Simulation Technology at NASA

Bimal L. Aponso

Aerospace Simulation Research & Development Branch
NASA Ames Research Center
Moffett Field, CA

Presented at the The National Academies' Workshop on Opportunities for the Employment of Simulation in U.S. Air Force Training Environments

November 17-19, 2014

Outline

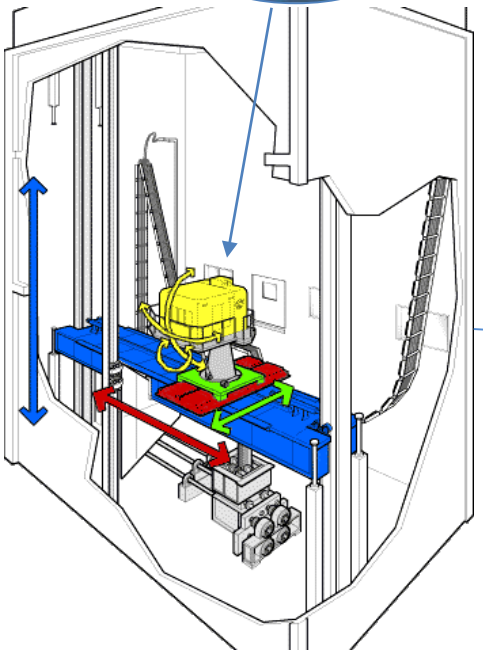
- Overview of simulation capability at NASA
  - Ames Research Center
  - Other facilities
- LVC development and uses
- Research uses and trends
- Limitations
- Thoughts on solutions

Simulation Uses at NASA

- Support Research and Development Projects
  - Vehicle Systems and Safety Technologies
  - System-wide Safety and Assurance Technologies
  - NextGen Concept and Technology Development
  - NextGen Systems Analysis and Integration
  - Fixed- and Rotary-Wing Technologies
  - UAS Integration in the NAS
- Support Human Spaceflight Program
  - Shuttle Orbiter Engineering Development
  - Shuttle Orbiter Flight Training
  - Orion Crew Vehicle/Space Launch System
  - Commercial Space Transportation
- Support Government and Industry R&D
  - Leverages high-fidelity simulation facilities and expertise
  - Users include FAA, DoD, major Aerospace companies

Simulation Facilities at NASA Ames

Unique, high-fidelity, simulation facilities and skilled staff enable a wide range of aerospace systems research



Vertical Motion Simulator (VMS)

Full-Motion Flight Simulators

Airport Control Tower Simulator

Air-Traffic Control Simulators

Internal Network

Distributed Simulation Research Lab

External Simulators

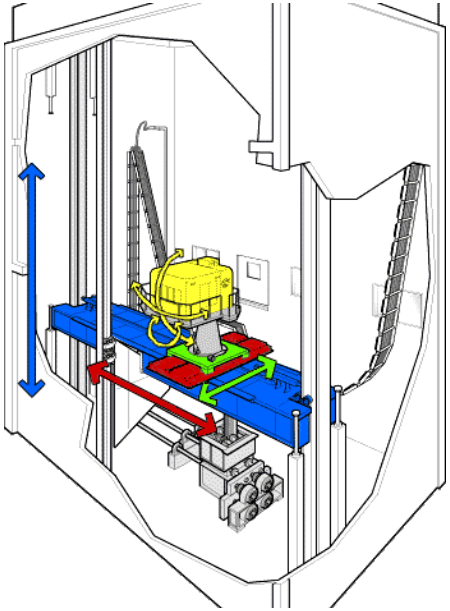
Vertical Motion Simulator (VMS)

- Large amplitude motion system
  - Accurate motion cues for precision maneuvering tasks
  - Customizable motion parameters
- Interchangeable cabs
  - Five cabs with varying visual fields-of-view and cockpit layouts
  - Programmable multi-function displays
  - Programmable force-feel systems with a variety of inceptors
- High-fidelity visual systems
- Flexible simulation architecture
  - Tailored to research applications
  - Accepts user software and hardware modules

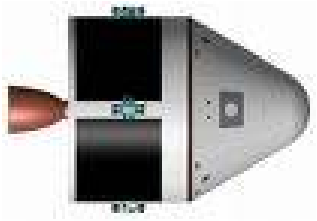
Unparalleled Visual/Motion Cueing

VMS Motion System

- Six independent degrees-of-freedom
  - One-to-one motion possible
- Large displacement
  - ±30 ft vertical
  - ±20 ft lateral
  - ±4 ft longitudinal
- Longitudinal and lateral axes can be swapped by orienting cab
- 0.7 g vertical acceleration capability



Vehicles Simulated on the VMS

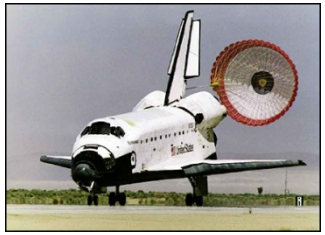


Crew Exp. Vehicle

Lunar Surf. Acc. Module

X-32B

X-35B



Space Shuttle

Speed Agile Concept

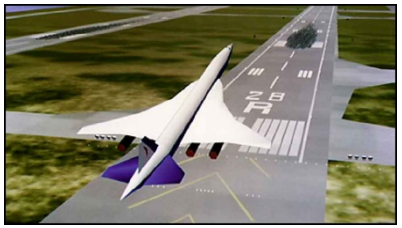
C-17

Tilt-Rotor

USAir 427

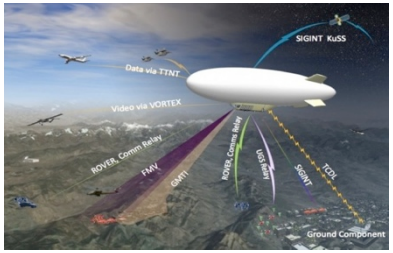
AV-8B

RAH-66



High Speed Civil Transport

UH-60



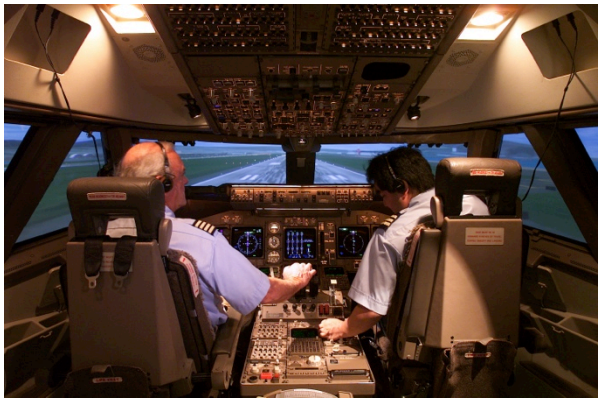
USAF MAV6 Airship

CH-47 with slung loads

NT-33

Crew Vehicle Systems Research Facility (CVSRF)

- Boeing 747-400 full-flight simulator
  - Certified to FAA Level D
  - NASA has access to model and display software
- Advanced Concepts Flight Simulator (ACFS)
  - Configurable for research
  - B737-800W, C-17, Generic twin-jet models
- Research applications include:
  - NextGen concepts/procedures
  - Quiet arrival/departure procedures
  - Avionics concepts
  - Cockpit human factors



B747-400 FFS

ACFS

High-fidelity simulation for flight operations/procedures research and training

Air Traffic Control Simulators

- Realistic emulation of the National Airspace System (NAS)
  - Aircraft performance
  - Airspace definitions
- FAA standard controller stations
  - DSR and STARS display simulations
- Actual STARS systems
- Pseudo-pilot stations
- Voice switched audio communication system
- Data and video recording system

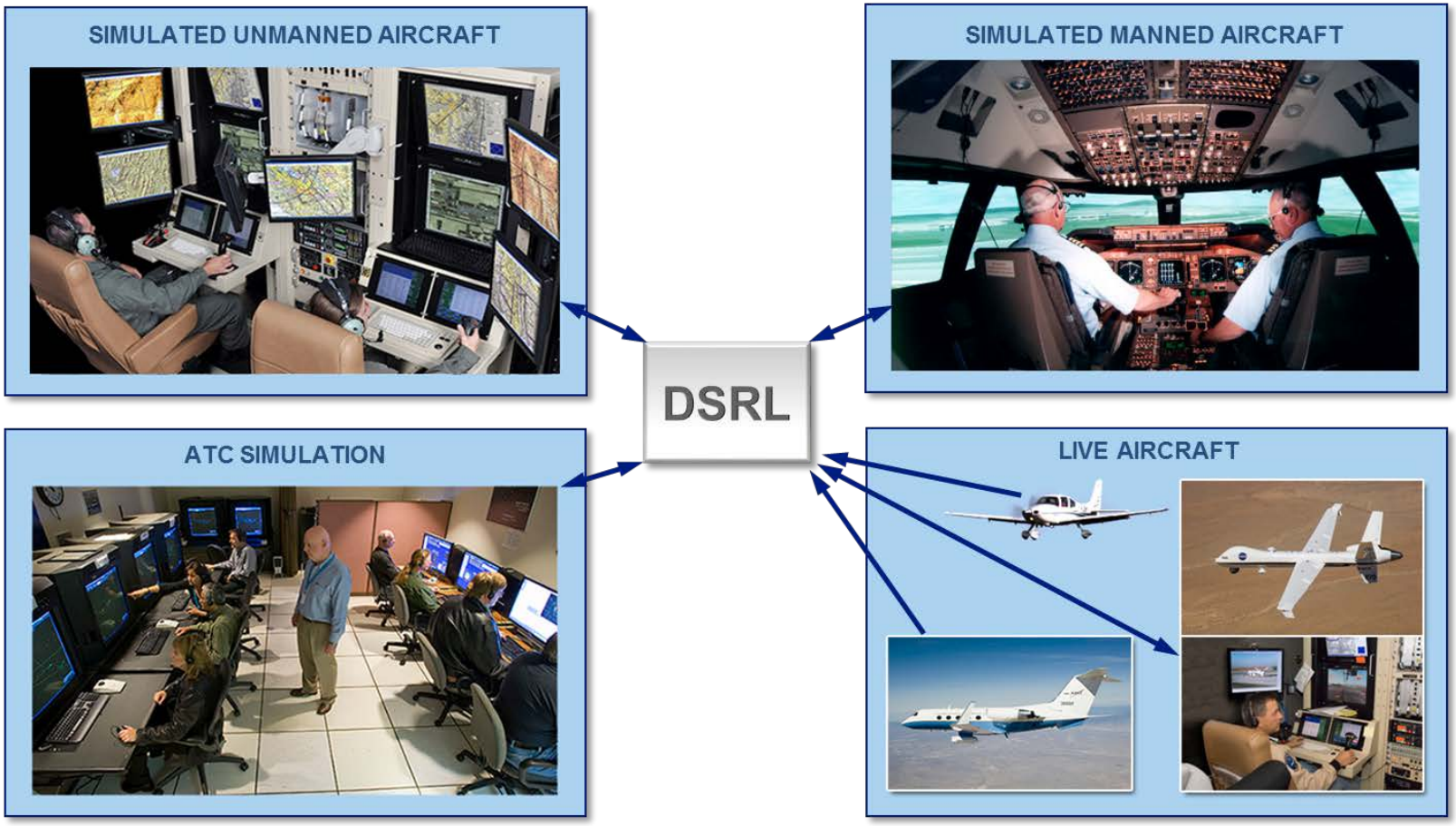
Adaptable, high-fidelity simulation environment for testing ATC concepts and procedures

Air Traffic Control Tower Simulator

- Full-scale, 20-ft diameter, airport control tower simulator
- 360-degree high-resolution out-the-tower displays
- Realistic traffic/environment simulation
- Adaptable software/hardware architecture for testing future concepts and systems
- Research applications include:
- NextGen concepts/procedures
- Airport design and safety research
- Remote robotic operation command and control

High-fidelity, adaptable, visual environment for research and training

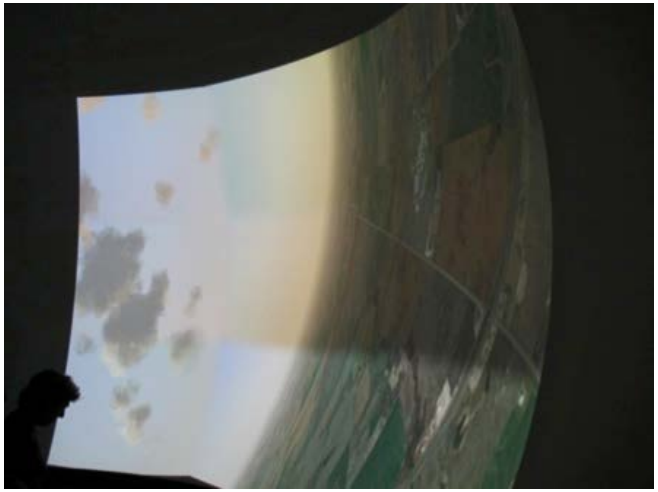
Distributed Simulation Research Laboratory



Flexible development environment for networked distributed simulation

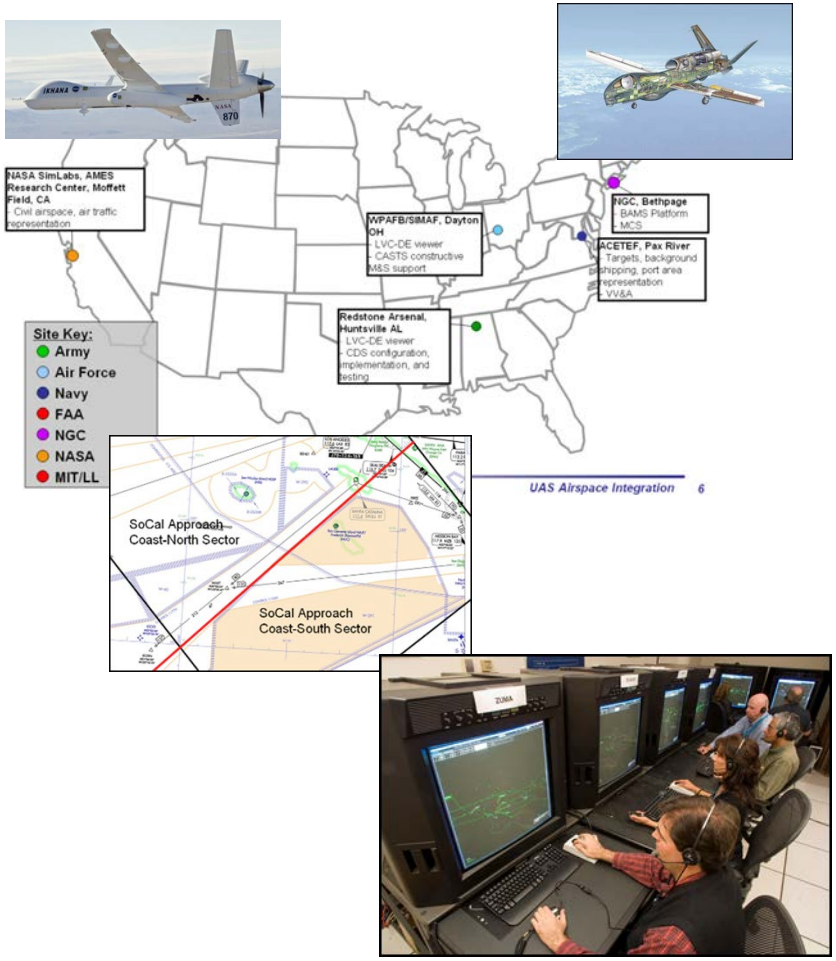
Operational Based Vision Assessment Simulator

- USAF needed to correlate clinical vision standards with aircrew operational performance
- Required simulator with visual acuity of 20/10 or better using COTS hardware/software
- System researched, designed, and built at NASA Ames with USAF funding
- Flexible simulation architecture using COTS hardware and software
- Complete simulator system installed at WPAFB in 2012



NASA Ames LVC Experience

- 2004 - Now: NASA Air Traffic Management Research leveraging AVSimNet and Virtual Airspace Simulation Technology (VAST)
- 2009 & 2010: Navy BAMS (RQ-4N) Live Virtual Constructive Distributed Environment (LVC-DE)
- 2011: American Recovery & Reinvestment Act (ARRA)
  - TCAS & GCS Automation Study
- NASA UAS-NAS Project IT&E
  - Progressive build-up and test of LVC capability



NASA UAS-NAS Project Research Themes

RT1

UAS Integration

- Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

RT2

Test Infrastructure

- Test infrastructure to enable development and validation of airspace integration procedures and performance standards.

LVC

An adaptable, scalable, and schedulable relevant test environment for validating concepts and technologies for unmanned aircraft systems to safely operate in the NAS

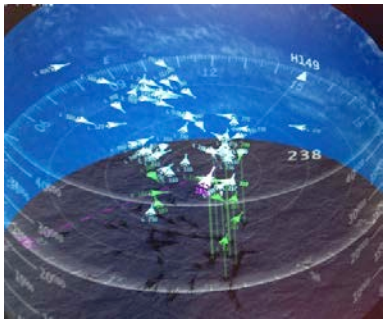
Early Equipment Integration and Checkout

ADS-B Integration on the Ikhana UAS

- Integrated a COTS (Garmin GDL-90) ADS-B onto a large UAS
  - Full ADS-B Out and In functionality
  - Unprecedented traffic situational awareness to UAS pilots
- Collected ADS-B "as installed" performance flight test data
  - Accuracy, uncertainty of position, velocity, and altitude reports
- Flight test results (Flight Test Series 1)
  - Verified ADS-B Out met FAA Advisory Circular AC 20-165 for ADS-B Out equipage
  - Valuable FAA Tech Center support with validated data analysis tools
  - **Connected Armstrong to LVC and Verified data exchange of live, virtual, and constructive traffic information between all participants**

Ikhana flight path as tracked by the national ITT ADS-B Surveillance Network

ADS-B Ground Tests on Ikhana UAS



Live ADS-B and TIS-B data shown on virtual cockpit display

Distributed Connectivity Demonstration

Initial test of distributed simulation capability among multiple participants

NASA Ames

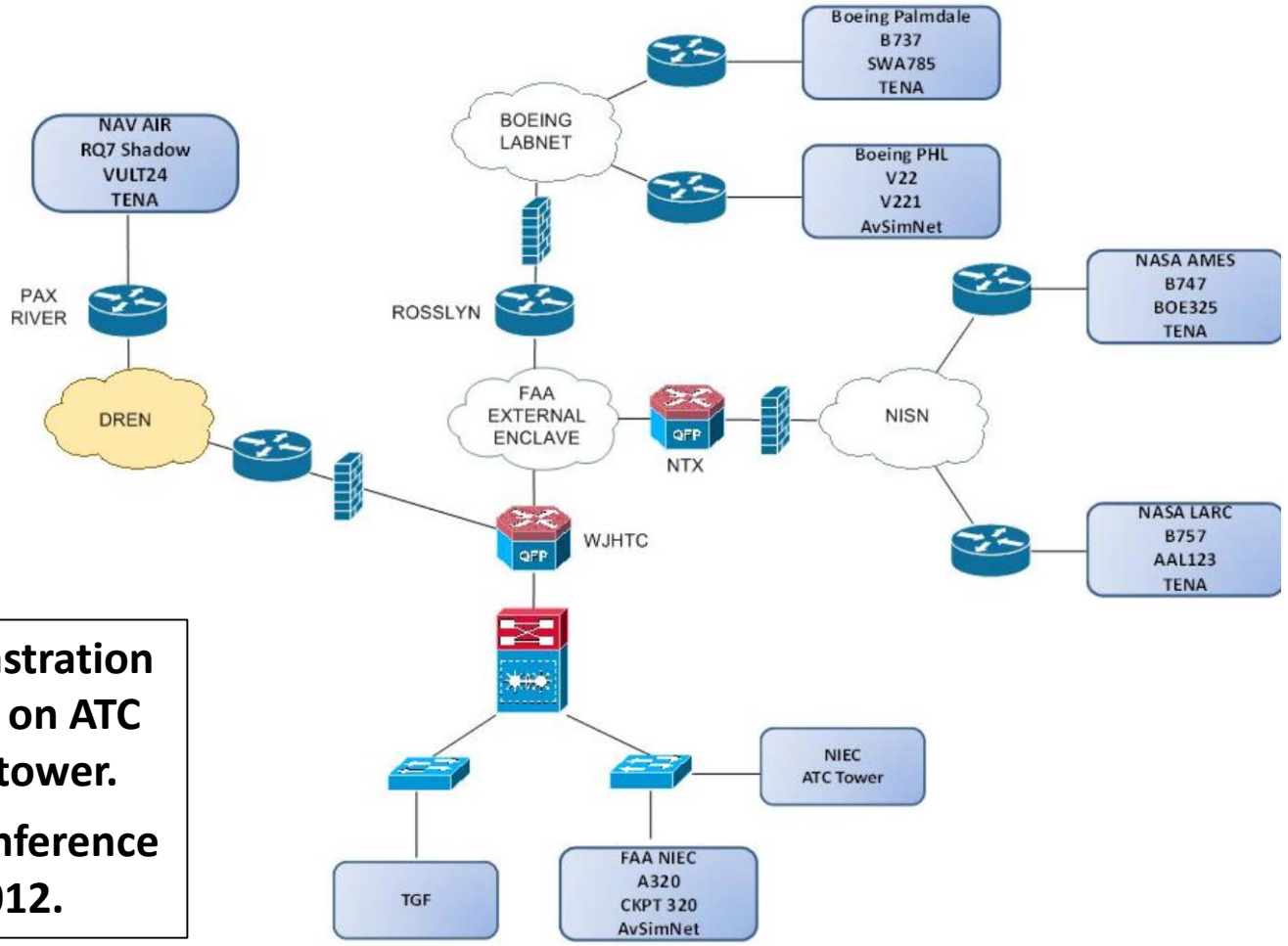
NASA Langley

DoD NavAir Pax River

Boeing Palmdale

Boeing Philadelphia

FAA Technical Center

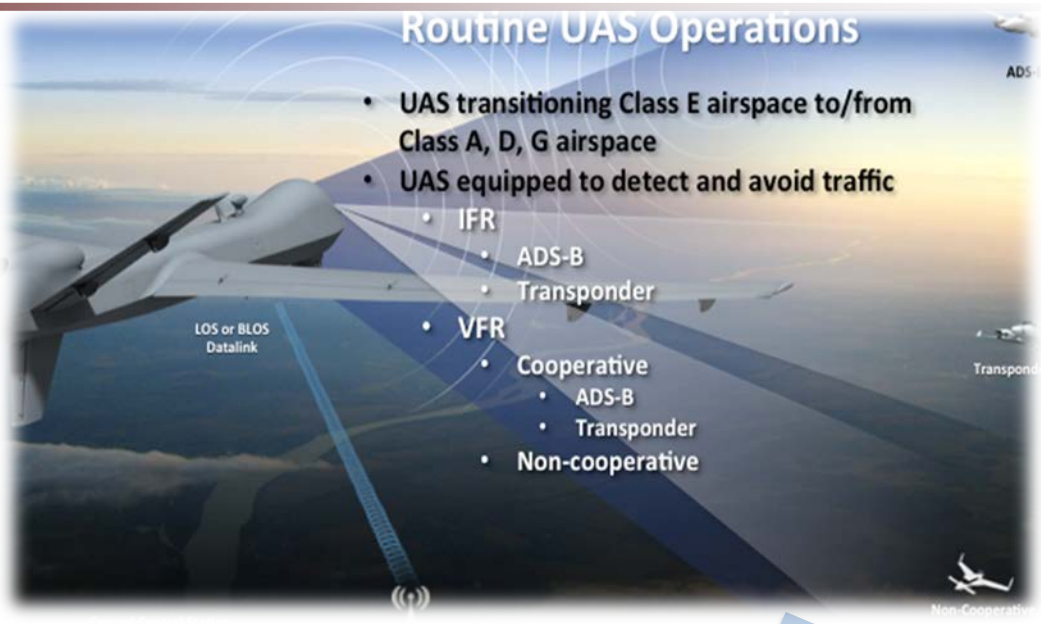


August 2012: Demonstration of simulated targets on ATC scopes and virtual tower.

Presented at ITEA conference in September 2012.

Integrated Human-in-the-Loop Simulation

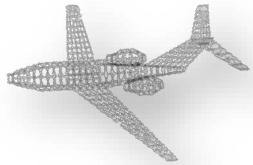
Completed Summer 2014



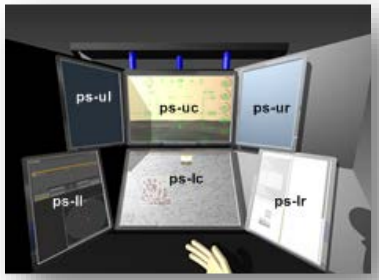
Virtual UAS

C2
Data Link Model

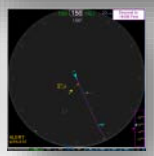
Virtual/Constructive Intruders



UAS Pilot as Subject



Research GCS



Basic and Advanced Displays of Proximal Traffic

VPN

ATC as Subject

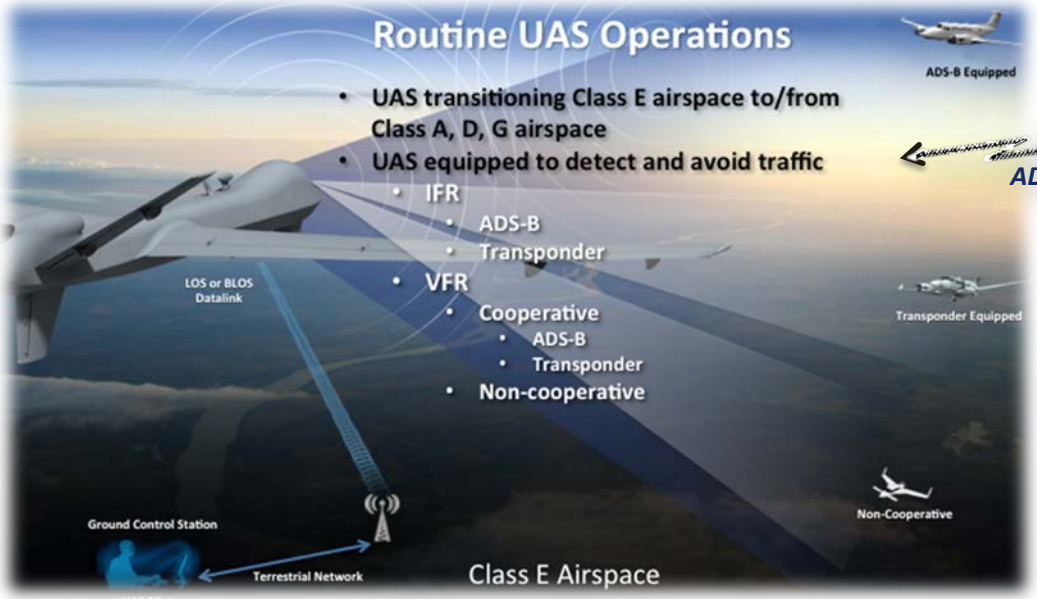
Multi-Aircraft Control System

UAS Flight Test

Summer 2015, Spring 2016

C2
Data Link Model

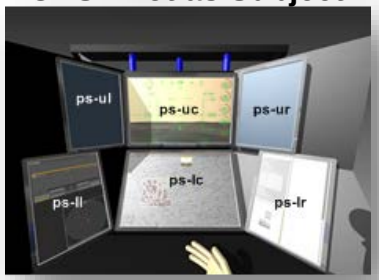
CNPC
Data Link
- *C2*
- *Voice*
- *H&S*
- *Video*
- *Traffic*



Live Intruders
ADS-B
TCAS II
High speed

Virtual/Constructive Intruders

UAS Pilot as Subject



Research GCS

Displays of Proximal Traffic

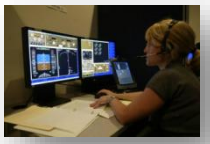
Real-World Airspace and Scenarios

VPN

Distributed Environment/Connectivity

Virtual ATC

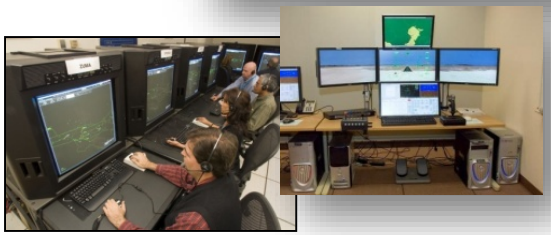
Virtual Intruder(s) (Pseudo Pilots)

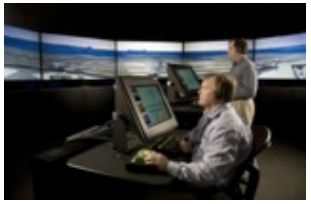


Multi-Aircraft Control System

Assets Connected to UAS LVC

- Live
  - Ikhana (NASA's MQ-9)
  - T-34C (Manned Intruder)
  - S-3B (Viking) (Surrogate UAS)
- Virtual
  - B747 Flight Simulator (NASA Ames)
  - Ikhana Sim (NASA Armstrong)
  - Multi-Aircraft Control System (MACS) ATC Emulator
  - Research Ground Control Station (GCS)
    - Vigilant Spirit Control Station (VSCS)
    - Multiple UAS Simulation (MUSIM)
  - Future Flight Central (NASA Ames)
- Constructive
  - NASA Airspace Simulation (MACS) Pseudo Pilot





Specific LVC Limitations

- Connection tested with a limited set of clients
- LVC infrastructure tested for a small number of aircraft (<100)
- Translate the location of the a live aircraft into an emulation of another real airspace (under development)
  - Magnetic variance
  - Altitude difference
  - Wind variance
- Matching live and virtual aircraft for precision maneuvers
  - Real vs. predicted wind variance
- Replacement of live target with virtual target
- Lack of aircraft and trajectory modeling for many aircraft classes
  - Small UAS
- Missing Emulation of ADS-B In and Out

Current Limitations

- Simulation modeling capability
  - Integrated high-fidelity fluid and structural dynamic effects for simulating, aerial refueling, close formation flight, etc.
- Consistency in modeling
  - Consistent coordinate systems, variable definitions, portable visual databases, etc.
- Network throughput for LVC simulation
  - Reduce simulation update times
- Quantify benefits of simulation relative to:
  - Risk mitigation
  - Transfer-of-training/"required level of fidelity"
- Funding to maintain/upgrade technical capabilities
- Workforce replenishment

Overcoming Limitations

- Dedicated funding stream to upgrade/maintain simulators to meet future simulation needs
- Improve perceptions on the benefits of simulation
  - Quantify cost/benefit in terms of risk-mitigation
  - Quantify transfer-of-training benefits
- “Plug-and-play” capability for LVC environments

Thoughts on Solutions

- Provide dedicated funding stream for maintaining and upgrading relevant simulation facilities
- Develop guidelines for interfacing distributed simulations – model interactions, communication protocols, IT security, etc.
- Develop guidelines on simulation fidelity requirements based on task
  - Modeling requirements
  - Human-system interface fidelity
  - Visual and motion fidelity

QUESTIONS?