



Digital HUD Enhanced Flight Vision System (EFVS) and Synthetic Vision System

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Introductions – Lockheed Martin/Collins

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Agenda

- Aerospace Vision Systems Experience and Benefits
- Overview of Digital Heads-Up Display (DHUD) System including Enhanced Vision Systems (EVS) changes
- Overview of EVS-3600 Sensor
- Developments to Date Including Risk Mitigations
- Anticipated C-130J Modifications
- Current Status
- Demonstration Efforts
- Next Steps Going Forward
- Advancements (Roadmaps)



Collins Experience with Vision Systems

- Collins has been in the business of developing, integrating and certifying Vision Systems for years
- With the evolution of the current Production DHUD and benefits from the Commercial 737 aircraft, Collins sees the risk of implementing EVS onto the C-130J, a low-risk effort
- Our off-the-shelf EVS-3600 Enhanced Vision Sensor has been approved to provide real-time IR Imagery, which can be displayed for pilot awareness
- Commercial aircraft have achieved Civil Certification (CFR 91.176)



Collins Aerospace is the Leading Vision System Provider for Enhanced Vision Capabilities

EFVS/EVS Positions and Experience



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Collins HUD

- Gulfstream fleet
- Boeing 757, 767, 777 (FedEx)
- Bombardier Global 5000/6000
- Bombardier Challenger 605
- Boeing BBJ
- Dassault Falcon 900
- Dassault Falcon 2000
- Dassault Falcon 7X
- Embraer E1 / Lineage 1000
- C-130J*

Collins HUD & Collins Sensor

- Bombardier Global 5500/6500
- Bombardier Global 7500/8000
- Bombardier Challenger 350
- Embraer Praetor 500/600
- CASA C-295 *
- Boeing 737 NG & 737 MAX
- EC-130J*
- French C-130H (EVS/HDD)*

Collins Sensor

- Airbus A320
- Airbus A350
- Lockheed Martin X-59 QueSST*
- Beechcraft King Air*



*Military, Experimental or Safety of Flight Certified Installations

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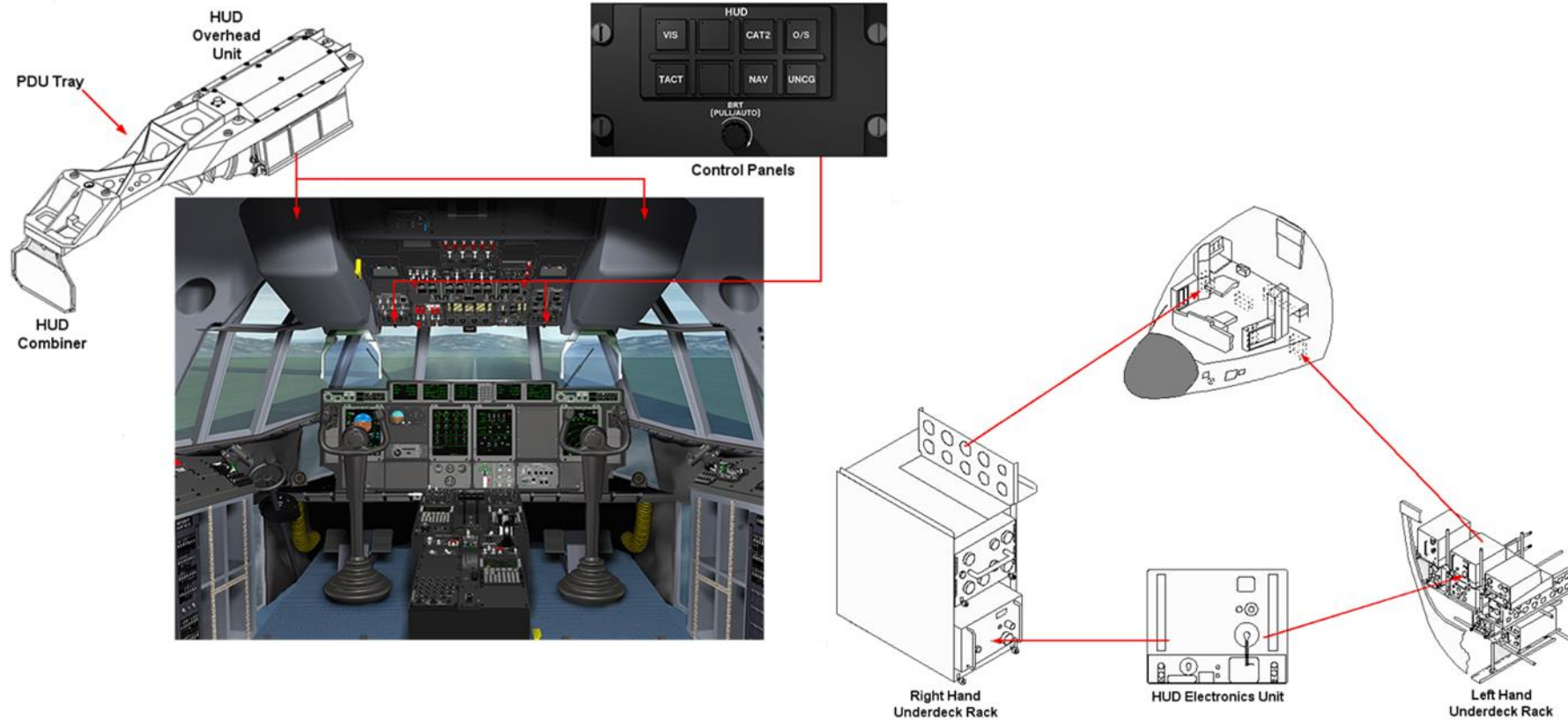
Vision System Benefits

- **Safety and Situational Awareness** – Greater safety awareness while flying in reduced visibility conditions
- **Night-time Enhancements** – Enhances runway, terrain and obstacles even in adverse conditions
- **Firefighting** – Increased margin of safety during transitional periods increased awareness of traffic conflicts in fire traffic area, possible expanded operational hours
- **Improved Approach and Landing** – Improves operational effectiveness while landing in low ceiling and visibility CAT I airfields and mission-essential austere fields
- **Search and Rescue (SAR)** – Capabilities enhance SAR operations in varying environments, sea and land-based search efforts



Adding Real-Time Imagery to the HUD Will Greatly Improve Situational Awareness and Safety

HUD System LRUs



Line Replaceable Unit (LRU) Installation Locations

Digital HUD System LRU Changes



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HUD Component	Existing Configuration	Proposed Configuration	
Combiner	Model 3000 697940-3	Existing C-130J HUD Combiner with modified optical coating to accommodate for change in light source (Light Emitting Diode (LED) versus Cathode Ray Tube (CRT)) to maintain Night Vision Infrared System (NVIS) and lighting performance. Ambient Light Sensor (ALS) and Combiner Alignment Detection (CAD) circuitry modified to accommodate change in light source.	Model 6500 697940-29
Overhead Unit (OHU)	Model 3000 697940-1	New based on Rockwell Collins Model 6000 Digital HUD System with packaging adapted for C-130J installation. Slight change in overall envelope from Model 3000 with no impacts to installation or maintenance.	Model 6500 697940-27
HUD Control Panel (HCP)	Model 3000 697940-11	New as a result of obsolete parts. Form, fit and functionally equivalent to Model 3000 HCP.	Model 6500 697940-31
HUD Electronic Unit (HEU)	Model 4500 697940-19/25	New, a Rockwell Collins Model 6000 Digital HUD System modified with a MIL-STD-1553B interface and packaged for C-130J installation. Includes re-hosted Model 4500 application software modified using DO-178C Level A.	Model 6500 697940-33
HEU to OHU Cabling	Copper wiring	A fiber optic cable for digital ARINC 818 video signals will be added in addition to the existing discrete signal wiring (aircraft change).	
LRU Trays	PDU Tray (697940-5) HEU Tray (697940-9)	No change. The existing HEU Tray and Pilot Display Unit (PDU) Tray for the OHU and Combiner are forward-compatible with the Digital HUD System.	

M6500 Digital HUD System Changes

Digital HUD And EFVS Overview



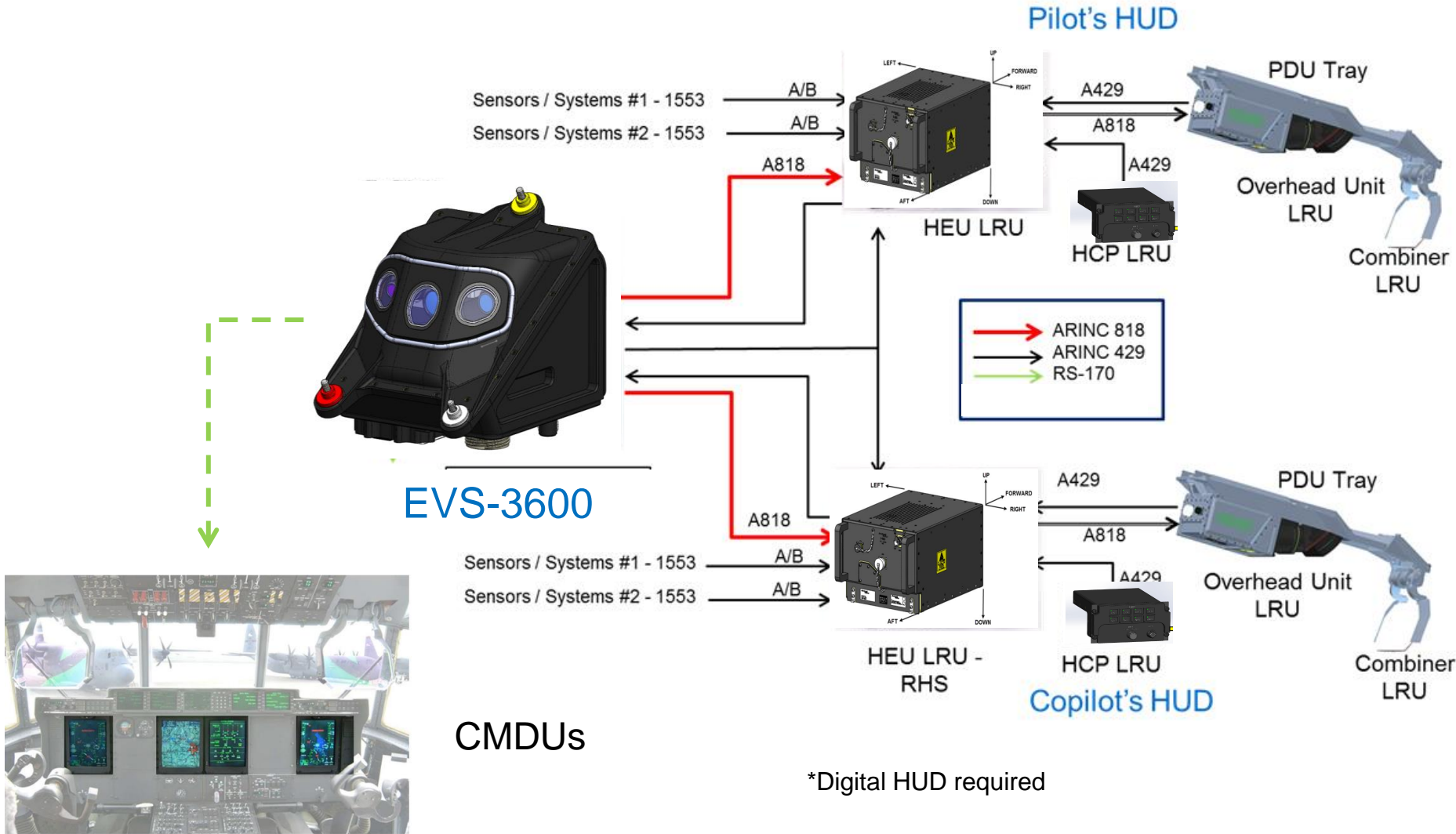
Digital HUD M6500 System

- Obsolescence Replacement for Legacy Analog HUD M3000/4500
 - Improves reliability and replaces obsolete parts
 - Requires additional fiber optic cable between HEU and OHU to carry digital video
 - Digital HUD fiber optic kits are available from Lockheed Martin to retrofit fielded aircraft
 - The Digital HUD allows for additional video capabilities and is not limited by draw time
 - Digital HUDs are installed on new production C-130Js and preferred spare replacement for Legacy HUD Systems

Enhanced Flight Vision System (EFVS): EVS-3600 Sensor

- Only compatible with Digital HUD System
- EVS-3600 is a multispectral infrared camera system that improves the pilot's situational awareness during low visibility environments, i.e., night time, fog, smoke, dust, rain, etc.

HUD/EFVS System Block Diagram

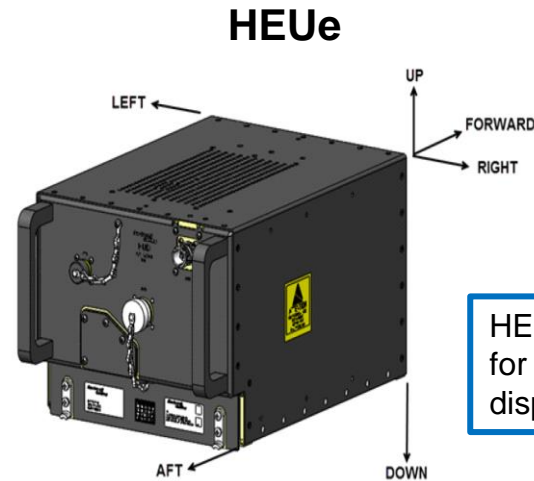


Digital HUD Changes for EFVS

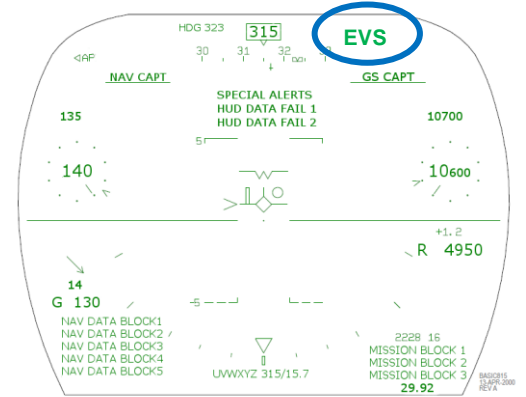
- Digital HUD – 4 LRU System
 - Overhead Unit (OHU)
 - Combiner (CMB)
 - HUD Electronic Unit (HEU)
 - HUD Control Panel (HCP)
- Provides Primary Flight Reference (PFR) information to the pilot and is a Primary Flight Display (PFD) on the C-130J
- EVS Capability Updates
 - HEU Software (S/W) update to HEU with EFVS enabled (HEUe) for Displaying EFVS/EFVS sensor alignment status
 - This S/W build has already been developed per DO-178C Design Assurance Level (DAL) A
 - HCP change to HUD Control Panel with EFVS (HCPe) for EFVS functions
 - Add buttons to activate the EFVS image and reset the EFVS sensor
 - Add knob to adjust contrast between HUD symbology and EFVS image



HCPe includes an EFVS bright-dim control

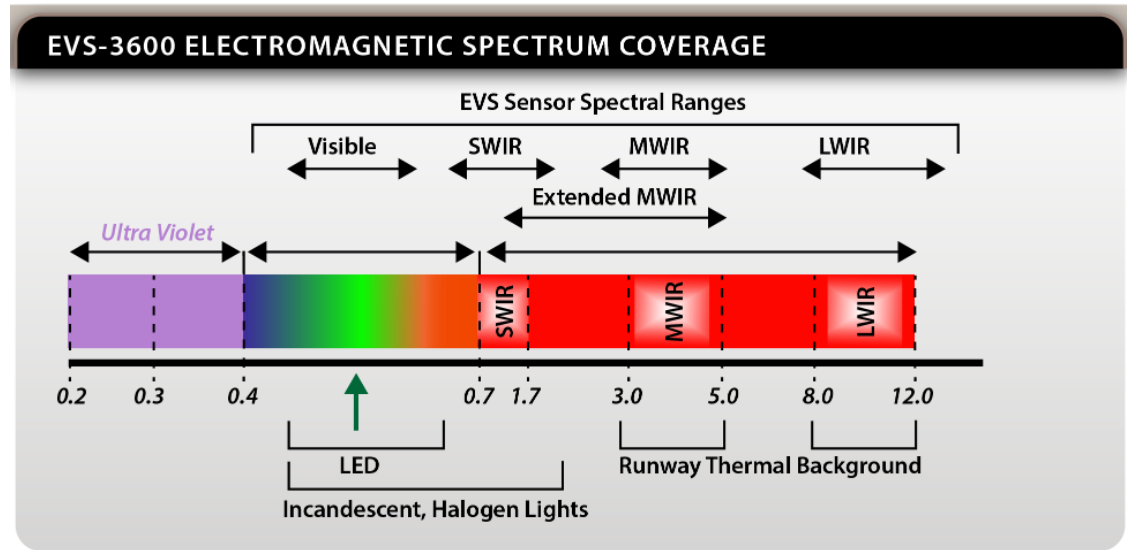
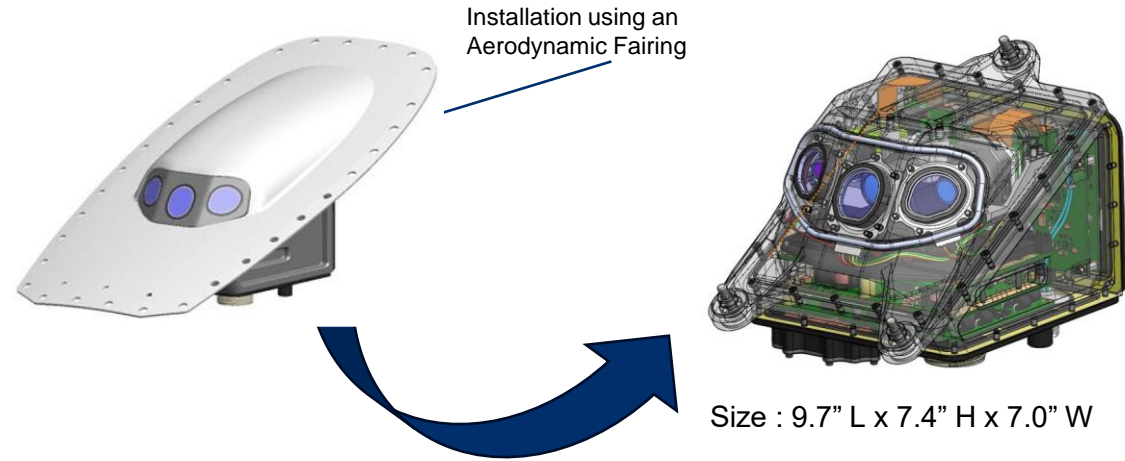


HEUe S/W load for EVS-enabled display on HUD



Off-the-Shelf EFVS Sensor (EVS3600)

- EVS provides a thermal image of real-world scene in video format
- Contains 3 sensors
 - Long Wave Infrared (LWIR)
 - Short Wave Infrared (SWIR)
 - Visual (VIS)
- Image Processing + Fusion allows automatic adjusting of gains for each sensor to provide the optimal image on the HUD



Development and Mitigations

- December 2020 – Lockheed Martin/Collins risk mitigation in Lockheed Martin Simulation Integration Laboratory (SIL) with Engineering S/W build and modified hardware
- August 2021 – Collins demonstrated DHUD and EFVS on EC-130J; Final report was "Transition EVS to Rapid Fielding"
- March 2022 – Collins successful lobbying to mature DHUD/EVS for C-130J firefighting demonstration; On contract with USAF
- October 2023 – Efforts to demonstrate DHUD/EVS in for increasing margins of safety and expanding operations for firefighting; Flight testing late October
- 2024 – Start of production and retrofit efforts for DHUD/EVS kit proofing



Adding Real-Time Imagery to the HUD will greatly improve Situational Awareness and Safety

Demonstration Results

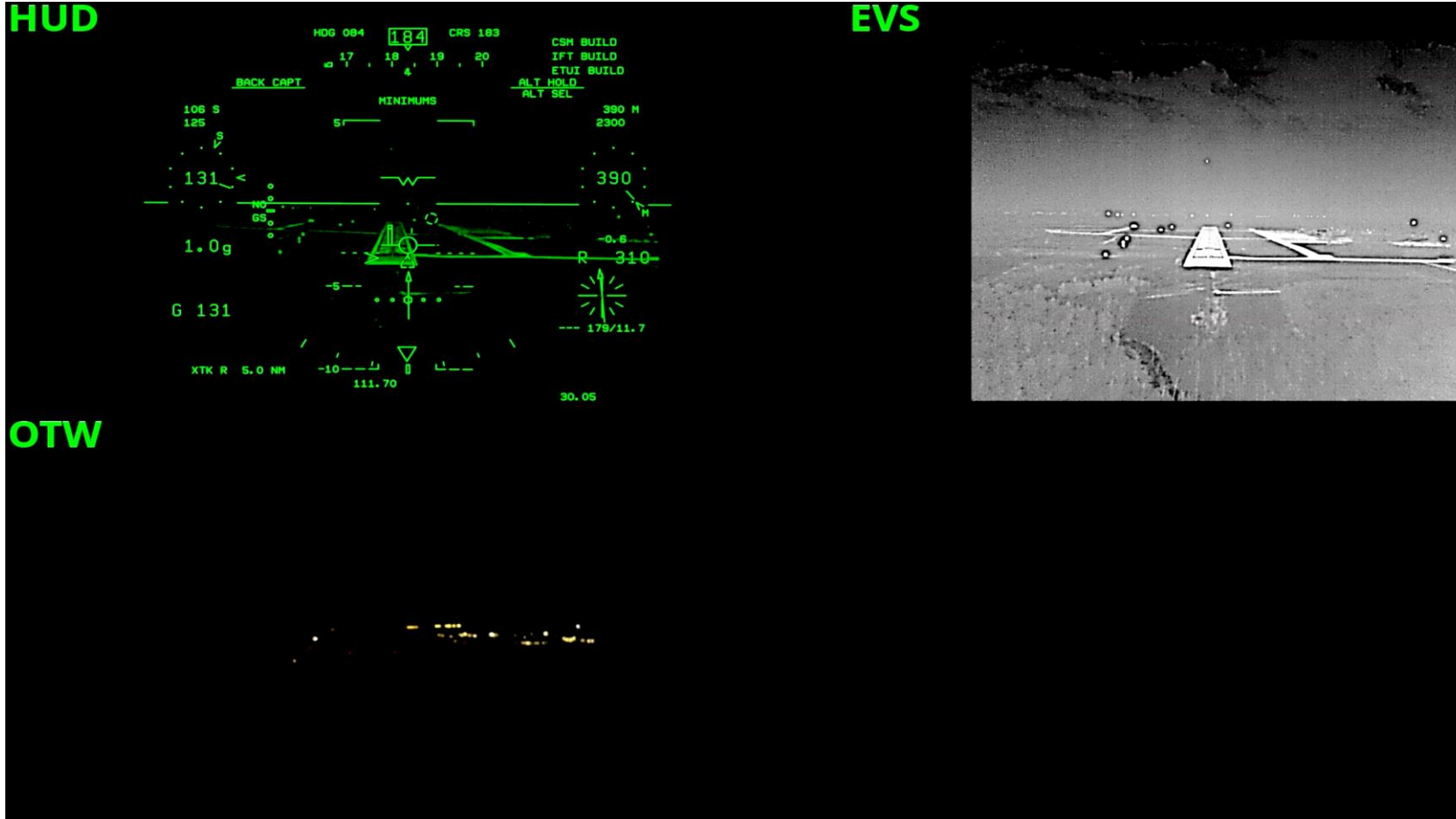
Approaches/Low Level



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HUD

EVS



OTW

Similar results can be observed during daytime adverse weather conditions.

Adds Improved Night-Time Situational Awareness and Safety

Notional C-130J Modifications

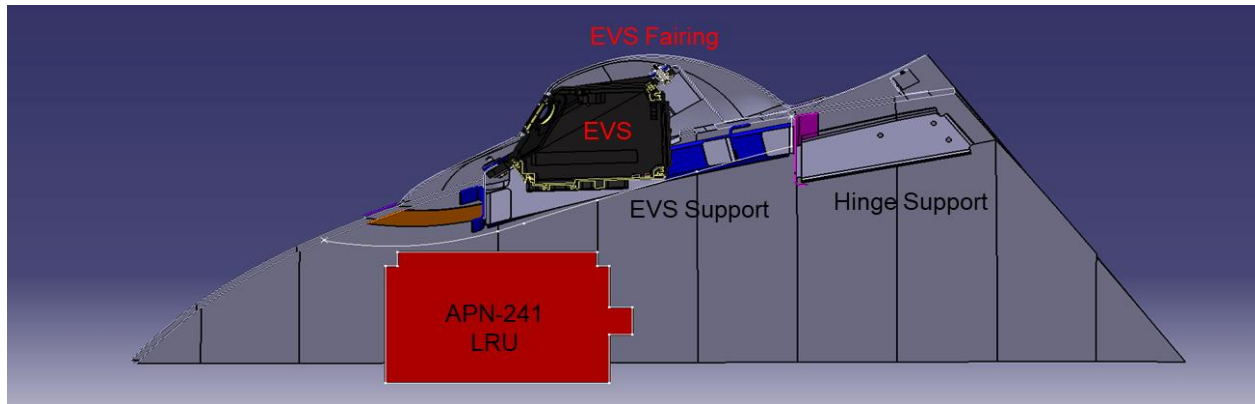
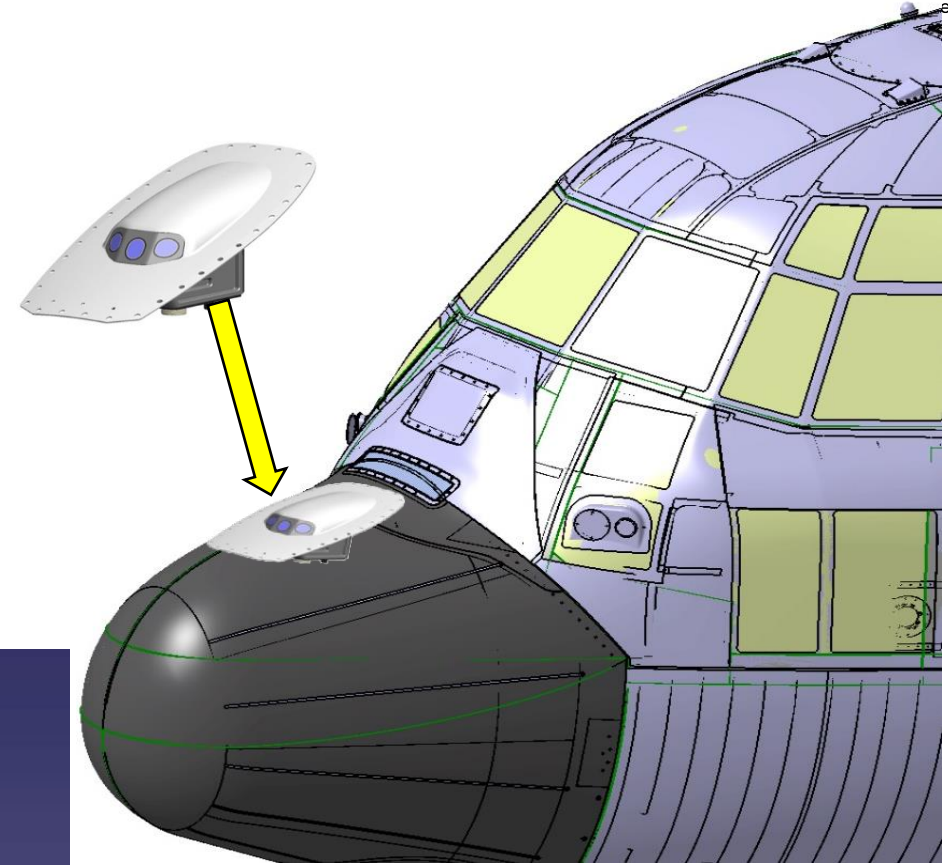
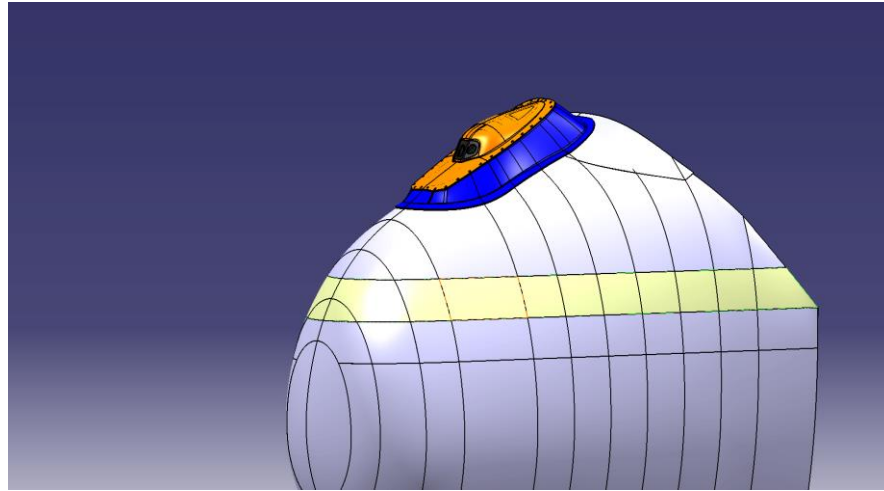


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EFVS Sensor Installation Design Concept

- Modified radome with EVS sensor
 - Remove and replace with existing 50JG procedure
- Current design concept is to modify the radome for installation



C-130J Modification Impact Summary for Digital HUD & EFVS

Upgrade from M3000/M4500 CRT HUD System to M6500 Digital HUD System

- Includes aircraft change for fiber optic cable routing between HEU and OHU

Digital HUD HEU SW development for EFVS implementation per DO-178C

Additional ARINC-429 wiring between pilot and copilot HEUs for cross-side communication

M6500 HCP redesign to add new EFVS buttons and brightness knob (HCPe)

EVS-3600 sensor installation

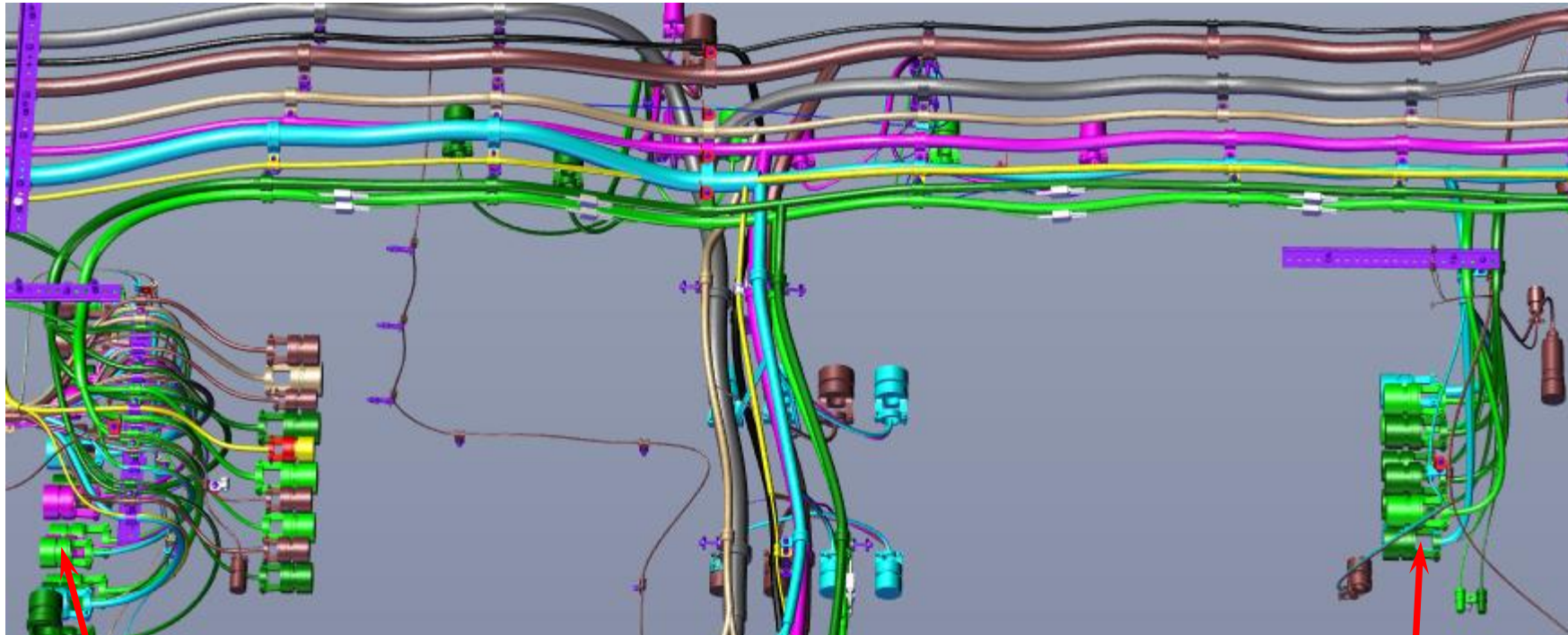
- Wiring for power, ARINC-429 communication, and ARINC-818 Fiber Optic Video
- Structural modifications to the existing Radome (conceptual design)

Minor Mission Computer (MC) Operational Flight Program (OFP) Impacts

- Additional 1553 commands for EFVS ACAWS/FD messages

Cross-Side ARINC 429 HEU Bus

- Underfloor Interconnect 16MJ101



LH Disconnect
15MA001

**Category 6 Are In Green
(View Looking Forward)**

RH Disconnect
14MA001

EFVS Current Status



- Past Actions:
 - Developed and is delivering Digital HUD Systems for production C-130J aircraft
 - Developed demonstration concept to interface EFVS video onto the Digital HUD (D-HUD) system
 - Successfully performed SIL demonstration in Integration Lab for C-130J (mitigate risk of MC OFP impacts)
 - Successful demonstration of D-HUD/EVS in flight on EC-130J and obtained video
- Actions in work:
 - An extended demonstration of HUD/EVS on C-130J – support firefighting season
 - Flight demo scheduled for October 27, 2023
 - Working to pursue a funded Phase 0 Study to mitigate installation and certification risks

Proposed Phase 0 Study Tasks



- Verify compatibility with EVS on Color Multi-Functional Display Unit (CMDU) (via RS-170)
 - Lab demo
- Environmental/Electro-Magnetic Interference (EMI) gap analysis on EVS-3600 sensor and HCPe
- Computational Fluid Dynamics (CFD) analysis on EVS-3600 sensor installation for air data and Reduced Vertical Separation Minima (RVSM) considerations
- Determine radome qualification impacts
- Develop suggested Modification Airworthiness Certification Criteria (MACC) and Communication, Navigation, and Surveillance - Air Traffic Management (CNS-ATM) certification criteria for airworthiness
- EVS-3600 Sensor installation and wiring concept
- EVS-compatible HCP
 - HCPe with new EVS knobs or touchscreen panel for future Synthetic Vision System (SVS) capability?
- Study Transmittivity Impacts to the Radome

EFVS Flight Demo Images (Approach)



HUD



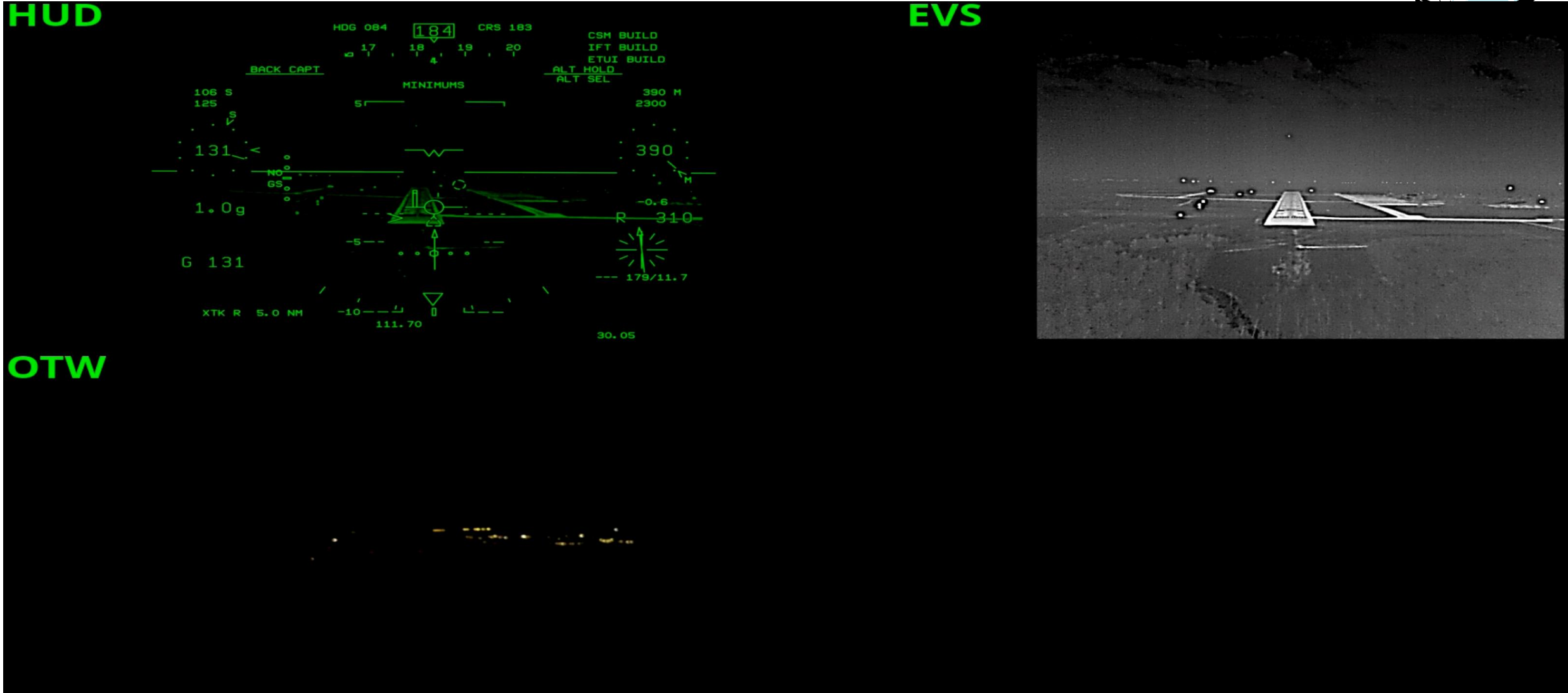
EVS



OTW



DHUD/EFVS Out The Window View vs. EFVS Image



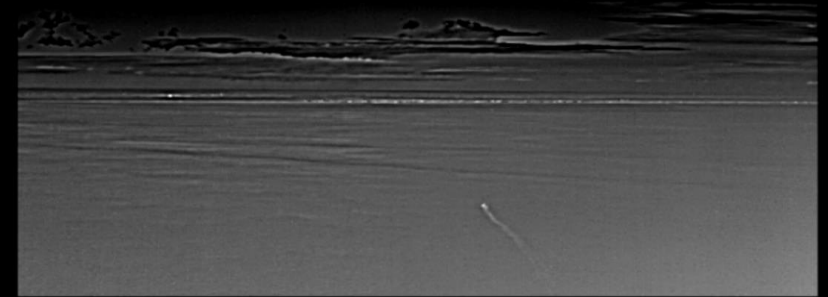
EFVS Flight Demo Images (Search and Rescue)



HUD



EVS



OTW



EFVS Flight Demo Images (Heavy Rain)



HUD



EVS



OTW



EFVS Flight Demo Images (Aerial Refueling)



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HUD



EVS



Future EFVS efforts



- Lockheed Martin/Collins to pursue complete Non-Recurring Effort (NRE)
 1. If required, conduct qualification testing on the EVS-3600 sensor, selected control panel and radome based on the qualification gaps found in Phase 0
 2. Air data/RVSM efforts based on Phase 0 results
 3. Lockheed Martin to review DO-178C/DO-254 development artifacts
 4. Lockheed Martin to update FWD fuselage drawings for EFVS incorporation
 5. Lockheed Martin to review Collins Kit design
 6. Lockheed Martin to update MC Software based on Phase 0 study
 7. Lockheed Martin to conduct regression testing on EFVS-compatible HEU SW build
 8. Lockheed Martin to develop appropriate documentation for flight test approval
 9. Lockheed Martin to perform a Trial Kit Installation (TKI)
 10. Lockheed Martin to perform Electromagnetic Compatibility, ground and flight test
 11. Lockheed Martin to develop required documentation for airworthiness
 12. Lockheed Martin to develop Technical Publications

Roadmap to Synthetic Vision System/Combined Vision System (CVS)



- SVS is graphics-generated and displayed on the HUD based on data from a Digital Terrain Elevation Database (DTED)
- CVS is the blend of EFVS and SVS being displayed in the HUD
- Collins is notionally planning to demonstrate this capability mid-2024 (proof of concept)

EFVS is the first step to development of future vision system capabilities such as SVS/CVS, Radio Frequency Imaging (millimeter Wave), Display Aperture System (DAS)



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