MQ-9 Ikhana

UAS-NAS Project Status:

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

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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 Predator-B; RQ-4 Global Hawk, DROID SUAS (and X-48 support)
  – 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.
    • 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.

• 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

• 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

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

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

- 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)
Current ADS-B Ground Stations and Coverage

Expanded satellite-based surveillance

- Operational radio stations
- Service volume coverage areas

Current as of February 2018
ADS-B “In” Architecture Design Overview

Target Sources

- ADS-B Direct
- Common Link e.g., 978 MHz
- ADS-B on Alternate Link
  - ADS-B 1090 MHz
  - ADS-R 978 MHz
- ADS-B Rebroadcast (ADS-R)
- Non-ADS-B Target
  - Transponder Reply
  - ATC Radar

Traffic Information System Broadcast (TIS-B)

Aircraft ADS-B Receiver

Antennas

ADS-B Receiver

Aircraft

Ground Control Station

ADS-B TIS-B ADS-R Reports
The research computer converts ADS-B target track files and aircraft state into the LVC aircraft flight state message format. This information will be transmitted through the gateway to the CSD and any other system that requires Ikhana state and ADS-B data.
• 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

Ikhana GCS

LOS/BLOS Command & Control Link

Ikhana Sim Lab

Virtual - Constructive

FAA Tech Center

Ames Sim Lab

Secondary Surveillance Radar

Transponder Replies

Live

ITC ADS-B Surveillance Network

ADS-B In

ADS-B Out

ADS-B In

ADS-B Out

ADS-B Out

ADS-B In

ADS-R / TIS-B

ADS-R / TIS-B

ADS-R / TIS-B

ADS-R / TIS-B

ADS-R / TIS-B

ADS-B Ground Station
• 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

ADS-B Performance

**ADS-B “Out” Requirements**
- $NAC_p < 0.05 \text{ nm}$ or value of 8
- $NIC < 0.2 \text{ nm}$ or value of 7
- $SIL = 2$ or $3$ or $1 \times 10^{-7}$

**Ground test results on Ikhana for ADS-B “Out” Performance**
- $NAC_p < 10 \text{ m}$ or value of 10
- $NIC < 25 \text{ m}$ or value of 10
- $SIL = 2$ or $1 \times 10^{-5}$
- GPS Alt $< 150 \text{ ft}$ 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
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
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

• 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

Multiple Circuits at FL230 to FL300

Flight Track for 01 May and 08 May 2012

15 March 2012 Flight Track
This display is a “repeater” from the ATC Radar Facilities. This display is typically utilized by Range Safety Officers for situational awareness and safety advisory.
Aircraft Icons:

- Virtual Traffic
- Real Traffic
- Ikhana
- “Own ship” (Simulated Ikhana)
**Ikhana ADS-B / LVC Flight Test Results**

- **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