Low-Boom Flight Demonstration: Phase 2 – Acoustic Validation

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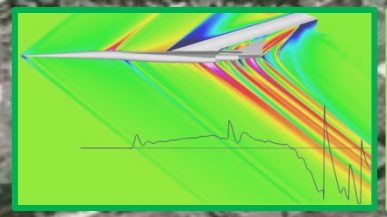
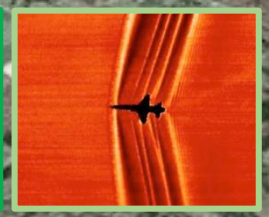
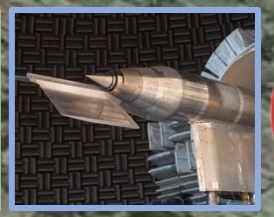
NASA Armstrong Flight Research Center

Commercial Supersonic Technology Project







NASA's Low-Boom Supersonic Technology is Ready For Flight

FIELD STUDIES

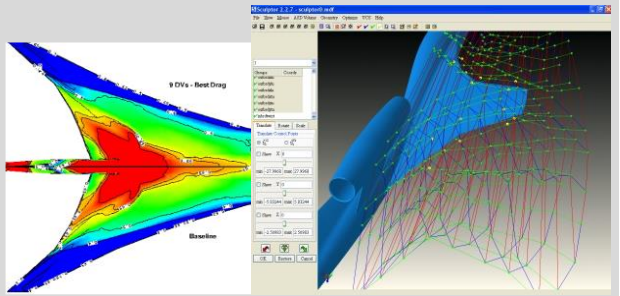
Field studies show the potential for acceptable low boom noise.

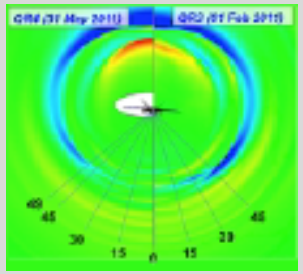
Low-Boom Flight Simulation using F-18 Dive Maneuver

Sonic Boom Acceptability Studies using Ground Simulators and in the Field

MODELING TOOLS

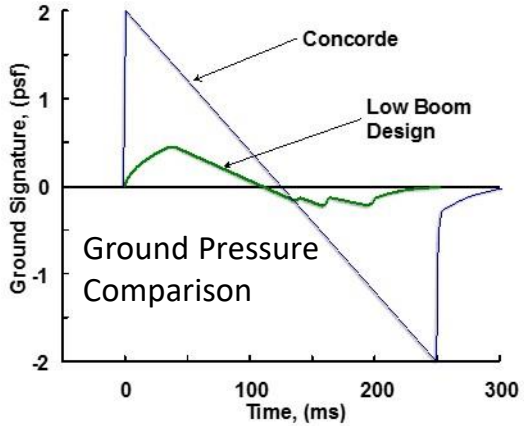
New advances in modeling tools allow us to design new low-boom configurations.

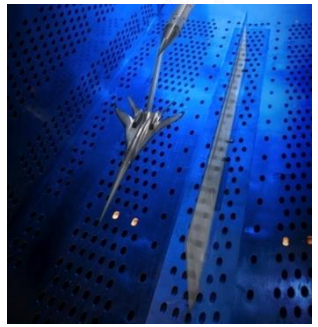




GROUND TESTING

Extensive wind-tunnel tests indicate that these new designs show the low-boom characteristics that we predict.



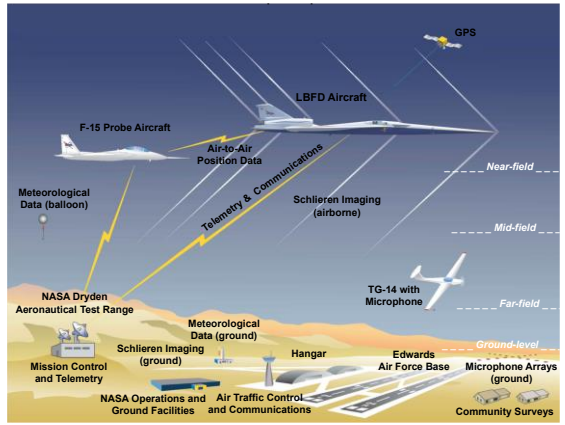


Low-Boom Flight Demonstration Mission Phases

Image Credit : Lockheed Martin

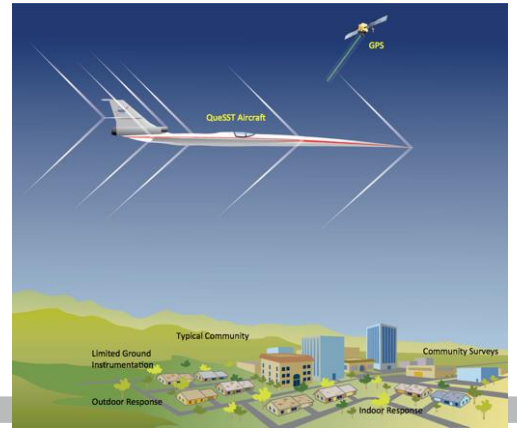
Phase 1 – Aircraft Development – FY18–22

- Detailed design
- Fabrication, integration, ground test
- Checkout flights
- Subsonic envelope expansion
- Supersonic envelope expansion



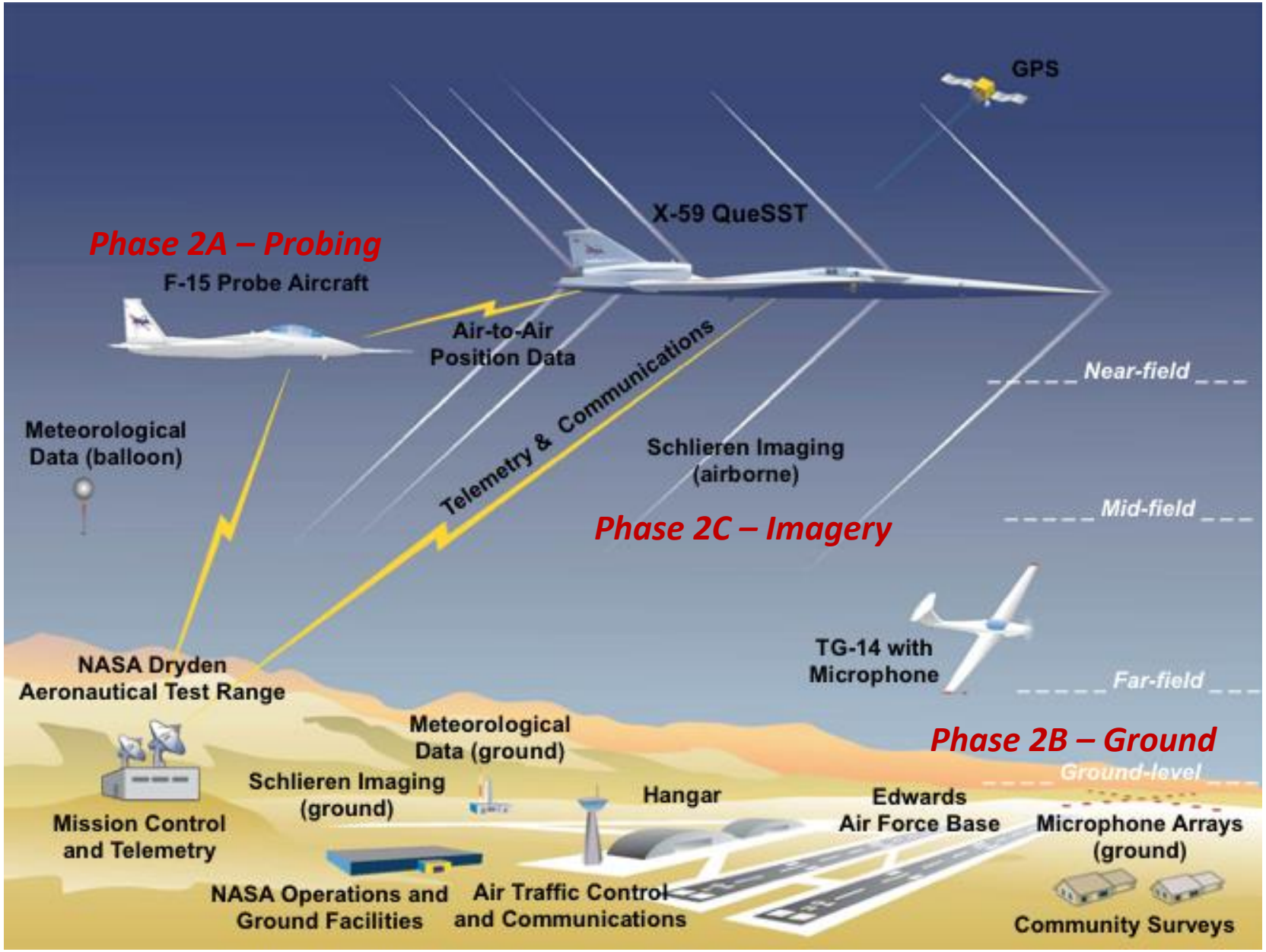
Phase 2 – Acoustic Validation – FY22–23

- Aircraft operations & support, range Ops, support aircraft
- In-flight measurements
- Ground measurements
- Validation of X-59 boom signature and prediction tools
- Development of acoustic prediction tools for Phase 3



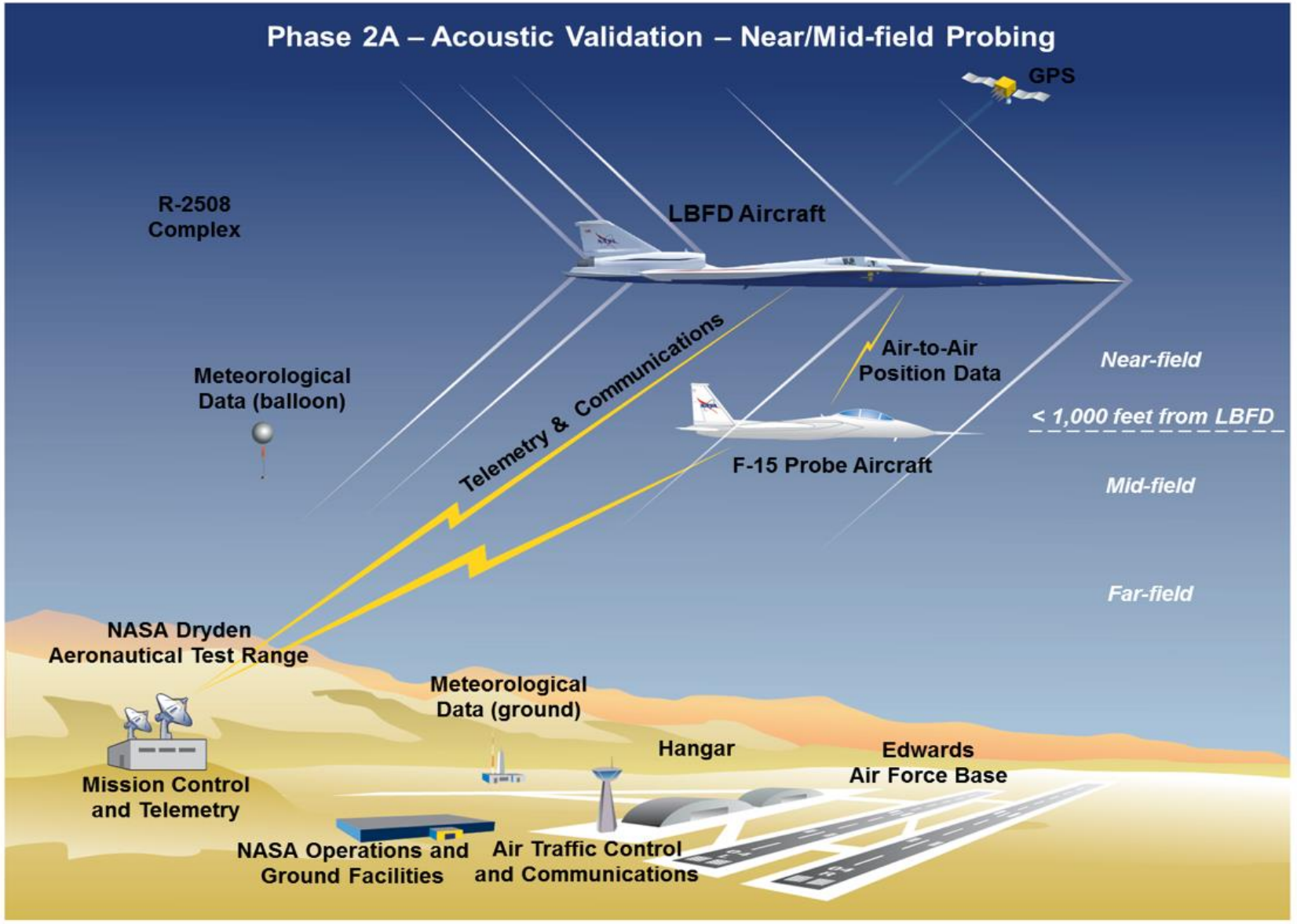
Phase 3 – Community Response Testing (FY23–26)

- Aircraft operations & support, deployment logistics
- Ground measurements
- Ground crew operations
- Noise exposure design
- Community response surveys
- Data analysis and database delivery



LBFD Phase 2 Combined Concept of Operations

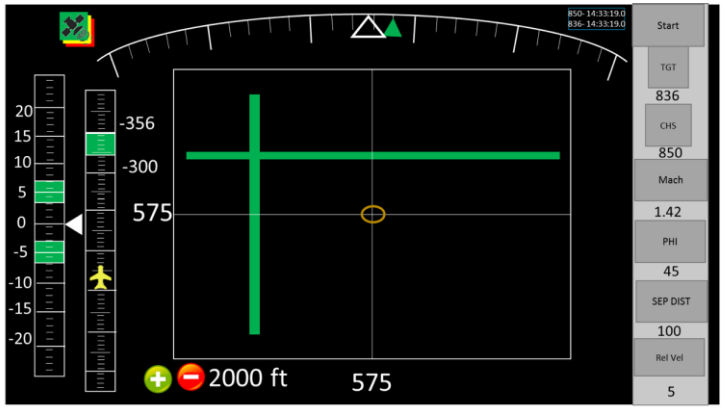
Phase 2A: Near/Mid-Field Probing Flights



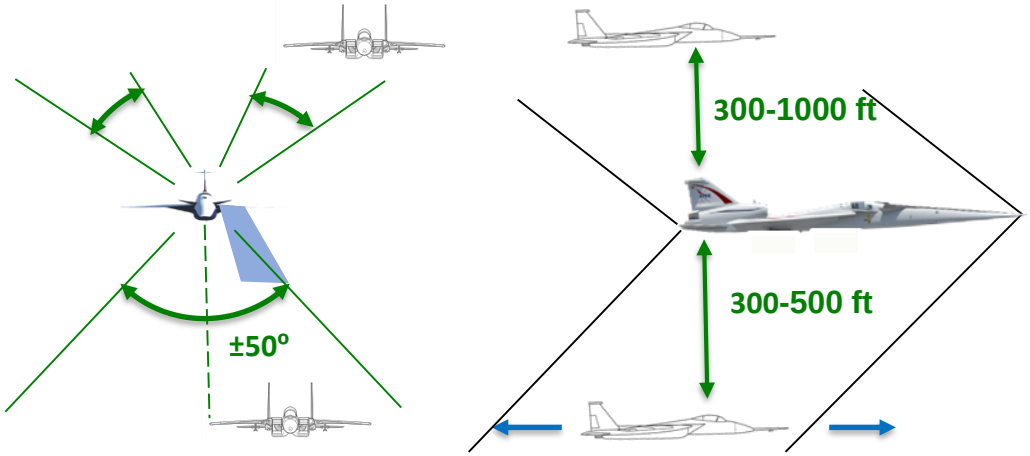
Phase 2A Probing: Flight Positioning

20 Flights	2 / day

- X-59 flies at low-boom design cruise conditions
- F-15 flies relative to X-59 – forward and aft for multiple passes
  - 25 test points 300-500 feet below X-59 (±50º lateral offset below)
  - Six test points 300-1,000 feet above X-59
  - Six test points 20,000 feet below X-59 (±20º mid-field)
- Research Support Aircraft (F-15)
  - Shockwave Sensing Probe and Modified Life Support System



F-15 Probing Positioning Display Prototype
Source: FDC project (ALIGNS)

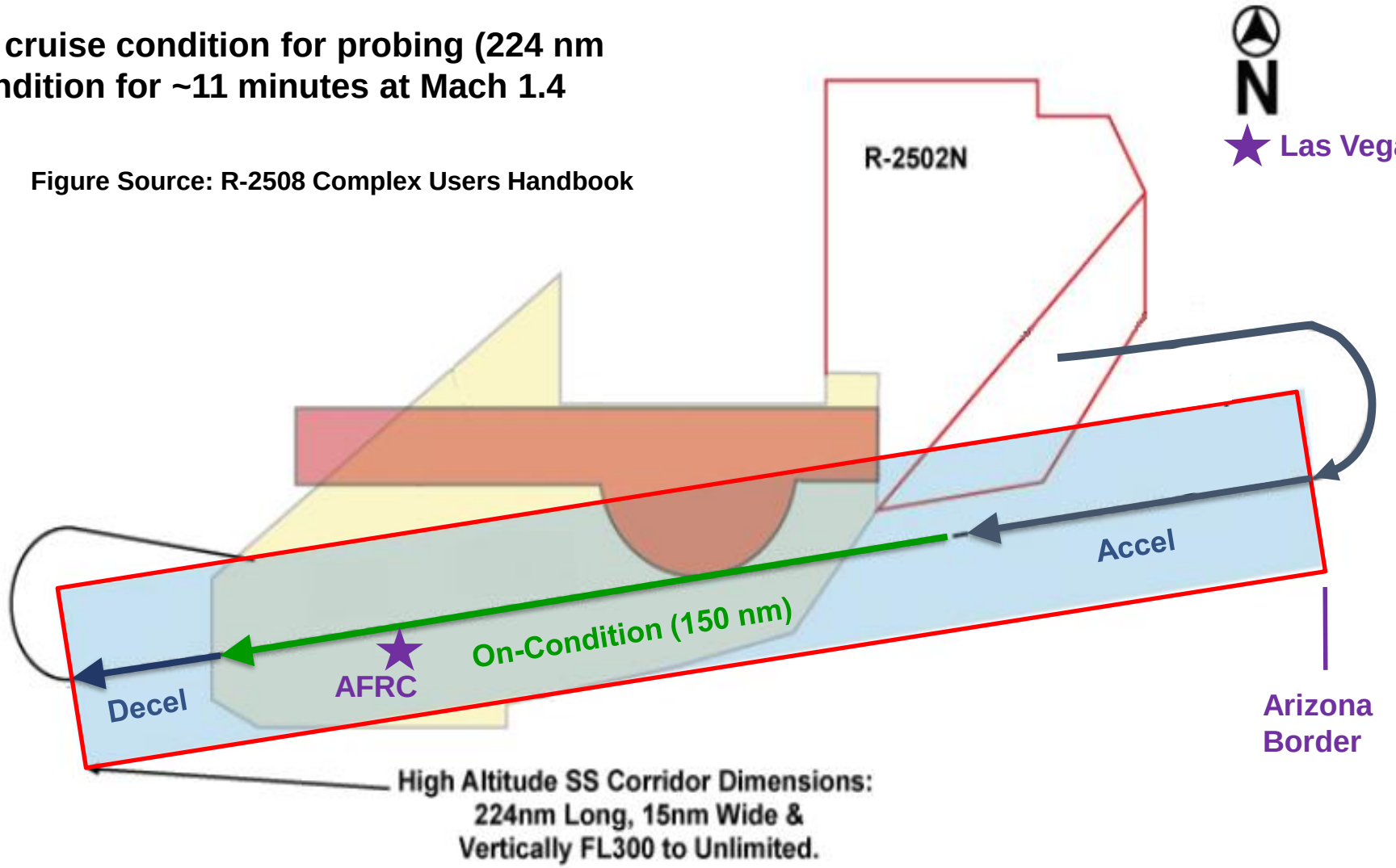


X-59 and F-15 Relative Positions

Phase 2A Probing: Flight Profile & Airspace

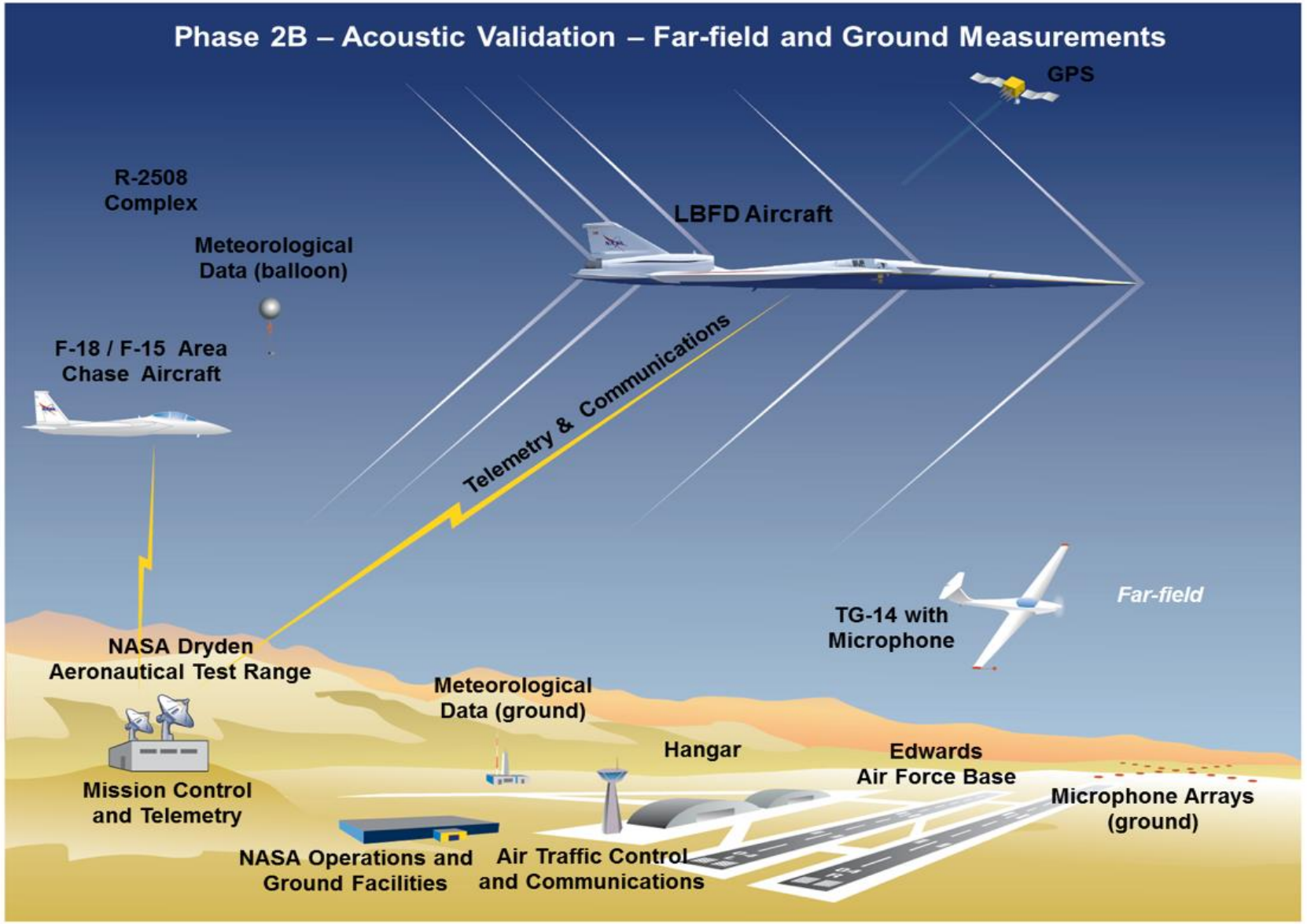
Up to 150 nm at cruise condition for probing (224 nm Corridor)On Condition for ~11 minutes at Mach 1.4

Figure Source: R-2508 Complex Users Handbook



Maximum pass length limited by AFRC airspace

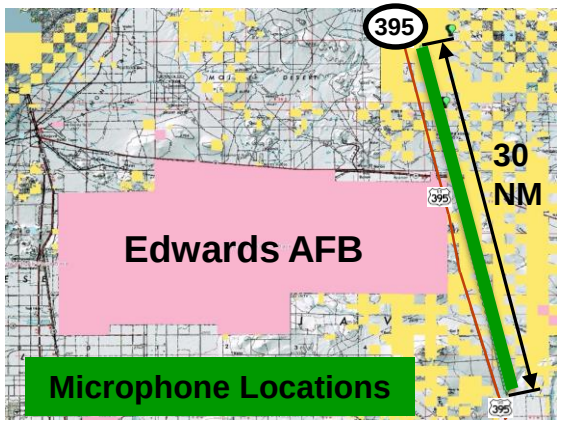
Phase 2B: Far-Field and Ground Measurement Flights



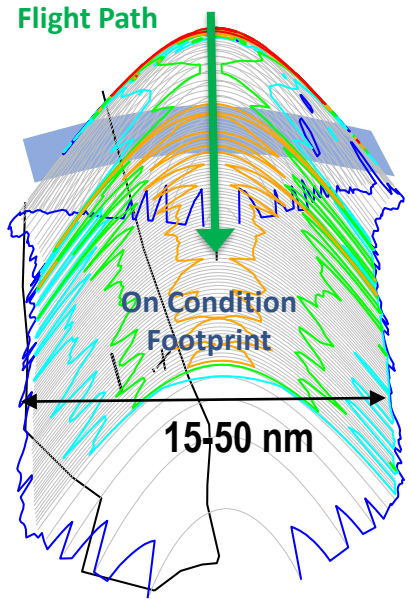
Phase 2B: Far-Field and Ground Measurement Flights

30 Flights	2-3 / day

- X-59 flies at low-boom design conditions
  - Flies a precise position based on weather data for the boom carpet to hit the microphone array
  - TG-14 above the turbulent layer in-line with microphones
- Area Chase Aircraft (F-15 or F-18)
  - Used for departure, recovery and emergency support
  - Positioned away from X-59 during boom recording
- Large microphone array required



Array Location and Microphones
Source: CST Project (CarpetDIEM)

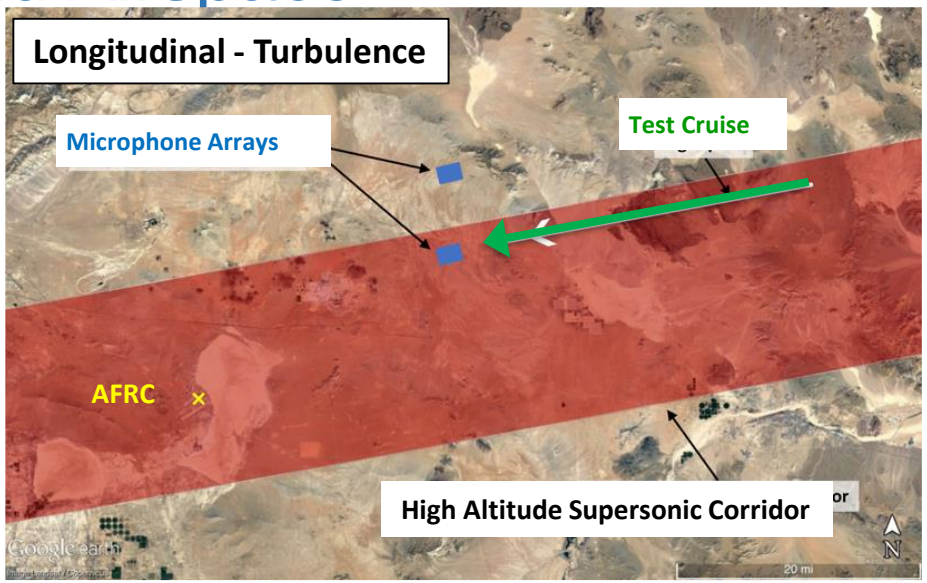


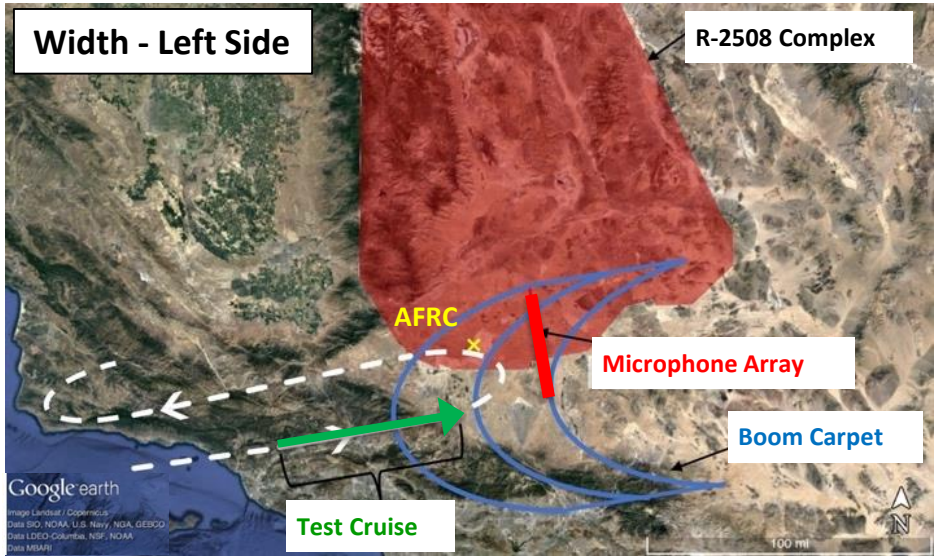
Sonic Boom Carpet
Source: CST Project (SonicBAT2)

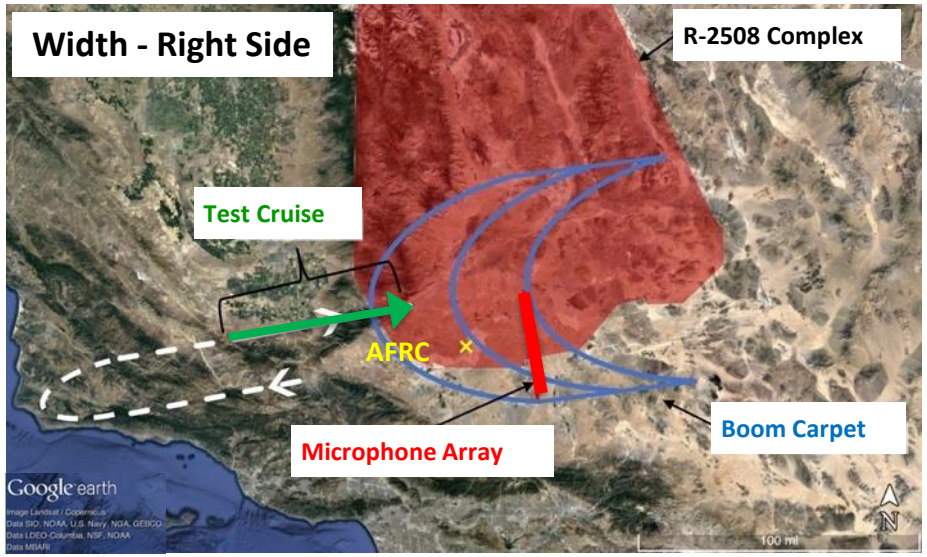
Phase 2 ConOps maturing with LBFD coordination

Phase 2B Far-Field: Flight Profile and Airspace

- Longitudinal Measurements
  - Turbulence
  - Accel Boom Measurement
  - 2 passes per flight
- Carpet Width Measurements
  - Boom carpet < 50 nm 90% of time
  - 30 nm microphone array
  - Requires 2 passes







Source: CST AVTPE ConOps

Next-Gen NASA Sonic Boom Recording System

NEED Statement:

NASA requires a portable, remotely deployable, acoustic based recording system for sonic boom characterization research missions

Ground Recorder System (GRS) Goals

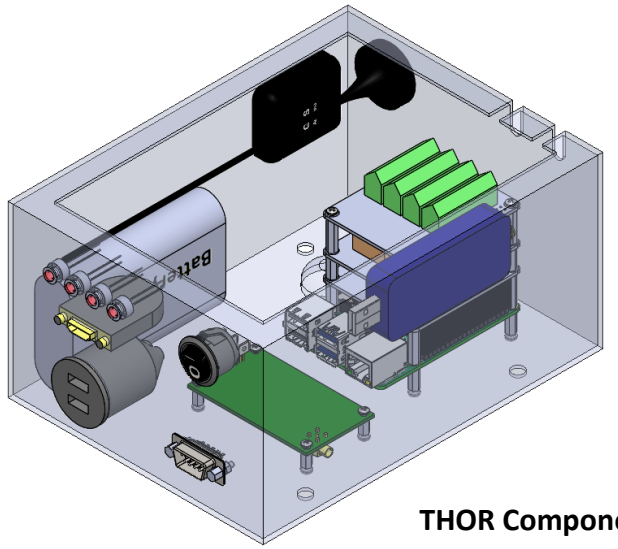
Req Ref#	Goal	Rationale
1.0	Acquire a GRS with acoustic resolution and dynamic range to produce detailed sound level metrics able to inform supersonic policy.	Noise perception sound level metrics are required for human response studies.
2.0	The GRS systems are to be deployed, setup, and operated anywhere by one person.	Remote, unattended field deployment in large numbers (80+) drives the goal for a small, compact, one person carry, secure, and environmentally protected unit. And in cases where just one unit is needed the unit must be capable of being operated without additional hardware once setup.
3.0	Acquire a GRS which will accommodate *expansion add-on / add-in modules and peripherals.	The systems will be for multi-purpose use. Different modular components will allow for use during both LBFD Phase 2 and Phase 3. Some envisioned expansion units may be; communications, data analysis and an AI triggering system.
4.0	Acquire a GRS whose operations & controlling software are expandable, modifiable & configurable.	Due to the missions this system must support and the vast array of add-on's in-depth access to the software is crucial.
5.0	Acquire a GRS that is capable of being operated remotely, from a range of at least 100 nmi while deployed within any community environment.	The GRS will be used for sonic boom community response testing. There is a need to have the capability to assess and configure each GRS, and to access its data daily. Due to the size of the test area (2,500 square nautical miles) and the number of GRS required to cover that area (~150), it is not reasonable to perform these tasks in situ.

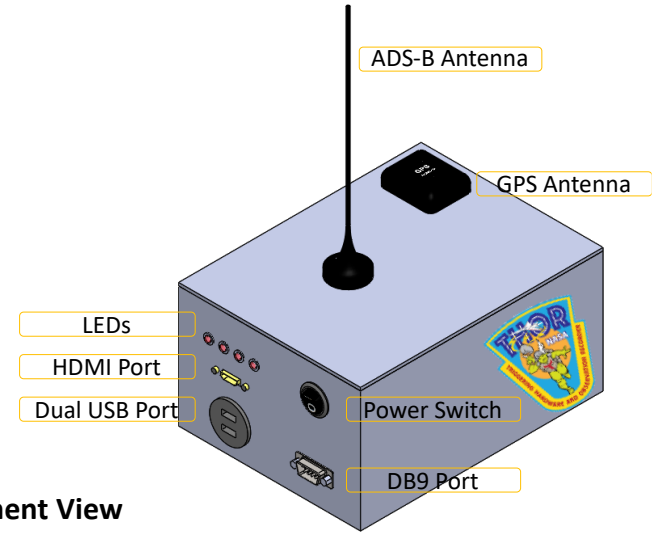
175 Functionality Requirements

Unattended Trigger Concepts

Goal: To evaluate and measure the feasibility of conceptual recorder triggering methods for a next-generation sonic boom measurement system

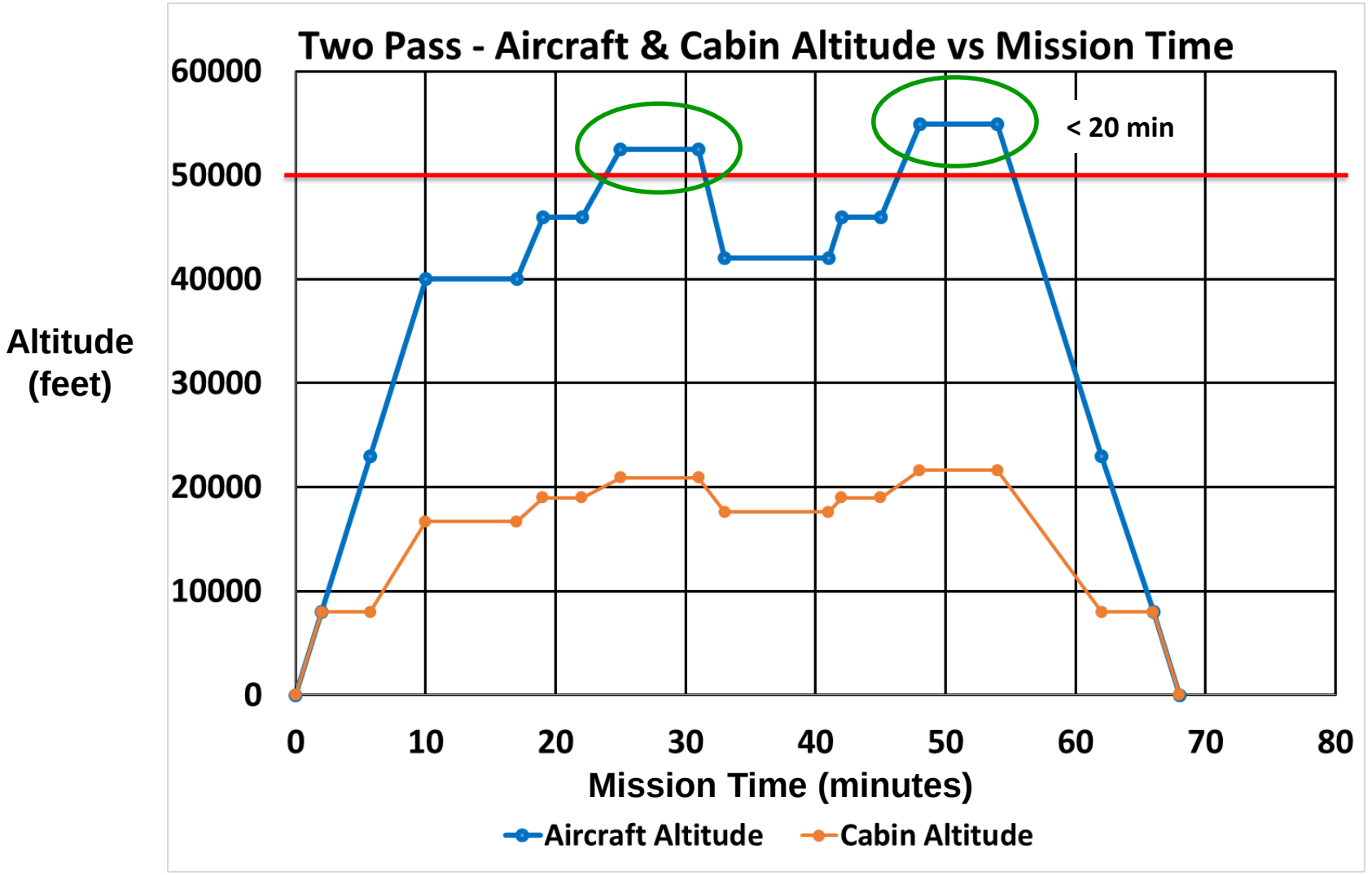
- Potential Concepts:
  - Manned
  - ***Remote/autonomous using ADS-B receiver***
  - Remote using local radio command (Wi-Fi, 900 MHz, etc.)
  - Remote using cellular modem command
  - ***Remote using satellite network***
  - Continuous (all day) recording
    - AF sensitivity considerations





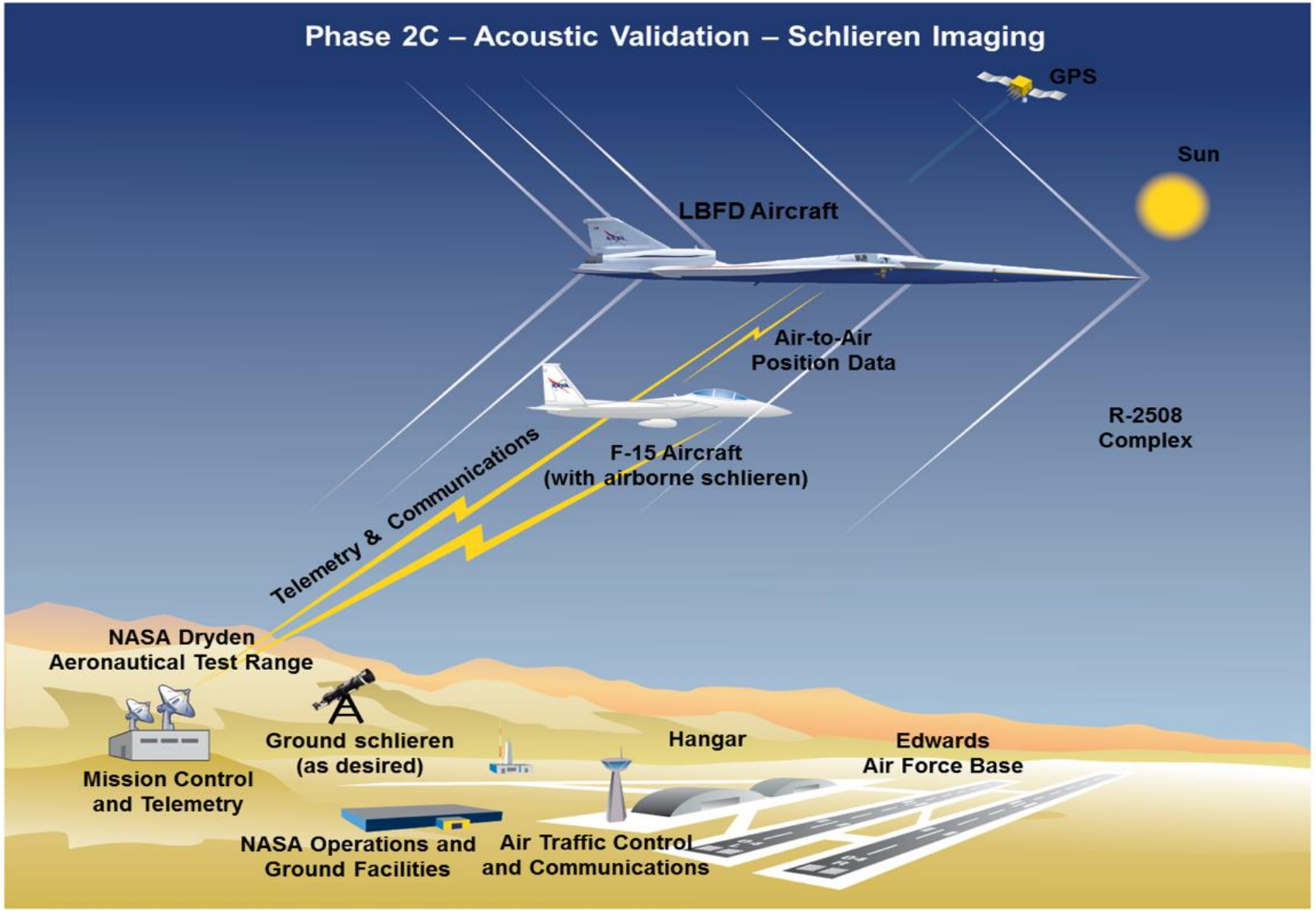
THOR Component View

Phase 2B Far-Field: Two-Pass Flight Profile



Cruise altitude depends on a constant C_L and Mach – impacted by weight

Phase 2C: Shockwave Imaging Flights



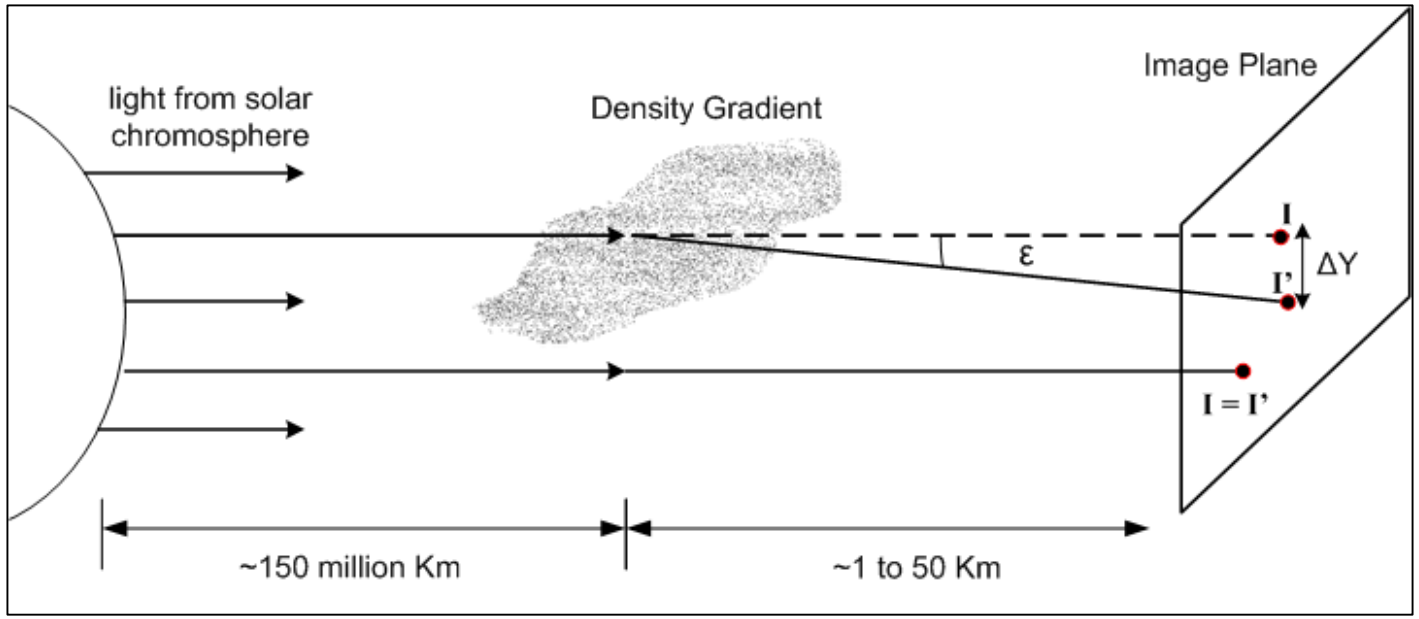
Shockwave Imagery – Background Oriented Schlieren

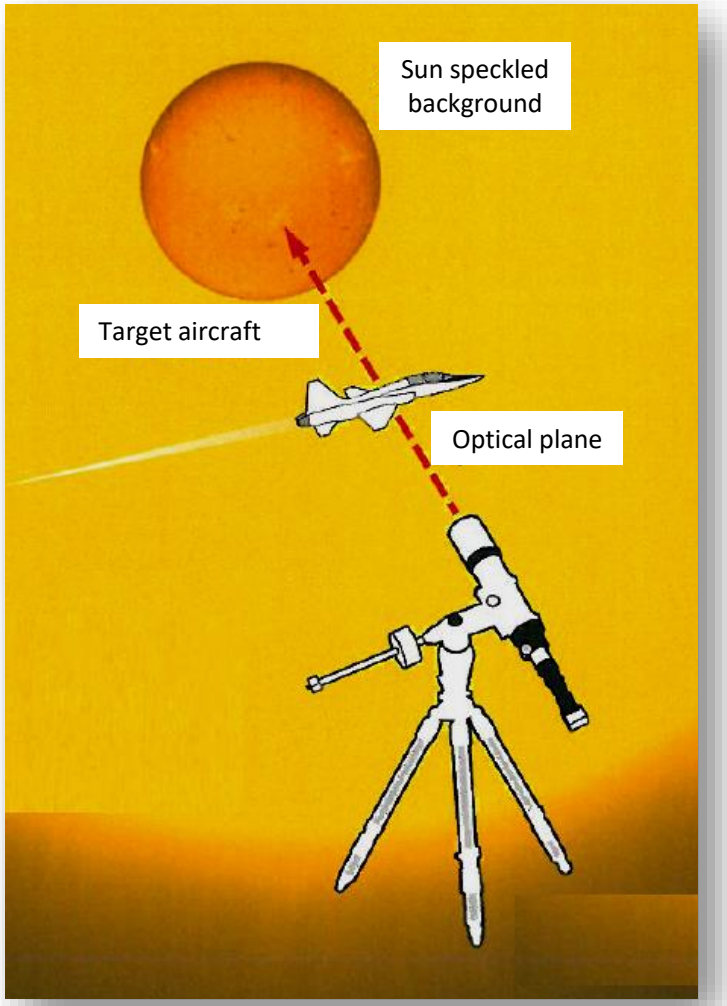
T-38
30,000 ft AGL
6.5-mile range
Mach 1.05

BOSCO Concept

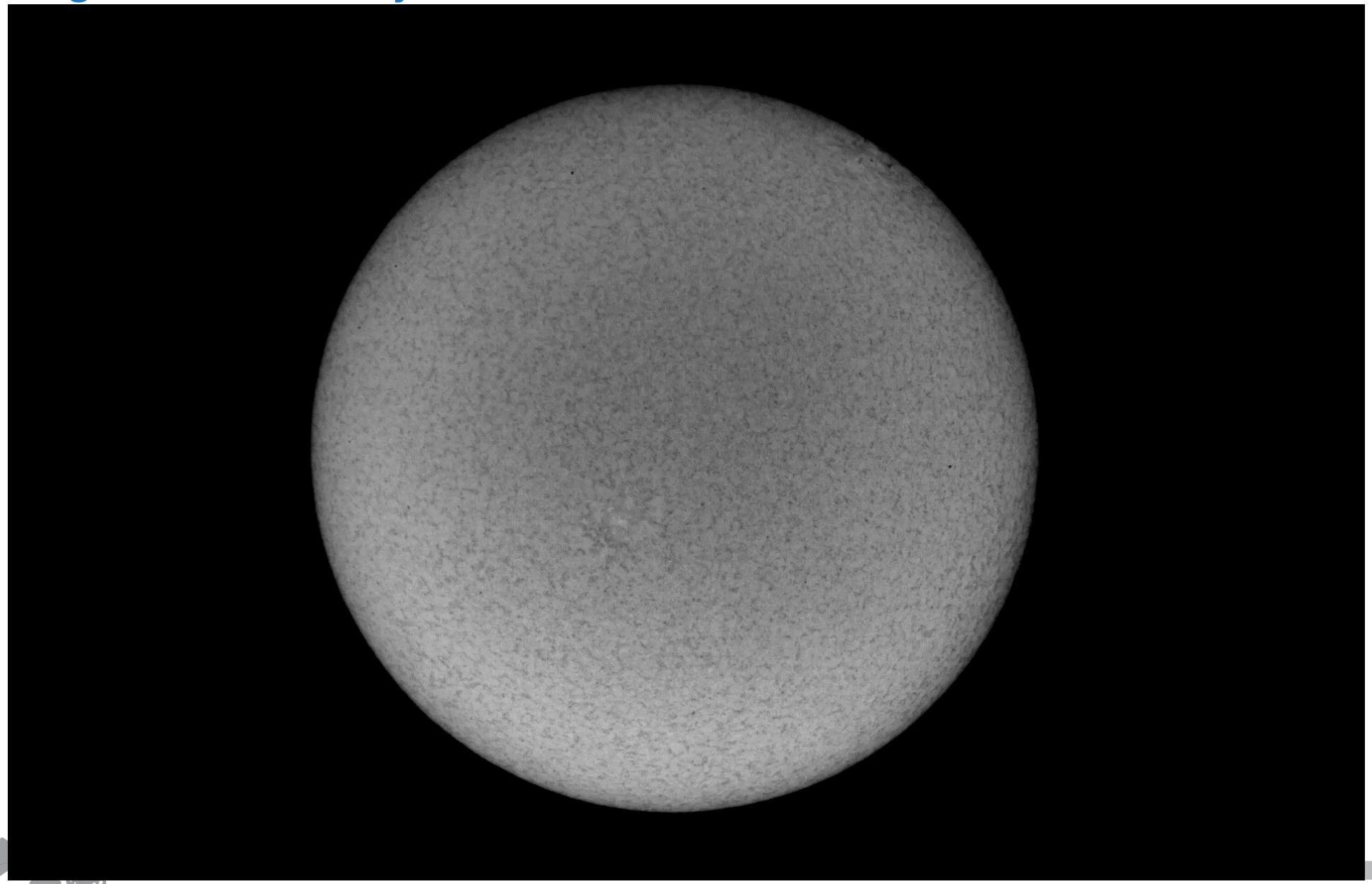
Background Oriented Schlieren using Celestial Objects (BOSCO)

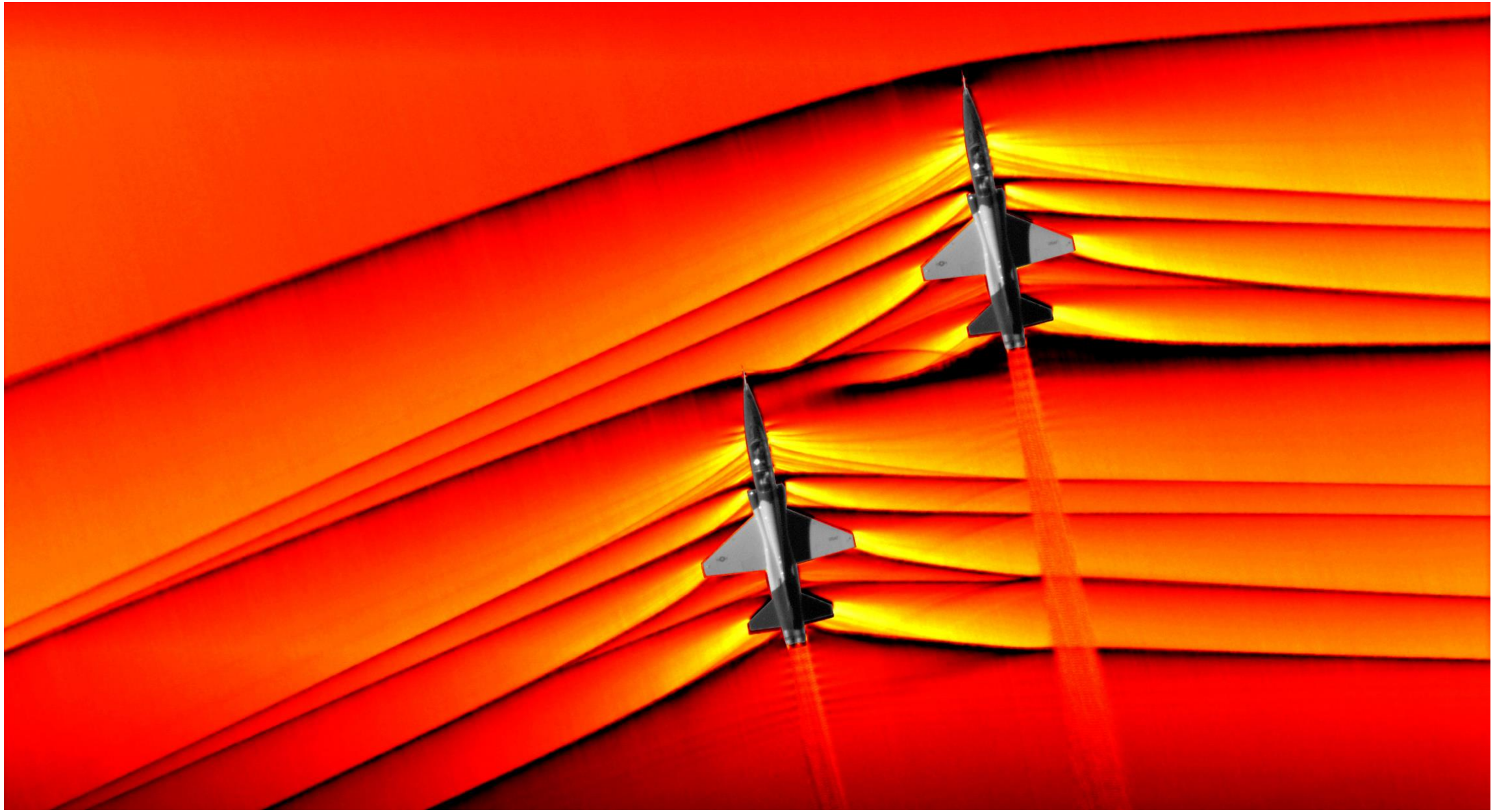
- Uses narrow band optical filters to give the sun a textured appearance.
  The texture allows for the Background Oriented Schlieren method
- Ability to image from below and to the side of the target aircraft





BOS using Celestial Objects – Raw Data



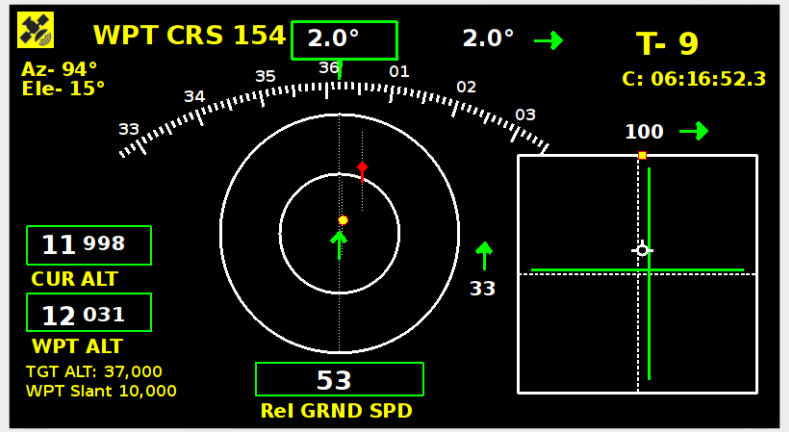


Phase 2C: Shockwave Imaging – BOSCO for X-59

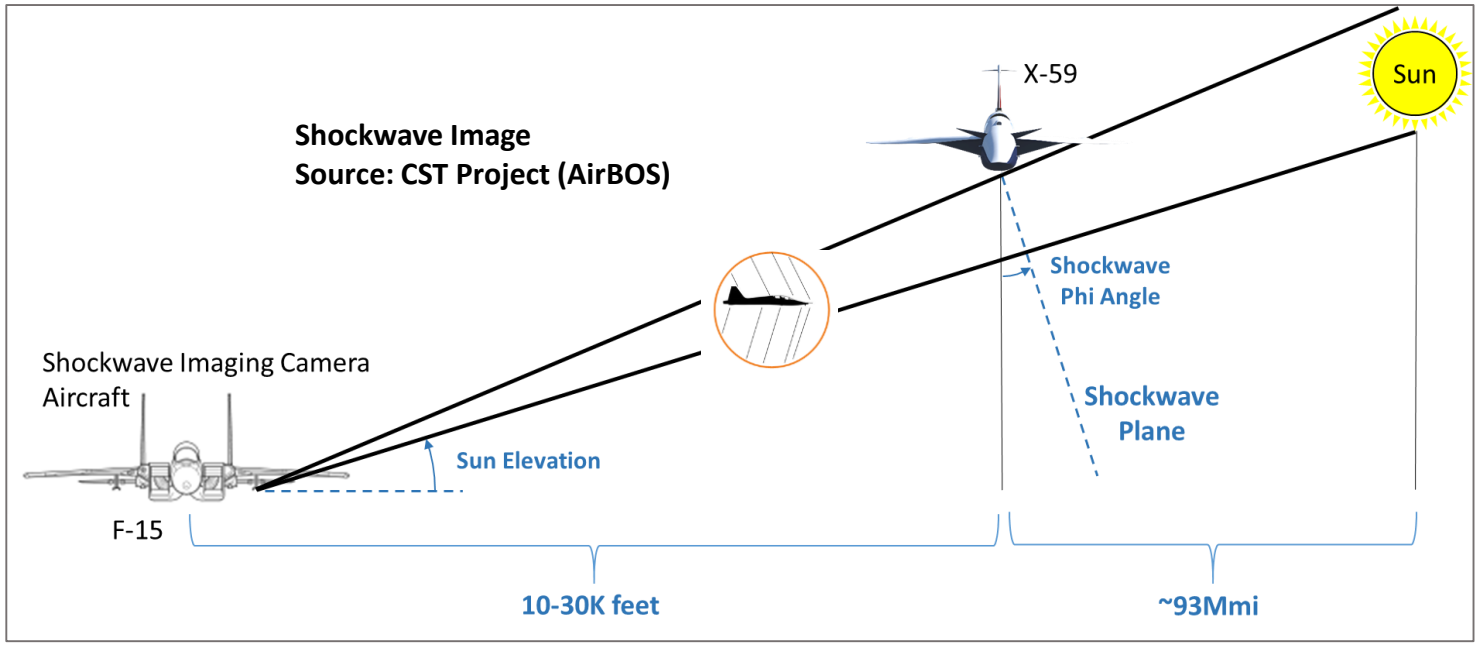
- Research Support Aircraft (F-15)
  - Shockwave imaging pod with Modified Life Support System
  - Requires X-59 GPS position data via air-to-air modem
  - F-15 positioning display and shockwave imaging pod in development

10 Flights	1 / day

- X-59 flies at low-boom design conditions
  - Imaging of shocks beneath X-59 aircraft at normal cruise altitude will require very low sun elevation angle.
  - Low elevation angles will require small differential altitude, So future imaging system will be airborne.



F-15 Positioning Display Prototype
Source: FDC Project (ALIGNS)



X-59 and F-15 Relative Positions

Thank You

NASA Armstrong Flight Research Center (AFRC)

Aeronautics Flight Research

- Named after Neil A. Armstrong, first man on the moon (Apollo 11)
- Over 70 years of flight research (NACA Muroc Flight Test Unit)
- Edwards Air Force Base (EAFB)
- Remote Location
- 350 Testable Days Per Year
- Extensive Range Airspace
- Supersonic Corridor

Overcoming the Barrier to Overland Flight

Standards to Replace Current Prohibitions

NASA's Low-Boom Flight Demonstration is specifically planned to 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