



Vision Systems Technologies Demos – Introductory Briefing

NASA Langley Research Center
9-10 Dec 2014

NASA



NACA



National Aeronautics and Space Administration

Langley Research Center



Historical Contributions



FIRST CENTER
Langley Memorial
Aeronautical Laboratory

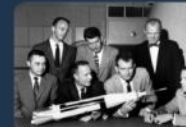


**FIRST SOLID
ROCKET BOOSTER
PAYLOAD-TO-ORBIT**
Scout

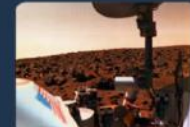
**FIRST PRESSURIZED
WIND TUNNEL**
Variable Density
Tunnel



**FIRST SCRAMJET-
POWERED
MACH 7 and 10
FLIGHT**
X-43A



**FIRST SPACE
GROUP**
Space Task Group

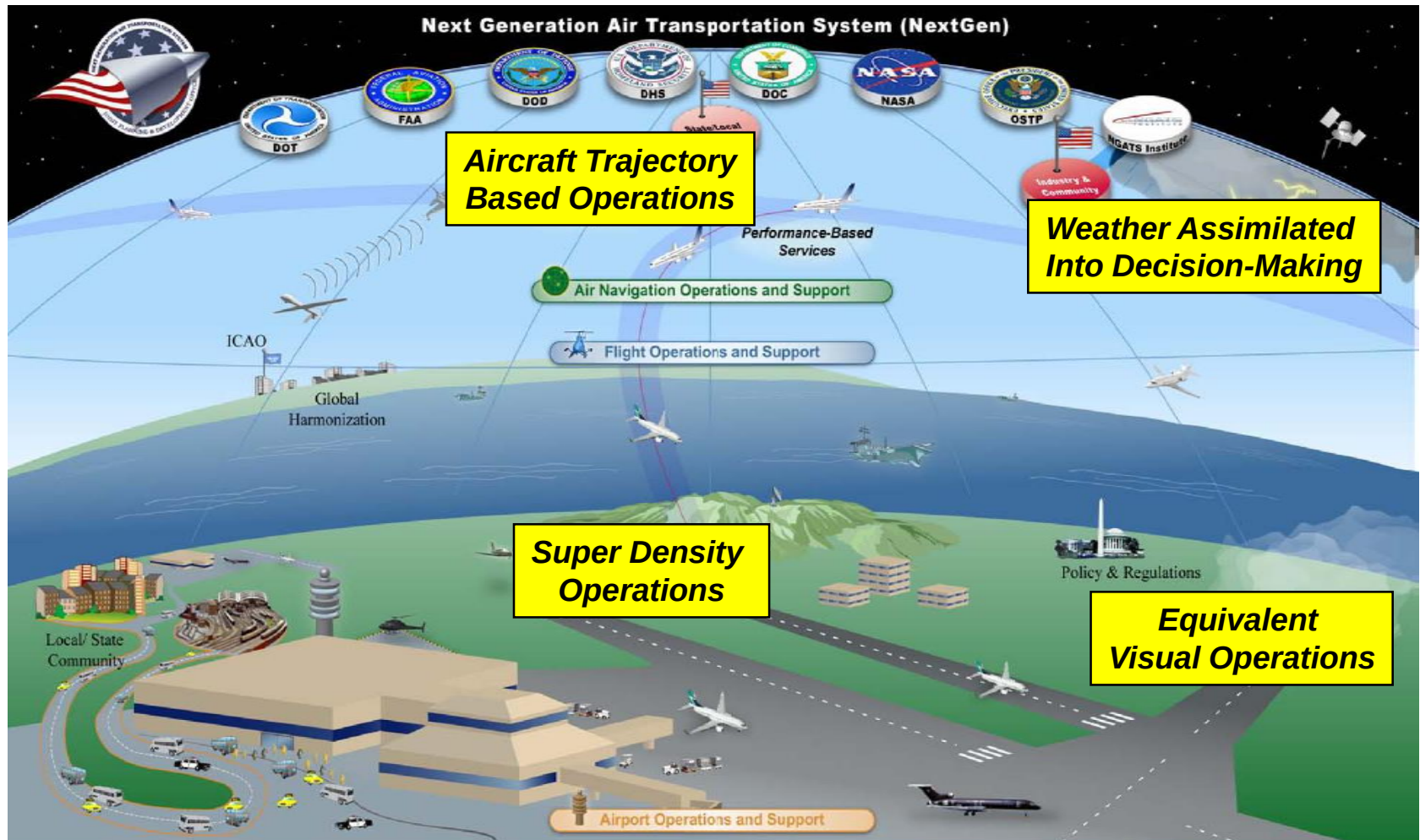


**FIRST MARS
MISSION**
Viking

***Vehicle Systems Safety Technologies (VSST) Vision:
Improve Vehicle Safety By Proactively Mitigating Current And Future Risks***



NextGen – Next Generation Air Transportation System



Equivalent Visual Operations (EVO)



Equivalent Visual Operations – An Electronic Means Provides “Equivalent” Visual References To That Of Natural Vision Independent Of The Actual Lighting And Atmospheric Conditions -

- The Safety And Capacity Of Visual Flight Rules (VFR) Operations Can Be Replicated and Improved Upon
- VFR Operational Procedures Can Be Utilized



- Safety Of VFR Ops**
- Safety of Head-Up Display Ops**
- Significant Equipage Benefits**

Enhanced Flight Vision Systems (EFVS)

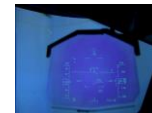


1) Head-Up Display (HUD)

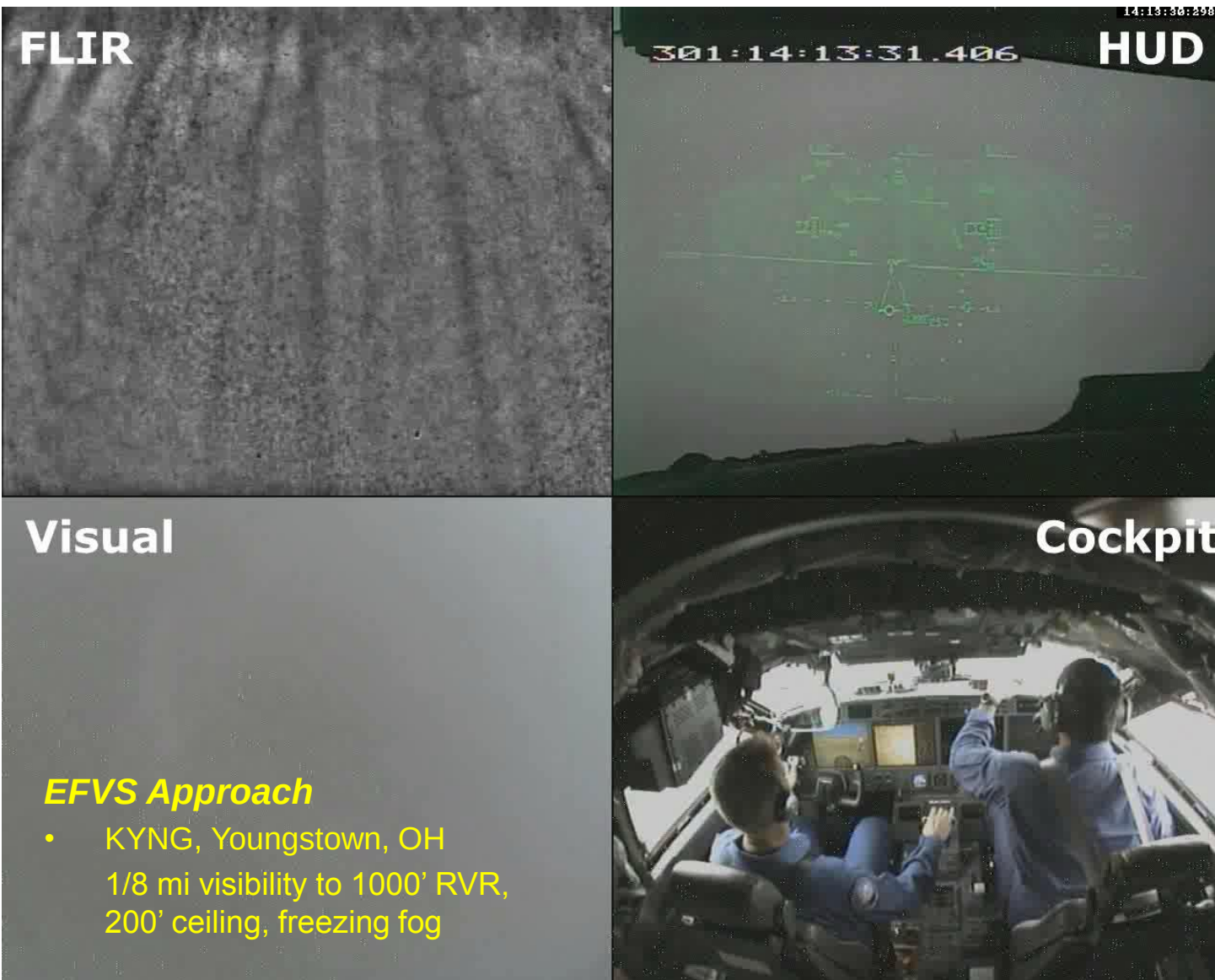
2) Imaging Sensor



3) Conformal Symbolology (Guidance and Situation Information)



EFVS Operations





300 Ft Runway Visual Range (RVR) Experiment

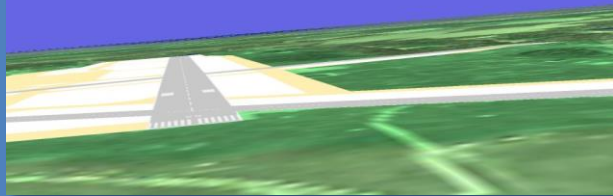
Lynda Kramer, Tim Etherington, and Kurt Severance

Improving EFVS



- Forward Looking Infrared (FLIR):
 - Outstanding: Night, Smoke, and Haze
 - **Not Perfect** – Cannot Penetrate All Weather Conditions

Synthetic Vision
– Database & Nav. Solution



Out the Window View
– 'Mark One' Eyeball



Enhanced Vision
– Infrared Imaging Camera



Honeywell Head-Down Display SV Concept



Rockwell-Collins Head-Up Display SV Imagery

EFVS <300 ft Runway Visual Range (RVR)

Challenge 1: Sensor Technology

“Flat Earth” / Radar



Fused Millimeter Wave Radar / Synthetic



- RTCA Document:
 - Minimum Aviation System Performance Standards For An EFVS:
 - To Enable All-Weather Approach, Landing, And Roll-Out To A Safe Taxi Speed
 - In Visibility As Low As 300 Ft RVR By Use Of An Approved EFVS **To Meet The Visual Requirements For Descent And Operation Below The DA/DH.**
 - **Performance, Availability, and Integrity**

Fail-Operational Design Challenges



Challenge 2: Fail Operational Design

Two Independent EFVS



Two Alternate Displays / Primary Flight Displays (PFD)

- Any Single Malfunction Or Any Combination Of Malfunctions Preventing Safe Landing And Roll-out Or Go-around Is Catastrophic.
 - Exposure Time Calculation From 200 Ft To Roll-out To Safe Taxi Speed.
- Below 50 ft Height Above Threshold, The EFVS Enables Successful Completion Of The Approach, Landing, And Roll-out With The Remaining EFVS Elements After Any Single Failure Not Shown To Be Extremely Improbable.
- Multiple Sensor Strings And Automated Fault Detection Ensure That System / Mode Transitions Are Without Noticeable Adverse Interruption Or Delay.



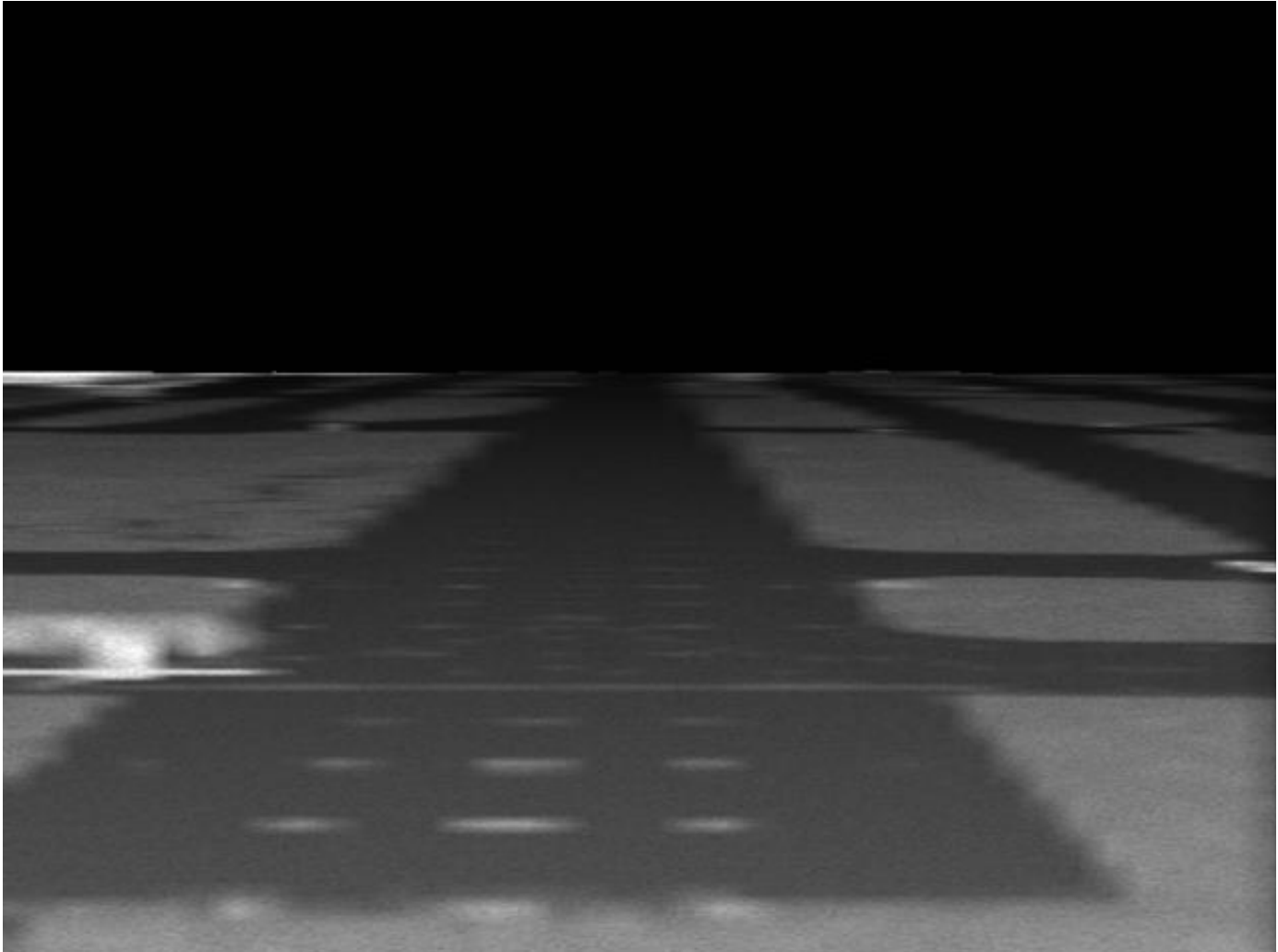
Sensor “Combination”

- **Goal: Create an Optimal Single Image**
 - Using Disparate Image Sources
 - Extract the Pertinent Information From Each Source
 - Without Degradation (Loss of Contrast, Distortion, etc.)
- **Imagery**
 - Synthetic Vision:
 - Perfect Resolution And Unaffected By Visibility Or Night
 - Millimeter Wave Radar (MMWR):
 - Weather Penetration, Unaffected by Atmospheric Conditions
 - Imperfect Resolution
 - Short Range Or High Cost
 - Forward Looking InfraRed (FLIR):
 - Imagery Dependent Upon Atmospheric Conditions, “Target” and Background
 - Excellent Texture, Resolution

Simulated MMWR Imagery Example



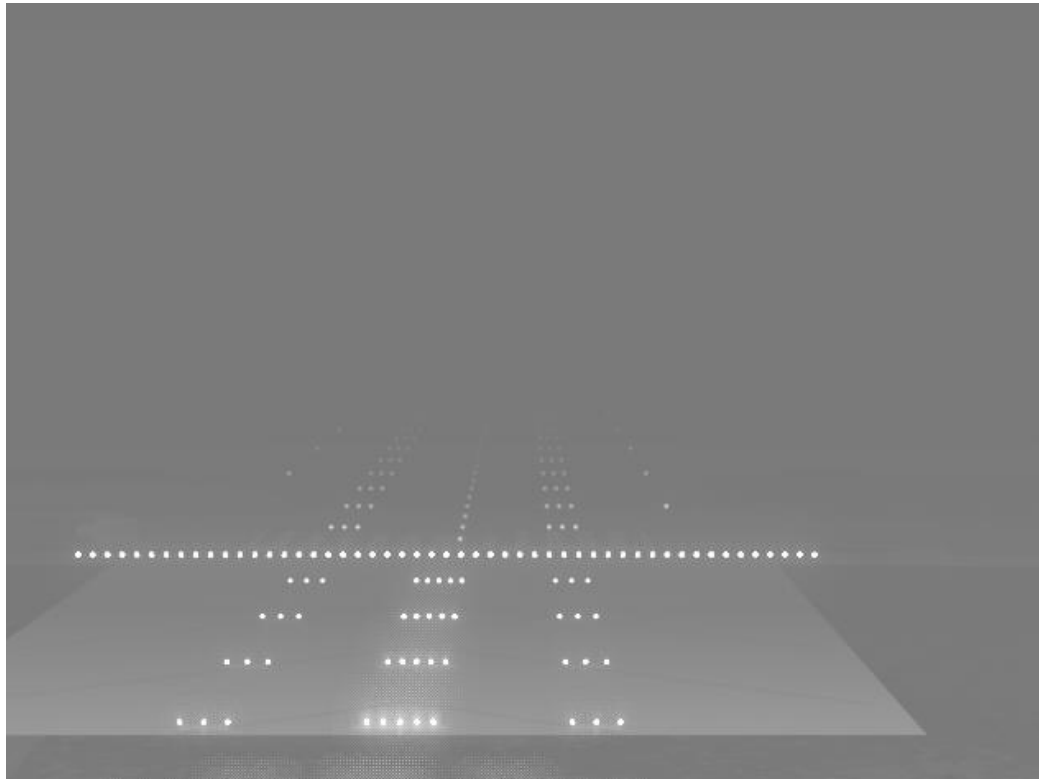
Millimeter Wave Radar (MMWR) At 100 ft HAT in 300 ft RVR conditions



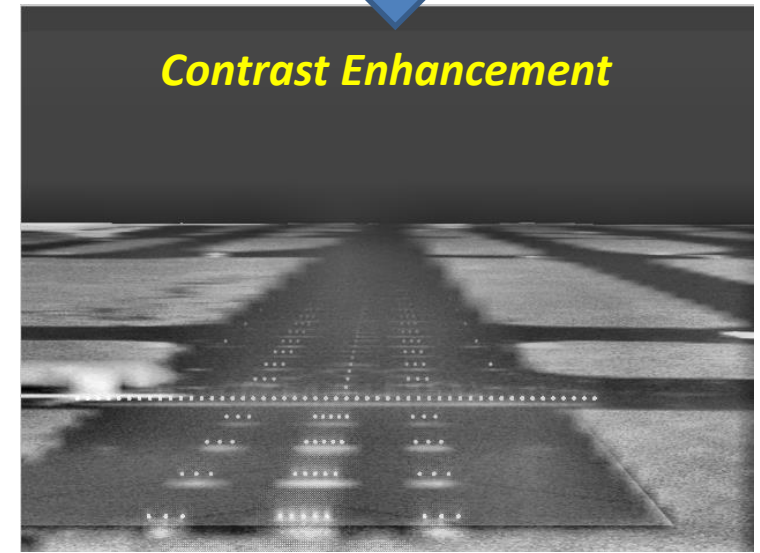
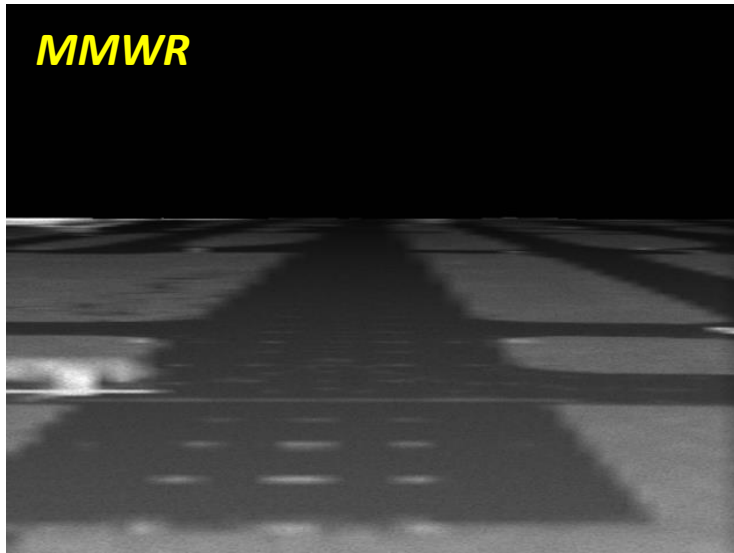
Simulated FLIR Imagery Example



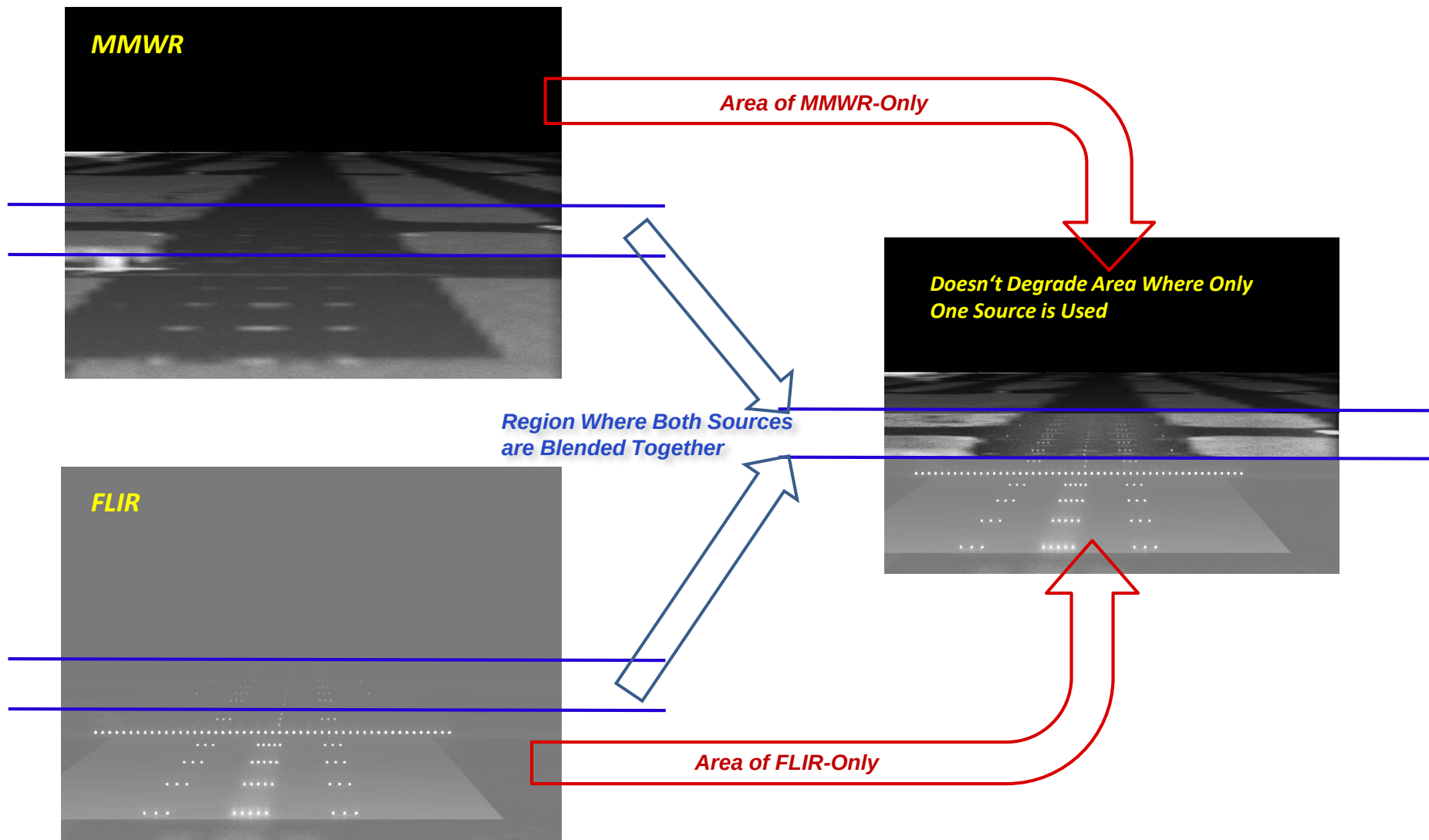
FLIR At 100 ft HAT, in 700 ft and 300 ft RVR conditions



Blending MMWR/FLIR with Contrast Enhancement



Slant Range Concept



Synthetic Vision System (SVS) Imagery



Memphis International Airport (MEM)

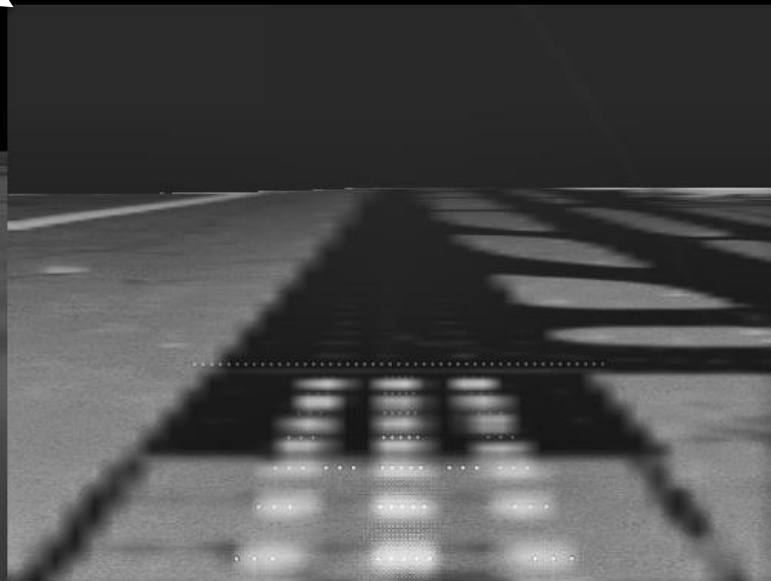


YTN0 SUS - (08_8

SVS and Blended EVS - Combined Vision System



Enhanced Vision
(MMWR/FLIR)
Sensor Window
(15° V x 20° H)



SVS outside of sensor window
(Fill Available HUD Field-of-View)

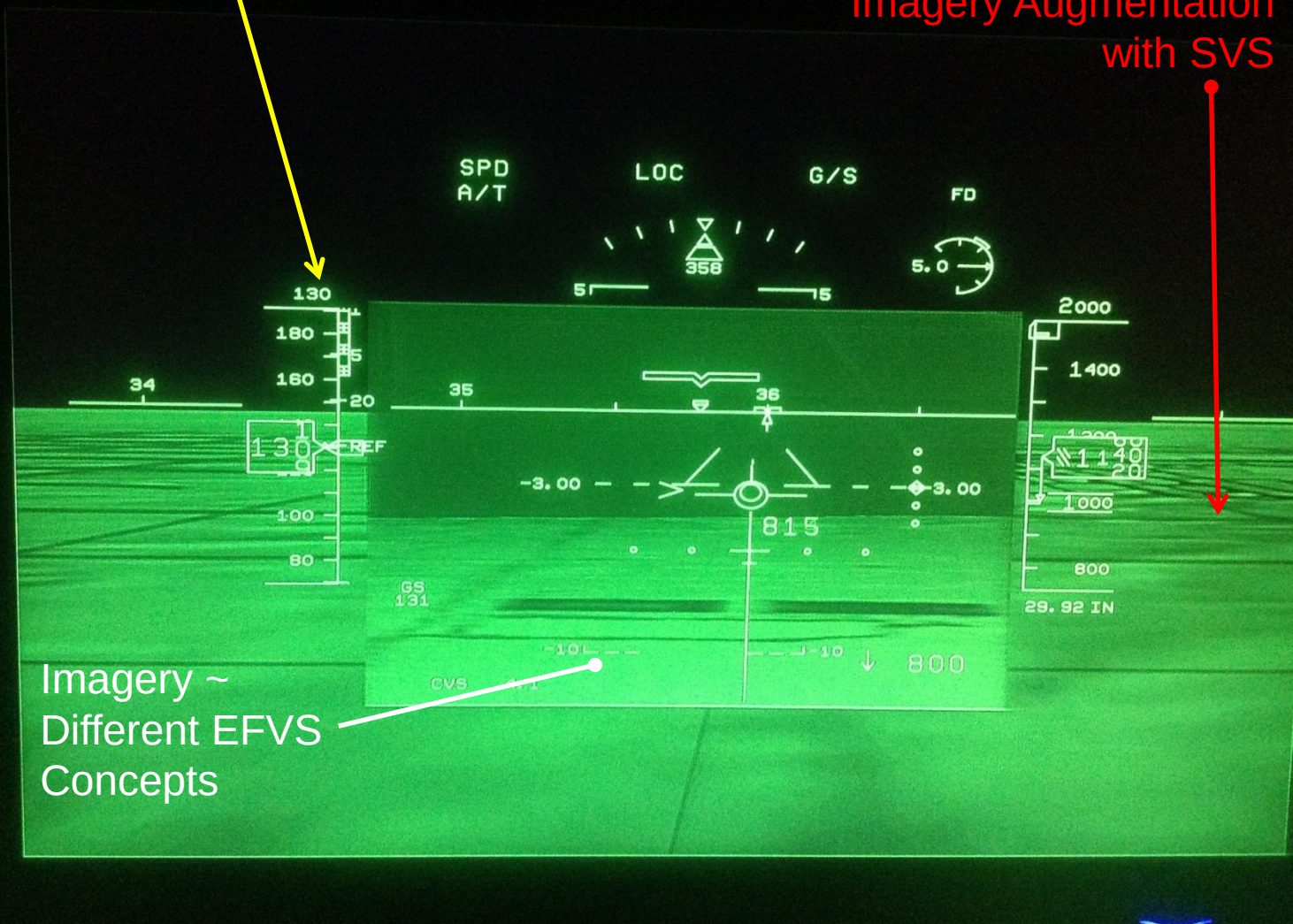
700 RVR - CONCEPT #5 (77_53_30) - SVS WITH MWR/FLR INSET

HUD Components



Symbology from HUD - HGS 6700

Imagery Augmentation
with SVS



Imagery ~
Different EFVS
Concepts



Toward Head-Up Display (HUD) Equivalence Using a Head-Tracked Head-Worn Display

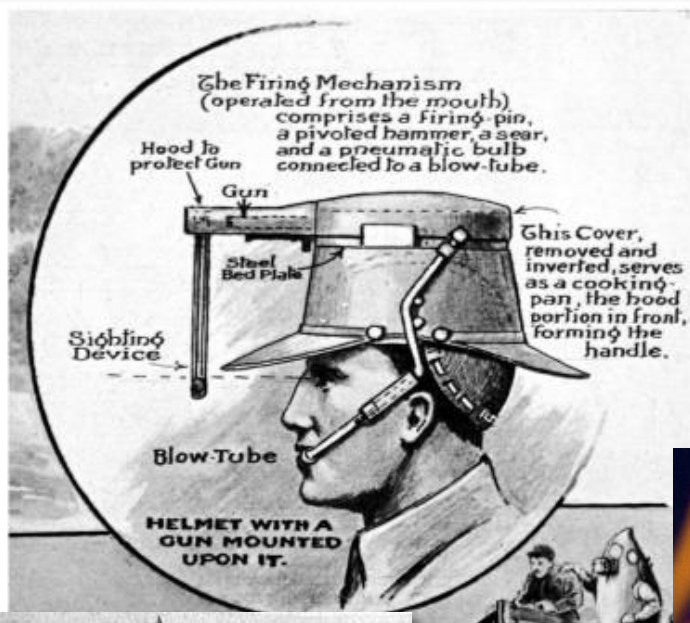
Trey Arthur, Kevin Shelton, and Stephanie Nicholas

EFVS: HUD or “Equivalent Display”



Head-Worn Displays (HWDs) – Virtual HUDs

In 1916 Albert Bacon Pratt of Lyndon, Vermont was issued [patent No. 1183492](#) for a "gun adapted to be mounted on and fired from the head of the marksman."



LaRC HWD/HMD History



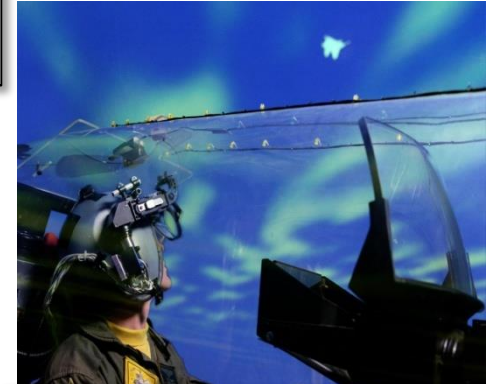
1988

- Monochrome
- Binocular



1991

- Monochrome
- Binocular



1991-1995

- High Angle of Attack Research



2003

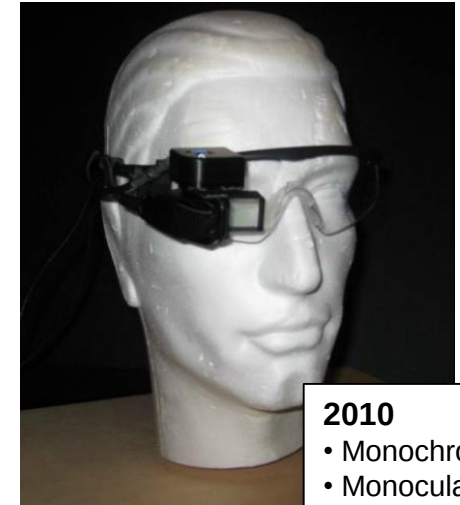
- Full Color
- Stereo
- Sunlight Readable

10 Pounds!



2007

- Full Color
- Monocular
- 2 Pounds



2010

- Monochrome
- Monocular
- 4 oz

- **Helmet Engineered to Military Missions**
- **Large Military Helmets a Non-Starter for Commercial Acceptance**

HWD Technical Challenges

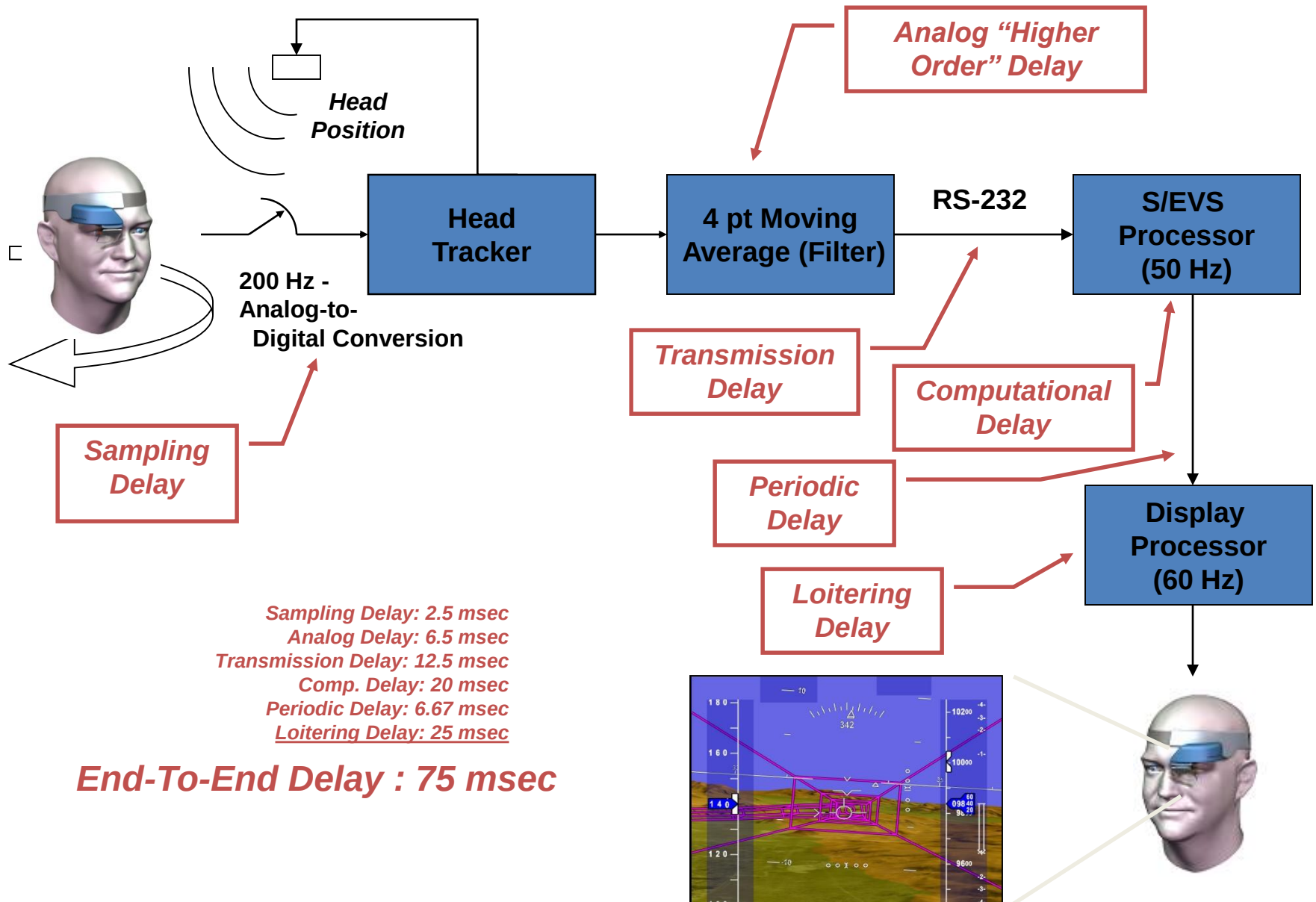


Head-Worn Displays (HWDs) – Equivalent Display to HUD

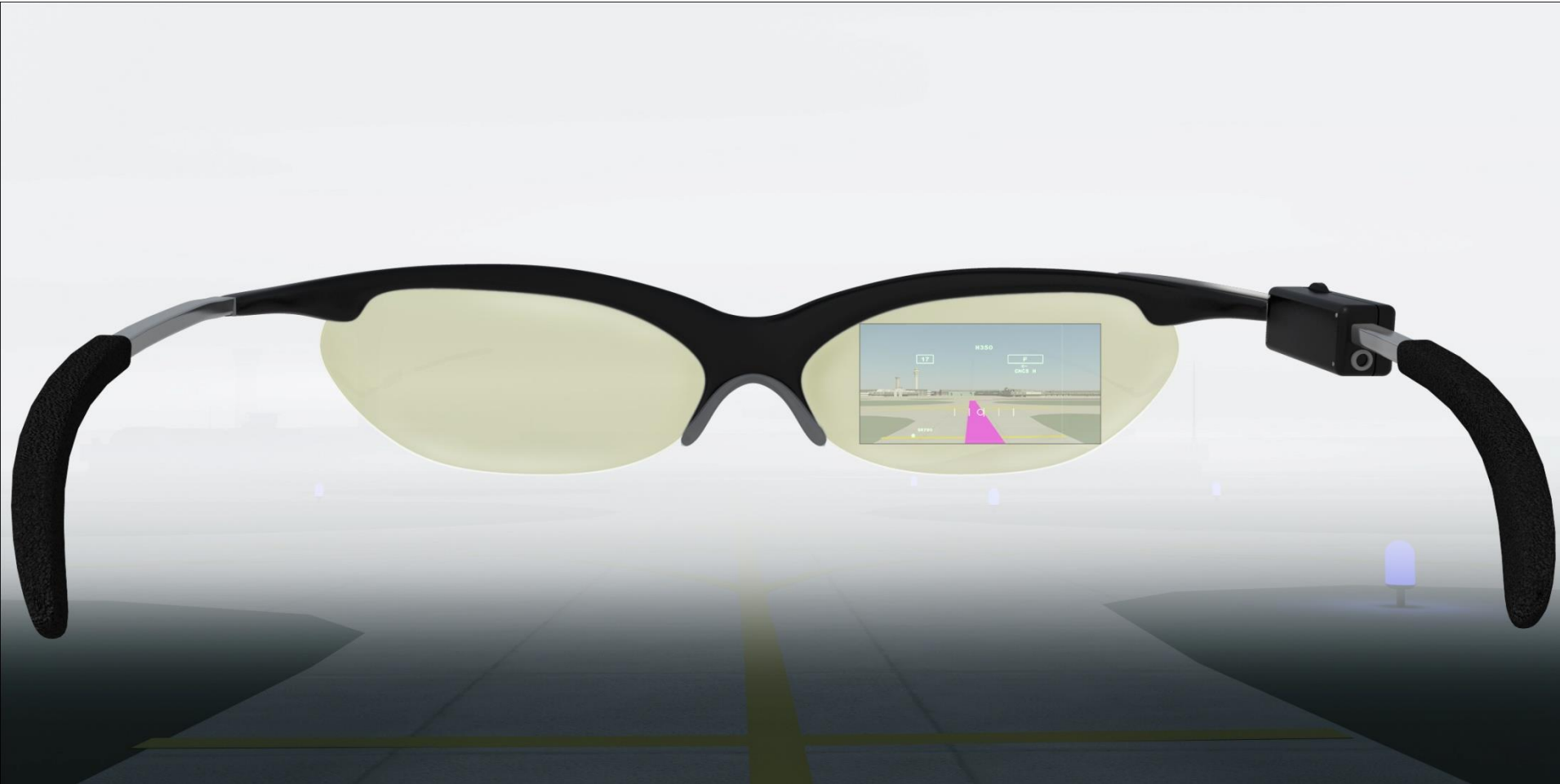


- User Encumbrance
 - HWD Design Goal: “No More Weight Or Encumbrance Than Current Aviator’s Head-Worn Equipment – Sunglasses”
- While Meeting HUD Optical Performance Requirements
 - Head-Tracking
 - Accuracy
 - Static
 - Dynamic
 - **Latency**
 - **Obscuration**
 - Where and When Real-World Visual Information Is Available, Clutter or Obscuration Is A Critical Issue

HMD End-to-End Latency



Display Clutter and Obscuration



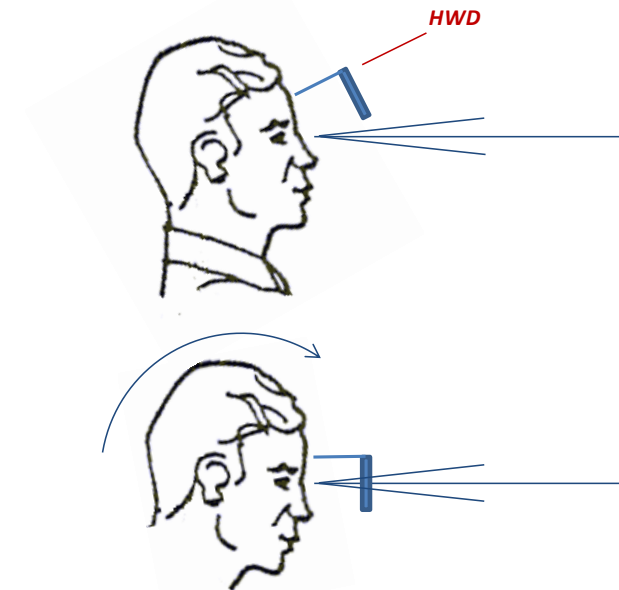
Where and When Real-World Visual Information Is Available, Clutter or Obscuration Is A Critical Issue

Clutter Control Options

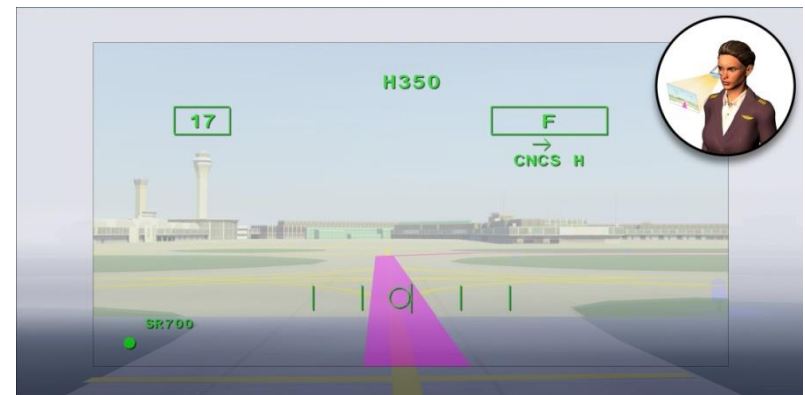


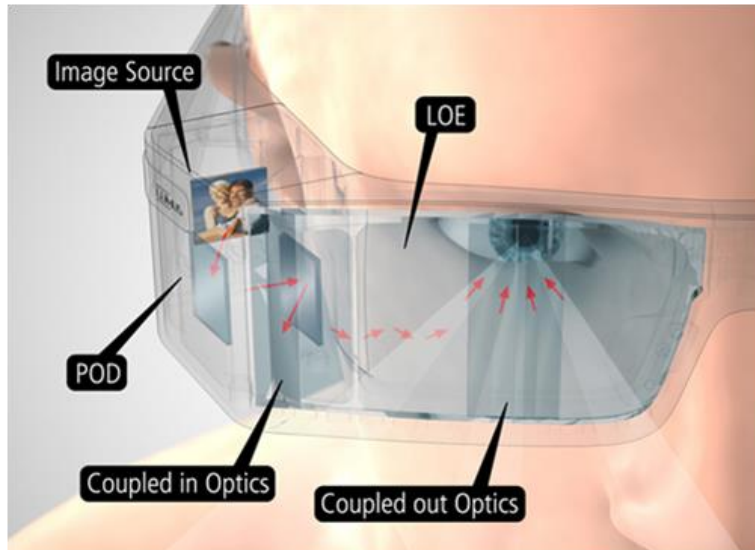
- Optical Differences
 - Bi-ocular Vs. Monocular
 - Binocular Rivalry?
- Clutter Control
 - Automatic / Manual HWD Declutter
 - On-Off of Symbolology
 - Augmented Reality / Min. Symbolology
 - “Semi-Conformal”
 - Head-Movement “Switching”
 - “Beyond RVR” Control
 - HWD Imagery Only Beyond The Natural Vision Limit

“Semi-Conformal” Concept



“Beyond RVR” Control



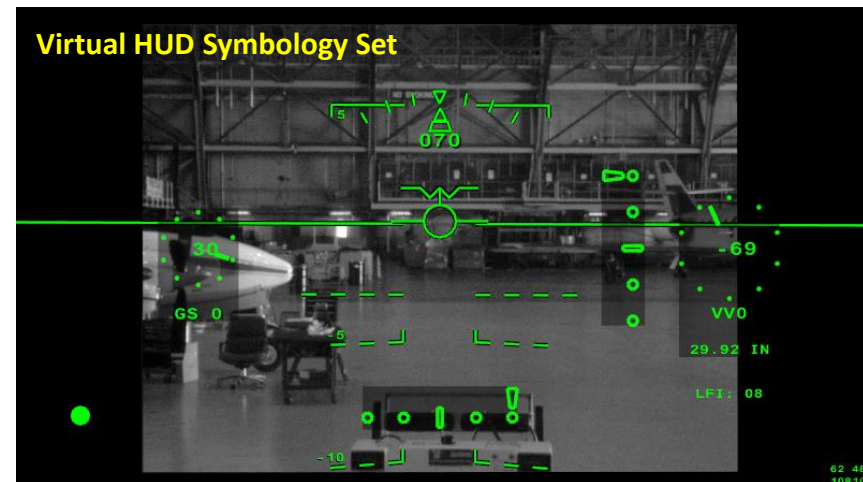
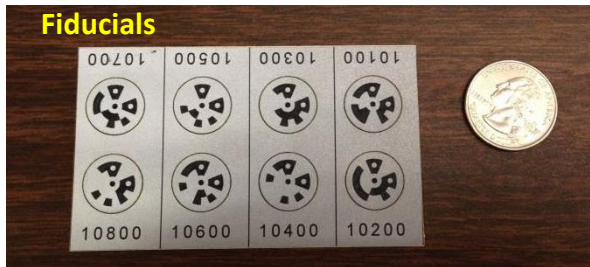


- Bi-ocular HWD
 - Commercial Off-the-Shelf
 - Lumus
 - Light-guide Optical Element (LOE)
 - Unique, Ultra-thin Lens Design That Embeds Miniature, See-through Elements In Front Of The Eye.
 - See-Through
 - 35° H x 20° V
 - SXGA 1280x720 Resolution
 - Glasses: 1 Oz (27 grams)
 - 36 pixels per degree
- Total Head-Borne Weight
 - 7 Oz (202 grams)
 - (Including part of cabling)

Coupled “Head-Track” HWD



- Head Tracker by InterSense (Thales)
 - Inertial / Camera Hybrid
 - Fiducials (stick on imaging targets)



Emerging Technologies



Google Glasses



High Performance



All Wx Ops



Next Gen Glasses





Commercial Aviation Safety Team (CAST) – Virtual Visual Meteorological Conditions (VMC) Display Technology (Virtual VMC Displays)

Kyle Ellis, Vince Houston, and Angela Harrivel

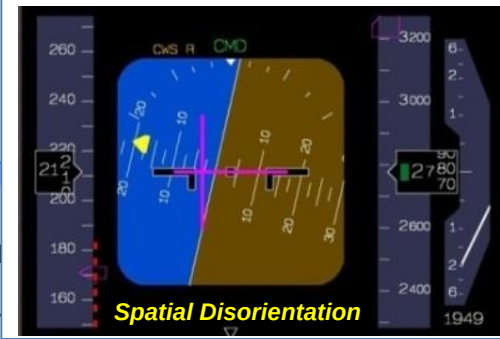
The Problem



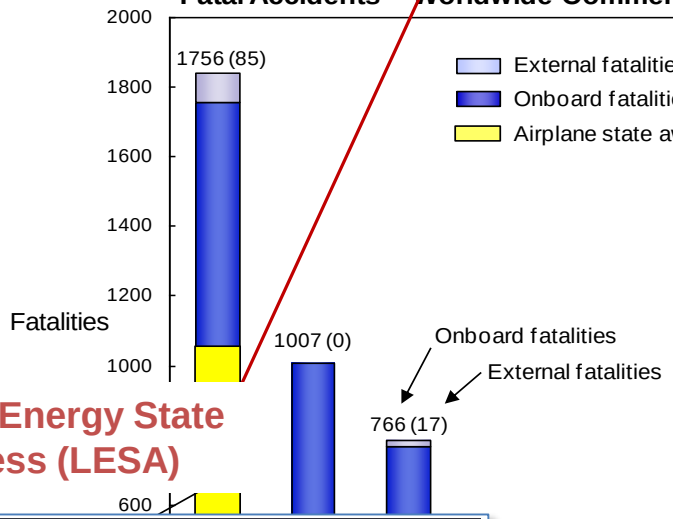
Bateman, D., "Some Thoughts on Reducing the Risk of Aircraft Loss of Control," *AIAA Guidance, Navigation, and Control Conference*, Paper No. 2010-918, Orlando, Florida, Canada, August 2010

Loss-of-Airplane State Awareness

Loss-of-Attitude Awareness (Spatial Disorientation)

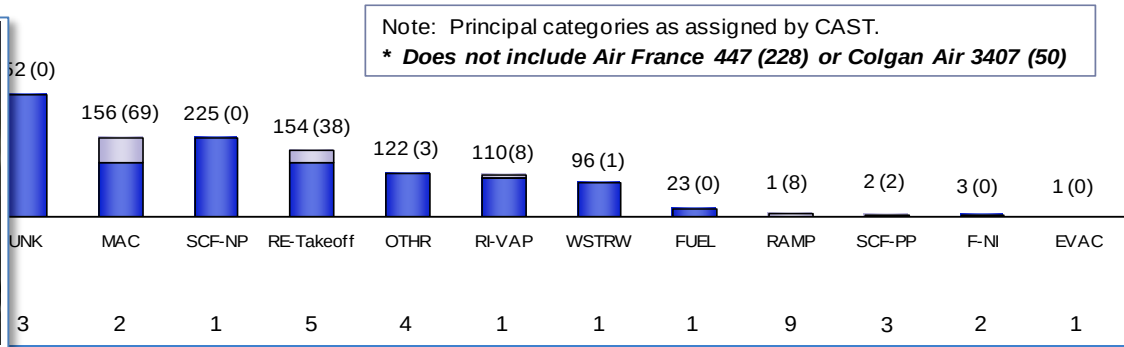


Fatalities by CAST/ICAO Common Taxonomy Team Aviation Occurrence Categories Fatal Accidents – Worldwide Commercial Jet Fleet – 2001 Through



- ARC Abnormal Runway Contact
- CFIT Controlled Flight Into or Toward Terrain
- EVAC Evacuation
- F-NI Fire/Smoke (Non-Impact)
- FUEL Fuel Related
- LOC-I Loss of Control – In flight
- MAC Midair/Near Midair Collision
- OTHR Other
- RAMP Ground Handling
- RE Runway Excursion (Takeoff or Landing)
- RI-VAP Runway Incursion – Vehicle, Aircraft or Person
- SCF-NP System/Component Failure (Non-Powerplant)
- SCF-PP System/Component Failure (Powerplant)
- UNK Unknown or Undetermined
- USOS Undershoot/Overshoot
- WSTRW Windshear or Thunderstorm

Loss-of-Energy State Awareness (LESA)



Note: Principal categories as assigned by CAST.
* Does not include Air France 447 (228) or Colgan Air 3407 (50)



- Coordinated Program Of Research, Development, Test, And Evaluation (RDT&E) Of New Flight Deck-Based Counter-Measures
 - Improve The Crew's Ability To Avoid, Detect, Mitigate, And Recover From Potential SD/LESA Accidents And Incidents.
- In Coordination / Collaboration with FAA and Industry as per CAST Research and Development Safety Enhancements (SE)
 - Published on http://www.skybrary.aero/index.php/Portal:CAST_SE_Plan
 - SE-207 through 211 and SE-200

Spatial Orientation



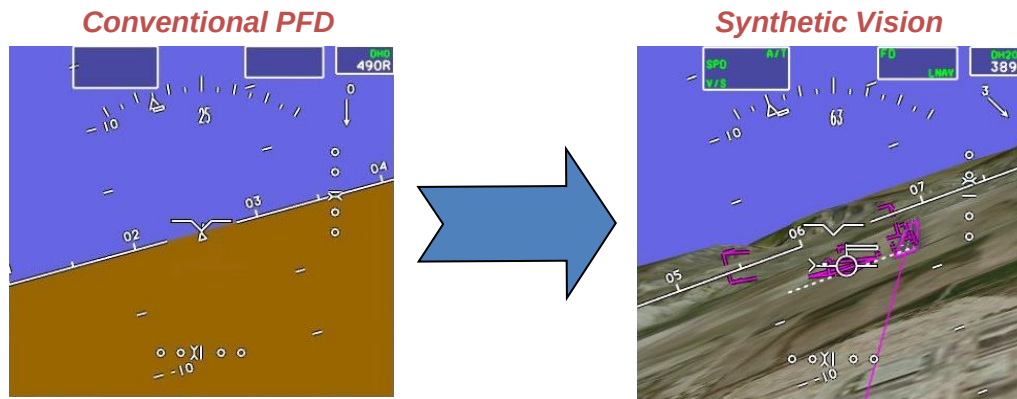
- Spatial Orientation
 - “Vision is by far the most important sensory system providing spatial orientation during flight.” (AFMAN 11-217)
 - *Ambient Vision – Visual Dominance*



Virtual Day VMC Display Technology



- Potential SD Counter-Measures:
Virtual Day VMC Displays Using Electronic Vision Systems?



Factors At Play:

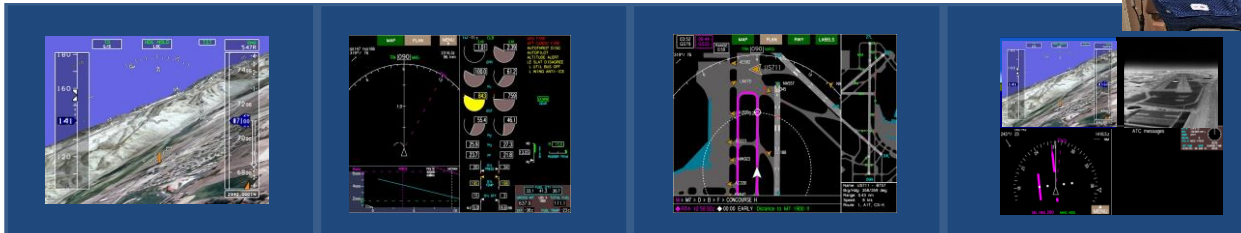
- 1) Abstract Attitude Indicator vs. Intuitive Synthetic Vision
- 2) Outside-In vs. Inside-Out
- 3) Attitude Alerting
- 4) Foveal Vs. Ambient Vision:
“Visual Dominance”

- Influences / Requirements?
 - Field-of-View
 - Scene Projected Beyond Binocular Visual Mechanisms
 - Temporal And Spatial Resolution Matches “Realism and Believability”
 - Sufficient Content To Stimulate Ambient Visual System and Create “Realism and Believability”

Attitude Alerting Vs. Visual Dominance?

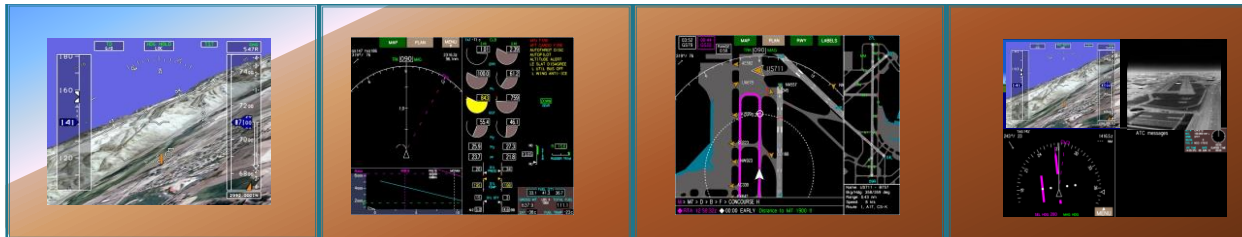


Large Flight Panel Displays



Background Attitude Indicator: Alternative to Peripheral Vision Device

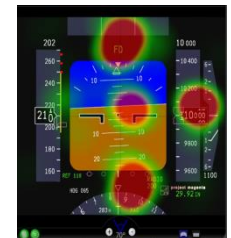
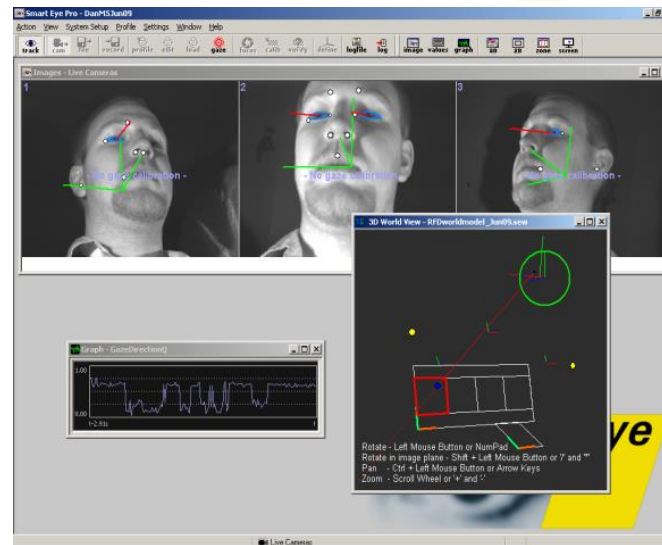
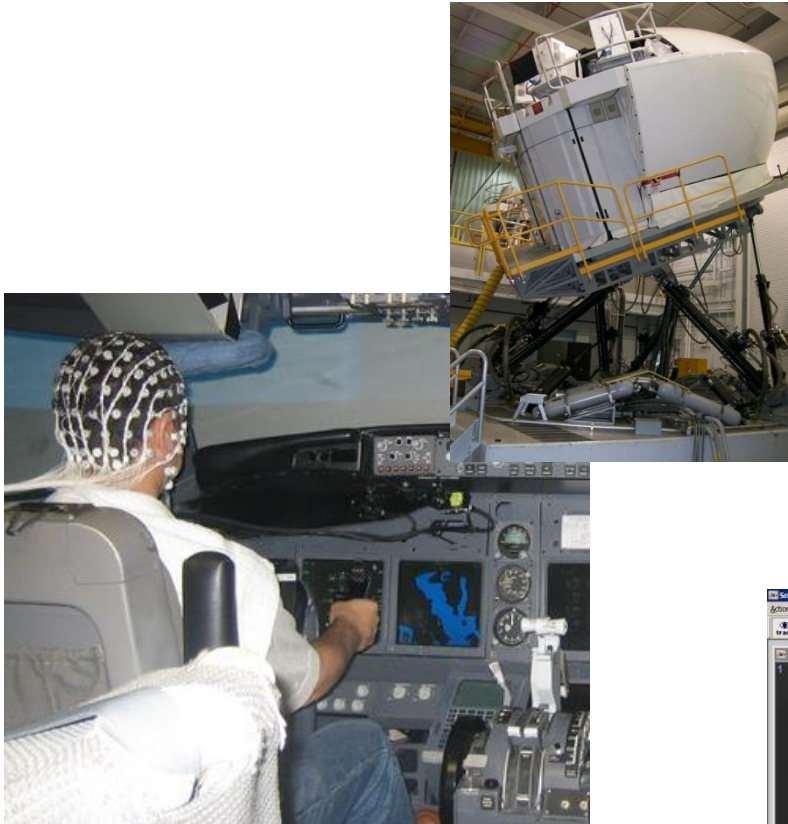
Reference to Captain's ADI



Reference to Center Panel



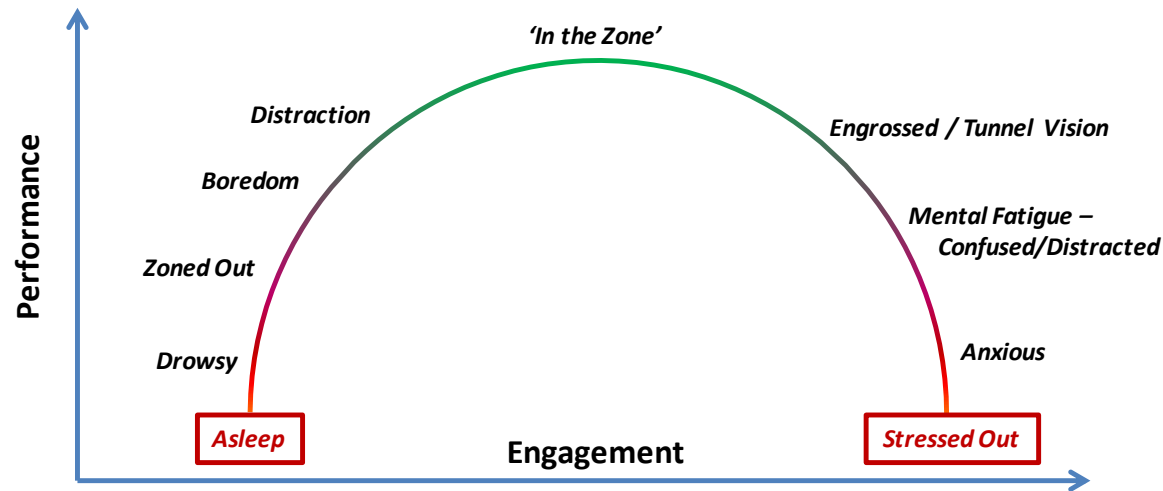
Crew State Monitoring (CSM)



CSM Challenges



- Quantify & Mitigate Effects of Channelized Attention, Confirmation Bias
- Create Methods to Improve and Ensure Proper Pilot Monitoring



Multi-Modal Fusion

Predictability

State Mode	Asleep	Drowsy	Zoned Out	Boredom	Distraction	In the Zone	Tunnel Vision	Mental Fatigue	Anxious	Stressed Out
Eye Tracking	✓	✓	✓	+	+	✓	✓	✓	+	✓
EEG	✓	✓	✓	✓	✓	✓	+			+
Physio	✓					+		✓	✓	✓
fNIRS		+	+		+	+	+			
Behaviour	✓					✓	✓		✓	✓
Voice										+

Concluding Remarks



- NASA's Aviation Safety Program, Vehicle Systems Safety Technologies (VSST) Project -
 - Increase Pilots' Ability To Avoid, Detect, And Recover From Adverse Events That Could Otherwise Result In Accidents/Incidents
- Three Demonstrations of Emerging Technologies
 - 300 ft RVR Experiment
 - Research Flight Deck (RFD) Simulator
 - *Lynda Kramer, Tim Etherington, and Kurt Severance*
 - HWD As HUD Equivalent Display
 - Development and Test Simulator (DTS)
 - *Trey Arthur, Kevin Shelton, and Stephanie Nicholas*
 - Virtual VMC Displays & Crew State Monitoring
 - Visual Imaging Simulator for Transport Aircraft Studies (VISTAS)
 - *Kyle Ellis, Vince Houston, and Angela Harrivel (Chad Stephens)*
- *Splitting Into 3 Groups, Rotating To Each Facility/Demo*



BACK-UPS



Why Vision System Technologies?

Why?

- Improve Aviation Safety
 - Visual-Like Flight References
 - Create Visual Dominance – Maintenance of Spatial Orientation
- Improve Operational Flexibility / Operational Tempo

ASA SE Concept Research - Attitude Awareness Research

To reduce fatal accidents due to loss of airplane attitude awareness, and prevent the occurrence of spatial disorientation, research should be conducted:

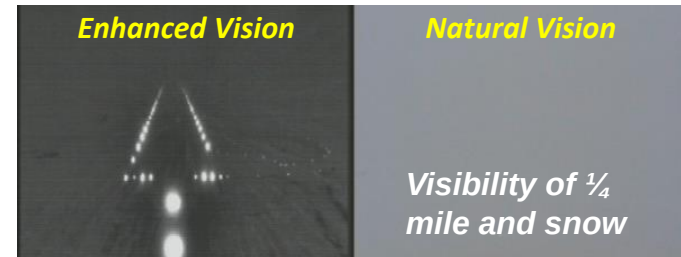
(1) define recommended guidelines for display parameters for synthetic vision systems to support continuous attitude, altitude and terrain awareness, necessary to prevent SD, such as optical flow, field of view, field of regard, display zoom and other display elements;

How is it done today, and what are the limits of current practice?

- Category II/III Landing Systems
- Special Aircrew and Aircraft Authorization Required (SAAAR)
 - Cat. II/III Qualified Aircraft
 - Cat. II/III Qualified Crew
 - Cat. II/III Airport Infrastructure
- Reduced Operational Tempos / Airspace, Surface Ops Restrictions

What is new in our approach?

- Use Synthetic / Enhanced Vision System (SEVS) Vision Technologies Instead of Airport Lighting and Automatic Flight Controls
 - **Creating an Electronic Means of Visibility for Flight Crew**



What are the payoffs if successful?

- Enable All-Weather Operations to All Runways
- Reduce Expense of All-Weather Operations to Aircraft Operators (i.e., non-SAAAR) and Airports
- Eliminate Spatial Disorientation (SD)



Still Limited?
200 ft Ceiling
1/2 Mile Viz



Why Head-Worn Displays?

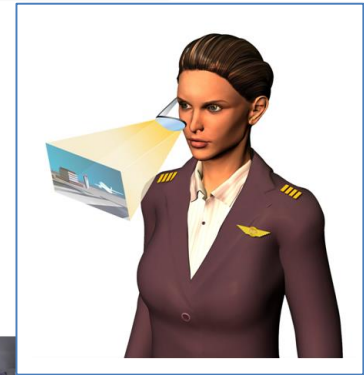
Why?

- Improve Aviation Safety
 - Replicate HUD Safety Advantages* Using “Virtual HUD”
 - Head-Up/Eyes-Out Conformal Symbology and Imagery
 - Create New “Off-Boresight” Safety Benefits
- Improve Operational Flexibility / Operational Tempo
 - HUD Operational Advantages Without Actual HUD Installation



How is it done today, and what are the limits of current practice?

- HUD Operational Credits:
 - Manual Landings Down To 600 ft Runway Visual Range (RVR)
 - Reduced Landing Minima
 - 300 ft RVR Take-Off
- HWD Instead of HUD - “Virtual HUD”
 - Aircraft Where HUD Installation Is Not Possible or Practical
 - Where Retrofit Is Not Cost-Effective
 - HWD Has Potential Return-On-Investment Advantage Over HUD (i.e., Weight = Fuel Savings)
- HWDs Are Not New (In Military) But Commercial Challenges Ignored



What is new in our approach?

- Create a “Virtual HUD” Using HWD and Low Latency
 - Minimal Encumbrance to Pilot
- Take Advantage Of HWD-Unique Capabilities
 - Unlimited Field-of-Regard
 - Spatially-Integrated Information Displays
 - Minimal Clutter / No Display Minification

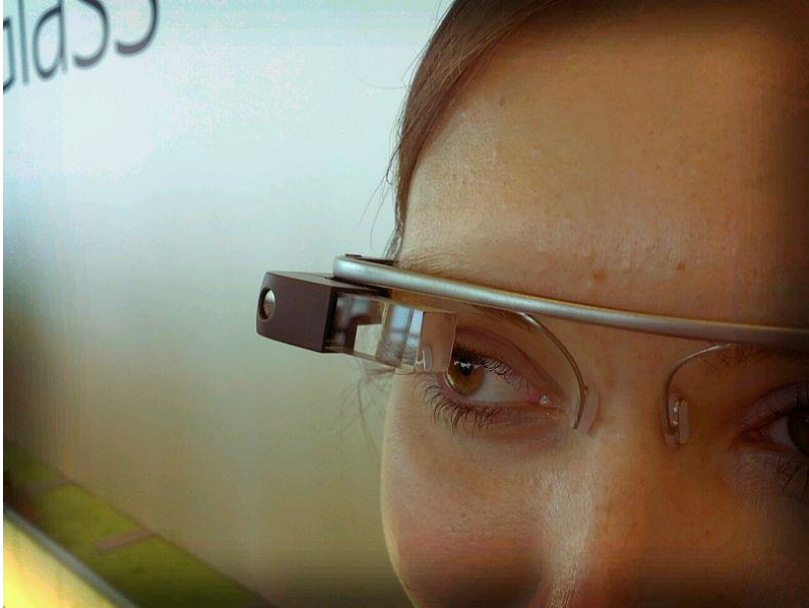


What are the payoffs if successful?

- HUD Benefits for All Aircraft

* Flight Safety Foundation,(2009) found that HUDs prevented or positively influenced 38% of accidents overall in modern glass cockpits. Of those accidents where the pilot was directly involved, such as takeoff or loss-of-control, the “safety advantage” of the HUD became much higher (69% and 57%, respectively).

Google Glasses



- Image: 640x360 pixels
- 43 grams (1.5 ounces)
- FOV: 13 deg H x 7.3 deg V
- 49 pixels per degree