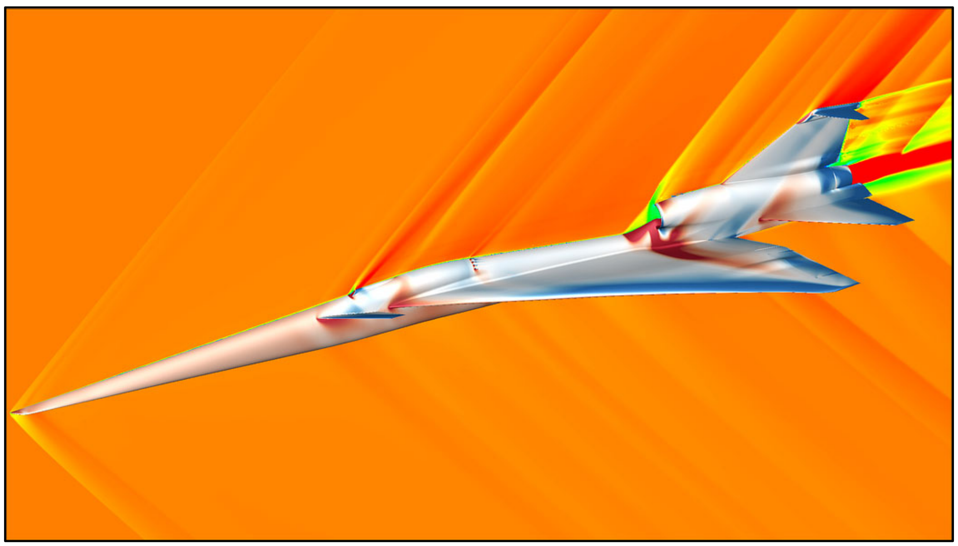
X-59 eXternal Vision System (XVS) Technical Overview

Randall Bailey

X-59 Aircraft

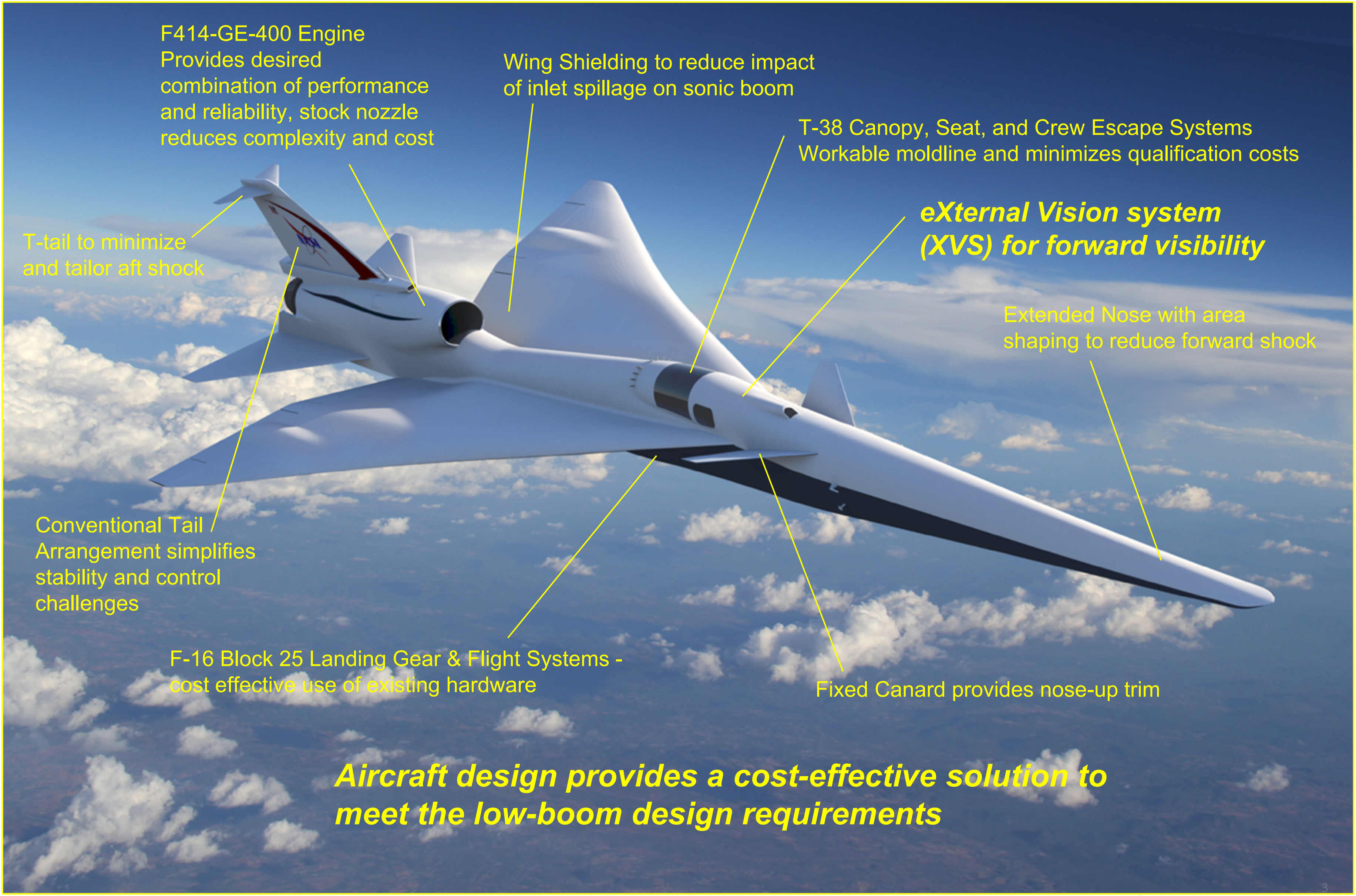
Courtesy: Lockheed-Martin



https://www.nasa.gov/feature/ames/x-59

- X-59 QueSST – Quiet SuperSonic Technologies
- Low Boom Flight Demonstration (LBFD) Mission
  1. Design and build a piloted, large-scale supersonic X-plane with technology that reduces the loudness of a sonic boom to that of a gentle thump; and
  2. Fly the X-plane over select U.S. communities to gather data on human responses to the low-boom flights and deliver that data set to U.S. and international regulators.

X-59 Design Features



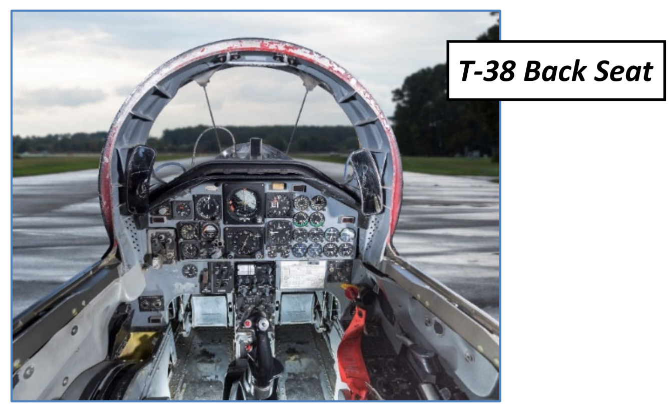
Courtesy: Lockheed-Martin

eXternal Vision System (XVS)

- eXternal Vision System (XVS)
  - XVS is the combination of sensor, display and computing technologies that provide visibility of the external scene topography (the natural or manmade features of a place or region) for the flight crew *analogous or equivalent* to forward-facing windows in conventional aircraft
- Mission-Critical
- Affordable State-of-Art Commercial Technology
  - Modified Commercial-Off-The-Shelf

X-59 Flight Deck Artist Conception

Credit: NASA

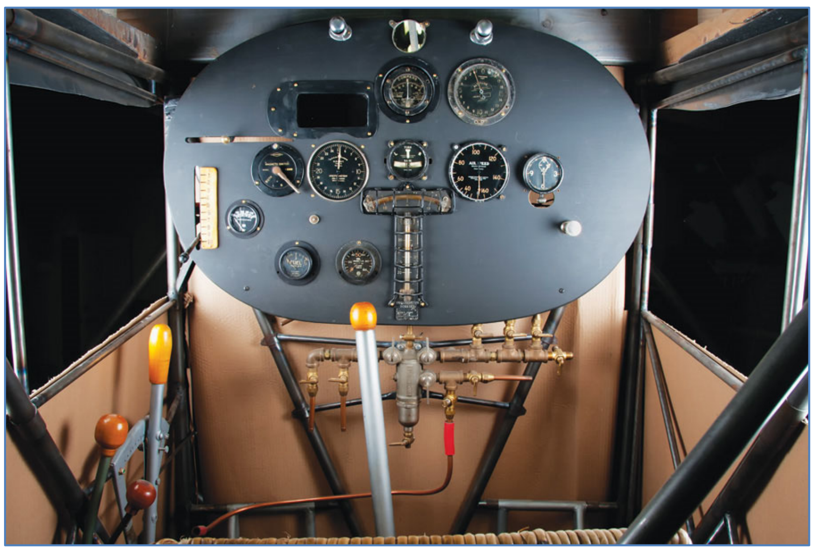


Credit: NASA

Legacy for Forward-Visibility Challenges

- The last manned airplane to fly in the National Air Space (NAS) without forward-facing windows:

https://feedsfree.com/wp-content/uploads/2021/01/spirit-of-st-louis-768x403.jpg



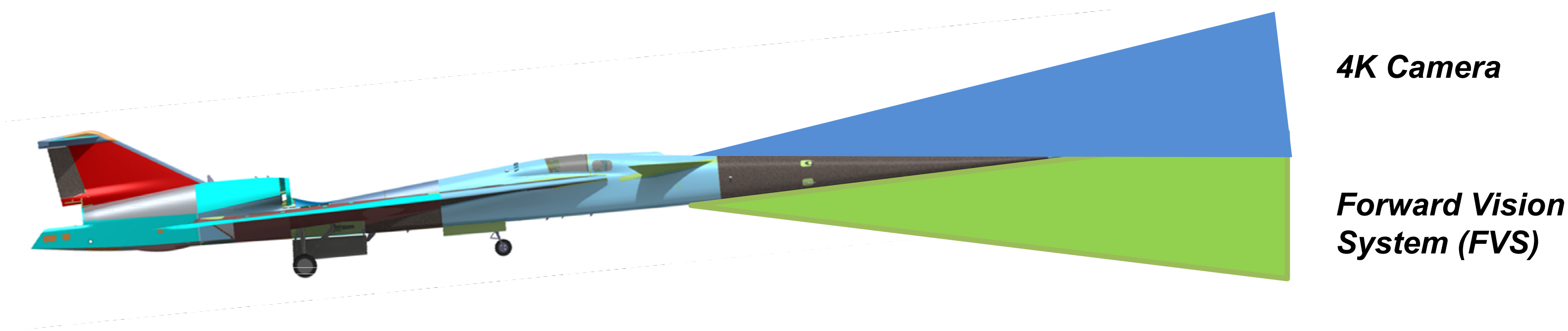
https://s28490.pcdn.co/wp-content/uploads/2019/05/spirit-of-st-louis_002.jpg

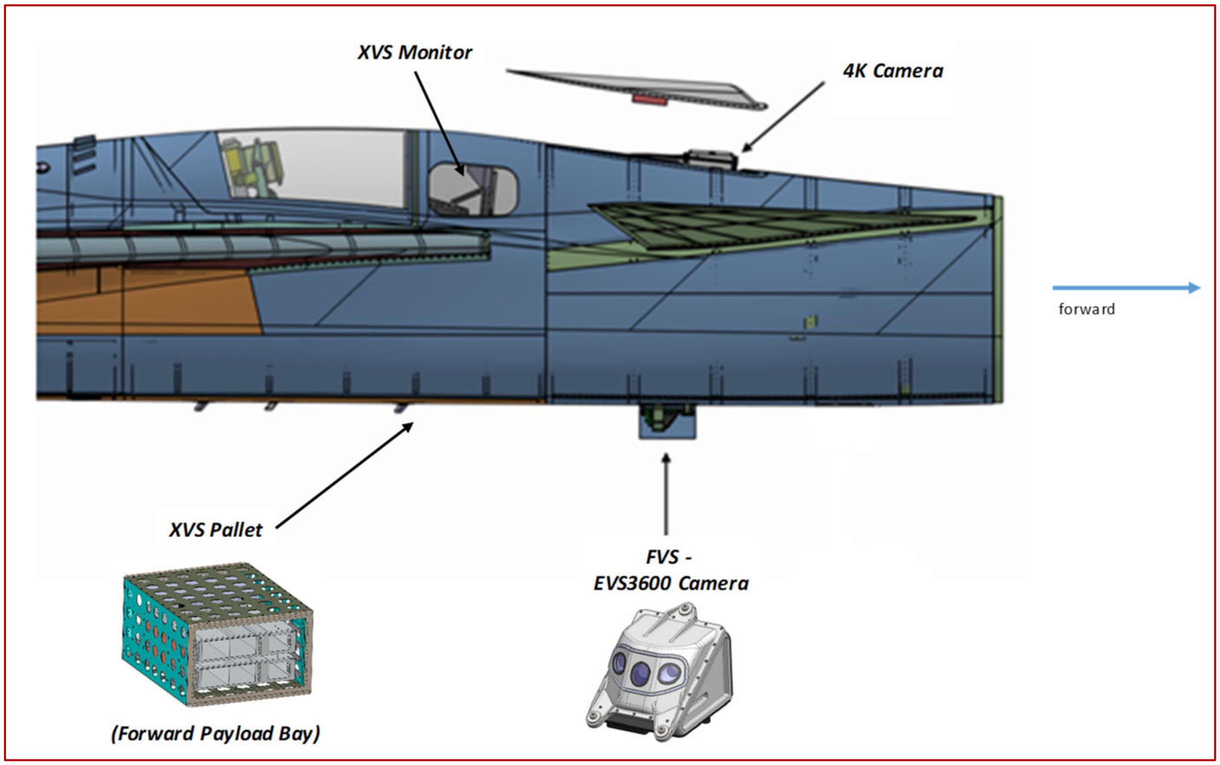
- The previous certificated airplane to fly in the NAS supersonically:

https://i1.wp.com/thepointsguy.com/wp-content/uploads/2019/02/GettyImages-966836392.jpg?fit=2048%2C2048px&ssl=1

https://qph.fs.quoracdn.net/main-qimg-3c6284ee05a3b3750d32bd2a67a67eca-c

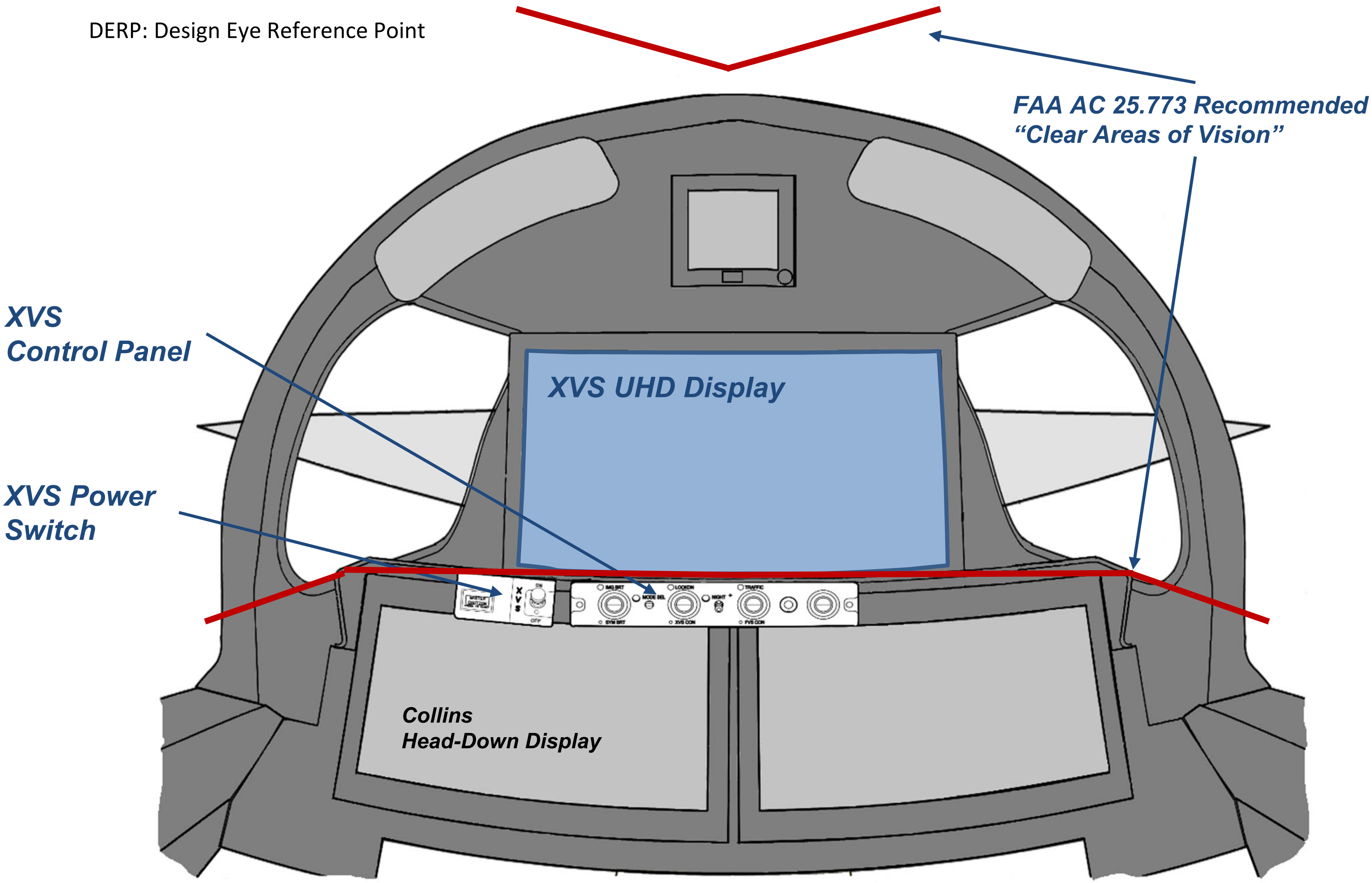
Intended Function – "Electronic Window"





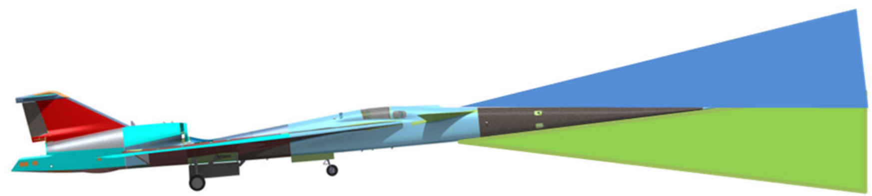
Field-of-View from DERP

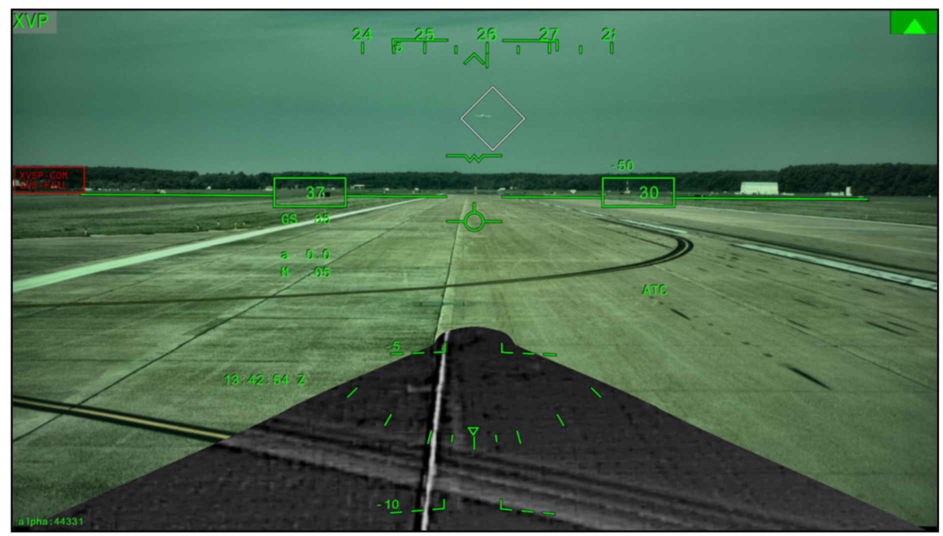
DERP: Design Eye Reference Point



Key XVS Attributes / Requirements

- "Electronic Window" Requirements
  - Derived requirements from "forward-facing windows"
    - Phase 3 mission-critical system / design
- ***Near State-of-Art,***
  Near Commercial-Off-the-Shelf
- Resolution & Contrast
- Conformal, Field-of-Regard
  - 17^o V x 29^o H
- Real-time Image / Fuselage "fill"
- Low Latency
- Head-Up Display (HUD) symbology
- Traffic awareness
  - Window-equivalence (see-and-avoid)
  - Traffic locator boxes
    - Azimuth / elevation from surveillance data





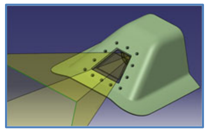
Credit: NASA

COTS / Modified COTS for Affordability

XVS 4K Camera

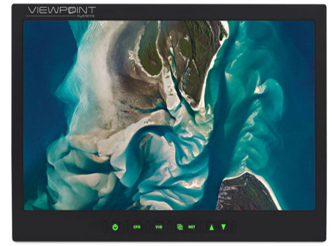
http://www.ioindustries.com/

Flare IO 12M180CCX



Heated Glass Window
N2-filled Chamber

XVS Display



https://viewpointproducts.com

Viewpoint Systems Monitor
Largest 3840 x 2160 format,
filling allocated X-59 volume
Modified for flight environment

XVS Pallet

https://www.nasa.gov/mission_pages/lowboom/images

Pseudo-Dual Redundant Design
Mission-Critical

https://www.trentonsystems.com/

Trenton System THS2085 HDEC 2U rack-mounted computer

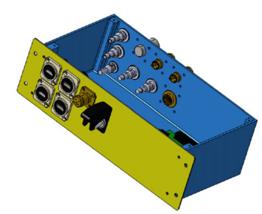
Forward Vision System

Collins EVS3600
(LM-Supplied)

XVS Control Panel

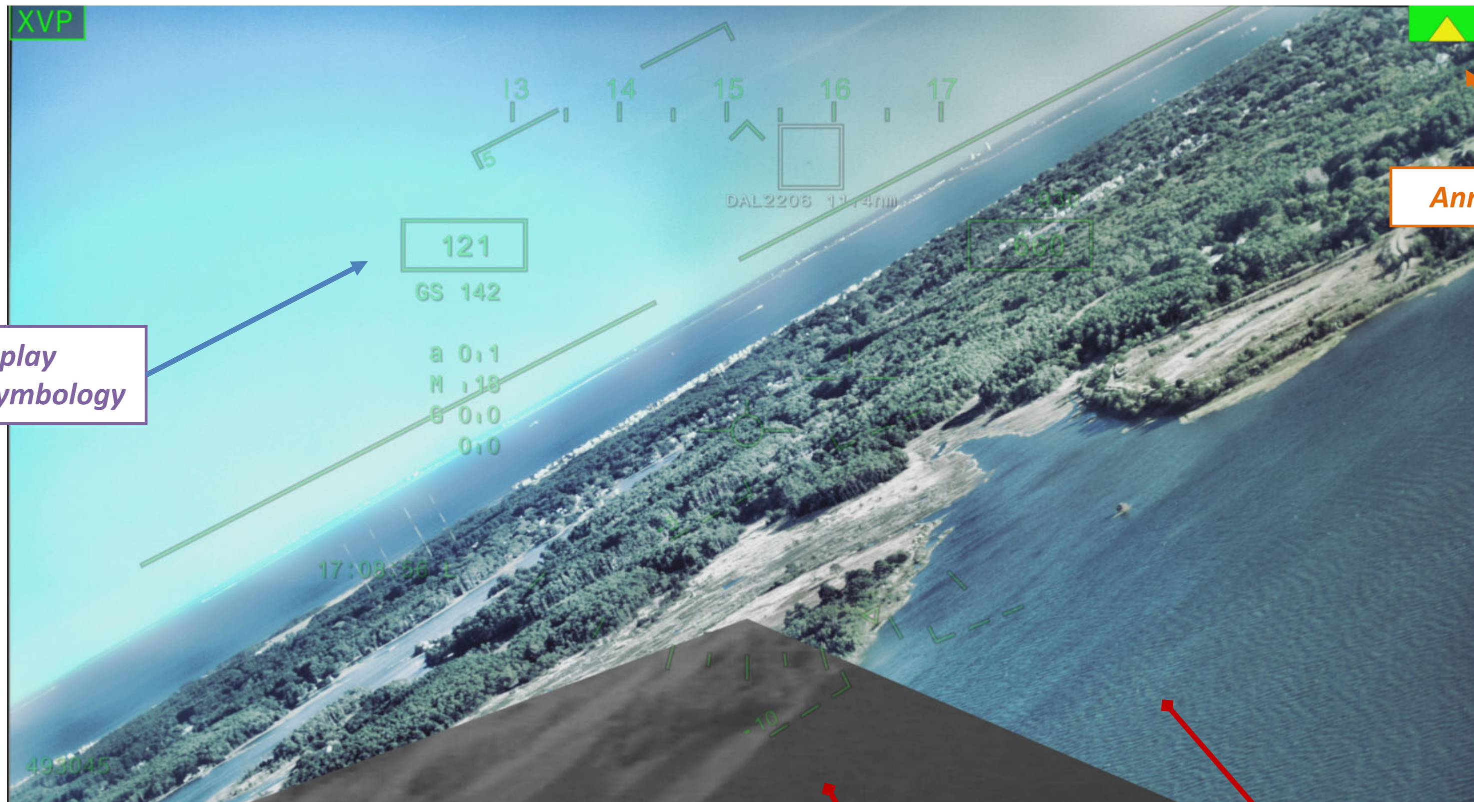
Credit: NASA

XVS Maintenance Panel



XVS Content – Electronic Window with HUD

- Three Elements: Imagery / Symbology / Annunciations
  - Three Imagery Sources
    - 1) 4K Camera; 2) FVS Camera; and 3) Synthetic Vision



Credit: NASA

Head-Up Display (HUD)-like Symbology

Annunciations

FVS Imagery

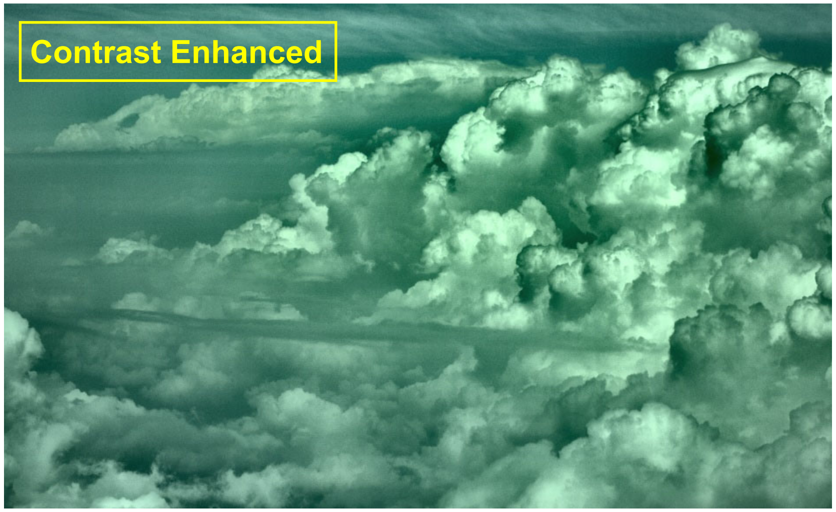
4K Imagery

Real-Time Operating System (RTOS) Conversion

- VxWorks® RTOS
  - XVS Operational Flight Program (OFP) runs on VxWorks RTOS
- Required new Graphics and Video Capture Cards
  - Custom Designs and Developments
    - Custom VxWorks Driver Development
  - Vulkan Libraries for Safety Critical Graphics Processing Unit (GPU)

Contrast Enhancement

- Performance Goal:
  - Equivalent Levels of Performance and Safety to Forward-Facing Windows
  - Project is trying to develop and disseminate quantitative data
- Image resolution is a necessary but perhaps not sufficient prerequisite for “human” equivalent performance
  - Contrast enhancement critical
- Local area contrast enhancement key
  - Working on Luminance
  - Contrast-Limited Adaptive Histogram Equalization (CLAHE)
    - 144 contrast processing threads
    - Created from 12-by-12 tiles of 320 H by 180 V pixels each.

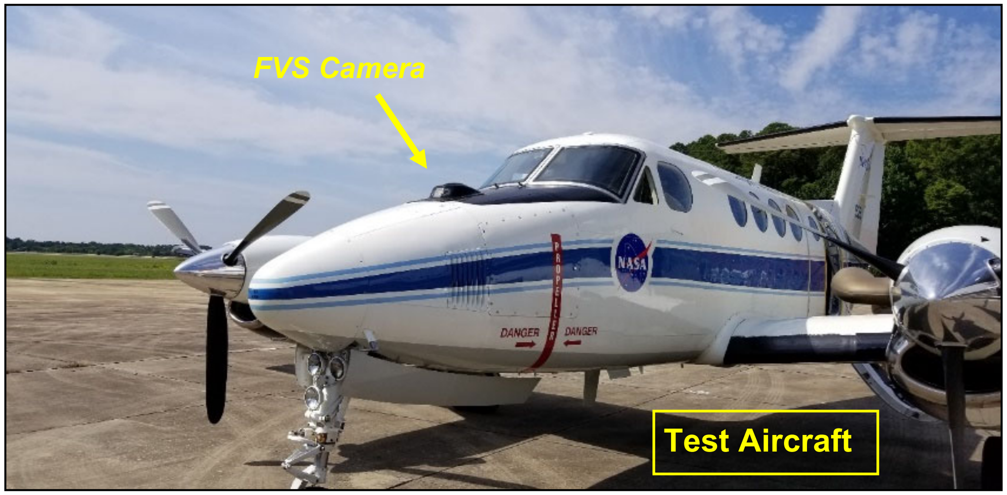


Credit: NASA

Development Path

- XVS Flight Test Development
  - Side-by-side comparative evaluation between forward-facing window (OTW) and XVS
    - *Event marker identified detection*
      - Automatic Dependent Surveillance-Broadcast (ADS-B) derived time/distance of detection

Credit: NASA



Credit: NASA

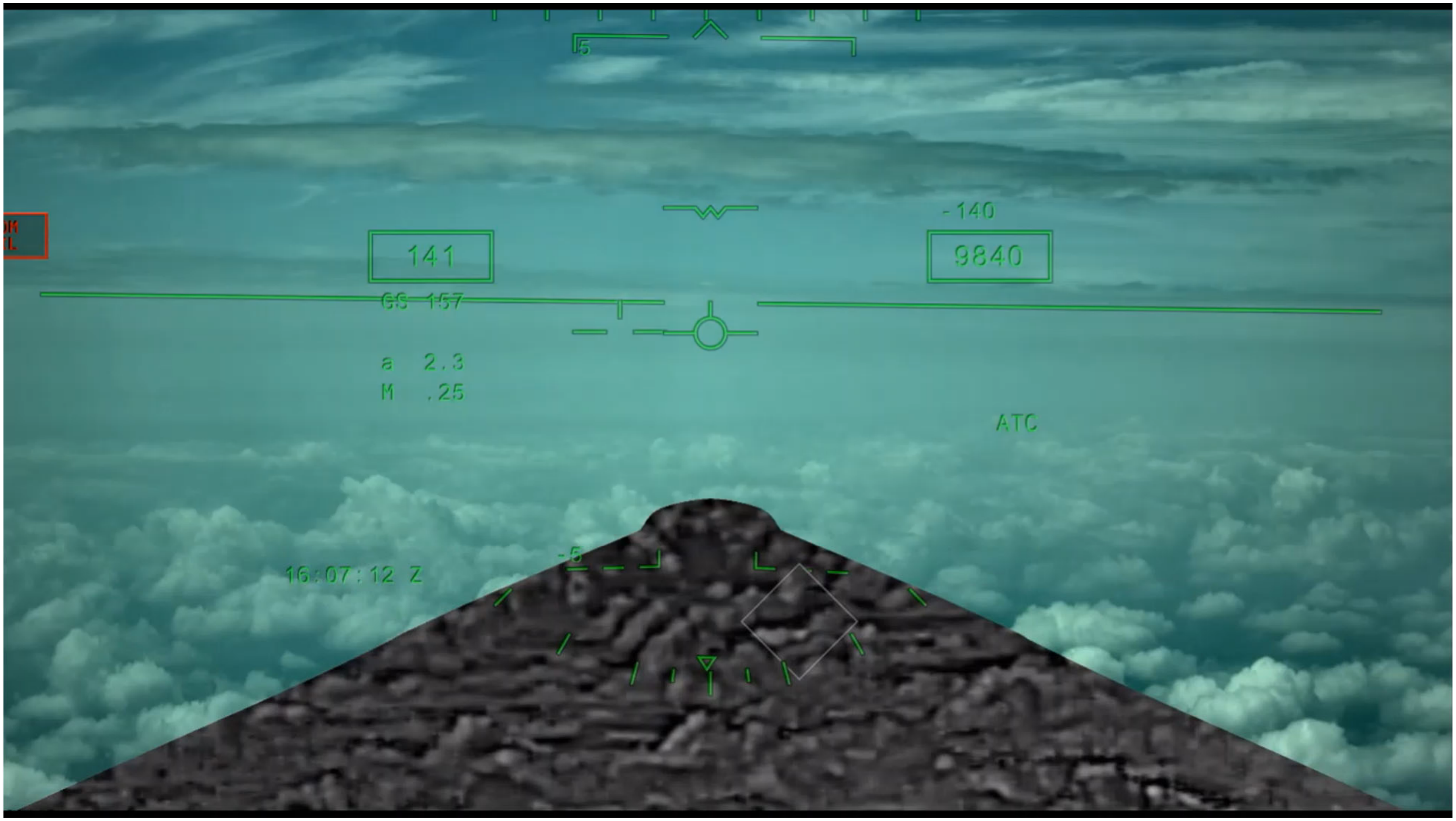
Credit: NASA

Low Rez Video, High Rez Target Example

Credit: NASA

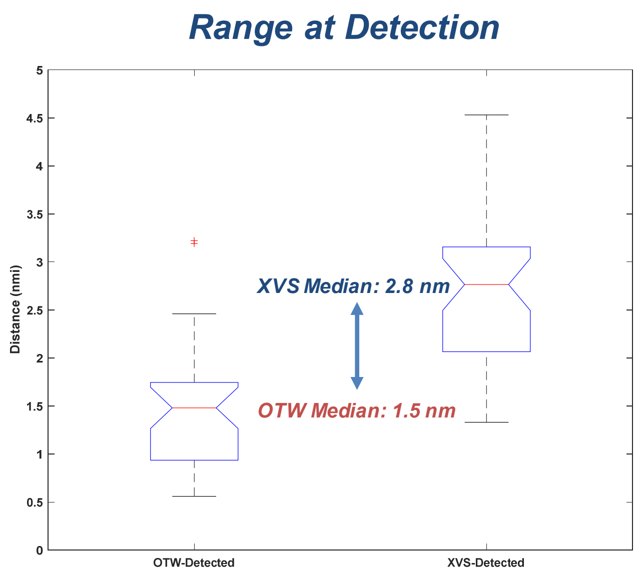
Contrast in See-to-Follow Video

Credit: NASA



Flight Test Results

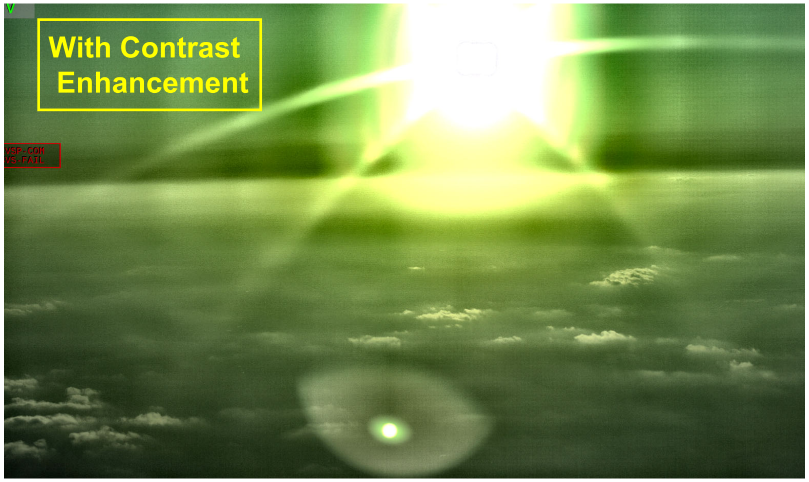
- In extremely challenging see-and-avoid, XVS provides equal and most often superior performance than windows



Of the 64 runs:
40 detections XVS
35 detections OTW

Mean closure of 323 kts; Target Aircraft Lancair LC-40

- Sensor Characterization



Credit: NASA

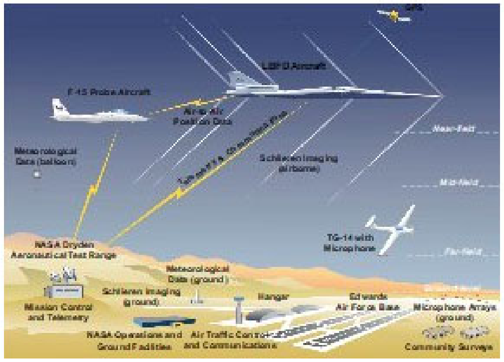
XVS Summary

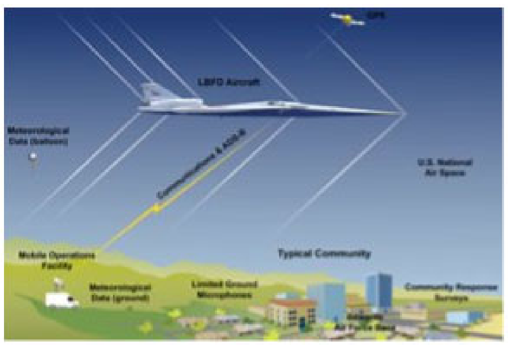
- Surrogate aircraft flight test conducted as a direct comparative evaluation of XVS performance against forward-facing windows.
  - Extremely demanding see-and-avoid maneuvers, challenging, yet operationally relevant flight conditions.
  - Data suggests XVS equal to and in fact, often superior to forward-facing windows
- Test was a “qualified” proof of Technology Readiness Level of 9 - “actual system is flight-proven in operation”
    - Pilots did not fly the aircraft by reference to the XVS
    - Speed and altitude test profile limited especially in comparison to the X-59
    - The weather conditions were limited.
- XVS Status:
  - Environmental Qual’d for Flight; Integrated into X-59 Systems Integration Lab
  - XVS Delivered and being installed in X-59
  - System checkout on X-59 starts in 2021; ground testing in 2022.
- X-59 First Flight in 2022

First Flight 2022

https://www.nasa.gov/aeroresearch/x-59-nose-makes-an-appearance

Low-Boom Flight Demo. Mission Overview





- ***Phase 1 – Aircraft Development***
  - *In Progress (FY18-23)*
  - Design, Fab a quiet supersonic research aircraft
  - Prove performance in test range flights
  - Prove safety for flights in normal airspace

- ***Phase 2 – Acoustic Validation***
  - *Preparation In Progress (FY18-23), Execution FY23-24*
  - Prove the acoustic characteristics match design targets
  - Detailed in-flight and ground measurement in test range

Systematic Approach Leading to Community Testing

- ***Phase 3 – Community Response Testing***
  - *Preparation In Progress (FY18-23), Execution FY24-27*
  - Conduct community tests
    - Select communities
    - Outreach and engagement (including STEM)
    - Obtain regulatory approvals
    - Plan surveys and recruit participants
    - Collect ground measurements.