

MQ-9 *Ikhana*

UAS-NAS Project Status:

- 1. FAA Pilot Training**
- 2. ADS-B Flight Tests**



Mark Pestana

Project Pilot

UAS-Integration-in-the-NAS

HSI & IT&E

NASA Dryden Flight Research Center

FAA UAS Pilot Training



Introductory NASA MQ-9 *Ikhana* (Predator-B) UAS Flight Operations Course



FAA Pilot Training: Purpose & Rationale

- **FAA Request** : Need for Aviation Safety Inspector (ASI) pilots to gain experience in UAS operations. Five ASIs attended the course.
 - Also included maintenance inspector.
- **Utilize NASA UAS experience**
 - Over 60-year history includes extensive RPV / UAV research flights.
 - Current UAS: MQ-9 Pred-B; RQ-4 Global Hawk, DROID SUAS (and X-48 support)
 - MQ-9 Predator-B (*Ikhana*) flown since 2007.
 - NASA developed standards for pilot training, qualification, currency.
 - Developed procedures and risk mitigation for simultaneous manned and UAS flight ops at Edwards AFB (airfield and airspace operations).
 - Extensive collaboration with FAA in COA development, hazard analyses/risk mitigation, and flight operations in the National Airspace System.
 - NASA- USFS Western States Fire Mission flown during wildfire seasons, 2007-2009.
 - U.S. Army TRACER missions flown 2010-2011 to/from Yuma, AZ, test range.



Training Plan

- Curriculum based on *General Atomics ASI* and USAF: adapted for NASA use.
- “Introductory” Curriculum previously developed and approved by NASA and USAF.
 - 2011: NASA DFRC provided first MQ-9 training for the USAF Test Pilot School.
- **NASA FAA Training Plan: 5-day introductory course; 07-11 May 2012.**
 - **1. Intro to UAS / MQ-9:** Tours of aircraft, GCS, and data-link systems. Controls, Landing gear
 - **2. Systems:** Fuel, Engine, Prop, Electrical, Lighting. Flight manual/checklist review.
 - **3. Systems:** Air data, Flight computers, Autopilot, Data-link, radios. Simulator sessions.
 - **4. Local Operations,** Limitations, EPs, Performance. Simulator sessions. Tech Brief to management.
 - **5.** Pre-flight brief, **Flight Demonstration,** Debrief, Forward planning.
- **Desktop Simulator: Part Task Trainer.**
 - Utilized for “hands-on” takeoff and landing, handling qualities and input response (including Ku latency).



Training Plan (cont.)

- **Flight demonstration conducted on 11 May 2012**
 - 2.4 hours total flight time, within Edwards AFB restricted airspace R-2515, C-Band Line-of-Sight C² only.
 - NASA pilots performed pre-flight checks, engine start, taxi, takeoff, climb, descent, landing.
 - Each FAA pilot flew about 0.4 hour: During “cruise” flight. With and without Autopilot engaged.
 - Autopilot engaged: Waypoint/flight plan generation/modification, navigation, lost-link flight planning.
 - “Hands on” flying: Pitch/bank/yaw demo; climbs/descents; input/response demo.
- **Follow-up plans:**
 - Continue training on MQ-9 simulator at FAA Tech Center, Atlantic City, NJ, with NASA DFRC Instructor Pilots.
 - Further collaboration and advising on flight crew standards, maintenance, airworthiness, safety analyses.
- **FAA investigating the utility of a traffic display system in GCS**
 - Planning to visit DFRC, interview UAS pilots, and conduct Part Task Simulations.





Ikhana – UAS-NAS ADS-B/LVC-DE Flight Tests



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Automatic Dependent Surveillance –
Broadcast (ADS-B)
Live Virtual Constructive –
Distributed Environment
Simulation and Flight Tests



LVC-DE Staffing



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- **Dryden Sim Lab**
 - Marlin Pickett
 - Martin Hoffman
 - Chris Howell
 - Jamie Willhite
 - Sam Kim (Alternate)
 - Carl Magnusson (Ikhana Sim Pilot)
- **Ikhana GCS**
 - Sam Kim
 - Martin Hoffman (Alternate)
 - Mark Pestana (Pilot)
 - Hernan Posada (Pilot)
 - David Ewers (SysMon)
 - Kathleen Howell (MD)
 - Ricardo Arteaga
 - Mike Dandachy
- **Ames Sim Lab**
 - Neil Otto
 - Srba Jovic
 - Jeffrey Hernandez
 - George Solar
 - Wayne Bridges
 - Dave Brown
 - Jacob Pfeiffer
 - Riva Canton
 - Jim Murphy



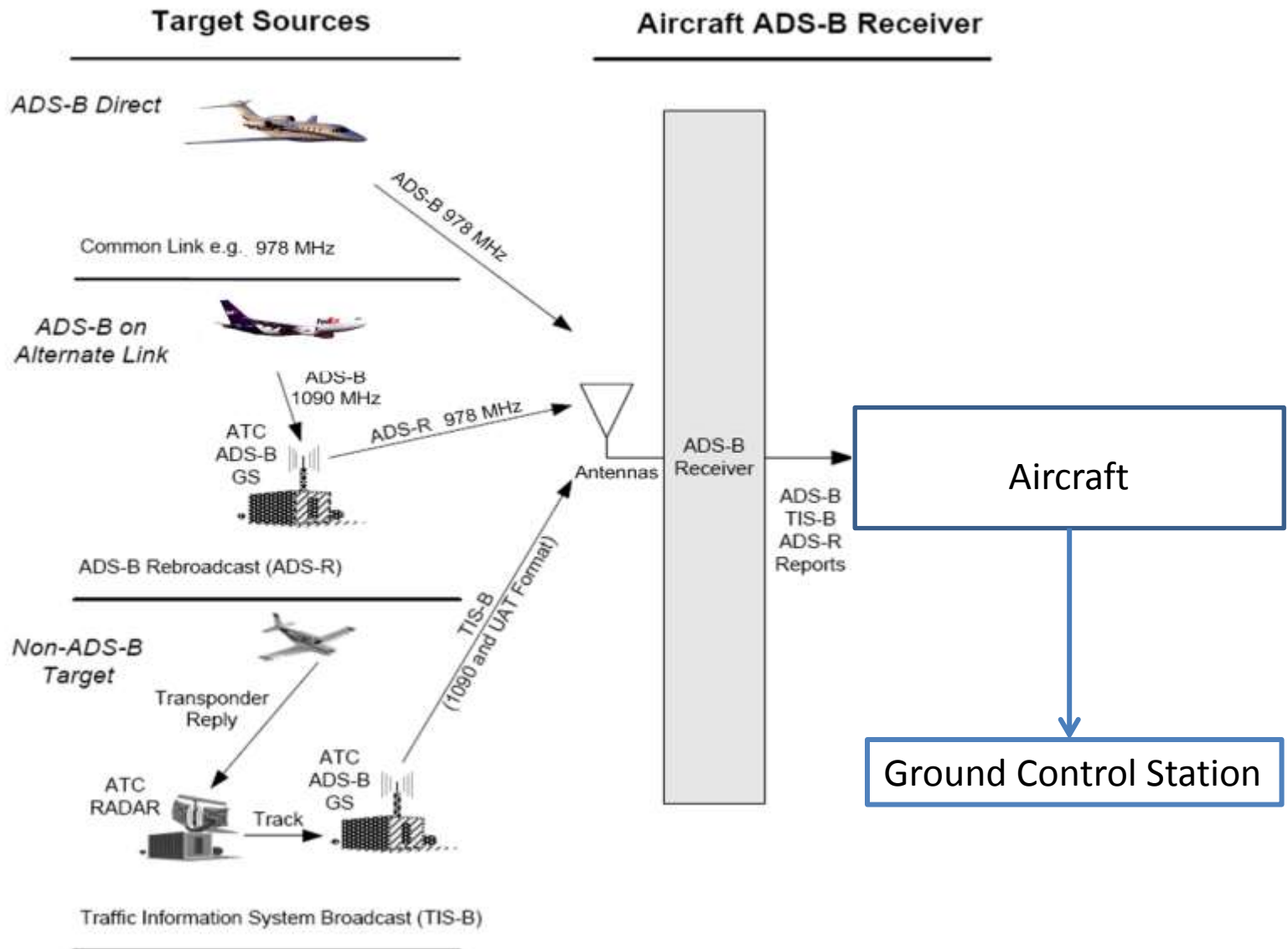
ADS-B Overview



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- **Automatic Dependent Surveillance Broadcast (ADS-B):** ADS-B is an advanced surveillance technology where ADS-B equipped aircraft share position, altitude, velocity, and other information with ATC and other appropriately equipped aircraft
- **ADS-B represents the backbone technology for airspace integration in the Next Generation Air Transportation System (NextGen)**
 - Assess navigation accuracies of the installed ADS-B system
 - Evaluate its suitability for providing separation assurance
- **The MQ-9 represents the UAS employed by several public agencies seeking routine access to the NAS**
- **ADS-B “In” is the reception by properly equipped aircraft of surveillance information**
 - ADS-B “Out” transmissions from nearby aircraft
 - Transmissions from ADS-B Ground Stations that include surveillance radar derived (TIS-B) and re-broadcast of ADS-B data (ADS-R)

ADS-B “In” Architecture Design Overview



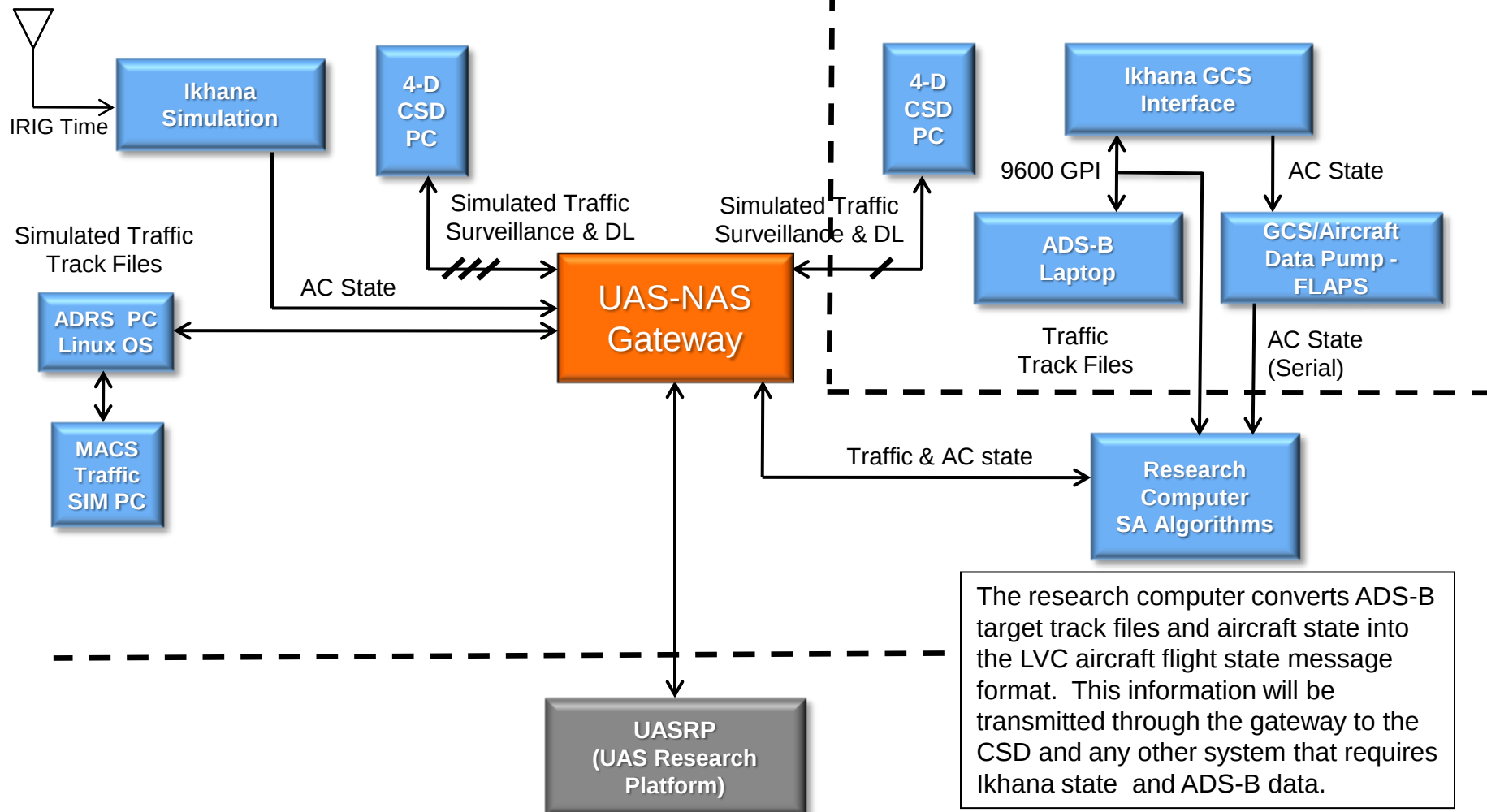


Dryden LVC-DE Logical Interface

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Building 4840 Ikhana Sim Lab

Ikhana GCS





LVC-DE Core Architecture Components

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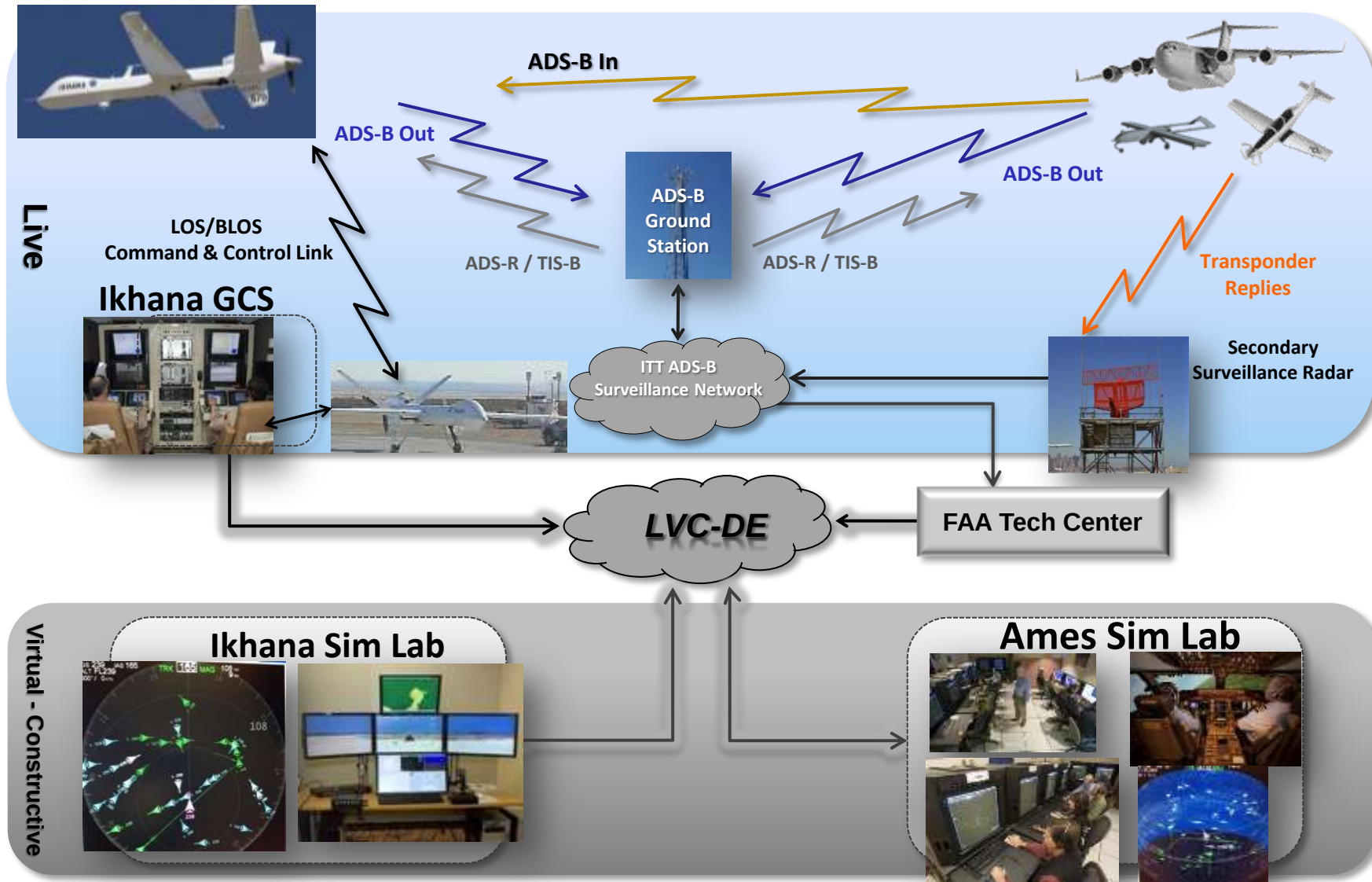
- **DSRL – Distributed Simulation Research Lab (Ames Research Center)**
- **UASRP – UAS Research Platform – DSRL gateway (Ames)**
- **UAS-NAS Gateway – local network gateway to DSRL (DFRC)**
- **MACS – Multi-Aircraft Control System**
 - Constructs aircraft traffic scenario
 - ATC Displays
 - Pseudo pilot control displays for constructive traffic
- **ADRS – Server allows external simulation interface to MACS**
- **CSD – Cockpit Situation Display**
- **Research Computer**
 - Aircraft state data reader software
 - ADS-B aircraft state data reader software
 - Convert & outputs data to UAS-NAS Gateway
- **ADS-B – Automatic Dependent Surveillance-Broadcast**
 - FAA approved airborne data link



Live Virtual Constructive Distributed Environment



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Software Development Tests

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- Performed tests with ADS-B mobile van for software code validation on April 20th
- Ground tests performed on Ikhana using ADS-B System Test and Verification Procedure (Rev F) on April 27th
- Used live ADS-B Ground Radio Station DS 293 (located by Victorville)
- ADS-B “In” functionality verified with real-time aircraft surveillance of TIS-B/ADS-B targets in the EDW’s traffic pattern



Ground Tests



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ADS-B Performance

ADS-B “Out” Requirements

- $NAC_p < 0.05$ nm or value of 8
- $NIC < 0.2$ nm or value of 7
- $SIL = 2$ or 3 or 1×10^{-7}



Ground test results on Ikhana for ADS-B “Out” Performance

- $NAC_p < 10$ m or value of 10
- $NIC < 25$ m or value of 10
- $SIL = 2$ or 1×10^{-5}
- GPS Alt < 150 ft from surveyed reference point

ADS-B “In”

- ADS-B “In” system was able to track up to ten real-time surveillance tracks
- ADS-B mobile van was configured as an F/A-18 target
- Verified the proper reception of ADS-B messages and the correct display of a stationary and moving target



Flight Test Objectives



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Prototype LVC-DE Flight Test Objectives:

- **Demonstrate LVC-DE prototype architecture with Ikhana UAS in flight**
- **Evaluate integration of live flight vehicle**
 - **Multi-Aircraft Control System (MACS) simulation scenario and ATC displays**
 - **Cockpit Situation Display (CSD)**
 - **ADS-B “In” traffic report processing and display**
 - **Identify UAS and simulation timing issues**
 - **Support future mission planning scenarios**



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More Bang for the Buck!

*Additional Test Points Requested by LaRC**

- Altitude
- Vertical velocity
- Body axis angular rates
- Angle of attack
- Angle of sideslip
- Airspeed
 - Calibrated
 - True
- Ground track angle
- Wind speed and direction
- Control surface deflections
- Time of command execution
- Commanded heading
- Commanded speed
- Commanded altitude or altitude change
- Commanded vertical rate
- From 5000' MSL to FL400 (in 5k' increments)
 - 90° heading change airspeed of 90 knots
 - 90° heading change airspeed of 140 knots
 - 90° heading change airspeed of 200 knots
 - From 90 knots, 140 knot, and 200 knots
 - 2000 foot climb at 500 ft/min
 - 2000 foot descent at 500 ft/min
 - 2000 foot climb at 1000 ft/min
 - 2000 foot descent at 1000 ft/min
 - 2000 foot climb at 2000 ft/min
 - 2000 foot descent at 2000 ft/min
 - 1000 ft/min climb/descent.
 - 2000 ft climb at maximum throttle
 - 2000 ft descent at idle
 - 2000 ft climb at “typical” rate

*** Subset of this was performed. Provided performance data for further modeling**



UAS-NAS LVC Project Overview



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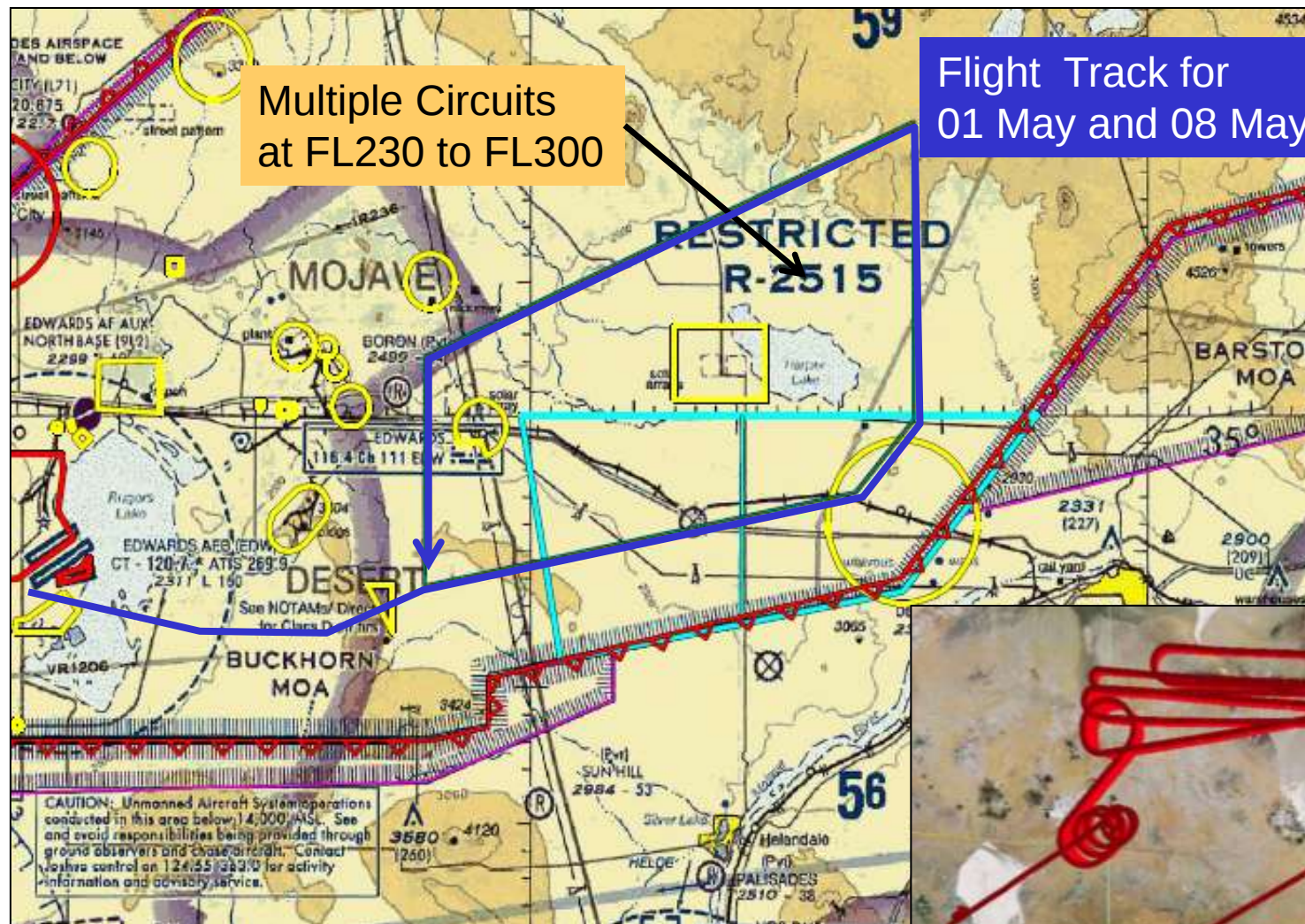
- ADS-B In – Demonstrate the acquisition of ADS-B traffic information (via GDL-90) and the ADS-B display in the Ikhana GCS. (Not used by aircrew during this test.)
- LVC-DE Sim – Demonstrate the acquisition of ADS-B In information (via FLAPS / SRFN) and its distribution to its Cockpit Situation Displays (CSD) located in the Ikhana GCS, the DFRC Simulation Lab and to the ARC Simulation Lab.
- Two “Stand-alone” Test Flights: 15 Mar (2.7 hrs), 20 Mar (2.5 hrs)
 - Ikhana/ADS-B “OUT” Functional Checks
- **Two Integrated LVC Test Flights**
 - 01 May 2012: 0.9 hour
 - 08 May 2012: 1.7 hours
- One “non-interference” flight
 - 11 May 2012: 0.9 hour, FAA Pilot Training Flight



UAS-NAS ADS-B In / LVC-DE Operations Area



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15 March 2012
Flight Track

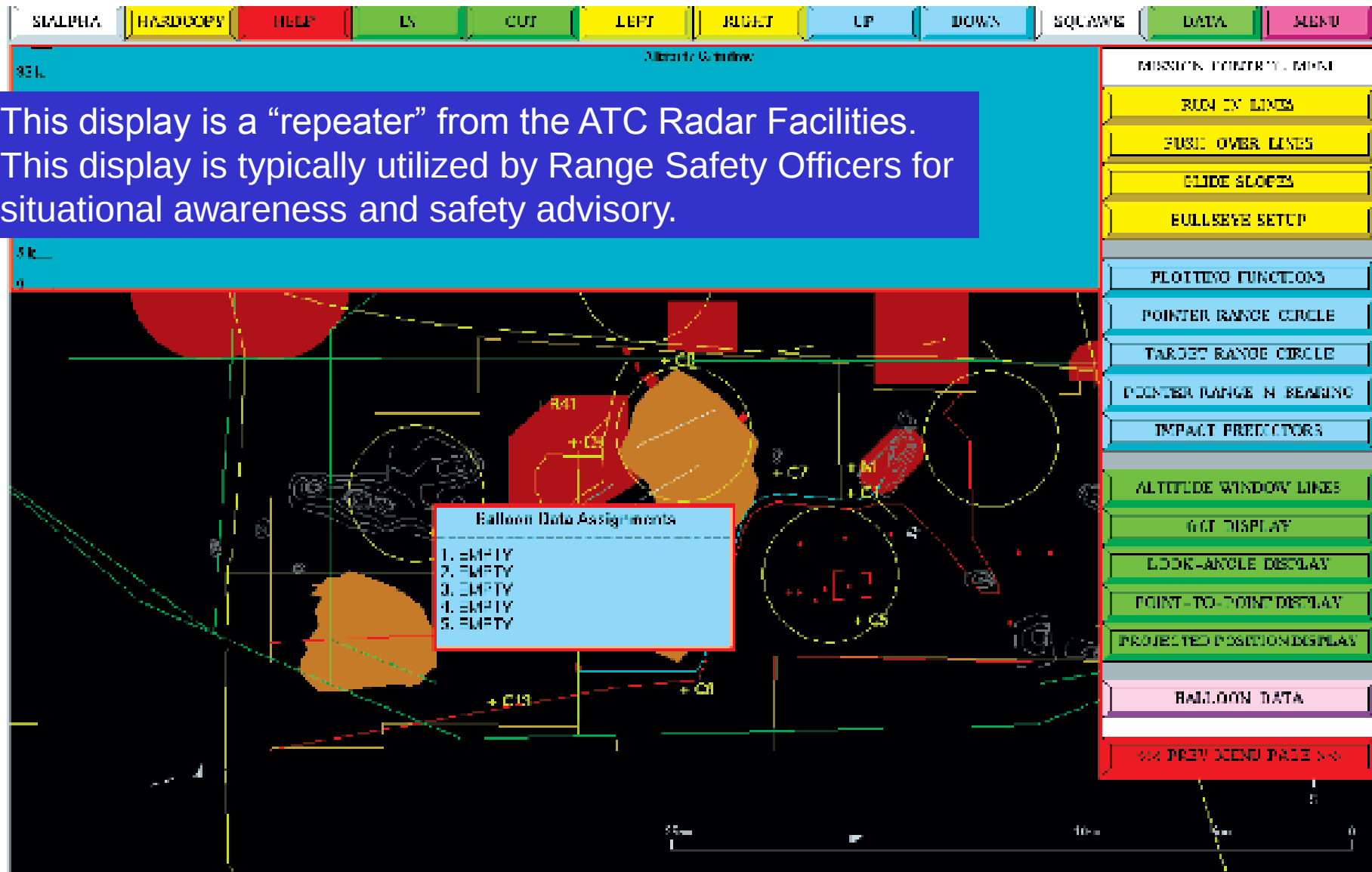




Edwards AFB Test Evaluation Command and Control System (TECCS)



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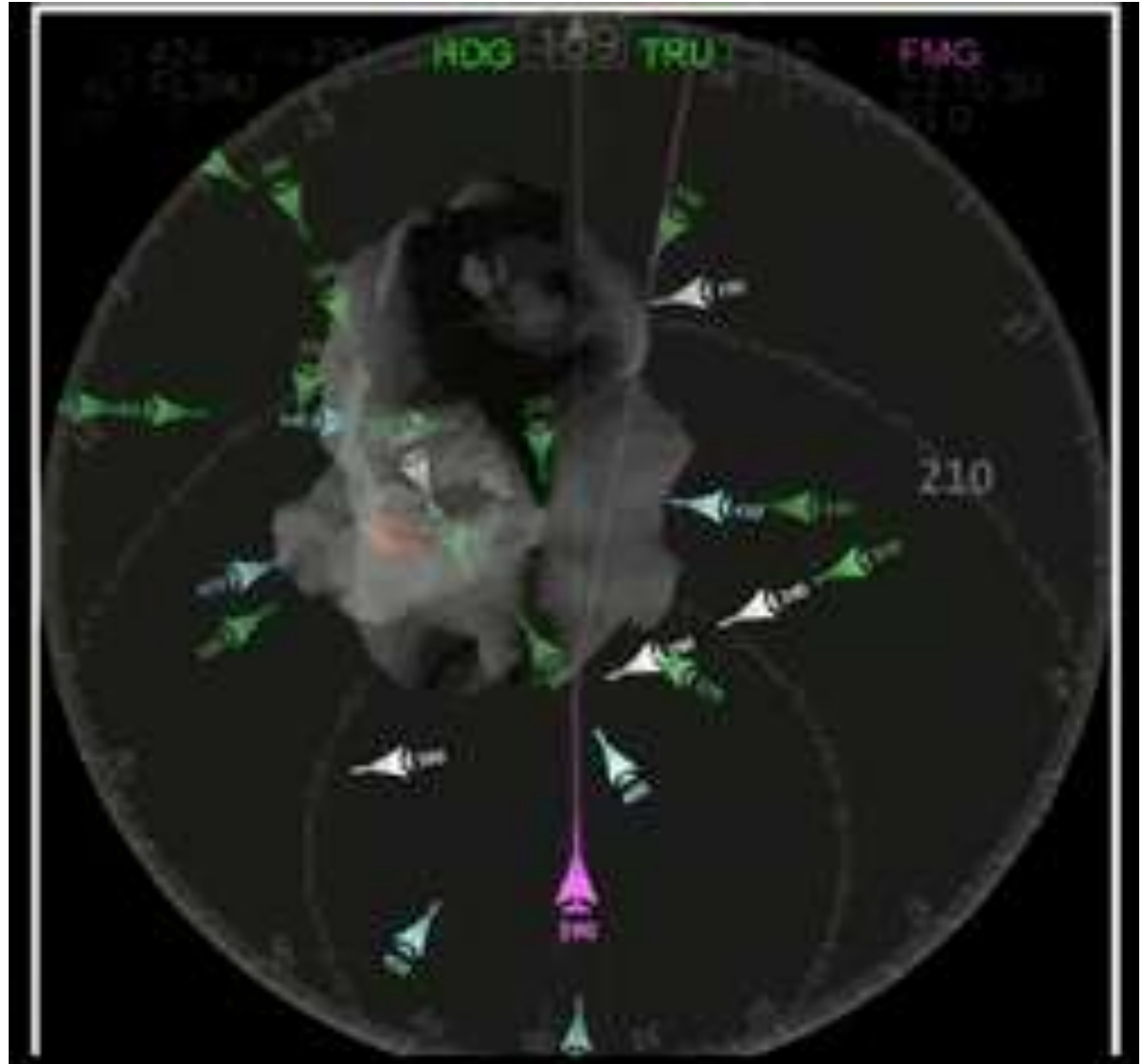


Ikhana Sim Lab Cockpit Situation Display

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Aircraft Icons:

- Virtual Traffic
- Real Traffic
- Ikhana
- “Own ship”
(Simulated Ikhana)





Ikhana ADS-B / LVC Flight Test Results



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- **Success!**
- Developed ADS-B “In” and “Out” capability for the Ikhana UAS
- Utilizing the FAA Technical Center’s validated data analysis tools, the analysis showed the ADS-B performance to **exceed FAA requirements.**
- Completed a full systems integration test of the Live Virtual Constructive – Distributed Environment (LVC-DE) between Dryden and Ames
- Cockpit Situation Display aided Sim Pilot in SA and maneuvering.
- Performance data acquired for LaRC modeling
- **Forward Plans:**
- **June-July:** Continue LVC development (full FAA surveillance data connectivity)
- **Aug-Sep:** Develop Research GCS (RGCS) and integrate into the LVC-DE network
- **Aug-Oct:** Modify the TG-14 into a UAS Surrogate, equip with ADS-B, and integrate command and control with the RGCS
- **FY 2013 - :** Re-integrate ADS-B system back onto the Ikhana UAS upon completion of its Block 1 upgrade
- Perform ADS-B and LVC flight tests with the TG-14 UAS Surrogate
- Global Hawk to be equipped with ADS-B: Evaluate navigational accuracy (FL600+) for the FAA