M&S Teachers Seminar
Real Time Virtual Simulators

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MSE

AVT Simulation
Providing Simulation and Training Solutions

Real time Virtual Simulation

- **Unit 8**
  - Unit Length: This unit will last approximately 50 weeks.

- **Goals**:
  - 8.1 Understand the concept and major components of real-time virtual simulators.
  - 8.2 Understand the applications of real time simulators
  - 8.3 Become familiar and conduct systems engineering for simulators

8.1 RTVS Concept & Components

- **Preparing for Careers in Real time Virtual Simulation**
- This course introduces the components of virtual simulation and their aspects that specifically relate to **real time use with a human operator**. Real time simulation expands the usual STEM areas to **include human perception, sensitivity, response, behavior and training methods**. Simulation and Training curriculum tools can be used to help provide experience with many of the STEM areas.

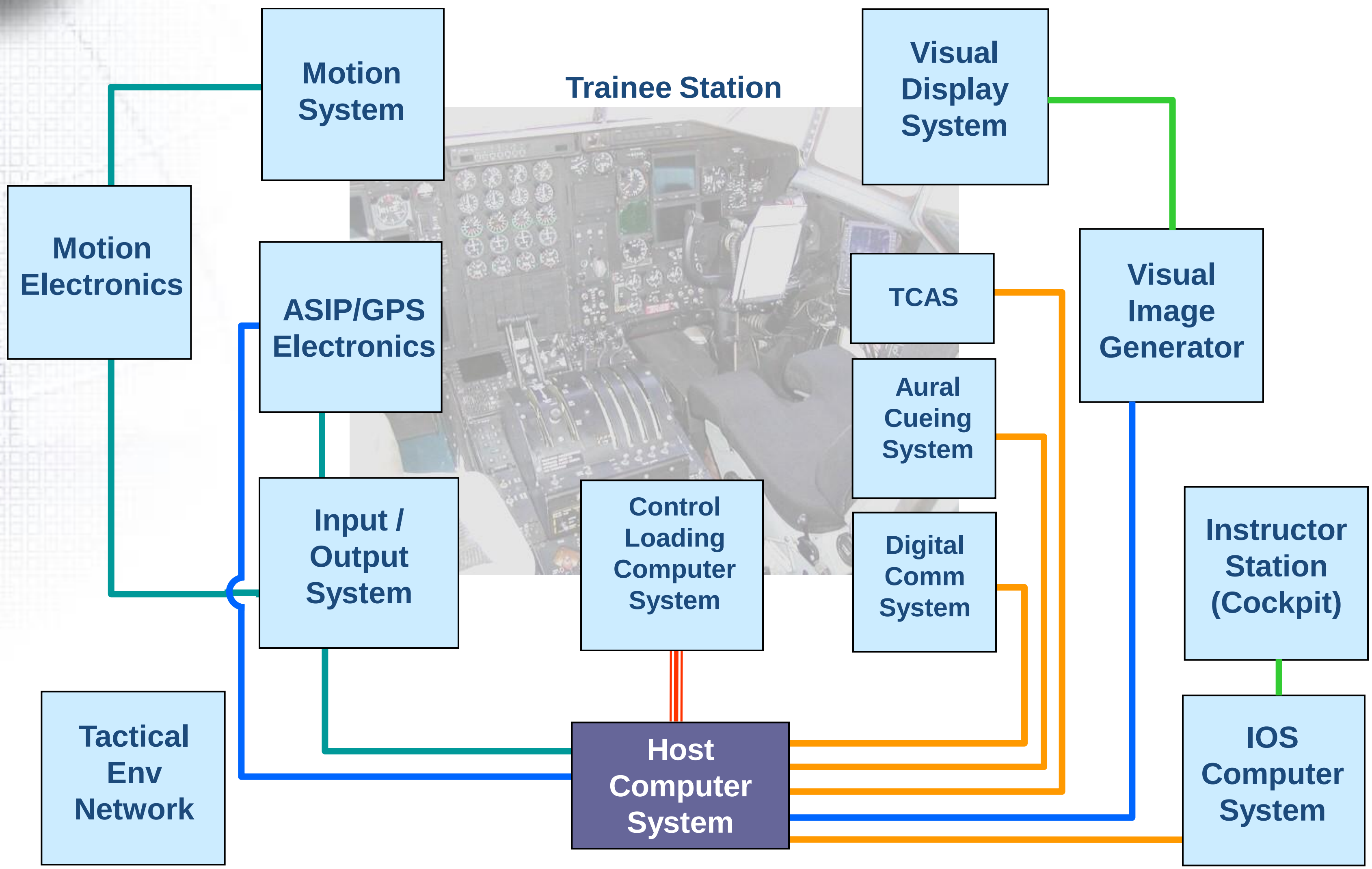
- **Training with Real Time Virtual Simulation:**
- Education and Training methods are often grouped by Knowledge, Skills and Abilities (**KSA**s). While Knowledge is usually obtained by self study and classroom teaching, **Skills and Abilities are effectively learned in simulator** training. Skills and Abilities can also be learned in real vehicles and hardware but since this is more expensive and can be dangerous they are commonly used in final qualification training. So **simulators are safe and cost effective** for introductory training, transition training, recurring skills training and emergency procedures training.
- Flight Simulators got their start with cockpit instrument and emergency procedures skills and abilities training and typically only cost **10% of the cost to train in the aircraft, avoids accidents and is available 24/7 rain or shine**.

System Description of RTVS

- **Capabilities**
  - Controls feel and operate like the real thing and its virtual environment seams real
  - Fast enough to be realistic (able to control like the real thing)
  - Accurate enough to be realistic (moves like the real thing)
  - Follows earths physics and weather (not the moons)
  - Separately generated environment stimuli (visual & motion) are in sync (avoids sickness)
  - Provides the vehicle’s cues and environment’s cues the operator expects and needs to operate
- **Operability**
  - Ease of simulator control (start, stop, freeze, resume, record, replay)
  - Variety of activity (scenario selection, malfunctions, emergencies)
  - Scoring (feedback on performance)
  - Interactivity (instructor role playing, automatic responses, networking with others)
- **Availability**
  - Affordable to acquire the simulator and the facility it needs
  - Affordable to operate and maintain
  - Reliable enough to support the use schedule (e.g. 24/7 or 5 days @ 8 hours each or ?)
  - Location in a fixed facility or being able to be relocated

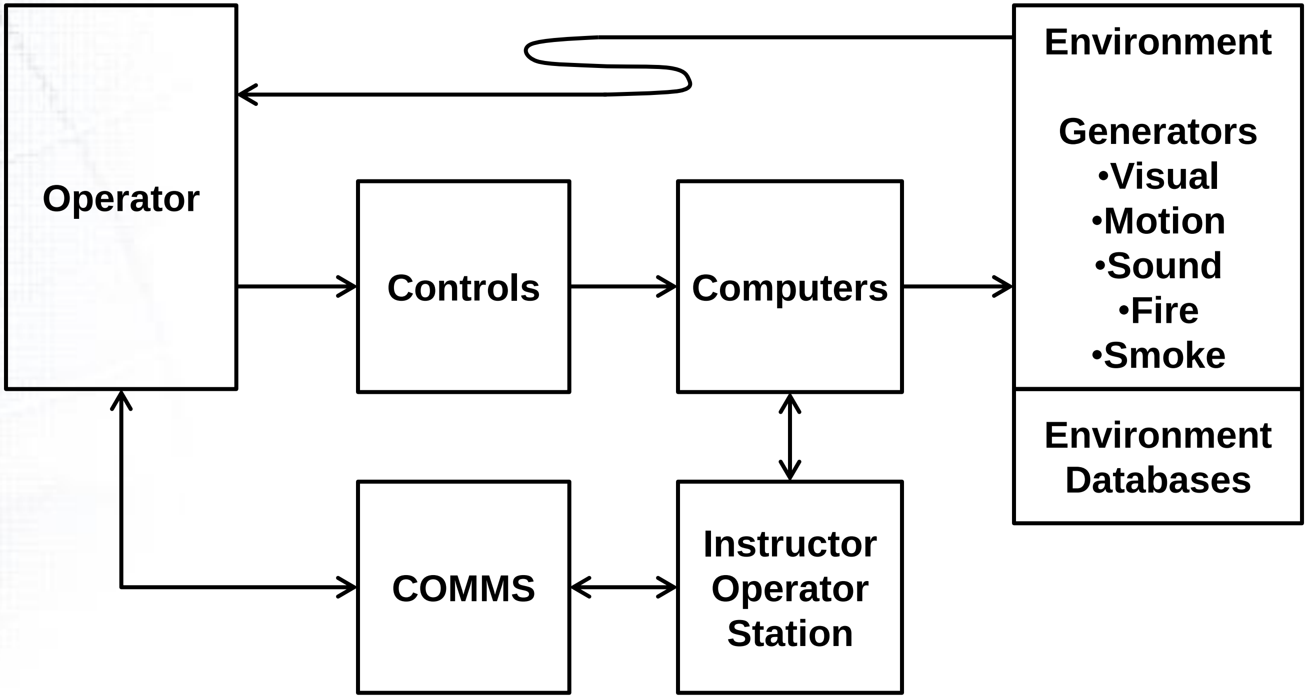
8.2 RTVS Applications

Flight Simulator Block Diagram



Real Time Virtual Simulator Types

RTVS Block Diagram



Simulator Components

Simulator Type	X-Box	Fire Fighting
Simulator Component Types	**Simulator Components**	**Simulator Components**
Operator	Gamer (entertainment)	Fireman (student or team)
Controls	Control Box	Fire hose with spray
Computers	PC	Host, IOS, Comms
Environment Generators	TV, Speakers	Burners, sensors, smoke
Environment Databases	World, Models, Avatars	Fire room, drains, exhaust
Interfaces	Cables	Cables

Flight Simulator
Simulator Components
Pilot (student, designer, testor, investigator)
Cockpit controls, switches (100s), Headset, Microphone
Host, IOS, Communications
IG, Display, Sound, Motion, SAF (Semi-automated Forces)
World, Models, Sounds, Avatars, Weather
Cables, I/O, Ethernet, Video, Audio

RTVS Component Analysis

- Example of a study of expanded requirements for one RTVS component:

- The visual display

- Analyze the requirements and constraints
- What alternative solutions are there
- What technology types are there
- What are their costs and benefits

E-2 Operational Flight Simulator Display Study Objective

Identify & evaluate alternative display approaches for the E-2C OFT to support expanded training requirements including …

… in order to replace flight hours in the aircraft.

E-2 Display Study Methodology

Study Tasks:

1. Define Training Requirements related to OFT Displays
2. Define OFT Display Requirements
3. Identify & evaluate available Display Technologies
4. Identify & evaluate practical Display Approaches
5. Identify viable Display Alternatives and trade offs

Translating Training Requirements to Solutions

- Task 1: Identify **Training Requirements** related to OFT Displays
  - "Voice of the Customer":
    - E-2 WTU, FRS, NSAWC SME Interviews
      - (Telecoms)
    - Site Survey Norfolk, Virginia
    - Site Survey Pt Mugu, California
    - In Flight Refueling SME Interview

  - Documented:
    - Customer Requirements Affinity Tree
    - Vertical Axis of House of Quality ("Voice of Customer")
    - Requirements & Constraints Document

Translating Training Requirements to Solutions

- Task 2: Define new OFT **Display Requirements**
  - Based on Customer Requirements and Program Constraints
    - Performance (Field of View and Image Quality)
    - Development/Integration complexity/risk
    - Acquisition Cost
    - Supportability/Availability
  - Documented:
    - Requirements & Constraints Document
    - <u>Horizontal</u> Axis of House of Quality (“Voice of Developer”)

User Priorities

House of Quality - Customer Requirements by Importance	Customer Importance
Customer Requirements	
Perform training	
Normal & Emergency Flight Maneuvers	
Control the aircraft with respect to the operaing environment	5
Maintain situational awareness (traffic, weather, etc.)	4
Observe OTW details across cockpit for control & sit. awareness	5
See OTW with same perspective as other pilot for control	4
Perform day & night VFR and IFR field & carrier landings & takeoffs	5
Operate on the tarmac and carrier deck	5
Perform in lfight normal and emergency maneuvers	5
See details such as landing aids (IFLOLS) at operational ranges	5
Experience "day" brightness effects in cockpit	3
Allow head movement as in aircraft	3
Formation Flight	
Perform rendezvous	5
Fly formation maneuvers as wingman	4
Check wingman's position	1
Self Defense	
Detect, identify, and avoid air threats at opreational ranges	4
Detect, identify, and avoid ground threats at opreational ranges	3
Perform as a coordinated crew duties to evade threats	4
Maneuver to evade threats	4
Fly Low Level Routes to evade threats	4
Perform Visual Inspections of Own Aircraft	
Inspect engine/nacelle, Props, Wings, Main Gear, Tires	4
Inspect radome, tail bushings	1
In Flight Refueling (Possible Future Requirement)	
Perform rendezvous and movement to contact	4
Make and maintain basket contact	2
React to emergencies	3

E-2 OFT
Crew Equipment

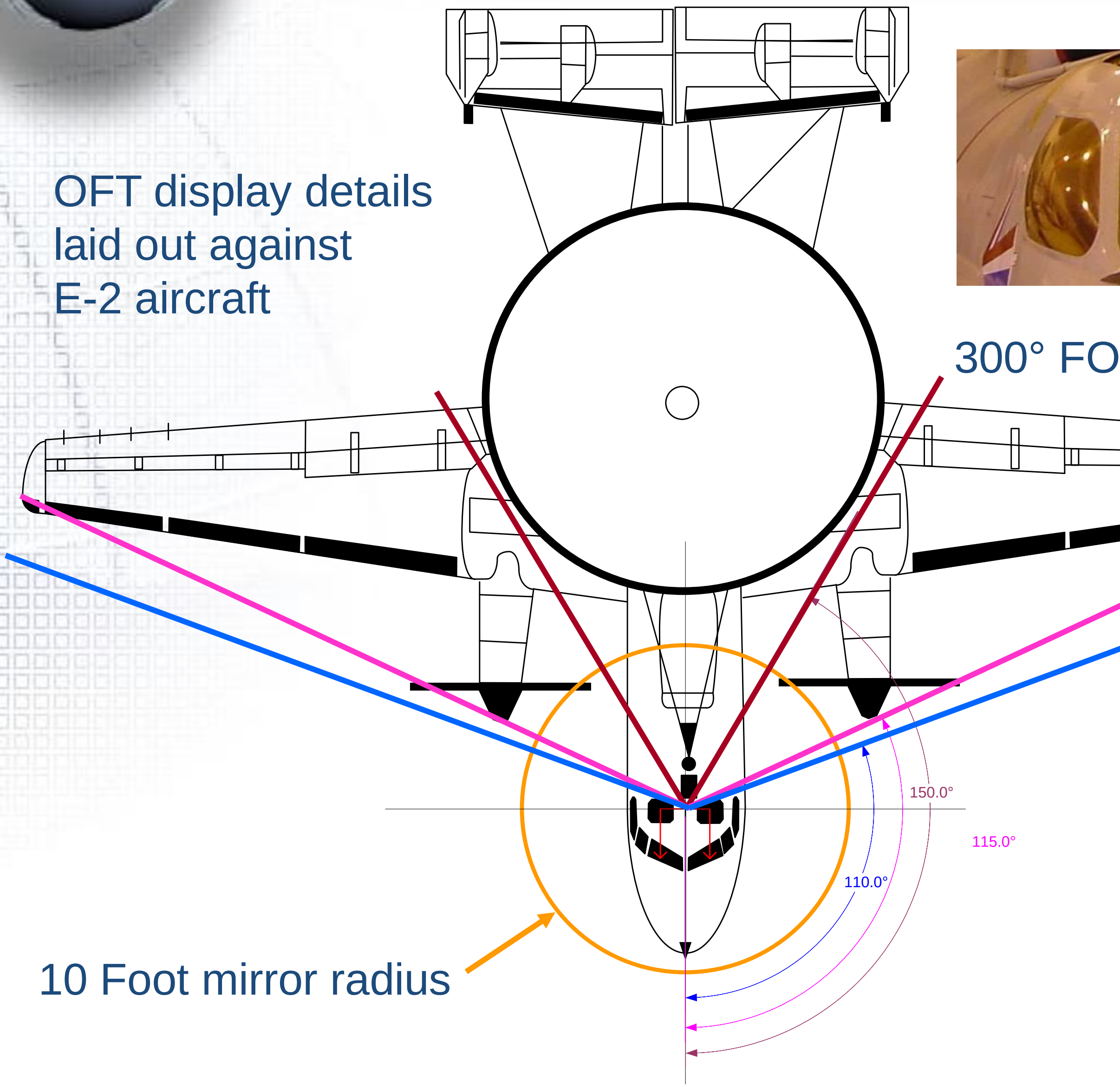
- **Crew Equipment impacts FOR & training effectiveness in the OFT**

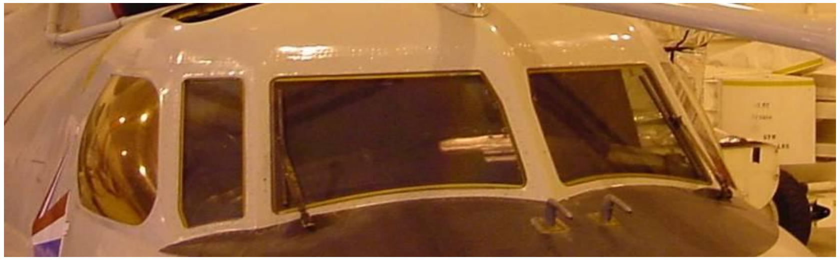
Donning Crew Equipment

Crew equipment
- Helmet and visor
- Comms
- **5-point harness**
- Survival gear

Main Windows

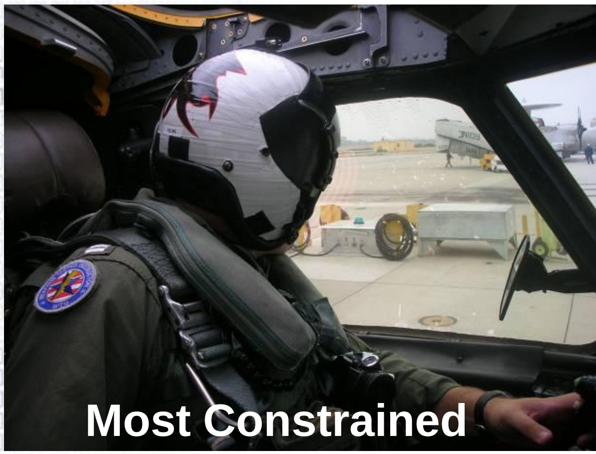
OFT display details laid out against E-2 aircraft





E-2 OFT
Seat Restraints

- **Level of restraint impacts FOR (& training effectiveness) in the OFT**



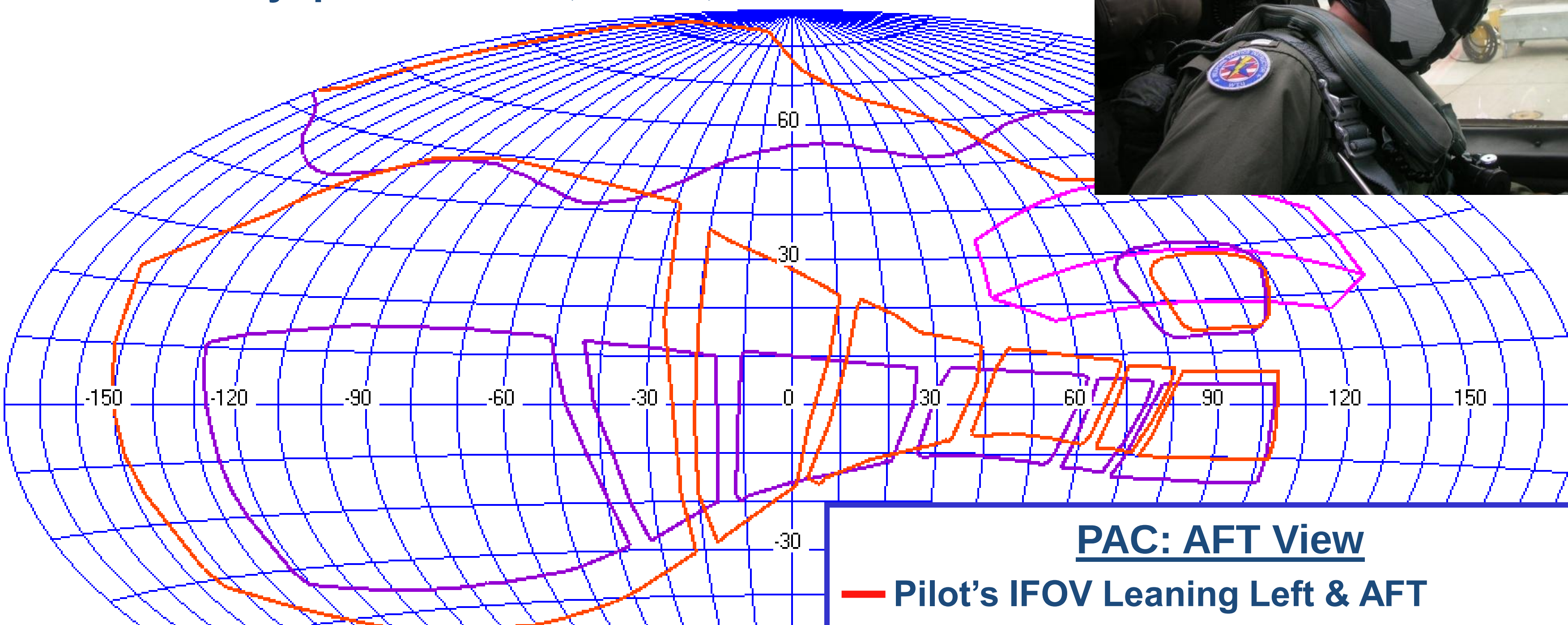
Koch fittings - connected
Harness - locked

Koch fittings – connected
Harness unlocked

Koch fittings disconnected

E-2 OFT
AFT Field of Regard

- **Pilot at Controls (PAC)/Moderately Constrained**
- **Leaning LEFT & Looking AFT**
  - **e.g. for aircraft inspection**
- **AFT Eyepoint*: 3' fwd, 8" left, 3" down from DEP**

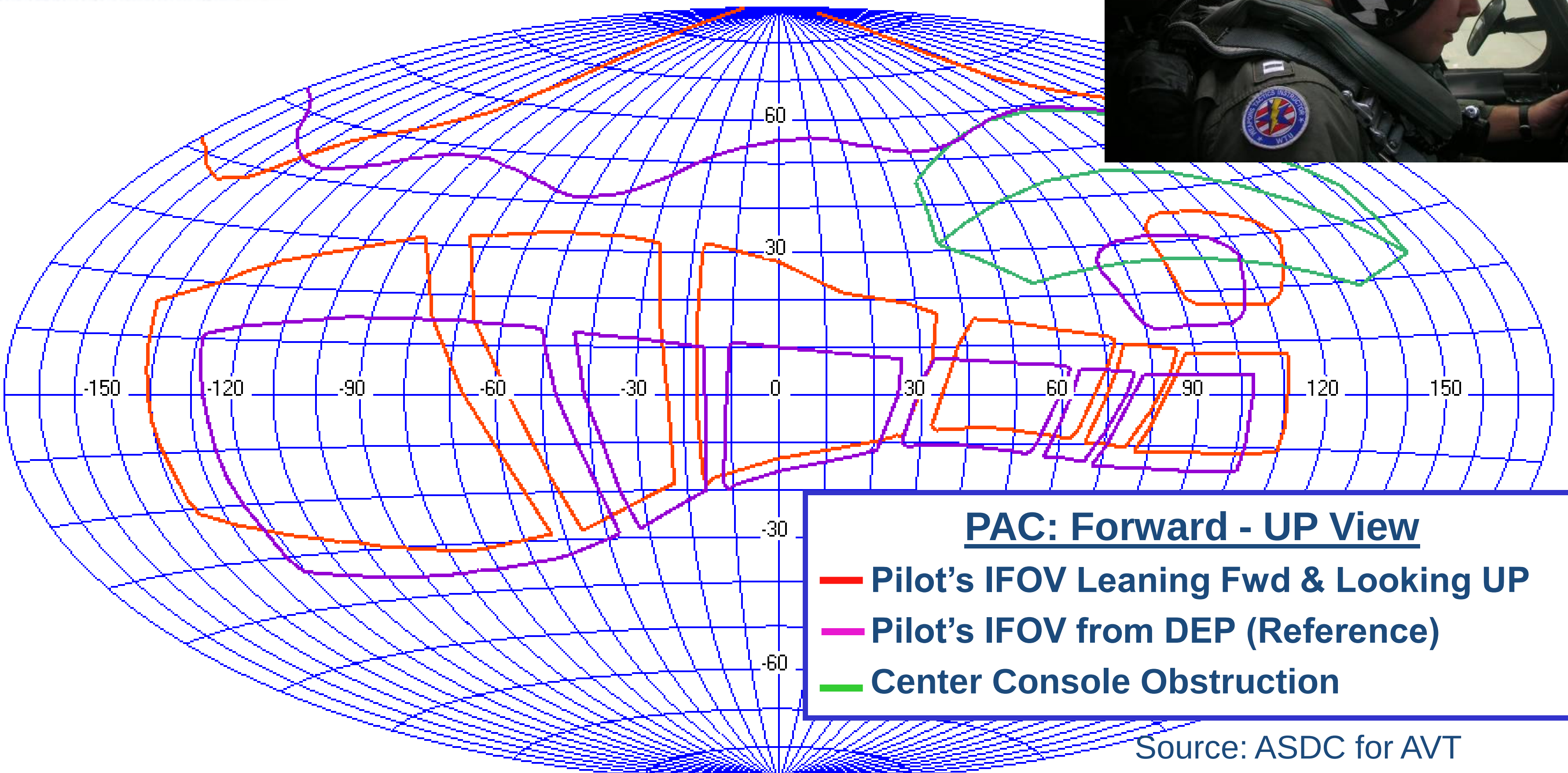


*** Recommended eyepoint for the aft view if a separate display from the main view.**

Source: ASDC for AVT

E-2C/D OFT
Forward-UP Field of Regard

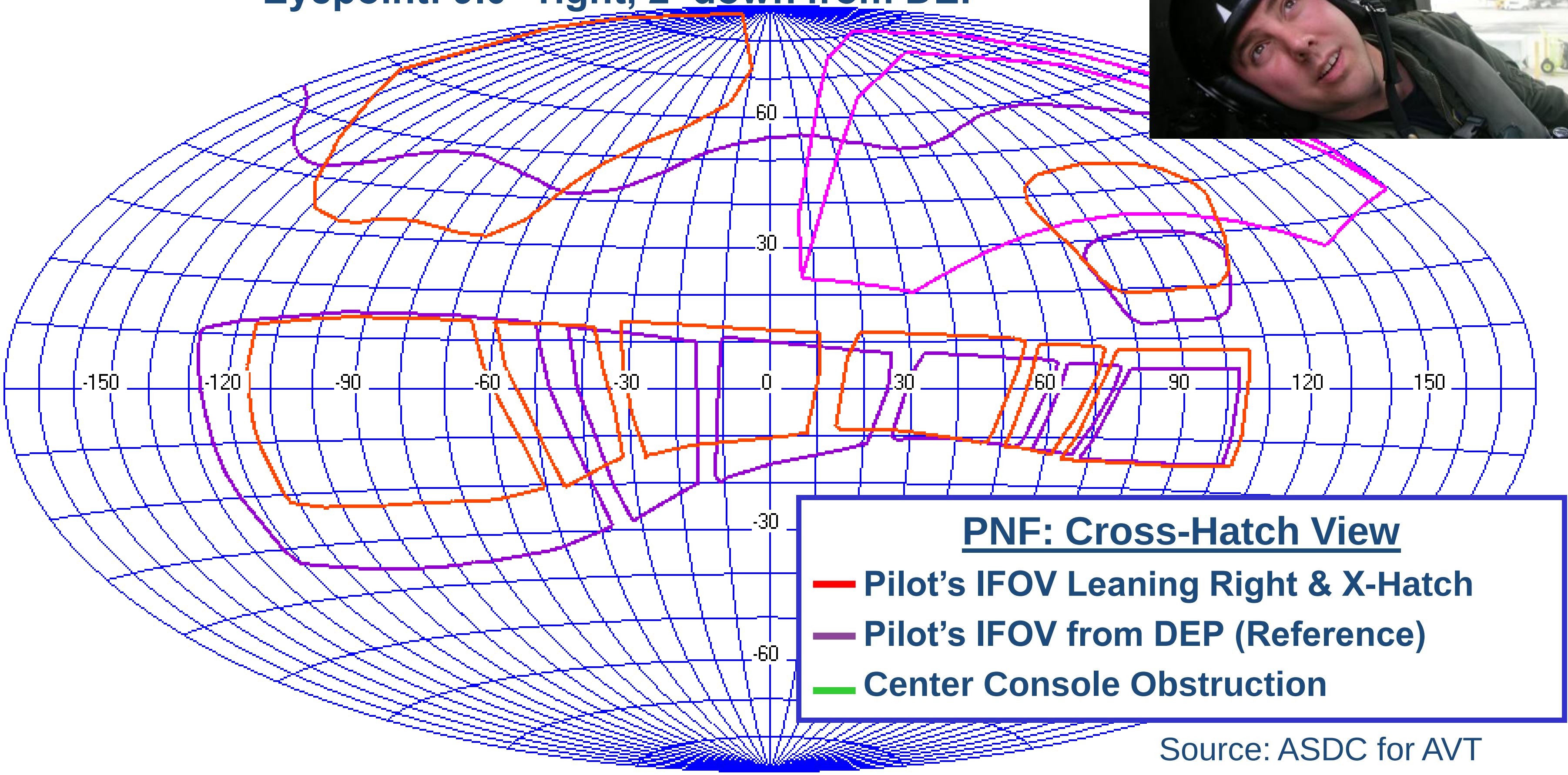
- **Pilot at Controls (PAC)/Moderately Constrained**
- **Leaning FORWARD & Looking UP**
  - **–e.g. Formation Flight, or In Flight Refueling**
- **Eyepoint: 8.5” fwd, 3.5” down from DEP**



Source: ASDC for AVT

E-2 OFT
X-HATCH Field of Regard

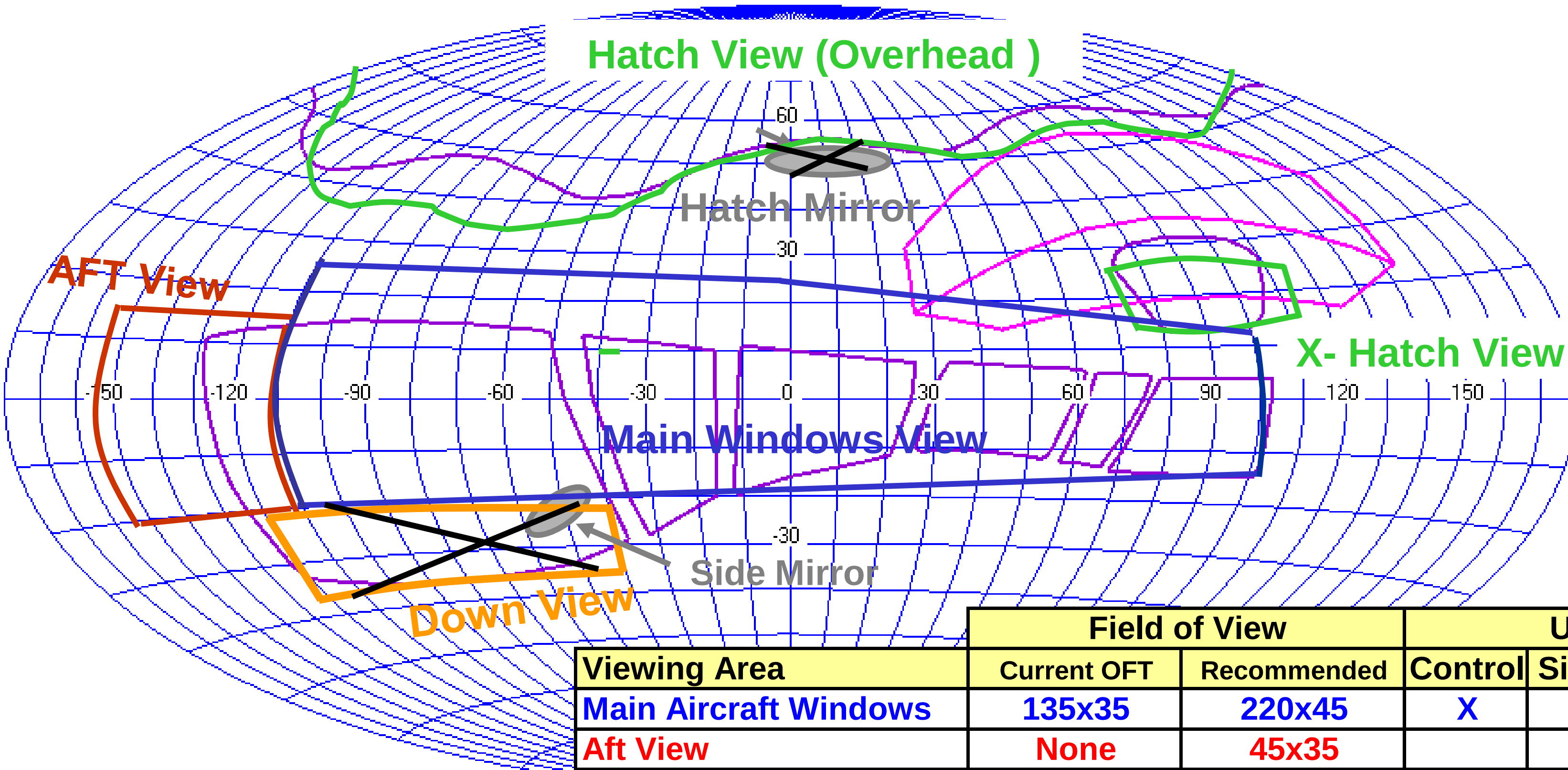
- **Pilot Not Flying (PNF) – Least Constrained**
- **Leaning RIGHT & Looking X-HATCH**
  - **e.g. for Self Defense**
- **Eyepoint: 9.0” right, 2’ down from DEP**



Source: ASDC for AVT

Viewing Areas Requirements Summary

- Recommended minimum Total Field of View (TFOV) based on training requirements:



Viewing Area	Field of View: Current OFT	Field of View: Recommended	Usage: Control	Usage: Sit.Aw.	Usage: Inspect.
Main Aircraft Windows	135x35	220x45	X	X	
Aft View	None	45x35		X	X
Side Mirror View	None	See Aft View			X
Hatch Overhead View	None	90x70	X	X	
Cross Hatch View	None	30x15	X	X	
Down View	None	(70x15)	(X)	X	
Hatch Mirror View	None	None			((x))

- Viewing areas not well supported by Training Requirements:
  - Down view
  - Hatch mirrors

E-2 OFT
Field of Regard (FOR)

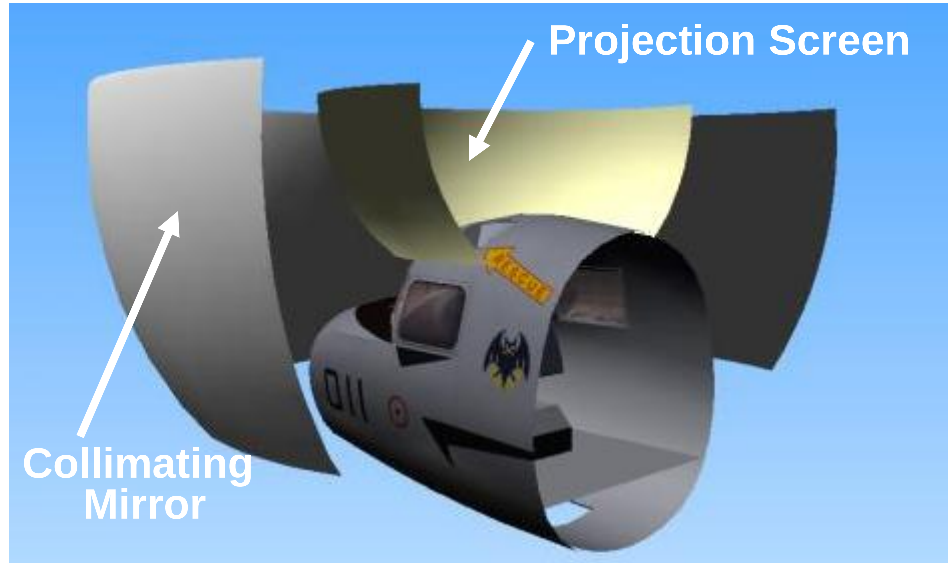
- Field of Regard (FOR) is the driving requirement for Field of View
  - What the crew can actually see
  - Considers eyepoint movement
- Eyepoint movement is function of:
  - Pilot Design Eyepoint (DEP) – location of pilots' eye in the cockpit
  - Crew equipment
    - Helmet and visor
    - 5-point harness with survival gear
  - Seat restraints (Koch fittings & harness lock)
    - Most Constrained: Koch fittings connected, harness locked
    - Moderately Constrained: Koch fittings connected, harness unlocked
    - Least Constrained: Koch fittings disconnected
  - Pilot Duties
    - Pilot At Controls (PAC) – moderate FOR
    - Pilot Not Flying (PNF) – extreme FOR (inspection & self defense)

Display System Requirements Analysis by Viewing Area

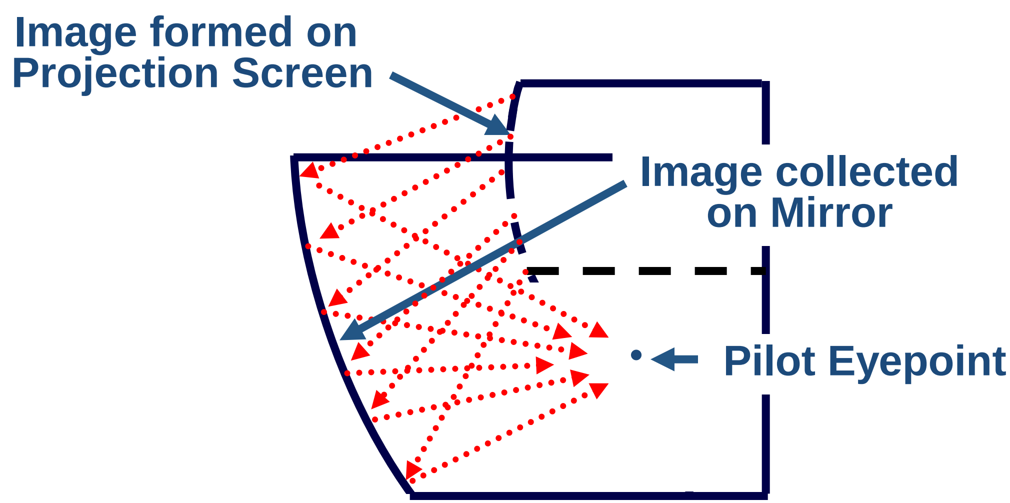
Main Windows, cont.

Key Features:

- Collimated image provides cross-cockpit view with common line up cues for both pilots
- TFOV: 220x45 (+25, -20)
- 100% COTS



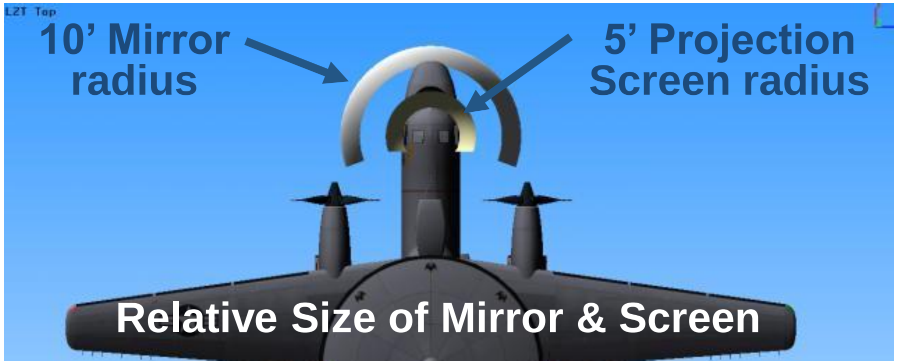
Typical 'WIDE' Display

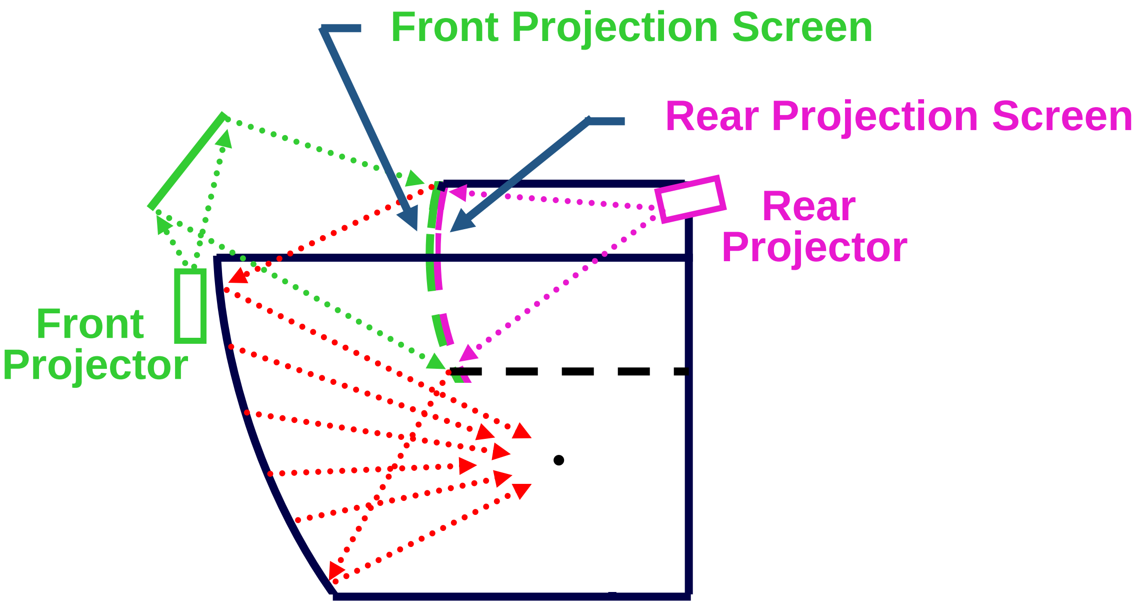


Main Windows, cont.

Options:

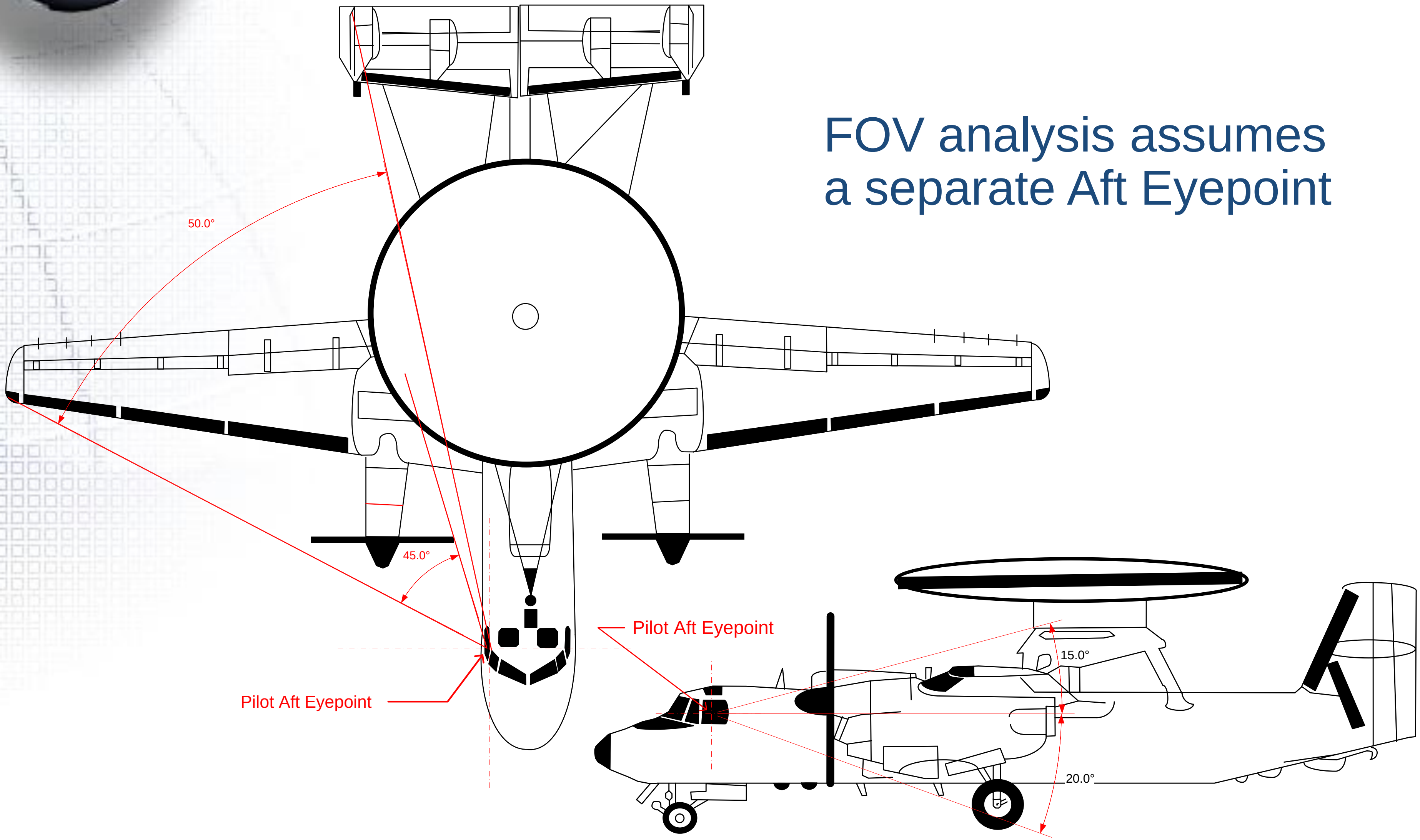
- **Mirror**
  - **Mylar**
    - **Lightweight, less costly**
    - **Not cleanable but easier to replace**
  - **Glass**
    - **Brighter, better collimation**
    - **Durable and cleanable**
- **Projection Screen**
  - **Front projection**
    - **Projectors front of screen**
    - **Brighter, more contrast**
    - **Greater HFOV, less costly**
  - **Rear projection**
    - **Projectors behind screen**
    - **Greater VFOV, more sources**



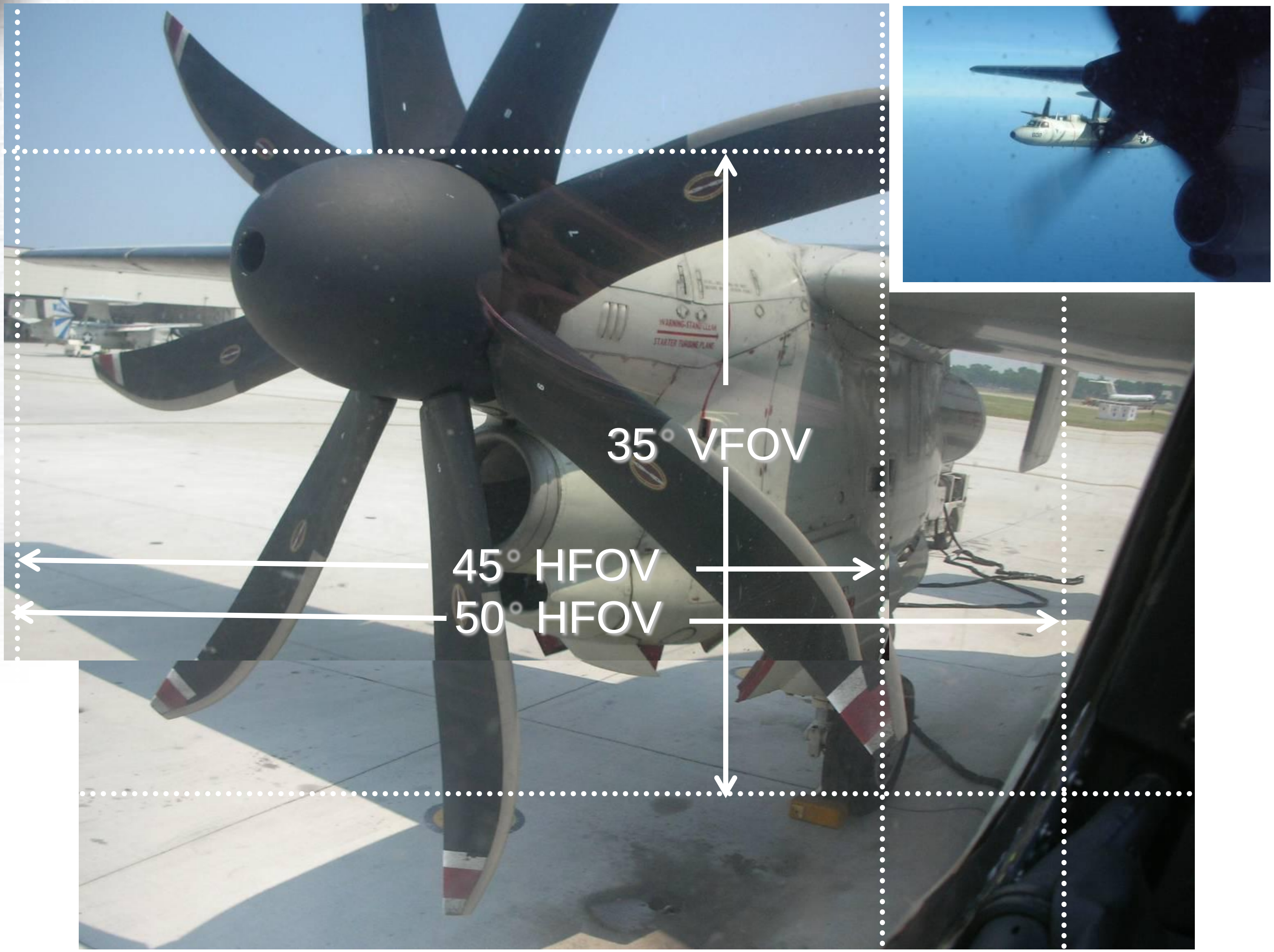


Aft View

FOV analysis assumes a separate Aft Eyepoint



Aft View, cont.



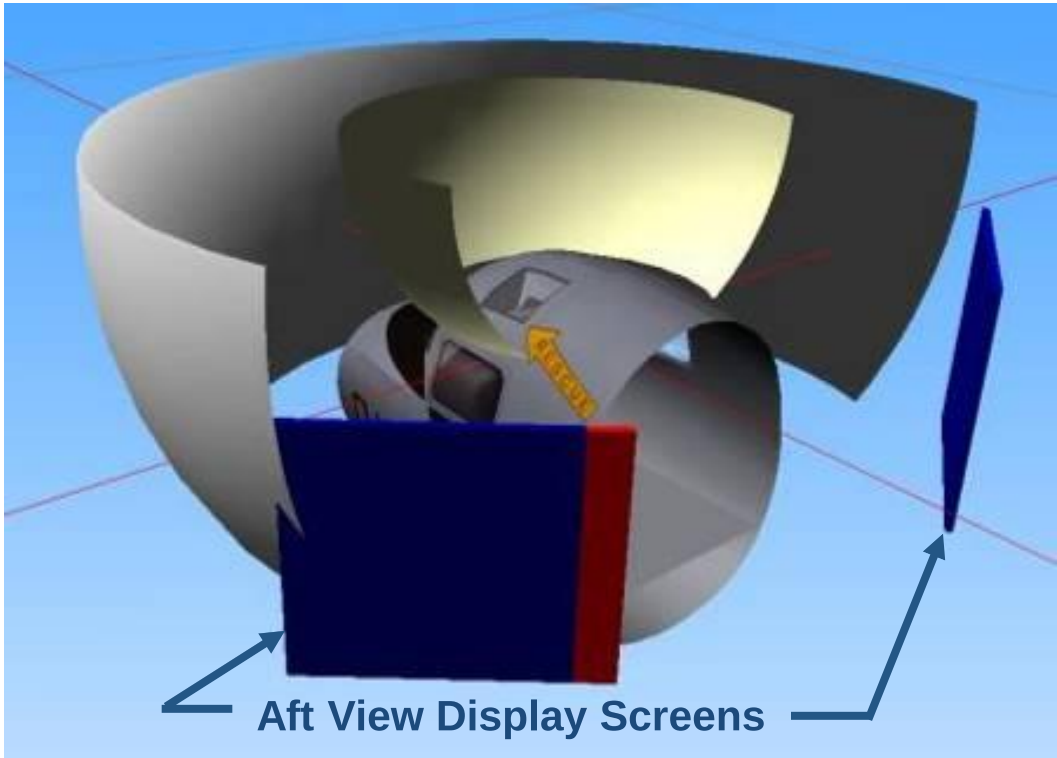
Aft View, cont.

Key Features:

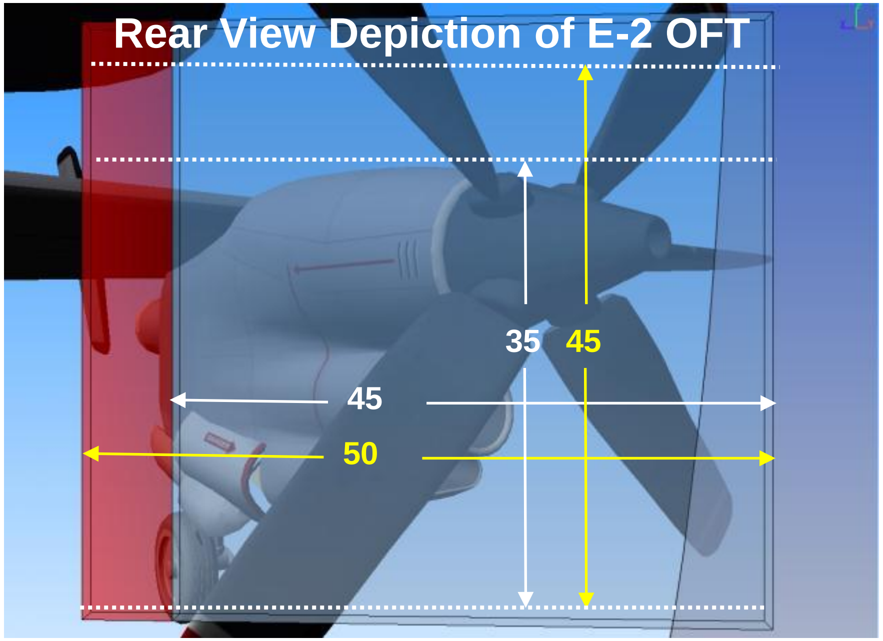
- **Main Windows Forward View plus…**
- **2 Aft Displays**
  - **FOV: 45x35**
  - **Projected or Direct View**
  - **Screen size may vary**
  - **Baffles to control Main display illumination**
  - **Allows use of side mirrors**

Aft View Options

- **Front or rear projection**
- **Flat or curved screen**
- **Direct view device**
- **Distance from eyepoint**
- **FOV: 50x45 or 45x35 or 45x45**
- **Use of "image minification"**



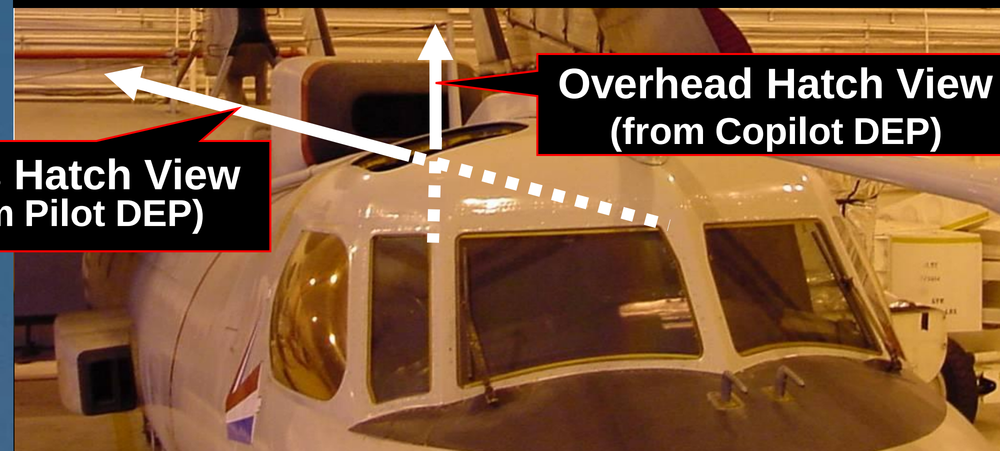
Aft View, cont..



Side Mirror View

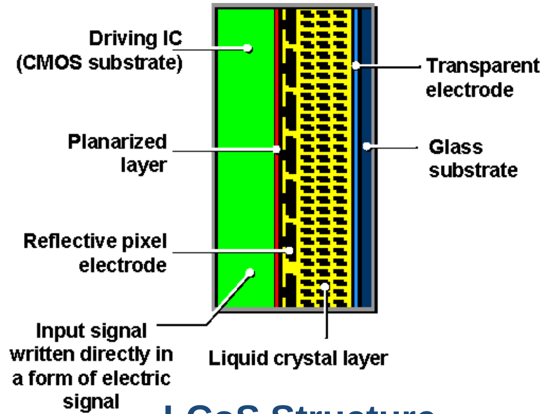
Ditching Hatch View

Two Ditching Hatch Views for each Pilot:

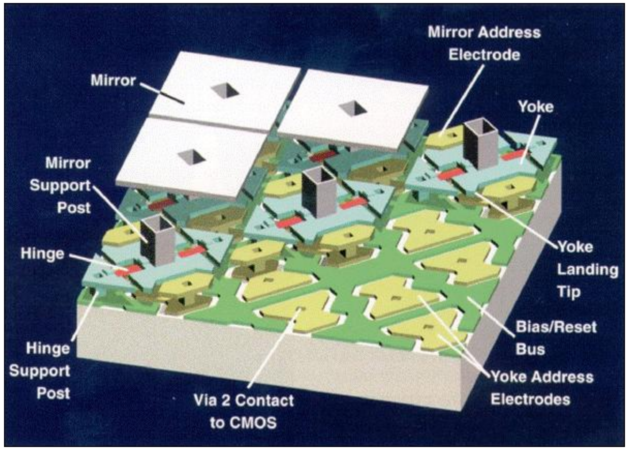


Technology Solutions Evaluated

- Task 3: Evaluate **Projector** Technologies against requirements
  - COTS
    - Direct View:
      - CRT Monitors
      - LCD
      - Plasma
      - OLED (small displays)
    - Projection:
      - CRT
      - LCD
      - DLP
      - LCOS
  - Emerging COTS:
    - LCOS Projectors
    - HMDs
  - Developmental:
    - Laser Projectors
    - OLED (large displays)
    - Stereo

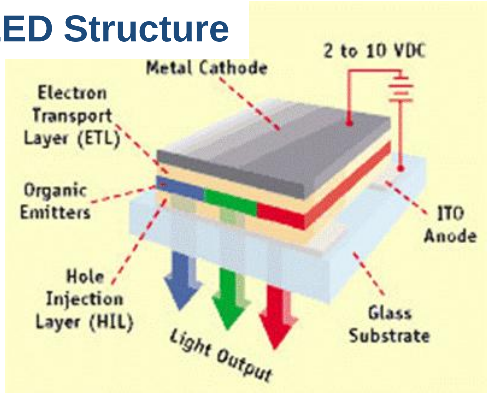


LCoS Structure



DLP (Digital Micro-Mirror Structure

OLED Structure

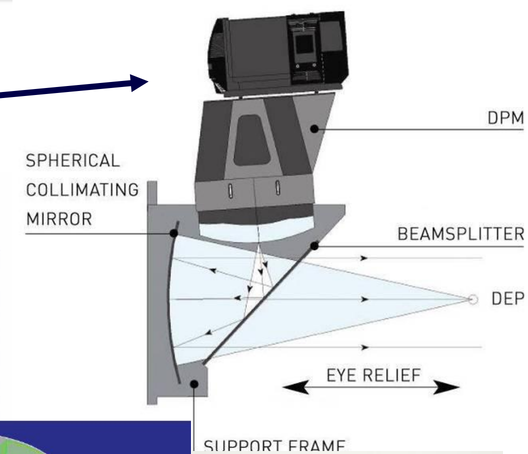


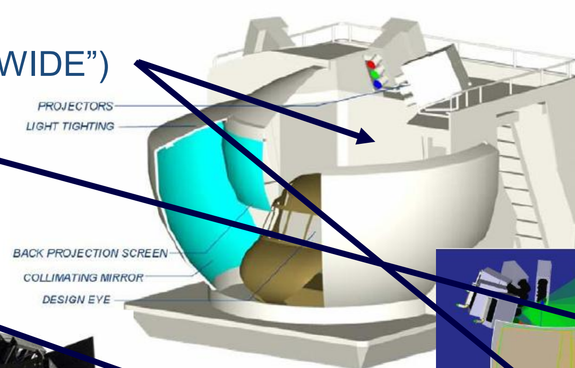
DLP Projector

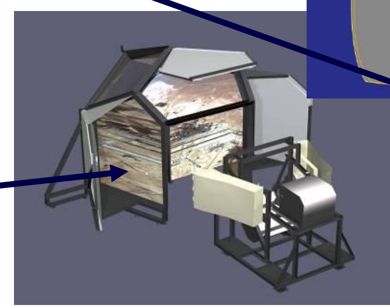
- **Bottom line:**
  - **Technology selection should be a supplier decision**
  - **LCoS and DLP projection technologies offer excellent brightness & resolution**

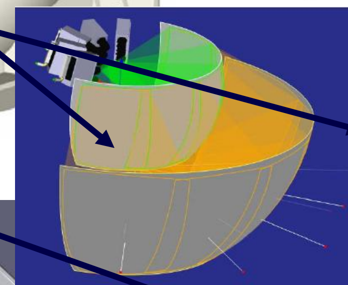
Display Approaches Evaluated

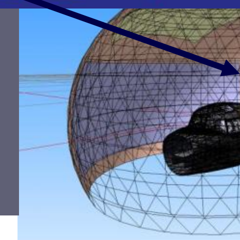
- Task 4: Evaluate Display Approaches
  - –Collimated (virtual image)
    - WAC
    - Cross Cockpit Collimated Display (“WIDE”)
    - Helmet-Mounted (HMD)
    - Pancake windows
  - –Real Image
    - Domes/dome sections
    - Curved screens
    - Flat screens
    - Faceted Screens
    - Direct View
    - Combined Images
    - Types:
      - – Direct View
      - – Front projection
      - – Rear Projection
  - –Hybrid

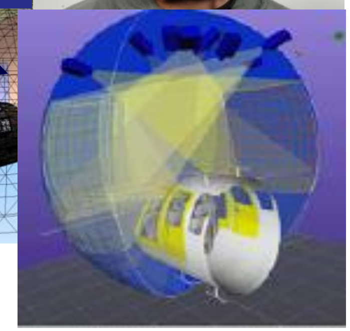












- **Bottom line:**
  - **Many good options; Specific approach is a supplier decision**
  - **Use of proven/COTS approaches is recommended for cost and risk reduction**

Display System
House of Quality
Analysis

House of Quality
Analysis of Display Alternatives

HOUSE OF QUALITY….
… a methodology to:

- Identify, group, & prioritize Customer Requirements
- Identify, group & prioritize Design Requirements
- Define Design Requirements as measurable Evaluation Criteria
- Evaluate alternative Design Approaches against the Evaluation Criteria

E-2 OFT Display Study: House of Quality (Final 19 Oct 06)		Field of View									Image Quality									Integr.		Availability				Acqn Cost		
Display Design Requirements	Customer Importance	Main Horizontal FOV	Main Up FOV	Main Down FOV	Aft FOV	Side Mirror View	Overhead Hatch FOV	Cross Hatch FOV	Cross Cockpit View / Parralax	Viewing Volume	Gaps (within viewing areas)	Resolution	Contrast	Luminance	Luminance Variation	Geometric Accuracy	Channel Matching	Collimation	Black Level	Cockpit Compatibility	Integration Complexity	Reliability	Maintainability	COMS Supportability	Consumables Cost	Display Cost	No. IG Channels	Facility Fit
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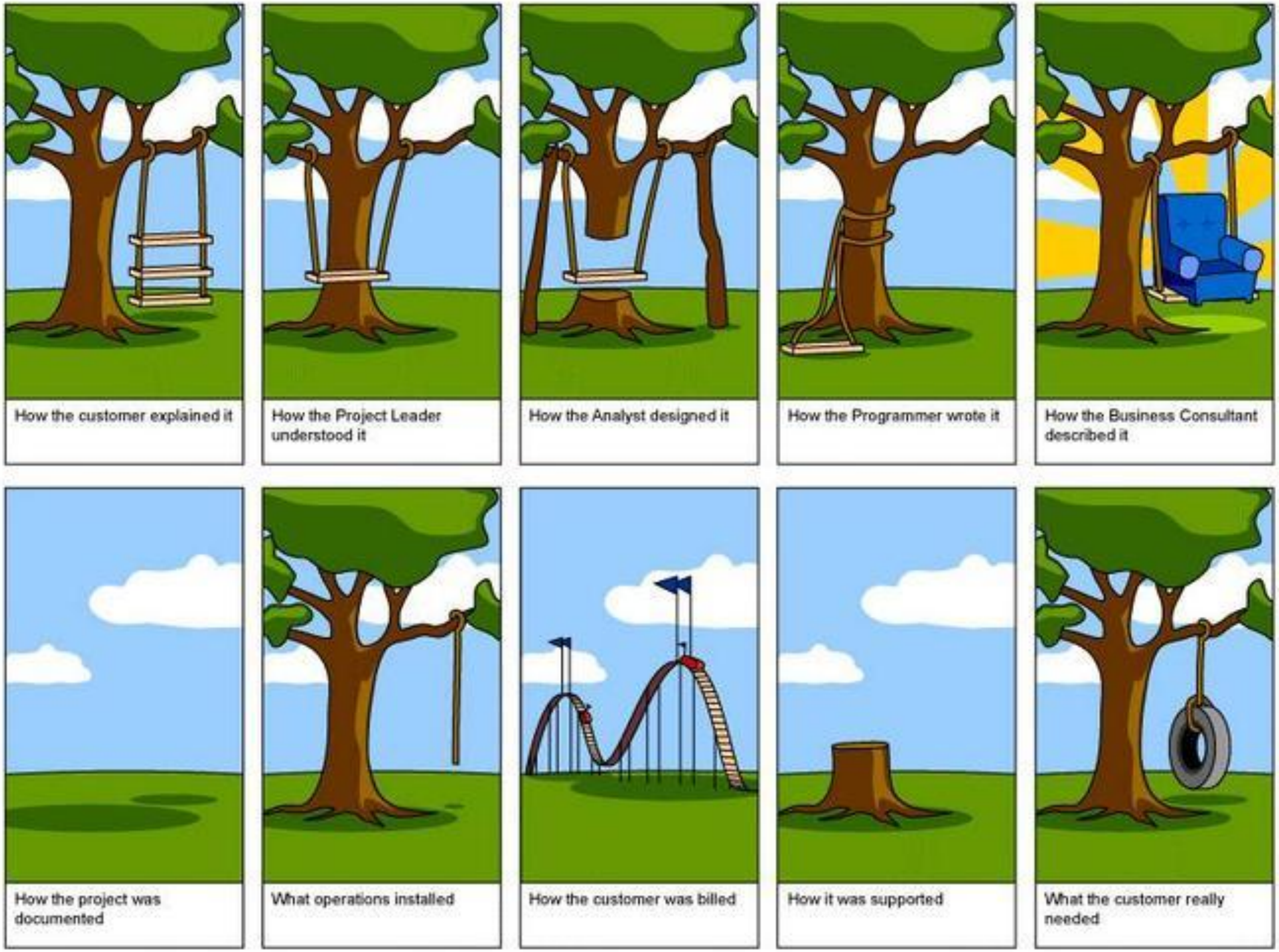
Affordable life cycle support cost	4																											
Technical Priority		5	5	2	4	3	4	4	5	4	3	5	5	4	3	4	5	5	4	5	5	5	5	5	4	5	4	5
Design Requirements - Desired		±115	+30	-45	50x45	Yes	120x100	40x15	Yes	6"	#1	#3	20:1	10fL	#4	#5	#6	#7	#8	No Cut	Med	#9	#10	Yes	#11	$1.5M	≤10	#12
Design Requirements - Minimum Acceptable		±110	+25	-20	45x35	Yes	90x70	30x15	Yes	6"	#1	#3	12:1	10fL	#4	#5	#6	#7	#8	Min Cut	Low	#9	#10	Yes	#11	$1.0M	≤12	#12
Design Approaches:																												
1 Collimated WIDE (220x45) (Mylar)																						+	+	+	+	1.0	5	
2 Collimated WIDE (220x45) (Mylar)+Real Im. Aft & Hatch Displays															--						--					1.8	10	
3 Collimated WIDE (300x45) (Mylar)+Real Image Hatch Displays											--				--							--	--	--		3.0	10	
4 Colllimated WIDE (300x60) (Mylar) + Real Image Hatch Displays				+							--				--							--	--	--		3.5	14	
5 Collimated WIDE (300x45) (Glass)+ Real Image Hatch Displays											--				--			+				+		--		2.3	10	
6 Collimated WIDE (220x45) (Mylar)+Real Image Aft Displays															--											1.3	7	
7 Collimated WIDE (220x45) (Mylar)+ Real Image Hatch Displays															--											1.5	8	
8 Collimated 220x45 (Mylar) + Helmet Mounted Displays											--										--	--	--	--	--	2.0	9	
9 Real Image ≥15' Dome (300x60+ Overhead)												+														1.8	10	
10 Real Image 15' Dome Section (300x60+ Overhead)												+			--						--					1.8	10	

8.3 Systems Engineering

Systems engineering is an interdisciplinary approach to manage the technical realization of a successful program.

Systems engineering processes provide technical insight into the holistic status of the program.

Requirements Matter



Reference: http://www.my-project-management-expert.com

So What do you Do?

So, how do you manage all this?

The systems engineering process provides tools to allow the team to provide the right level of data and insight for the program team to make the right

decision.

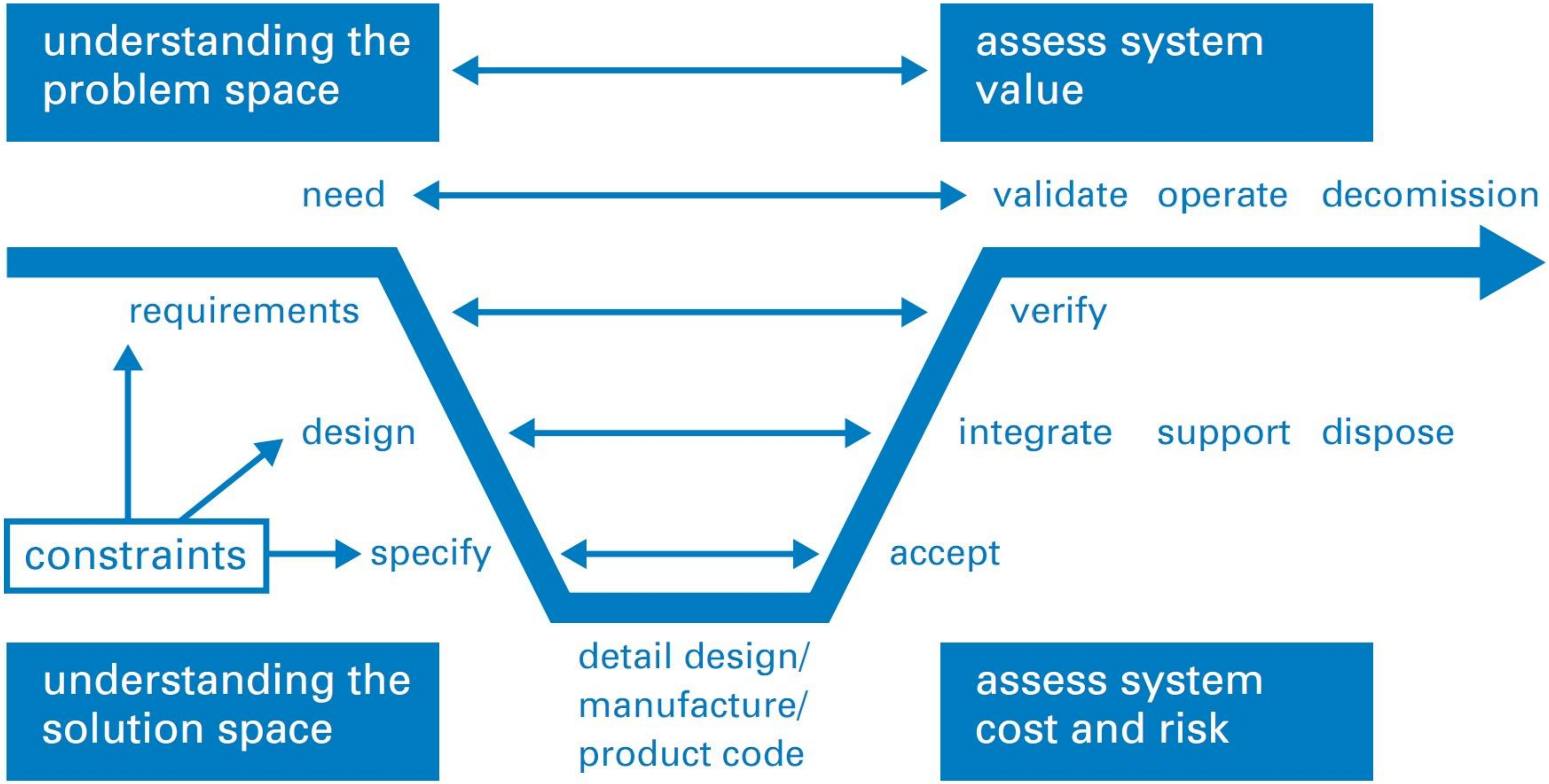
The systems engineering process allows you to break down the complexity to address and manage program risks for Cost, Schedule and Performance (CSP).

The systems engineer looks at the holistic aspect of the system and provides technical recommendations to the Program Manager and Team Members.

What's so hard?

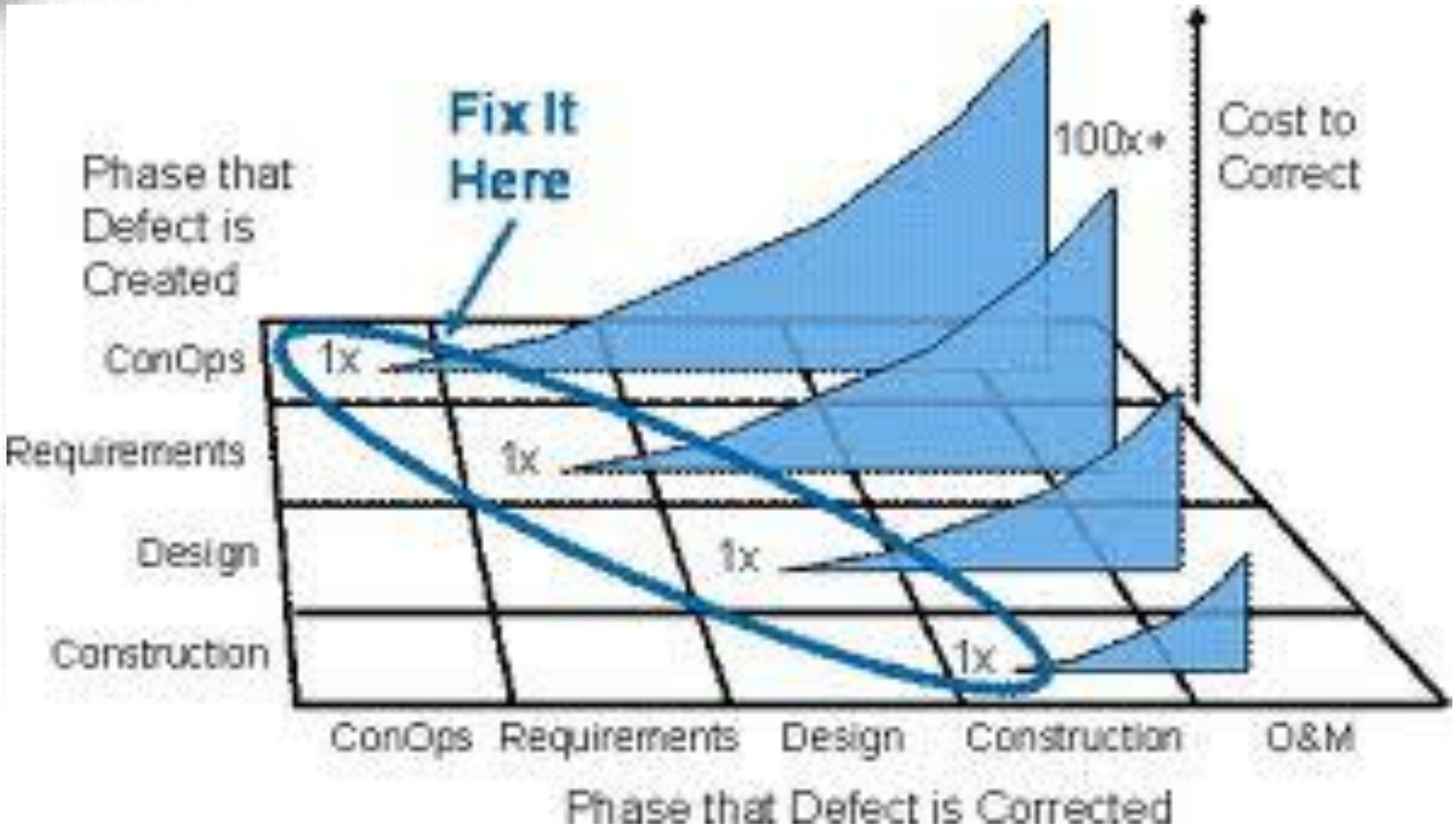
- Need to integrate many technical disciplines
- Cost considerations that impact desired approach
- Schedule considerations
- Manage Trade-offs among technical disciplines
- Technical solution may be too expensive to run or maintain, may exceed initial system cost
- Architecture (software/hardware) may not support future changes
- Requirements / Resources may change

Systems Engineering V



Reference: http://www.incoseonline.org.uk

Why can't you fix it later?



Reference: *http://ops.fhwa.dot.gov/publications*

SE Fundamentals

- Know the requirements (what's needed?!)
- Derive further details from requirement
- design
- Trace requirements and design in a Requirements Traceability Matrix (RTM)
  - Why? The RTM allows changes in design to flow back to the base requirements and customer stated need (or training objectives for virtual training systems)
- The RTM also flows thru design documentation, resulting in the basis for your testing (Inspection, Verification, Validation)..

SE Fundamentals
(continued)

- Capture Program Risks - document with impact and mitigation strategies
  - Regularly share risks across (no surprises!)
- Technical design reviews – these are held based on the progression of the design (event vs. schedule driven)
- SE process breaks complex problem down into manageable components
- Utilize overarching project schedule (Integrated Milestone Schedule, IMS)

SE Fundamentals

(continued)

- Project documentation
  - Project documentation and review is critical to project success, but can be difficult to prioritize when a project gets behind schedule.
  - Challenge to manage the entire program vs. the daily fire drills that may have bigger impacts to the program later

SE Continually evaluates the technical teams' status, product status, known risk areas, integration across system components, integration progress, overarching schedule status, personnel requirements, interim product item completion, test status, risk and issue management

Job Opportunities

- System Engineering
- Project Engineering
- Research and Development
- STEM Expertise
  - Requirements Analysis
  - Visual Systems
  - Motion Platforms
  - Sound Systems and Communications
  - Software Programming
  - Architecture Design (Hardware and Software)

Job Opportunities
(continued)

- STEM Expertise *(continued)*
  - Vehicle Dynamics Modeling – Platform, Threats
  - Environments Data and Modeling
  - Weather Modeling
  - Networking
  - Interoperability
- Action Environments
  - Scenario Generation
  - Team Interactions
  - After Action Review

Job Opportunities

(continued)

- Infrastructure
  - – Facilities
  - – Security
    - Information Assurance
    - Classification Level
    - Anti-Tamper
- Training Effectiveness Evaluations
- Logistics Planning and Support

Thank you!

Questions?