X-59: The First Chapter in the Quesst for Quiet Commercial Supersonic Flight



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Agenda

- Quesst Mission Overview
- X-59 Design Overview
- From First Chip to Flight Test
- Flight Test Overview
- Flight Test: Findings Overview
- What's Next for X-59 & Quesst



Quesst Mission Overview

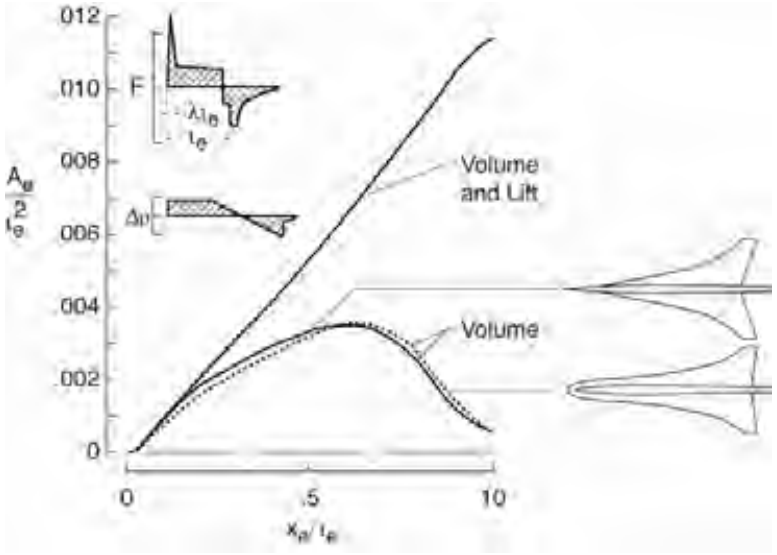
Barriers to Commercial Supersonic Flight

Sonic Boom Noise and Overland Flight Prohibitions



- 1st supersonic flight: 1947 (over 75 years ago)
- Sonic boom testing in 1960s brought the problem of sonic boom noise to public attention & showed sonic boom noise to be unacceptable
- Over 50 years ago, a “speed limit” was put in place – no commercial supersonic flight over land allowed in the US or internationally

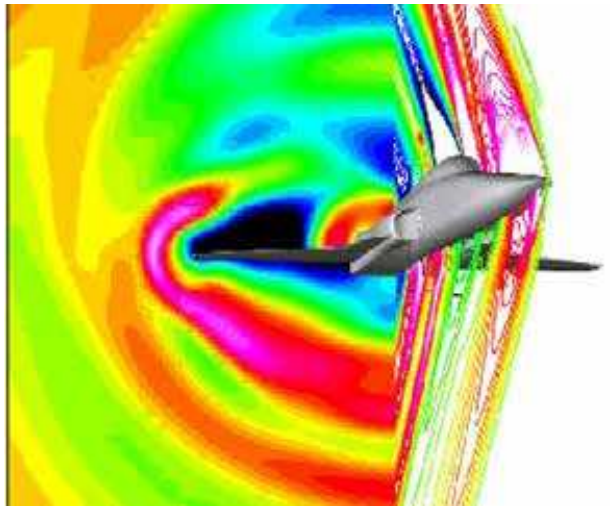
A Very Brief History of a Very Tough Problem



Designs based on Area Distribution



Early Wind Tunnel Validation



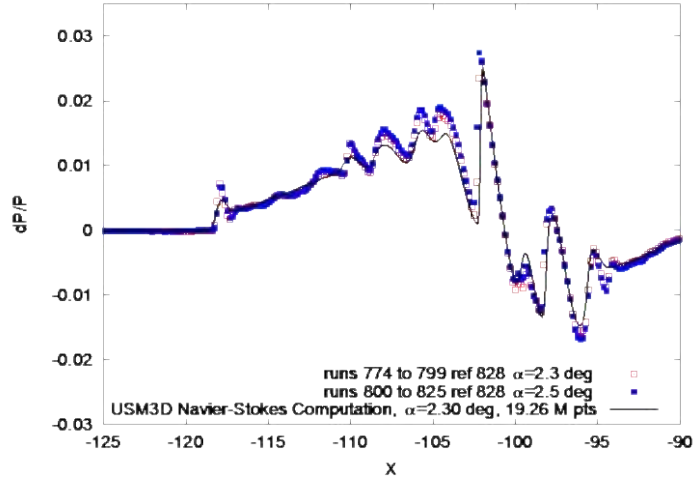
CFD Applied in Analysis and Design



Flight Validation of Signature Shaping



High Fidelity Wind Tunnel Validation



Validated Tools and Design Approaches

PHOTO CREDITS: NASA

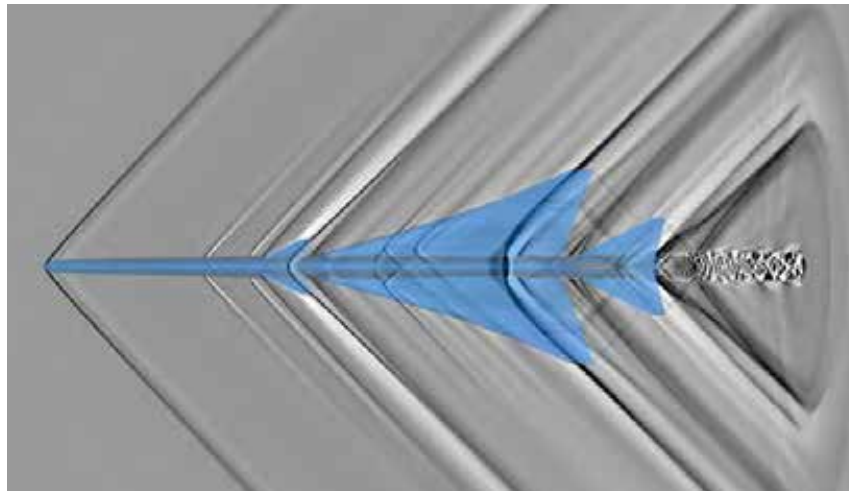
Breakthrough: Quiet, Practical Supersonic Airliner Designs

Acoustic pressure wave is “shaped” by controlling the strength and position of shock waves generated by aircraft components

Important advances:

- Higher fidelity analysis
- Faster computers
- Integrated design systems
- Innovating thinking

Design approaches originally developed in studies of airliner size concepts



Overcoming the Barrier to Overland Flight

- **For decades NASA has led research into quiet supersonic flight over land**
  - Quiet aircraft design
  - Response to sounds from supersonic flight
- **Community overflight testing directly supports development of a new sound level-based standard**
  - Relevant data from large and diverse populations
  - Engagement with the international community for broad acceptance of results



Quesst Mission Goal:

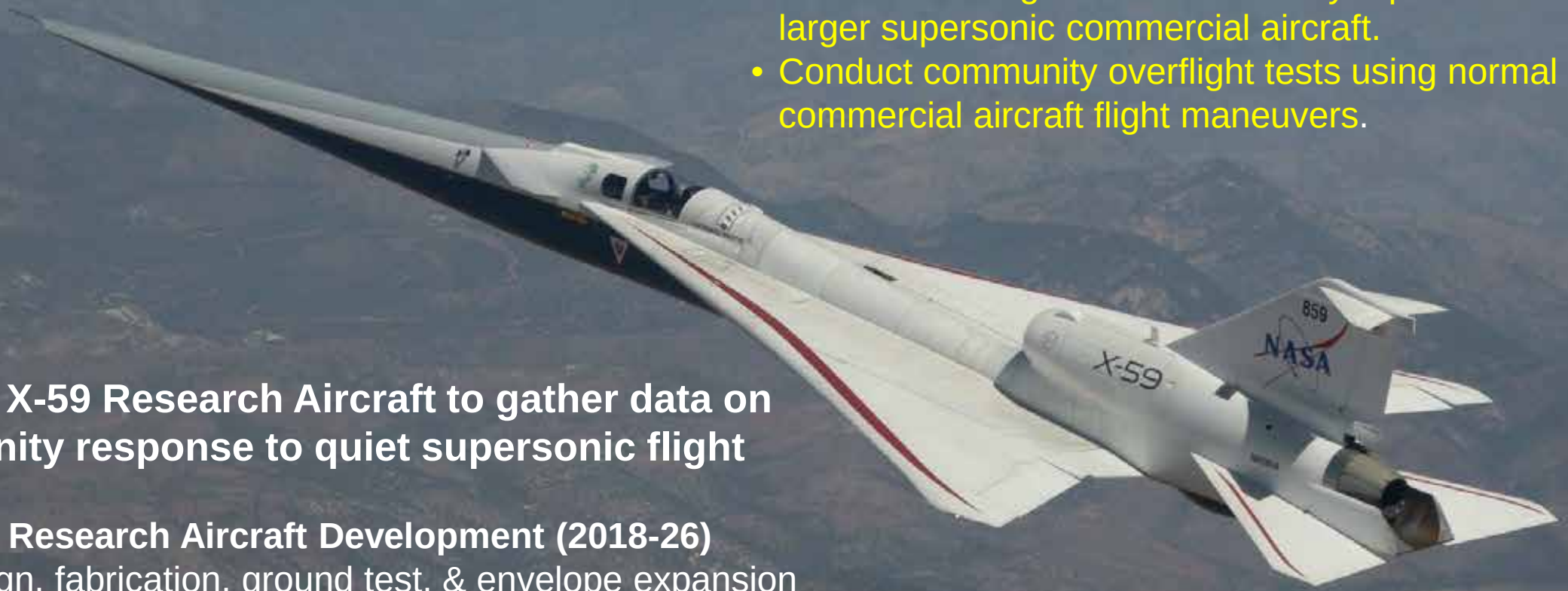
Collect scientifically accepted data to support an ICAO-CAEP effort to develop an En Route Noise Standard

PHOTO CREDIT: NASA

Quesst Mission Overview

Community test requirements drove the X-59 design

- The acoustic signal must effectively replicate that of future larger supersonic commercial aircraft.
- Conduct community overflight tests using normal commercial aircraft flight maneuvers.



Use the X-59 Research Aircraft to gather data on community response to quiet supersonic flight

Phase 1: Research Aircraft Development (2018-26)
Design, fabrication, ground test, & envelope expansion

Phase 2: Acoustic Validation (2026-27)
Detailed ground and flight measurement to prove design

Phase 3: Community Response Testing (2027-29)
Overflights, sound measurement, surveys

PHOTO CREDIT: NASA

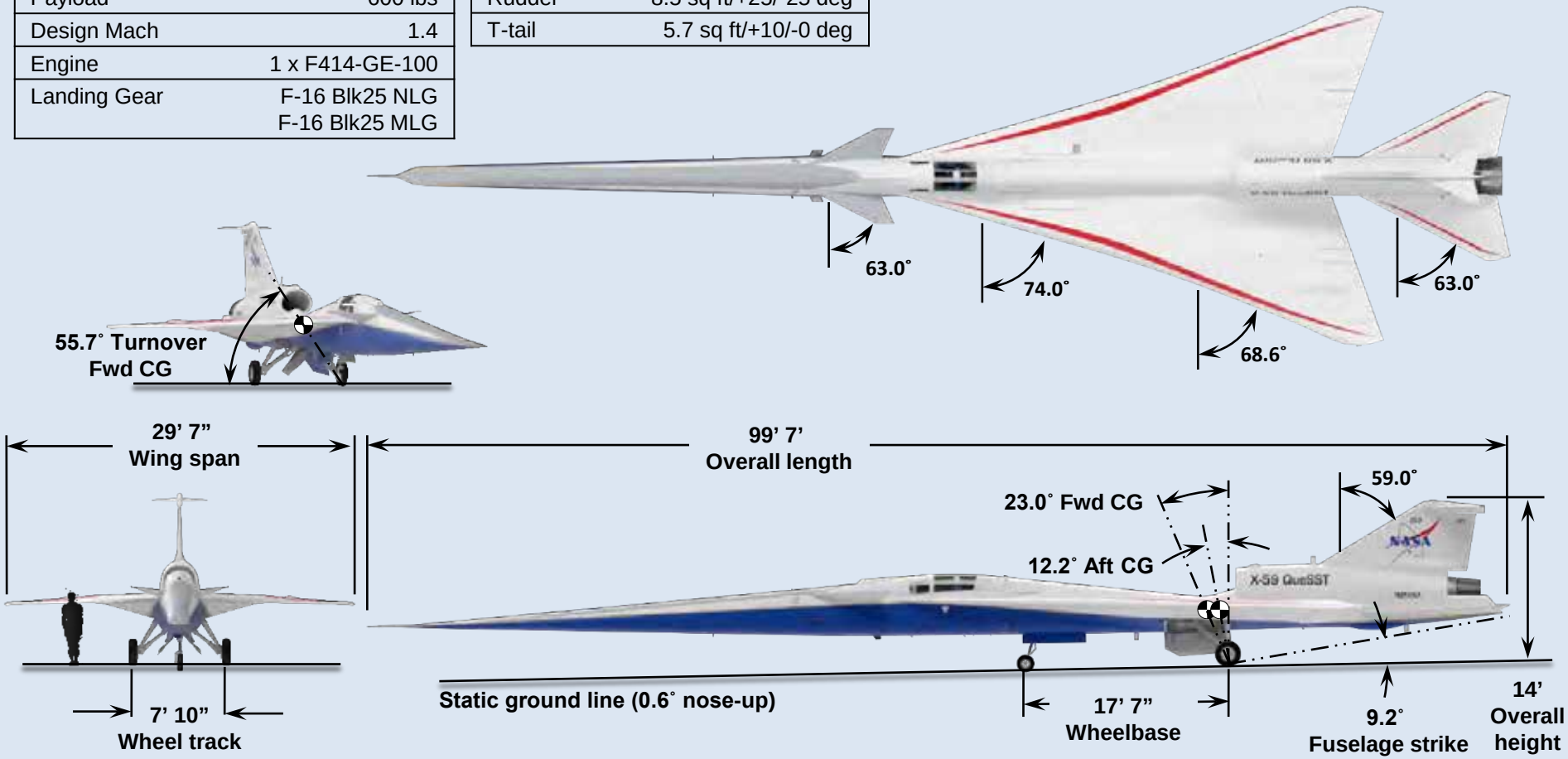
X-59 Design Overview

X-59 Configuration Overview

Configuration C612A	
Max Ramp Weight	25,000 lbs
Max Takeoff Weight	24,300 lbs
Max Fuel Capacity	8,700 lbs
Payload	600 lbs
Design Mach	1.4
Engine	1 x F414-GE-100
Landing Gear	F-16 Blk25 NLG F-16 Blk25 MLG

Control Surfaces	
Aileron	12.9 sq ft/+35/-25 deg
Flap	12.4 sq ft/+30/-3 deg
Stabilator	39.9 sq ft/+20/-15 deg
Rudder	8.5 sq ft/+25/-25 deg
T-tail	5.7 sq ft/+10/-0 deg

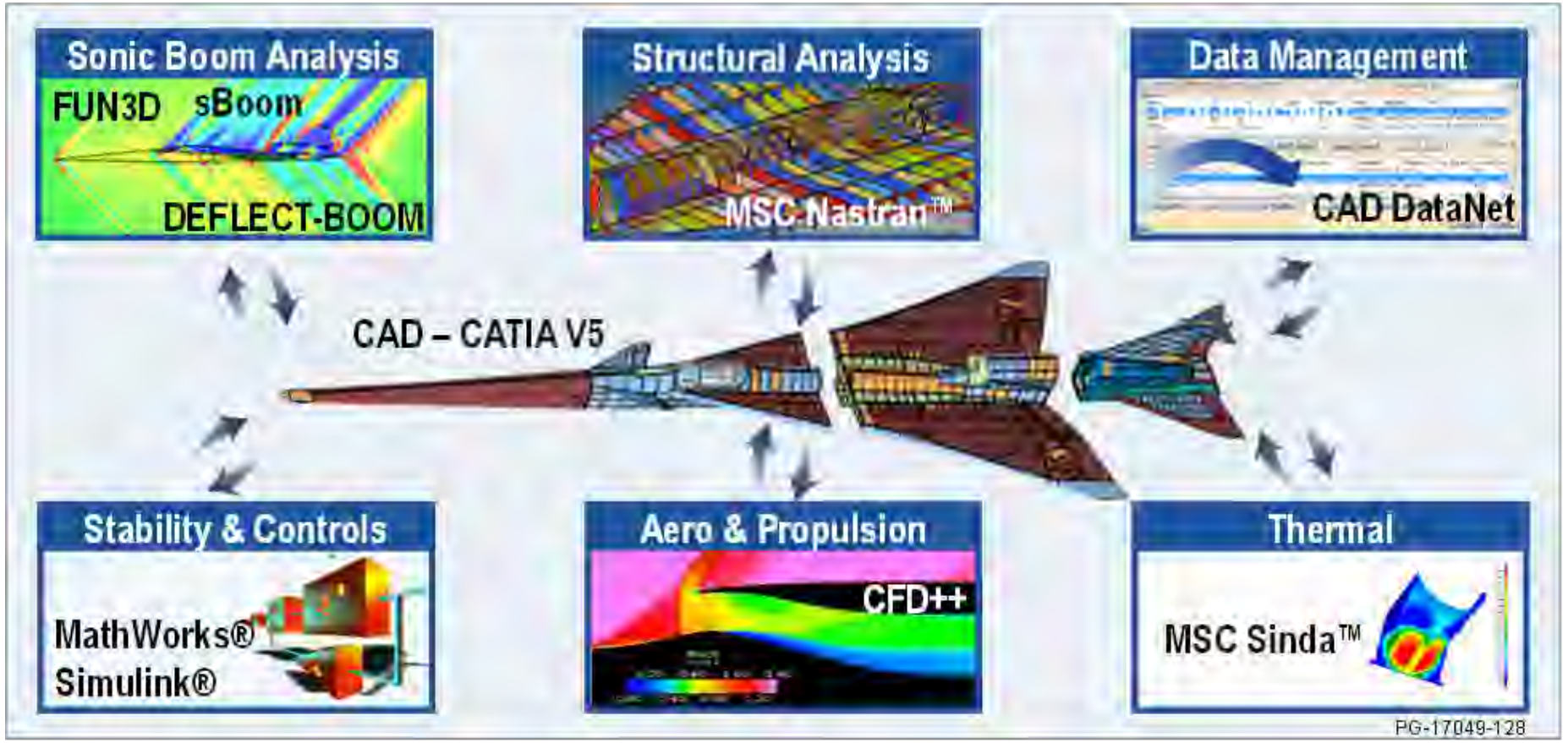
Performance	
Peak Loudness	<75 PLdB
Mission Fuel	7,500 lbs (Std Day) 7,200 lbs (Hot Day4)



Challenges of Quiet Supersonic Technology

- **High Fidelity Analysis Requirements**
  - ***Until recently CFD methods were not accurate enough to predict the required complex shock propagation behavior***
- **Simultaneous Minimization of Full Boom Carpet**
  - ***Challenging multi-objective optimization problem due to the fact that the vehicle "looks" different to different observers depending on location***
- **Vehicle Trim**
  - ***Low boom features drive lift far aft and makes the vehicle difficult to trim***
- **Propulsion Effects**
  - ***Inlet and nozzle flow and geometry variability & uncertainty can negatively impact signature***
- **High Fineness Ratios & Flexibility Effects**
  - ***Aeroelastic effects and static structural deformation can degrade low boom performance***

Shaped Boom Design Methodology



Converging on a closed, low boom design for X-59 has required a multidisciplinary approach and thousands of CFD simulations

X-59 Design History

- Number of Engines
- Engine Selection
- Engine Integration

- Landing Gear Trade
- Inlet Configuration
- Inlet Vortex Study
- Tail Type Trade

- Cockpit Visibility Study
- Canopy Integration
- Design-to-Cost
- Material Selection
- Nozzle Shield Study

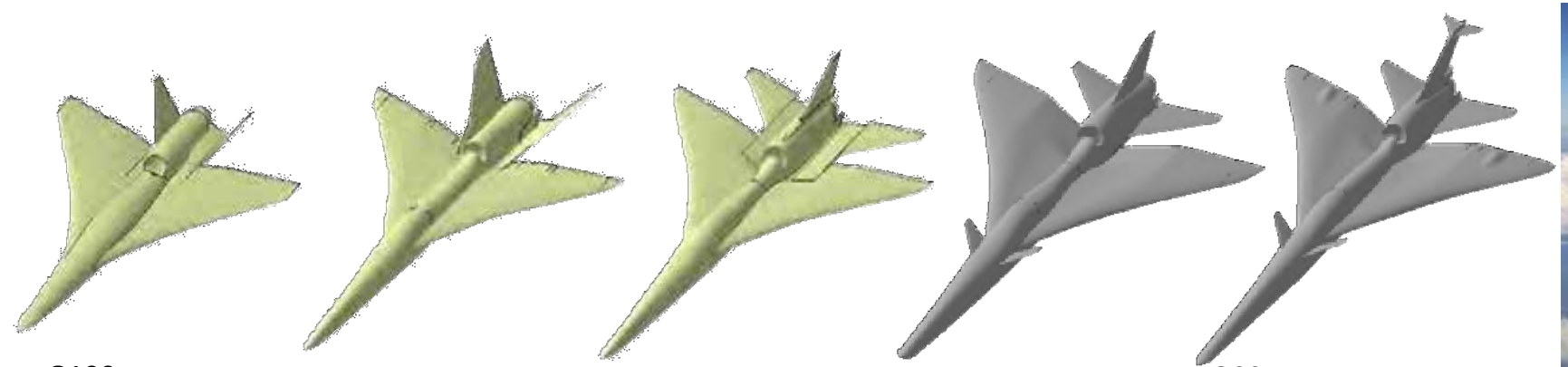
- Flap Study
- Emerg. Power
- Mini T-tail Addition
- FC Actuator Selection

- Secondary Start
- Control Architecture

Configuration Development & Trade Studies

Conceptual Design | ***Preliminary Design*** | ***Design, Fab, Test***

2013 Concept Formulation *2014* | *2014* Concept Refinement *2015* | *2016* QueSST *2017* | LBFD





C100
Point of Departure

C435
Ultimate evolution of V-tail Point-of-Departure design

C506
Switched to conventional tail to address pitch-up

C603
Added canard for nose-up trim

C605
T-tail added for boom tailoring

X-59 Aircraft Features

Design Parameters
- **Length: 99.6 ft (~3 Buses)**
- **Span: 29.7 ft**
- **Speed: Mach 1.4 (925 mph)**
- **Altitude: 55,000 ft**

T-tail to minimize aft shock

Wing shielding to minimize impact of inlet spillage on sonic boom

T-38 aft canopy & ejection seat to minimize qualification cost and schedule

Matt anti-static paint

Fixed canard for nose-up trim at low-boom design point



Long nose to shape forward shock

Single GE-F414 engine with standard nozzle to minimize cost and schedule

Conventional tail arrangement to simplify stability and control considerations

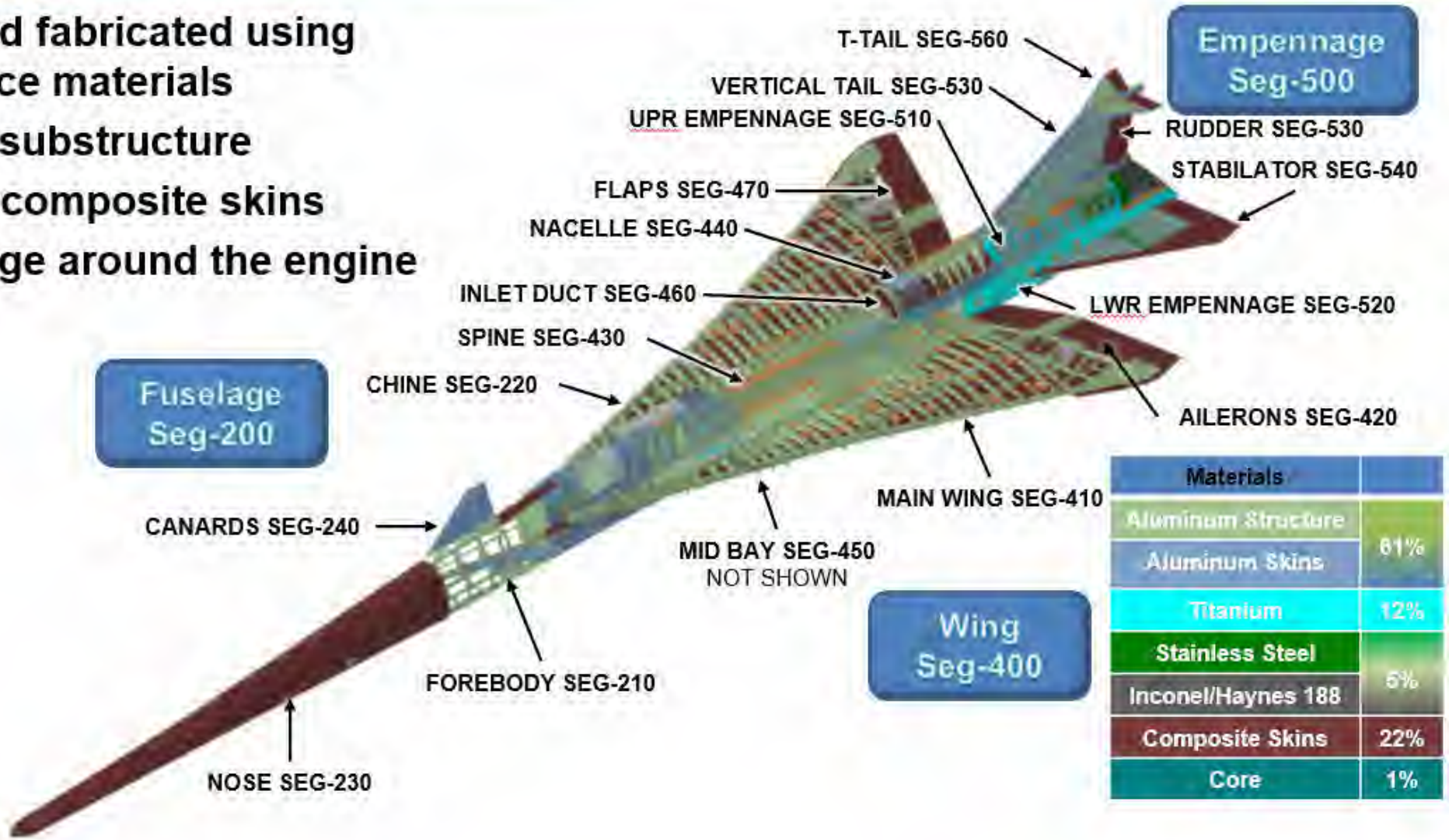
External and forward visions systems for forward visibility

F-16 landing gear and other systems from high performance aircraft to minimize qualification cost and schedule

PHOTO CREDIT: NASA

Material Composition

- X-59 was designed and fabricated using conventional aerospace materials
  - Largely aluminum substructure
  - Wings & nose use composite skins
  - Titanium empennage around the engine



From First Chip to Flight Test

We've come along way!!!



CDR



Ship 21 – Fly 22

Move to Runstall GCT & SCT





Fort Worth Testing



Max Afterburner

Furlough

2018	2019	2020	2021	2022	2023	2024	2025

COVID

Delta PDR



Fuselage – Wing Mate



Integration & Test







Rollout



Credit: Lockheed Martin

2025 was an awesome year…

Credit: Lockheed Martin



















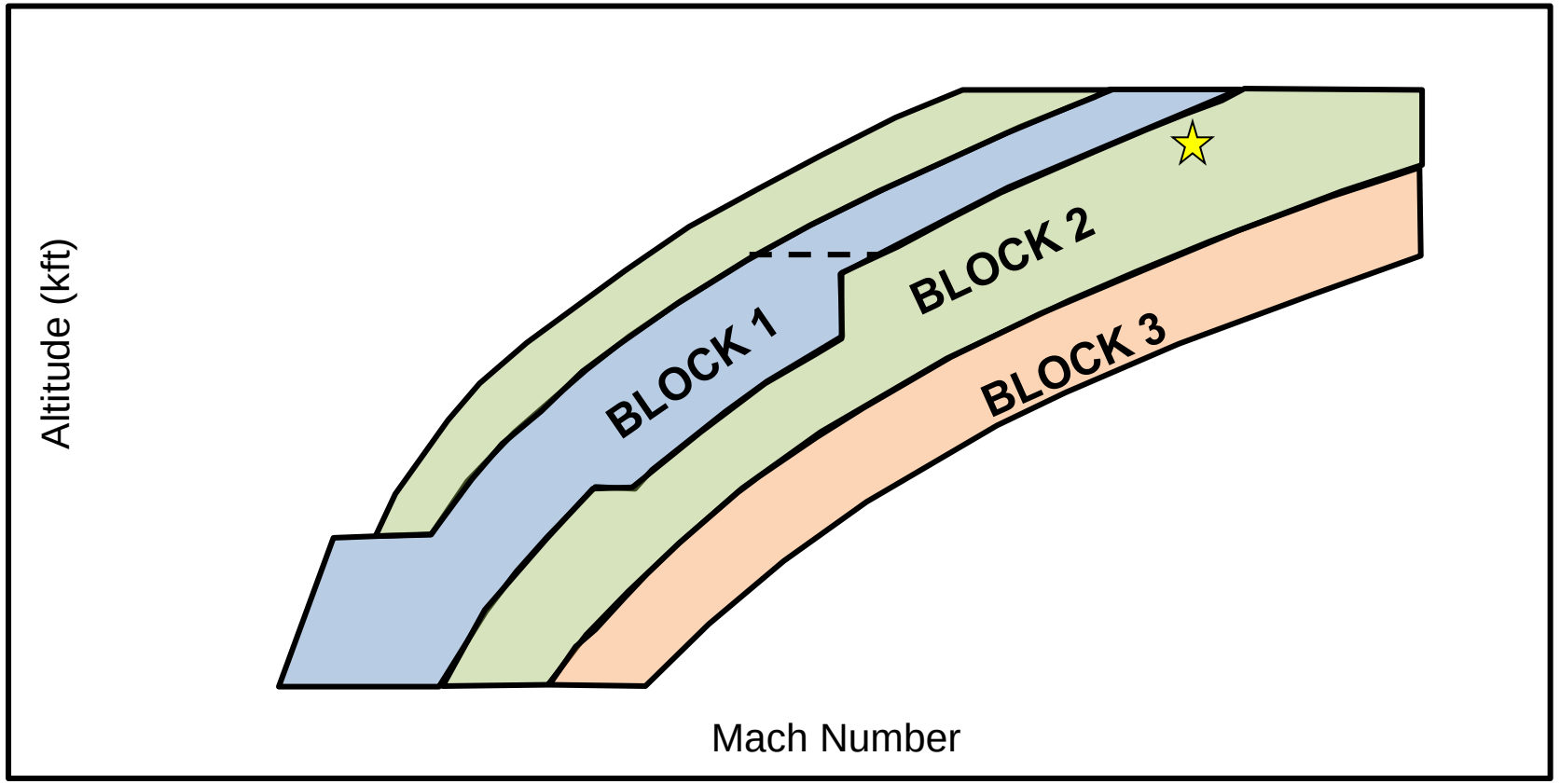
LBFD Project Challenges Leading to First Flight

- Overly optimistic planning throughout
- 2018-2019 Government Furlough (5 weeks)
- COVID-19 pandemic through 2022
- Proof Loads Test & Fuel System Test moved to Fort Worth facility
- Engineering: Staffing issues (experience & stability), delayed design, ”technical debt”
- Production Operations: Inexperience, inefficiencies, unplanned work, workmanship issues
- Parts & Supply Chain: Contracts initial delays & increased costs, delivery delays, rework / scrap, increased number of parts, late identification
- Significant system integration & system checkout work deferred to after Ft Worth Testing & full scope unknown
- “White” wire / Electrical System
- Almost every planned activity required some level of rework, troubleshooting and/or retest
- Close calls, incidents, mishaps and resulting aircraft impounds & Safety Standdown
- Vehicle Management System hardware issues impact on vehicle testing and software development
- Aluminum Bird Test addition
- Flight test leadership, lack of planning & flight test transition

Overcame these challenges by working through complex technical efforts, exceptional teamwork, and unwavering dedication

Flight Test

Phase 1 Envelope Expansion



Higher, Better, Faster, Stronger
Systematic approach to expand the X-59 envelope

First Flight Profile

Objectives

a. Land safely
b. Demonstrate aircraft stability and control
c. Demonstrate air data system performance
d. Collect data to de-risk 2nd flight

Profile (~1.0 hour)

a. T/O: MIL power, rotate at VREF-20 (~150 KEAS)

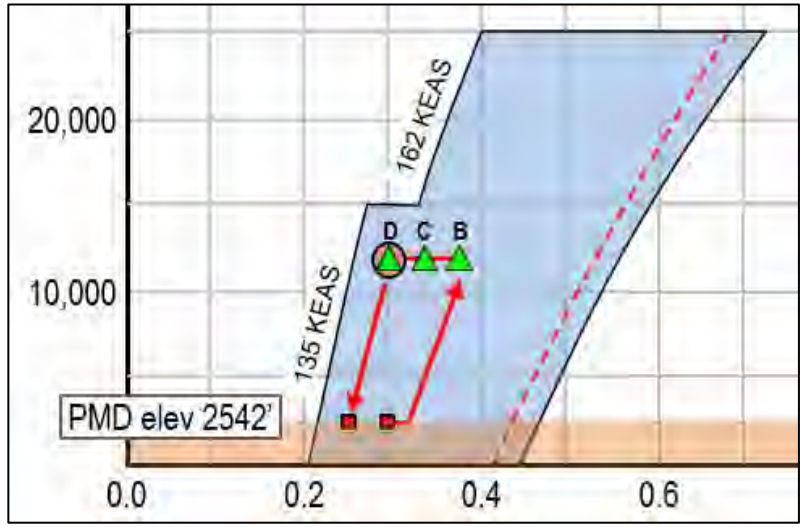
b. 200 KEAS MIL climb to 12kft, landing gear stays down

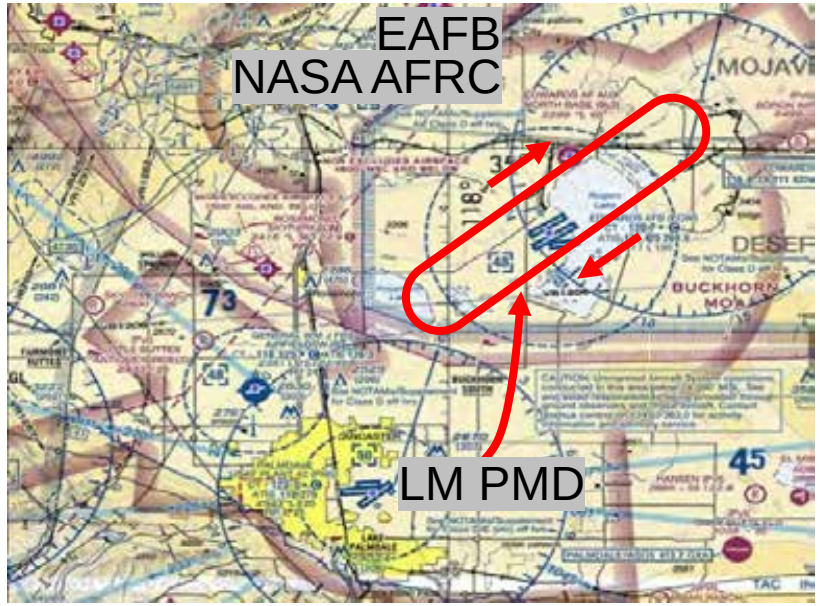
c. A/P checks (SPD HOLD, gamma, ALT HOLD)

d. 12kft ITBs (3 Speeds):
   - 200 KEAS (0.38M)
   - 180 KEAS (0.36M)
   - VREF

Integrated Test Block (ITB)
- Trim
- AOA vs θ, airspeed/alt check with chase
- Mild PRY doublets
- 3211s
- WUT to 8α / 2.0g (whichever lower)
- RTSM / FES (ASE at 200 & Vref only)
- Wings-level sideslips (WLSS)
- Mild push
- Assess normal CLAW and gamma cmd

e. Practice approaches
   - General pilot control, flare practice
   - Approaches to waveoff (go-around)
   - Evaluate FVS / XVS, normal CLAW and gamma cmd







First Flight…

Exciting but Uneventful

Just what you want in a First Flight

Flies like the Sim

eXternal Vision System (XVS)



Combination of Ultra-High-Definition (UHD) sensor, forward vision system, display, and image processing technologies to provide the pilot with equivalent forward vision



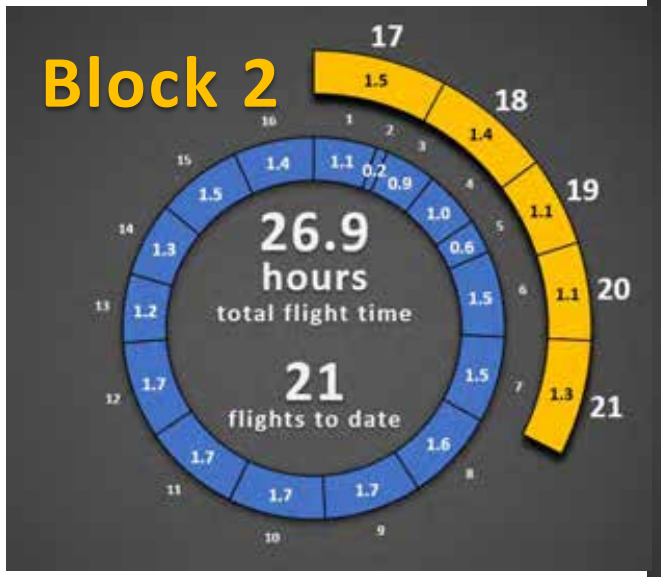
Pilot's Forward View from X-59 Cockpit with XVS/FVS Image

- System components qualified for flight environment – imagery integrated with HUD symbology
- System performance verified in early flight test - guest pilots evaluated normal vision and XVS on see-to-avoid and see-to-follow tasks
- Final component qualification, installation, and checkout in the X-59 aircraft completed

Flight Test
Findings Overview

Flight Test Highlights To Date

- Phase 1 flight test campaign priorities: envelope expansion
  1. Reach mission condition as soon as safely possible: 55k ft MSL and 1.4M (high and fast)
  2. Clear out the remainder of the envelope (low and slow)
- First flight 28 October 2025, then down for planned maintenance
- Jet and team have been performing well
- Words < statistics < photo < video

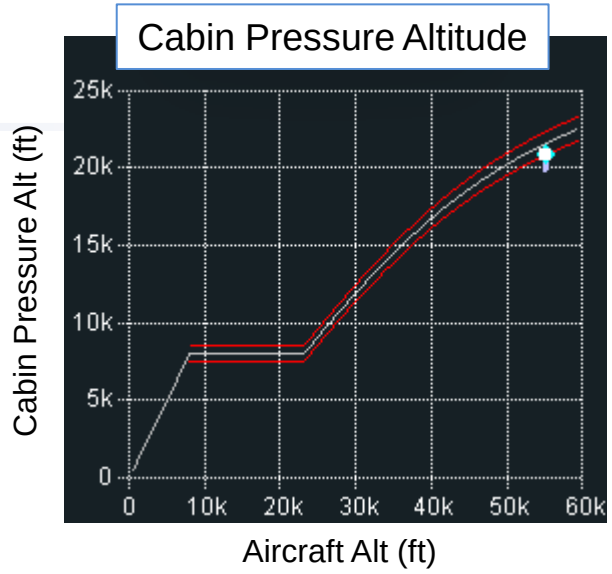


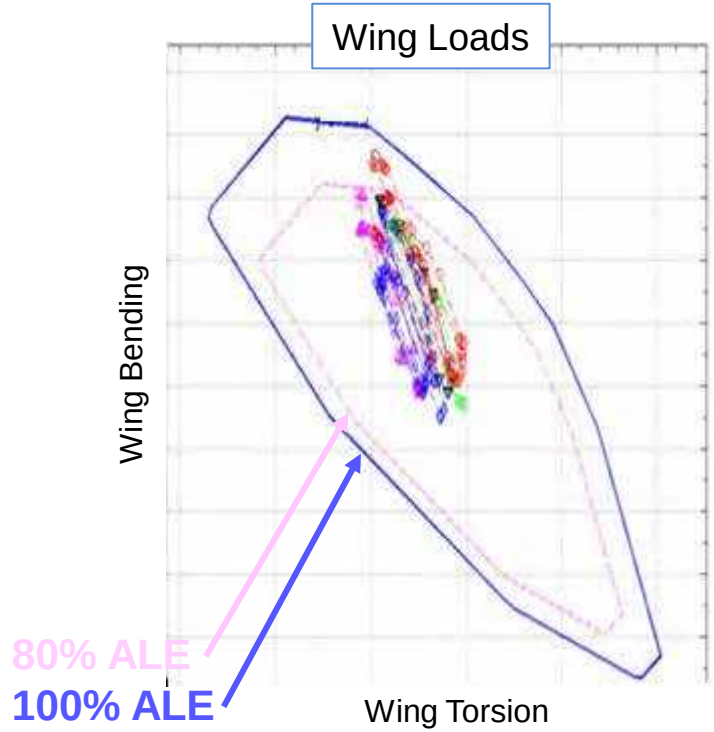




Summary of Results to Date

- **Subsystems performing nominally**
  - **Cockpit pressurization on schedule up to mission altitude**
  - **Top-mounted inlet performing across range of AoAs and betas**
  - **XVS and FVS effective substitute for lack of forward windscreen**
  - **Divergence between nose probe and multifunction probe solutions while supersonic**
- **Flying Qualities show good agreement with predictions**
  - **Real-time digital twin, parameter identification, and stability margins**
- **Measured flight Loads show good agreement with predictions**
  - **Elevated control surface hinge moments above 275 KEAS confirmed**
- **No adverse trends regarding Flutter or Aeroelasticity**



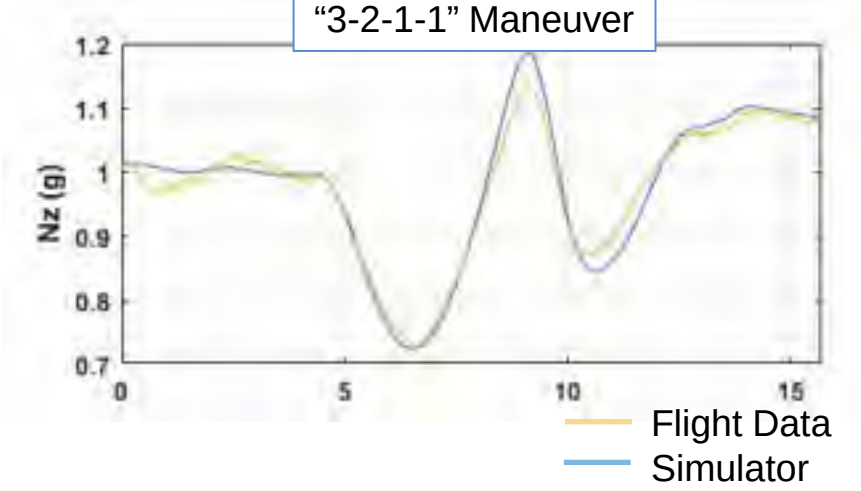


Summary of Findings to Date (Continued)

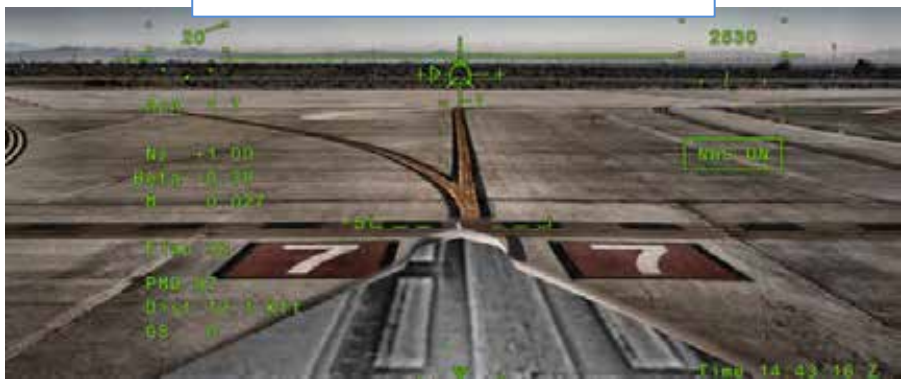
- **Excellent agreement between the simulator and flight dynamics data recorded during flight test**

- **Software updates have been implemented to address minor findings**
  - **Eliminated cockpit nuisance alerts asserting as cautions**
  - **XVS alignment correction**
  - **Air data correction**
  - **Minor control law updates**

"3-2-1-1" Maneuver



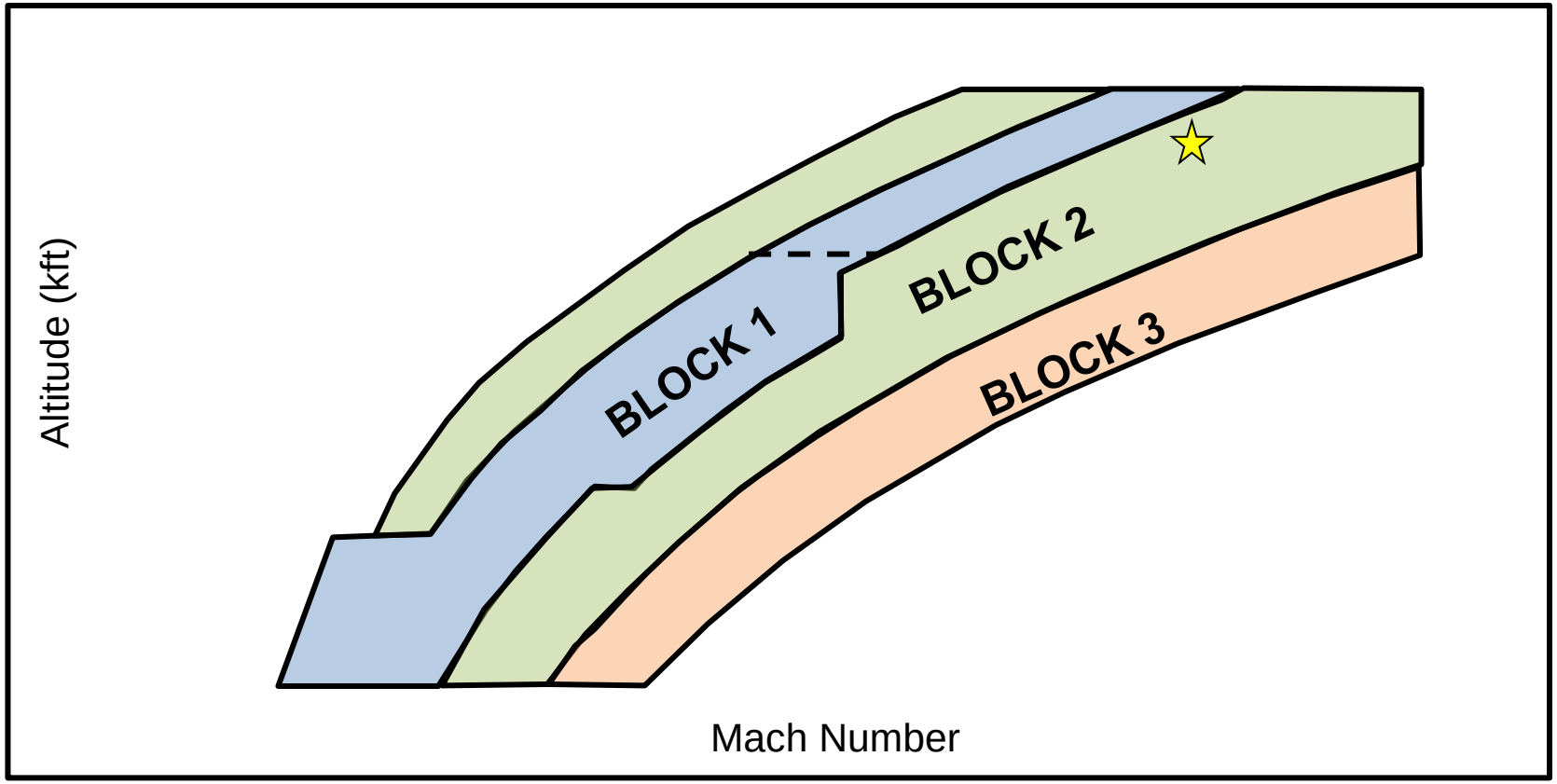
XVS Parallax Effect –> Fixed



Ready To Finish Envelope Expansion!

What’s Next for X-59 & Quesst

What's Next: Completion of Phase 1 Envelope Expansion



Higher, Better, Faster, Stronger
Systematic approach to expand the X-59 envelope
Enable Phase 1 & 2 complete by end of 2026

Envelope Expansion Flights

Combination of Integrated Test Blocks (ITB) & Non-ITB Objectives

ITB is a series of maneuvers that serve multiple disciplines (i.e. doublets, wind up turns, push-pulls)

Block 2

275 KEAS 40kft to 55kft
350 KEAS 20 kft to 55kft
Block 1 Remaining Test Points

Block 2 Milestones

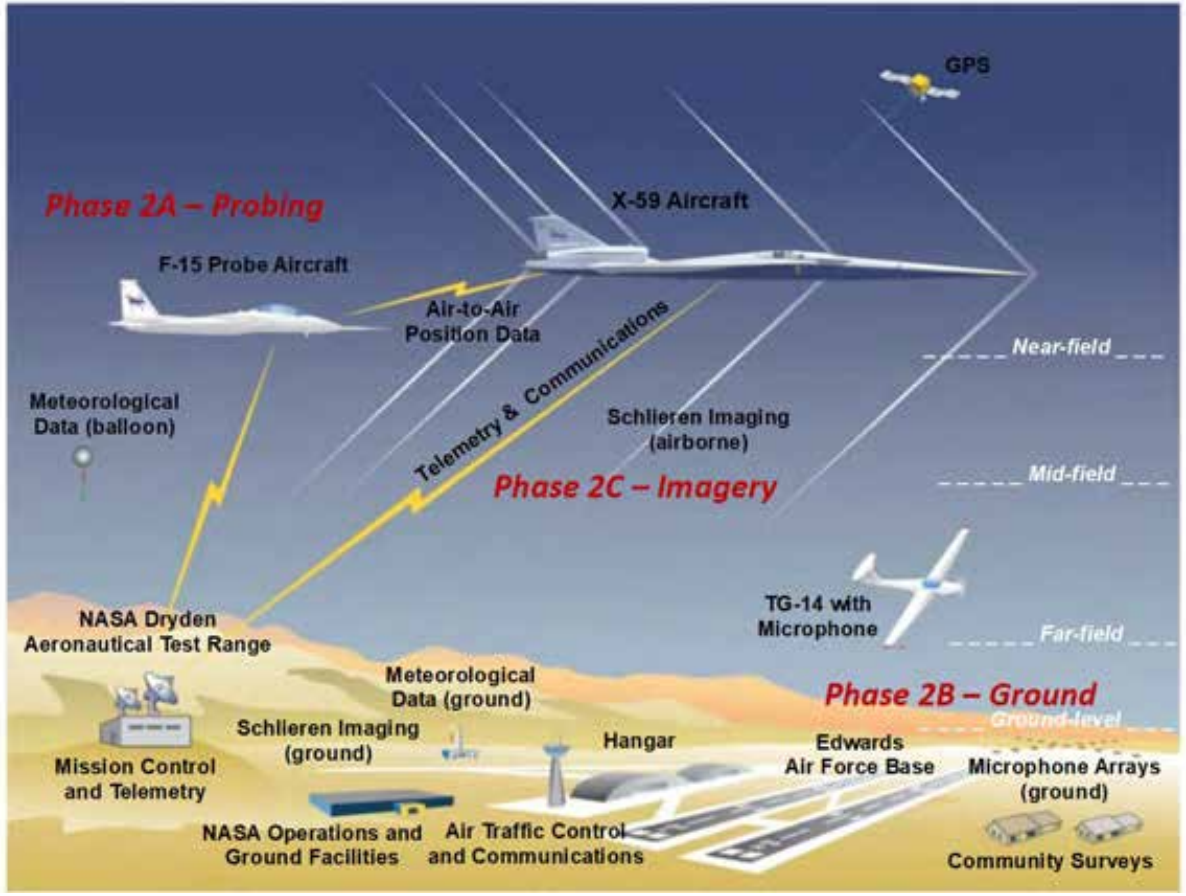
First Supersonic Flight (June 5th)
First Mission Condition (June 19th)
Highest & Fastest Test Point

Block 3

425 KEAS Test Points

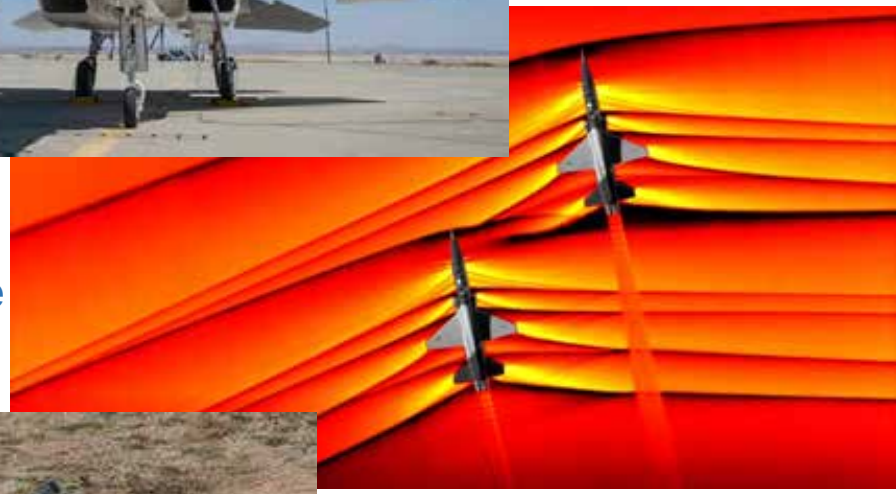
Quesst Phase 2 – Acoustic Validation of X-59

- Develop & demonstrate Quesst mission Phase 2 capabilities:
  - Near-field acoustic characteristics of the X-59 aircraft
  - Atmospheric effects on the far-field acoustic pressure signatures
  - Ground measurements





F-15 with shockwave measurement probe



Airborne shockwave imaging

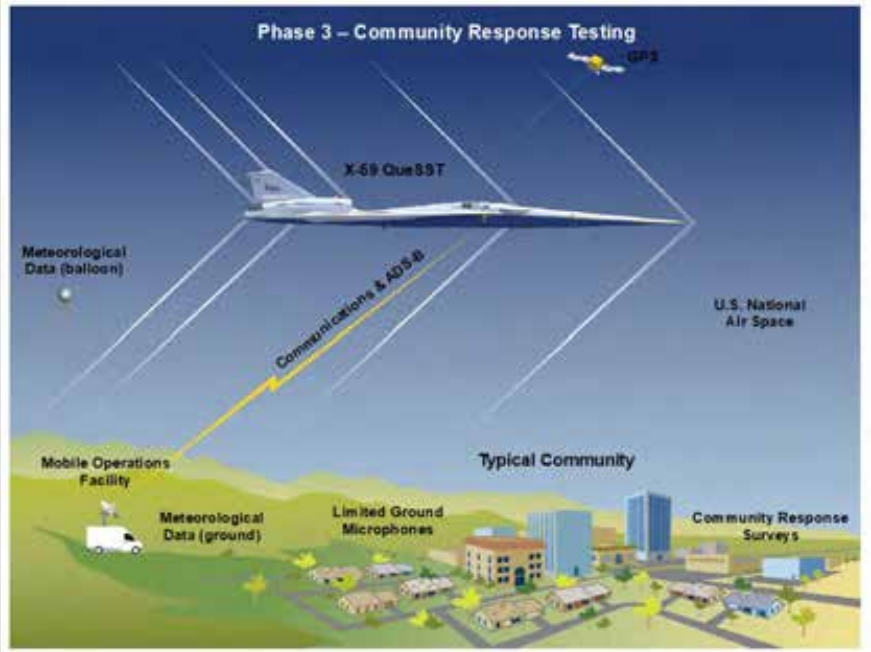


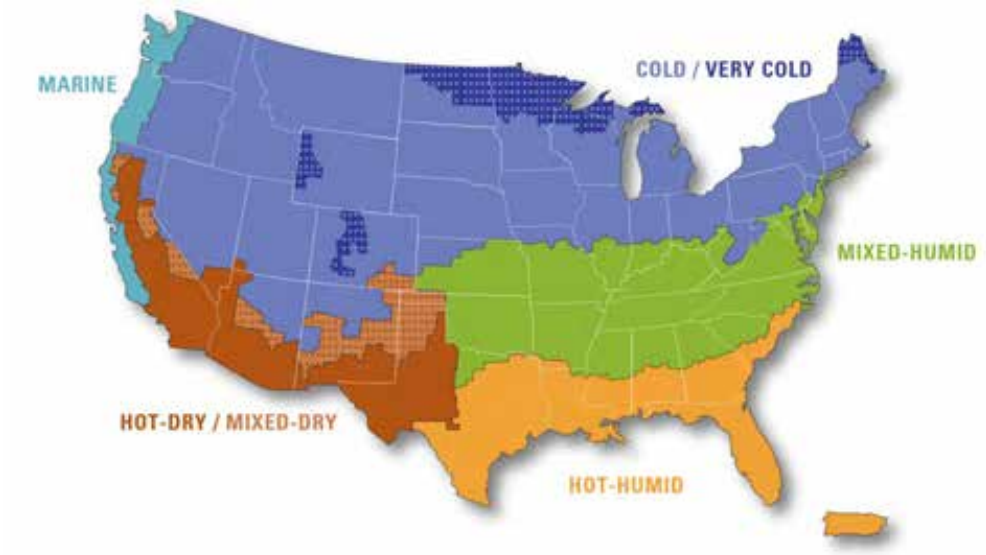
Sonic boom ground recording system

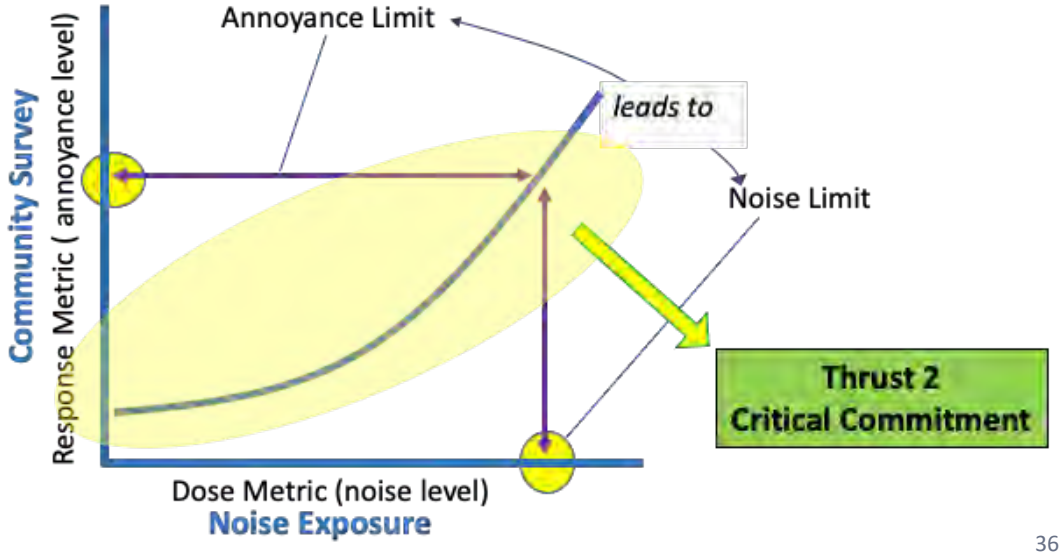
Quesst Phase 3 – Community Response Testing

Provide a *nationally representative* dataset of community response to quiet supersonic flight

- Community Tests with geographic and population demographic diversity
- Ground measurements and public survey responses to X-59 overflight
- Estimated test duration of one month over a ~30 mi x ~50 mi community region
- Gather response to a range of sound levels during waking hours

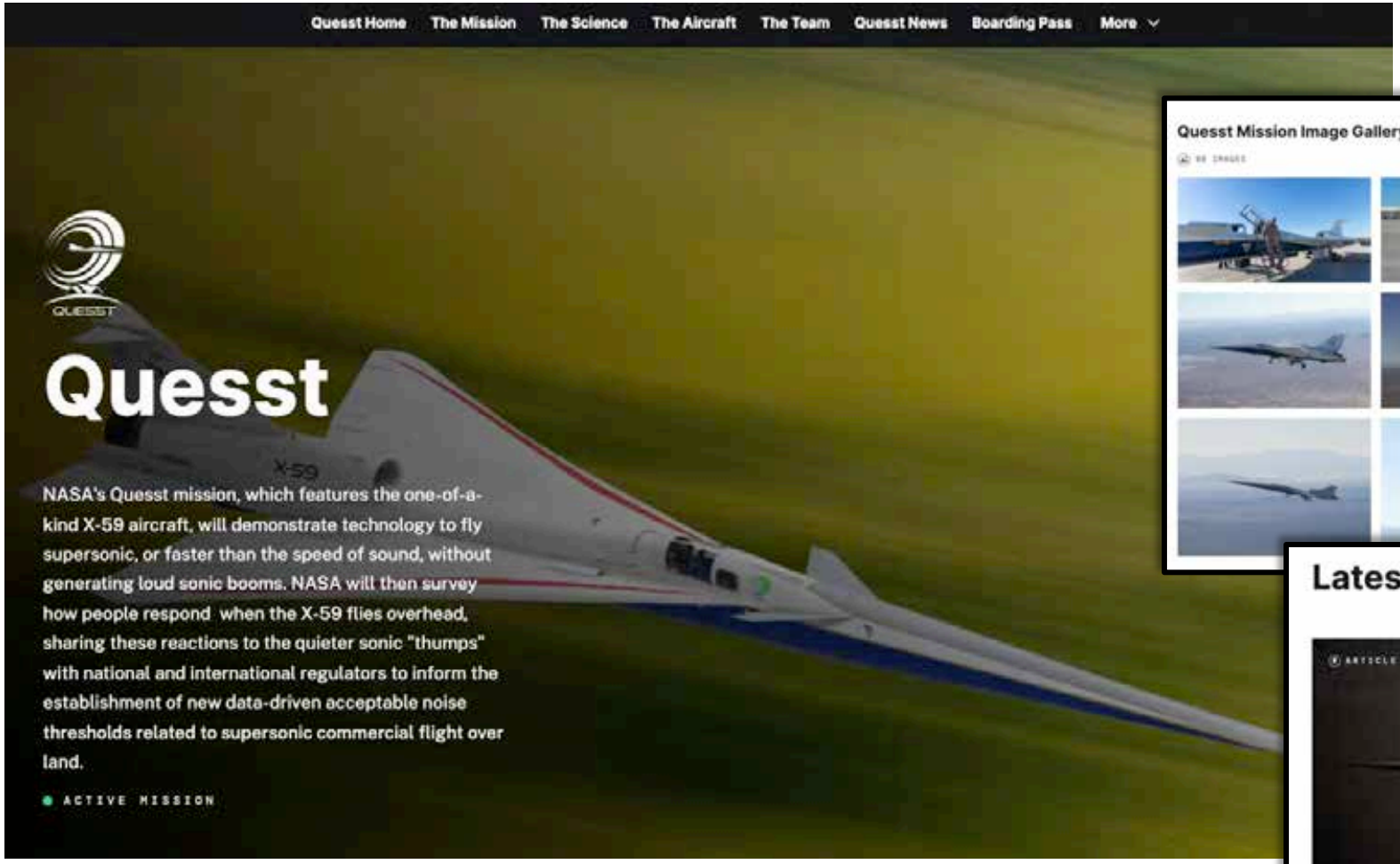


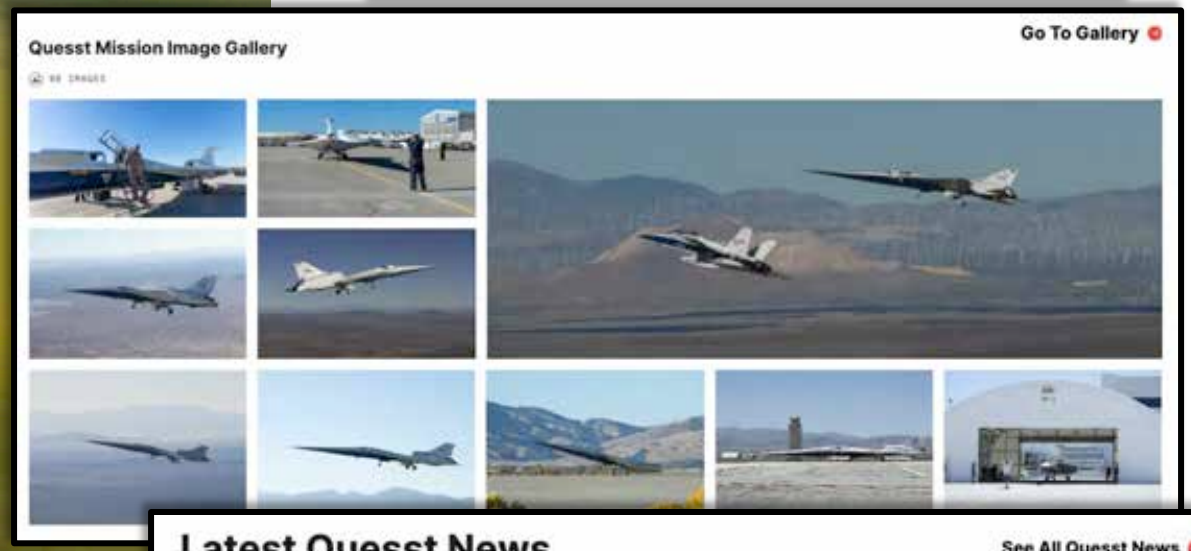


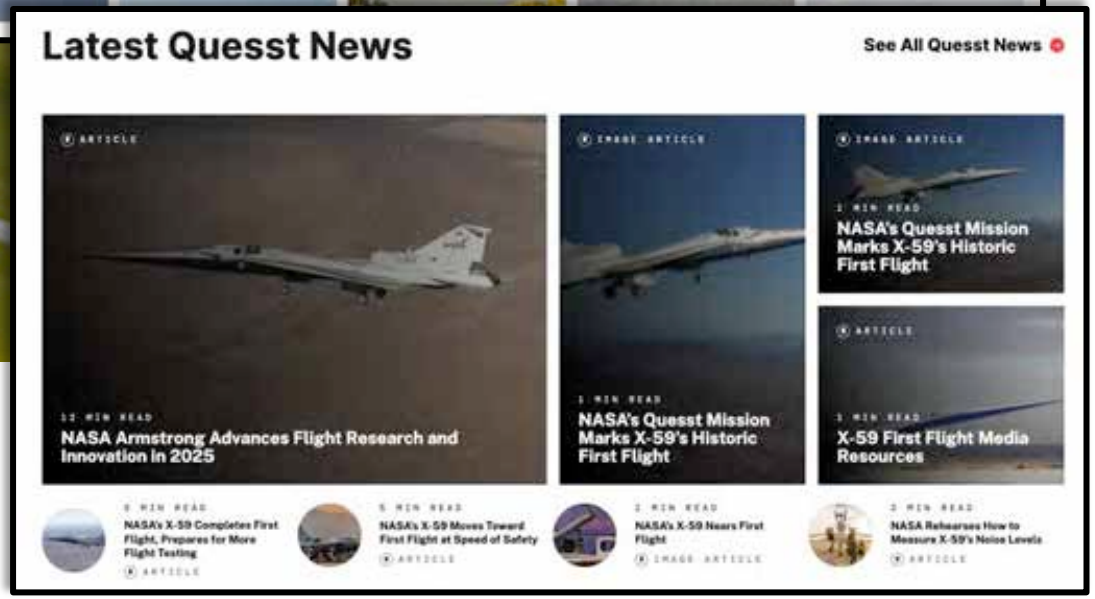


Quesst Mission Web Page

https://www.nasa.gov/quesst







Latest news, picture gallery, videos, science behind the boom, stem resources



Any QUESSTions???

PHOTO CREDIT: NASA

Backup



PHOTO CREDIT: NASA

Quesst Mission Overview

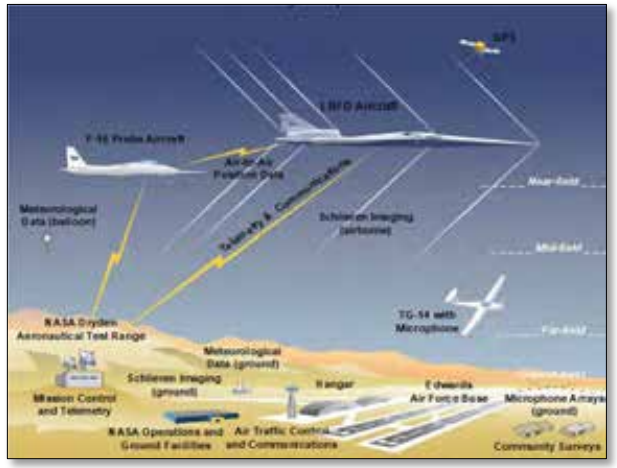


Credit: Lockheed Martin

Phase 1 – Aircraft Development

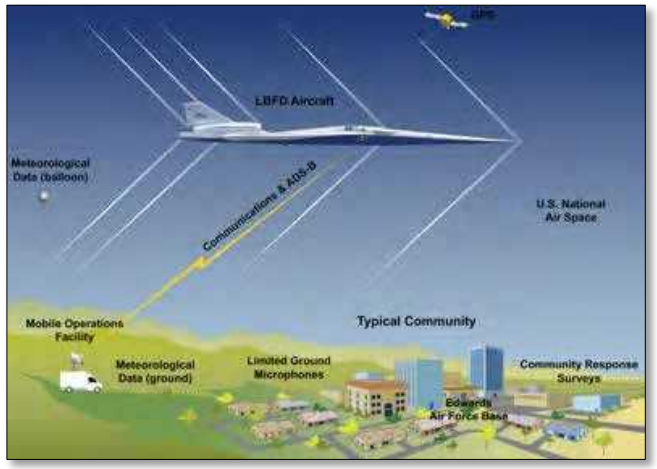
- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion

Systematic Approach Leading to Community Testing



Phase 2 – Acoustic Validation

- In-flight and ground measurement capabilities
- Aircraft Operations / Facilities



Phase 3 – Community Response

- Initial community response overflight study based at NASA AFRC
- Multiple campaigns over representative communities across the U.S.

NASA Sonic Boom Ground Recording System (GRS)

- New recorder designed/built by Crystal Instruments Co to NASA-set requirements
- Dual analog-to-digital converter (ADC) used to acquire data from 4 microphone channels
- Texas Instruments DaVinci dual-core processor for onboard processing tasks
- Satellite and cellular communication modules

