XVS for the LBFD

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Low Boom Flight Demonstrator (LBFD)

- 1/3 Scale single-pilot demonstrator
- No forward facing windows
- XVS technology required
- First flight: 4Q/2020 (If approved by OMB, NASA HQ)
High-Level System Requirements

Overall System Objective: Use a combination of sensor, computing, and display technologies to provide an equivalent level of safety and performance as provided by the forward-facing windows in standard aircraft.

Forward-facing Window Functionality:
- Aircraft take-off and departure
- Land aircraft and taxi safely
- See-to-Follow
- See-and-Avoid

Forward-Facing Visibility

![Diagram showing Forward-Facing Visibility](image-url)
Forward-Facing Acuity

Requirements:

• 20/20 Snellen acuity requires a minimum of 60 pixels/degree (ppd). More than adequate for taxi, departure, and landing.
  
  *Rationale:* 20/20 letter (“E”) -> 2 arc min per cycle -> 2 pixels per cycle -> 60 arc min per degree -> 60 pixels per degree (ppd)

• See-and-Avoid detection requires a minimum 72 ppd
  
  *Rationale:* Detection time of 12.5 seconds (AC90-48C) at closure rate 578 knots (true) with 3 cycles needed for recognition of a small (C-172) size aircraft.

• See-to-Follow recognition requires 69 – 140 ppd
  
  *Rationale:* Small (C-172) sized aircraft at 3-miles. Large (B-757) sized aircraft at 5-miles.
High-Level System Requirements (cont.)

Forward-Facing Acuity: Other Factors

- **Sensor Performance**
  - Resolution
  - Field-of-View
  - Sensitivity
  - Noise
  - Output/Input Transformation

- **Display / Monitor**
  - Resolution
  - Luminance
  - Contrast
  - Distance from DERP
  - Window Glare
    - Is a top window needed?
    - Glare shield might be required.

- **Scene Content**
  - Target Characteristics
  - Background Characteristics
  - Lighting
  - Motion
  - Clutter

- **Atmospheric Transmittance**
  - Haze
  - Fog
  - Rain
  - Dust
  - Clouds
  - Etc.
Background: HSR XVS Legacy

Circa 1998

- Big and Heavy
- Mechanically Complicated
- Power Hungry
Background: 2012 Flight Test

- Small and Light
- Mechanically Uncomplicated
- High Performance
Background: 2012 Flight Test (cont.)

- **Camera Assembly**
  - Cameras mounted in portrait orientation
  - Aligned to maximize horizontal FOV
  - Zero image overlap with 63 ppd

- **Monitor Assembly**
  - 3 – HD LCD laptop monitors in portrait
  - Configured to match camera angles
Background: 2012 Flight Test (cont.)

- One NASA Crew (Pilot)
- Two Research Subjects (1 Visual Out-The-Window, 1 XVS)
- Two Researchers
Background: 2012 Flight Test (cont.)

**Cockpit – Glare Shield**
- HD Cameras (3)

**Cabin – Racks**
- Triple LCD Display
- Recorders (3)
- Image Mixers (3)
- Display Computer

**Cabin – Workstation**
- Operators Console/Laptop
- Keyboard/mouse

**Simplified Block Diagram**

Aircraft State Data
RS232
ADS-B In
RS232
Background: 2012 Flight Test (cont.)

XVS Display Installed in Aircraft
Background: 2012 Flight Test Snapshots

XVS Camera/Symbology Images
Cameras set to different resolutions for comparison
Background: 2012 Flight Test Snapshots

Traffic: B-200 11 O’Clock 1 mile
Background: 2012 Flight Test Snapshots

B-200
Co-altitude head-on at 1.5 nm

B-200
Climbing out of ground clutter at 1.0 nm
System Description: 2015 Components

- **Emergent HS-12000**
  - 4K UHD Resolution
  - 84 fps max frame rate
  - 350 grams
  - 176mm x 50mm x 50mm

- **NEC 24” UHD – EA244UHD-BK**
  - 4K UHD Resolution
  - 60 fps
  - LED Backlit LCD Panel
  - 22.0” x 13.2” x 2.8”
System Description: 2015 Components (cont.)

- EmbeddedLine EL1082
- Intel® Core™ i7-3610QE (4 × 2.3 GHz)
- 8 GB Ram
- 250GB Hard Drive
- 260 x 200 x 89 mm

- RGB Spectrum SuperView
- 4K Multiviewer/Mixer
- 4K UHD Resolution
- 60 fps
- 17” x 18” x 3.5”
- Candidate for custom hardware development
System Description: Nominal Operation

UHD: 3840x2160  HD: 1920x1080

CCU = Camera Control Unit
System Description: Primary Cameras Fail

Primary Cameras Fail

Mixer

Symbology Generator
- MS-1787c HUD
- Traffic Designators

Switch1

RTVIS

Switch2

Up Convert to UHD

Down Convert to HD

A/C State Data

Surveillance Data (ADS-B, TCAS)

Pilot Interface: Display Control

Real Time Video Image Stabilizer

UHD XVS Display
24” diagonal
53 degrees H, 31 degrees V
36 pixels/degree

Switch3

Pilot Interface: Symbology Control

HD: 1920x1080

UHD: 3840x2160

CCU = Camera Control Unit

Imagery good enough to land. But, not good enough to self-separate.

HD

Backup Mounted on belly under pilot station

RTVIS

Imagery good enough to land. But, not good enough to self-separate.

HD

Pilot over-shoulder

Switch1

Switch2

Downlink

IFR?
System Description: Mixer Fail

**UHD**: 3840x2160  
**HD**: 1920x1080

CCU = Camera Control Unit

- **Switch1**: UHD → CCU → Switch1 → RTVIS
- **Switch2**: RTVIS → Switch2
- **Switch3**: Switch3
- **Real Time Video Image Stabilizer**: RTVIS

**Symbology Generator**:
- MS-1787c HUD
- Traffic Designators
- Synthetic Vision

**Display Control**: UHD XVS Display
- 24” diagonal
- 53 degrees H, 31 degrees V
- 73 pixels/degree

**Camera Control**
- Mounted in or under nose
- Heated Window

**Pilot Interface: Camera Control**
- Switch2 used by pilot to select either imagery, symbology, or symbology plus synthetic vision.
- Switch2 used by pilot
- Switch2
- Switch3
- HD
- Pilot over-shoulder

**Downlink**

**Surveillance Data (ADS-B, TCAS)**

**A/C State Data**

**Camera Control Unit (CCU)**

**Pilot Interface: Display Control**
System Description: Symbol Generator Fail

- **UHD**: 3840x2160
- **HD**: 1920x1080
- **CCU**: Camera Control Unit

Components:
- **UHD**
- **CCU**
- **RTVIS** (Real Time Video Image Stabilizer)
- **Switch1**
- **Switch2**
- **Switch3**
- **UHD XVS Display**
- **Downlink**
- **Heated Window**
- **Pilot Interface: Camera Control**
- **Pilot Interface: Display Control**

Flow of Signals:
- UHD data goes through CCU and then to Switch1.
- Switch1 sends data to RTVIS, which stabilizes the video.
- Switch2 determines whether the signal goes to HD or downlink.
- HD signal sends data to Switch3 and then to the Downlink.
- Pilot over-shoulder signal goes through Switch3 and connects to the Downlink.

Dimensions:
- **UHD XVS Display**: 24” diagonal, 53 degrees H, 31 degrees V, 73 pixels/degree.
System Description: All Cameras Fail

- **Symbology Generator**
  - MS-1787c HUD
  - Traffic Designators
  - Synthetic Vision

- **Pilot Interface: Symbology Control**

- **Pilot Interface: Display Control**

- **UHD XVS Display**
  - 24" diagonal
  - 53 degrees H, 31 degrees V
  - 73 pixels/degree

- **A/C State Data**

- **Surveillance Data (ADS-B, TCAS)**

- **Downlink**

- **HD**

- **Pilot over-shoulder**

- **Switch2**

- **Switch3**

**Specifications:**
- **UHD:** 3840x2160
- **HD:** 1920x1080

**CCU = Camera Control Unit**
System Description: XVS Display Fail

**System Description: XVS Display Fail**

- **UHD:** 3840x2160
- **HD:** 1920x1080

**CCU = Camera Control Unit**

**Symbology Generator**
- MS-1787c HUD
- Traffic Designators

**Backup Display (HD)**

**Pilot Interface:**
- Camera Control
- Symbology Control

**Switches:**
- Switch 1
- Switch 2
- Switch 3
- Switch 4

**HD**

**Downlink**

**A/C State Data**

**Surveillance Data (ADS-B, TCAS)**

**IFR**

**Real Time Video Image Stabilizer**

**Mounted in or under nose**

**Heated Window**

**Switches**:
- Switch 4
- Switch 3

**PILOT INTERFACE**

**HD**

**Backup Display (HD)**

**Existing Multi-Function or separate dedicated display?**

**Pilot over-shoulder**

**UHD: 3840x2160**

**HD: 1920x1080**

**CCU = Camera Control Unit**
System Description: Night Operation

- UHD: 3840x2160
- HD: 1920x1080
- CCU = Camera Control Unit

Night operation uses Night mixing algorithms to blend synthetic vision imagery with high-contrast lights seen by the camera system.

- UHD: 3840x2160
- HD: 1920x1080

CCU = Camera Control Unit