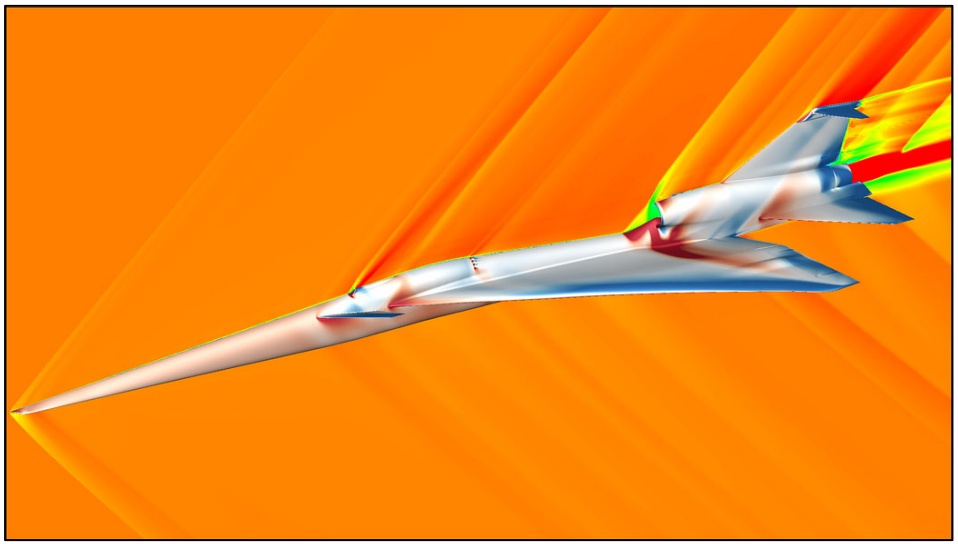
X-59 eXternal Vision System (XVS) Technical Overview

Randall Bailey

X-59 Aircraft

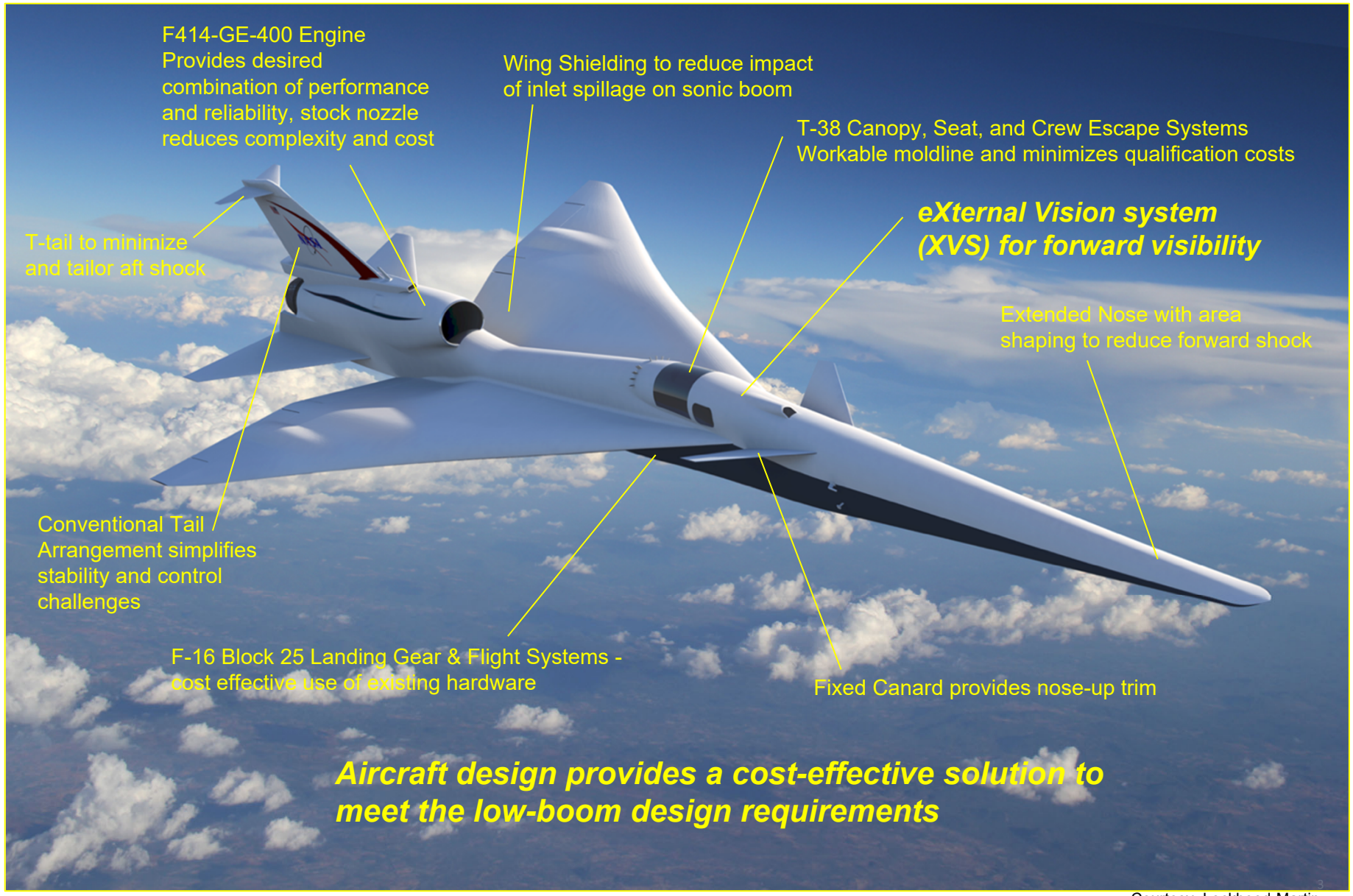
Courtesy: Lockheed-Martin



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



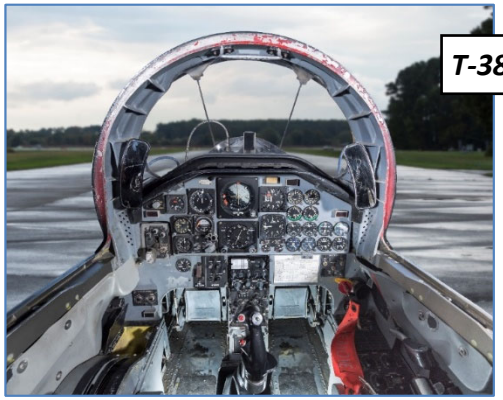
Courtesy: Lockheed-Martin

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



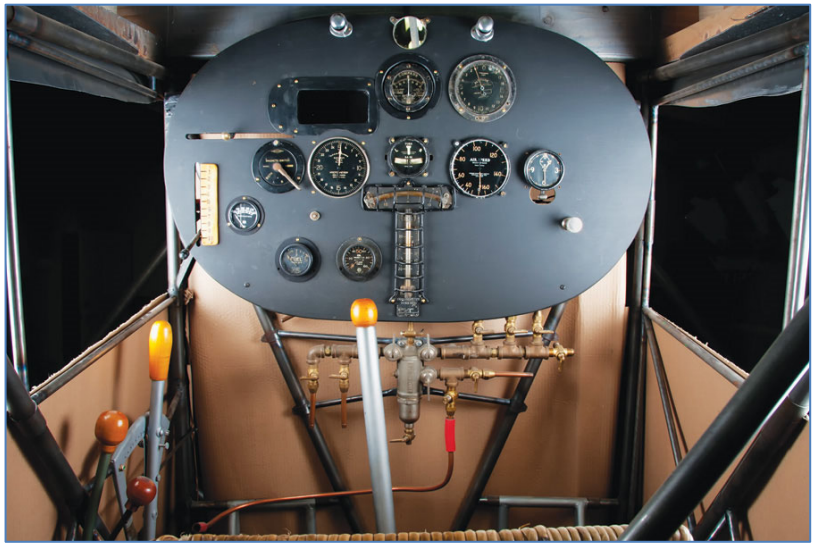
T-38 Back Seat

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



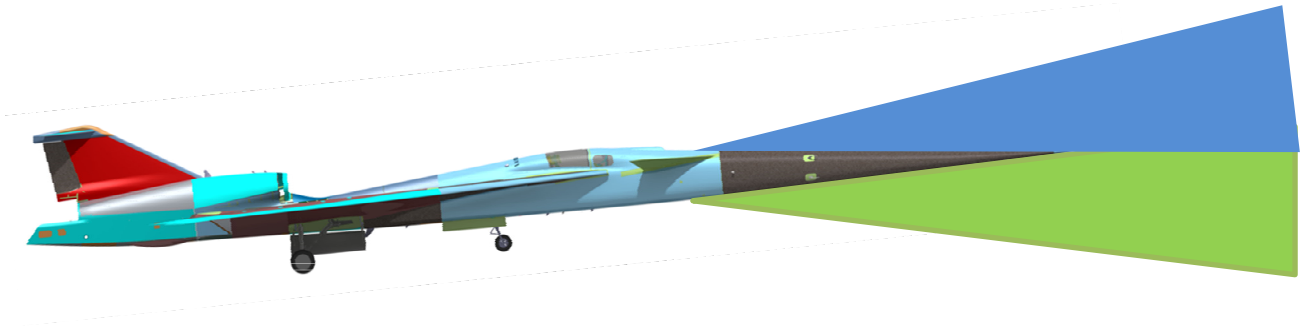
https://s28490.pcdn.co/wp-content/uploads/2019/05/spirit-of-st-louis_002.jpg

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

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

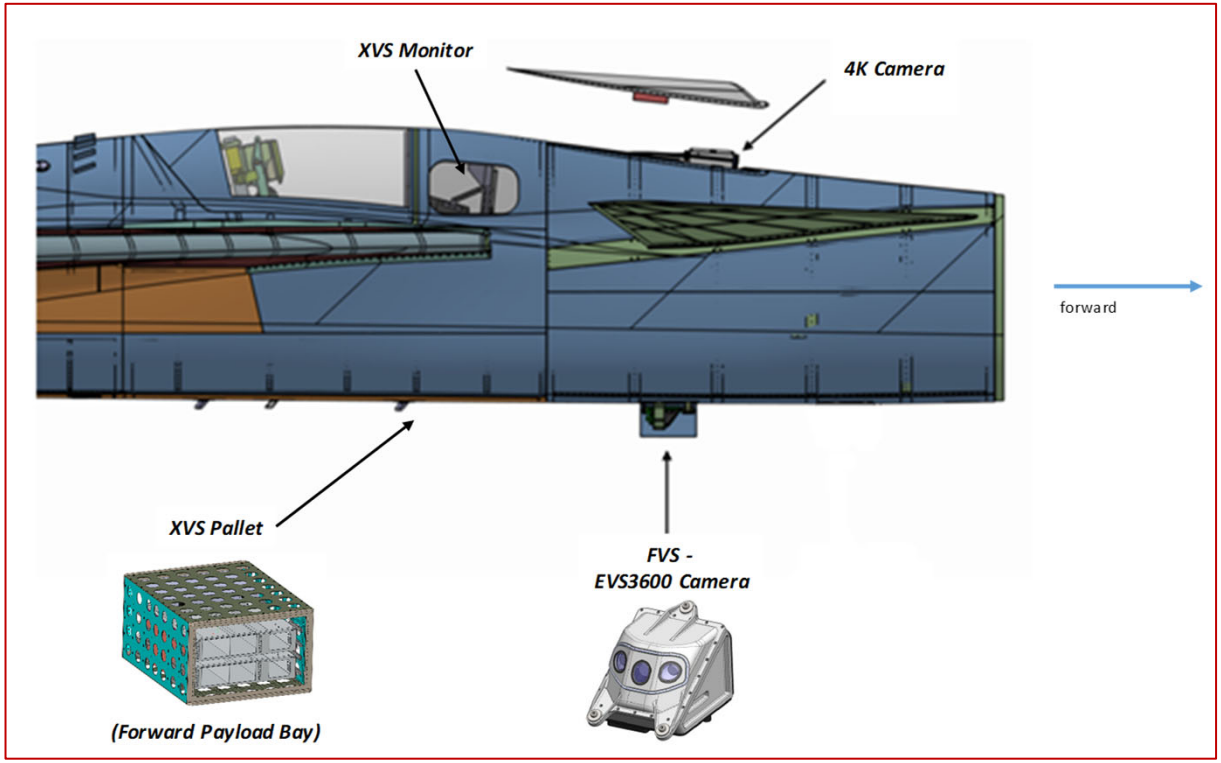
https://i1.wp.com/thepointsguy.com/wp-content/uploads/2019/02/GettyImages-966836392.jpg?fit=2048%2C2048px&ssl=1

Intended Function – “Electronic Window”



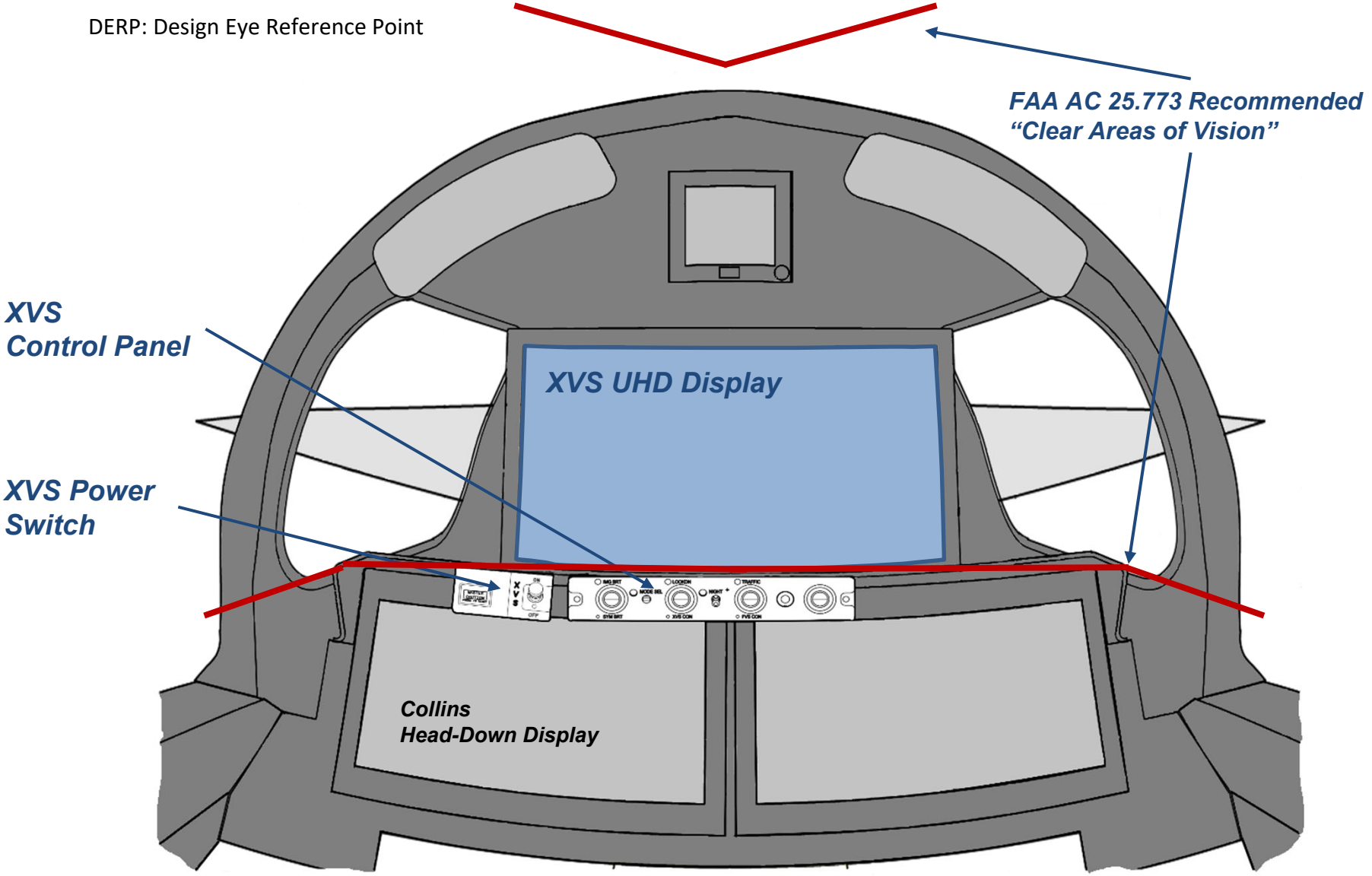
4K Camera

Forward Vision System (FVS)



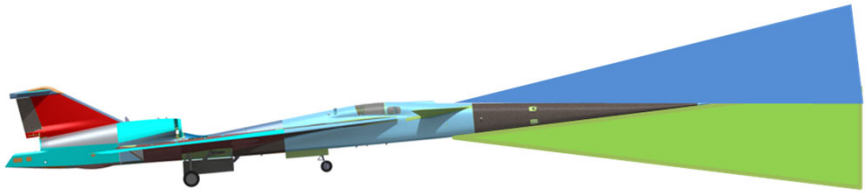
Field-of-View from DERP

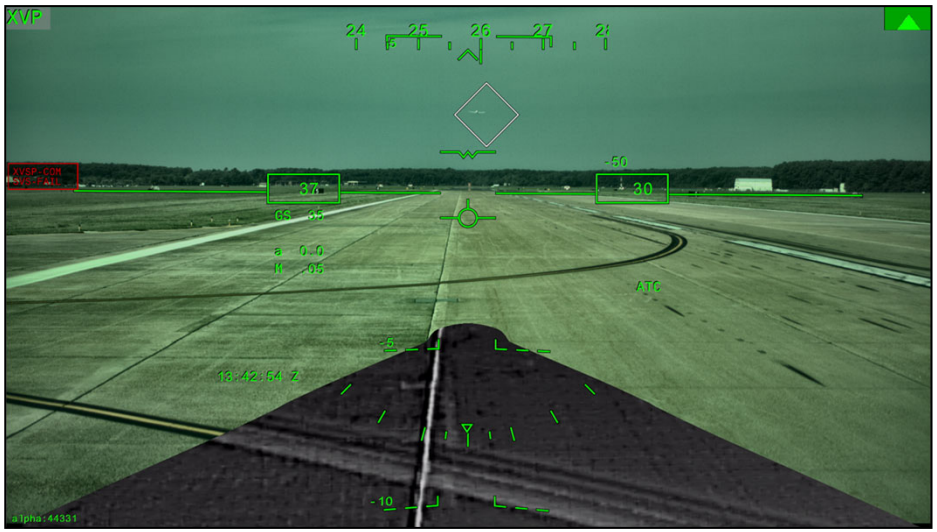
DERP: Design Eye Reference Point



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° V x 29° 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





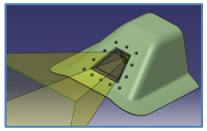
Credit: NASA

COTS / Modified COTS for Affordability

XVS 4K Camera

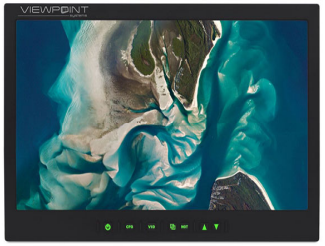
http://www.ioindustries.com/

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

XVS Mounting Brackets Installed in X-59 Aircraft; check-fit with pallet mock-up

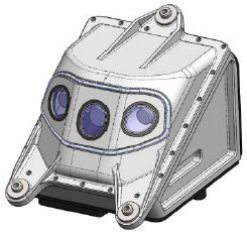
https://www.nasa.gov/mission_pages/lowboom/images

https://www.trentonsystems.com/

Pseudo-Dual Redundant Design
Mission-Critical

Trenton System THS2085 HDEC 2U rack-mounted computer

Forward Vision System

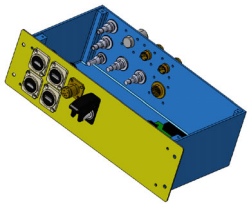


Collins EVS3600
(LM-Supplied)

XVS Control Panel

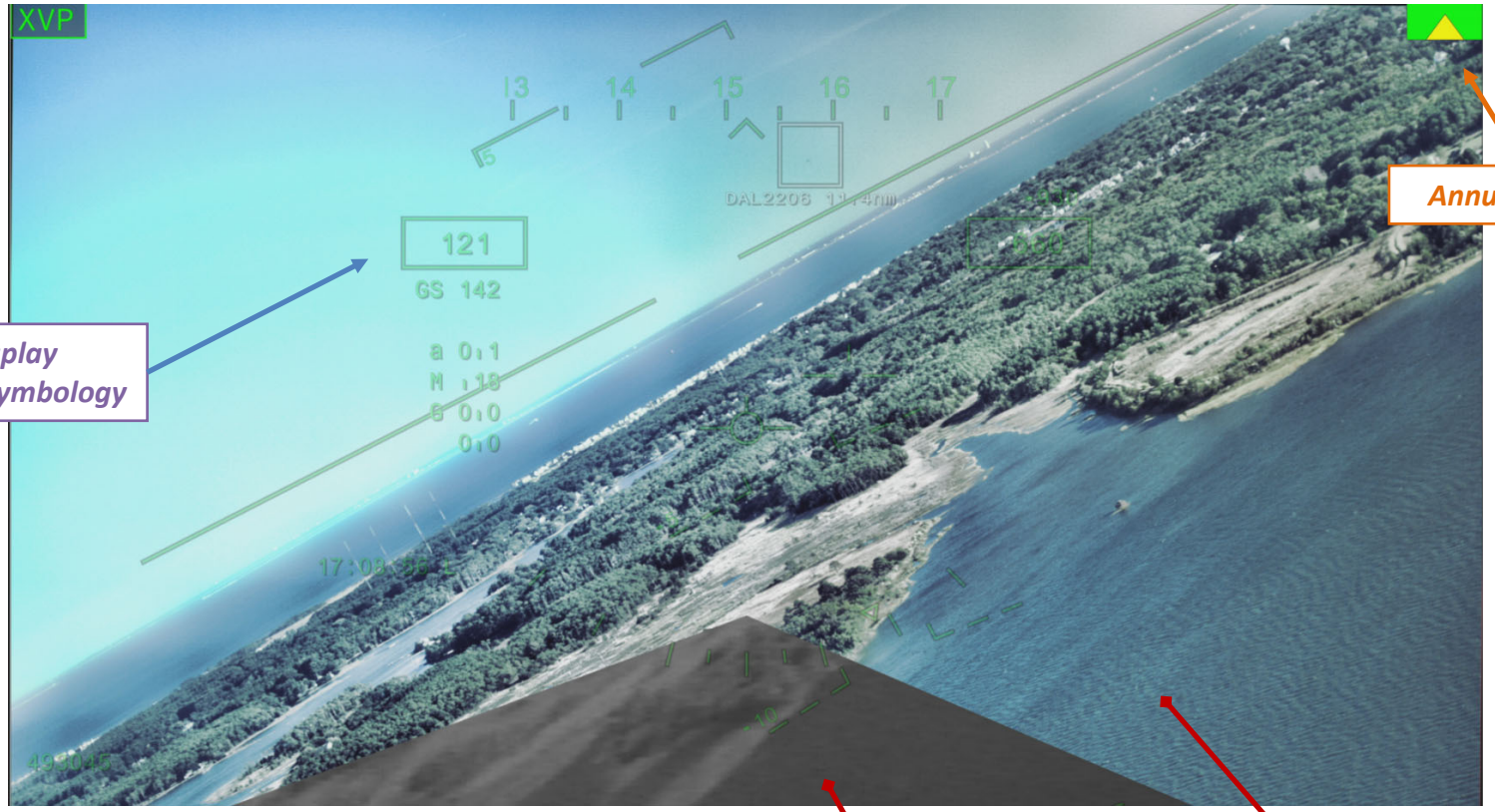
Credit: NASA

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

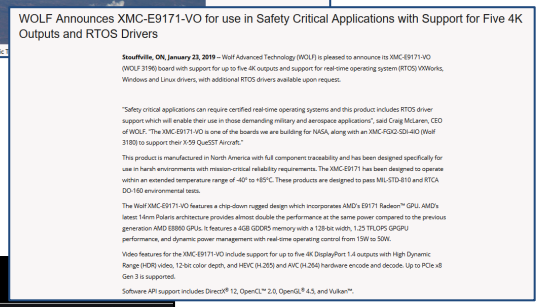
Real-Time Operating System (RTOS) Conversion

- 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)


NASA Chooses WOLF Products to Support the eXternal Vision System for the X-59 QueSST Aircraft

Stouffville, ON, September 26, 2018 – WOLF Advanced Technology ("WOLF") is pleased to announce that NASA has chosen two WOLF video graphics modules to take part in the development of NASA's X-59 Quiet SuperSonic Technology (QueSST) aircraft. The X-59 is designed to reduce the noise generated by a sonic boom.

The chosen products, the XMC-E9171-VO (WOLF-3196) and the XMC-FGX2-SDI-8IO (WOLF-3180), provide video capture, process, encode, and display capabilities to help enable NASA's "windowless cockpit display system", the eXternal Vision System (XVS). NASA's XVS is designed to replace a front windshield with video display technology in NASA's Low-Boom Flight Demonstration mission.


WOLF Announces XMC-E9171-VO for use in Safety Critical Applications with Support for Five 4K Outputs and RTOS Drivers

Stouffville, ON, January 23, 2019 – Wolf Advanced Technology (WOLF) is pleased to announce its XMC-E9171-VO (WOLF 3196) board with support for up to five 4K outputs and support for real-time operating system (RTOS) VxWorks, Windows and Linux drivers, with additional RTOS drivers available upon request.

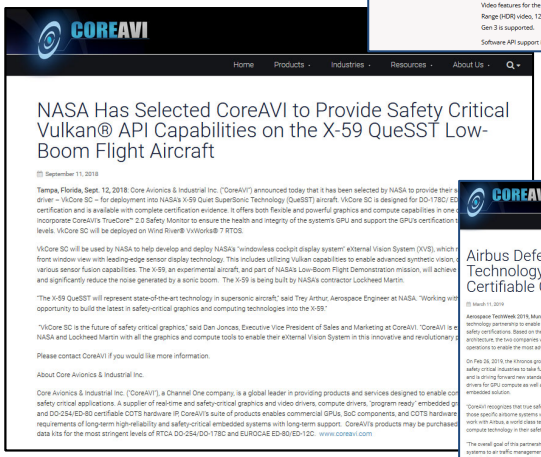
"Safety critical applications can require certified real-time operating systems and this product includes RTOS driver support which will enable their use in those demanding military and aerospace applications", said Craig McLaren, CEO of WOLF. "The XMC-E9171-VO is one of the boards we are building for NASA, along with an XMC-FGX2-SDI-4IO (Wolf 3180) to support their X-59 QueSST Aircraft."

This product is manufactured in North America with full component traceability and has been designed specifically for use in harsh environments with mission-critical reliability requirements. The XMC-E9171 has been designed to operate within an extended temperature range of -40° to +85°C. These products are designed to pass MIL-STD-810 and RTCA DO-160 environmental tests.

The Wolf XMC-E9171-VO features a chip-down rugged design which incorporates AMD's E9171 Radeon™ GPU. AMD's latest 14nm Polaris architecture provides almost double the performance at the same power compared to the previous generation AMD E8860 GPUs. It features a 4GB GDDR5 memory with a 128-bit width, 1.25 TFLOPS GPGPU performance, and dynamic power management with real-time operating control from 15W to 50W.

Video features for the XMC-E9171-VO include support for up to five 4K DisplayPort 1.4 outputs with High Dynamic Range (HDR) video, 12-bit color depth, and HEVC (H.265) and AVC (H.264) hardware encode and decode. Up to PCIe x8 Gen 3 is supported.

Software API support includes DirectX® 12, OpenCL™ 2.0, OpenGL® 4.5, and Vulkan™.


COREAVI

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NASA Has Selected CoreAVI to Provide Safety Critical Vulkan® API Capabilities on the X-59 QueSST Low-Boom Flight Aircraft

September 11, 2018

Tempe, Florida, Sept. 12, 2018: Core Avionics & Industrial Inc. ("CoreAVI") announced today that it has been selected by NASA to provide their s driver – VkCore SC – for deployment into NASA's X-59 Quiet SuperSonic Technology (QueSST) aircraft. VkCore SC is designed for DO-178C/ ED certification and is available with complete certification evidence. It offers both flexible and powerful graphics and compute capabilities in one c incorporate CoreAVI's TrueCore™ 2.0 Safety Monitor to ensure the health and integrity of the system's GPU and support the GPU's certification t levels. VkCore SC will be deployed on Wind River® VxWorks® 7 RTOS.

VkCore SC will be used by NASA to help develop and deploy NASA's "windowless cockpit display system" eXternal Vision System (XVS), which front window view with leading-edge sensor display technology. This includes utilizing Vulkan capabilities to enable advanced symbiotic vision, various sensor fusion capabilities. The X-59, an experimental aircraft, and part of NASA's Low-Boom Flight Demonstration mission, will achieve and significantly reduce the noise generated by a sonic boom. The X-59 is being built by NASA's contractor Lockheed Martin.

"The X-59 QueSST will represent state-of-the-art technology in supersonic aircraft," said Trey Arthur, Aerospace Engineer at NASA. "Working wit opportunity to build the latest in safety-critical graphics and computing technologies into the X-59."

"VkCore SC is the future of safety critical graphics," said Dan Joncas, Executive Vice President of Sales and Marketing at CoreAVI. "CoreAVI is e NASA and Lockheed Martin with all the graphics and compute tools to enable their eXternal Vision System in this innovative and revolutionary p

Please contact CoreAVI if you would like more information.

About Core Avionics & Industrial Inc.

Core Avionics & Industrial Inc. ("CoreAVI"), a Channel One company, is a global leader in providing products and services designed to enable cor safety critical applications. A supplier of real-time and safety-critical graphics and video drivers, compute drivers, "program ready" embedded gr and DO-254/ED-80 certifiable COTS hardware IP, CoreAVI's suite of products enables commercial GPUs, SoC components, and COTS hardware requirements of long-term high-reliability and safety-critical embedded systems with long-term support. CoreAVI's products may be purchased data kits for the most stringent levels of RTCA DO-254/DO-178C and EUROCAE ED-80/ED-12C. www.coreavi.com


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Airbus Defence and Space and CoreAVI Announce Technology Partnership to Bring to Market Safety Certifiable GPU Compute for Autonomous Systems

March 11, 2019

Aerospace TechWeek 2019, Munich, Germany, March 12, 2019: Airbus Defence and Space and Core Avionics & Industrial Inc. ("CoreAVI") announced today a technology partnership to enable the use of GPU compute in airborne systems and applications that require the highest RTCA DO-178C/EUROCAE ED-12C DAL A safety certifications. Based on the use of CoreAVI's platforms for safety certifiable applications, including its VkCore™ SC Vulkan®-based compute driver architecture, the two companies will work together to fully define and be ready to deliver software and systems that perform safety critical GPU compute operations to enable the most advanced autonomous systems and other avionics applications that can take advantage of GPU compute functions.

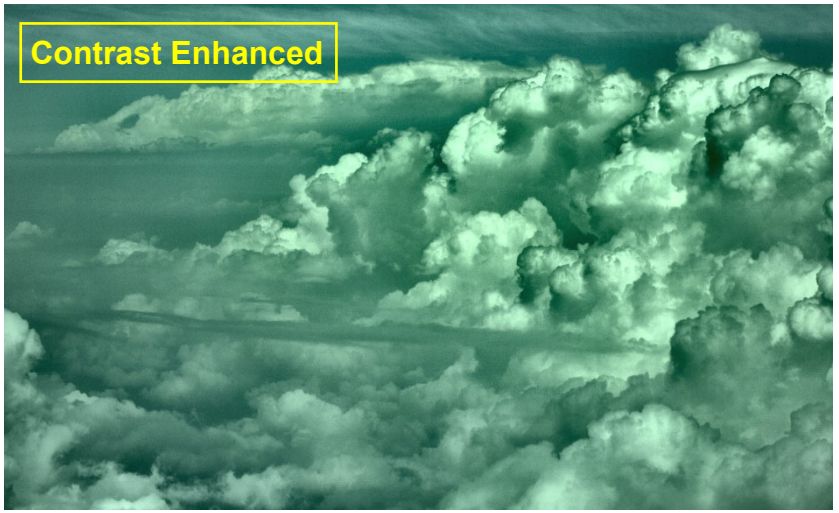
On Feb 26, 2019, the Khronos group announced the creation of the Vulkan Safety Critical Working Group Standards Initiative, a new committee designed to enable safety critical industries to take full advantage of the graphics and compute technology available with the Vulkan API. CoreAVI chairs the Vulkan SC Working Group and is driving forward new standards to support true GPU compute capabilities using graphics processors. Today, the company offers Vulkan-based safety critical drivers for GPU compute as well as the COTS-D line of safety critical hardware IP to enable modern avionics platforms access to a complete safety critical embedded solution.

"CoreAVI recognizes that true safety critical GPU compute is the future of mil/aero autonomous systems. Airbus agrees that this technology is the solution for those specific airborne systems with huge processing demands, especially for autonomous applications," said Damian Pickard CEO at CoreAVI. "We're excited to work with Airbus, a world class technology leader, to ensure that aerospace operators and integrators are able to harness the full capabilities and benefits of GPU compute technology in their safety certifiable platforms."

"The overall goal of this partnership is to facilitate world leading compute capabilities in the full spectrum of certified aerospace applications – from control systems to air traffic management, sensor analysis, autonomous flight systems, aerial refuelling, and more," said Francisco José Lagares Carrasco, Head of Air to Air Refueling Engineering at Airbus. "CoreAVI's platforms for safety certifiable applications and Vulkan architecture is the best platform in the market to face this ambitious challenge for building true safety critical compute applications."

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.

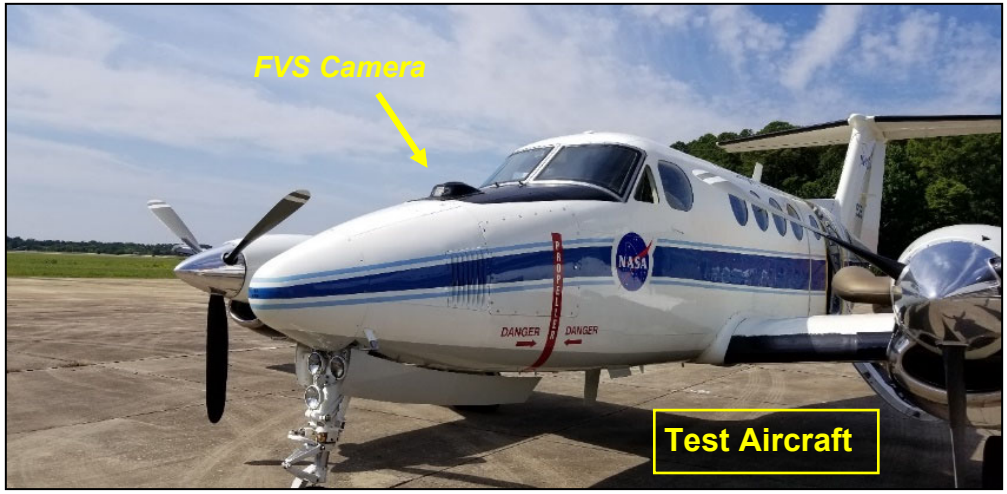


Credit: NASA

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

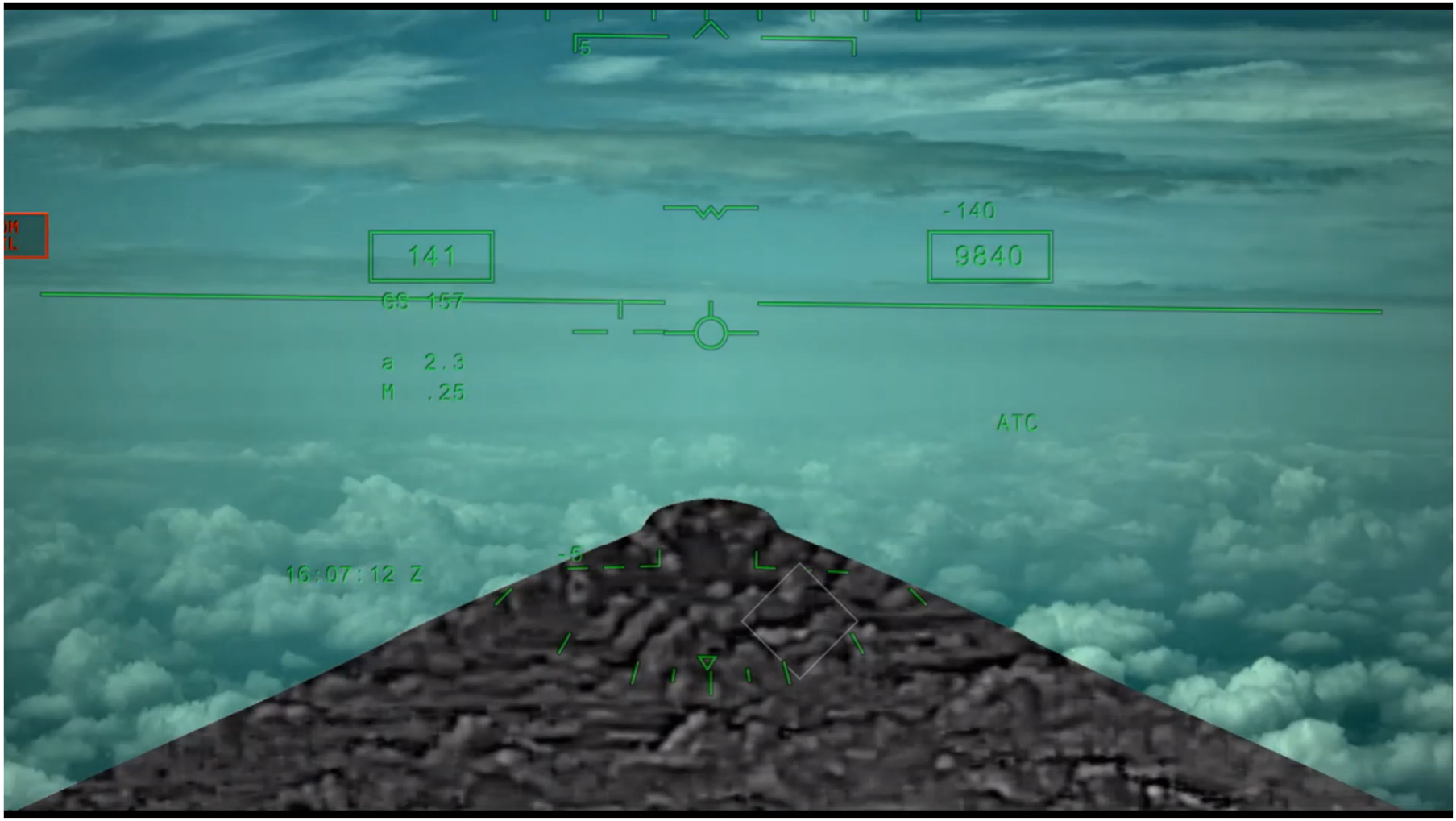
Credit: NASA

Low Rez Video, High Rez Target Example

Credit: NASA

Contrast in See-to-Follow Video

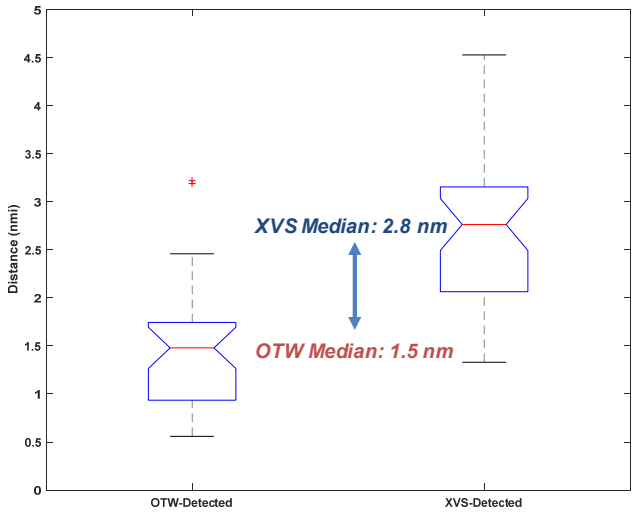
Credit: NASA



Flight Test Results

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

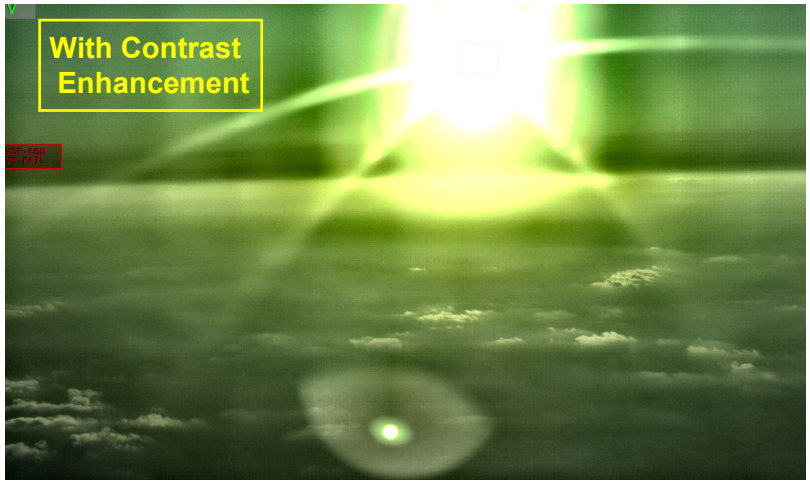
Range at Detection



Of the 64 runs:
40 detections XVS
35 detections OTW

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

- Sensor Characterization



Credit: NASA

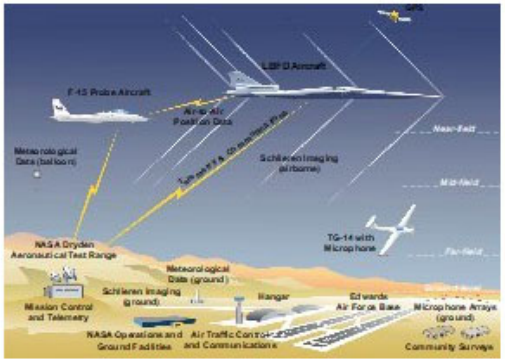
XVS Summary

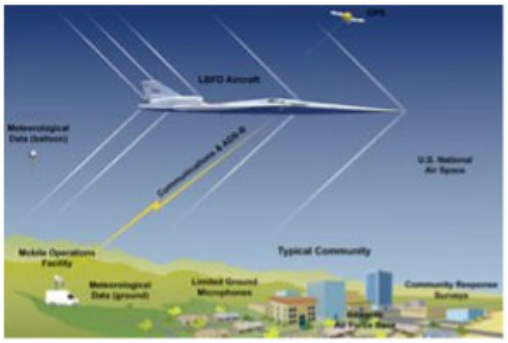
- Surrogate aircraft flight test conducted as a direct comparative evaluation of XVS performance against forward-facing windows.
  - Extremely demanding see-and-avoid maneuvers, challenging, yet operationally relevant flight conditions.
  - Data suggests XVS equal to and in fact, often superior to forward-facing 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
- ***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.

Systematic Approach Leading to Community Testing


LOW-BOOM FLIGHT DEMONSTRATION
X-59
QueSST
NASA