eXternal Vision System (XVS) Development and Testing for X-59 Low Boom Flight Demonstrator

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Overview

- Low Boom Flight Demonstrator Vehicle
- eXternal Visibility System (XVS)
- Flight Test Objectives
- Flight Test Overview
- Results
- Summary

X-59 Low Boom Flight Demonstrator (LBFD) Vehicle

Low Boom Flight Demonstrator Project

- Low Boom Flight Demonstrator (LBFD) Project
  - Part of Integrated Aviation Systems Program (IASP) under NASA's Aeronautics Research Mission Directorate (ARMD)
  - Lockheed-Martin (L-M) under contract to build X-59 aircraft
  - X-59: A shaped sonic boom signature with a calculated loudness level of 75 PLdB (Perceived Level (PL), dB) or less during supersonic cruise (Mach ≥ 1.4) flight
  - Validation of design tools and technologies applicable to low sonic boom aircraft
  - Create a database of community response supporting the development of a noise-based standard for supersonic overland flight

X-59 Low Boom Flight Demonstrator (LBFD) Vehicle

XVS Overview

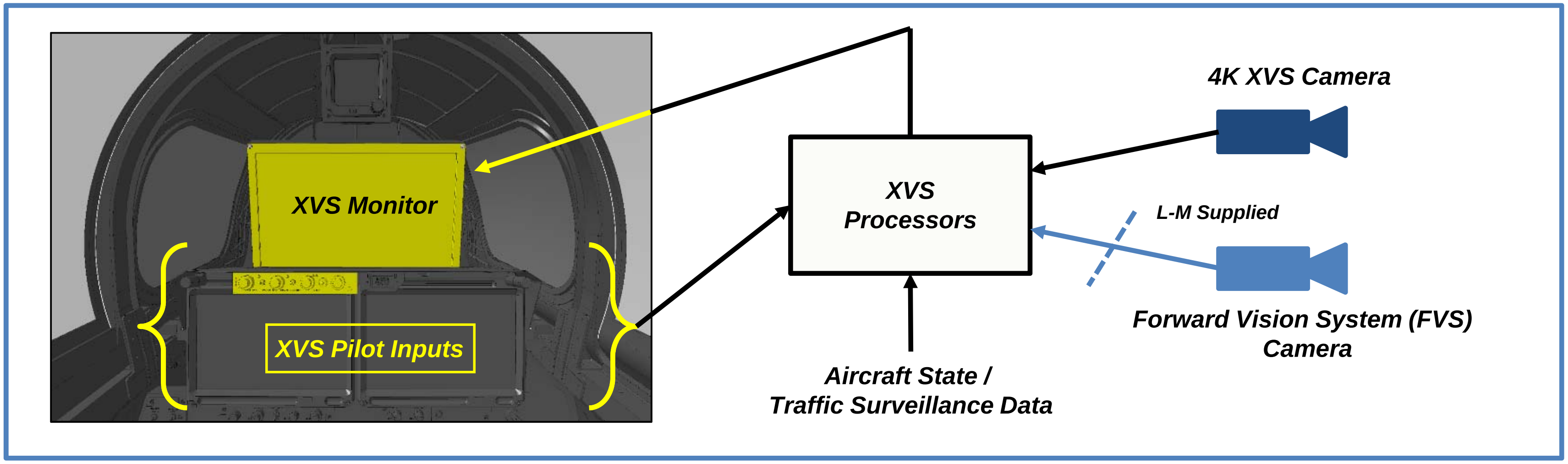
- eXternal Visibility System (XVS)
  - XVS is the combination of sensor, display and computing technologies that provide visibility of the external scene for the flight crew *analogous or equivalent* to forward-facing windows in conventional aircraft
- XVS is being developed by NASA LaRC
  - Government Furnished Equipment to X-59 Aircraft / L-M

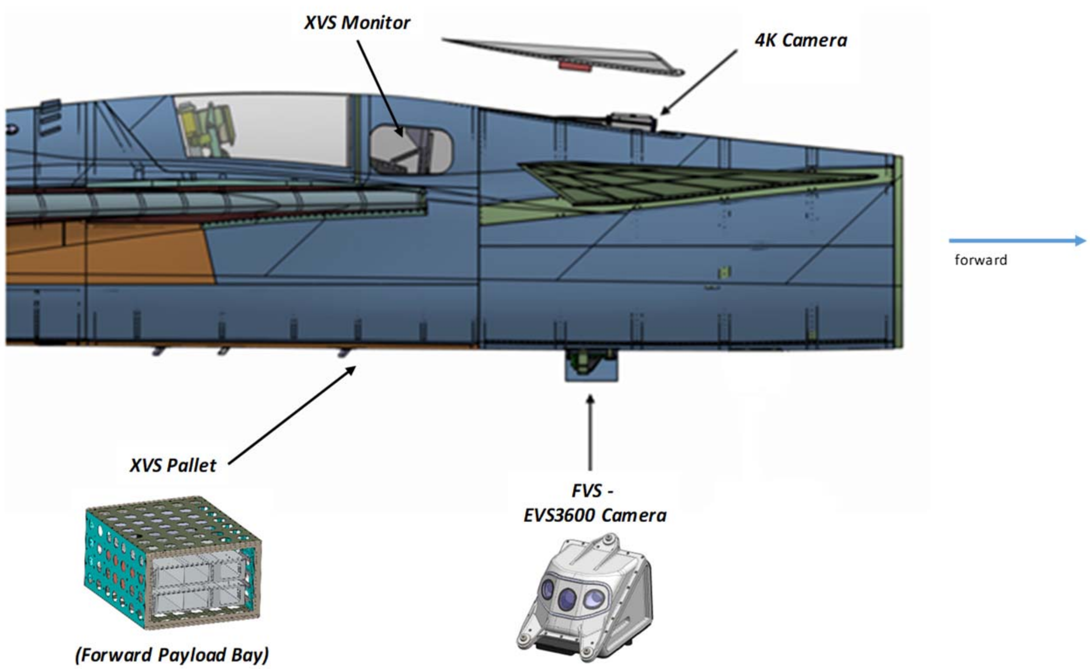
Legacy for Forward-Visibility Challenges

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

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

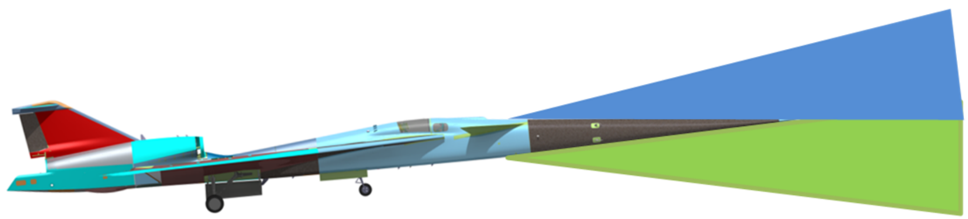
XVS System – "Electronic Window"





Key XVS Attributes

- “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
- Fuselage “fill”
- Low Latency
- Head-Up Display (HUD) symbology
- Traffic awareness
  - Window-equivalence (see-and-avoid)
  - Traffic locator boxes
    - Azimuth / elevation from surveillance data



Surrogate Aircraft Flight Test

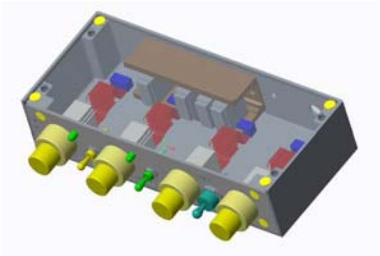
- The primary objective of this flight test
  - Evaluate actual LBFD XVS flight hardware during in-flight operations for “see-and-avoid” and “see-to-follow” operations in visual meteorological conditions.
    - Real-Time Operating System (RTOS)
  - Assist in verifying XVS functionality, usability, and maturity in real-world flight conditions for its use on the Low Boom Flight Demonstrator aircraft (X-59).
    - Replicate X-59-like H/W and S/W to extent practical and possible
- Surrogate Aircraft
  - UC-12 Aircraft (Military Equivalent of Be-200 King Air)
  - Eleven data flights
    - Evaluation Pilots (EPs) from industry, FAA, NASA

Direct Comparative Test: OTW vs. XVS

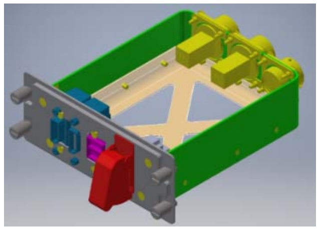
- Two crew stations for test
  - *Right Side Cockpit*: Out-the-window (OTW) observer
  - *Cabin*: XVS evaluation station
  - No piloting duties at either position
- UC-12 Data
  - Data concentrator developed to "mimic" X-59 Vehicle Management Computers (VMCs)

X-59 XVS Prototype Control Panels Installed

XVS Control Panel

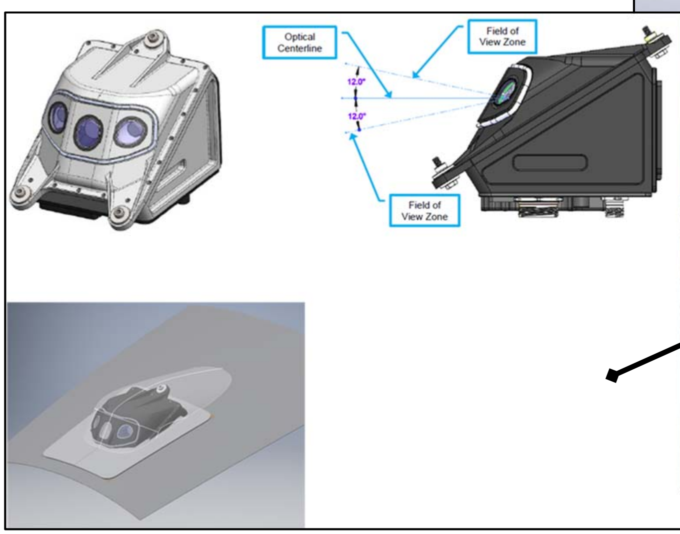


XVS Mx Panel



NASA LaRC UC-12 Camera Installations

- Two cameras installed:
  - a) 4K, Color, Visible band;
  - b) Enhanced Vision System, EVS-3600 – Tri-Band "Forward Vision System"
- No obscuration of their view from UC-12 structure

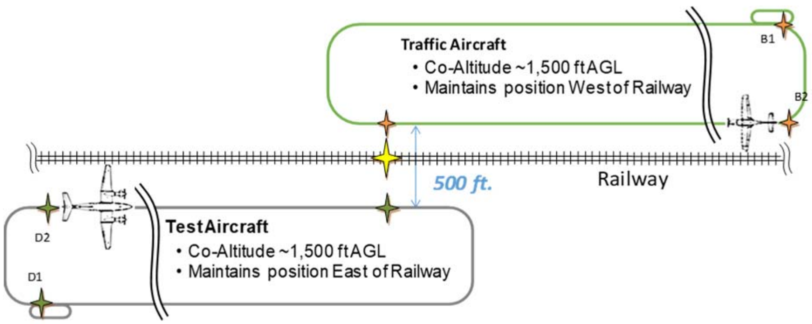


RTOS Flight Test Overview

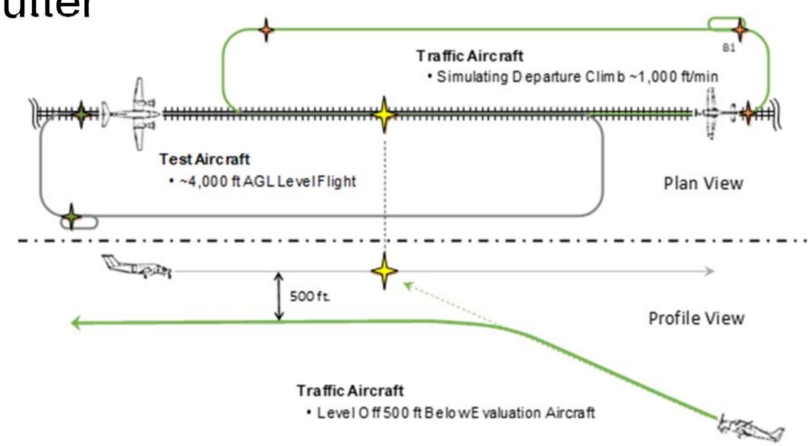
- See-and-avoid flight testing
  - Side-by-side comparative evaluation between forward-facing window (OTW) and XVS
    - *Event marker identified detection*
      - Automatic Dependent Surveillance-Broadcast (ADS-B) derived time/distance of detection
- See-to-Follow demonstration
- Approach and landing demonstration
  - Pilot-Vehicle Interface (PVI) evaluation
- Sensor characterization

See-and-Avoid Flight Test Scenarios

- Constant Altitude Traffic – Expanding Targets
  - Co-Altitude, 500 ft Lateral Offsets
  - +/- 500 ft Altitude differences

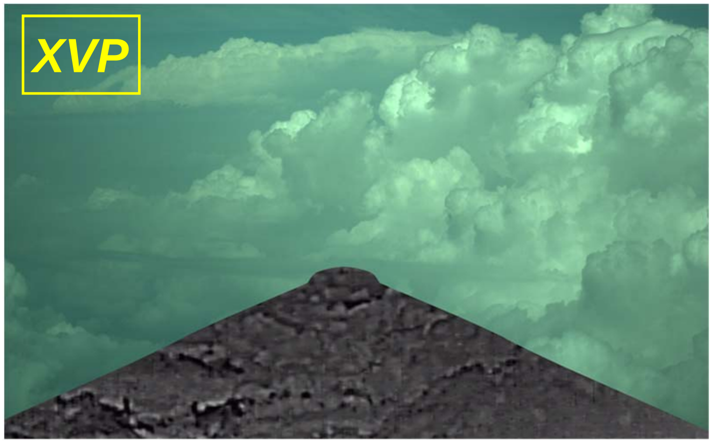


- Climbing Traffic – Expanding Targets
  - Level Test Aircraft
  - Traffic Aircraft climbing from ground clutter
    - o Level off 500 ft below



See-and-Avoid Experiment Design

- The salient points in the experiment design were:
  - No HUD symbology during data runs.
  - Grease pencil marks on OTW windshield
  - 8 runs nominally per flight
    - o 4 see-and-avoid runs per flight with XVS, per Evaluation Pilot (EP).
    - o Two runs with the 4K camera-only condition (per EP) – XV Mode
    - o Two runs with the XVS 4K with FVS fill – XVP Mode
  - The dependent variables were:
    - o Scenario
    - o Viewing configuration
      - XVS configuration – XV
      - XVS configuration – XVP
      - OTW condition.
  - A Likert type survey was administered after each run to each EP as to the difficulty of the scenario.



See-and-Avoid Example

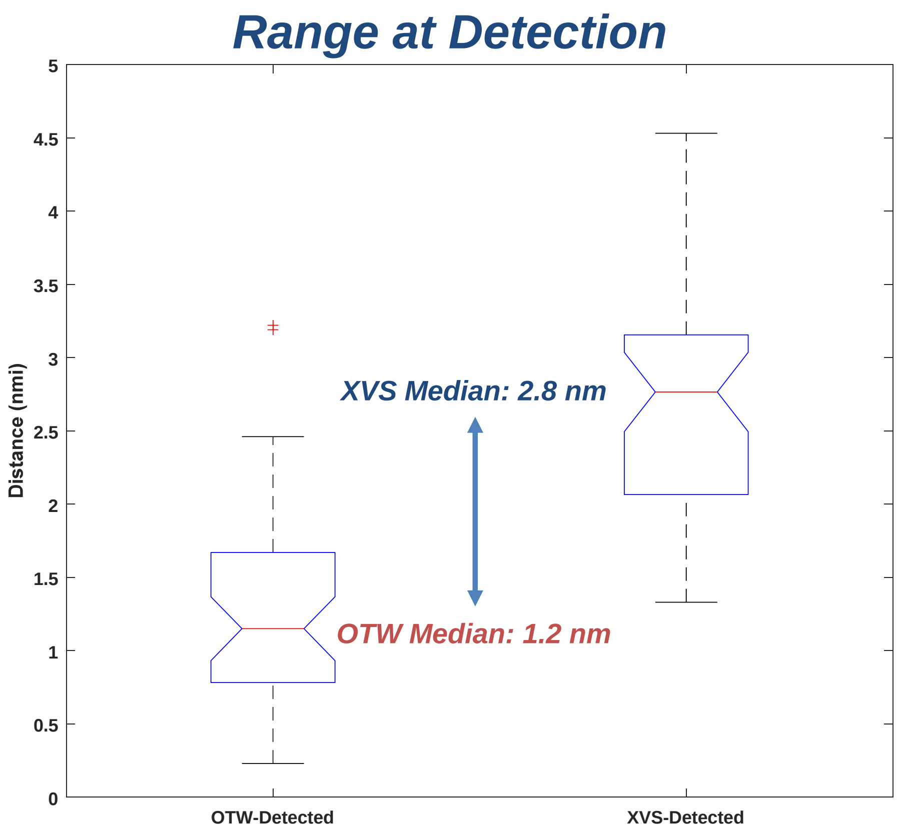
- *Low resolution video (comparatively); High contrast target run*

Traffic Detection – All

- From the 64 see-and-avoid runs:
  - No detection by either subject: 11 runs (17%).
  - Traffic aircraft only detected OTW: 13 runs (20%).
  - Traffic aircraft only detected XVS: 12 runs (19%).
  - Traffic aircraft detected by both: 28 runs (44%).
- Equivalent performance
  - XVS observer detected the traffic aircraft
    40 out of 64 runs (~63% detection rate)
  - OTW observer detected the traffic aircraft
    41 of 64 total runs (~64% detection rate).
- No impact of XVS configurations:
  - Twenty-one (21) of the 41 XVS detections made with XV configuration
  - Twenty (20) of the 41 XVS detections made using the combined 4K and FVS image,
    - Analogous to the nominal X-59 planned XVS mode.

Range at Traffic Detection – All

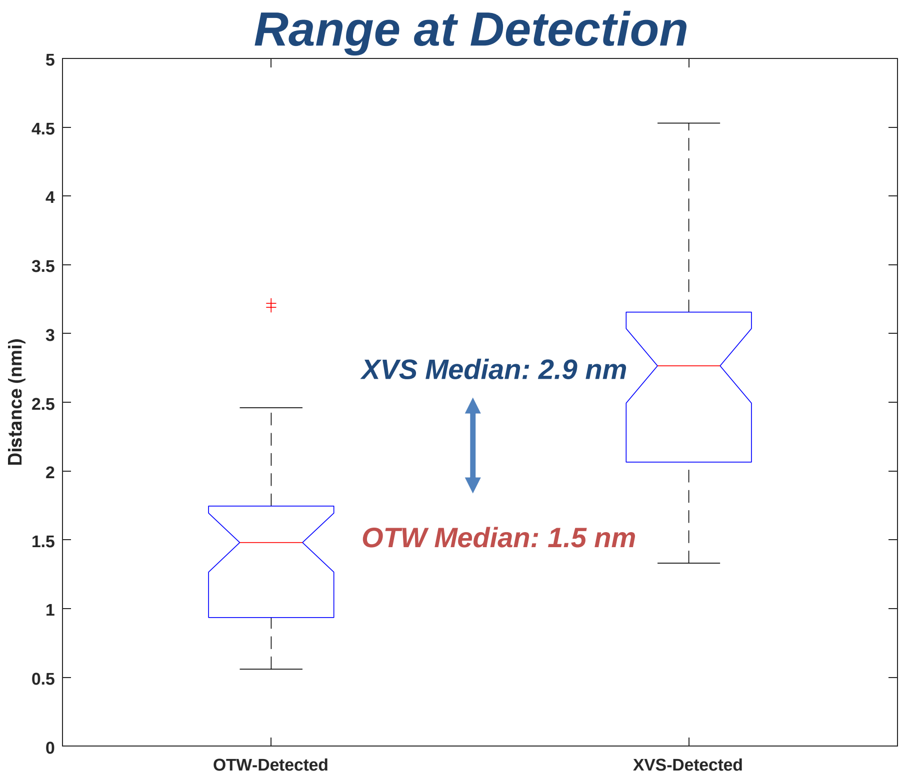
- The range at traffic detection was significantly better using XVS than OTW
- Performance of XVS unaffected by scenario
  - OTW observer had difficulty with detection in ground clutter
  - OTW observer detected all co-altitude scenarios

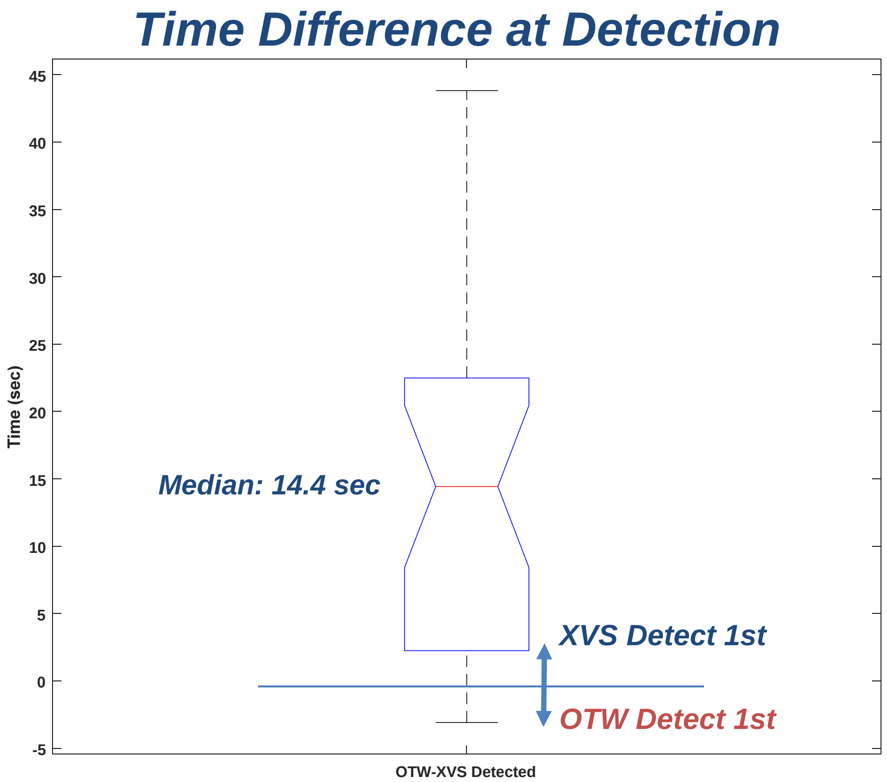


Vertical Offset	*Total*	*XVS Detection*	*OTW Detection*
High	16	9	9
None	16	11	16
Low	17	11	11
Climbing	15	9	5

Distance and time for same run

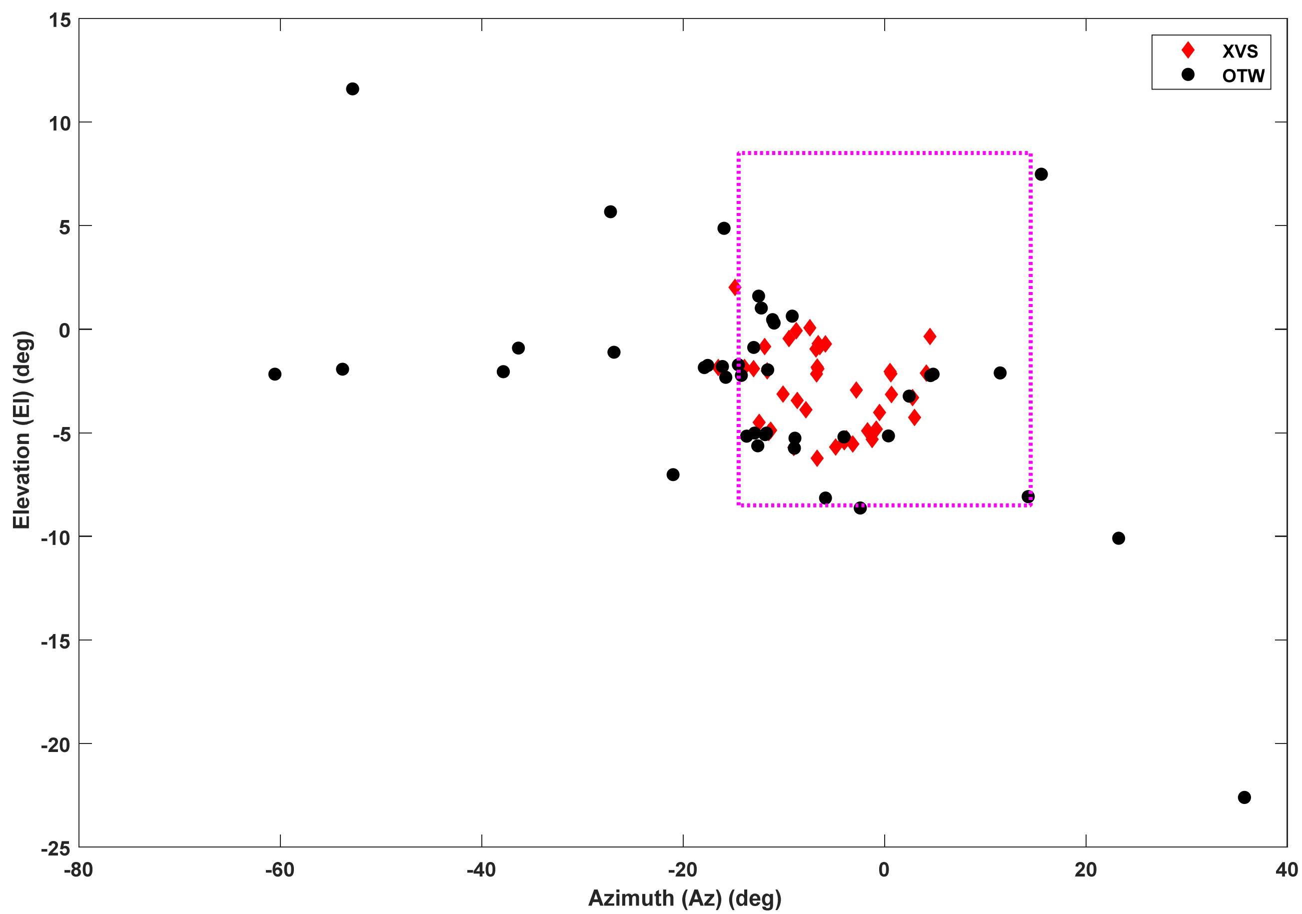
- On 28 runs, both XVS and OTW subject detected traffic aircraft
- Range when detected was significantly greater using XVS than OTW
- 50% of XVS detections happened >14.4 second before OTW observer





Location in Visual Field at Detection

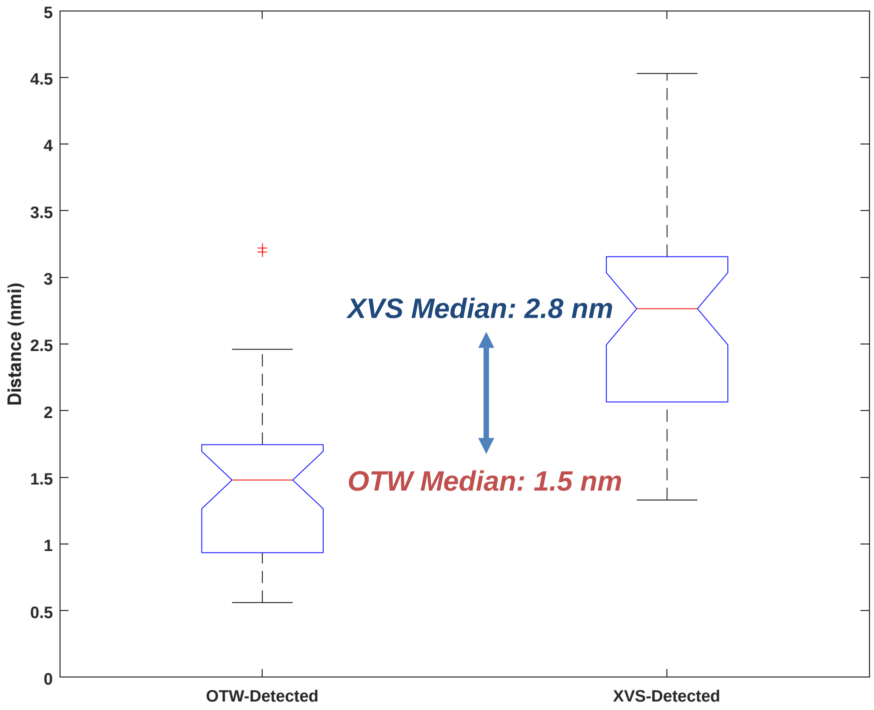
- The azimuth & elevation position of traffic shows numerous detections by OTW observer outside XVS field-of-regard
  - Grease pencil outline



Detections – within FOV

- Traffic detections greater than 30 degrees in azimuth removed.
  - Latency in event marker activation
- Minor effect on range difference for detections
- The bigger effect is that the number of detections significantly changes.
- Of the 64 runs:
  - 40 detections XVS
  - 35 detections OTW
- Data suggests significant advantage of XVS over OTW in a see-and-avoid operation
  - Increased range
  - Increased probability of detections.

Range at Detection



Summary

- See-to-avoid is very difficult, visually challenging task
  - "Against a small GA representative aircraft under the environmental condition in which we tested, the target (aircraft) was almost impossible to see out the cockpit window but was almost always detected on the XVS display at 3-4 miles range"
  - "Without target cueing, XVS is better than eyeballs but still inadequate for see-and-avoid"
    - however, "with target cueing, XVS is way better than eyeballs and *adequate* for see-and-avoid."

Concluding Remarks

- A 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.
  – Eleven (11) data flights totaling 21 flight hours using industry, NASA, and FAA pilots.
- Data suggests XVS equal to and in fact, often superior to forward-facing windows
  – The XVS pilot detected traffic, on average, at 1.4 nmi before OTW observer.
  – Distance translates to approximately 15 seconds more time
  – Traffic detection rates by the XVS subject pilot were the same, if not superior to the OTW subject pilot.
- 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.

Questions?

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