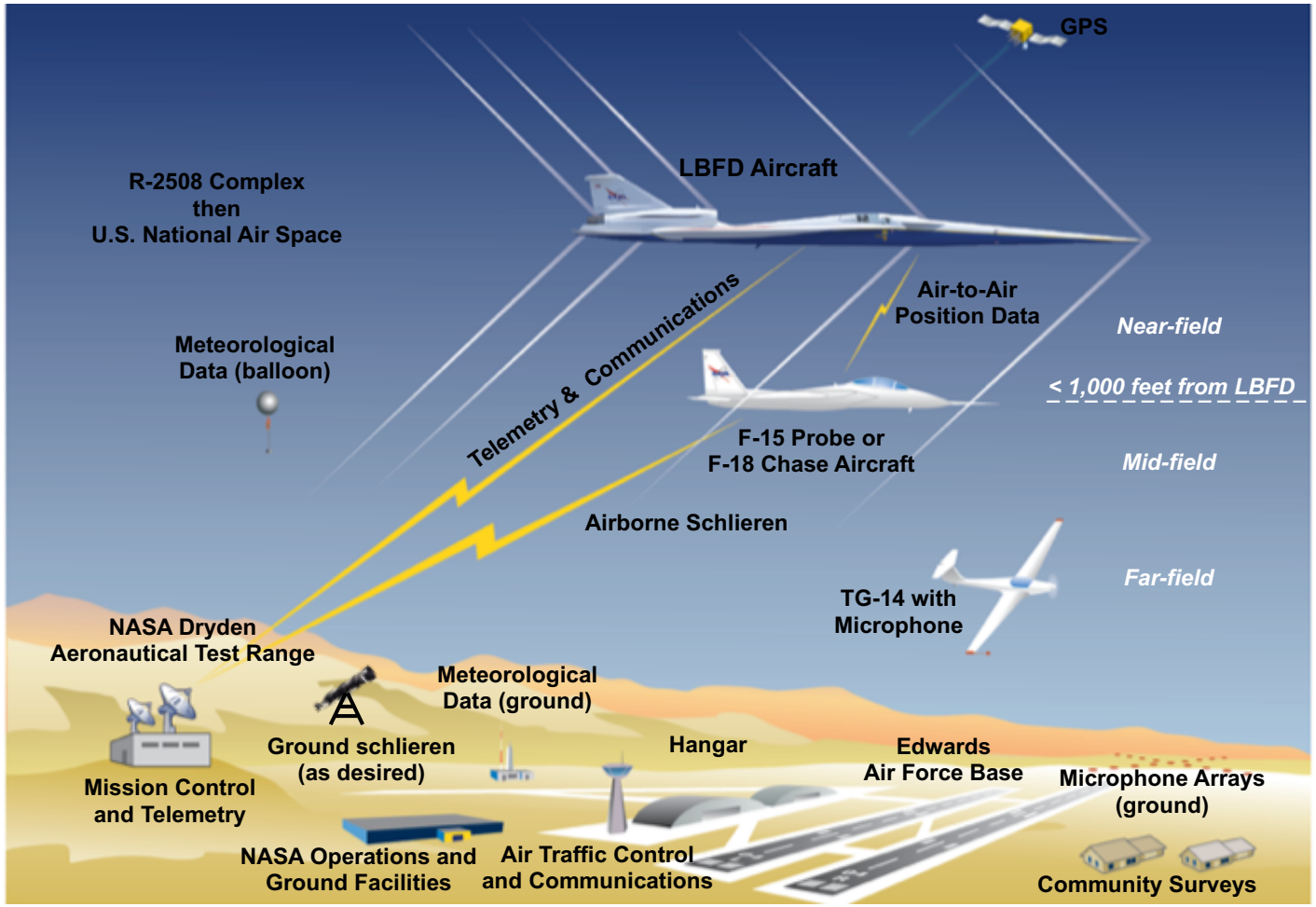
Key Assumptions

Ground signature traceability (indoor) - peak acoustic energy ≤ 10 Hz
Ground signature loudness (outdoor) ≤ 75 PLdB boom carpet
Ground signature variability 70 - 80 PLdB
Cruise deviations (turbulence)
Cruise Mach ≥ 1.4
Two passes ≥ 50 nm in length per flight, passes ≥ 20 minutes apart
Three flight operations / day
Day/night, and IFR flight operations in the public airspace
Low/no-focus supersonic acceleration/climb performance
Mission performance (hot day)

Baseline Mission



Concept of Operations (ConOps) - Overview



LBFD Mission Phases

Phase 1 - Aircraft Development

- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion

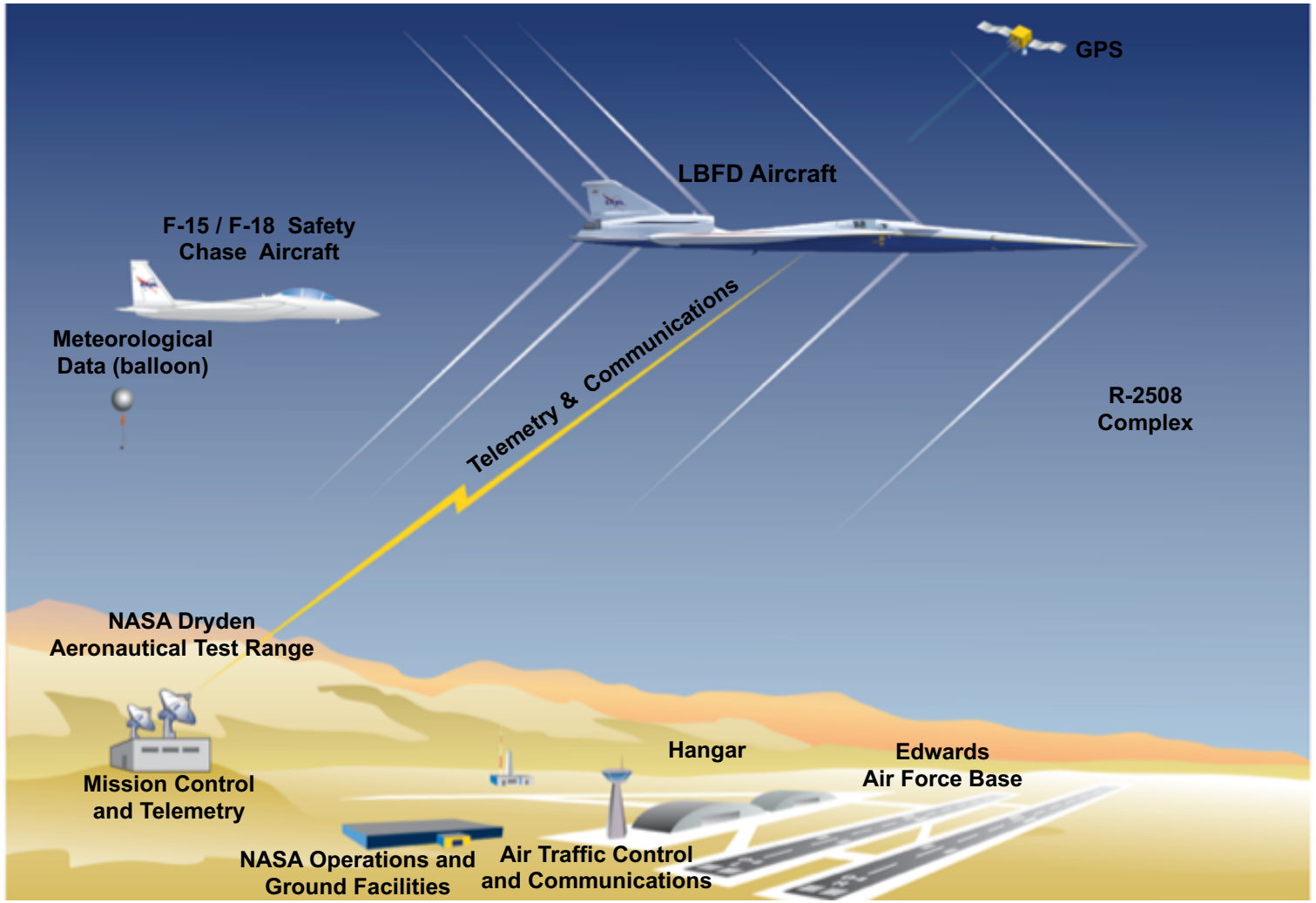
Phase 2 – Acoustic Validation

- Near-, Mid- and Far-field Measurements
- Ground Measurements

Phase 3 – Community Response

- Initial community response overflight study
- Multiple campaigns (4 to 6) over representative communities and weather across the U.S.

Phase 1 Functional Checkout and Envelope Expansion



Checkout Flights

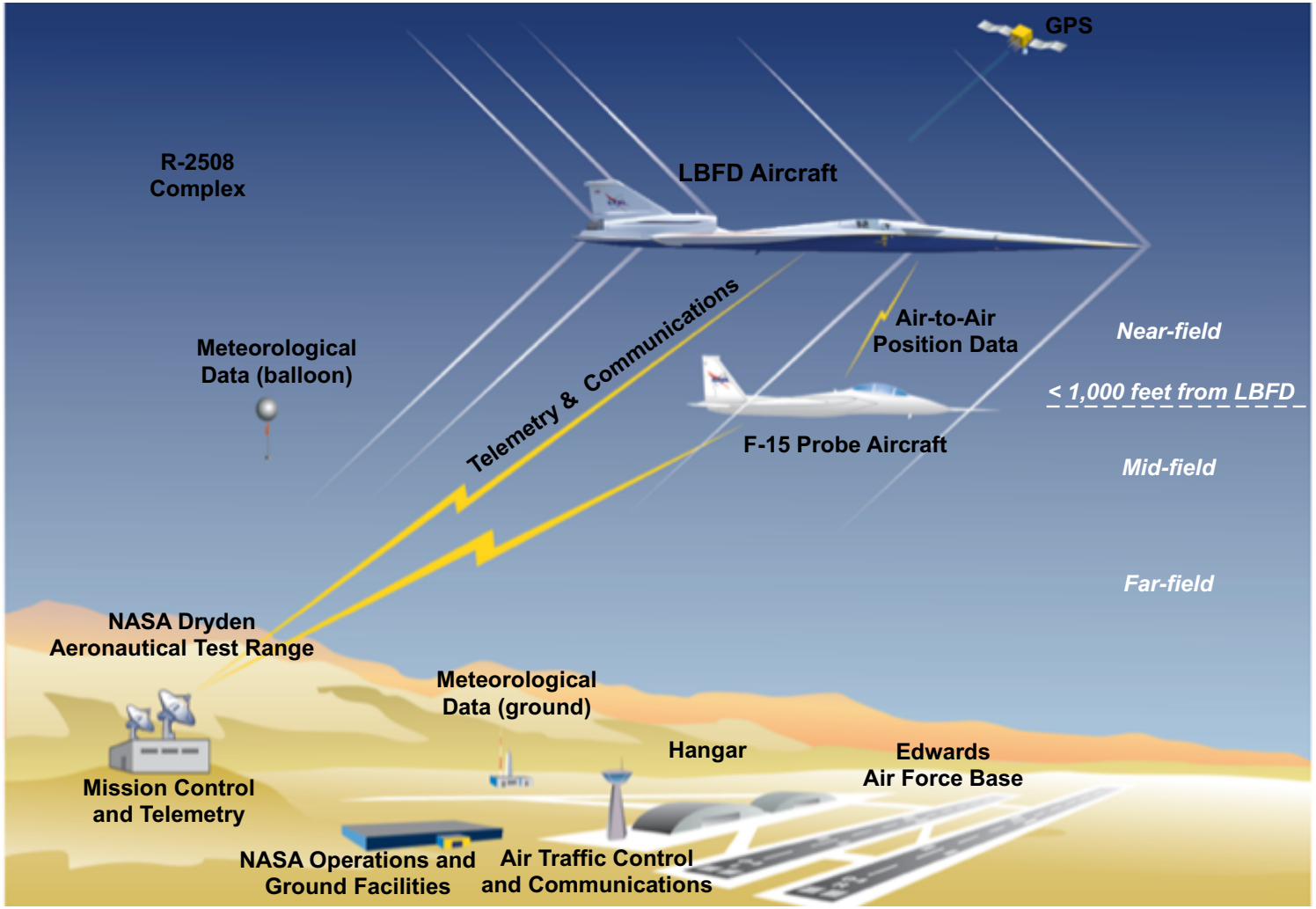
Subsonic Envelope Expansion

Supersonic Envelope Expansion

LBFD Mission – Test & Validation Research Objectives

LBFD Project Objectives	Low-Boom Flight Demonstration Mission Test & Validation (TV) Research Objectives
During Phase 1, demonstrate that the LBFD aircraft meets the LBFD airworthiness certification, safety, and performance standards throughout the flight envelope.	**LBFD TV-01:** Gather LBFD aircraft shape data on the ground to validate the jig shape design tools/methods, and predicted vs measured aircraft shape at design cruise conditions.
During Phase 2, support CST to measure and validate: 1) the near-field acoustic characteristics of the LBFD aircraft and 2) the atmospheric effects on the far-field and ground sonic boom signatures.	**LBFD TV-02:** Gather and analyze dataset for measurements of shock signature in the near-field (<10 BL) of the LBFD aircraft to validate the capability of low-boom design tools to predict near-field acoustic characteristics of the LBFD aircraft at design cruise conditions.
	LBFD TV-03: Gather and analyze dataset for lateral ground measurements of shock signature across width of sonic boom carpet to validate the capability of acoustic propagation tools to predict the sonic boom ground signature and loudness (including atmospheric effects) of LBFD aircraft at design cruise conditions. Maneuvers designed to minimize the sonic boom ground signature and loudness will also be investigated.
	LBFD TV-04: Gather and analyze dataset for measurements of shock signature in the far-field above the atmospheric boundary layer to validate the capability of acoustic propagation tools to predict the sonic boom far-field acoustic characteristics (with minimal atmospheric turbulence effects) of the LBFD aircraft at design cruise conditions.
	LBFD TV-05: Gather and analyze dataset for longitudinal ground measurements of shock signature along sonic boom carpet to validate the capability of acoustic propagation tools to predict the sonic boom ground signature and loudness of LBFD aircraft at supersonic accel/climb and focus boom conditions.
	LBFD TV-06: Gather and analyze dataset for flow visualization of shock structure in the near-field (<10 BL) of the LBFD aircraft to validate the capability of low-boom design tools to predict near-field acoustic characteristics of the LBFD aircraft at design cruise conditions.
	LBFD TV-07: Gather and analyze dataset for measurements of shock signature in the mid-field (>10 BL) of the LBFD aircraft to validate the capability of low-boom design and acoustic propagation tools to predict mid-field acoustic characteristics of the LBFD aircraft at design cruise conditions.
Ensure the LBFD aircraft is capable of generating low-noise sonic boom signatures and producing the mission performance required to conduct community response overflight studies during Phase 3.	**LBFD TV-08:** Gather and analyze Low-Boom Flight Demonstration mission Phase 2 test data to validate the test design, instrumentation, logistics, and operational considerations for application to Low-Boom Flight Demonstration mission Phase 3 community response testing.
Overall LBFD Mission Objective	**LBFD TV-09:** Gather and analyze Low-Boom Flight Demonstration mission Phase 3 community response test data and deliver the community response database to ICAO.

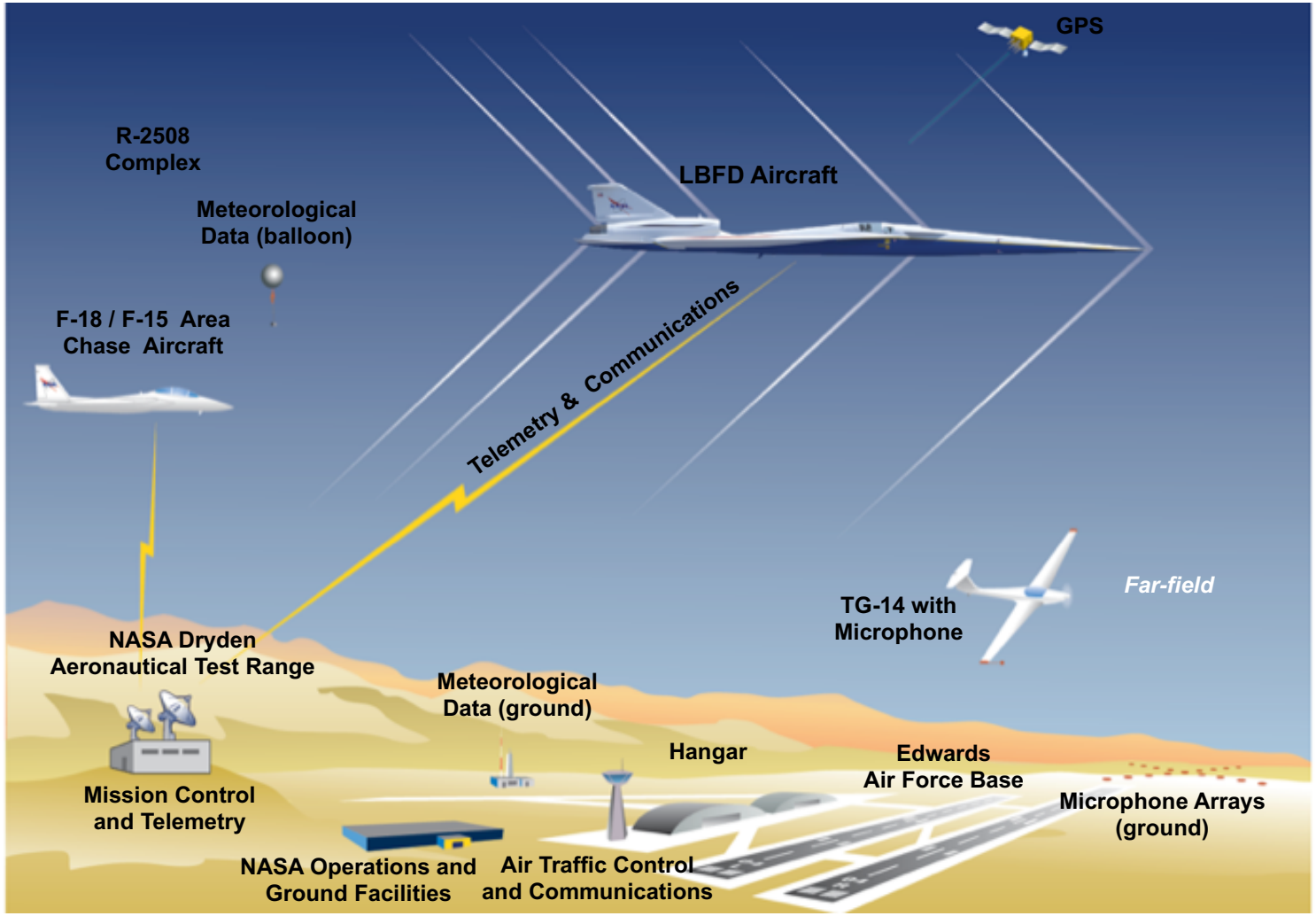
Phase 2A Acoustic Validation - Near/Mid-field Shockwave Probing



LBFD TV-02: Gather and analyze dataset for measurements of shock signature in the near-field (<10 BL) of the LBFD aircraft to validate the capability of low-boom design tools to predict near-field acoustic characteristics of the LBFD aircraft at design cruise conditions.

LBFD TV-07: Gather and analyze dataset for measurements of shock signature in the mid-field (>10 BL) of the LBFD aircraft to validate the capability of low-boom design and acoustic propagation tools to predict mid-field acoustic characteristics of the LBFD aircraft at design cruise conditions.

Phase 2B Acoustic Validation - Far-field & Ground Measurements

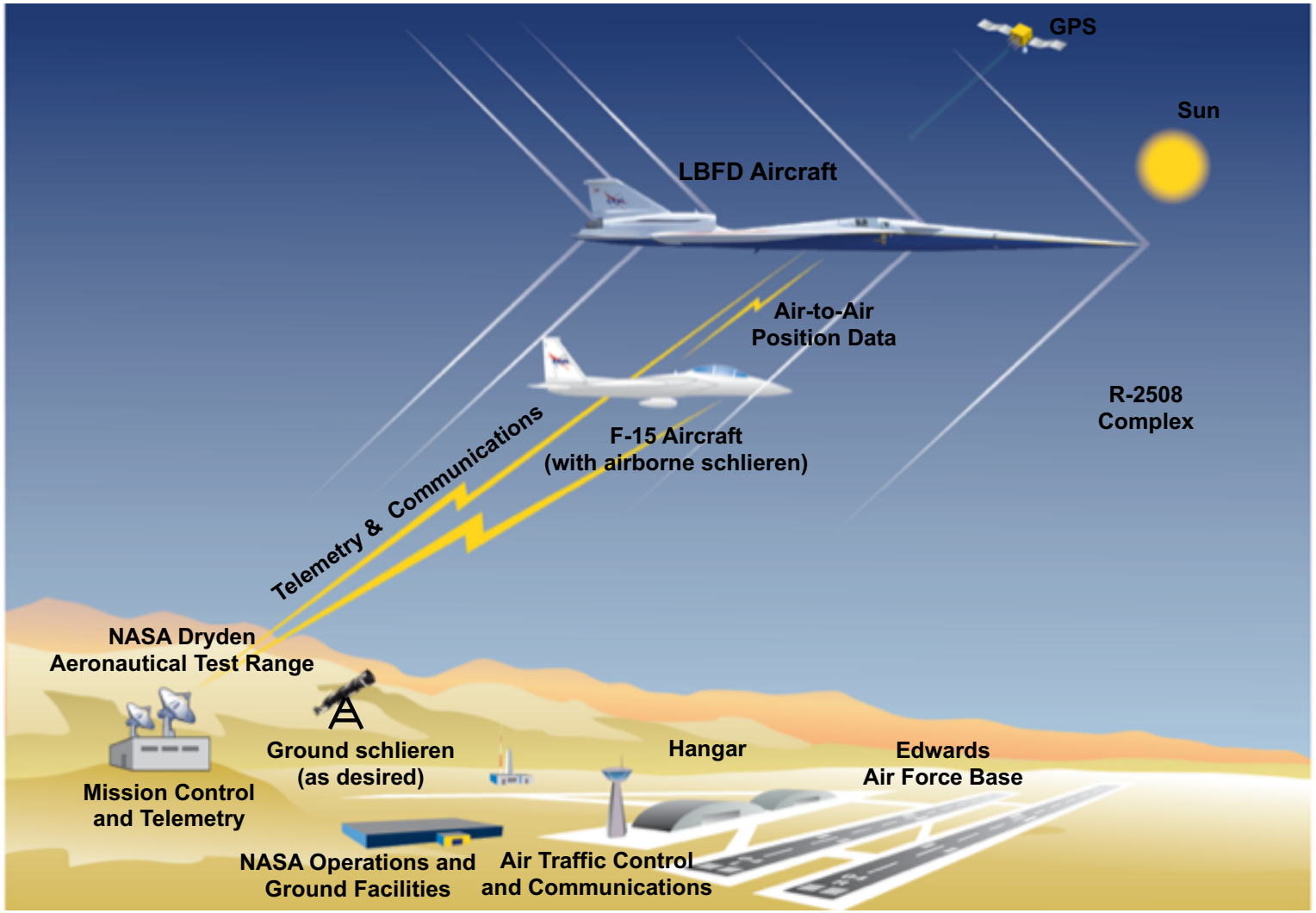


LBFD TV-03: Gather and analyze dataset for lateral ground measurements of shock signature across width of sonic boom carpet to validate the capability of acoustic propagation tools to predict the sonic boom ground signature and loudness (including atmospheric effects) of LBFD aircraft at design cruise conditions. Maneuvers designed to minimize the sonic boom ground signature and loudness will also be investigated.

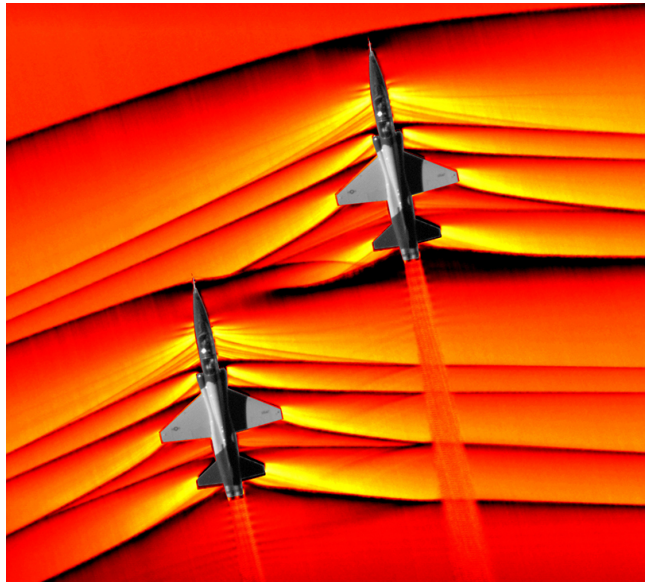
LBFD TV-04: Gather and analyze dataset for measurements of shock signature in the far-field above the atmospheric boundary layer to validate the capability of acoustic propagation tools to predict the sonic boom far-field acoustic characteristics (with minimal atmospheric turbulence effects) of the LBFD aircraft at design cruise conditions.

LBFD TV-05: Gather and analyze dataset for longitudinal ground measurements of shock signature along sonic boom carpet to validate the capability of acoustic propagation tools to predict the sonic boom ground signature and loudness of LBFD aircraft at supersonic accel/climb and focus boom conditions.

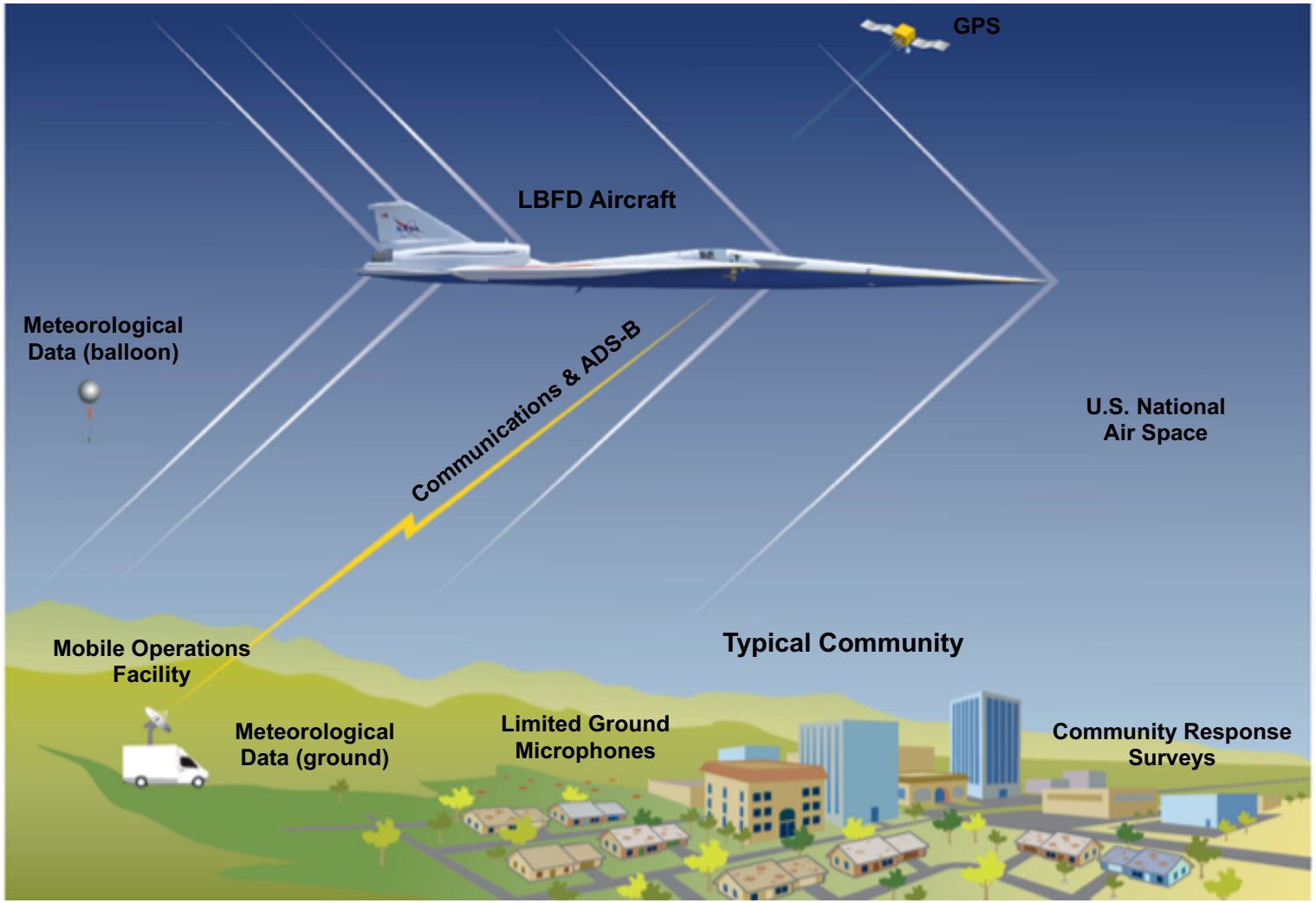
Phase 2C Acoustic Validation - Schlieren Shockwave Imaging



LBFD TV-06: Gather and analyze dataset for flow visualization of shock structure in the near-field (<10 BL) of the LBFD aircraft to validate the capability of low-boom design tools to predict near-field acoustic characteristics of the LBFD aircraft at design cruise conditions.



Phase 3 – Community Response Testing



LBFD TV-08: Gather and analyze Low-Boom Flight Demonstration mission Phase 2 test data to validate the test design, instrumentation, logistics, and operational considerations for application to Low-Boom Flight Demonstration mission Phase 3 community response testing.

LBFD TV-09: Gather and analyze Low-Boom Flight Demonstration mission Phase 3 community response test data and deliver the community response database to ICAO.

Summary

- NASA's Low-Boom Flight Demonstration mission is a comprehensive, scientifically-driven effort to provide U.S. and international regulators with statistically valid flight data required to approve new rules that will allow commercial supersonic flight over land.
- Development of key toolsets, requirements, research objectives, and ConOps during early design studies has provided the LBFD mission with a steady path forward
- Overview of research objectives and ConOps was presented
- First flight of X-59 aircraft scheduled for late-2021 followed by envelope expansion and acoustic validation flights in 2022
- NASA anticipates that the initial community response data will be delivered to U.S. and international regulators in 2024

Questions?