UAS-NAS
NASA 870 Ikhana UAS
No Chase COA (NCC) Flights

Flight Test Report

Mike Marston, NASA AFRC Operations Engineer
Steffi Valkov, NASA AFRC Operations Engineer
Alex Flock, NASA AFRC Operations Engineer

NASA Armstrong Flight Research Center
UAS-NAS IT&E Subproject

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Overview

This document is a flight test report from the operational perspective for the No Chase Certificate of Waiver or Authorization (COA) flights, or NCC flights, a major milestone of the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) project. Discussions of a demonstration event began as early as 2014 and the actual flight of the Ikhana UAS into the NAS without a safety chase vehicle in Class A, E, and D airspace was accomplished on 12 June, 2018.

The major goal of this flight was to demonstrate an alternate means of compliance to the see and avoid regulations for a UAS using Detect and Avoid (DAA) technology.

Participants in this flight activity and planning included the National Aeronautics and Space Administration (NASA) Ames Research Center, NASA Armstrong Flight Research Center, General Atomics Aeronautical Systems, Inc. (GA-ASI), Honeywell International, Inc., and the Federal Aviation Administration (FAA).

During system checkout (SCO), stakeholders analyzed their DAA system in flight test scenarios known as Scripted Encounters. The Ikhana ownship flew encounters against intruders of various equipage and performance. Once the system was tested with stressing cases that could be encountered in the NAS, a photo chase flight was performed for operational rehearsal and execution, and finally, the flight without chase was achieved.

Table 1 is a summary of events for NCC, with major milestones highlighted in green.

Ultimately, all NCC phase 1 project milestones were fully achieved. The minimum success criteria of receiving the COA to fly without chase was obtained in March 2018. Full success criteria was achieved once the flight without chase was completed in June 2018. This positive outcome is largely attributed to the experience acquired from the Airborne Collision Avoidance System (ACAS) Xu Self Separation (SS) Initial flight test flown in December 2014, Flight Test Series 3 (FT3) flown in the summer of 2015, Flight Test Series 4 (FT4) flown in the summer of 2016, and ACAS Xu Flight Test 2 (FT2) flown in the summer of 2017.

Thanks to the training, member participation, systems integration/testing, in-depth analysis of the test points, safety discussions, route feedback, and support from the FAA, the UAS-NAS team was able to achieve a successful, safe, and aviation-history making flight into the NAS with a UAS employing DAA technology.

Table 1. No Chase COA Summary.

No Chase COA Summary		
Date	**Event**	**Description**
2/25/2013	NAC Aeronautics Committee, UAS Sub Committee recommendation to conduct a bold demonstration in the NAS	NAC recommendation to do more than just conduct research and collect data but to employ its unique capabilities to conduct a "Bold Flight Demonstration".
6/2/2014	Demonstration Kick-Off Meeting	Initial planning activities; develop goals and objectives
Dec. 2014	ACAS Xu SS	ACAS Xu Flight Testing
Summer 2015	Flight Test Series 3	FT3 Flight Testing
Summer 2016	Flight Test Series 4	FT4 Flight Testing
12/15/2016	NCC Strategy Meeting	Meeting at GA-ASI to discuss planning for NCC
2/2/2017	NCC Coordination WG	Earliest meeting on record with NCC name
5/31/2017	Phase I MOPS Released	DAA and ATAR Phase I MOPS
Summer 2017	ACAS Xu FT2	ACAS Xu FT2 Flight Testing
10/27/2017	AFRC COA Brief to Management	Brief to AFRC upper management
10/30/2017	COA Submission	Old system for COAs
12/20/2017	COA Re-submission into CAPS	Added "CONOPS" section, route modified
2/1/2018	NCC SCO Tabletop	Team training
2/8/2018	NCC SCO Tech Brief	Brief to AFRC upper management
2/14/2018	NCC SCO Flight 1	Ikhana only
2/15/2018	NCC SCO Flight 2	With intruder
2/21/2018	FAA SRMP Day 1	AFRC hosted FAA event, day 1
2/22/2018	FAA SRMP Day 2	AFRC hosted FAA event, day 2
2/28/2018	NCC SCO Flight 3	With intruder, attempt 1
3/30/2018	COA Approved	FAA FORM 7711-1 UAS COA Attachment, 2017-WSA-148-COA
3/21/2018	NCC Flight 3 Follow-up Tech Brief	Brief to AFRC upper management
3/28/2018	NCC SCO Flight 3	With intruder, attempt 2
4/5/2018	C-Band C2 STA Not Approved	STA to approve use of C-Band LOS C2 outside of SUA was denied due to the FAA Spectrum Office requiring clarification on the NCC operations and risk mitigations. Multiple FAA Spectrum Office and UAS Integration Office coordination meetings followed.
5/10/2018	NCC Demo Tech Brief	Brief to AFRC upper management
5/10/2018	NCC Demo Tabletop	Team training
5/23/2018	STAs for Operations <u>with</u> Chase Approved	STAs included C-Band C2, DPX-7 Transponder, TPA-100 TCAS, ARC-210 VHF Radio
5/24/2018	NCC Demo With Chase	Mission execution (photo chase)
6/6/2018	STAs for Operations <u>without</u> Chase Approved	STAs included C-Band C2, DPX-7 Transponder, TPA-100 TCAS, ARC-210 VHF Radio, ATAR
6/12/2018	NCC Demo Without Chase	Mission execution (no chase)

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1 Introduction

The desire and ability to fly UAS in the NAS is of increasing urgency. The application of unmanned aircraft (UA) to perform national security, defense, scientific, and emergency management are driving the critical need for less restrictive access by UAS to the NAS. UAS represent a new capability which will provide a variety of services in the government (public) and commercial (civil) aviation sectors. The growth of this potential industry has not yet been realized due to the lack of a common understanding of what is required to safely operate UAS in the NAS.

NASA's UAS Integration in the NAS (UAS-NAS) Project is conducting research in the areas of Separation Assurance/Sense and Avoid Interoperability, Human Systems Integration (HSI), and Communications to support reducing the barriers to routine UAS access to the NAS. This research is broken into two research themes namely, UAS Integration and Test Infrastructure.

UAS Integration focuses on airspace integration procedures and performance standards to enable UAS integration in the air transportation system, covering Sense and Avoid (SAA) performance standards, command and control performance standards, and human systems integration. With the help of the UAS-NAS Integrated Test & Evaluation (IT&E) team, the Phase I Minimum Operational Performance Standards (MOPS) for DAA and Air-to-Air Radar (ATAR) systems was released in May 2017.

The focus of Test Infrastructure was to enable development and validation of airspace integration procedures and performance standards, including integrated test and evaluation. In support of integrated test and evaluation efforts, the Project developed an adaptable and scalable relevant test environment capable of evaluating concepts and technologies for UAS to safely operate in the NAS.

To accomplish this task of establishing relevant test environments, the Project conducted a series of Human-in-the-Loop and Flight Test activities that integrated key concepts, technologies, and procedures in a relevant air traffic environment, leading up to the NCC demonstration. Each of the integrated events was built on the technical achievements, fidelity and complexity of the previous tests and technical simulations, and resulted in research findings that supported the development of regulations governing the access of UAS into the NAS.

To demonstrate the achievements of phase 1 of the NASA UAS Integration in the NAS Project, the team elected to pursue a flight activity with NASA 870 ("Ikhana") UAS operating in the NAS without a safety chase vehicle. This report details the events that led up to this NCC flight.

1.1 Scope

Detailed NCC flight activity and design coordination began in early 2017, although high-level discussions of executing a demonstration flight without chase began much earlier than this date, in 2014. The COA application for approval to fly without chase was submitted into the older COA Online system on 30 October, 2017, and re-submitted with additional information on 20 December, 2017. System checkout flights with the DAA system within Edwards Air Force Base (EAFB) R-2515 airspace occurred February-March 2018. Finally, a flight with photo chase was executed on 24 May, 2018, and the flight into the NAS without chase was executed on 12 June, 2018.

This report addresses the genesis of the design of the COA route and safety case, submission, design iterations, system checkouts, NAS flights, deficiencies with the DAA system or methods, preliminary tests results and analysis, and lessons learned. Further details about this configuration are described in the main body of this test report. This report also serves as a general progress report for the IT&E sub-project.

1.2 Purpose

The purpose of the NCC flight demonstrations was to obtain FAA operational approval of a UAS, equipped with DAA capabilities as an alternate means of compliance to see and avoid regulations, to execute a specific route of flight in the NAS without a safety chase aircraft. This effort engaged the FAA certification, safety, and operational approval organizations and in the process, informed policy development and the processing of similar COAs to enable less restrictive UAS access to the NAS. During the flight demonstrations which transited several airspace classes, the UAS pilot employed the DAA system to coordinate with Air Traffic Control (ATC) and maintain safe separation from other aircraft.

Testing facilities were Government owned, managed, leased, or under agreement and fall into two categories:

1. Development Facilities:
    - Research Aircraft Integration Facility (RAIF) at NASA Armstrong
    - GA-ASI Grey Butte Flight Test Facility
    - GA-ASI Poway System Integration Lab
    - Honeywell International Inc., Redmond, WA
2. Test Facilities:
    - RAIF at NASA Armstrong
    - Dryden Aeronautical Test Range (DATR) at NASA Armstrong
    - Mission Control Center 3 (MCC3) Mission Control Room at NASA Armstrong
    - The Radio Frequency (RF) Communications facility at NASA Armstrong
    - Edwards R-2508 Complex

1.3 Stakeholders, Participants, and Responsibilities

The NASA Integrated Aviation Systems Program (IASP) provided direction for the UAS-NAS project. The project office had the overall responsibility for NCC flight test activity. NASA Ames, NASA Armstrong, GA-ASI, Honeywell, and the FAA supported the project or were participants. The following is a brief description of responsibilities:

- **NASA Ames Research Center (ARC):** NASA Ames provided ATC expertise on development of the NCC route through the NAS. They were also present at Oakland Air Route Traffic Control Center (ARTCC) during the demonstration flights.
- **NASA Armstrong Flight Research Center (AFRC)**: NASA Armstrong was the responsible test organization for all test missions flown from AFRC. AFRC hosted the Live Virtual Constructive (LVC) infrastructure for data collection and distribution. AFRC also provided some live manned aircraft used as intruders during system checkout. NASA 870 (“Ikhana”) was the unmanned aircraft ownship platform for Scripted Encounters within the R-2515 airspace (part of R-2508), as well as the flight into the NAS. The Ground Control Station (GCS) housing part of the DAA system and Ikhana pilots was also located at AFRC.

- **General Atomics Aeronautical Systems, Inc. (GA-ASI)**: Provided hardware, software and integration support on the Ikhana UAS, in particular the GA-ASI designed DAA system. GA-ASI provided the ATAR and other DAA system related avionics. GA-ASI also provided the DAA algorithm, the Conflict Prediction and Display System (CPDS), which was used to fly scripted encounters and operate in the NAS.
- **Honeywell International, Inc.:** Honeywell provided the hardware, software and integration support for the Surveillance and Tracking Module (STM)/ACAS prototype processor that contained the Honeywell Fusion Tracker and TCAS II.
- **Federal Aviation Administration (FAA):** The FAA provided guidance through the development of the COA application and ensured the pertinent information was provided for COA approval. The FAA provided critical feedback throughout the route design. They also held a Safety Risk Management Panel (SRMP), hosted at AFRC, to review the hazards associated with the proposed mission of flying a DAA equipped UAS in the NAS without chase and their corresponding mitigations. Finally, the FAA provided coordination to ensure resolution of spectrum management issues associated with the equipment and airspace needed for the demonstration.

1.4 Working Groups

Throughout the flight test activity, communication was critical in order to achieve proper coordination, deadlines, and milestones. For this reason, several working groups (WG) were held to facilitate planning activities.

1.4.1 NCC Coordination

The NCC Coordination WG, which met weekly, involved software and hardware integration leads, operations, and project engineers and managers. This WG was the main platform to discuss changes or updates to the aircraft, Ikhana GCS, system safety gap analysis, and overall timeline planning. The operational planning perspective of this WG fed into the Operations Working Group (OWG) as the team came closer to the actual flights.

1.4.2 Operations Working Group

The NCC OWG was a collaborative effort between all stakeholders and participants for the NCC flights. The OWG, which met weekly and fortnightly prior to testing, discussed all NCC ground and flight operations topics. This WG was responsible for flight planning and coordination, assigning actions items, safety concerns which would feed into the System Safety Working Group (SSWG), hardware integration and testing discussion, training, and readiness. The OWG was a pre-established meeting for success, its pedigree being built upon since the ACAS Xu 2014 flight tests.

1.4.3 System Safety Working Group

The SSWG included project engineers and Subject Matter Experts (SMEs) to review, discuss, and track existing hazards, identify new hazards, and to decide what mitigations to put in place for each. The NCC project team conducted a Hazard Analysis for SCO and the Demo. A Safety Engineer was present for all operations planning and chaired the SSWG. The SSWG performed a hazard analysis by identifying potential hazards, mitigation methods, evaluating the final probability and severity of the mitigated hazards, and documenting the hazard analysis on a formal Hazard Report. This WG was available as a forum to discuss and refine concerns through the lifecycle of the NCC project.

2 Development

Although the main goal of the project was to receive a COA and to conduct a single safe and successful flight in the NAS using a DAA system without a chase, great benefits were obtained from the development and test process, which spanned several years prior to the 12 June, 2018 flight.

The UAS-NAS project involvement in the flight test activity began with its support and participation in the 2014 flight test of ACAS Xu and SS Initial Flight Test. This was followed in 2015 with FT3, FT4 in 2016, and ACAS Xu FT2 in 2017. Each of these flight test series significantly contributed to building up infrastructure, developing procedures, and reducing risk for the NCC flight activity. These flight events greatly supported the tasks of performing checkout flights of the system, as well as increasing team readiness for flying into the NAS. Much of the same team members whom supported the initial flights were part of the NCC flight campaign and their knowledge, experience, and lessons learned aided with this activity. Over 1000 air-to-air encounters were accomplished safely and successfully during the span of these flight tests.

2.1 Objectives

The NCC activity was divided into two separate and distinct flight activities. The first activity, SCO, served to provide a final checkout of the system before flying into the NAS. The second, called Demonstration "Demo" flights, sought to employ the DAA technology while flying in the NAS: once with chase (as an operational rehearsal) and once without.

2.1.1 System Checkout

The DAA system (Figure 1) being employed as an alternate means of compliance to 14 Code of Federal Regulations (CFR) §91.111(a) and §91.113(b) "see and avoid/remain well clear" rules was comprised of airborne sensors and track processors to detect, track, and generate DAA alerts and maneuver guidance information against proximate aircraft if their trajectories were predicted to lead to loss of well clear. Additional information on the system can be found in Section 2.3.

The NCC SCO primary technical goal, described as Scripted Encounters, was to conduct regression testing on the NCC system release 1108.1.0 Rev-, conduct air-to-air encounters representative of NAS operations (including Collision Avoidance (CA) with a Traffic Alert and Collision Avoidance System (TCAS) and stressing Special Committee (SC)-228 operational cases), and ensure DAA remain well clear maneuver operations while in full Ku SATCOM C2 (uplink and downlink).

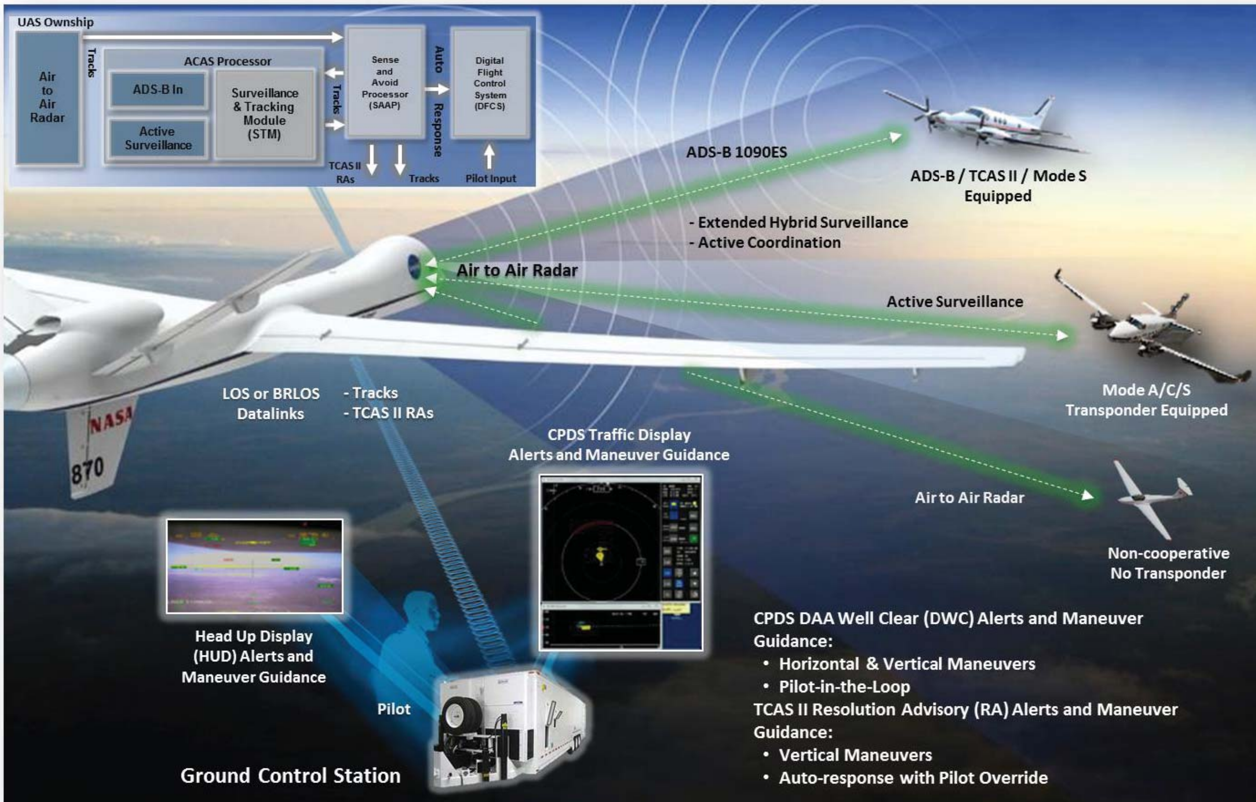


Figure 1. NCC System Architecture.

2.1.1.1 *IT&E Objectives*

The test objectives were developed by the IT&E team and informed the flight test matrix and objectives matrix. Similar to the test objectives template used in FT4, which tested multiple geometric encounters with diverse types of intruders, the NCC objectives included the geometry of the encounter, hardware/software configuration for the ownship and intruders, and overall objective of the encounter. Table 2 shows the objectives matrix for each type of encounter. In order to ensure DAA system functionality and performance before flights into the NAS, regression testing was required to stress the system. It was determined select modified encounters from FT4 would suffice to meet the overall purpose of the NCC SCO. Use case Concept of Operations (CONOPS) encounters, such as a Ku-band C2 link only encounter, were also required to replicate scenarios which would occur when in the NAS.

Table 2. No Chase COA System Checkout Objectives Matrix.

Encounter Objective	Name	Alt Regime (ft MSL)	Intruder	Vert Offset	Maneuver	Coop/Non-Coop	Priority	Notes
1. Test Modes (Ikhana) Mode 253 TCAS Only	TM-1	>10k	G-III/KA	300 ft	Unmitigated	Cooperative	1	Test Mode set to 253, fused targets will drop and only Mode C targets will remain.
2. CONOPS Use Cases (4) a. ATC coordinates maneuver (VFR Traffic) b. Int. maneuvers after DWC maneuver has begun, causes change in DWC maneuver c. Ikhana encounters VFR traffic and maneuvers prior to ATC approval d. Ikhana PIC maneuvers to a TCAS II RA	a. UC-2 b. UC-3 c. UC-4 d. UC-5	a. >10k b. <10k c. <10k d. >10k	KA/T-34	a. 200 ft b. 300 ft c. 200 ft d. 200 ft	Mitigated	Cooperative	1	Directly from MOPS. Encounter for each use case. "TC acts as ATC – Inform SPORT".
3. Radar only (squawk off)	SQK -6 SQK-7 SQK-8	<10k	T-34/TG-14	300 ft	Mitigated	Non-Coop.	1	Non-Coop <10k ft MSL. Pin wheel (0, 45, 90 deg.).
4. TCAS II Reversal	LOB-9 LOB-10	>10k	G-III	200 ft	Advisory/Auto	Cooperative	3	Unique TCAS implementation.
5. High Speed under 10k ft ~250 KGS	HS-11 HS-12	<10k	G-III	500 ft	Mitigated/Un-mitigated	Cooperative	3	High speed aircraft landing at airport transitioning through airspace.
6. Nuisance	NUIS-13 NUIS-14	>=10k	T-34/KA	1000/500 ft	Unmitigated	Cooperative	2	Demonstrate system will provide preventative, but not corrective, alerting. System ready to fly in the NAS.
7. Double Blunder	DB-15	>=10k	T-34/KA	500 ft	Mitigated	Cooperative	2	Demonstrate representative NAS encounter.
8. High Descent Rate	HDR-16	>=10k	G-III/KA	500 ft	Mitigated	Cooperative	2	Demonstrate representative NAS encounter.
9. Intruder Overtake	IOT-17 IOT-18	>=10k	T-34/KA	300 ft	Unmitigated	Coop/Non-Coop.	2	System ready to fly in the NAS.
10. Ikhana Overtake	OOT-19	>=10k	T-34/KA	300 ft	Mitigated	Cooperative	2	System ready to fly in the NAS.
11. Blunder Maneuver, Left 45/90 deg.	LT-20 LT-21	>=10k	T-34/KA	300 ft	Mitigated	Cooperative	2	Demonstrate representative NAS encounter.
12. TCAS auto at 20k ft MSL	ATCAS-22 ATCAS-23	>=10k		300 ft	Advisory/Auto	Cooperative	3	Demonstrate ownship performance with increased alerts and TCAS alerts at a higher altitude.
13. Low Altitude at 3000 ft AGL	LALT-24	3000 ft AGL	T-34/KA	200 ft	Advisory	Coop/Non-Coop.	1	Intruder below at 2,800 ft MSL. Fly in Ku, C-Band VCV operations.
14. Ikhana Turn & Descend	OTD-25	>=10k	T-34/KA	500 ft	Mitigated	Cooperative	2	Top of demo route, Ikhana turn & descend from left & right.

2.1.1.2 *SC-228 Stressing Cases*

In addition to the IT&E objectives, it was determined to be prudent to flight test certain stressing operational use cases delineated in the DAA MOPS. The primary objectives of these cases were to have the Ikhana pilot employ the DAA and ATAR systems and interacts with ATC to fulfill the see and avoid responsibilities for safe flight operations. Since these encounters were conducted in R-2515, the IT&E Test Conductor (TC) acted as “ATC”.

There are four use cases described in the No Chase COA CONOPS:

1. Ikhana pilot in command (PIC) calls out Visual Flight Rules (VFR) traffic to ATC and coordinates maneuver.
2. Intruder maneuvers after DAA Well Clear (DWC) maneuver has begun; causes change in DWC maneuver.
3. Ikhana encounters VFR traffic and maneuvers prior to ATC approval.
4. Ikhana PIC maneuvers to a TCAS II RA.

For the NCC SCO, it was determined that only one of these stress cases needed to be conducted. The second use case required the most coordination with ATC while still heavily relying on the DAA displays. The CONOPS for this use case is as follows: Ikhana is transiting Class E airspace and descending at 1,000 fpm from a cruise altitude of 15,000 ft MSL to 7,000 ft MSL as depicted in Figure 2. While descending through 9,000 ft MSL, the Ikhana PIC receives a corrective (yellow) alert on the heads-up display (HUD) from its DAA system for an aircraft on a converging course level at 7,500 ft. The PIC observes the intruder is to the front and left converging at a 30° to 45° angle. Even though Ikhana has the right of way per 14 CFR §91.113, the PIC cannot assume that the other aircraft will see Ikhana and maneuver to avoid, so the Ikhana PIC decides to maneuver. Since the projected encounter is still 55 seconds out, the PIC calls ATC and requests a left turn to pass beside the intruder, e.g.: “Joshua Approach, NASA 870 requests deviation left for traffic below.” After permission, the Ikhana PIC acknowledges and, while continuing the descent, maneuvers the aircraft left so that the intruder will pass to the right.

After the maneuver, the Ikhana PIC observes the intruder turning right and converging again; the corrective alert has not cleared. Due to the more urgent situation, the PIC levels off the UA at 8,300 ft to allow the intruder to pass underneath. After the level-off is complete, the Ikhana PIC notifies ATC of the level-off due to traffic, e.g.: “Joshua Approach, NASA 870 just leveled off due to traffic, will continue descent to seven thousand when clear of traffic.” ATC then acknowledges: “NASA 870, acknowledge advisory for traffic.” When clear of traffic, the Ikhana PIC informs ATC of their intent to continue: “Joshua Approach, NASA 870 continuing descent to seven thousand.”

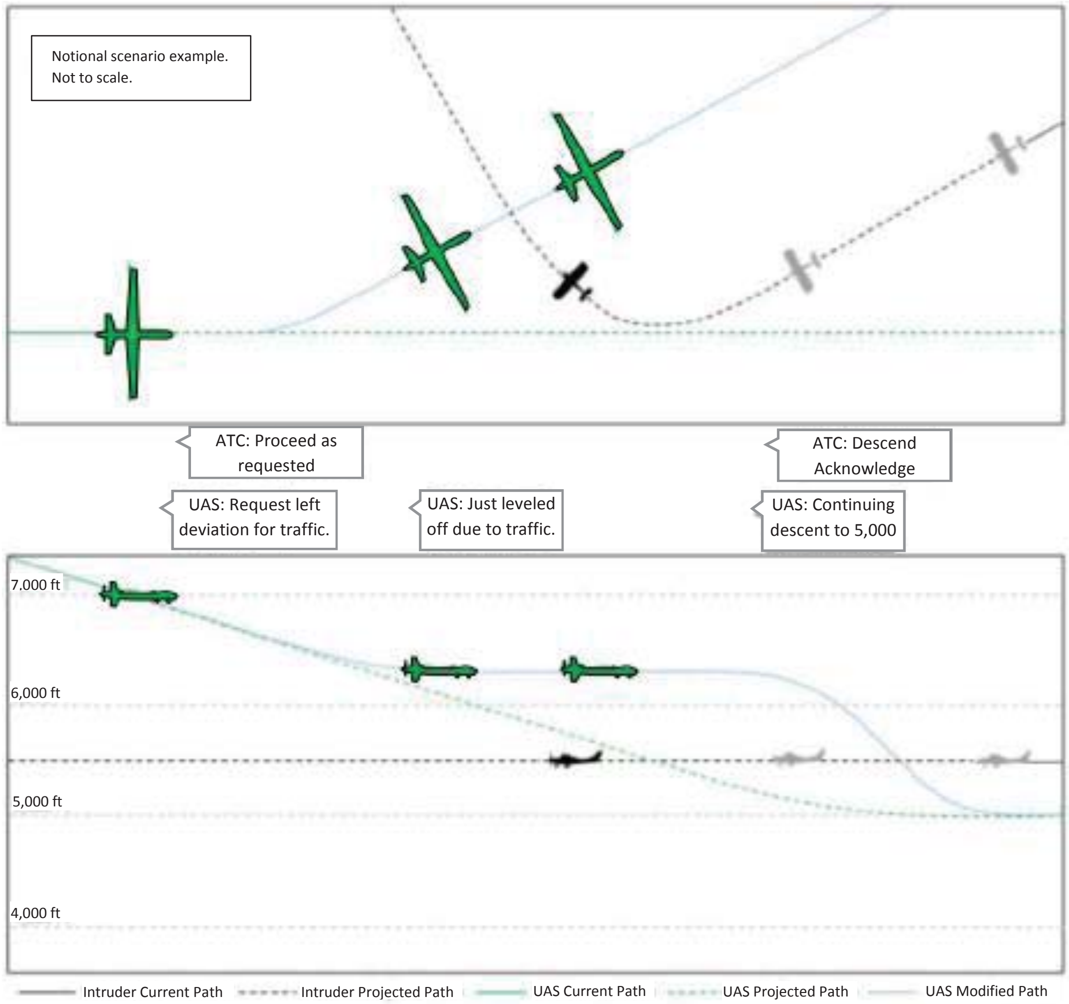


Figure 2. Maneuvers after DWC Maneuver has Begun.

2.1.2 Demonstration

The NCC flight sought to demonstrate that a UAS equipped with a DAA system could safely perform a mission with other aircraft in the NAS. The DAA capabilities delineated in the NCC effort were commensurate with the Phase 1 DAA and ATAR systems MOPS. The operational environment (Figure 3) is a UAS transitioning from Class A or Special Use Airspace (SUA) to/from Class E and D (not including the airport traffic pattern) using its DAA systems to detect, track, and remain well clear of other aircraft, as well as transition through two ARTCCs. The planned duration was about two hours, with a duration of about one hour outside of SUA.

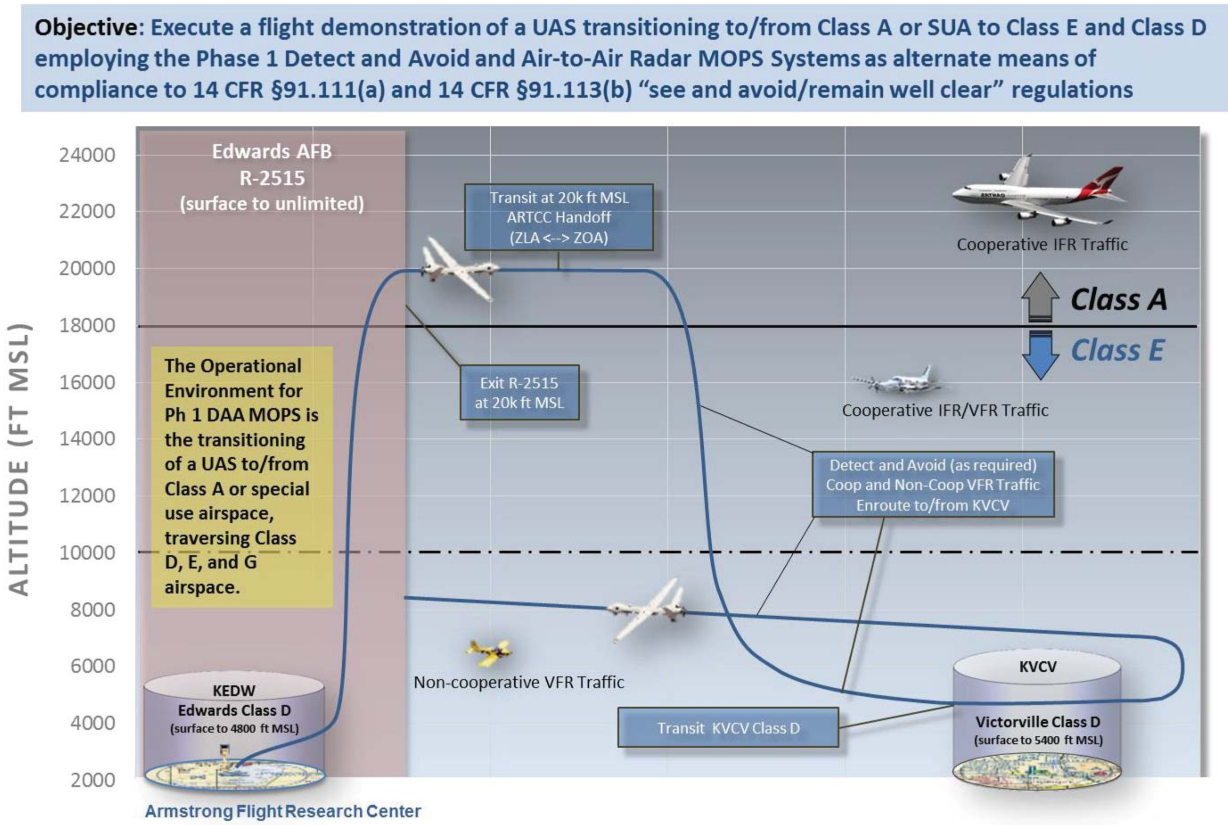


Figure 3. NCC Concept of Operations (Demo).

The goal of this flight profile was to demonstrate operational capability of a DAA system by remaining well clear of other cooperative or non-cooperative traffic while transitioning through Class A, E and D airspace. Ultimately, the ground-breaking event would be to transition into class E airspace without a chase (previously, other UAS as well as Ikhana have flown above 18,000 ft MSL without a safety chase).

2.2 Flight Schedule and Roadmap

In order to efficiently achieve the flights into the NAS, several activities needed to occur to satisfy gateways for the final demo flights. Figure 4 shows these operational gateways. First, the team used its experience from previous flight tests to create the documentation and safety case required to submit the COA. Additionally, the route of the flight into the NAS needed to be created, with feedback from the FAA, and satisfy project requirements. Once this information was submitted, the track split off into NASA performing its briefings to management and performing system checkout flights. Meanwhile, the FAA assessed the COA and asked additional questions to NASA, with COA approval received in March of 2018. Finally, the paths converged and NASA performed its briefing to management (Tech Brief — the briefing to AFRC Senior Management where approval and conditions to proceed with flight missions is provided) to obtain authorization to perform the mission with the particular aircraft configuration briefed. After this briefing NASA management approved the proposed mission and the project proceeded with the demonstration flights. The first demonstration flight included chase. After this flight the project provided its findings to NASA management before proceeding to the final flight into the NAS without chase.

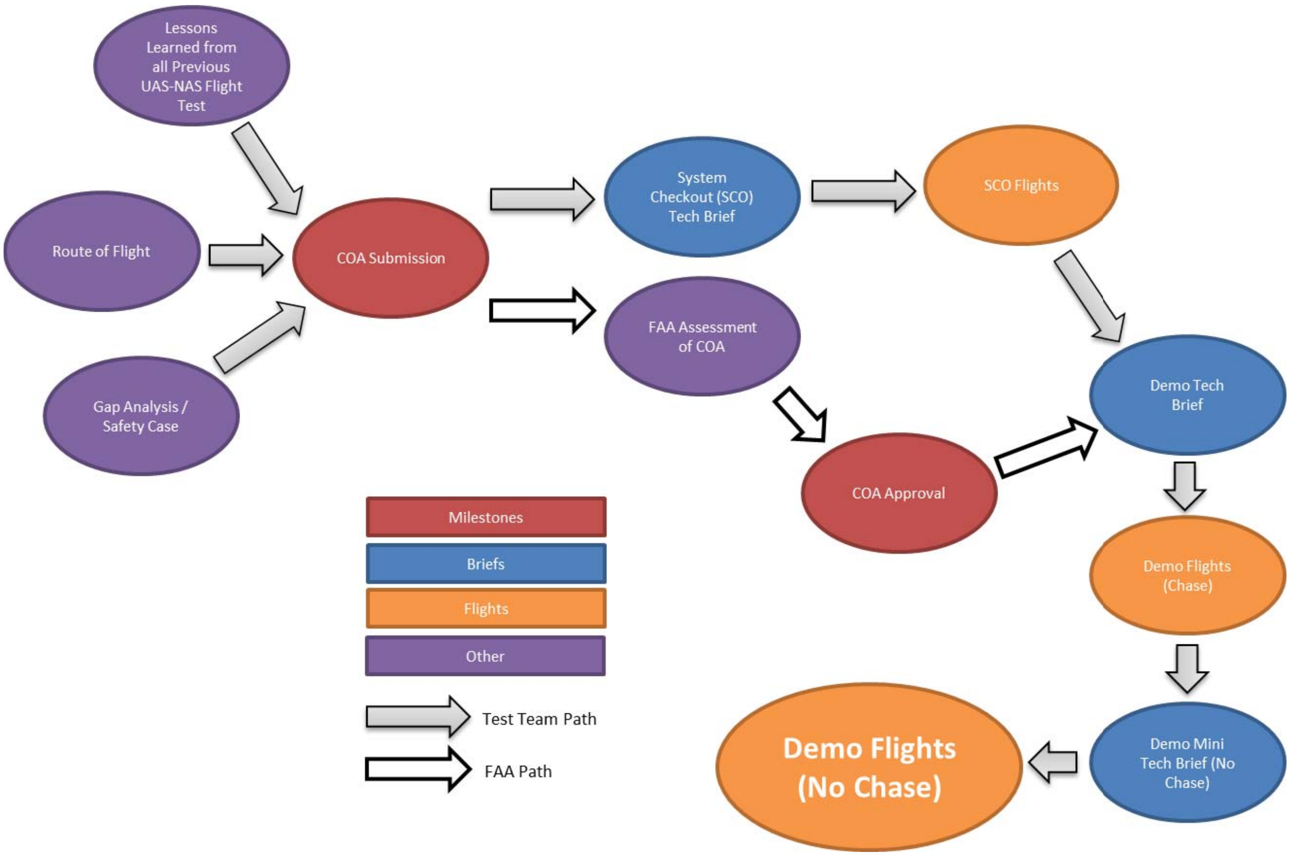


Figure 4. NCC Operational Roadmap.

2.3 Aircraft and System Configuration

The team elected to use the configuration of Ikhana that was used during ACAS Xu FT2. Below is a description of the Ikhana Ownship that was used for the SCO and Demo flights, as well as a description of the intruders used in the SCO.

2.3.1 Ikhana Predator B (NASA 870) and DAA System

The NASA AFRC Predator B (Ikhana) is a turbo-prop single engine MQ-9 unmanned aircraft built by GA-ASI, shown in Figure 5. Its general performance characteristics are shown in Table 3.

Figure 5. NASA870 "Ikhana" UAS.

Table 3. NASA 870 General Performance Characteristics.

NASA 870 General Performance Characteristics	
Weight	10,500 lb
Speed	200 kts
Ceiling	40,000 ft
Endurance	24 hr

Ikhana was configured with the GA-ASI prototype DAA system that included integrated hardware and software components enabling the aircraft to perform pilot initiated maneuvers to remain well clear and respond to collision avoidance resolution advisories, either manually or automatically. The system was dependent upon DAA sensors. The DAA cooperative sensors in the aircraft included an Automatic Dependent Surveillance-Broadcast (ADS-B) In/Out compatible Identification Friend-or-Foe (IFF), and a TCAS II system. An Active Electronically Scanned Array (AESA) ATAR was installed to detect all airborne targets.

2.3.1.1 ***Active Surveillance / TCAS II***

Ikhana was equipped with TCAS II v7.1 hosted in the Honeywell TPA-100 ACAS Processor. TCAS determines the relative range, altitude, and bearing of other aircraft equipped with Mode S and Air Traffic Control Radar Beacon System (ATCRBS) Mode A/C transponders. TCAS calculates the trajectory of the other aircraft to determine if a potential conflict exists. TCAS operates by sending interrogations to other aircraft and monitoring their replies. When the TCAS II logic determines an intruder to be a collision threat, a vertical resolution advisory (RA) is issued. If enabled, TCAS II RAs are sent to the flight control system to automatically respond to vertical commands. The pilot can override these commands. During the NCC flight demonstrations, Ikhana was configured to respond automatically to TCAS II RAs. TCAS II RAs are displayed to the pilot on a head-down traffic display and the HUD in the GCS. This system is used to detect and track cooperative aircraft.

2.3.1.2 *Air-to-Air Radar*

The ATAR detected and tracked aircraft within its field of regard (±15° elevation and 110° azimuth) regardless of whether that aircraft had other electronic means of identification. The X-Band ATAR, manufactured by GA-ASI, enabled detection and track of non-cooperative aircraft.

2.3.1.3 *ADS-B In*

ADS-B surveillance was provided by the Honeywell TPA-100 ACAS Processor. It receives 1090ES signals and provides track data to the fusion tracker for correlation with other sensor data. Once the ADS-B track data is validated by active interrogations from the ACAS processor, ADS-B track data is employed in an extended hybrid surveillance mode to reduce 1030/1090 MHz band transmissions. This system was used to detect and track cooperative aircraft.

2.3.1.4 *Fusion Tracker*

The Fusion Tracker, hosted in the Honeywell TPA-100 ACAS Processor, correlated intruder tracks from multiple surveillance sensors (i.e., Active Surveillance/TCAS II, ADS-B In and ATAR) into a fused track. A cross-check algorithm validates the fusion tracker outputs with TCAS active surveillance or ADS-B In data (extended hybrid surveillance) to ensure fusion track accuracy.

2.3.1.5 *Sense and Avoid Processer*

The Sense and Avoid Processor (SAAP) served to interface DAA systems, condition track data for downlink to the GCS, and archive data for post-flight processing.

2.3.1.6 *Conflict Prediction and Display System*

Figure 6 depicts the CPDS traffic display. The traffic display and the algorithm that predicts DAA loss of well clear was hosted in the GA-ASI laptop within the Ikhana GCS. The CPDS parsed the track data received from the Ikhana downlink and probed estimated trajectories for possible losses of well clear as DAA alerts and maneuver guidance information. This information was presented to the pilots as colored conflict areas or probes and “no-go” heading bands. Information was also presented on the HUD as text information (Figure 7) to direct the pilot to look at the traffic display for more detailed information. Loss of well clear occurs when the predicted closest point of approach (CPA) penetrates the well clear volume around the ownship defined with a 4,000 ft horizontal radius and ±450 ft altitude separation (Figure 8). When the loss of well clear is predicted to occur within 75 secs, a corrective (displayed as yellow) alerting and maneuver guidance is provided. When the loss of well clear is predicted to occur within 25 secs, a warning (displayed as red) alerting and maneuver guidance is provided.

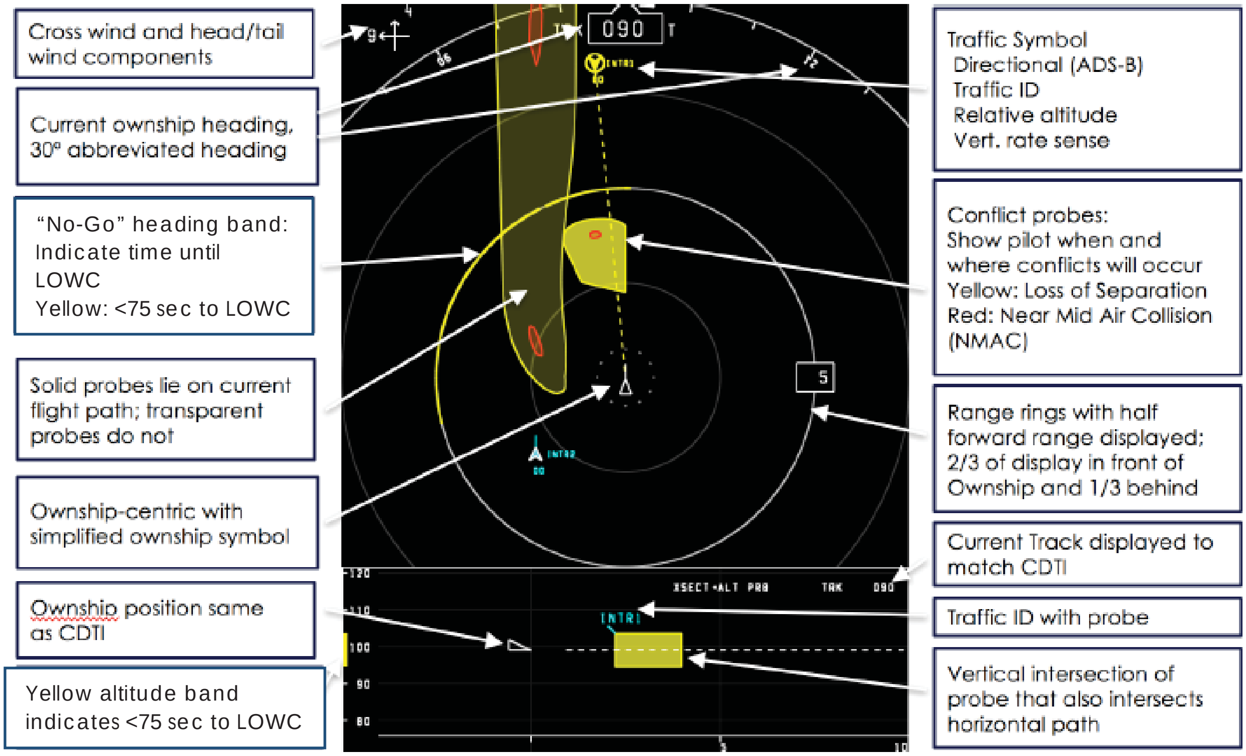


Figure 6. CPDS Traffic Display.

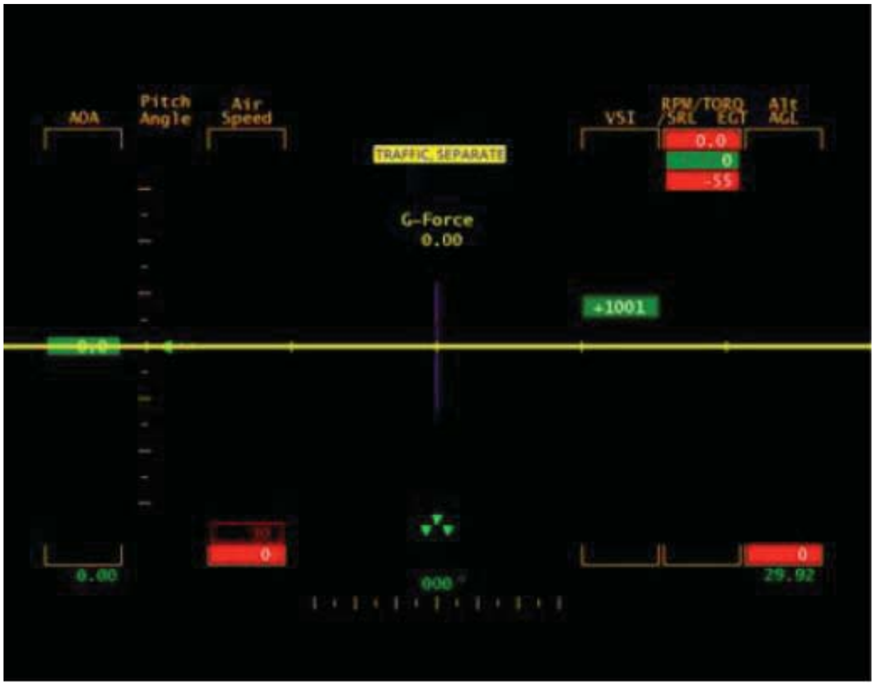


Figure 7. DAA "Corrective" Alerting on HUD.

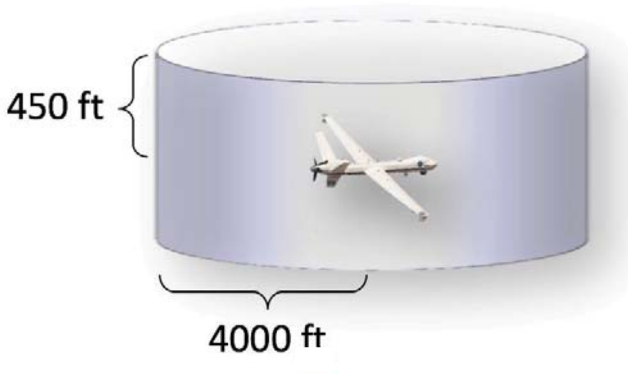


Figure 8. DAA Well Clear Volume.

2.3.1.7 *Datalinks*

Sensor tracks and TCAS RAs were downlinked to the GCS via the Ku-Band SATCOM beyond radio line of sight (BRLOS) system or the digital line of sight (DLOS) system. DAA track updates were provided at a nominal 1 Hz rate.

2.3.2 System Checkout Intruders

In order to fully test the system for flights into the NAS, a variety of intruders and equipage were flown against Ikhana in the R-2515 airspace during SCO. A summary of these intruders is shown in Table 4.

Table 4. Ownship and System Checkout Aircraft Summary and Equipage.

Aircraft	Role	ATAR	ADS-B	DGPS	TCAS-II	TCAS-I	Mode S	Mode C
	Ownship Ikhana UAS	✓	✓		✓		✓	✓
	Intruder T-34C (Backup)		✓	✓		✓	✓	
	Intruder King Air		✓	✓		✓	✓	
	Intruder G-III (Backup)		✓	✓	✓		✓	
	Intruder TG-14		✓	✓			✓	✓

2.3.2.1 *T-34 C Mentor (NASA 865)*

The NASA AFRC T-34C Mentor is a turbo-prop single engine aircraft that seats two pilots in tandem. The T-34C supported the test mission as an ADS-B and TCAS I equipped intruder aircraft, and could function as a low-speed intruder. NASA 865 is also equipped with an Ashtech Z-12 Differential Global Positioning Systems (DGPS) system.

- Weight: 4,300 lb
- Speed: 214 kts
- Ceiling: 25,000 ft
- Endurance: 4 hrs

2.3.2.2 *Beechcraft B200 (NASA 7)*

The NASA AFRC Beechcraft B200 is a twin engine turbo-prop aircraft. NASA 7 supported the test mission as an ADS-B and TCAS I equipped intruder aircraft. NASA 7 is also equipped with a Novatel ProPak6 DGPS system.

- Weight: 12,500 lb
- Speed: 292 kts
- Ceiling: 35,000 ft
- Endurance: 4.5 hrs

2.3.2.3 *Gulfstream G-III (NASA 808)*

The NASA AFRC Gulfstream III (G-III) is a twin engine turbojet aircraft. NASA 808 supported the test mission as a high speed, ADS-B and TCAS II equipped intruder aircraft. NASA 808 is also equipped with a Novatel ProPak6 DGPS system.

- Weight: 69,700 lb
- Speed: 340 kts
- Ceiling: 45,000 ft
- Endurance: 5.5 hrs

2.3.2.4 *Ximango TG-14 (NASA 856)*

The NASA AFRC Ximango AMT 200S (TG-14) is a single engine motorglider aircraft. NASA 856 supported the test mission as a low-speed, ADS-B equipped intruder aircraft. NASA 856 is also equipped with an Ashtech Zextreme DGPS system.

- Weight: 1,874 lb
- Speed: 132 kts
- Ceiling: 10,000 ft
- Endurance: 3.5 hrs

2.4 Airspace

Because of the experience and success gained during previous flight tests, the team used the R-2508 Complex and specifically R-2515 to perform its system checkout flights. For the demonstration flight, an analysis was performed for a route that would satisfy all the requirements of traversing controlled airspace and ARTCCs.

2.4.1 System Checkout

The operating area for SCO Scripted Encounters occurred in the Restricted Airspace, R-2515, located at EAFB, along with the Buckhorn Military Operating Area (MOA), with operations scheduled and coordinated through the Air Force Test Center (AFTC). Specific airspace scheduled each day during these flight tests included the Four Corners Area, Mercury Spin Area, overflight of the Precision Impact Range Area (PIRA) East/West, and the Buckhorn MOA. These areas within R-2515 are depicted within the yellow shaded area shown in Figure 9.

This operating area was adequate for the majority of the encounters. However, there were some encounters that required either or both the intruder and ownship to extend north or west, remaining within R-2515, of the airspace. The extensions were required to either start or complete these encounters. For those encounters where an extension was required to accomplish the test encounter, approval from the controlling agency, Space Positioning Optical Radar Tracking (SPORT), was required. The Buckhorn MOA was used by the manned intruder aircraft, only.

Additionally, during these flights, the NASA operations remained a lower priority within the complex. Because of this, occasional changes to the flight cards needed to occur. If the change was minute enough that the test point would still gather the required data, a redline was announced, recorded, and the card executed. However, if the change was too extensive, the test point was moved to another flight date.

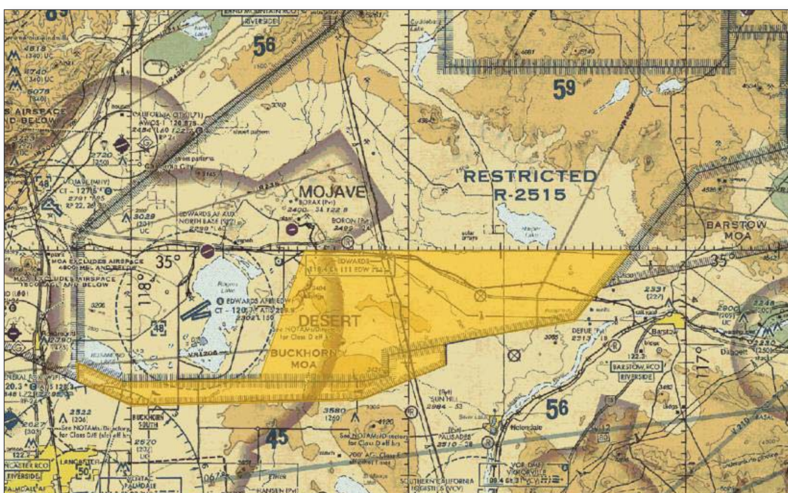


Figure 9. R-2515 Flight Test Area.

2.4.2 Demonstration

The purpose of the demonstration flights was to choose a flight plan for NASA 870 to fly outside of restricted airspace, into the NAS, and without a chase vehicle into Class A (above 18,000 ft Mean Sea Level (MSL)), Class E (at or above/below 10,000 ft MSL), and Class D (above 2,500 ft Above Ground Level (AGL) at an airport with an operational control tower) airspaces, as well as flying through multiple ARTCCs. Due to the launch location of NASA 870 (EAFB), the team chose to keep the demonstration flights within California, flying into Los Angeles ARTCC (ZLA) and then Oakland ARTCC (ZOA) and back. These ARTCCs are highlighted in yellow in Figure 10. The flight also transited E10 Joshua Control Facility (JCF) enroute to Victorville airport, shown in the center of Figure 11.

Figure 10. ZLA and ZOA ARTCCs. Snippet from faa.gov.

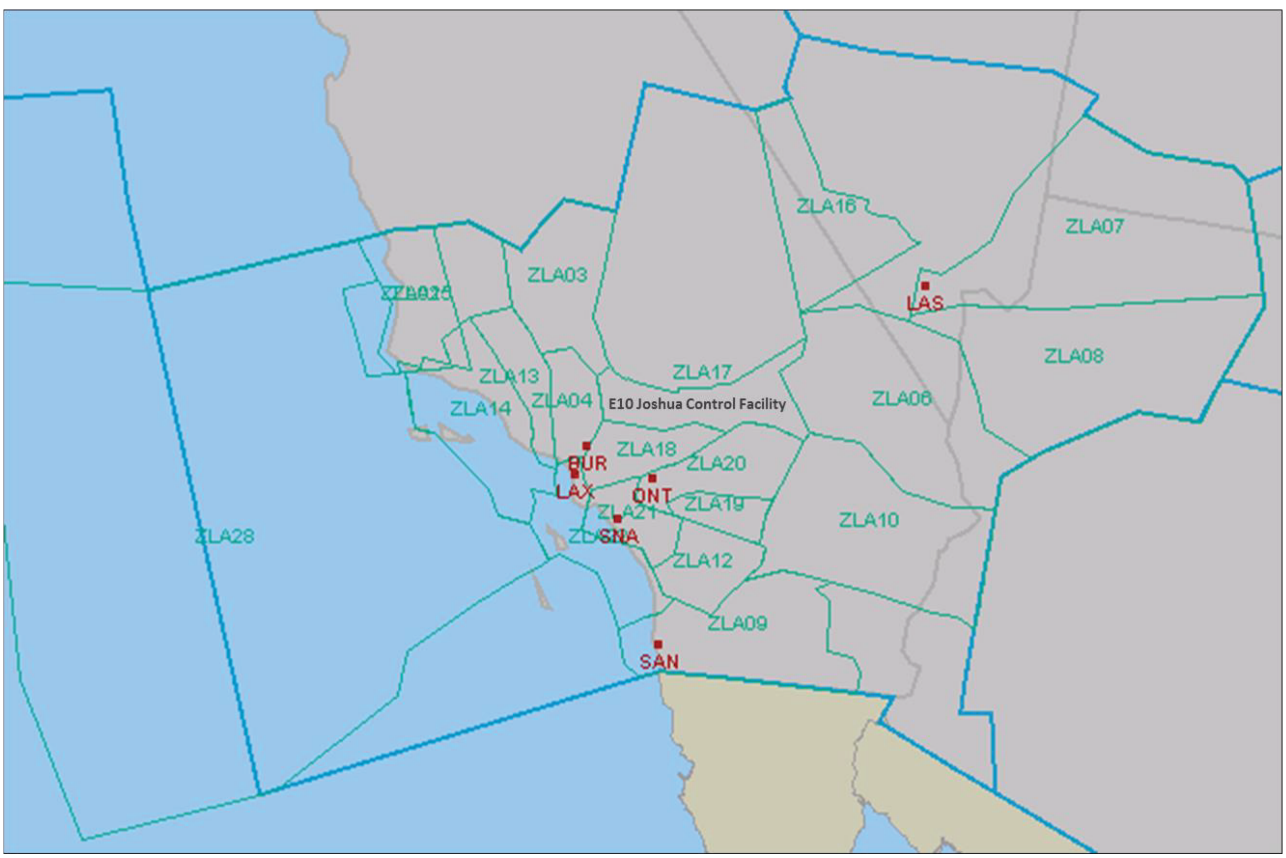


Figure 11. ZLA ARTCC Low Sectors. Snippet from faa.gov.

2.5 COA Process

Prior to submitting the actual application to the FAA for the COA, the team conducted numerous discussions on the safety case, route itself, and other hardware/software configuration specifications for the flight. However, before the discussions were finalized, the FAA notified the UAS-NAS team that the older "COA Online" system would no longer be accepting new applications as of 30 October, 2017. For this reason, and with agreement with the FAA, the team elected to submit a "draft" application through the old system with the intent of it being reviewed and re-submitted at a later date.

Since the Ikhana team already had experience with submitting, using, and receiving COAs from the COA Online system, most of the required sections within the COA could be created quickly based on the current aircraft configuration. The sections that required additional modifications included the Operational and System descriptions, Lost Link procedures, Electronic Surveillance and Detection Capability, Visual Surveillance and Detection Capability (due to the waiver asking for a flight without chase), Flight Operations Area/Plan, and Special Circumstances, which included the safety case. The required sections were created, briefed to Armstrong upper management, and submitted to the COA Online system on 30 October, 2017. The COA was then reviewed by the FAA and released back to Armstrong. The release back asked for a CONOPS document to summarize the flights. This release also allowed the team to make minor modifications to the route of flight (based on comments from the FAA) and add additional information to the safety case. On 20 December, 2017, the COA was re-submitted into the new online COA Application Processing System (CAPS).

The next phase in the process required a thorough review from the FAA, which included conducting a SRMP in February 2018, described in further detail in Section 2.12.2. Once this review was conducted, some additional questions were brought up on the route of flight. The FAA provided modifications, and the COA document was officially released on 30 March, 2018.

Upon release of the COA, additional questions arose from the FAA pertaining to the back-up command and control (C2) of Ikhana. A Special Temporary Authorization (STA) to approve use of C-Band Line of Sight (LOS) C2 outside of SUA was initially declined by the FAA Spectrum Office. In clarifying the purpose for this particular item, the project engaged in valuable discussions with the spectrum management community. These discussions led to further clarifications, for all parties, regarding research equipment onboard the aircraft that meet the intent of the MOPS/Technical Standard Orders (TSOs) but are not certified to those standards and how the project intended to use them only for the particular mission proposed. Eventually all parties understood the operational limitations for the equipment and the commensurate mitigations for the mission, and STAs for the DAA equipment were approved first for flight with chase; this flight occurred on 24 May 2018. Once the results from this flight were reviewed, STAs for operations without chase were approved, and the flight without chase was finally conducted on 12 June 2018. The details for which equipment was authorized for each flight can be found in Table 1.

2.6 Route Development

The NCC mission plan was developed from early objectives dating back to 2014. Of the original objectives, one led to the development of the demonstration flight plan: "Demonstrate DAA and C2 MOPS technologies within the NAS on specific flights to/from Class A airspace, through Class E, D and possibly G airspaces."

In order to meet minimum requirements of that objective, a local "SoCal Demo" mission was created. The SoCal routing would start within R-2515 where Ikhana would exit the SUA at flight level (FL)200 to the southeast and transit Class E airspace at 6,000 ft MSL to Southern California Logistics Airport, Victorville (VCV) Class D. The aircraft would fly a low approach to the VCV active runway, go missed approach and continue on its mission through Class E heading west. During the western leg of the mission, a "chance" encounter with a non-cooperative intruder aircraft would occur. Lastly Ikhana would either re-enter restricted airspace in Class E or climb to Class A and re-enter restricted airspace.

Over time this original plan evolved through iteration and peer review to the mission flown in June of 2018. Considerations for meeting the baselined objectives included such things as entering Class G airspace at Gray Butte shooting an approach to the active runway, flying Ikhana in Class A airspace to Grand Forks, North Dakota, and flying an approach at the regional airport, flying a western mission off the California coast transiting through the warning areas located there, to flying the established UAS corridor created for the Riverside Air National Guard (ANG). Ultimately a route of flight that remained overland and within 3 hours of EAFB was chosen.

Several mission planning tools were used to design the route of flight including FalconView, SkyVector, Google Earth, Sectional Aeronautical charts and DoD Flight Information Publications. The route of flight was evaluated for Maximum Elevation Figure (MEF), Minimum Enroute Altitude (MEA), Minimum Obstacle Clearance Altitude (MOCA), Off-route Obstruction Clearance Altitude (OROCA), and Minimum Vectoring Altitude (MVA). MVA for the VCV radar sectors was provided by the FAA Western Service Center.

The NCC mission plan was carefully developed to remain off of published airways and away from known flight activity associated with gliders and other small aircraft that NASA did not fully test the ATAR system against. Flight tests were utilized to validate ATAR performance predictions using radar cross section (RCS) modeling and simulations for medium and large aircraft. Modeling and simulation results show sufficient detection and track performance against small RCS aircraft such as gliders; however, to further reduce risk, the flight demonstration was planned to remain clear of areas with known glider activity.

Development of the flight demonstration mission was a collaborative effort that included contributions from NASA, GA-ASI, Honeywell, and the FAA.

2.6.1 Final Route

In order to meet the objectives established for the flight demonstration, the mission needed to depart restricted airspace, transit Class A, to include communication with at least two ARTCC facilities, transition to Class E airspace above and below 10,000 ft MSL and transition through Class D airspace before returning to restricted airspace. The NAS portion of the mission was flown entirely under Instrument Flight Rules (IFR).

The final route, shown in Figure 12, was a culmination of the inputs from the UAS-NAS, the Ikhana team, FAA, and industry partners, and ensured all objectives previously outlined would be met. The final route was comprised of 18 waypoints. The route began and finished within R-2515 at EAFB, traveling counterclockwise from waypoints 1-10, and then entering the VCV Area to a minimum altitude of 5,000 ft MSL. The NAS portion of the route was originally intended to be about 2.5 hours, but with modifications on speeds, altitudes, and changes to routing, the actual flights were around 2.0 hours.

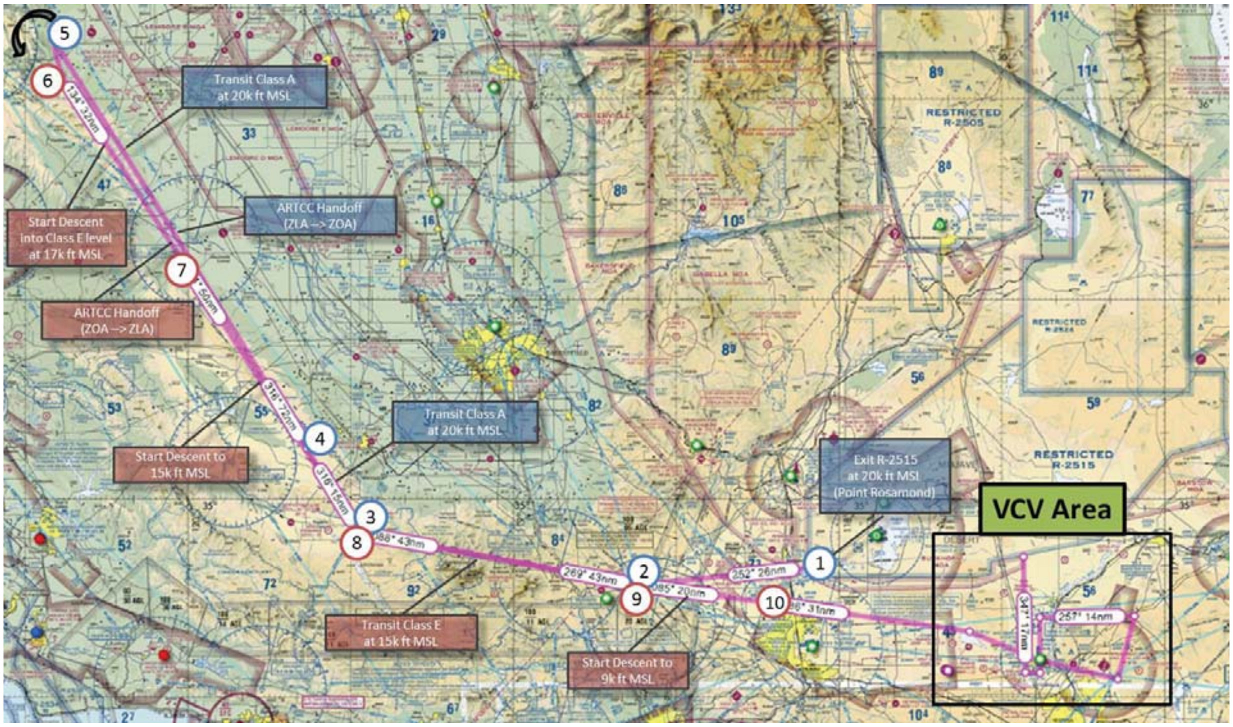


Figure 12. Final Demonstration Route.

The route began within EAFB R-2515, where the team powered up the DAA system to fly into the NAS. NASA 870 would begin its journey into the NAS at waypoint 1, at 20,000 ft (Class A airspace), under ZLA control. Ikhana would then transition through waypoints 2, 3, and, 4, with a handoff to ZOA between waypoints 4 and 5. After taking a sharp left turn to waypoint 6, the Ikhana pilot would request a descent to 15k ft MSL (Class E) and be handed back to ZLA between 6 and 7. The pilot would transition the aircraft through waypoint 8, request a descent to 9,000 ft MSL, and begin a descent after waypoint 9, waypoint 10, and then the VCV area, shown in Figure 13.

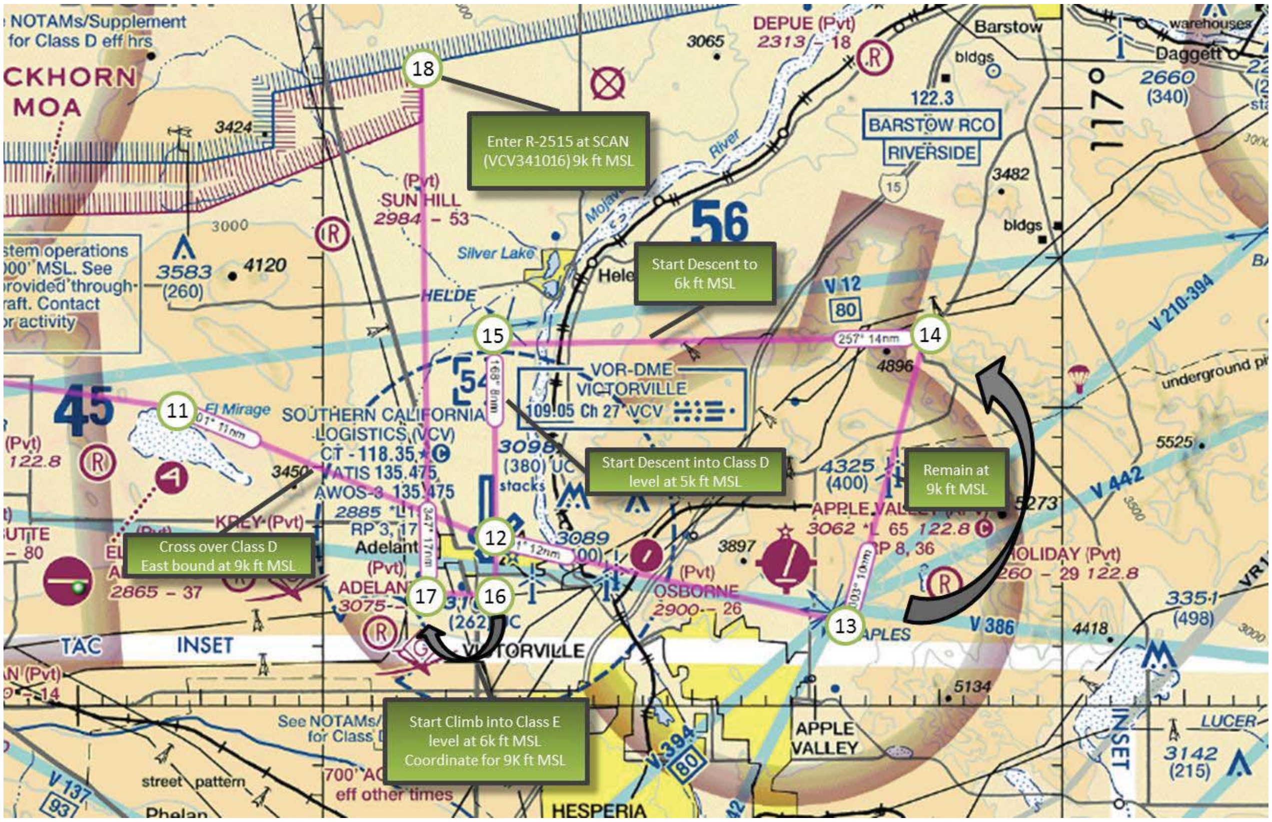


Figure 13. Zoom-in of Demo VCV Area.

Once within the VCV area, the pilot would maintain the aircraft at 9,000 ft MSL through waypoints 11, 12, 13, 14, and once westbound to 15, request a descent to 6,000 ft MSL through waypoint 15. At waypoint 15, the pilot would request a descent to 5,000 ft MSL and officially dip into the Class D airspace between 15 and 16. At the next turn between 16 and 17, the pilot would request a to climb to 6,000 ft MSL and coordinate the climb up to 9,000 ft MSL and back into R-2515 at waypoint 18.

2.6.2 Coordinates

Due to the way Notices to Airmen (NOTAMs) were required to be submitted, each waypoint required a Very High Frequency (VHF) omnidirectional range (VOR)/distance measuring equipment (DME) associated with it. Details on the waypoint, name, coordinates (latitude/longitude), VOR/DME, fix, altitude of the route of flight are shown in Table 5.

Table 5. Demo Route of Flight Coordinates, Fixes, and Altitudes.

WP	LATITUDE (N)	LONGITUDE (W)	VOR	Fix (DD175)	ALT	Remark
1	34° 49' 40.00"	118° 05' 48.00"	Edwards	EDW 233/12	FL200	Exit R2515
2	34° 47' 00.00"	118° 37' 00.00"	Lake Hughes	LHS 330/06	FL200	
3 (CROWY)	34° 54' 54.00"	119° 28' 34.00"	CROWY	CROWY	FL200	Turn North
4	35° 07' 41.38"	119° 38' 09.42"	Fellows	FLW 067/12	FL200	5 min to OAK
5	36° 09' 00.00"	120° 25' 0.00"	Priest	ROM 075/12	FL200	Turnaround/Overfly
6	36° 03' 35.73"	120° 23' 25.22"	Priest	ROM 098/14	FL200	Begin Descend to 17
7	35° 36' 31.31"	120° 01' 36.78"	Avenal	AVE 214/3	17,000	Begin Descend to 15
8 (CROWY)	34° 54' 54.00"	119° 28' 34.00"	CROWY	CROWY	15,000	Turn East
9	34° 47' 00.00"	118° 37' 00.00"	Lake Hughes	LHS 330/06	15,000	Begin Descend to 9
10 (GWF)	34°44'19.00"	118° 13' 0.00"	Wm J Fox NDB	GWF	9,000	(PMD 299/10)
11	34° 40' 00.00"	117° 36' 00.00"	Victorville	VCV 282/11	9,000	
12 (VCV)	34° 35' 39.00"	117° 23' 24.00"	Victorville VOR	VCV	9,000	
13 (APLES)	34° 32' 54.48"	117° 08' 58.14"	APLES	APLES	9,000	Turn North
14	34° 42' 20.35"	117° 05' 34.95"	Victorville	VCV 054/16	9,000	Turn W, Descend
15 (HELDE)	34° 42' 16.29"	117° 22' 57.18"	HELDE	HELDE	6,000	Turn S, Descend
16	34° 33' 43.03"	117°23' 00.88"	Victorville	VCV 159/2	5,000	Turn W, Climb to 6
17	34° 33' 47.96"	117° 25' 43.42"	Victorville	VCV 215/3	6,000	Turn N, Climb to 9
18 ~~(VEGAS)~~	34°51' 19.00"	117° 26' 03.00"	Victorville	VCV 341/16	9,000	Enter R2515

2.6.3 Mission Profile

Figure 14 shows the mission profile, which includes the transition points of altitudes, classes of airspace, and ARTCCs.

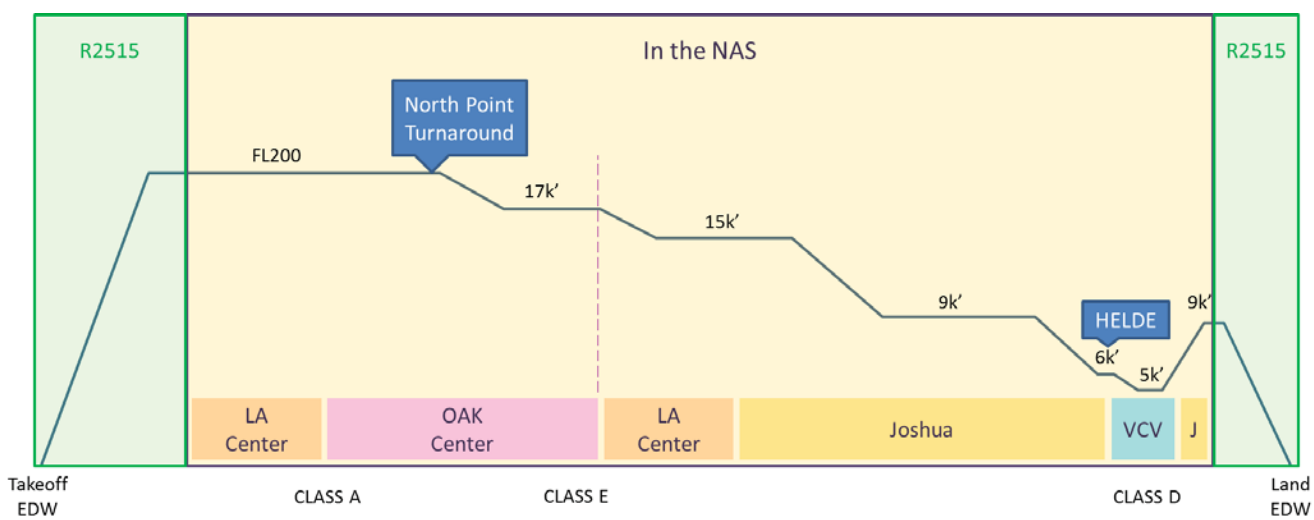


Figure 14. Demo Mission Profile.

2.6.4 Lost Link

Although the mission routing changed through the lifetime of the project, the concept behind the lost link mission stayed the same. If Ikhana lost link, the lost link mission profile would follow a very similar, predictable path to the mission profile, and fly back into R-2508 and R-2515. Once back in R-2515, the aircraft would fly a "hexagon" pattern around a set of waypoints until the team could determine the appropriate course of action. The original plan by the IT&E team was to follow the mission route back as the lost link mission; about 3 lost link routes – however, the FAA deemed it better to break up the lost link routes into smaller sections, with a shorter route back into R-2508. Once the new and additional lost link missions from the FAA were provided, NASA reviewed and updated these routes to ensure the stricter AFRC agency range safety "keep out" over-fly zones were incorporated into these routes (red/yellow areas in Figure 15).

The lost link mission was divided into five separate lost link missions, based on flight segment. The lost link missions was continually updated by the pilot during flight with the entry waypoint, altitude, and correct mission number. Additionally, each of the lost link missions' entry waypoints was kept greater than 5 minutes of the current position. Figure 15 shows the five segments laid out on top of one another, following the mission route. All lost link missions were entered with the current assigned altitude, excluding the last six "hexagon" waypoints, which were programmed at 7,500 ft MSL.

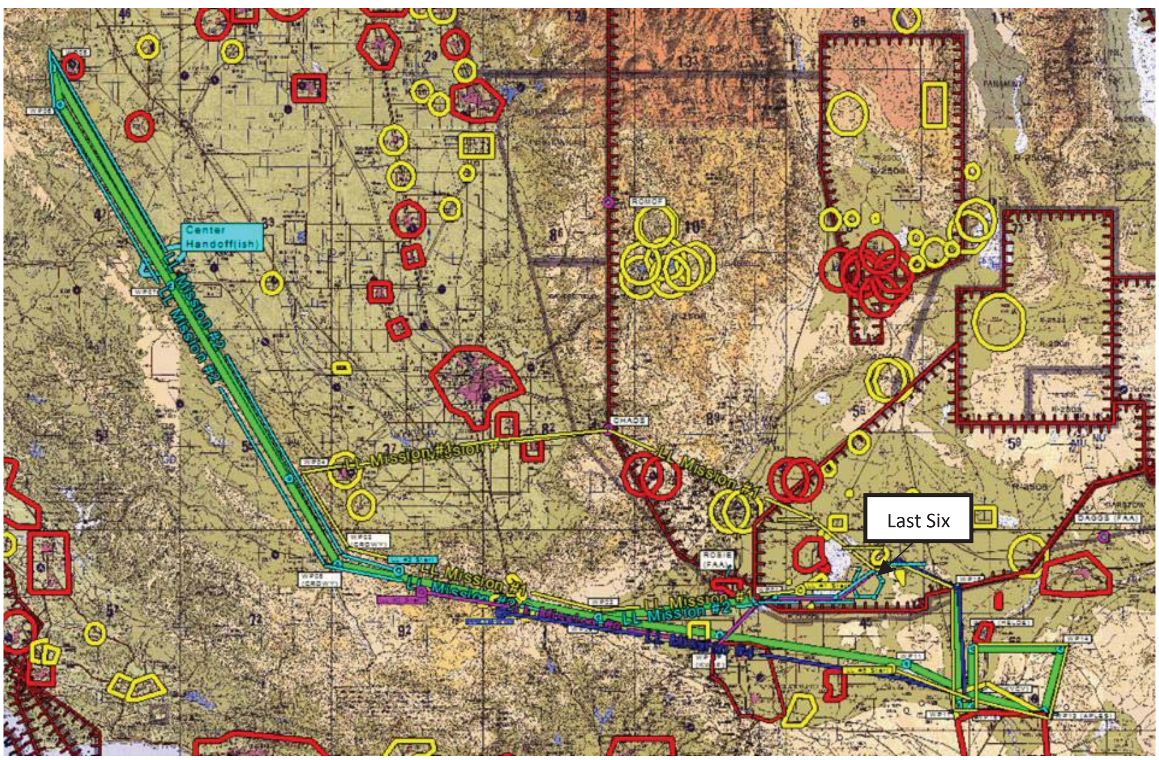


Figure 15. Full Lost Link Missions Route.

The first lost link mission, shown in Figure 16, would cause the aircraft to enter at CHADS R-2508 point (labeled and shown as the kink at the top of the lost link route), and then to the last six waypoints (labeled and depicted in cyan in Figure 15). This lost link would be used prior to and including waypoint 4.

The second lost link mission, in Figure 17, would be loaded by the Ikhana pilot slightly prior to waypoint 4. This lost link mission would cause the aircraft to circle around to the north, following the mission routing, back to waypoint 2, and finally re-enter R-2515 and to the last six waypoints.

Figure 18 shows the third lost link mission, which would be loaded prior to waypoint 9. The mission would be followed to waypoint 10, and then waypoint 1, re-entering R-2515 to the last six waypoints.

The fourth lost link mission, in Figure 19, would be executed slightly prior to reaching waypoint 9. The mission would reach waypoint 12 and then re-enter R-2515 at waypoint 18 to the last six waypoints.

Finally, Figure 20 shows the fifth lost link mission. This mission would be loaded slightly prior to waypoint 11, follow the VCV box pattern, and re-enter R-2515 at waypoint 18 and then to the last six waypoints.

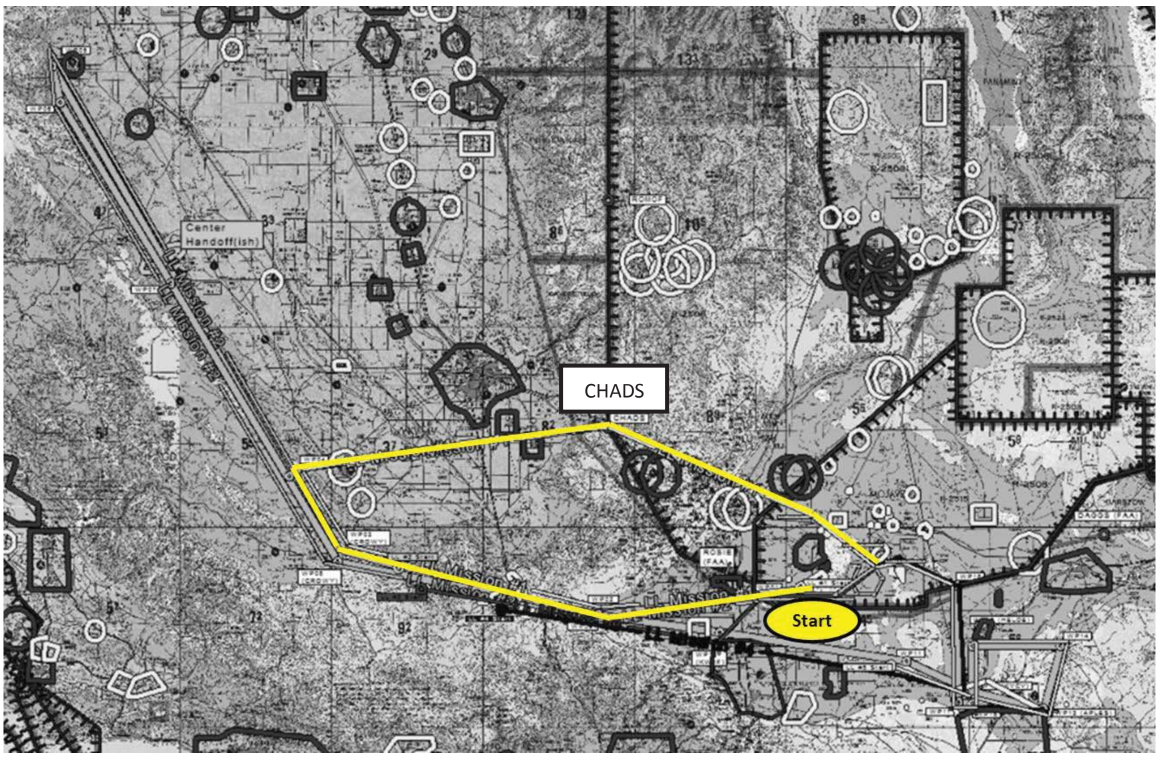


Figure 16. Lost Link Route 1.

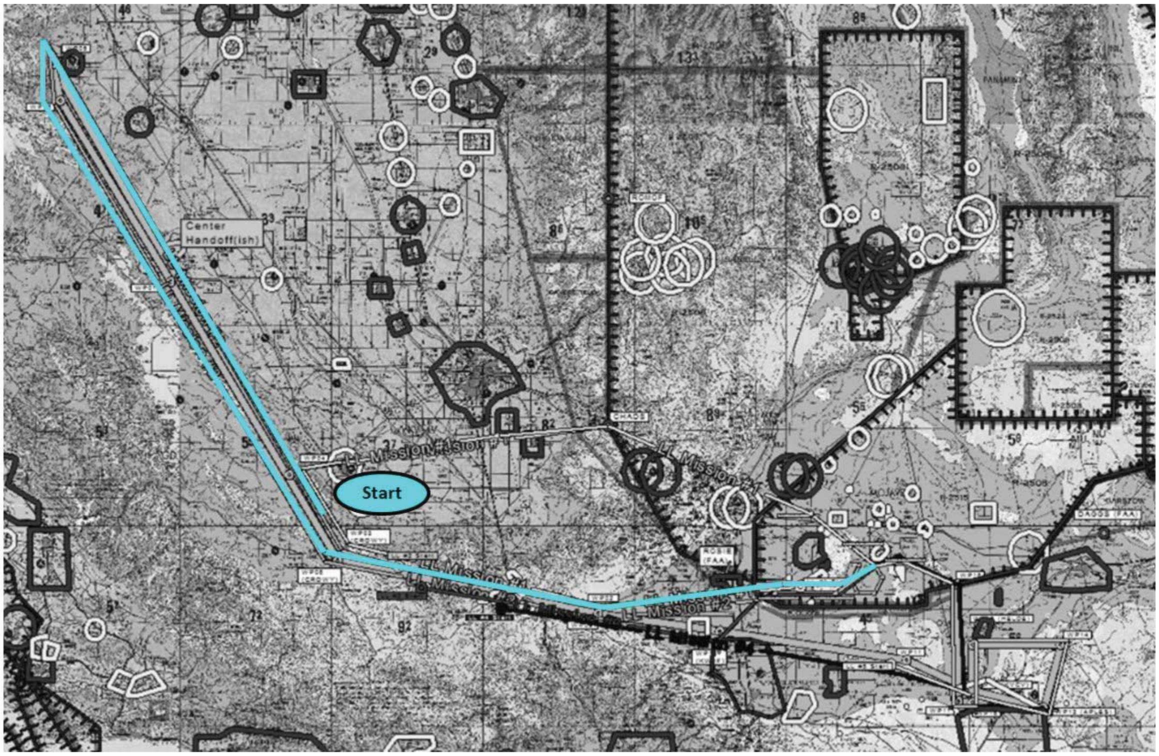


Figure 17. Lost Link Route 2.

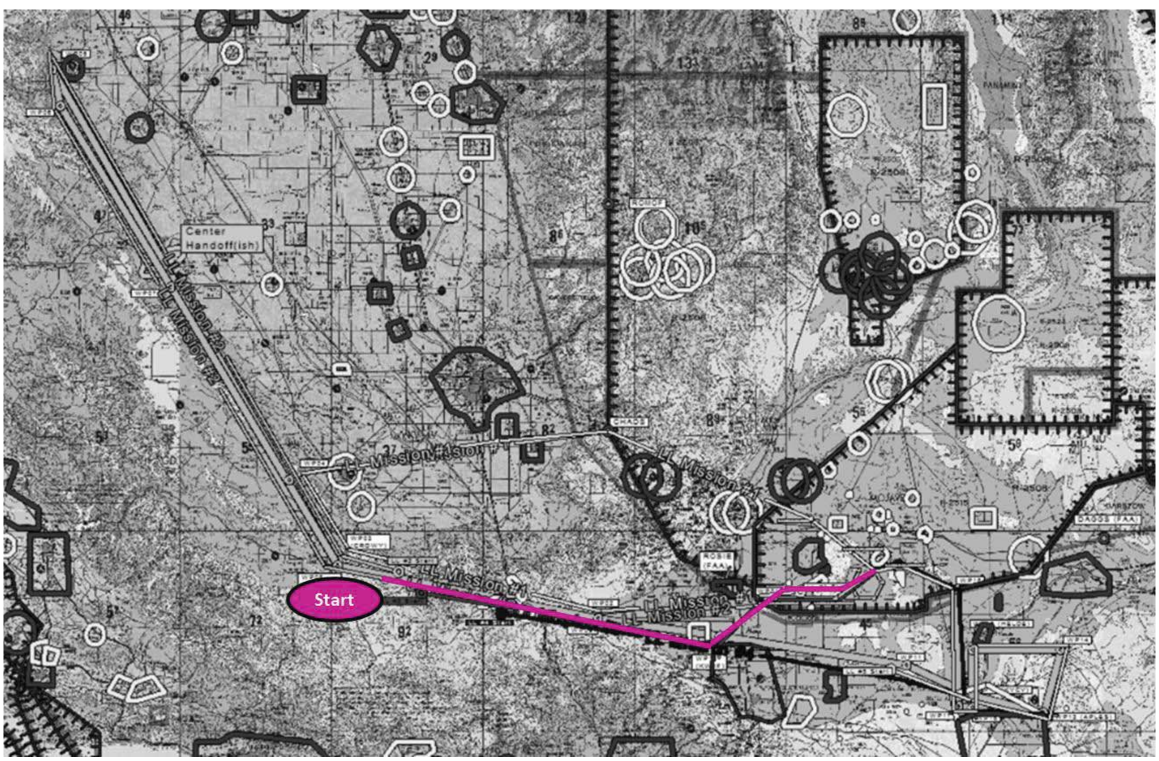


Figure 18. Lost Link Route 3.

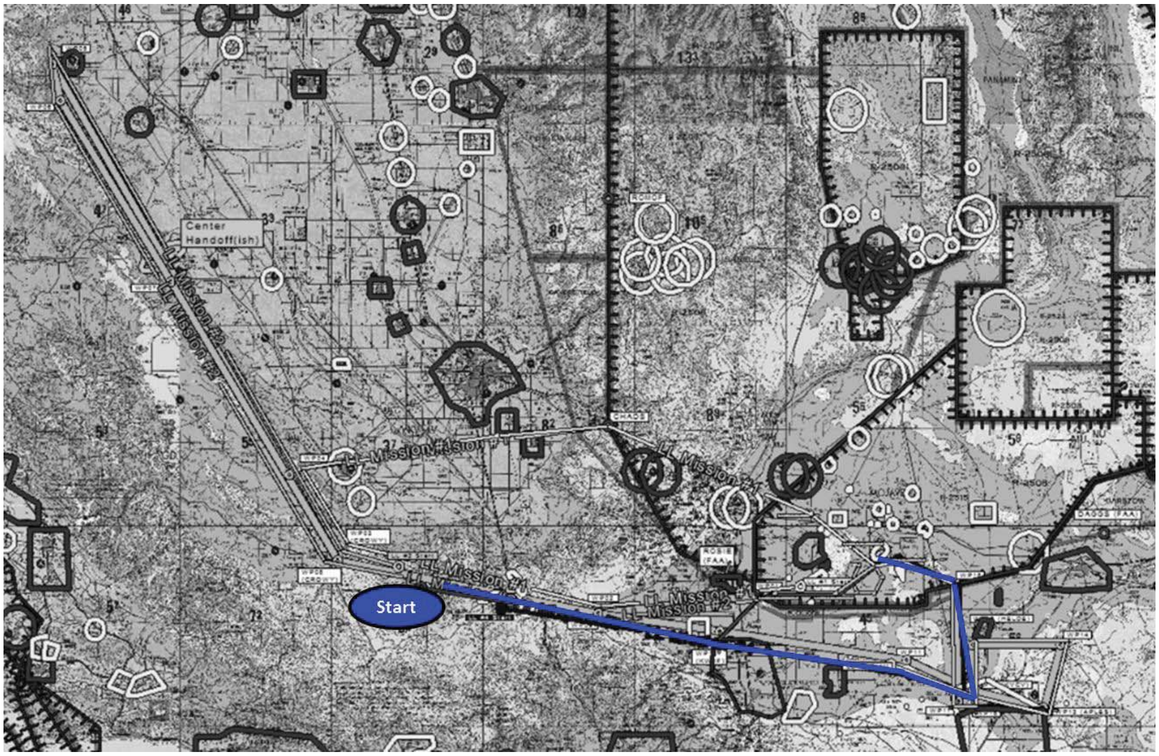


Figure 19. Lost Link Route 4.

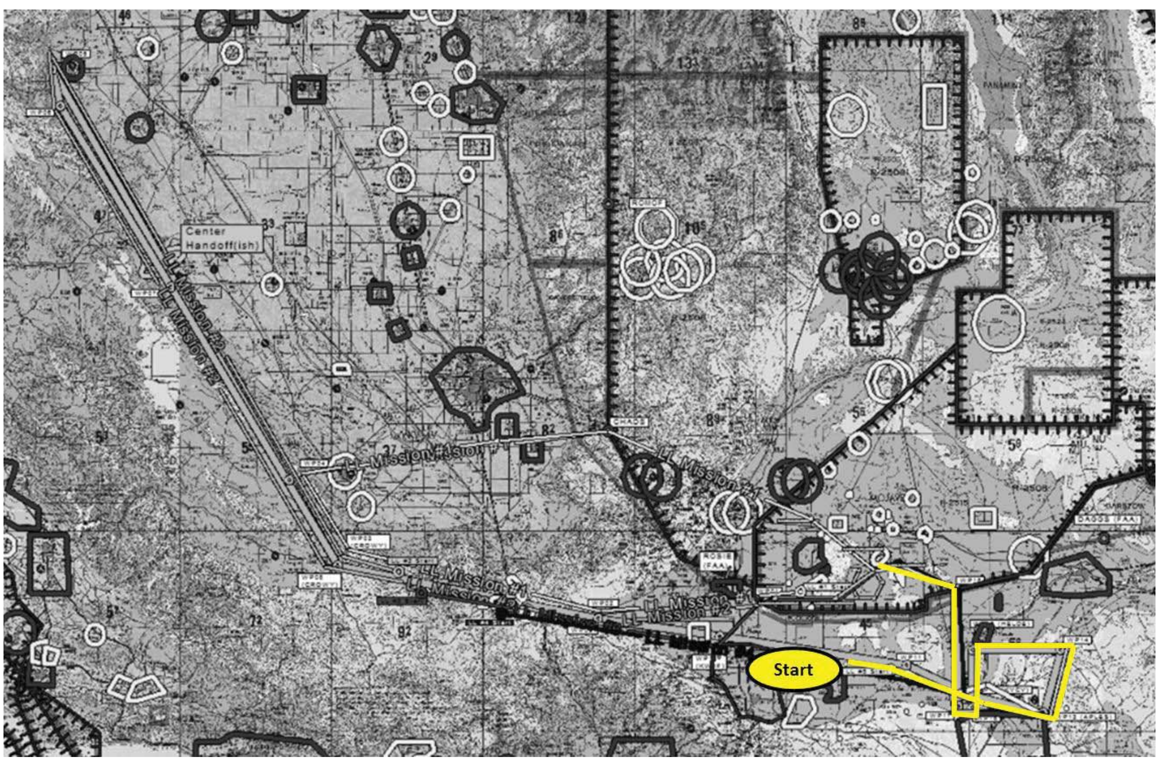


Figure 20. Lost Link Route 5.

2.7 Methodology

To perform all phases of flight successfully, the team put together a methodology for each flight segment prior to commencing. The system checkout methodology was unique and developed through the years of flight testing with the UAS-NAS project. The methodology prior to demonstration flights included requirements from the FAA for flights into the NAS.

2.7.1 System Checkout

The SCO methodology was unique for this portion of flights. Encounters from previous flight tests were slightly modified to encompass a variety of scenarios, while also incorporating unique operational encounters which had not been previously performed. The overall objective was to demonstrate situations which could be expected while flying in the NAS in any class of airspace.

2.7.1.1 *Encounter Nomenclature / Geometries*

In order to meet the SCO objectives, encounters were designed to stress the system. A unique nomenclature shown in Table 6 below was also created to easily identify each encounter.

Table 6. No Chase COA System Checkout Nomenclature.

Name	Definition
TM	Test Mode
UC	Use Case
SQK	Squawk Off
LOB	Level-Off Blunder
HS	High Speed
NUIS	Nuisance
DB	Double Blunder
HDR	High Descent Rate
IOT	Intruder Overtake
OOT	Ownship Overtake
LT	Left Turn
ATCAS	Auto TCAS
LALT	Low Altitude
OTD	Ownship Turn and Descend

Figure 21 through Figure 33 show the encounters that were performed during the SCO.

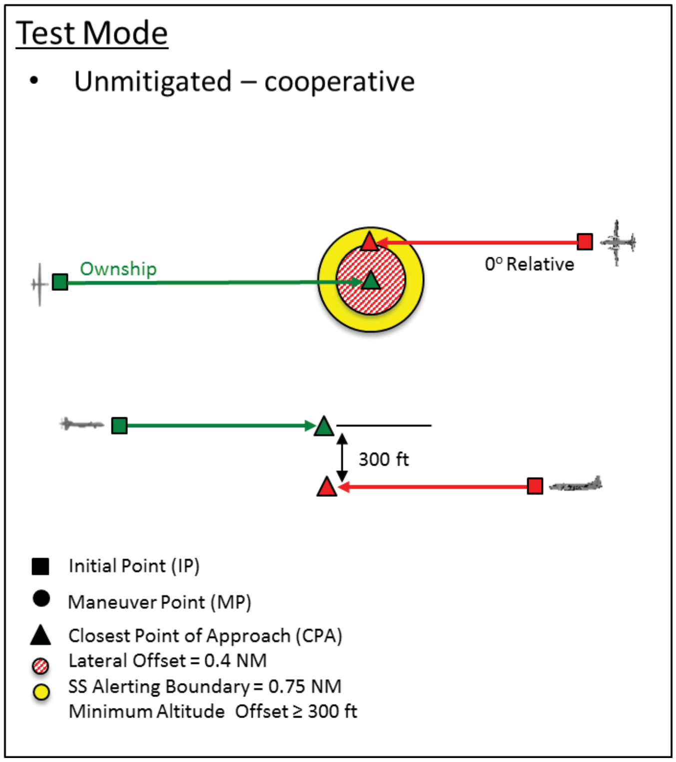


Figure 21. Test Mode Encounter. The DAA system test mode would be set to 253, which forced the system to drop fused targets.

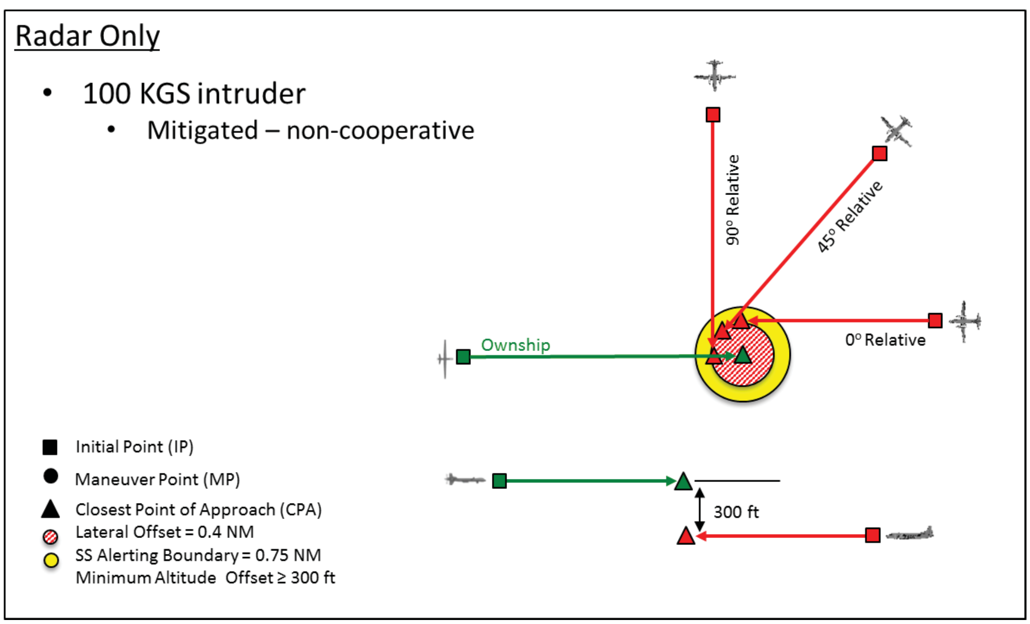


Figure 22. Radar Only Encounter. In order to simulate non-cooperative targets, the radar would be the only active sensor feeding the DAA algorithms. The intruder aircraft would turn their transponder off in this encounter.

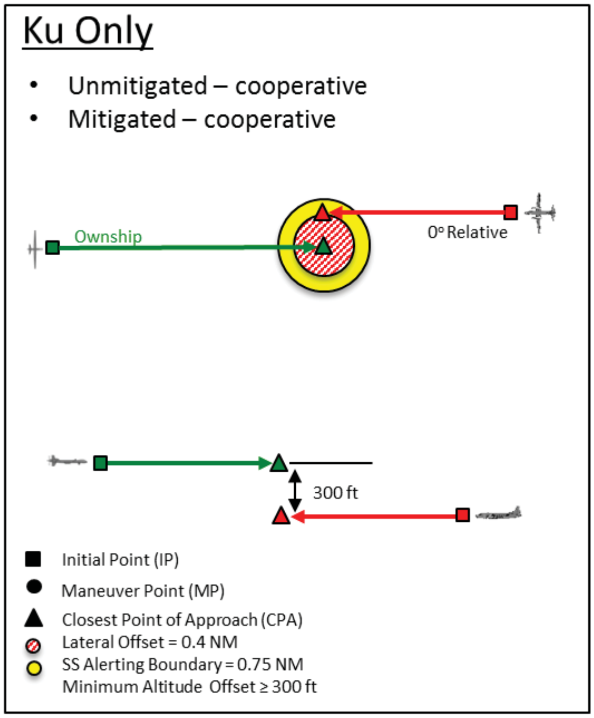


Figure 23. Testing Ikhana while only having Ku as the C2 Link.

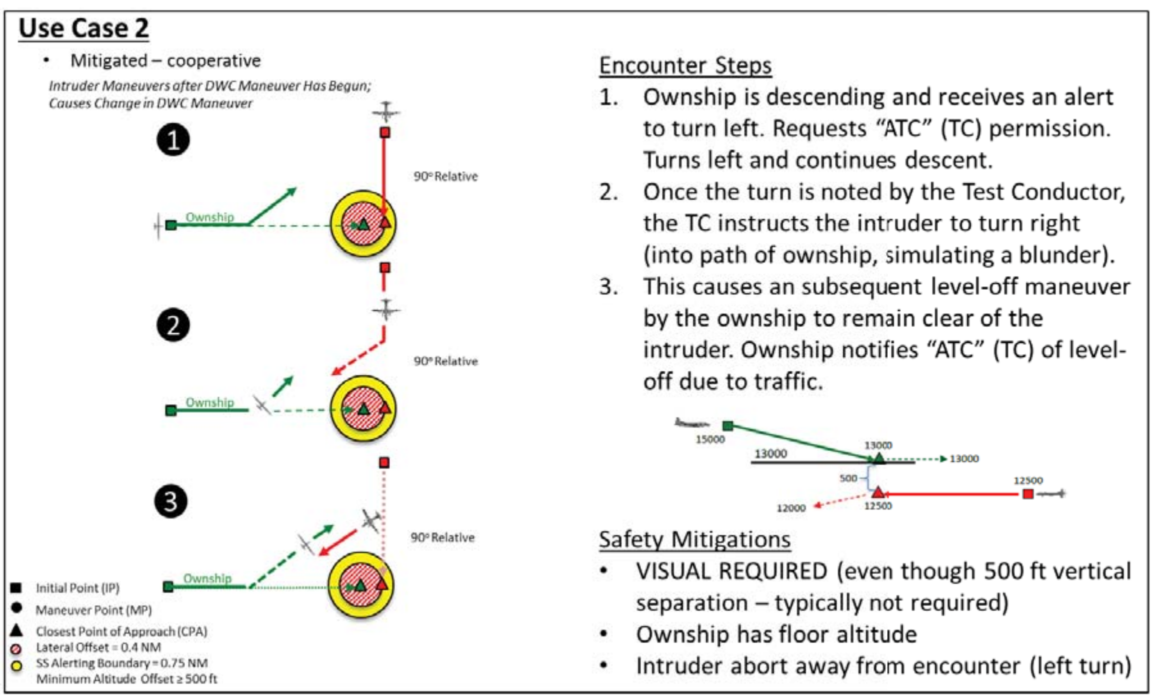


Figure 24. CONOPS for Use Case 2. The Ikhana pilot would employ the DAA system and interact with ATC to fulfill the "See and Avoid" responsibilities.

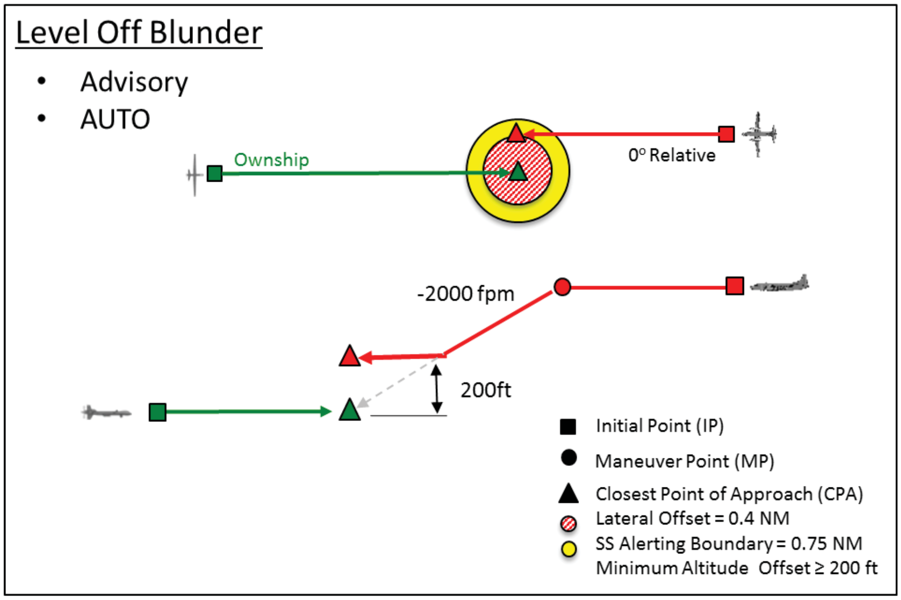


Figure 25. Intruder Level-Off Blunder.

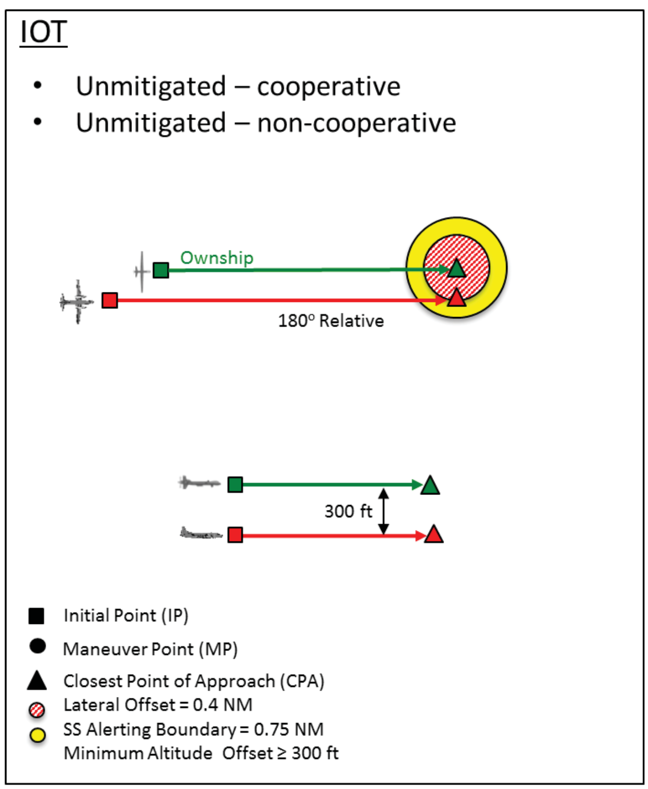


Figure 26. Overtaking Intruder. This encounter would be used to represent an encounter that may occur in the NAS due to the slower speed of Ikhana.

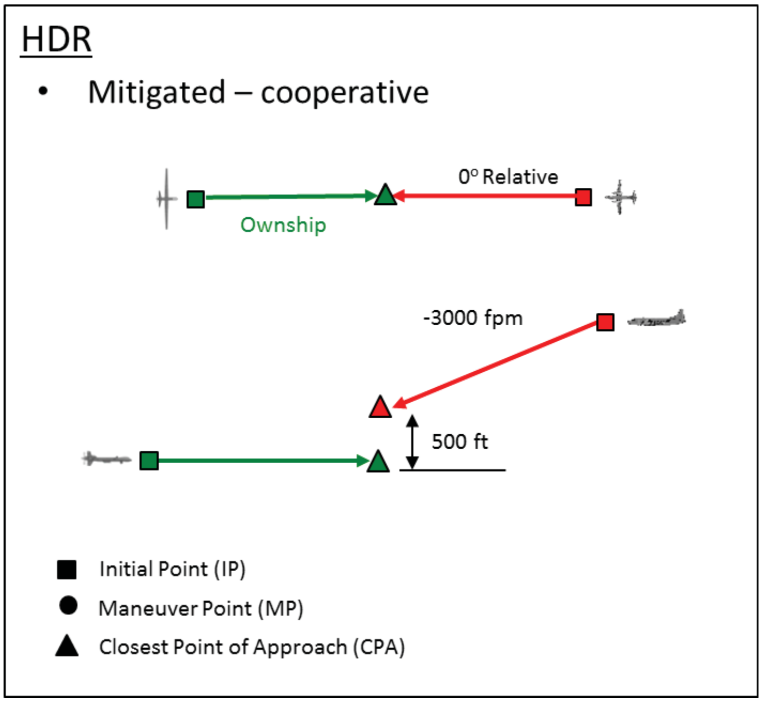


Figure 27. Intruder High Descent Rate.

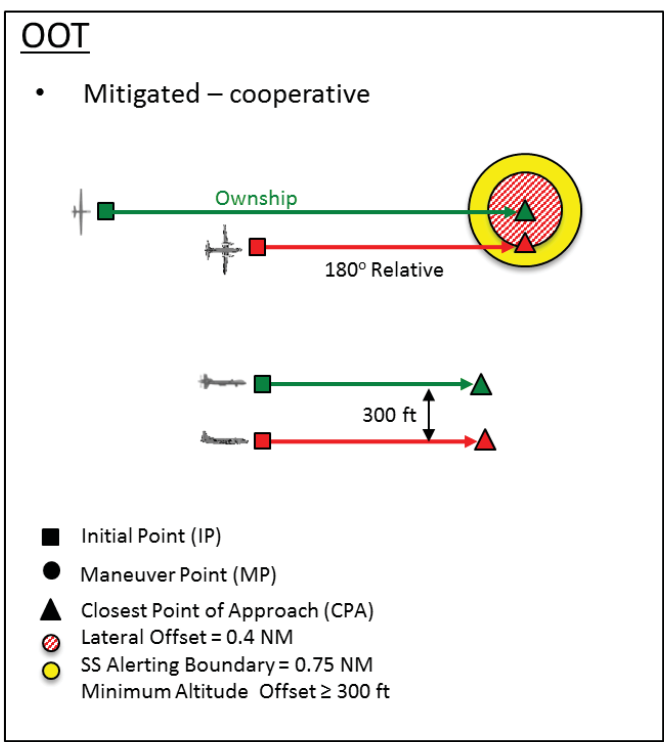


Figure 28. Ownship Overtake. This encounter represented Ikhana overtaking a slower general aviation aircraft.

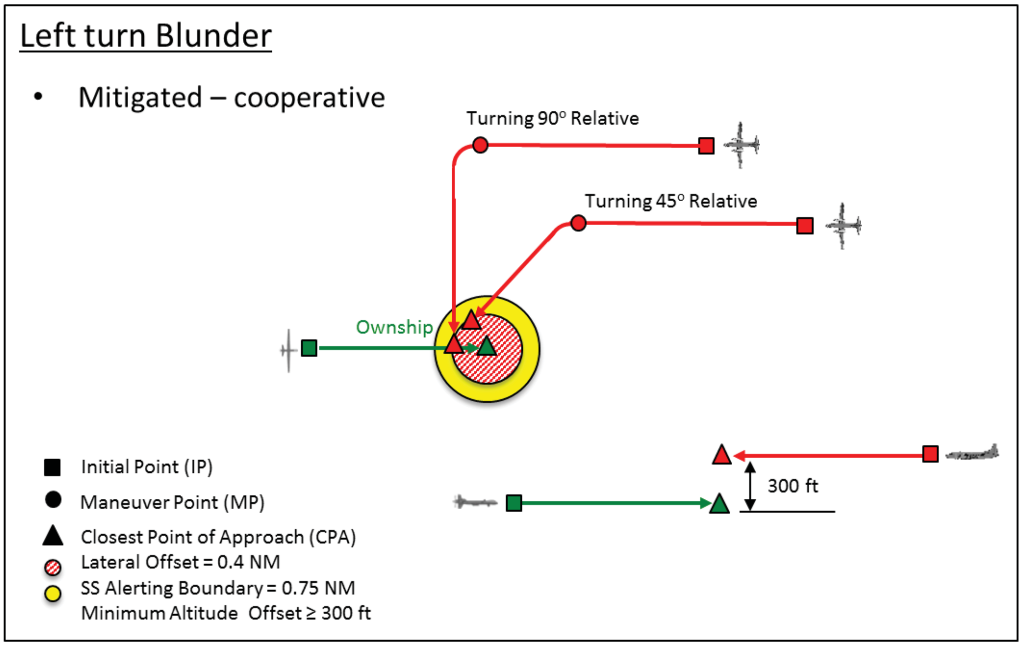


Figure 29. Left Turn Blunder Maneuver.

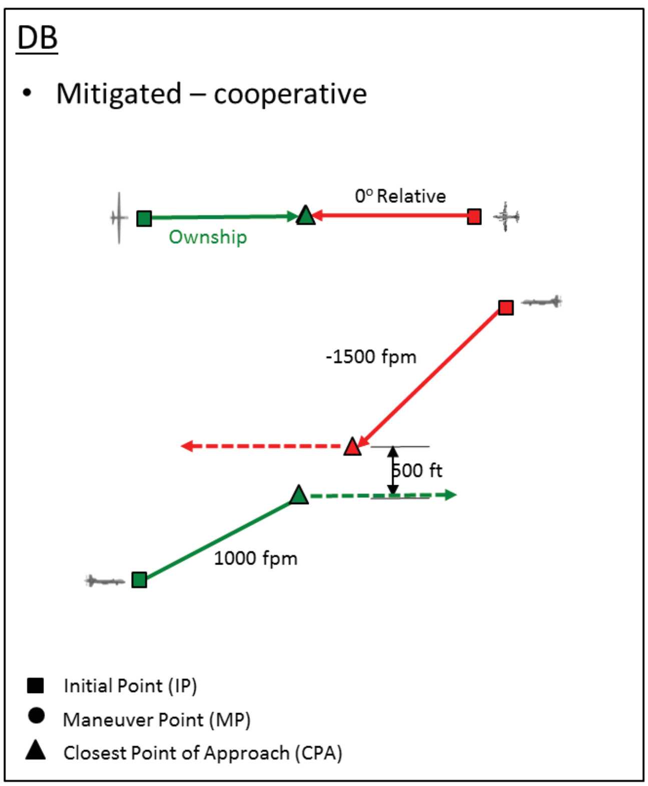


Figure 30. Double Blunder Maneuver.

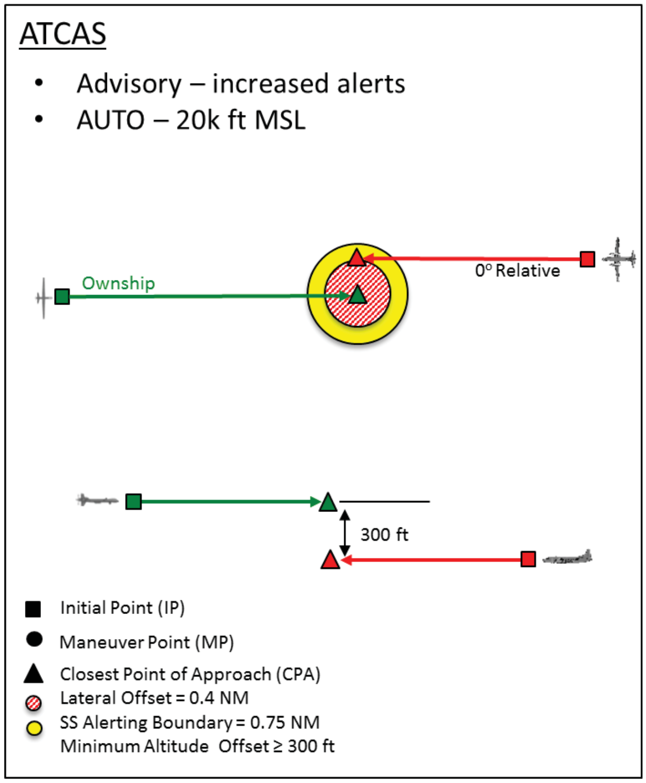


Figure 31. Increased TCAS Alerts Triggering an Auto Maneuver.

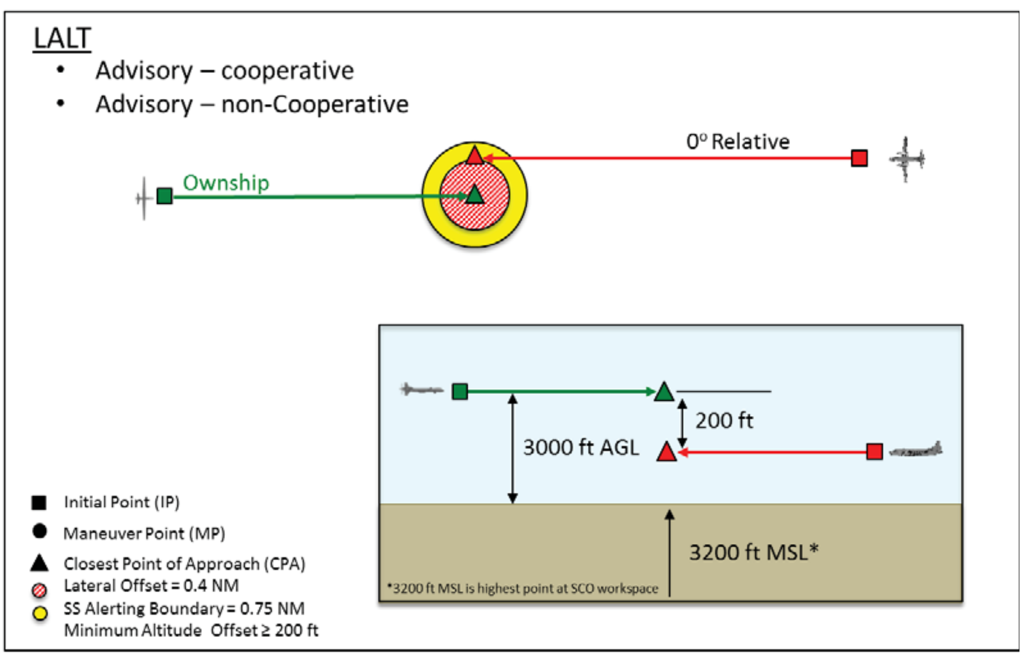


Figure 32. Low Altitude. This encounter was used to simulate flying into Class D airspace to demonstrate TCAS/radar performance at a low altitude.

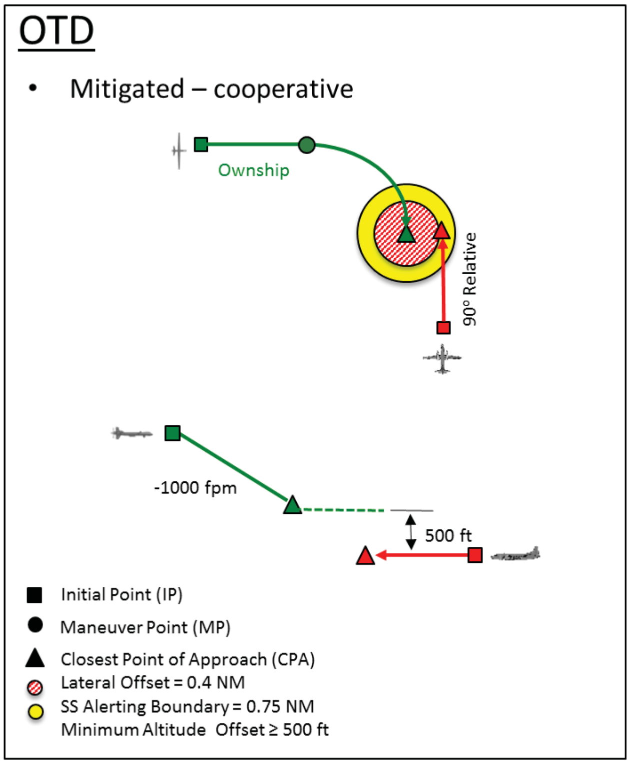


Figure 33. Ikhana Turn and Descend.

2.7.1.2 *Flight Test Matrix*

A detailed flight test matrix was built for the NCC SCO encounters based on the objectives and requirements described in Section 2.7.1.1. The encounters were grouped into sections based on their type.

Because the use of this matrix was highly successful in previous flight campaigns, it was used again for SCO. The purpose of the matrix was to input all required test geometries, planned coordinates, and populate the flight cards with information and requirements/objectives for each encounter.

The matrix was built in Microsoft Excel® and used Visual Basic for Applications (VBA) for calculated pertinent values, such as Global Position System (GPS) Coordinates in multiple formats. Additionally, Excel was useful for calculated Initial Point (IP) to Maneuver Point (MP) and CPA using dead-reckoning equations.

- **Scenario (Encounter) Number (S/N):** The Scenario Number was the most critical number for each encounter. This number served as an identification number for the unique geometry.
- **Type:** The type of encounter is based off the geometry and specific objective.
- **Name:** Names were based from the type of the encounter. The Name was a quick reference to gain Situational Awareness (SA) on what type of encounter was being performed.
- **OWN True Course:** True Course of the ownship. This value was used to calculate GPS coordinates (magnetic course was later calculated in a separate table).

- **Leg Time:** This is a partial time of the encounter. It could be between a Commence Exercise (COMEX) and first CPA.
- **Total Encounter Length:** Time for the encounter from COMEX to finish. Most encounters were 2 or 3 minutes.
- **Ownship Angle:** Angle of ownship turn for ownship maneuvering encounters.
- **Angle Into:** Relative angle of the intruder into the ownship for that geometry. This value was used to calculate GPS coordinates.
- **Vertical Offset:** Smallest vertical separation between ownship and the intruder at CPA. If the vertical separation necessary for an encounter was ≤500 ft, a lateral offset was required for safety.
- **Lateral Offset:** A lateral offset of 0.4 nmi (~2,400 ft) was calculated into the geometry for encounters with a vertical separation of ≤500 ft. This was to ensure that if visual was not acquired according to mission rule, there would still be a safety buffer.
- **GS OWN:** Groundspeed of the ownship. Groundspeed was preferred for calculations since aircraft were required to be at a certain set of coordinates at a certain time.
- **GS INT1:** Most encounters required the intruder to fly at 150 or 180 KGS. For high-speed encounters, intruders were required to fly ≥300 KGS. For low-speed encounters, usually 100 KGS was used.
- **Altitude Regime:** At various altitude regimes, a different vertical separation between aircraft is required for TCAS to trigger. Since some encounters were testing for TCAS interoperability, it was critical to note and design the encounter at the proper altitude.
- **Ownship Initial Altitude:** Altitudes chosen for each encounter took Ikhana and intruder flight performance into consideration, as well as airspace. Encounters began 10k-20k ft MSL or under 10k ft MSL. Low-altitude radar encounters took the highest point on the terrain (3,200 ft MSL) and added 1,000 ft for the flight level (thus 4,200 ft MSL).
- **Ownship Vertical Velocity:** For some encounters, a climb or descent was required by the ownship. Most common rates required were either 1,000 fpm (climb) or -1,000 fpm (descent).
- **Ownship Final Altitude:** Once more, the final altitude was within the block of 10k-20k ft MSL, under 10k ft MSL, or 1,000 ft above the highest terrain point.
- **Intruder 1 Initial Altitude:** Identical to ownship.
- **Intruder 1 Vertical Velocity:** Identical to ownship, although in some cases a high climb/descent rate up to 3,000 fpm was required.
- **Intruder 1 Final Altitude:** Identical to ownship.
- **CPA OWN:** The CPA of the ownship was one of its most important parameters. The CPA was the point where the ownship and intruder would be nearest in space for each encounter. CPAs were chosen to accommodate for the legs in the airspace, planned for sun angles for manned intruders, and were used to build the Ikhana Lost Link mission. Additionally, the CPAs made it easier to group encounters based on matching CPA when building these geometries in Zeus SA display in the MCC3. Finally, the CPAs were used in a lookup table to build GPS coordinates for all geometries.
- **CPA OWN Lat/Lon:** Chosen latitude and longitude for each CPA in Decimal Degrees (DD) format. The CPA latitude/longitude was found using FalconView.

- **IP OWN:** The IP of the ownship was chosen to fit within the airspace and to accommodate for the encounter lengths. The IP served as the point where the encounter would start and where the aircraft needed to be at the COMEX. Each IP had an identification number based on its coordinates, and for encounters that used the same IP, an identical IP ID was used. The IP was also used on the flight cards for reference on the top view.
- **IP OWN Lat/Lon:** Calculated latitude and longitude of the ownship IP from the CPA using dead reckoning equations, in DD format.
- **IP OWN DME:** Calculated distance in nmi from the CPA to the IP for ownship.
- **IP INT:** The same procedure was used for intruder IP as for ownship.
- **IP INT Lat/Lon:** Calculated latitude and longitude of the initial point for intruder from the CPA in DD format.
- **IP INT DME:** Calculated distance in nmi from the CPA to the IP for intruder.
- **CPA INT:** Similar to the ownship, the CPAs for the intruder were also grouped based on GPS coordinates. However, since the geometries for the intruders were built around those for the ownship, there were many more CPAs for intruders than for the ownship (due to various angles into, groundspeeds, etc.).
- **CPA INT Lat/Lon:** Calculated latitude and longitude of the intruder CPA in DD. The CPA for the intruder was either the same as the ownship (>500 ft vertical separation) or calculated to be 2,400 ft away (≤500 ft vertical separation) from ownship CPA using the relative angle into.
- **MP INT:** For some encounters, a maneuver was required in the middle of the encounter for the ownship or intruder to create a "blunder" type scenario. Maneuver points once again held the same ID if they had the same GPS coordinates.
- **MP INT Lat/Lon:** Calculated latitude and longitude in DD that the intruder was expected to begin their standard rate turn to the CPA.
- **On Condition:** Each encounter required that the aircraft be on condition a certain number of seconds from CPA. This was to ensure that the algorithm would have enough time to pick up the aircraft in the encounter for their required conditions (speeds, altitudes, vertical speed, etc.).
- **Tolerance:** This value was determined from simulation by the researchers or from previous experience. As time went on, it became apparent that tolerance was not as critical for SCO (especially for non-maneuvering encounters) as much as maintaining stable conditions.
- **Ikhana Lost Link:** In the case that Ikhana would lose link, a Lost Link mission was programmed into its flight computer. The Lost Link mission was based on the CPA the ownship would be heading to for that encounter. For this reason, it was critical for the Ikhana team to have all CPAs prior to flight testing so they could build this mission. The Lost Link mission was input in the flight matrix using a lookup table based on CPA.

Table 7. Summarized No Chase COA System Checkout Matrix.

2	3	4	7	9	11	13	15	16	21	22	23	24	25	27	28	29	30	031
PE Name/Type	Priority (1-high, 2-medium, 3-	Name	Leg Time (min)	Angle Into Int 1	Vertical Offset Int 1 (ft)	Lateral Offset INT1 (ft)	GS OWN	GS INT1	Altitude Regime	Ownship Initial Altitude	Ownship Vertical Velocity	Ownship Final Altitude	Ownship Abort Alt	Intruder 1 Initial Altitude	Intruder 1 Vertical Velocity	Intruder 1 Final Altitude	Intruder 1 Abort Alt	Intruder 1 Abort Hdng
High Speed	3	HS-11	2.0	0	500	0	180	300	<10K MSL	9000	0	9000	9000	8500	0	8500	8000	123
	3	HS-12	2.0	0	500	0	180	300	<10K MSL	9000	0	9000	9000	8500	0	8500	8000	123
Squawk Off	1	SQK-6	2.0	0	300	0	120	150	<10k MSL	9000	0	9000	9000	8700	0	8700	8000	348
	1	SQK-7	2.0	45	300	0	120	150	<10k MSL	9000	0	9000	9000	8700	0	8700	8000	258
	1	SQK-8	2.0	90	300	0	120	150	<10k MSL	9000	0	9000	9000	8700	0	8700	8000	213
Auto TCAS	3	ATCAS-22	1.0	0	300	2430	150	210	>10K MSL	21000	0	21000	21000	20700	0	20700	20000	123
	3	ATCAS-23	1.0	0	300	2430	150	210	>10K MSL	21000	0	21000	21000	20700	0	20700	20000	123
Test Mode	1	TM-1	2.0	0	300	0	160	180	>10k MSL	12000	0	12000	12000	11700	0	11700	11000	348
Use Case	1	UC-1-NOTUSED	2.0	0	200	0	150	180	>10k MSL	12000	0	12000	12000	11800	0	11800	11000	348
	1	UC-2	2.0	0	800	0	150	180	<10k MSL	9000	0	9000	9000	8200	0	8200	8000	348
	1	UC-4-NOTUSED	2.0	90	200	0	150	180	<10k MSL	9000	0	9000	9000	8800	0	8800	8000	348
	1	UC-5-NOTUSED	2.0	0	200	0	150	180	>10k MSL	12000	0	12000	12000	11800	0	11800	11000	348
Intruder Overtake	2	IOT-17	3.0	180	300	2430	160	180	>10K MSL	12000	0	12000	12000	11700	0	11700	11000	033
	2	IOT-18	3.0	180	300	2430	160	180	>10K MSL	12000	0	12000	12000	11700	0	11700	11000	033
Left Turn	2	LT-20	3.0	45	300	2430	160	180	>10k MSL	12000	0	12000	12000	12300	0	12300	13000	123
	2	LT-21	3.0	90	300	2430	160	180	>10k MSL	12000	0	12000	12000	12300	0	12300	13000	123
Ownship Overtake	2	OOT-19	3.0	180	300	2430	180	160	>10K MSL	12000	0	12000	12000	11700	0	11700	11000	123
High Descent Rate	2	HDR-16	3.0	0	500	2430	160	180	>10K MSL	10500	0	10500	10500	18000	-3000	11000	11500	123
Low Alt 3k AGL	1	LALT-24	3.0	0	200	2430	150	180	3000 AGL	6200	0	6200	6200	6000	0	6000	5200	348
	1	LALT-25	3.0	0	200	2430	150	180	3000 AGL	6200	0	6200	6200	6000	0	6000	5200	348
Double Blunder	2	DB-15	2.0	0	500	0	150	180	<10k MSL	7000	1000	9000	9000	12500	-1500	9500	10000	123
Level Off Blunder	3	LOB-9	2.0	0	200	0	150	180	>10k MSL	10000	0	10000	10000	12200	-2000	10200	11000	303
	3	LOB-10	2.0	0	500	0	150	180	>10k MSL	10000	0	10000	10000	12200	-2000	10200	11000	303
Ownship Turn & Descend	2	OTD-25	2.0	0	500	2430	150	180	<10k MSL	15000	-1000	13000	13000	12500	0	12500	12000	213
Nuisance	2	NUIS-13	2.0	0	1000	0	150	180	<10k MSL	9000	0	9000	9000	12000	-1500	10000	10000	123
	2	NUIS-14	2.0	0	500	0	150	180	<10k MSL	9000	0	9000	9000	12000	-1500	9500	10000	123

2.7.1.3 ***Flight Cards***

Flight cards were developed based on cards created during FT3, FT4, and ACAS Xu FT2, which in turn were based on cards for ACAS Xu SS flight program by personnel from Massachusetts Institute of Technology (MIT) Lincoln Laboratory. These flight cards were used for similar types of encounters during that flight test.

Due to the successful use of these flight cards through various flight campaigns, a similar format was used for the NCC SCO. With the collaborative effort of NCC Ikhana Operations, Armstrong IT&E Operations, and researcher input, the product was designed to provide a simple, easy-to-use, and easily modifiable card that met the requirements for mission success. The cards also presented a familiar format to that of an instrument approach plate which enabled the aircrew to quickly determine test parameters and critical flight information.

Flight cards were built in Excel and were directly linked to the flight test matrix. The matrix had the capability of auto-populating much of the information for the card based on look-up tables from the scenario number: IP/CPA names and coordinates, altitudes, headings, distances, groundspeeds, lost link mission for Ikhana, on-condition timing, CPA tolerances, sensor selection, deconfliction altitudes, notes, and abort procedures. Manual input was required for the images, although this was simplified to a single button to input all views.

The cards were designed to fit on an 8.5” x 11” sheet of paper, with one half dedicated to ownship and the other to intruder. This allowed users to either cut the deck in half or fold their card to the one of interest.

There were over 26 flight cards for the NCC SCO, each with unique properties and characteristics from each encounter. Pictured below in Figure 34 is an example ownship flight card that was used. Figure 35 show an intruder flight card for the same encounter. Each flight card had its own spreadsheet and the cards were later converted into PDF, packaged into a document for that particular flight day, and distributed in soft- and hard-copy form to all NCC SCO participants.

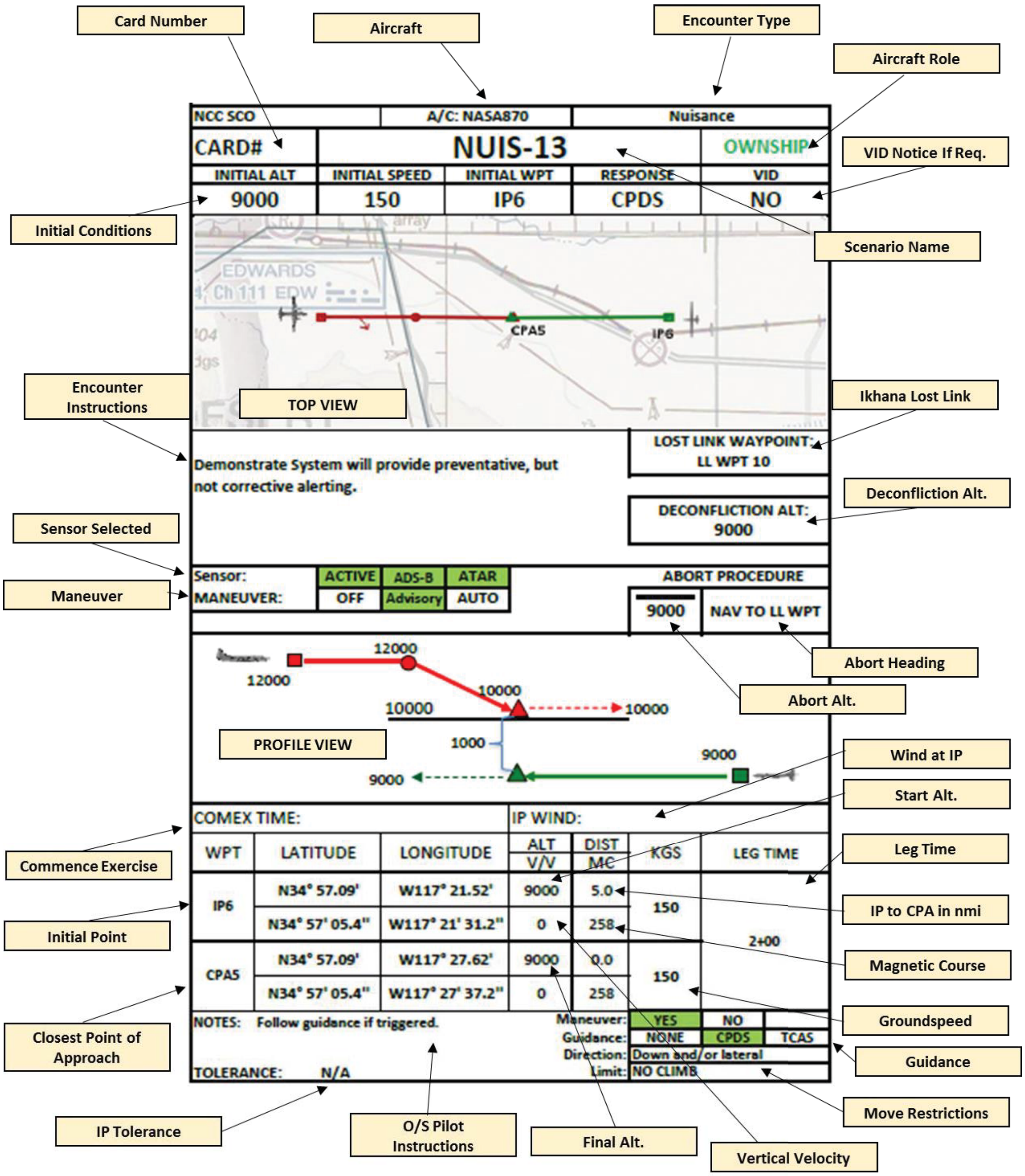


Figure 34. NUIS-13 Flight Card for Ownship.

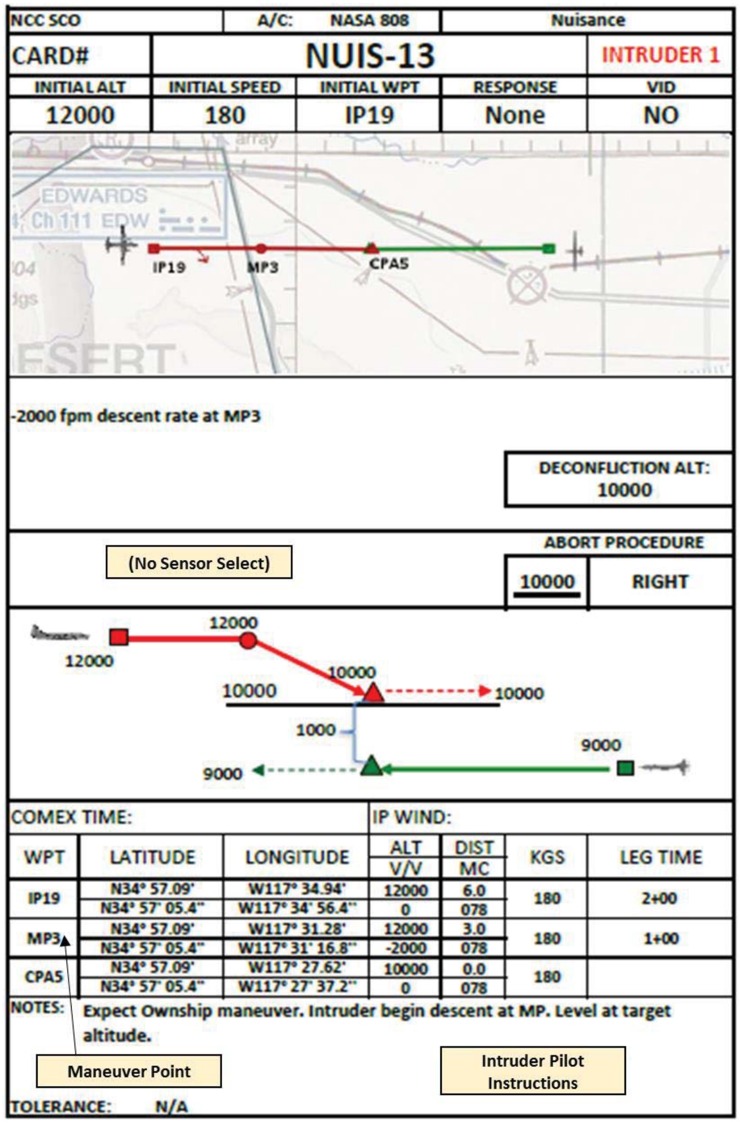


Figure 35. NUIS-13 Flight Card for Intruder.

2.7.1.4 *Altimeter Calibration*

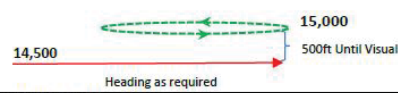
An altimeter calibration was required for all SCO encounters where the vertical separation between intruders and ownship was less than 500 ft (SCO Mission Rule MRNCC-02, Section 2.10.1.1). The mission rule was enforced for all flights.

The altimeter calibration was designed to take out the standard errors found within the pitot-static systems in order to ensure the planned vertical separation was as close to planned as possible. According to Federal Aviation Regulation (FAR) 91.411 and Appendix E of Part 43 aircraft pitot-static systems must be within 75 ft of field elevation when dialed into the local altimeter setting. Additional errors come with changes in altitude and airspeed. Since some of the planned encounters were with a 200 ft vertical separation, it was possible to be much closer with the errors identified above if they were not mitigated with the calibration.

The calibration was conducted at a flight condition that closely approximated all the planned encounters. In order to accomplish the calibration, Ikhana acted as the lead aircraft with intruder aircraft joining on Ikhana's wing in close formation. The Ikhana platform set standard 29.92 inHg and the other aircraft adjusted their altimeter settings to indicate the same altitude readout. At those conditions each participating aircraft observed the difference from Ikhana.

The altimeter calibration was performed prior to each flight that required it using the flight card shown in Figure 36.

NCC SCO ALTIMETER CALIBRATION (MEDIUM SPEED)



REJOIN AND ALTITUDE CALIBRATION:
Start conditions ALL AIRCRAFT
- Joined, straight and level, 140 KIAS, heading as required
- 29.92

1. HOLD - left hand turns, at altitude
2. JOIN & SET - INTRUDER
   - Maintain 500 ft alt/sep until visual
   - INTRUDER "Joined, rollout heading AS/REQ"
3. REPORT - "29.92 set showing 15,###" - OWNSHIP / INTRUDER
4. ADJUST - altimeter to 15,000 - INTRUDER
   - Call "29.## showing 15,000"
   - maintain new altimeter setting for encounters
5. COMPLETE - "Complete, [callsign] cleared off <dir> <alt>"

PT	LATITUDE	LONGITUDE	OWNSHIP ALTITUDE	CHASE ALTITUDE	A/S
CPA1	N34° 54.14'	W117° 30.29'	15000		140 KIAS
	N34° 54' 08.2"	W117° 30' 17.4"			

Figure 36. SCO Altimeter Calibration Card.

2.7.1.5 *Encounter Flow*

Lessons learned from previous flight tests were utilized during the execution of the encounters above. A schedule listed below in Table 8 was determined which covered two flight test days. In order to keep the aircrew safe, a buildup philosophy was used: e.g., conducting "simpler" geometries first, higher vertical separation to smaller, grouping encounters with the same intruder aircraft, unmitigated to mitigated, and advisory to AUTO maneuvers.

Table 8. Flight Test Buildup Schedule.

Day 1	Day 2
UC-3	SQK-7
HS-11	SQK-8
SQK-6	IOT-18
IOT-17	UC-2
UC-4	TM-1
OOT-19	HS-12
LALT-24	UC-5
LT-20	LT-21
ATCAS-22	NUIS-14
OTD - 25	DB-15
NUIS-13	HDR-16
LOB-9	LOB-10
	ATCAS-23

Priority 1
Priority 2
Priority 3

2.7.2 Demonstration

The flights into the NAS were unique in that they were the first time a UAS would fly without a chase vehicle into lower altitude Class E and D airspace. In addition to the normal operations with NASA 870 within R-2508, additional notifications and reports needed to be created.

Operations within R-2508 required filing local NOTAMs, weather checks, frequency allocations (which included Line of Sight (LOS) and Satellite Communications (SATCOM) Ku-band), receiving ops numbers, airspace reports, and airspace coordination. In addition to that, when flying into the NAS, the team was required to file an IFR form 175. Per the COA, an additional requirement was satisfied by notifying local ATC such as ZLA, ZOA, Joshua, and filing a separate notification with Victorville operations, with information relating to: filed flight plan, waypoints with fixes, altitudes, lost link procedures, and flight route. In short, two types of NOTAMS were filed: distant NOTAMS for operations within ZLA and ZOA (filed with the Flight Service Stations (FSS) per the COA) and local NOTAMS for operations at Edwards and VCV. Finally, a requirement of the COA was to submit an operational report through the CAPS system, even if a flight did not occur.

2.8 Mission Planning and Information

As mentioned previously, the NASA UAS-NAS and Ikhana teams had a history of performing the type of flight testing required to check out the system before flights into the NAS, as well as experience in flying with a COA.

2.8.1 System Checkout

Executing SCO flights required significant coordination. Flights were planned at a rate of two flights per week due to the duration of each sortie and the amount of test cards executed per sortie. Flying the encounters was user work load intensive, with about 10 minutes allocated to each encounter, and setup required in between runs.

As a pre-requisite to executing flight test, a T-1 crew briefing was accomplished the day prior to the event. The T-1 briefing covered, in detail, the following aspects related to the upcoming flight:

- Roll Call
- Mission Summary
- Mission Timeline
- Weather / NOTAMs
- UAS Status
- Mission Information
- GCS Status
- Airspace / Airfield
- Support Assets
- Contingencies
- Miscellaneous
- Flight Card Review
- Lessons Learned

A flight could be delayed or postponed based on information discussed during the T-1 briefing. All team members were required to participate in the briefing either in-person or remotely.

All SCO flights started at 0600 (local) Pacific Time. Subsequently, the morning brief was held at 0415L. The morning briefings covered at a higher level the same information with emphasis on any changes from the previous T-1 briefing. The intent was for this briefing to be about 15 minutes in length. A final go/no-go decision was made at this briefing. After the brief, the team was dismissed to prepare for the flight and in some cases additional crew familiarity training was conducted for the DAA system. The MCC3 was staffed at approximately 0530L to support any systems troubleshooting or coordination efforts required by the supporting aircraft teams.

In general, flights were planned for approximately 5 hours. Part of that flight time was allocated to transit, altimeter calibration, and DAA system startup procedures. The limiting factor for Ikhana was frequency coordination and typically required an off time of 1200L for both SATCOM and LOS frequencies. For the intruders, fuel available was the limiting factor.

A flight debrief was mandatory in order to discuss the day's flight events, identify any aircraft discrepancies, and discuss test inefficiencies which may have decreased the number of encounters and test objectives achieved. Action items were assigned for issues and lessons learned which needed to be closed out prior to the next flight. A post-flight test card review and high level data analysis was conducted as well. If the next flight occurred on the following day, a T-1 was then conducted to review test objectives for that next flight, otherwise the T-1, as appropriate, was conducted prior to the next test opportunity.

Figure 37 shows the basic timeline previously discussed. Start of test day was typically 0415L and completed around 1415L.

	NASA870 4332-1	NASA7 4332-2
0415	Mass Brief	
0435	Individual Aircrew Brief	
0500	Step	
0600	Take Off	
0615		Take off (EDW) **(Call MCC3 prior)**
0630	ALT CAL / NCC SCO Encounters	
1100 (5+00)	RTB (EDW) **(Freqs until 1200)**	RTB EDW
1130	Chock Time	
~1200	Debrief	
1415	End of Test Day	

Figure 37. Typical SCO Timeline.

2.8.2 Demonstration

Since the demonstration flights consisted of only two flights, one with chase and one without chase, the operations tempo was low in comparison to previous flight test series. The team was only required to schedule frequencies and perform the tasks outlined in Section 2.7.2 prior to conducting flights.

The demonstration flights had a similar timeline as the SCO, with the team conducting T-1 briefing the day before flight, and the morning brief T-0 once again beginning at 0415L. Figure 38 shows the typical timeline for one of the demonstration flights. Instead of a flight card review, the team would review the mission route and discuss the criteria for success for the flights into the NAS. Additionally, the review provided contact information of the air control facilities which NASA 870 would utilize.

Time of Day	Relative time	KEDW NASA870
1200-1400	N/A	T-1 (In-Person if possible)
0415	-2+15	T-0 Prebrief (In person for all on-site participants. Off-site call in WEBEX)
0500	-1+30	Step
0530	-1+00	MCC3 Staffed
0600	0+00	**Takeoff**
0630	**0+30**	**Demonstration (2+30 hours on station)**
0900	3+00	End of Demo - RTB (Frequency Limited 1230)
0945	3+15	Recover
1200	6+00	Debrief
1400		End of Test Day

Figure 38. Typical Demo Timeline.

2.9 Roles and Responsibilities

During SCO flights, the focus was within the MCC3. The coordination summary can be found in Figure 39. For the demonstration flights, the focus left the MCC3, and instead was centralized on the Ikhana GCS. The communication structure for this phase is shown in Figure 40.

2.9.1 System Checkout

For scripted encounters, the main point of contact was the TC. The TC would be responsible for managing the mission execution over voice communication on the mission net (VHF radio) with the Ikhana pilot, intruder pilots, and SPORT, the local EAFB air traffic control agency. The TC was responsible for managing the tempo of encounters, watching air safety, and relaying real-time changes or adjustments to the aircrew. The Test Director (TD), who sat next to the TC, was the primary liaison with the TC. The TD would listen to the back channels, such as the engineering channels, and communicate whether flight cards needed to be repeated or adjusted, as well as other issues that may arise. Additionally, the TD would also maintain the air picture SA and support the TC, and communicate with the SOR, local agencies, and non-local agencies as required. The third role in the MCC3 was the Test Coordinator (TCOR), whose main duties were to be a scribe for the flights, keeping track of when encounters were executed, the quality of the results, the quality of the encounter itself, redlines, airspace changes, and other pertinent information that could be used during the debrief and improve later flights operations.

During all flights a Senior Operations Representative (SOR) was required to be present in the MCC3 (SCO) or the GCS (Demo). The SOR acted as a spokesperson for the NASA AFRC Director of Flight Operations and their responsibility was to monitor general conduct of the flight test operations, monitor the team's real-time decisions, and initiate the Aircraft Incident Response Procedure (DCP-S-001) in the case of an aircraft mishap.

The pilots, along with managing their aircraft and aviating safely, were responsible for being at the set location on the card on time and on condition, adhering to all mission rules.

Within the GCS, the Mission Director (MD) communicated directly with co-located pilots within GCS, TD, and other agencies (as required). The MD was responsible for overall health of the aircraft, ensuring the aircraft was in the correct configuration for the current flight card, and also maintaining SA for conducting flight of Ikhana within the airspace.

The LVC team communicated directly with the TD on the test team net and provide real-time discussions on the DAA display performance. The LVC lab was also where the data was being recorded.

Finally, the Range Control Officer (RCO) was responsible for monitoring and making coordination calls with AFRC communication and the AFRC test range mission systems operations representatives.

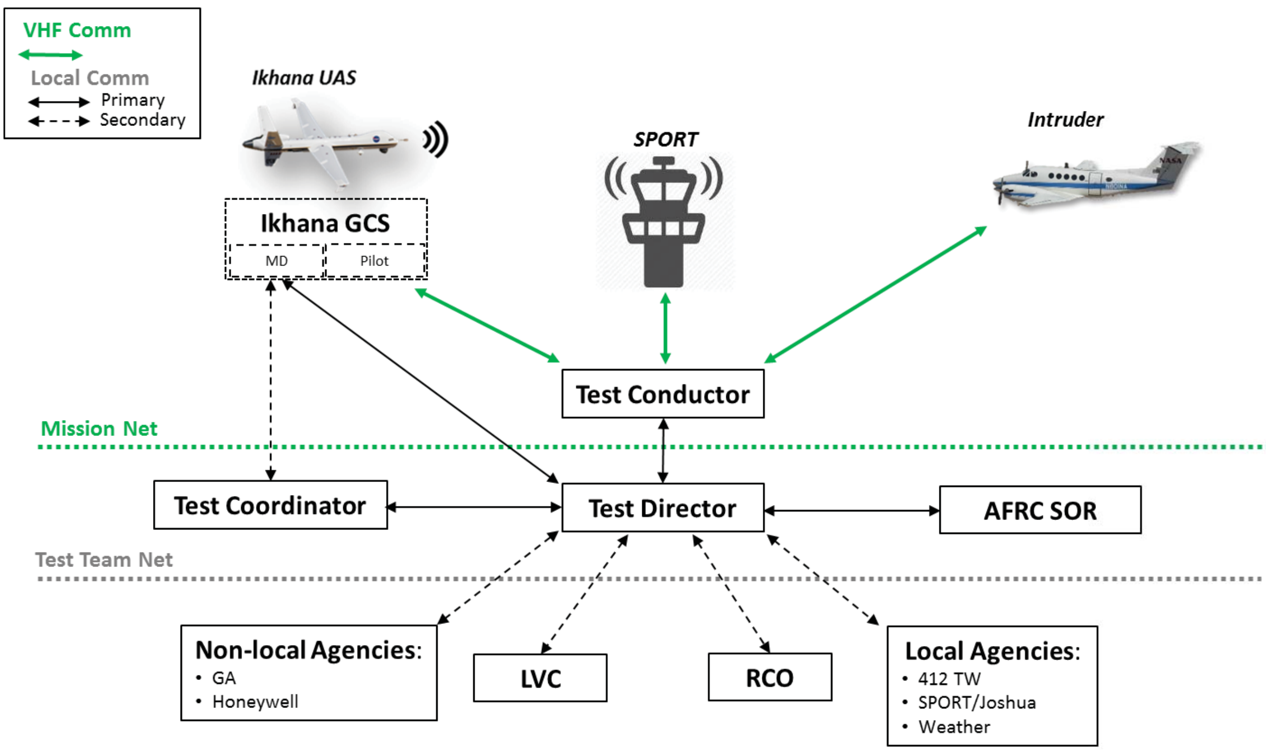


Figure 39. Coordination Summary for SCO.

2.9.2 Demonstration

Since the demonstration flights' goal was to show how a UAS can file and fly like any piloted vehicle, the operation was focused on the Ikhana pilot conducting a flight with the team in the GCS to support. All primary VHF communication occurred between the Ikhana pilot and ATC, with chase (when required for the first flight) checking in on the same net as "two". For this reason, too, the SOR was located in the GCS for the demonstration flights.

The MCC3 acted as a backup to these flights and received a VHF relay, or "mirror", of the communications that the Ikhana pilot was receiving. The TC and TD provided backup support and could communicate with industry partners, the LVC, RCO, or other local agencies for support.

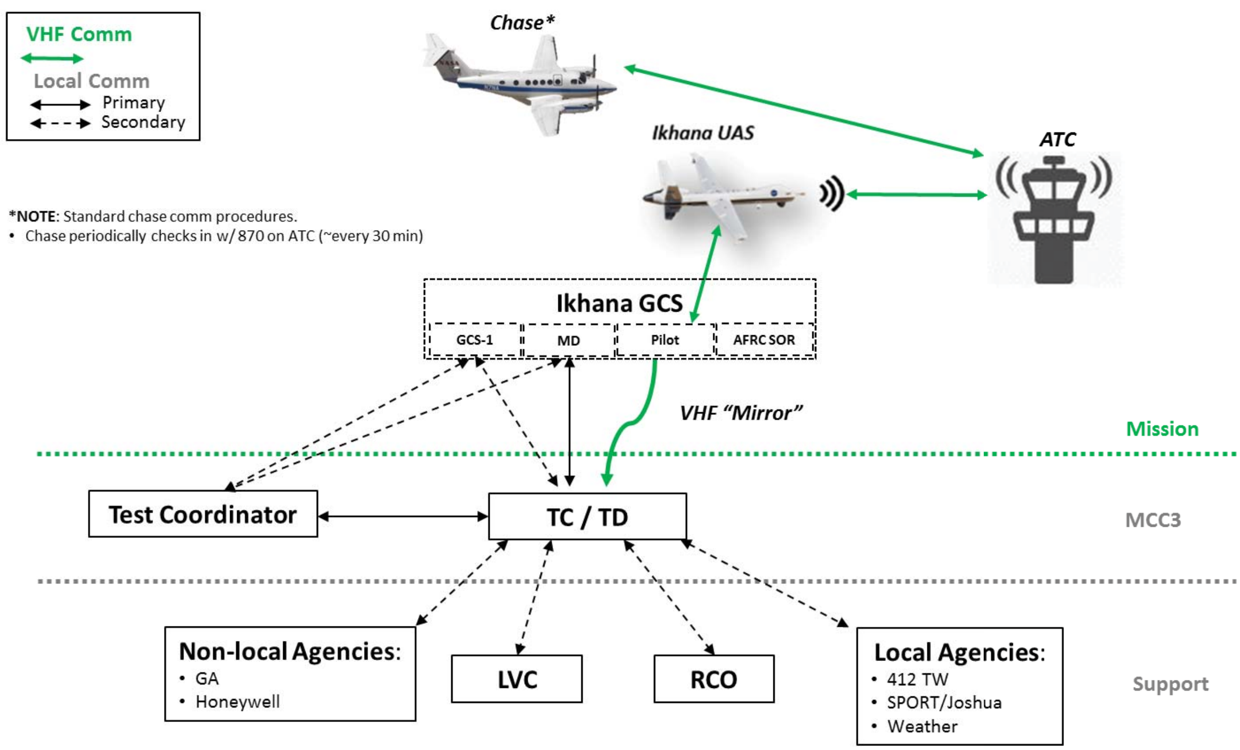


Figure 40. Coordination Summary for Demo Flight.

2.10 Safety, Mission Rules, and Contingencies

All operations were conducted in accordance with NASA AFRC safety policies AFOP-8715.3-005, Hazard Management Procedure, and AFOP-8715.3-007, System Safety Support.

For NCC hazard analysis, the SSWGs took into consideration:

- Encounter geometries (SCO)
- The different equipped aircraft that may be encountered (SCO, Demo)
- The results from the FAA SRMP (Demo)
- The different classes airspace (Demo)

In order to maintain approved levels of safety, which are paramount to flight test operations, mission rules were developed and were associated with the project specific Hazard Reports. All encounters and configurations were concurred with by the safety representative. All Hazard Reports were presented to the NASA AFRC Tech Brief board for each phase of the project (SCO, Demo, etc.). The signed Hazard Reports were kept by the Systems Safety Engineer and copies were stored electronically in the Project's files.

Additionally, a range safety analysis was conducted by the NASA range safety team. For both the system checkout and demonstration (after route modifications) the range safety analysis was within acceptable limits for NASA Armstrong.

2.10.1 System Checkout

Due to the unique nature of some of the encounters planned for SCO, the hazards and mission rules were vetted through an SSWG with the entire team, which included the IT&E, the Ikhana team, GA-ASI, and Honeywell. These Mission Rules, Go/No-Go's, Contingencies, and Mitigations were based off previous flight tests and had a pedigree, from all previous missions.

2.10.1.1 *Mission Rules*

The Mission Rules for SCO can be found in Table 9. These Mission Rules were based on previous flight tests and held a pedigree, from all previous flights. During a Mission Rules WG (a part of the OWG), MRNCC-08 was evaluated and was able to be removed for the SCO flights as it is covered under MRNCC-07. IT&E Operations Engineering ensured that each of the Mitigations referenced in each Rule had been satisfied.

Table 9. SCO Mission Rules.

Rule #	Rule Description	Rationale / Hazard Report	Notes	Responsible Position
MRNCC-01A	The test conductor shall control the setup, timing and progression of the planned encounters at all times, including between encounters.	NCC-21 Mitigation 3		TC
MRNCC-01	Systems under test shall not be used as the primary method to maintain safe separation of aircraft.	NCC-16 Basic Hazard		All
MRNCC-02	Test runs will be aborted if intruder aircraft do not have visual on all aircraft within 1 nmi (2 nmi for high speed) lateral and less than 500' vertical separation, except when aircraft are diverging. During altimeter calibration, the intruder aircraft has visual responsibility for both aircraft.	NCC-01 Mitigation 8 NCC-06A Mitigation 3 NCC-06A Mitigation 17 NCC-03 Mitigation 7 NCC-16 Mitigation 4	Airspeed, heading, altitude divergence, etc. Ikhana Overtaking	TC, PICs
MRNCC-03	Intruder aircraft will only follow TCAS RA guidance if following test card direction or they have reason to believe the alert is caused by non-participating aircraft AND have SA on all participating aircraft.	NCC-06A Mitigation 3 NCC-06A Mitigation 5 NCC-06A Mitigation 19	TCAS II equipped intruders only	Intruder PIC
MRNCC-04	Update of the appropriate Ikhana Lost Link Mission variables will be verified, by aircrew and the Mission Director prior to commencing each test run.	NCC-03 Mitigation 3 NCC-03 Mitigation 8	Lost link entry point identified on	MD/PIC

			each test card.	
MRNCC-05	Flight operations outside of the approved mission flight envelope for Ikhana are prohibited.	NCC-14 Mitigation 8		MD/PIC
MRNCC-06	Abort the encounter for the following reasons (but not limited to): loss of situational awareness, task saturation, Ikhana lost link, DAA system failure, emergency condition, or mission rule violation.	NCC-01 Mitigation 3 NCC-01 Mitigation 4 NCC-17 Mitigation 1 NCC-17 Mitigation 3		TC, PICs, MD
MRNCC-07	When not on a test run, Ikhana crew will ensure "Maneuver Mode" is selected to ADVISORY or OFF.	NCC-07 Mitigation 5 NCC-21 Mitigation 08		MD, SO
~~MRNCC-08~~	~~During test runs below 7000' MSL, "Maneuver Mode" shall be selected to ADVISORY or OFF by Ikhana crew.~~	~~Recommend removing this rule (reference MR-7) or changing to 5000' MSL?~~	~~Review for SCO, AGL~~	~~MD, SO~~
MRNCC-09	During auto TCAS runs, the test run will be aborted if Ikhana begins an automatic maneuver contrary to the test card instructions.	From ACAS Xu Results NCC-01 Derived NCC-06A Mitigation 20		TC, PIC, MD
MRNCC-10	All participants will ensure their navigation quality error does not exceed 0.1 nmi for runs with less than 500' vertical separation.	NCC-01 Mitigation 6 NCC-06A Mitigation 2 NCC-01 Basic HR		MD/ Intruder PIC
MRNCC-11	Confirm each participant's time management tools match the time hack made prior to starting encounters.	Standard Practice NCC-01 Mitigation 1 NCC-01 Mitigation 6 NCC-01 Mitigation 9 NCC-01 Mitigation 10		TC, PICs
MRNCC-12	During encounters when within 1 nmi, maintain at least 150' vertical separation of other aircraft's planned altitude.	Standard Practice Mission Success NCC-01 Derived		Intruder PIC
MRNCC-13	Test runs will be conducted with the following environmental criteria: - 3 or greater statute miles visibility - Clear of clouds 1000' above and below the planned test block including abort maneuvers	Ikhana Standard Mission Rules NCC-21 Mitigation 5		MD/TC, PICs
MRNCC-14	Between test runs, all participating aircraft shall establish and maintain deconfliction altitude from previous encounter until directed by the TC.	NCC-21 Mitigation 6 NCC-17 Mitigation 4 Standard practice / Test Plan		TC, PICs

MRNCC-15	All participating aircraft will conduct an altimeter calibration using Ikhana as the baseline prior to executing encounters with less than 500' planned vertical separation. Aircraft will maintain altitude and/or lateral separation until visual acquisition is confirmed.	NCC-01 Mitigation 5	Per flight day	TC, PICs

2.10.1.2 *Go / No-Go*

In addition to the mission rules, prior to executing a mission, a set of "Go/No-Go" criteria were required to be met in order to begin flights. For SCO, these can be found in Table 10.

Table 10. SCO Go / No-Go.

	Rule Description	Rationale	Notes
1	Strobe/anti-collision lights – FUNCTIONAL	Ikhana Standard Go/No-Go Criteria	In accordance with MEL or applicable Flight Manual requirements
	Position/Nav lights – FUNCTIONAL	Ikhana Standard Go/No-Go Criteria	
	Planned transponder equipment – OPERATIONAL	Mission Requirement (DAA System)	
2	All redundant flight control systems – FUNCTIONAL	Ikhana Standard Go/No-Go Criteria	In accordance with MEL or applicable Flight Manual requirements
3	Two VHF radios – FUNCTIONAL	Mission Requirement (Test and Airspace Requirements)	Required for ATC and TC coordination TG-14 capable of monitoring 2 VHF freqs
4	If the GCS/SMURF configuration is single string fiber optics (no redundant fiber optics) then a GCS/PGDT or GCS/GDT LOS lakebed runway must be available for an emergency landing.	A GDT or PGDT directly connected to the GCS is the emergency procedure in the event of fiber optic system failure.	Ikhana Standard Go/No-Go Criteria
5	Zeus display – FUNCTIONAL Ikhana encounters are limited to 500 ft vertical separation with visual required when MCC3 Zeus is not available	Mission Requirement (Test Command & Control) NCC-01 Mitigation 7 NCC-06A Mitigation 4 NCC-07 Mitigation 2 NCC-17 Mitigation 8	MCC3 only.

6	Ku SATCOM or DLOS link – Available/READY	Mission Requirement (Primary link for DAA System) NCC-03 Basic HR	Required for Ikhana
8	Situation awareness display – FUNCTIONAL	Mission Requirement NCC-01 Mitigation 7	As equipped
9	Navigation system and time management tools – FUNCTIONAL	Mission Requirement (DAA System) NCC-01 Mitigation 6 NCC-01 Mitigation 7	As equipped
10	Barometric Altimeter – FUNCTIONAL and Meets Maintenance Standards	NCC-01 Mitigation 5 NCC-06A Mitigation 2	
11	Intruder TSPI truth source – FUNCTIONAL	Test plan	

2.10.2 Demonstration

Because the flights into the NAS were new to the test team as a whole, a new set of Mission Rules were created. These Mission Rules, like the SCO set, were vetted by the entire test team and through the SSWG to ensure that all hazards were being covered, as a part of the AFRC safety process. Since this was to be treated as a "routine" flight into the NAS, the Ikhana team followed its own project specific set of Go/No-Go's criteria, established for their normal flight operations.

2.10.2.1 *Mission Rules*

The Mission Rules for the demonstration flights into the NAS can be found in Table 11. Since the team would be relying on the DAA system, command and control, and SA to operate safely with other vehicles in the NAS, the rules focused mainly on these areas. Rules 1, 3, 6 focused on the DAA system and SA, and rules 2, 4, and 7 focused on the command and control of the airplane.

Table 11. Demo Mission Rules.

Rule #	Rule Description	Rationale / Hazard Report	Notes	Responsible Position
MRNCC-01	Zeus display will be functional before leaving R-2515.	Mission Requirement (Test Command & Control) NCC-06 Mitigation 2 NCC-07 Mitigation 2 NCC-06 Mitigation 13 NCC-07 Mitigation 13 NCC-17 Mitigation 8	GCS only If Zeus is lost outside R-2515 it does not constitute a RTB. Zeus provides additional SA.	MD/PIC

MRNCC-02	Ku SATCOM and DLOS link will be available and ready.	Mission Requirement (Primary link for DAA System) NCC-38 Basic HR NCC-39 Basic HR	This mission rule applies prior to leaving R-2515	PIC/MD
MRNCC-03	At pilot's discretion, any DAA system anomaly that results in degraded situational awareness will be cause for RTB.	Mission Requirement NCC-06 Basic NCC-17 Basic	Not applicable with chase	PIC/MD
MRNCC-04	Update of the appropriate Ikhana Lost Link Mission variables will be verified, by aircrew and the Mission Director prior to each flight segment.	NCC-38 Mitigation #4 NCC-38 Mitigation #4 NCC-38 Mitigation #2 NCC-39 Mitigation #2		PIC/MD
MRNCC-05	Flight operations outside of the approved mission flight envelope for Ikhana are prohibited.	NCC-14 Mitigation 8	DAA OML configuration	MD/PIC
MRNCC-06	Operate in Day, VMC.	Ikhana Standard Mission Rules NCC-06 Mitigation 18 NCC-07 Mitigation 18	14 CFR 91.155	MD, PICs
MRNCC-07	In the case of a degraded C2 link, RTB.	NCC-38 Basic NCC-39 Basic	Pilot's discretion	PIC
MRNCC-08	Except when in Class D, the minimum altitude is 3000 ft AGL.	DAA radar fidelity limitation		PIC

2.10.2.2 *Demonstration Mission Contingencies*

For all phases of flight, with chase and without chase, the team put together contingencies in case of losing voice communication and general mission contingencies. These procedures were separate from the aircraft emergency procedures, which all aircraft are required to adhere to, since they were unique to the operational environment. The procedures were easy to read, use, and were placed in the GCS and MCC3.

2.10.2.2.1 Demo Contingency Voice Comm (With Chase)

First, the team created communication contingencies when flying with chase. These procedures, shown in Table 12, show a variety of contingency scenarios which include: NASA 870 losing radio, the DAA system not functioning, a combination of the DAA system not functioning and NASA 870 losing radio, NASA 870 going lost link (which assumes no radio), chase aircraft losing radio, both NASA 870 and the chase vehicle losing radio, and finally, NASA 870 going lost link and chase losing radio concurrently.

The assumptions for this set of contingencies were that NASA 870 would act as the lead aircraft, chase would check in periodically (approximately every 30 minutes) on ATC frequency, the lost link routing was specific and defined by the COA, and the SOR as well as a Project Manager (PM) resided in the GCS.

Table 12. Demo Contingency Voice Comm (With Chase).

Scenario w/ CHASE	A	B	C	D	E	F	G
All Classes	870 NORDO	DAA Sys Down	DAA Sys Down + 870 NORDO	870 Lost Link (NORDO)	Chase NORDO	870 NORDO + Chase NORDO	870 Lost Link (NORDO) & Chase NORDO
I	• **870** RTB at last assigned alt ❖ Squawk 7600 • Follow LL Mission routing • **870** informs ATC (phone) • ATC informs chase	• **870** RTB at last assigned alt • Follow LL Mission routing • **870** informs chase and ATC	• **870** RTB at last assigned alt ❖ Squawk 7600 • Follow LL Mission routing • **870** informs ATC (phone) • ATC informs chase	• **870** RTB at last assigned alt ❖ Squawk 7400 ❖ LL Mission routing • **870** informs ATC (phone) • ATC informs chase	• **Chase** squawk 7600 • ATC informs 870 • **870** RTB LL Mission routing w/ NORDO chase • **870** lead chase to EDW straight-in final & coordinate clearance to land for NORDO chase	• **870** RTB ❖ Squawk 7600 • **Chase** squawk 7600 • **870** informs ATC (phone) • **870** RTB LL Mission routing w/ NORDO chase • **870** lead chase to EDW straight-in final & coordinate clearance (Tower phone) for NORDO chase to land 1st, then 870	• **870** RTB at last assigned alt ❖ Squawk 7400 • **Chase** squawk 7600 • **870** informs ATC (phone) • **870** follow LL Mission w/ NORDO chase • **Chase** break off at pilot's discretion

2.10.2.2.2 Demo Contingency Voice Comm (Without Chase)

The second set of contingency scenarios were designed for the flight without chase and are displayed in Table 13. This table was simpler than the procedures for flight with chase since the activity only included NASA 870. Contingency scenarios included: NASA 870 losing radio, DAA system not functioning, the combination of DAA system being down and NASA 870 losing radio, and NASA 870 going into its lost link.

The assumptions for this flight were that the COA defines the lost link procedures and that the SOR and PM are in the GCS.

Table 13. Demo Contingency Voice Comm (Without Chase).

Scenario NO CHASE	A	B	C	D
All Classes	870 NORDO	DAA Sys Down	DAA Sys Down + 870 NORDO	870 Lost Link (NORDO)
II	• **870** RTB at last assigned alt ❖ Squawk 7600 • Follow LL Mission routing • **870** informs ATC (phone)	• **870** RTB at last assigned alt • Follow LL Mission routing • **870** informs ATC	• **870** RTB at last assigned alt ❖ Squawk 7600 • Follow LL Mission routing • **870** informs ATC (phone)	• **870** RTB at last assigned alt ❖ Squawk 7400 • Follow LL Mission routing • **870** informs ATC (phone)

2.10.2.2.3 Mission Contingencies

In addition to the lost communication and normal emergency procedures, the team created a set of contingency procedures unique to the mission. These procedures, shown in Table 14, were once more vetted with the entire team through OWGs and SSWGs, and a copy was placed within each of the control rooms.

The procedures in this table included the chase vehicle going blind (losing visual on NASA 870), the chase vehicle having an in-flight emergency (IFE), NASA 870 experiencing an IFE, NASA 870 not being able to return to base (RTB) and no longer being in control, NASA 870 not being able to RTB but with control, Edwards runways closed, GCS becoming inoperable, and a serious atmospheric event affecting the flight.

Assumptions for this table were similar to the voice communication table: NASA 870 would act as the lead aircraft, chase would check in periodically (approximately every 30 minutes) on ATC frequency, the lost link routing was specific and defined by the COA, and the SOR as well as a PM would reside in the GCS. When flying without chase, chase steps or columns would simply be omitted from this table.

Table 14. Demo Mission Contingencies.

Scenario	A	B	C	D	E	F	G	H
All Classes	**Chase* BLIND**	**Chase* IFE**	**870 IFE**	**870 cannot RTB No longer in control**	**870 cannot RTB IS in control**	**Edwards Runways are closed**	**GCS becomes INOP**	**Serious atmospheric weather**
III	• **Chase** informs 870/ATC, BLIND • **ATC** gives chase vector for rejoin **NOTE:** If rejoin not possible, RTB LL Mission routing	• **Chase** ensure safe separation from 870 • **870** Declare IFE ❖ Squawk 7700 • Vector away (split up) • **870** RTB LL Mission routing	• **870** Declare IFE ❖ Squawk 7700 • RTB on LL routing • Search map for unpopulated ditch location • Ku off-field landing; Kill engine prior to impact; mark location	• **Chase*** will declare an emergency for 870 • **870** will manually disable uplink causing the ACFT to squawk 7400 • **MD** will call ATC (phone) • **SOR** will be prepared to initiate the mishap procedures	• **870** will evaluate options for potential landing sites • **Chase*** will talk to **870** and assist in potential landing sites • **MD/PIC** will notify ATC • **SOR** will initiate MISHAP procedures **NOTE**: Chase assists ATC with eyes on 870. **NOTE**: This scenario results in a <u>high potential</u> for 870 crash in a selected location where there will be minimum risk to public.	• **870** will decide best course of action based on situation: ❖ **870** can loiter in a specific location until runway is re-opened ❖ **870** can land at lake bed ❖ **870** can contact Gray Butte for potential of landing at their location. • **MD/PIC** will notify ATC/ SPORT on contingency situation and action plan • **SOR** will notify management on contingency situation and action plan **NOTE**: Gray Butte is ~ 4 hour delay for proper request to land	• **870** will disable uplink causing the ACFT to squawk 7400 • **870** will fly lost link plan • Return to PIRA • **MD/PIC** will notify ATC on contingency situation and action plan • **MCC3** will assist in notifying ATC if needed	• **870** will make a decision on best contingency plan ❖ **870** RTB ❖ **870** can loiter • **MD/PIC** will notify ATC/ SPORT on contingency situation and action plan • **SOR** will contact management on contingency situation and action plan

2.11 Training and Qualifications

Due to the unique nature of both Scripted Encounters and the demonstration flights, a training plan was required to be put into place, as it related to specific portions of each mission. Any personnel in training had a qualified individual providing the training. All flight crew team members, including for SCO and the demonstration, were qualified for their position in accordance with AFRC requirements.

Aircrew were required to be current and qualified per organization requirements (AFRC Pilot's Office), attend or be represented on tabletop training days (described below), and receive test specific training (DAA) prior to performing encounters.

A training event, or tabletop, was conducted prior to both the SCO and the demonstration flights. Representatives from all aircraft, DAA stakeholders, and IT&E operations were present. At the completion of this training event all stakeholders and aircrew were considered prepared and ready to support the SCO and demonstration events in the planned airspace, by all oversight organizations.

Additionally, DAA specific training was conducted by the CPDS SME prior to flights.

2.11.1 System Checkout Tabletop

The system checkout training was based off the training plans that were put in place for previous UAS-NAS flight test campaigns. Given the experience of the test team, the tabletop was conducted as a refresher of flying encounters within R-2515. This training included:

Admin / Motherhood

- Introductions (Roll Call)
- International Traffic in Arms Regulations (ITAR)
- Required Training
- NCC SCO CONOPS
- Staffing
- Required Aircraft
- Schedule
- Ops Planning

Test Admin / Specifics

- Roles and Responsibilities
- Safety
- Mission Rules / Go / No-Go
- Airspace Brief
- Comm Plan
- Motherhood / Contingencies / Aborts / Lost Link
- Timeline (Test Day / Test Encounter)
- Project Pilot Comments
- Altimeter Calibration
- Crew Resource Management (CRM)
- Objectives / Success Criteria
- Brief / Debrief Plan
- Weather

Test Execution

- Test Card / Geometries Review
- CPDS User Interface Briefing

2.11.2 Demonstration Tabletop

Since the demonstration was unique, the training had to be tailored to the route outside of the NAS and studying the COA. Elements were similar to SCO but included these new talking points, especially in the test admin and review sections. The pilots had a greater role in conducting the training, since the mission was to simulate a file-and-fly scenario with a UAS.

Admin / Motherhood

- Introductions (Roll Call)
- ITAR
- Required Training
- NCC Demo CONOPS
- Staffing
- Required Aircraft
- Schedule
- Ops Planning

Test Admin / Specifics

- Roles and Responsibilities
- R-2508 Complex Brief
- NCC Route Overview
- Lost Link Planning
- Comm Plan
- Mission Rules / Go / No-Go
- Motherhood / Contingencies / Aborts / Lost Link
- Safety
- Project Pilot Comments
- Objectives / Success Criteria
- COA Talking Points
- Brief / Debrief Plan
- Day of Timeline
- Weather

NCC Review

- Lessons Learned from SCO#3 Review
- CPDS User Interface Briefing
- Contacts

2.11.3 Detect and Avoid Display Training

The aircrew team assigned to conduct the SCO and demonstration flights had used the CPDS DAA technology for many previous flight tests, including FT3, FT4, and ACAS Xu FT2. Because of this, they were very experienced with the system and its characteristics, providing continuity for these flights.

A DAA refresher display training was conducted closer to the actual flight dates. Although most DAA training was conducted at the tabletop, due to aircrew availability and SME availability, some training was conducted as a supplement meeting. This training was used to inform the aircrew who would be executing the flights what the SME was expecting from them. The following questions were addressed during these exchanges:

- Test configuration. What does the SME/Researcher want; ON, OFF or de-energized?
- Maneuver type. Maneuvering (mitigated) or non-maneuvering (unmitigated).
- Guidance type. Will the DAA system provide directive or descriptive guidance?
- Display under test familiarity. What display will the aircrew be using to gain SA and make a maneuver decision?
- Miscellaneous expectations. Is there anything specific to CPDS (updates, etc.) that the aircrew need to know?

Representations of the CPDS screen in both picture format as well as a replay of previous simulated events were presented to the crew. Using the lessons learned from previous flight test campaigns, more efficiencies were gained by the test team and better data collected during the SCO. The flight crew better understood the DAA system and expectations on its use during flight. Additionally, playback from the SCO flights was provided to the aircrew.

With the years of experience, DAA system training, and SME involvement, the crew was ready and capable of flying into the NAS using this system.

2.11.4 Control Room Training

Personnel in all control rooms were required to have formal training in their position or workstation.

For the MCC3 control room, the TC and TD were required to obtain a formal approval from the NASA Armstrong Director of Flight Operations in order to serve in that capacity. The requirements for the test conductor were derived from NASA Armstrong AFPL-7900.3-001, Mission Control Qualification & Training Plan. The requirements were tailored from the mission controller section. For these flights, two test conductors and three test directors were qualified.

Within the Ikhana GCS, a MD was also qualified, per the Mission Control Qualification & Training Plan, to serve that role. These flights included two qualified MDs. The Ikhana GCS also had one Systems Operator qualified.

Within the LVC, all personnel required were trained for their respective work station.

2.11.5 ATC Training

Outside entities also conducted training pertaining to the NCC flights. Worth mentioning, the FAA requested that their ATC controllers received their own specific training prior to the flights of Ikhana into the NAS. The training was conducted by and within their own organization.

2.12 Safety Analysis

The flight into the NAS with NASA 870 required a special safety case approach that would be addressed in the COA by NASA. Along with this, the FAA conducted its own safety analysis for the flights into the NAS.

2.12.1 Safety Case Approach

In order to safely operate UAS in the NAS, it was shown that the Phase 1 DAA and ATAR Systems can provide alternate means of compliance to 14 CFR §91.111(a) and 14 CFR §91.113(b) "see and avoid/remain well clear" regulations. The approach taken for this safety case entailed the following:

1. Performed gap/compliance analysis of the DAA and ATAR systems "as installed" on the Ikhana UAS against published Phase 1 MOPS and TSOs for the DAA and ATAR systems.
    - DO-365 MOPS (dated 31 May, 2017) and TSO-C211 (dated 25 Sep 2017) for DAA Systems.
    - DO-366 MOPS (dated 31 May, 2017) and TSO-C212 (dated 22 Sep 2017) for ATAR for Traffic Surveillance.
    - The majority of the gaps were related to the display of DAA and ATAR system health and status information to the UAS pilot. It was determined that updates to the system software to display this information were not required for this demonstration due to Ikhana's architecture and flight test operations concept. For Ikhana operations, system health and status telemetry data is downlinked to the Ikhana GCS and displayed to Ikhana's pilots, who are experienced with the DAA system, and to test engineers with subject matter expertise to accurately assess system status.
2. Performed gap/compliance analysis of the DAA and ATAR systems "as installed" on the Ikhana UAS against DO-178C software certification guidance (dated 13 Dec 2011).
    - Determined that Design Assurance Level (DAL) for all DAA related software was Level D for overall process/documentation, plus Level C for software testing per DO-178C (full code statement coverage). Table 15 DAA and ATAR Systems DALs depicts that the critical DAA functionality was tested to DAL C rigor requiring full code structural coverage.
    - As denoted in Table 15, the only software component of the DAA System not being tested to DAL C full code statement coverage was the Honeywell sensor fusion tracker hosted in the TPA-100 ACAS processor. To address this gap, Honeywell implemented an I/O crosscheck algorithm, to DAL C standards, that validated the fusion tracker's output with TCAS/Extended Hybrid Surveillance. This feature ensured that the tracker's output is accurate.

Table 15. DAA and ATAR Systems DALs.

Software Component	Function	Manufacturer	DO-178 DAL Level	Artifacts	DO-178 DAL C Statement Coverage	Notes
DFCS	Flight Code	GA-ASI	D	Available for review at GA-ASI	x	
DGCS	Ground Code	GA-ASI	D	Available for review at GA-ASI	x	
SAAP	DAA System Interface Formats DAA Data	GA-ASI	D	Available for review at GA-ASI	x	
TPA-100	Collision Avoidance (TCAS II) Track Correlation/Fusion ADS-B In	Honeywell	D	Summary Report	x	I/O Cross Check TCAS RA Mapping
CPDS	Cockpit Display of Traffic DAA Alerting and Maneuver Guidance	ISD	D	Summary Report	x	Fault Detection
ATAR	Non-Cooperative Traffic Detection	GA-ASI	D	Available for Review at GA-ASI	x	Fault Detection

3. Leveraged the FAA Safety Risk Management Document (SRMD) for UAS DAA System Safety Assessment (SSA). Its fault tree influenced NASA's hazard report development and risk mitigation strategy.
4. Developed operational mitigations to reduce risk and address performance gaps.
   - Air Traffic Management (ATM) Services:
     - The NCC route of flight ensures its mission stays above MVA to leverage the legacy ATM safety systems (primary and secondary surveillance radar coverage).
   - Datalink Management:
     - Although the Ku SATCOM BRLOS link has been very reliable on the NASA Ikhana UAS, the NCC route of flight was tailored to minimize operations in Class E <10k ft MSL until the UAS was within C-Band DLOS range. This was expected to occur prior to waypoint 7 (Figure 12) before initiating the descent from 15k ft MSL to 9,000 ft MSL.
   - Route of Flight:
     - The NCC mission plan was carefully developed to remain off of published airways and away from known flight activity associated with gliders and other small aircraft that NASA had not fully tested the ATAR system against. Flight tests were utilized to validate ATAR performance predictions using RCS modeling and simulations for medium and large aircraft. Modeling and simulation results showed sufficient detection and track performance against small RCS aircraft such as gliders; however, to further reduce risk, this flight demonstration was planned to remain clear of areas with known glider activity.
5. Pedigree of DAA Flight Tests.
   - Ikhana UAS DAA flight test campaigns completed:
     - (Nov - Dec 2014): ACAS Xu: 9 flights, 170 mission encounters flown (1 intruder)
     - (June - July 2015): FT3: 11 flights, 212 encounters flown (up to 2 intruders)

- (April - June 2016): FT4: 19 flights, 321 mission encounters flown (up to 4 intruders)
- (June - July 2017): ACAS Xu FT2: 12 flights, 241 mission encounters flown (up to 2 intruders)

- Over 4 flight test campaigns, completed over 1,000 encounters inclusive of mission encounters and system checkout activities.
  - A majority of these encounters were setup with horizontal and vertical separation that penetrated the DAA well clear definition of 4,000 ft lateral distance and ±450 ft vertical offset. Many encounters were conducted with vertical separation as low as 200 ft (with lateral separation of 2,400 ft). Beak-to-beak encounters with no lateral separation were conducted with 500 ft vertical separation.
- No major DAA nor ATAR systems failures have occurred
  - An intermittent Ethernet communications link between the Honeywell TPA-100 processor and the SAAP was corrected with an interface redesign that does not utilize this Ethernet link and is more production representative.
  - No link loss of the C-Band LOS nor the Ku SATCOM BRLOS links has occurred.
  - During these scripted encounters, the intruder aircraft, ranging from a TG-14 motorized glider to a G-III business jet, were detected and tracked by the ATAR typically at the start of the encounter at approximately 10 – 15 nmi. This performance is well in excess of the 6 nmi radar declaration range minimum standard delineated in the DO-366 ATAR MOPS and TSOC212.

2.12.2 Safety Risk Management Panel

The FAA chose to hold a SRMP in order to help review and construct the SRMD. This panel was conducted at NASA AFRC and included experts from the FAA that addressed the hazards and safety case of flying into the NAS without chase. It was beneficial both to the FAA and to the UAS-NAS team for the panel to be held at AFRC: this way, any questions that the FAA had were quickly be addressed by the team and action items could be distributed rapidly.

The FAA created three main hazards to address: loss of DAA, lost link, and DAA failing to detect low RCS non-cooperative equipped aircraft. These hazards were discussed in depth and mitigations were captured. Limitations to each of the hazards were also captured during this panel (e.g., what would constitute a RTB). The action items brought up from discussions of these hazards included providing maintenance procedures and technical orders for Ikhana, checklists, pilot training, proof of mishap plans, lost link occurrence rates, and DAA equipment failure rates.

In addition, discussions from this panel helped to modify the route further. Changes were made to the Victorville routing and the lost link was updated to procedures that the FAA found more suitable than the original proposition.

With the cooperation of the FAA, UAS-NAS, and Ikhana teams, a SRMD was written and eventually approved to supplement the COA, providing a waiver to finally fly into the NAS without a chase vehicle. The mitigations identified in the SRMD were called out in the COA as requirements to comply with in order to operate.

3 Results and Analysis

The culmination of all efforts lead to the team performing the SCO and demonstration flights. The SCO flights served their purpose, as problems were identified during these flights, allowing the team time to resolve them prior to the demo flights. A description of the results and team's analysis of the flights is below.

3.1 System Checkout Flights

Once the team had conducted the No Chase COA System Checkout Tech Brief, an approved flight request was given. The aircrew conducted a tabletop training session to prepare for the upcoming encounters. Specific details were given on the DAA display and what to expect during the avoidance maneuvers.

3.1.1 Flight 1 – 14 February 2018

There were three main purposes for flight 1 of the system checkout. The first was to ensure that the pilots and aircrew were proficient and current in order to complete the upcoming SCO flights safely and efficiently. The second purpose was to power up the DAA system to verify that all the components were working appropriately and that no errors were experienced. The final purpose was to complete the remainder of the Ikhana envelope expansion test points. Envelope expansion was necessary because AFRC management had not yet approved the entire MQ-9 envelope for Ikhana with the modified nose. Opening up the envelope ensured greater flexibility that could be needed in the NAS. For this flight, no encounters were planned.

The flight was completed on 14 February 2018 within R-2515 airspace. Ikhana took off from EAFB runway 22 Left at 0610L and proceeded to climb to test altitude. The first checkout was powering the DAA system at 0640L. Once powered, the Ikhana team searched for valid data telemetered to the ground and that no anomalies were found. All checks looked good and the team powered the DAA systems down and concluded the DAA system checkout at 0708L.

The next objective for this flight was the envelope expansion. This series of test points were to verify the aircraft's ability to fly at 30,000 ft MSL at various airspeeds with the modified nose. The test began at 0722L and was concluded at 0903L. The team completed test points required to expand the envelope and made an uneventful landing at EAFB on runway 22L at 0942L.

3.1.2 Flight 2 – 15 February 2018

This was the first No Chase COA System checkout flight where the DAA system was being tested. Eighteen flight test cards were planned for this test day and the team successfully completed 16 encounters. Two intruder aircraft were used for this flight: NASA 856 (TG-14) and NASA 808 (G-III). See the flight details and MCC3 recorded data below in Table 16.

Notes: The Ikhana UAS took off at 0706L, NASA 856 took off at 0658L. Ku SATCOM hits were noted at the encounter with COMEX 0801. Due to the momentary loss of the DAA system, the encounter was aborted and was repeated. At 0815L NASA 808 took off and NASA 856 landed at 0833L. It was noticed that there were no increased TCAS alerts with the encounter at COMEX 0915. However, TCAS alerts were received when executing ATCAS-23 at 0928L. At the encounter with COMEX 1020, an alert for a bad SAAP was received in the GCS. The team reset the SAAP and radar with no further issues. The encounter with COMEX 1041 was aborted due to the intruder not acquiring visual identification of Ikhana within 1.0 nmi.

Airspace: After the encounter at 0928L, SPORT required that Ikhana stay between 16,000 ft and FL220. Due to this restriction it was determined that card 11 would be conducted next with redlines to the altitudes, fitting the altitude restriction. This restriction was lifted for the rest of the test day at 0956L.

Table 16. No Chase COA System Checkout Flight 2 Data and Observation Notes.

Flight	2									
Run#	Encounter	COMEX	Intruder	VID	Wind O/S	Term.	Maneuver	TA	RA	Redlines
1	SQK-6 - No VID	0726	856	1.1	325/11	0728	Fly Through	Yes	Yes	
2	SQK-6	0738	856	4.5		0739	Left Turn			
3	SQK-7	0748	856	Yes		0749	Right Turn	Yes		
4	SQK-8 - Abort	0801	856			abort				Mode C / Latitude N34° 57.47'
5	SQK-8	0809	856	2.6		0810	Right Turn			Mode C / Latitude N34° 57.47'
6	LALT-24	0820	856	1		0823	Fly Through	Yes	Yes	
7	LALT-25	0830	856			0832	Right Turn	Yes		
8	ATCAS-22 No VID	0859	808	0.5		0900	Fly Through	Yes	Yes	O/S No descent
9	ATCAS-22	0915	808	0.5	244/46	0916		Yes	Yes	O/S No descent
10	ATCAS-23	0928	808	2.5		0929		Yes	Yes	
11	NUIS-13	0945	808			0947	Left Turn; Heading 190	Yes		Altitudes +7000ft
12	NUIS-14	0956	808	2		0958		Yes		
13	DB-15	1020	808			1022	Left Turn; Leveling at 8000	Yes	Yes	
14	HS-11	1033	808	1.7		1035	Fly Through	Yes	Yes	
15	TM-1	1041	808	0.7		1042	Fly Through	Yes	Yes	
16	HDR-16	1051	808			1053	Fly Through			

3.1.3 Flight 3 Attempt 1 – 28 February 2018

For the third SCO flight, Ikhana experienced a degraded C-Band datalink which caused the team to call a “knock it off”, return to base, and conduct an investigation. More information on this event can be found in the Flight Systems Comments Section 3.3.1.

3.1.4 Flight 3 Attempt 2 – 28 March 2018

Once the investigation was completed and the team had gone back to tech brief, the Ikhana UAS was approved to fly again. Flight details and MCC3 recorded data is below in Table 17.

Notes: The test day started with Ikhana taking off at 0605L and NASA 7 (B200 King Air) taking off at 0630L. The Unique Ku only and Use Case test cards were completed successfully. The encounter with a COMEX of 0751 encountered multiple resets and an abort call due to the sensors turning off but was completed successfully with a COMEX of 0850. Each test card was completed including two cards that were unable to be accomplished during the second SCO flight.

Airspace: During the same encounter mentioned above, SPORT had placed an FL180 restriction in the area that was being tested. Due to this, 10,000 ft was added to the test point altitudes, including abort and deconfliction altitudes, in order to complete these test cards.

Table 17. No Chase COA System Checkout Flight 3 Attempt 2 Data and Observation Notes.

Flight	3									
Run#	Encounter	COMEX	Intruder	VID	Wind O/S	Term.	Maneuver	TA	RA	Redlines
1	KU-1	0655	NASA 7	1		0657	Fly Through	Yes	Yes	
2	KU-2	0705	NASA 7	5.5		0707	Left Turn	Yes		
3	OTD-25	0716	NASA 7	2.5		0718	Right Turn	Yes		
4	UC-2	0731	NASA 7	1.4		0733	Climb / Left Turn	Yes	Yes	
5	IOT-17	0741	NASA 7	4.5		0745	Fly Through	Yes	Yes	Altitudes +10000ft
6	IOT-18	0850	NASA 7	2.4		0852	Right Turn	Yes		Altitudes +10000ft
7	OOT-19	0906	NASA 7	2		0908	Left Turn	Yes	Yes	Altitudes +10000ft
8	LT-20	0915	NASA 7	2.5		0917	Right Turn	Yes	Yes	Altitudes +10000ft
9	LT-21	0925	NASA 7	2		0928	Descent	Yes	Yes	Altitudes +10000ft
10	LT-21 - Repeat	0935	NASA 7	1.1		0931	Descent	Yes	Yes	Altitudes +10000ft
11	KU-01 - Repeat	0946	NASA 7	2.1		0948	Fly Through	Yes	Yes	Altitudes +6000ft
12	LOB-9	0956	NASA 7	1.5		0958	Descent	Yes	Yes	Altitudes +11000ft
13	LOB-10	1006	NASA 7	2.8		1008	Descent	Yes	Yes	Altitudes +11000ft

3.2 Demonstration Flights

Previously thought to take 2.5 hours, the flights into the NAS went smoothly. Due to the early takeoff time, the traffic in the NAS was not as high as other times during the day. Because of this, fewer interactions with ATC and route diversions occurred, but the DAA system properly provided awareness. All scenarios encountered in the NAS had been previously tested during the many flight test and system checkouts performed by the team.

3.2.1 With Chase

The first flight into the NAS, with chase, was flow on Thursday, 24 May 2018. Ikhana took off at 0624L and landed at 0900L at EAFB. The route into the NAS had a duration of 1 hr, 51 min. The chase vehicle for this flight was NASA 801, the B200 King Air. On board were a photographer and videographer in order to record the historic event. The flight began with NASA 801 taking off slightly before NASA 870 and performing an airborne pickup while in R-2508.

Inside R-2508, Ikhana climbed to FL200, departed this airspace as the lead of the formation, and began its flight into the NAS. At approximately 0735L, after waypoint 6, it descended to 17,000 ft MSL. At 0742L, after waypoint 7, it descended to 15,000 ft MSL. At 0809L, after waypoint 9, it descended to 9,000 ft MSL. At 0832L, after waypoint 14, it descended to 6,000 ft MSL. At 0836L, NASA 870 descended to 5,000 ft MSL after waypoint 15. And finally, Ikhana climbed back to 9,000 ft MSL after waypoint 17, then flew back into R-2515.

Table 18 below is a summary of the time to each waypoint. All times are in local Pacific Time.

Table 18. Summary of Time at Waypoints for Flight into NAS with Chase, 24 May 2018.

Waypoint	Time (local)	Waypoint	Time (local)
1	0654	**10**	0814
2	0701	**11**	0823
3	0712	**12**	0826
4	0715	**13**	0830
5	0731	**14**	0832
6	0734	**15**	0836
7	0743	**16**	0839
8	0757	**17**	0839
9	0808	**18**	0845

This flight had a few significant firsts, such as an encounter executed safely in the NAS, a DAA system used to fly into Class E and D airspace, and a transition into two ARTCCs by a UAS in the NAS.

At approximately 0707L, NASA 870 received a corrective alert on SWA462, the team's first "encounter" in the NAS. Additionally, all objectives for this flight were met, including being handed off to several ARTCCs: checking in with ZOA at 0721L and back with ZLA at 0736L. NASA 870 also started its descent and transit of Class D airspace at 0836L.

Generally, all DAA systems worked as expected. The team saw extended hybrid surveillance on ADS-B equipped traffic, witnessed sensor fusion working on the DAA system, and received DAA alerting and guidance from aircraft (specifically, the brief corrective alert on the descending SWA462 737 until it leveled off at ATC-assigned altitude 2,000 ft above Ikhana). Additionally, a TCAS TA was seen on the DAA system on SWA462 as it descended to 1,000 ft above Ikhana and passed safely 1.3 nmi away. Surveillance on VFR traffic was also observed at low altitudes. Finally, there were some ATAR split tracks observed but nothing outside the range of the mission rules and the agreements with the FAA. The flight operations around Victorville also went successfully, with a smooth transition to tower. During all phases of flight, ATC was providing guidance.

Overall, the flight was a tremendous success and gave the team great experience and confidence of what to expect of the flight without chase.

3.2.2 Without Chase

The demonstration flight of NASA 870 Ikhana without chase into the NAS occurred on a clear day, on Tuesday, 12 June 2018. NASA 870 took off at 0604L and landed at 0846L. The duration of the flight into the NAS was 1 hr, 50 min. The approximate length of the route of flight outside R-2515 was 415 nmi.

For this flight NASA 870 performed the same route as the flight with chase. The aircraft took off and climbed to FL200 within R-2515. After transiting at this flight level, it descended to 17,000 ft MSL at 0711L, after waypoint 6. At 0718L, slightly prior to waypoint 7, NASA 870 descended to 15,000 ft MSL. At 0743L, after waypoint 9, the aircraft descended to 9,000 ft MSL. At 0806L, after waypoint 14, Ikhana descended to 6,000 ft MSL, followed by a descent to 5,000 ft MSL at 0810L after waypoint 16. Finally after this waypoint, at waypoint 17, Ikhana climbed back to 9,000 ft MSL and into R-2515 which was the conclusion of the mission.

Check in with ZOA was at 0659L (prior to waypoint 5), check in with ZLA at 0715L (prior to waypoint 7), and the final descent into Class D occurred at 0810L (after waypoint 15).

Table 19 below is a summary of the time to each waypoint. All times are in local Pacific Time.

Table 19. Summary of Time at Waypoints for Flight into NAS without Chase, 12 June 2018.

Waypoint	Time (local)	Waypoint	Time (local)
1	0628	**10**	0748
2	0635	**11**	0756
3	0646	**12**	0800
4	0650	**13**	0803
5	0708	**14**	0805
6	0710	**15**	0809
7	0719	**16**	0812
8	0731	**17**	0813
9	0742	**18**	0818

Once more, this flight experienced milestone events for UAS in the NAS. At approximately 0747L, a first-of-its-kind ATC interaction occurred, where ATC provided a traffic advisory on an opposite direction VFR traffic with an intermittent transponder and unverified altitude. Ikhana responded with "Traffic Detected" and ATC acknowledged. No further traffic advisories were provided on that VFR traffic since Ikhana had the traffic detected. Additionally, at approximately 0801L, an ATC/pilot interaction occurred where a C-172 was provided an advisory of a UAS overtaking it to the right and 1,500 ft above. The C-172 pilot reported "Traffic in Sight", affirming the information that was also already available on the NASA 870 DAA system display.

Once more, a successful flight was flown into the NAS, but this time without a chase. All DAA systems worked as expected, which included the extended hybrid surveillance on ADS-B equipped aircraft, sensor fusion, and ATAR track on a VFR traffic with an intermittent transponder. The DAA alerting and guidance was successful, and although there were some Ku hits (momentary signal degradation), these hits were minor and did not significantly affect the mission, pilot SA, or break any Mission Rules, or guidelines from the FAA.

This flight successfully proved that a UAS can fly into the NAS, without chase, and use a DAA system to safely navigate its way on a route of flight, traversing several ARTCCs and transiting through Class A, E, and D airspace.

3.2.3 Data Collection and Analysis

During both flights into the NAS, the LVC was collecting data on the performance of the DAA system. Specifically, the data was recorded in a "quad" format, which included for every instance of flight, information from the Ikhana HUD, CPDS displays, and a snapshot of the Solipsys Zeus SA display tool.

3.2.3.1 *NASA 870 No Chase COA Mission with Chase Aircraft (Ikhana Flight #250)*

The NASA 870 mission in the NAS with chase aircraft (Ikhana Flight #250) was flown as a rehearsal for the flight demo mission (to be flown without chase). Mission objectives were to:

- Validate route of flight and mission planning
- Validate Ku SATCOM C2 link capability throughout the route of flight
- Validate ATC voice communications and evaluate interactions
- Ensure adequate C-Band LOS C2 signal levels during mission segments within Class E airspace

The majority of the time that Ikhana was operating in the NAS was uneventful; however, screenshots of the CPDS and Zeus displays during the mission were captured in order to highlight notable traffic events.

Early during the mission while in Class A airspace, NASA 870 encountered descending commercial airline traffic (SWA462) that triggered a DAA corrective (yellow) alert due to predicted loss of well clear within 75 sec if the current flight trajectories remained unchanged (Figure 41). Lateral separation between NASA 870 and SWA462 was approximately 12 nmi. ZLA ARTCC controller was actively managing the situation, clearing SWA462 to descend and maintain FL220. The controller further cleared SWA462 to descend and maintain FL210. The subsequent descent and level-off at FL210 triggered a TCAS TA and "Traffic, Traffic" alert (audio and head-up display) to the pilot. At the closest point of approach, SWA462 was 1,000 ft vertical and 1.3 nmi lateral from NASA 870. Figure 42 depicts the track at CPA showing at clear of traffic condition.

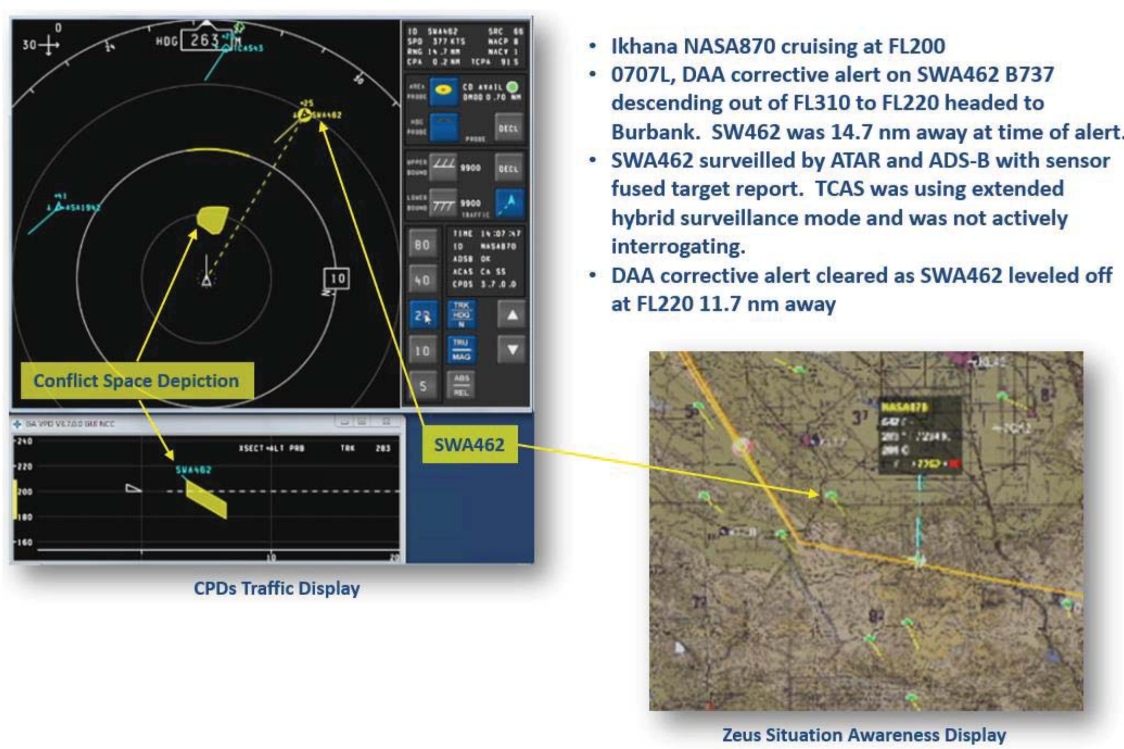


Figure 41. Class A DAA Corrective Alert with SWA462.

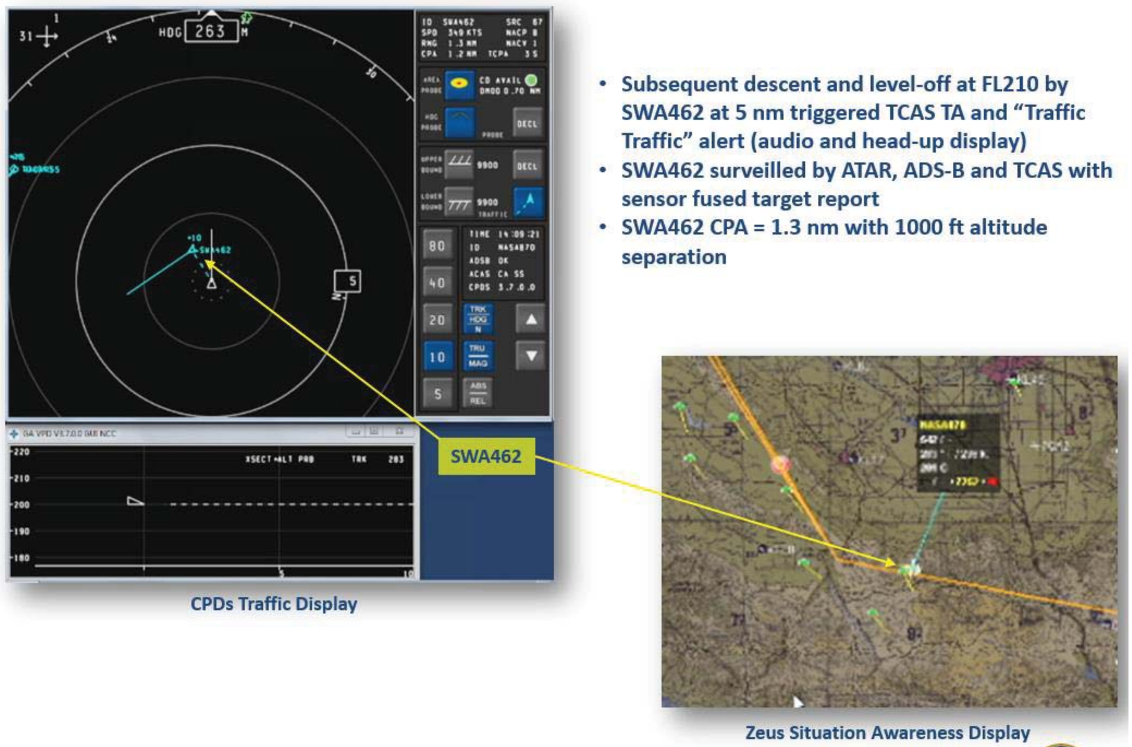


Figure 42. Clear of Traffic with SWA462.

During the transit through Class E airspace while descending from 15,000 ft MSL at 9,000 ft MSL, NASA 870 detected VFR traffic operating in the vicinity of Gen William J. Fox Airfield (KWJF). TCAS surveillance tracks were depicted on the CPDS display for the pilot (Figure 43). Later these tracks were fused with ATAR sensor data.

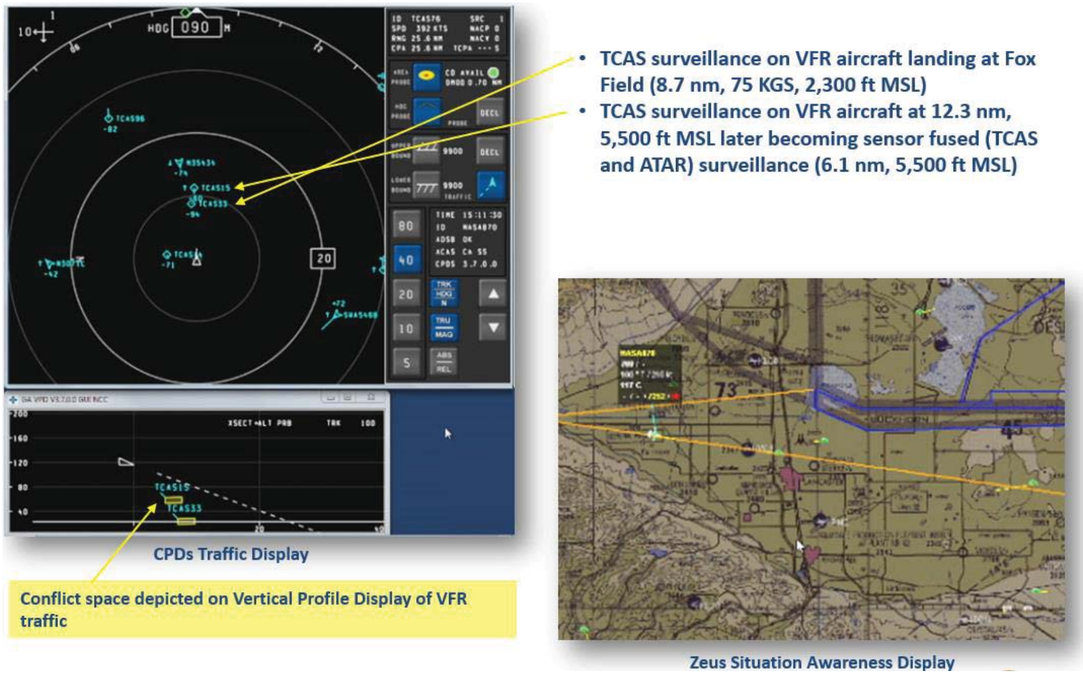


Figure 43. TCAS Traffic near KWJF.

While at 9,000 ft MSL approaching Apple Valley Airport, NASA 870 detected VFR traffic operating in the VFR pattern (Figure 44). While at 5,000 ft MSL transiting Class D airspace at VCV, NASA 870 detected VFR traffic operating in the VFR pattern (Figure 45).

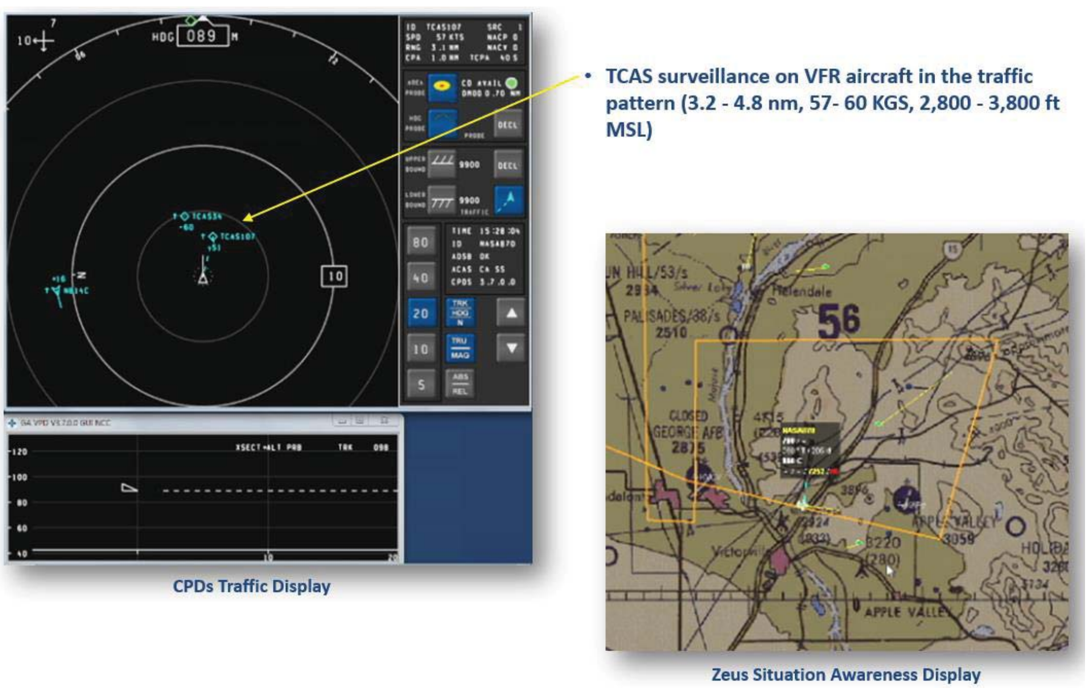


Figure 44. TCAS Traffic near Apple Valley Airport.

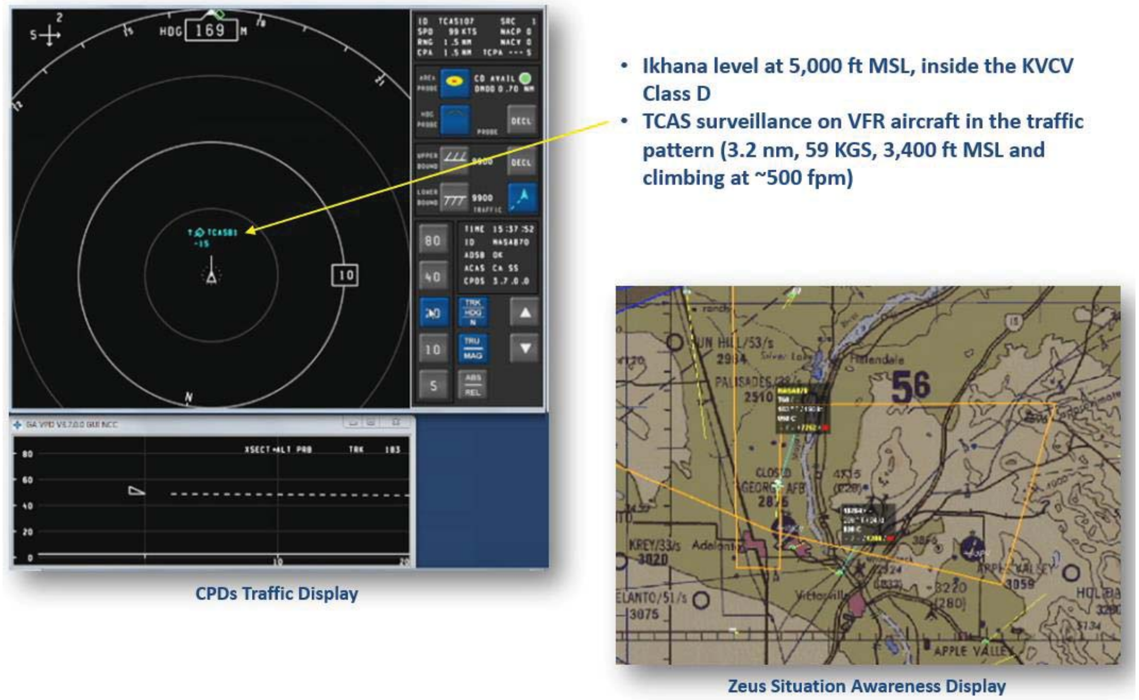


Figure 45. TCAS Traffic near VCV.

During the transition from VCV Class D airspace to return to restricted airspace (R-2515), NASA 870 detected TCAS traffic within 10 nmi of its location (Figure 46). Both TCAS and ATAR surveillance tracks were developed. One track depicted a "fast mover" exiting R-2515 at 12,400 ft MSL, while the second track depicted a sensor fused track in an orbit at 11,000 ft MSL. This track was later determined to be an MQ-9. Notable on the CPDS display that the Vertical Profile Display depicted conflict space between Ikhana and the two detected intruder aircraft.

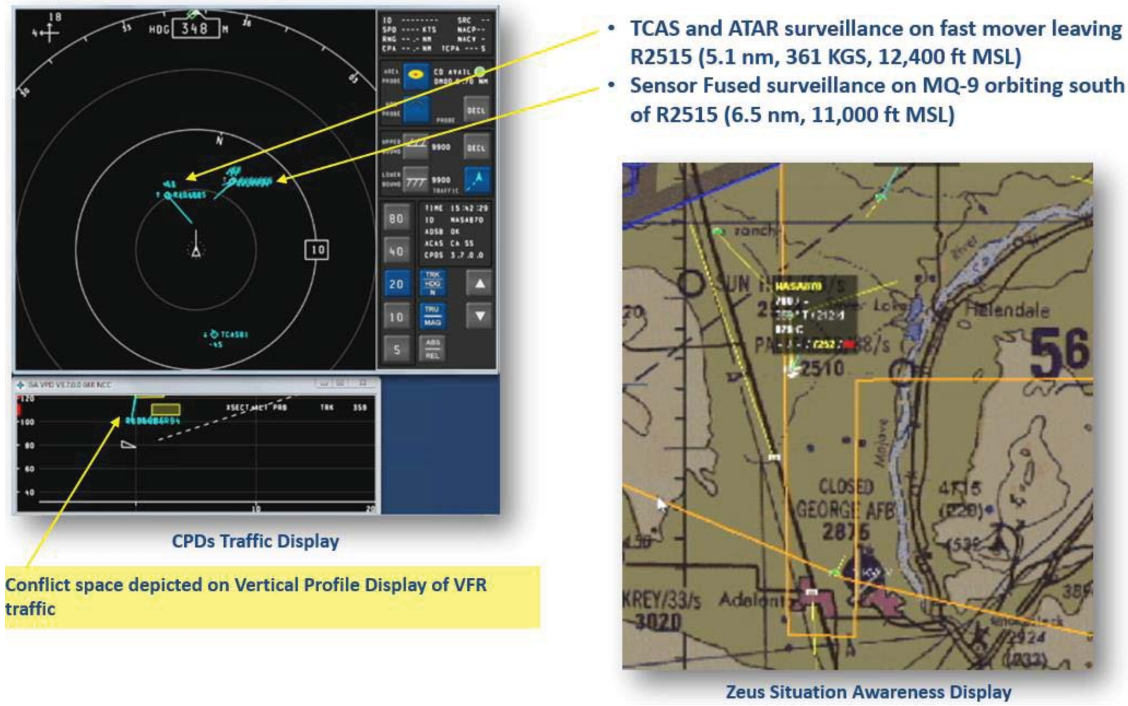


Figure 46. TCAS / ATAR Traffic near R-2515.

3.2.3.2 *NASA 870 No Chase COA Mission without Chase Aircraft (Ikhana Flight #251)*

The NASA 870 mission in the NAS without chase aircraft (Ikhana Flight #251) flew the same flight profile as on Flight #250. The mission was uneventful throughout the transit through Class A and "high" Class E (above 10,000 ft MSL). Once NASA 870 was eastbound and level at 9,000 ft MSL, a chance encounter with a general aviation aircraft flying on a reciprocal path but 1-2 nmi to the north of Ikhana led to a first of its kind interaction with ATC (Figure 47). The Joshua controller reported opposite direction VFR traffic with an intermittent transponder and unverified altitude. The NASA 870 pilot replied back "Traffic Detected", signaling the fact that the aircrew had detected the aircraft through its on-board DAA equipment. With the controller's acknowledgment ("NASA 870 roger") this exchange established a first-ever communication of a large UAS operating alone in low Class E airspace using onboard traffic to effect an equivalent level of safety and compliance with 14 CFR §91.111(a) and 113(b) "see and avoid/remain well clear" regulations.

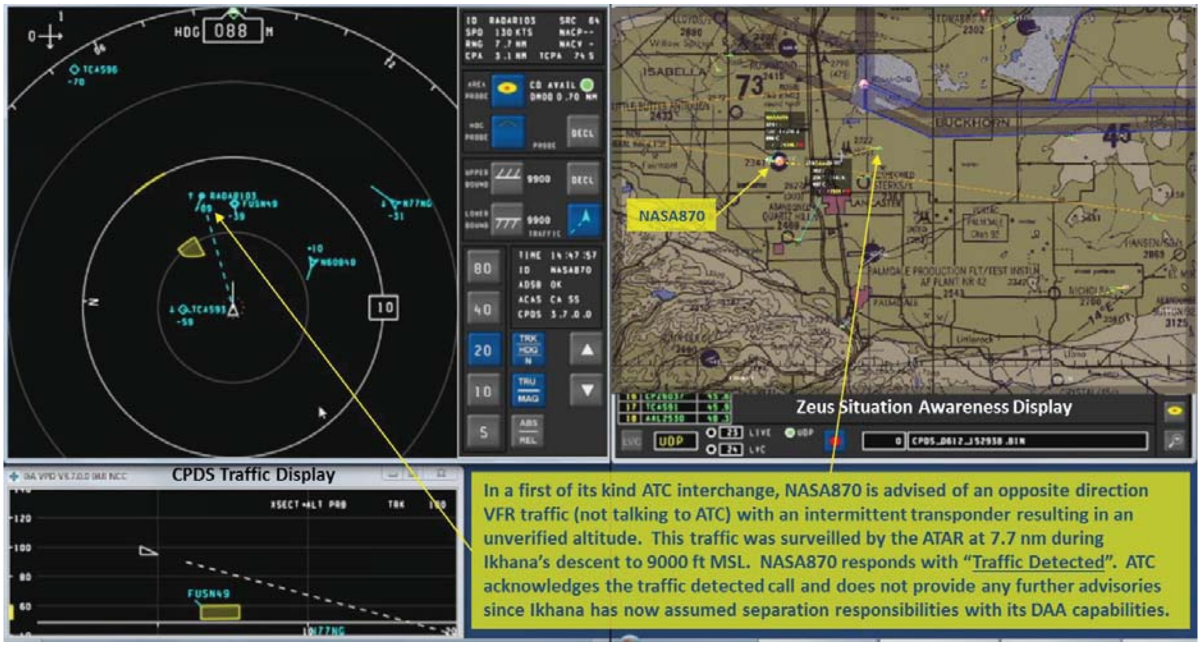


Figure 47. "NASA 870, Traffic Detected".

Fourteen minutes after the first VFR traffic advisory, Joshua provided another advisory to a C-172 flying a parallel flight path but in the same direction with NASA 870 (Figure 48). In this case, ATC notified N469MB that he had a UAS overtaking him to the right at 9,000 ft (1,500 ft above). N469MB pilot reported "Traffic in Sight". During the encounter, NASA 870 surveilled the Cessna using TCAS and ATAR sensor sources.

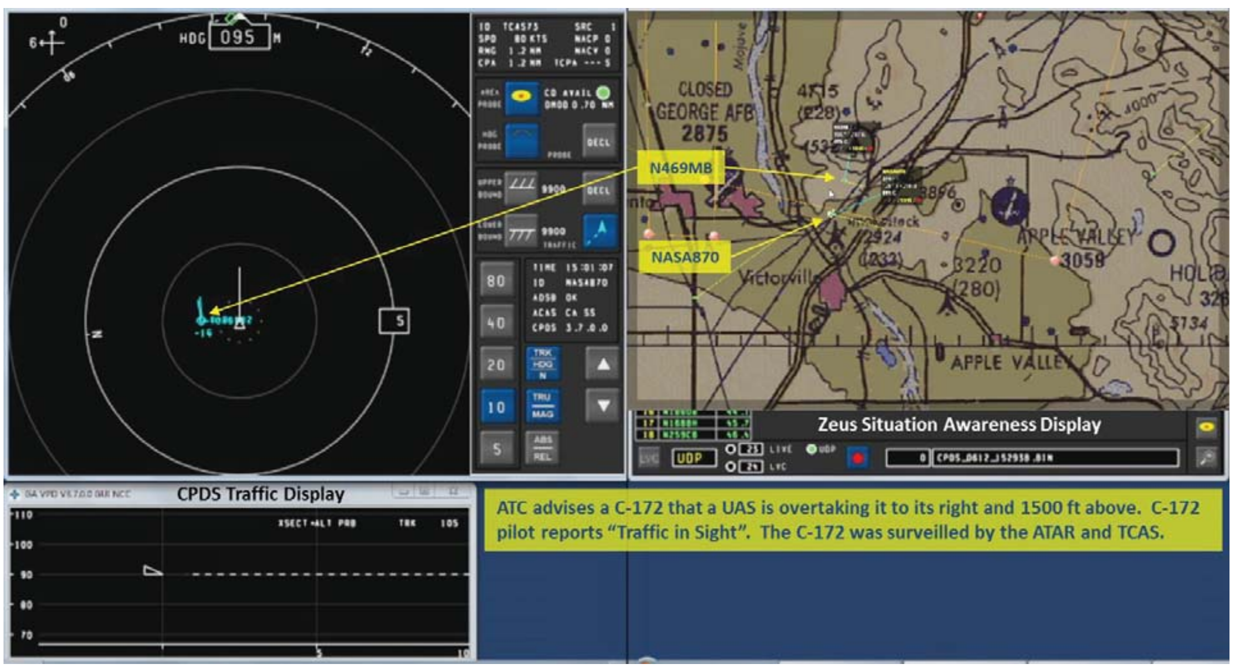


Figure 48. TCAS / ATAR Traffic near VCV.

Outside of the two previously described events, two other noteworthy situations occurred during the flight. The first situation occurred when NASA 870 was in Class E airspace having departed 15,000 ft MSL, descending to 9,000 ft MSL and approximately 5 nmi west of KWJF. Joshua directed a Mooney (N6084Q) at 10,500 ft MSL to adjust their current heading (Figure 49). The Mooney was on an intercept heading with NASA 870 prior to the call from the controller. Joshua identified “opposite direction descending unmanned aerial vehicle traffic, fly heading 270 and expect to resume own navigation in 10 miles”.

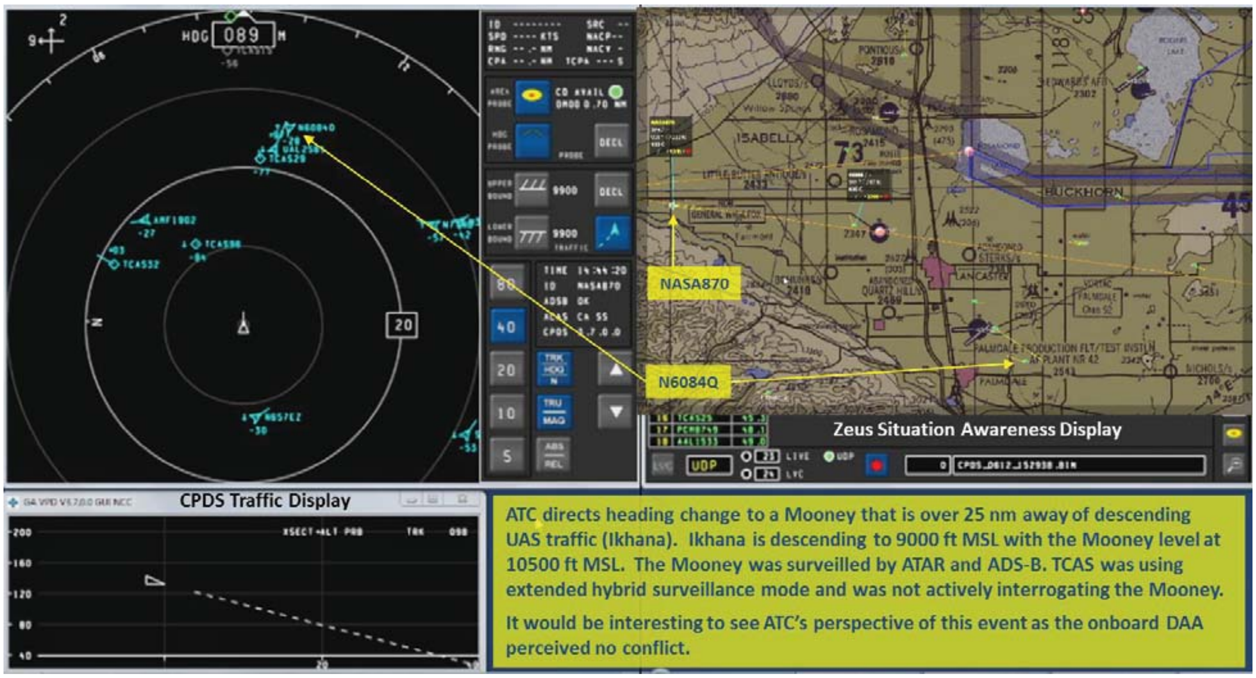


Figure 49. ATC Alters N6084Q Course from NASA 870.

From the NASA 870 pilot perspective, no adjustment to his current flight path was necessary based on the SA display perspective. The project has speculated that the Joshua controller had information available from their perspective that identified a potential conflict between NASA 870 and the Mooney aircraft considering the larger enroute separation criteria employed by ATC. Figure 50 and Figure 51 show the sequential progression of the aforementioned scenario.

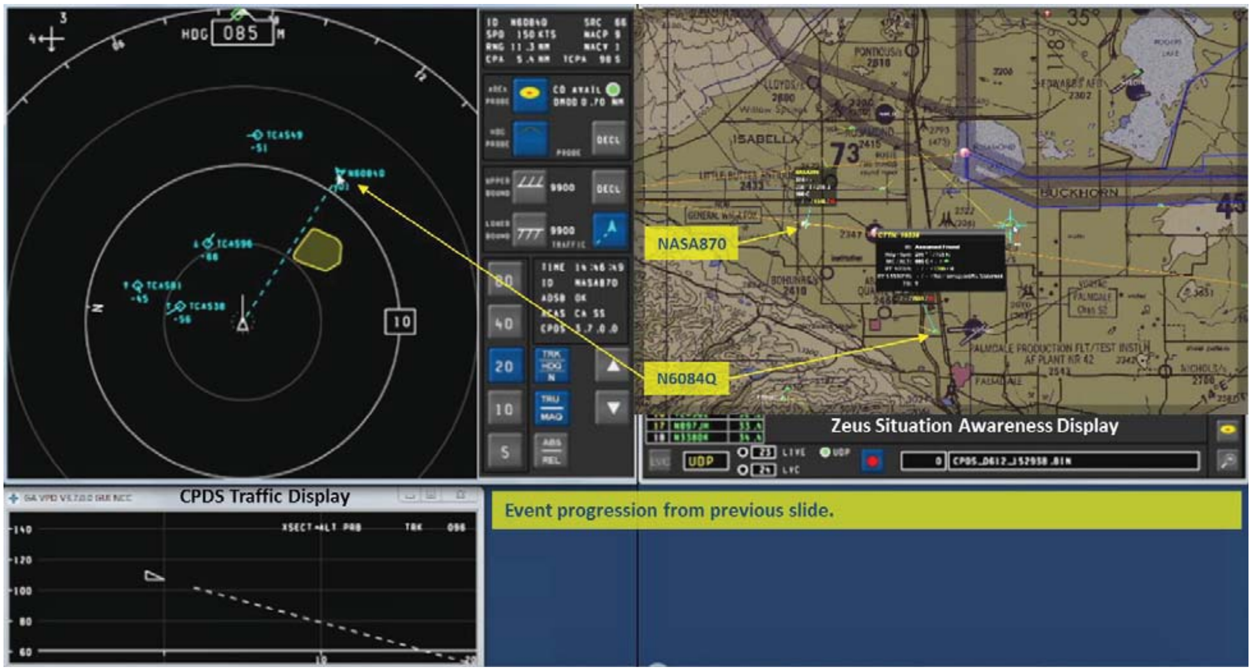


Figure 50. N6084Q Established on 270° Heading.

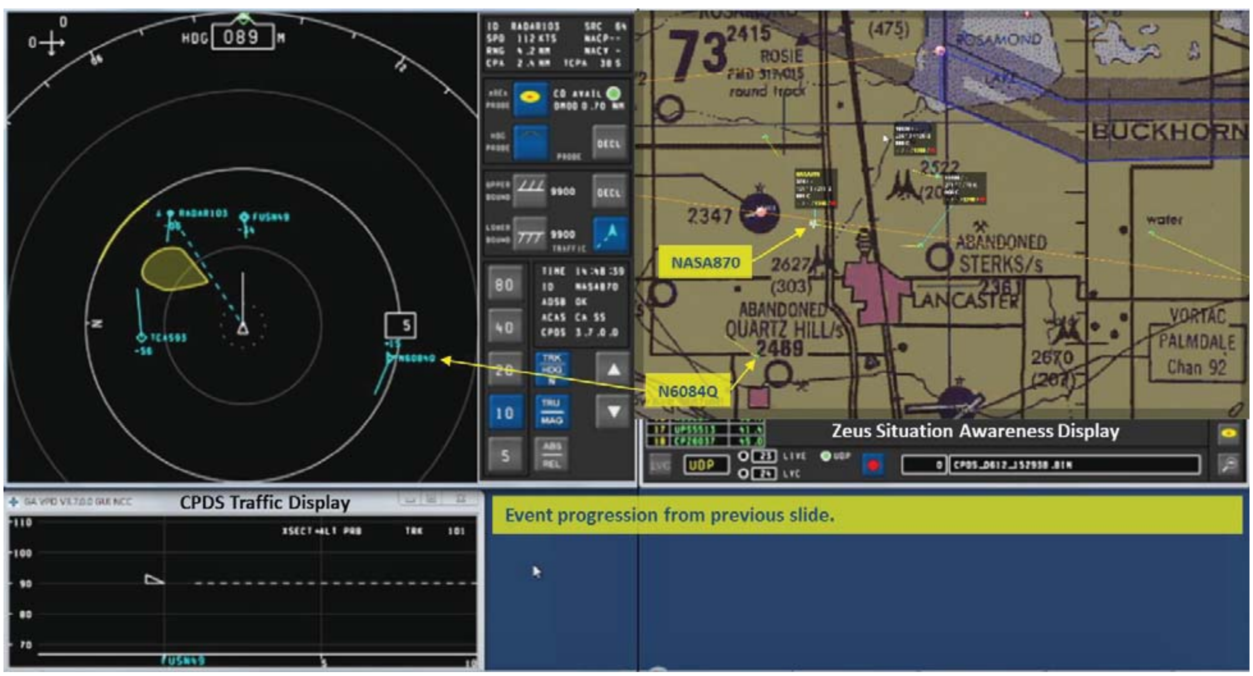


Figure 51. N6084Q Passes Abeam NASA 870.

The final scenario observed during Flight #251 was an interaction between ATC (ZLA) and UPS938. NASA 870 was in Class A airspace flying at FL200 headed west along the early portion of the mission plan when

LA Center controller contacted UPS938 who was in a climb 25 nmi southeast of NASA 870 position. LA Center directed USP938 to "maintain 1500 fpm or greater through FL210 for traffic" (Figure 52).

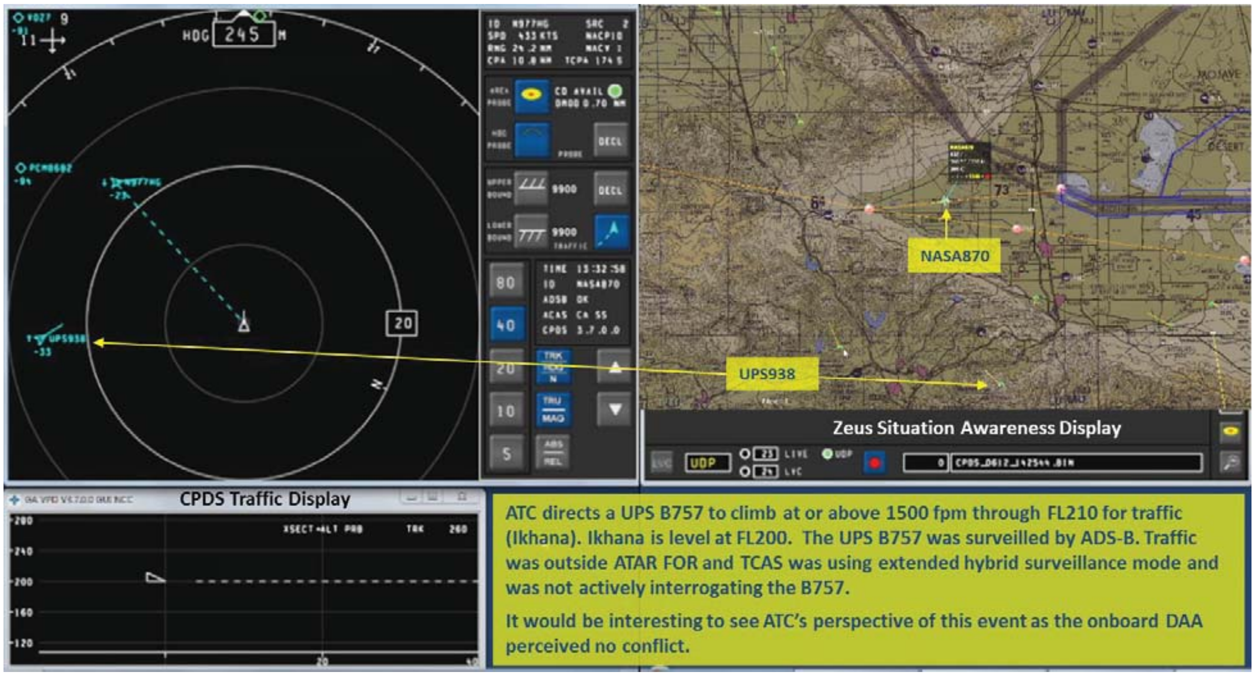


Figure 52. LA Center Contacts UPS938.

Figure 53 and Figure 54 sequentially depict the progression of the scenario with UPS938. From the NASA 870 pilot perspective, the SA display did not identify a conflict and the Vertical Profile Display (part of CPDS) did not show a conflict probe with UPS938. It can also be noted that as the situation progressed (Figure 54), UPS938 "lagged" NASA 870 which reinforces the lack of conflict display information. As in the previous scenario with the Mooney, the direction to the UPS B757 was most likely the result of ATC employing larger separation criteria for enroute traffic.

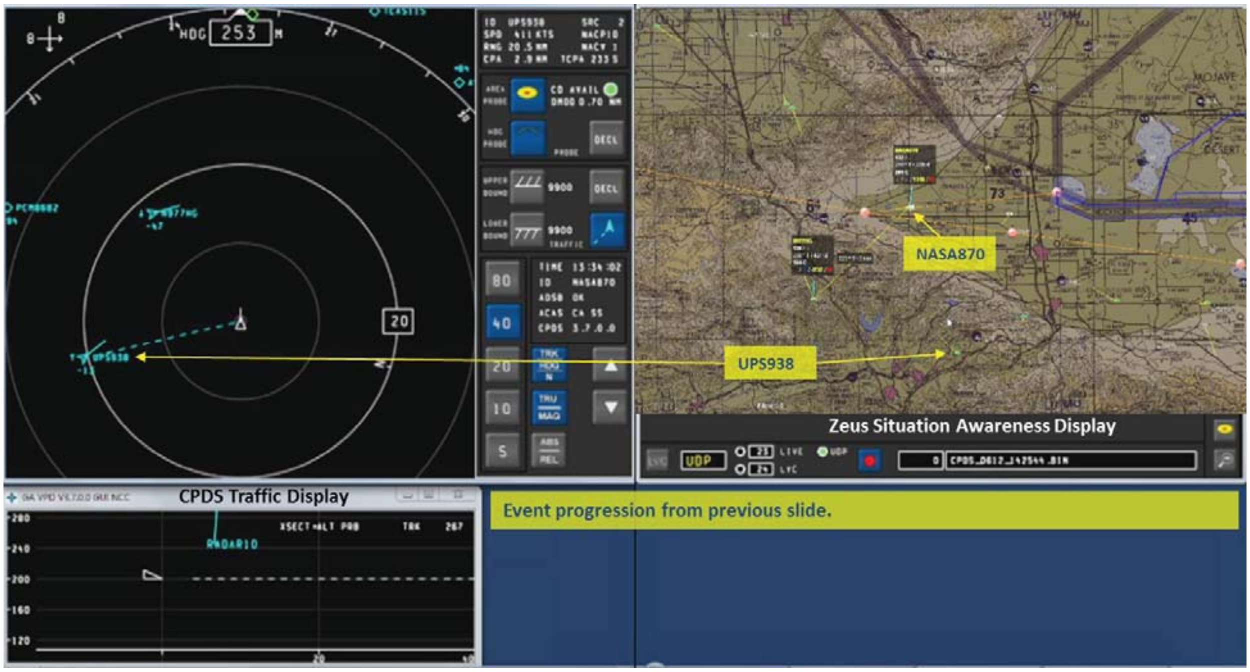


Figure 53. UPS938 20 nmi Southeast of NASA 870.

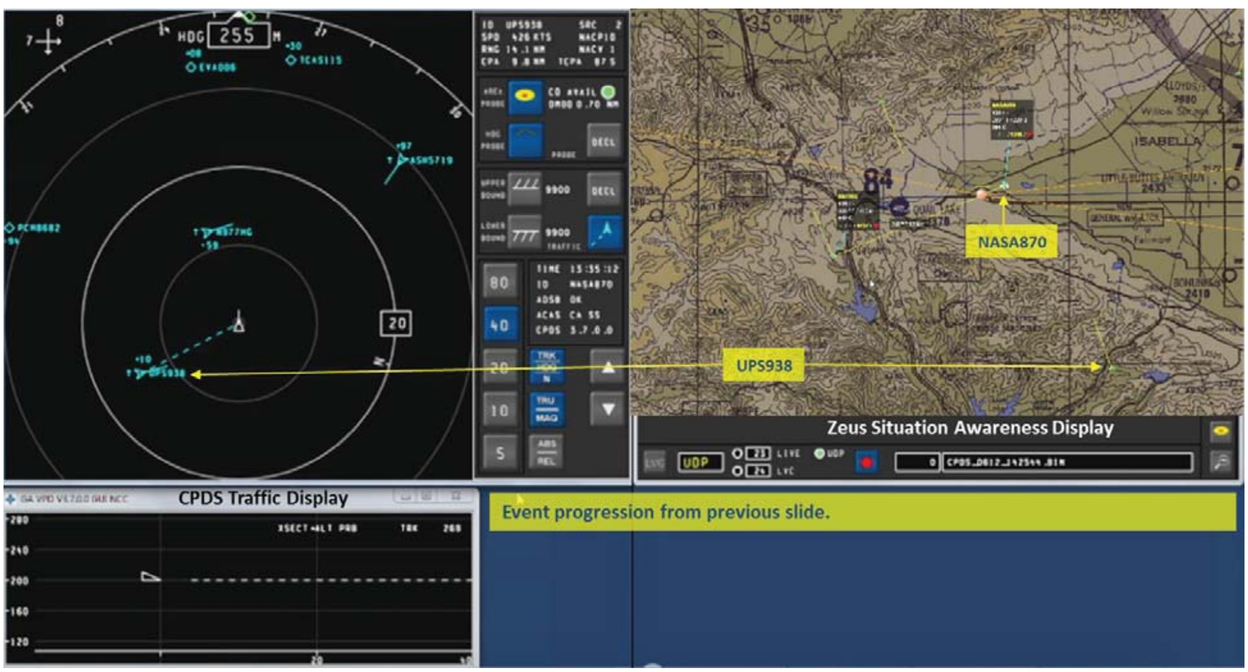


Figure 54. UPS938 "Lagging" NASA 870.

3.3 Detect and Avoid Display Performance

Throughout all flights, it was important to have the DAA system performing smoothly. The feedback from flight systems and the pilots gave the team information on how to improve for each subsequent flight.

3.3.1 Flight Systems Comments and Discrepancies

Prior to the two NCC demonstration flights, a set of verification and validation ground and flight tests were executed to check basic functionality of the system, electromagnetic compatibility (EMC) between components, no electromagnetic interference (EMI) between systems, verification of guidance and alerting system in nominal and off-nominal conditions, and validation of mission systems that would be used to support the demonstration flights. Although the results of the ground tests were nominal, the NCC SCO flights several revealed anomalies in the system that required a satisfactory resolution prior to the NCC demonstration flights. The solutions, lessons learned, and workarounds developed for the issues observed during the SCO flights proved extremely effective since they enabled the flight crew and test team to maintain excellent SA of proximal traffic during the entirety of the two NCC flights with only minor anomalies previously experienced and briefed to the FAA and NASA AFRC review boards.

3.3.1.1 *System Checkout Flights*

Three SCO flights were conducted to perform regression testing of the modified Ikhana flight software, basic DAA payload power up checks, verification of the payload safety nets, performance of DAA remain well clear maneuver while in Ku-band SATCOM command & control, and validation of DAA system for air-to-air encounters representative of NAS operations.

3.3.1.1.1 SCO Flight 1

The first SCO flight (SCO-1: Ikhana Flight 245) was executed without issues, but it did not exercise the DAA system since it only included a quick power up and shutdown of the DAA system.

3.3.1.1.2 SCO Flight 2

In the second SCO flight (SCO-2: Ikhana Flight 246), data to the traffic display was lost and an unexpected system state was observed on the Variable Information Table (VIT-78: SAA Sensor Status) health and status (H&S) display. Based on the VIT information, a real-time assessment of the issue pointed to a problem between the SAAP and ATAR interface link. However, the lack of data to the traffic display could not be traced to the state of the H&S displays. The H&S states displayed to the flight systems engineer should have allowed, at a minimum, Ikhana ownship data to be displayed on the traffic display. The system operated nominally after a power cycle of all the DAA systems was performed by the sensor operator. Post-flight analysis of the issue traced the problem to a design flaw in the Ballard Technology (PMC05) Ethernet board that provided the data interface between the SAAP (Ballard Technology AB3000 computer) and ATAR. This intermittent board failure caused the SAAP to fail leading to lack of data to the traffic display. The manufacturer refurbished the AB3000 computer with a new PMC05 board since they suspected the issue was caused by degradation of the board due to aging. This issue was captured as a discrepancy report (DR), Flight 246 DAA SAAP Health Bad.

3.3.1.1.3 SCO Flight 3 Attempt 1

For the third SCO flight (SCO-3: Flight 247), the Ikhana UAS encountered an intermittent issue with the fiber optic multiplexers (FOM) that provides the command & control interface between the Ikhana ground control station (GCS) and the Semi Mobile UAS Remote Facility (SMURF) antenna station. This caused severe degradation of the C-Band datalink that triggered a “Knock-it-Off” condition and a RTB. This event was reported as a “close-call” using the AFRC safety process. The Ikhana team developed a thorough “Go-Forward” plan that included new checklist procedures, system monitoring procedures, ground tests, and flight test. After a Tech Brief on the findings and corrective actions proposed by the Ikhana team for this particular DR, AFRC Senior Management approved the team to execute the “Go-Forward” plan without any issues.

3.3.1.1.4 SCO Flight 3 Attempt 2

Since the required SCO-3 test points could not be completed during Ikhana Flight 247, the SCO flight was repeated a month later during Ikhana Flight 248. In this flight, two anomalies were observed by the engineering team. During a scripted encounter, the expected ADS-B symbology for the intruder dropped from the traffic display. On one of the engineering displays, the ADS-B and fused target reports for local traffic disappeared from the traffic list. Only active surveillance/TCAS tracks were observed on the traffic and engineering displays. A visual scan of the VIT-78: SAA SENSOR STATUS and VIT-77: SAA Processor H&S displays showed a mostly healthy system with unexpected states for a few sensor parameters. After approximately 40 seconds, the traffic symbology and system status returned to a nominal state on all DAA payload displays. Post flight analysis performed by Honeywell determined that the Honeywell Fusion Tracker software restarted automatically after an unexpected failure. During the software restart, the Honeywell TPA-100B Processor failed automatically to the certified TCAS II v7.1 Collision Avoidance System (CAS) path. In the implementation of the NCC architecture, the team decided to design a feature in the Honeywell system that would perform validation cross-checks between the tracks reported by the Fusion Tracker and TCAS logic. This design consideration was implemented since the Fusion Tracker could not be tested to the required DAL C requirements. The DAL C requirements were instead placed on the validation cross-checker to ensure that the system would revert to a TCAS option if the tracker failed. Although the restart was unexpected, the system behavior reacted in accordance with the expected design. This failure would not be observed again, but it was captured in the following DR: Honeywell Sensor Fusion/Tracker Software Restart

A second minor anomaly was observed when the ADS-B sensor contribution to the Honeywell Fusion Tracker was deselected. The expected behavior was a single fused track with DAA guidance on the single track. However, the tracker reported the single intruder as two tracks (radar-only and TCAS-only) on the traffic display, shown in Figure 55. The DAA algorithm provided alerting and maneuvering guidance for each track separately. Post flight analysis confirmed that a software error in the Fusion Tracker software prevented the fusion of TCAS Mode S and Radar targets. This observation, reported to the FAA, was treated as a nuisance anomaly with additional training as the disposition.

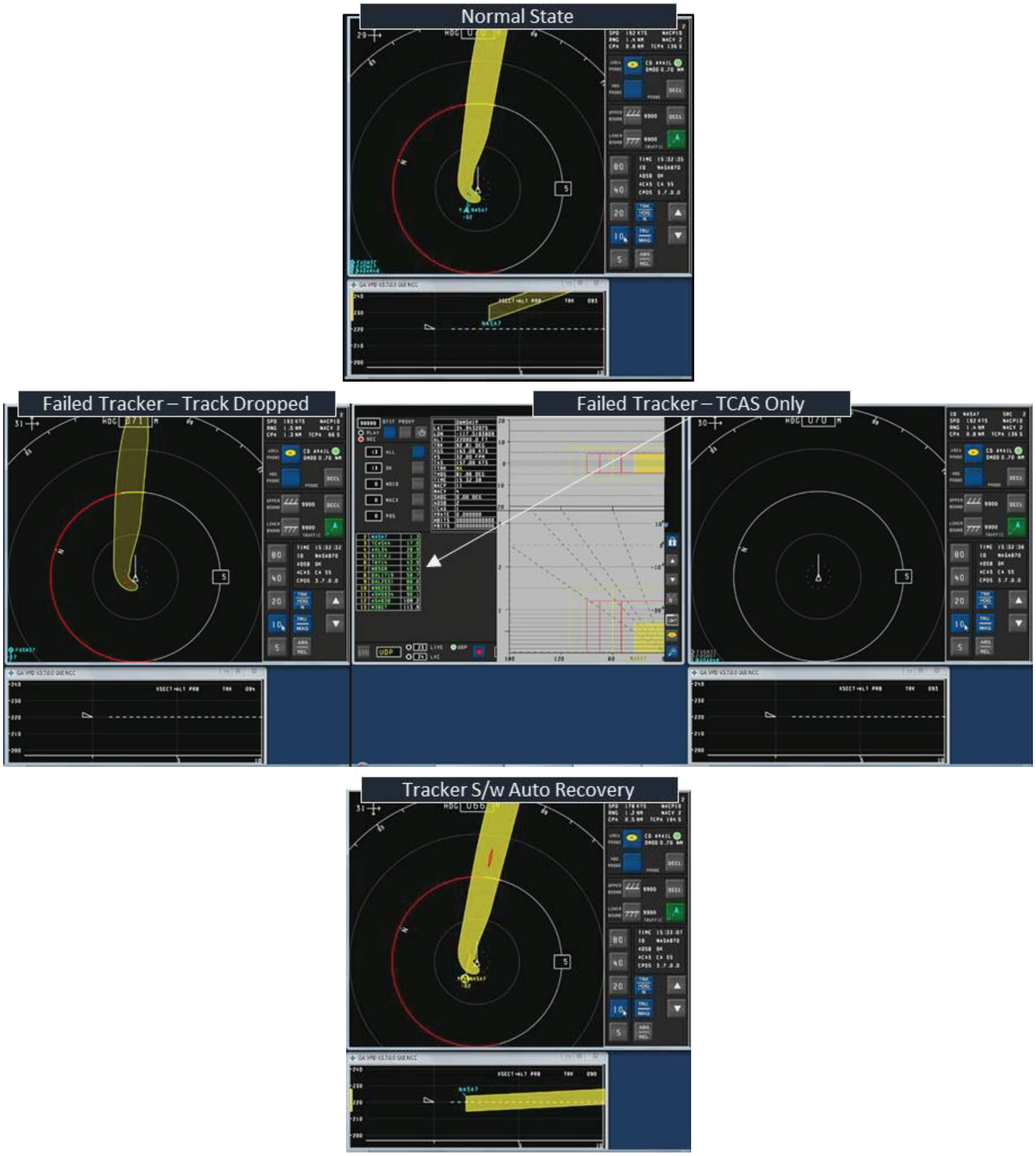


Figure 55. A transition from nominal state, dropping the track, dropped ADS-B and radar tracks, and finally, tracks return.

3.3.1.2 ***Demonstration Flights***

In both flights with and without chase, the DAA system behaved well and without unexpected problems. Below are some additional comments for each phase.

3.3.1.2.1 With Chase

The NCC Demonstration Flight with a chase aircraft (Flight 250) was mostly uneventful with only a brief encounter with a Southwest Airlines (SWA462) aircraft that caused a DAA corrective alert to trigger; see Figure 56. The SWA462 encounter was tracked by the engineering team and test pilots as it descended from FL310 to FL220. The target was acquired by all three sensors (ATAR, ADS-B, and TCAS) and was successfully fused by the Honeywell Fusion Tracker throughout the encounter. The DAA system's alerting and guidance logic behaved exactly as expected and observed in previous flight tests with similarly scripted geometry encounters. Throughout the flight, targets observed on the DAA traffic display were visually validated against the Zeus traffic display, which uses a network of ground sensors (radars and ADS-B) for its traffic feed. The DAA system behaved well during this flight without any unexpected issues. The DAA traffic and H&S displays provided sufficient SA of the system's status and airspace picture to the engineering team and test pilots in the GCS.

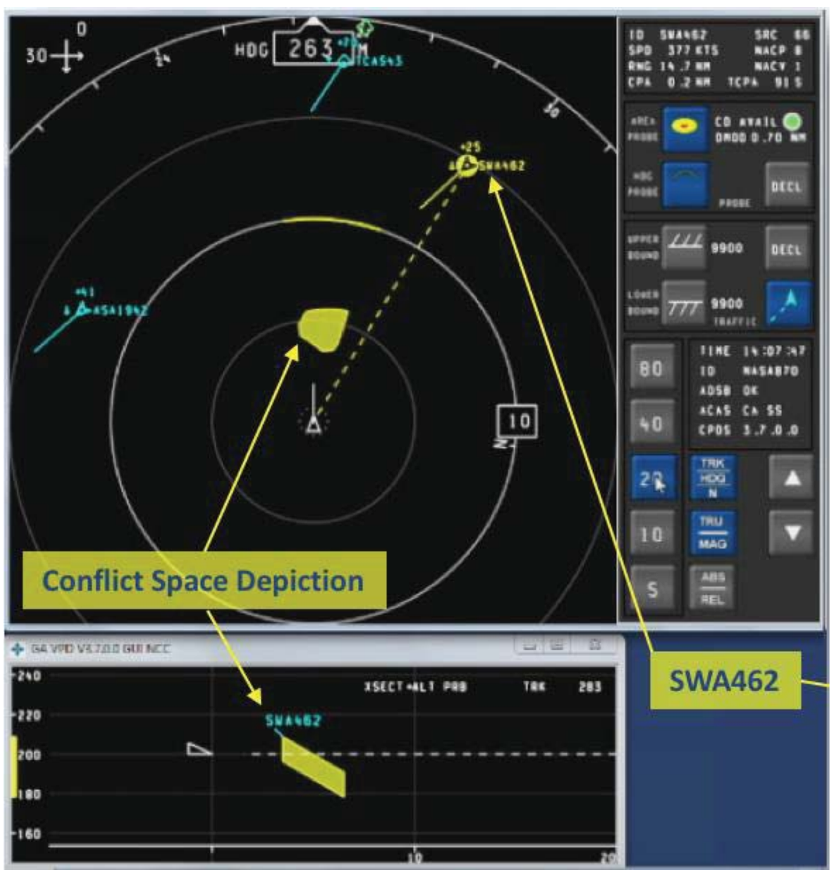


Figure 56. DAA Traffic Displaying during SWA462 Encounter.

3.3.1.2.2 Without Chase

In the NCC demonstration flight, the DAA system functioned as expected without any issues. As shown in Figure 57, the ATAR sensor detected and reported a target with an intermittent transponder to the DAA traffic display. The Ikhana pilots responded to ATC with "Traffic Detected" once the VFR traffic was detected on the DAA system. The DAA system provided a clear airspace picture to the engineering team and pilots. Traffic reported by ATC was easily acquired on the DAA display. The only system problems encountered during this flight were the intermittent Ku-band downlink hits that stopped data flow to the DAA traffic display. Although the issue was close to turning into a nuisance, the engineering team maintained sufficient SA on the traffic trends from the intermittent data that a decision to switch to the backup DLOS datalink was not called. Unexpected “pop-up” radar targets that triggered brief warning alerts were also observed as the aircraft entered EAFB. This behavior has been observed in previous flight test campaigns where the same ATAR system was used. Due to the targets reported characteristics (airspeed, altitude, vertical velocity), they were reported as “false tracks.” Further analysis into the raw radar data needs to be performed to verify the cause of these “pop-up” targets.

Figure 57. DAA System Tracking VFR Traffic.

3.3.2 Ikhana Aircrew Comments

For NASA 870’s pilots, the scripted encounters and DAA system had evolved over the years and were smooth and understandable. The team had developed guidelines and training, keeping the same crew throughout the flights, in order to achieve the high rate of success. Within the DAA system, the pilots suggested that although the range rings on the traffic display were useful for estimating airspace range, the option to enable/disable a geo-referenced background of aeronautical charts or terrain would have provide better SA on the distance between targets. Workload was also still high for both the NASA 870 and manned intruder aircraft, but due to the years of training and flight tests, the aircrew gathered data successfully.

Because of this, doing the flights into the NAS was simpler, and it was an easy transition to an operational mission. With the countless hours, more than 1,000 encounters within R-2515, and operational structure, the demonstration flights held no surprises for the pilots when it came to flying the DAA system in the NAS. Coupled with ATC audio, the pilots watched encounters develop in the NAS, just as they had trained for within R-2515 with scripted encounters. The team had excellent SA with the DAA system.

3.4 Route Assessment

The route was assessed and feedback was provided by the Ikhana pilots, ATC, and Air Traffic Services (AJT). Their comments are below.

3.4.1 Ikhana Pilot Comments

In terms of the submission of the COA, the pilot workload was minimal. They were tasked with getting maps and providing some routing. Most of the interactions for the COA and the FAA were through the Operations Engineers and the UAS-NAS team.

The planning meetings were also extremely successful when it came to safety and contingency planning. Topics that the team had not initially considered were vetted through the SSWGs and the OWGs, creating a sound plan for the route.

In terms of the flights into the NAS, the Ikhana pilots felt they were worked slightly differently than other aircraft. For example, one controller mentioned to the NASA 870 pilot about changing altitude "before waypoint 9". To other traffic on that frequency, this callout could have been seen as confusing, as this was specific to the NCC route of flight. The route of flight could also have been expanded by varying the routing and altitudes to record additional data. Other than this, the pilots felt it was a normal file-and-fly mission and felt comfortable flying in the NAS.

3.4.2 ATC Comments

The team asked to receive feedback from ATC from the perspective of operations during flight, in the hopes to improve future flights. Below is a brief summary of comments received from a NASA Ames Senior Air Traffic Control Associate, who was at ZOA at the time of both missions.

3.4.2.1 *With Chase*

The ZOA-11 radar controller indicated that NASA 870 did not impact the overall workload of the sector any more than any other aircraft. They did not handle the aircraft any differently than any other aircraft under their control. Aside from the request from NASA 870 for descent to 17,000 ft, the controller issued any clearance to NASA 870.

The Area South supervisor reported that the NASA 870 did not impact area operations and did not require any special actions on their part.

The controller had an information sheet for NASA 870 and the sector which provided flight plan information and the visual depiction of the route. The controller had also received a verbal briefing on the flight, which reviewed this materiel. The controller felt the information provided was more than adequate for the flight.

The assessment from the NASA Ames Senior Air Traffic Control Associate was that NASA 870 was a routine flight that proceeded without issue. Traffic in ZOA-11 was very light and the complexity was not difficult. The track on NASA 870 was excellent with the secondary target and primary target displayed.

Table 20 was provided as a summary of events from the perspective of ZOA ARTCC from the flight with chase.

Table 20. Event Log Summary from ZOA for Flight with Chase.

Time (UTC)	Event
1350	Plugged into ZOA Sector 11. NASA 870 orbiting in R-2515. Sector configuration: Sector 11 combined at the R-side. NCT and SCT operating on the West Plan. Sector MAP: 12. Forecast ETMS traffic: 3 to 8 aircraft every 15 minutes.
1415	Controller displayed the Full Data Block for NASA 870.
1420	Handoff initiated by ZLA-15 and accepted by ZOA-11. ZLA-15 initiated coordination with ZOA-11 to advise that NASA 870 had a chase aircraft with him and asked if ZOA-11 was briefed on the flight. ZOA-11 advised that they were aware of the NASA 870 flight. ZOA Traffic: 6 aircraft displayed, 2 on Frequency.
1421	NASA 870 checked in with ZOA-11. NASA 801 checked in immediately following (“two”). ZOA acknowledged NASA 870. Controller commented on NASA 870’s ground speed of 261 knots. He checked wind aloft and noted a 30 knot following wind. No aircraft noted on the display within 40 nmi of NASA 870.
1425	NASA 870 enters ZOA-11 airspace.
1426	ZOA-11 Traffic: 2 aircraft displayed, 1 aircraft on frequency.
1429	Radar controller relieved at 1429. D-side controller added with arrival of additional area staffing. Standard position debrief completed including information on NASA 870.
1431	NASA 870 initiated left turn at waypoint 5 in accordance with the flight plan. ZOA-11 Traffic: 3 aircraft displayed, two aircraft on frequency.
1433	NASA 870 requested descent to one-seven-thousand. ZOA-11 radar controller advised NASA 870 to stand by and the D-side controller initiated a point out to ZOA-10 for 17,000 ft. ZOA-10 approved the request.
1434	ZOA-11 cleared NASA 870 to one-seven-thousand, altimeter three-zero-zero-one. NASA 870 read-back the clearance and began to descend.
1435	Hand-off initiated by ZOA-11 to ZLA-15. ZLA-15 accepted the hand-off.
1436	ZOA-11 advised NASA 870 to contact ZLA-15. Acknowledged by NASA 870.
1440	NASA 870 departed ZOA airspace and the Full Data Block was removed from the display.

3.4.2.2 *Without Chase*

The ZOA-16 radar controller indicated that NASA 870 did not impact the overall workload of the sector any more than any other aircraft. They did not handle the aircraft any differently than any other aircraft under their control. The controller issued a clearance to 17,000 ft to NASA 870 at the request of the pilot. No other clearances or traffic advisories were issued.

The Area South supervisor reported that the NASA 870 did not impact area operations and did not require any special actions on their part.

The Sector 11 controller had an information sheet for NASA 870, which provided flight plan information and the visual depiction of the route. Identical information was delivered to the Sector 16 controller prior to the aircraft being handed-off. The Sector 16 controller recalled that they had received a verbal briefing on the flight, but indicated that they did not recall the complete contents of the briefing. The controller felt the information provided adequate information on the route of flight. However, the controller expressed concern on the lack of information provided for contingencies, such as lost link or No Radio (NORDO) procedures. This controller also indicated that more information on how the UAS operated and information on aircraft characteristics would have been helpful.

The area supervisor indicated that the information provided in the graphic lacked specific locations for the waypoints flown by NASA 870. They expressed the opinion that this information would have been beneficial to the controllers working the aircraft. The area supervisor suggested that the graphic would have been more effective if the background had depicted the Low Altitude Chart rather than the sectional chart.

The assessment from the NASA Ames Senior Air Traffic Control Associate was that NASA 870 was a routine flight that proceeded without issue. Unlike the original flight with the chase aircraft, the controller at Sector 11 opted to hand NASA 870 off to the low altitude sector, ZOA-16, rather than initiate a Point Out. Traffic in Sector 11 began at a moderate level and decreased to light traffic while Ikhana was on the frequency. Traffic in Sector 16 was very light. The complexity in both sectors was not difficult. The track on NASA 870 was excellent with the secondary target displayed.

Table 21 was provided as a summary of events from the perspective of ZOA ARTCC from the flight without chase.

Table 21. Event Log Summary from ZOA for Flight without Chase.

Time (UTC)	Event
1350	Plugged into ZOA Sector 11. NASA 870 observed in ZLA-15 airspace progressing waypoint 3 as an enhanced limited data block. Sector configuration: Sector 11 combined at the R-side. NCT and SCT operating on the West Plan. Sector MAP: 12. Forecast ETMS traffic: 3 to 8 aircraft every 15 minutes.
1354	Handoff initiated by ZLA-15 and accepted by ZOA-11. Full Data Block for NASA 870 displayed. ZOA-11 traffic: 11 aircraft displayed, 9 aircraft on frequency, light to moderate traffic density, complexity not difficult.
1355	ZOA-11 accepted the handoff from ZLA-15.
1358	ZOA-11 initiated coordination with ZOA-16 to ensure that the controller had the briefing material for NASA 870. The supervisor provided the material to the ZOA-16 controller. ZOA-11 advised ZOA-16 of his intention to hand-off NASA 870.
1359	NASA 870 checked in with ZOA-11, level FL200. NASA 870 ground speed: 242 knots. ZOA-11 traffic: 6 aircraft displayed, 4 aircraft on frequency, light traffic density, complexity not difficult.
1401	NASA 870 enters ZOA-11 airspace. ZOA-11 initiated a handoff to ZOA-16. ZOA-16 accepted the hand off. ZOA-11 directed NASA 870 to contact ZOA-16.
1402	Plugged in to ZOA-16. Sector 16 combined with sector 22. Sector 16 staffed with a radar controller only. NASA 870 checked in with ZOA-16, level FL200. ZOA-16 traffic: 3 aircraft displayed, 3 aircraft on frequency, very light traffic density, complexity not difficult.
1409	ZOA-16 traffic: 4 aircraft displayed, 4 aircraft on frequency, very light traffic density, complexity not difficult.
1410	NASA 870 requested descent to one-seven-thousand. ZOA-16 radar controller cleared NASA 870 to one-seven-thousand, Lemoore altimeter two-niner-eight-three. NASA 870 read-back the clearance and began to descend.
1413	Hand-off initiated by ZOA-16 to ZLA-15. ZLA-15 accepted the hand-off. NASA 870 level at 17,000 ft.
1415	ZOA-16 advised NASA 870 to contact ZLA-15 on 119.05. Acknowledged by NASA 870.
1416	NASA 870 departed ZOA airspace and the Full Data Block was removed from the display.

3.4.3 AJT Comments

AJT began their involvement in advance of the final mission design. All air traffic facilities proposed for involvement had representation at the SRMP, as well as bargaining unit members from those facilities represented by the National Air Traffic Controllers Association (NATCA). These personnel provided input for use in the flight planning and the mitigations to any hazards presented at the panel through their respective AJT Headquarters (HQ) panel member or NATCA panel member as appropriate.

Review of the proposed flight plan route by personnel from ZLA, ZOA, and E10 JCF at the SRMP presented an initial challenge to the desired goal of the NASA team to complete flight through Class A airspace, Class E airspace above 10,000 ft, Class E airspace below 10,000 ft where non-cooperative traffic (primary only, no transponder) equipped aircraft would be located, and through Class D airspace. The portion of flight from the original proposal by NASA did not allow the access to the Class D airspace at VCV because of MVAs west of the airport. The JCF personnel were asked to review the proposed route and develop a solution to allow access to the Class D airspace, a challenge they accepted, embraced, and completed in a short amount of consultation time at the facility, and upon return, provided the full mission opportunity sought by NASA.

The completion of the no chase flight ended with no incidents. There was positive interaction with ATC and the PIC of Ikhana during the flight. Some non-cooperative traffic was not detected by the onboard DAA system. This is likely due to the fact that the DAA system is only designed to return primary returns in altitudes which are in proximity to the Ikhana, not all the way to the ground.

Coordination, planning, and the time of day in which this operation occurred contributed significantly to the success of this project. Route planning and coordination were executed seamlessly within air traffic and between NASA pilots.

Overall, it was a successful event from the ATC and UAS advancement perspectives. In nominal state and following normal ATC/PIC protocols, this was no different than a manned flight under the same conditions.

The following are more detailed comments in regards to the flights with and without chase from the several centers.

3.4.3.1 *With Chase*

AJT personnel, in conjunction with NATCA, prepared briefing materials for the facility personnel involved and conducted preparation telecon coordination and expectation set. Planning continued in the background. Technical issues concerning spectrum availability and clearance of this issue delayed the original proposed flights for several weeks. After the technical issue resolution, the initial flight as originally proposed with a chase aircraft was conducted on 24 May 2018.

NASA 870 and accompanying chase departed the Edwards Restricted Area Complex. They were handled by ZLA then ZOA, back to ZLA, then JCF. NASA 870 was in the NAS for 1 hour and 51 minutes, completing all proposed airspace access before returning to the Edwards Complex. Below are the operational assessments from the first flight with a chase.

3.4.3.1.1 ZLA

- **Operational Assessment:**
  ZLA did not experience any problems with the “chase operation”.
- **Impact to the operation:**
  Low impact due to the time of day.

3.4.3.1.2 ZOA

ZOA reported no operational issues with Ikhana NASA 870 chase flight.

3.4.3.1.3 JCF

- **Operational Assessment:**
  After completing low approach at VCV, NASA checked on Joshua's frequency climbing to 9,000 ft. NASA's assigned altitude was 5,000 ft.
- **Impact to the operation:**
  NASA started a climb to 9,000 ft without an ATC clearance. The incident with the errant climb by the NASA PIC off the "low approach" at VCV, was reported and proper investigation proceeded.
- **Feedback to improve future operations:**
  NASA should comply with all ATC clearances.

3.4.3.2 *Without Chase*

After the flight with the chase aircraft, NASA was granted further monetary and operational extension for the Ikhana program to complete the no chase flight. Again, parties involved were given much shorter flight scheduling notice than would have been ideal, so AJT and NATCA along with ZLA/ZOA and JCF personnel again provided briefings to personnel on the mission.

The no chase mission was flown on 12 June 2018. The route was the same as the previous mission with the chase aircraft. The following reports were received by AJT.

3.4.3.2.1 ZLA

ZLA had no issues with the operation, just as planned.

3.4.3.2.2 ZOA

ZOA provided the following collaborative feedback on the NASA NCC operations:

On its current route of flight, the NASA no chase flight had minimal impact to the operation. There was one other aircraft who was impacted by the flight. The aircraft was held high to keep away from the traffic, but that flight usually remained high. On a different route there could be significant impact to operations, depending on the specific routing.

With regard to the training, because controllers had full training (for the delayed mission) and then full refresher training, the refresher could have been condensed. If this mission happened on a regular or routine basis, a briefing sheet in the area would be all that was needed for employees who received the initial training. If the mission happened only rarely, refresher training would be offered to employees who were scheduled to work during the mission. This would ensure that employees were familiar with the Lost Link procedure. In either case, new employees in the area would need to receive the initial training prior to working a mission.

As with all missions, changes to route, altitude, or timing might require additional training and have a bigger impact on operations.

3.4.3.2.3 JCF

NASA 870 performed very well, without a chase aircraft, while under the jurisdiction of JCF.

The methods by which the flight was performed were slightly different, departing on a local beacon, picking up an IFR clearance for exit of R-2515 at FL200 only when ready to receive it after climbing up within that protected airspace; the handoff to ZLA occurred without incident.

Upon the return of NASA 870 to the Antelope Sector, the aircraft seemed to have no issues. The controller vectored one VFR aircraft to remain south, while intending to fly westbound, climbing with VFR flight following from an altitude below 9,000 ft to VFR/10,500 ft and eventually crisscrossed the flightpath of NASA 870 once they passed.

Abeam Palmdale Regional Airport (PMD), NASA 870 was given traffic on an aircraft off to the left of it which was indicating 8,600 ft while squawking 1200, and NASA 870 responded with “Traffic detected”. Another aircraft VFR/7,500 ft was overtaken from PMD toward VCV just after VCV and prior to APLES fix; a descent was only provided once requested, when north of that aircraft.

The pilot requested lower – requesting 6,000 ft when MVAs prevented the controller from providing it immediately; NASA 870 was provided 7,000 ft and told to expect lower in one minute. Upon passing HELDE fix, NASA 870 requested 5,000 ft and the controller had already coordinated with VCV to get approval for a point out – descending NASA 870 into VCV’s Class D but remaining on Joshua Approach frequency (which seemed acceptable to the pilot, as well). On departure, NASA 870 remained at 5,000 ft, requesting 6,000 ft now but also 9,000 ft for re-entry of R-2515: since there was no traffic, the controller provided a climb to 9,000 ft, and advised to expect handoff to SPORT shortly (they opened after NASA 870 had departed an hour prior from Edwards). NASA 870 was terminated prior to the restricted area boundary to SPORT for entry, and frequency change was accomplished matter-of-factly.

4 Lessons Learned

Through all phases of flight to receive the NCC approval, many lessons learned were gathered and recommendations have been made. Some of the main lessons learned are described below.

4.1 Spectrum Authorization

- Description: IT&E and the AFRC Range Frequency Spectrum Management Office (RFSMO) did not have a good understanding of the Frequency Spectrum allocation/assignment/approval process for operations outside of SUA when developmental equipment interfaces with the operational NAS. Although the COA was approved in March 2018, addressing the spectrum issues caused an additional delay that pushed the flights into the NAS to May and June with chase and without chase, respectively.
- Recommendation: Involve the RFSMO early in project to initiate National Telecommunications and Information Administration (NTIA) certification process (Fed Agency) or FAA licensing (non-Federal)

4.2 FAA Operational Approval

- Description: FAA operational approval is independent of spectrum approval. The spectrum approval was an additional process to the COA being approved.
- Recommendation: Involve FAA Spectrum Office early in formulation and Safety Risk Management (SRM) process. This task was missed during initial discussions due to lack of understanding of the process.

4.3 Mission Design

- Description: The final route of flight for NCC was iterative and protracted. IT&E initiated the development of the mission. Initial consideration focused on meeting the minimum objectives but also there were several options for executing the demonstration dating back to early 2015. As the mission plan got more refined (2017) the project tried to coordinate with the FAA for feedback. Routing was requested in August 2017; however, actual FAA review and recommendations came much later (March 2018) and some recommendations were to abandon early planning and go with a route where traffic was light or were existing COAs permitted operations (i.e. Riverside ANG route). The final mission plan was a variation of the San Joaquin Valley route. FAA leadership helped ensure that this flight plan was the best to demonstrate DAA.
- Recommendation: Early involvement by the FAA to consider the route of flight and make recommendations is highly desired.

4.4 Operational Rehearsal Mission

- Description: Flight into the NAS with photo chase prior to executing full demonstration was beneficial to pilots and all flight crew. Practicing the route provided the crew with expectations for the second flight and allowed them to execute more smoothly. Additionally, the rehearsal mission provided the FAA confidence in the UAS system, as well as showing ATC what the flight without chase would look like in terms of control.
- Recommendation: Operational "rehearsal missions" are beneficial to the team. Any time a similar mission will be executed, a rehearsal is recommended.

4.5 Popup Radar Tracks

- Description: During the flight into the NAS without chase, a near range popup track was displayed on CPDS 15 seconds prior to CPA. Although noted, the crew did not respond, since the track was assumed to be a nuisance anomaly.
- Recommendation: Support engineers should acknowledge the track and note it if it is not "real" traffic (e.g. birds). The crew, however, should call out "Check Display" to the pilots in order to increase their SA in case of an actual conflict. Additionally, the DAA system range circle can be reduced to below 10,000 ft to reduce tracks within range of conflict.

4.6 DAA Phraseology

- Description: During cruise at FL200 in the NAS (with photo chase), NASA 870 received a corrective alert on SWA462, B737 descending out of FL310 to FL220. ATC reported the traffic to NASA 870 and pilot replied "looking".
- Recommendation: The correct terminology in the MOPS for a UAS flying a DAA system is "traffic detected". It's important to use correct terminology in order to educate others on the difference between UAS and piloted aircraft wording. During the flight with chase, the correct phrasing was used in another encounter.

4.7 Adherence to IFR Altitude

- Description: During flight out of VCV (out of class D airspace), the NASA 870 pilot began climb before receiving clearance from Joshua control.
- Recommendation: Altitude changes, even planned and approved waypoint altitudes in this case, need to be cleared with ATC prior to commencing maneuver due to IFR flight plan.

4.8 Radar Coverage

- Description: Flights both with/without chase into the NAS experienced degraded ground radar coverage in ZOA around waypoints 5-6 (about 100 nmi away).
- Recommendation: Consider receiving additional radar information (if available) for backup SA displays such as Zeus.

4.9 DAA System Terminology

- Description: In system checkout flights, pilots and some crew members were using corrective/warning and Traffic Advisory (TA)/RA terms interchangeably. These terms are not the same and caused some confusion between engineers.
- Recommendation: Additional training/continuous review of terminology. Terminology "currency" is a must.

4.10 Degraded C2 Link

- Description: During the third SCO, NASA 870 experienced a degraded C2 link event. The aircraft which would have been used as an intruder (NASA 7, B200) was directed to turn into a safety chase. During this event, all crews practiced good CRM to land both NASA 870 and NASA 7 safely.
- Recommendation: Continue assessing situations in real-time (remain vigilant) and follow CRM procedures.

4.11 Close Call Reporting

- Description: Although the team was initially unsure of whether the degraded C2 event was considered a close call, they elected to self-report it as one. This led to an investigation by the NASA 870 team, which although delayed the next flight by a month, did provide insight into the system and how to mitigate in case of another event as this. The updated procedures did assist and were used on the next SCO flight. The crew followed their checklist and the flight continued as normal.
- Recommendation: Report what may be considered a close call, even if unsure.

4.12 High Speed Intruder Mission Rule

- Description: During SCO, a G-III was employed as a "medium speed" TCAS II type intruder. The nature of medium speed would be to call a visual on NASA 870 1 nmi prior to CPA. Due to the more challenging maneuverability of the G-III within R-2515, 1 nmi for an abort may not provide adequate time/airspace for this aircraft to execute abort procedures safely.
- Recommendation: All encounters using a G-III, regardless of card airspeed, should be considered "high-speed" and employ the 2 nmi visual required mission rule.

5 Conclusion

The collaborative efforts between NASA, industry partners, and the FAA made it possible to perform the No Chase COA flights into the NAS: the entire process was an extremely successful demonstration of the DAA technology available and an exercise in securing a COA to fly a large UAS into the NAS without a chase vehicle.

Although with delays, the demonstration flight into the NAS satisfied all phase 1 project milestones, using standards from the MOPS not previously executed operationally. The lessons learned gathered from all previous NASA UAS-NAS flights significantly reduced the amount of time to complete such an activity.

With this flight, the hope is that the routine access of UAS into the NAS will increase, and that UAS operators will be able to file-and-fly easily and safely, without a COA into the NAS, just like any piloted aircraft.

As a whole, the demonstration flight was an excellent conclusion of the flights with the NASA 870 Ikhana MQ-9. The milestone flight, traversing Class A, E, and D airspace and two ARTCCs, using DAA technology and without a chase vehicle, was truly a history making event and a milestone, for not just UAS development, but the future of all aviation.

6 Appendix

6.1 Acronyms

A/C	Aircraft
A/S	Airspeed
ACAS	Airborne Collision Avoidance System
ACFT	Aircraft
ADS-B	Automatic Dependent Surveillance-Broadcast
AESA	Active Electronically Scanned Array
AFRC	Armstrong Flight Research Center
AFTC	Air Force Test Center
AGL	Above Ground Level
AJT	Air Traffic Services
ALT	Altitude
ALTCAL	Altimeter Calibration
ANG	Air National Guard
AOA	Angle of Attack
ARC	Ames Research Center
ARTCC	Air Route Traffic Control Center
ATAR	Air-to-Air Radar
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATM	Air Traffic Management
AUTO	Automatic
BRLOS	Beyond Radio Line of Sight
C2	Command and Control
CA	Collision Avoidance
CAPS	COA Application Processing System
CAS	Collision Avoidance System
CDTI	Cockpit Display of Traffic Information
CFR	Code of Federal Regulations
COA	Certificates of Waiver or Authorization
COMEX	Commence Exercise
CONOPS	Concept of Operations
CPA	Closest Point of Approach
CPDS	Conflict Prediction and Display System
CRM	Crew Resource Management
DAA	Detect and Avoid
DAL	Design Assurance Level
DATR	Dryden Aeronautical Test Range
DD	Decimal Degrees

DFCS	Digital Flight Control System
DGCS	Digital Ground Control System/Software
DGPS	Differential Global Positioning Systems
DIST	Distance
DLOS	Digital Line of Sight
DME	Distance Measuring Equipment
DR	Discrepancy Report
DWC	DAA Well Clear
EAFB	Edwards Air Force Base
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FL	Flight Level
FOM	Fiber Optic Multiplexers
FSS	Flight Service Stations
FT2	Flight Test 2
FT3	Flight Test Series 3
FT4	Flight Test Series 4
GA-ASI	General Atomics Aeronautical Systems Inc.
GCS	Ground Control Station
GDT	Ground Data Terminal
GPS	Global Positioning System
GS	Groundspeed
H&S	Health and Status
HDG	Heading
HQ	Headquarters
HSI	Human Systems Integration
HUD	Heads-Up Display
IASP	Integrated Aviation Systems Program
ID	Identification
IFE	In-flight Emergency
IFF	Identification Friend-or-Foe
IFR	Instrument Flight Rules
IP	Initial Point
IT&E	Integrated Test & Evaluation
ITAR	International Traffic in Arms Regulations
KA	King Air
KEDW	Airport Code for Edwards AFB
KVCV	Airport Code for Victorville

KWJF	Airport Code for Gen William J. Fox Airfield
JCF	Joshua Control Facility
LL	Lost Link
LOS	Line of Sight
LOWC	Loss of Well Clear
LVC	Live Virtual Constructive
Mag	Magnetic Course
MC	Magnetic Course
MCC3	Mission Control Center 3
MD	Mission Director
MEA	Minimum Enroute Altitude
MEF	Maximum Elevation Figure
MEL	Minimum Equipment List
MIT	Massachusetts Institute of Technology
MOA	Military Operating Area
MOCA	Minimum Obstacle Clearance Altitude
MOPS	Minimum Operational Performance Standards
MP	Maneuver Point
MSL	Mean Sea Level
MVA	Minimum Vectoring Altitude
NAC	NASA Advisory Council
NACP	Navigational Accuracy Category for Position
NACV	Navigational Accuracy Category for Velocity
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NAV	Navigation
NCC	No Chase COA
NCT	Northern California TRACON
NMAC	Near Mid Air Collision
NORDO	No Radio
NOTAM	Notices to Airmen
NTIA	National Telecommunications and Information Administration
O/S	Ownship
OML	Outer Mold Line
OROCA	Off-route Obstruction Clearance Altitude
OWG	Operations Working Group
PE	Project Engineer
PGDT	Portable Ground Data Terminal
PIC	Pilot in Command
PIRA	Precision Impact Range Area

PM	Project Manager
PMD	Palmdale Regional Airport
PT	Point
RA	Resolution Advisory
RAIF	Research Aircraft Integration Facility
RCO	Range Control Officer
RCS	Radar Cross Section
REQ	Required
RF	Radio Frequency
RFSMO	Range Frequency Spectrum Management Office
RNG	Range
RTB	Return to Base
SA	Situational Awareness
SAA	Sense and Avoid
SAAP	Sense and Avoid Processor
SATCOM	Satellite Communications
SC	Special Committee
SCO	System Checkout
SCT	Southern California TRACON
SME	Subject Matter Expert
SMURF	Semi Mobile UAS Remote Facility
SOR	Senior Operations Representative
SPD	Speed
SPORT	Space Positioning Optical Radar Tracking
SRC	Source
SRM	Safety Risk Management
SRMD	Safety Risk Management Document
SRMP	Safety Risk Management Panel
SS	Self Separation
SSA	System Safety Assessment
SSWG	System Safety Working Group
STA	Special Temporary Authorization
STM	Surveillance and Tracking Module
SUA	Special Use Airspace
TA	Traffic Advisory
TC	Test Conductor
TCAS	Traffic Alert and Collision Avoidance System
TCOR	Test Coordinator
TCPA	Time to Closest Point of Approach
TD	Test Director
TRACON	Terminal Radar Approach Control Facilities

TRK	Track
TSO	Technical Standard Order
TSPI	Time, Space, Position Information
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAS-NAS	Unmanned Aircraft Systems Integration in the National Airspace System
V/V	Vertical Velocity
VBA	Visual Basic for Applications
VCV	Victorville Airport
VFR	Visual Flight Rules
VHF	Very High Frequency
VID	Visual Identification
VIT	Variable Information Table
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
VSI	Vertical Speed Indicator
WG	Working Group
WP	Waypoint
WPT	Waypoint
ZAB	Albuquerque ARTCC
ZDV	Denver ARTCC
ZLA	Los Angeles ARTCC
ZLC	Salt Lake ARTCC
ZOA	Oakland ARTCC
ZSE	Seattle ARTCC

6.2 References

Document Number	Document Title
NASA NCC FTP 20180417	No Chase COA Flight Test Plan 17 April 2018
NASA AFRC AFOP-7900.3-006	Aircrew Flight Operations Manual
NASA AFRC AFPL-7900.3-001	Mission Control Qualification & Training Plan
NASA AFRC DCP-S-001	Aircraft Mishap Response Procedure
NASA AFRC AFOP-8715.3-005	Hazard Management Procedure
NASA AFRC AFOP-8715.3-007	System Safety Support
EDWARDSAFBI 13-100	Edwards Air Force Base Instruction 13-100
R-2508 1 Jan 2017	R-2508 Complex User's Handbook
FAA FORM 7711-1 UAS COA Attachment, 2017-WSA-148-COA	Department of Transportation: FAA Certificate of Waiver or Authorization
NASA DAA SRMD v1.2	SRMD for UAS Operations in the NAS with Onboard DAA Technology with No Chase/Observer
RTCA DO-365	Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems
RTCA DO-366	Minimum Operational Performance Standards (MOPS) for Air-to-Air Radar for Traffic Surveillance
FAA TSO-C211	Detect and Avoid (DAA) Systems
FAA TSO-C212	Air-to-Air Radar (ATAR) for Traffic Surveillance
DO-178C	Software Considerations in Airborne Systems and Equipment Certification
Title 14 CFR Part 91	General Operating and Flight Rules
14 CFR Appendix E to Part 43	Altimeter System Test and Inspection

6.3 Definition of Terms

Scripted Encounters	This test configuration investigates the advisories generated by the DAA and Collision Avoidance Algorithm display provided by GA-ASI and fed by data from live aircraft during flight.
Ownship	Ownship aircraft provides the DAA algorithm host solution for testing airborne geospatial encounters with target (intruder) aircraft. The ownship was the Ikhana NASA 870 UAS. DAA alerting solutions are presented to the ground control station pilot who determines the best course of action based on display alerting evaluation and ATC coordination.
Intruder	Intruder aircraft (when properly equipped) provided a target solution for the DAA algorithm. Various encounter geometries were planned using intruder aircraft.
Blunder	A planned vertical or horizontal maneuver performed by the intruder, ownship or both aircraft that occurs at some point during the flight test encounter.
Mitigated	Flight test encounters that are designed for the controlling UAS pilot to either manually respond to a DAA or RA alert or monitor the aircraft response during an automatic RA alert. Mitigated test encounters are typically planned with vertical, lateral, and timing flight safety margins designed into the flight test encounters to help minimize the potential for an inflight collision.
Unmitigated	Flight test encounters that due to adequate vertical offsets do not require an associated lateral offset for flight safety. Unmitigated encounters are non-maneuvering.
Class A	Class A airspace is from 18,000 ft MSL up to and including FL600. This airspace is conducted under IFR.
Class E	Class E airspace is up to but not including 18,000 ft MSL (Class A lower limit), with most of the United States being within Class E. Without a base, Class E begins at 14,500 ft MSL. Most areas depict this airspace base as 1,200 ft AGL, 700 ft AGL, or surface.
Class D	Class E airspace refers to airspace around airports with an operational control tower. This airspace is from surface to 2,500 ft AGL of the airport elevation.
Class G	Class G airspace, or uncontrolled airspace, extends from surface to the base of the overlying Class E airspace.

6.4 Approved COA

The following is the No Chase COA approved by the FAA dated 30 March 2018.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO

Public Agency – NASA Part 91

ADDRESS

NASA – AFRC Operations
Attn. of: Dana Purifoy, Director of Operations
P.O. Box 273, Mail Code 2802
Edwards, CA 93523-0273

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation
pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not

OPERATIONS AUTHORIZED

Operation of the NASA Ikhana Unmanned Aircraft System (UAS) in Class A, Class D, Class E airspace at or below Flight Level 200 in the vicinity of R-2508/R-2515 Complex under the jurisdiction of Edwards AFB (EDW), Los Angeles ARTCC (ZLA), Oakland ARTCC (ZOA), and Joshua Control Facility (JCF), and Victorville Airport Traffic Control Tower (ATCT). Operation will use Detect and Avoid (DAA) and Air-to-Air (A/A) radar sensor technology.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

14 CFR 91.113(b)

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions A thru E, inclusive, are set forth on the reverse side hereof.

The certificate 2017-WSA-148 is effective from April 2, 2018, to May 31, 2018, and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

FAA Headquarters, AJV-115
(Region)

Scott J. Gardner
(Signature)

March 30, 2018
(Date)

Acting Manager, UAS Tactical Operations Section
(Title)

FAA Form 7711-1 (7-74)

Purpose: To prescribe UAS operating requirements in the National Airspace System (NAS) for the purpose of Public Aircraft Operations. The holder of this COA will be referred herein as the "Proponent."

Public Aircraft

1. A public aircraft operation is determined by statute, 49 USC §40102(a)(41) and §40125.
2. All public aircraft flights conducted under a COA must comply with the terms of the statute.
3. All flights must be conducted per the declarations submitted in the application, and as specified in the following Standard/Special Provisions.
4. This COA provides an alternate means of complying with 14 CFR §91.113(b) for unmanned aircraft operations.
5. All operations will be conducted in compliance with Title 14 CFR §91 and the conditions of the authorization issued herein. If the operator cannot adhere to any of these requirements a separate FAA Form 7711-2 Waiver application may be required.

STANDARD PROVISIONS

A. General.

1. The review of this activity is based upon current understanding of UAS operations and their impact in the NAS. This COA will not be considered a precedent for future operations. As changes occur to policy, procedures, and regulatory requirements, limitation and conditions for UAS operations will be adjusted.
2. All personnel connected with the UAS operation must read and comply with the contents of this authorization and its provisions.
3. A copy of the COA including the special limitations must be immediately available to all operational personnel at each operating location whenever UAS operations are conducted.
4. This authorization may be canceled at any time by the Administrator, the person authorized to grant the authorization, or the representative designated to monitor a specific operation. As a general rule, this authorization may be canceled when it is no longer required, there is an abuse of its provisions, or when unforeseen safety factors develop. Failure to comply with the authorization is cause for cancellation. The proponent will receive a written notice of cancellation.
5. During the time this COA is approved and active, a site safety evaluation/visit may be accomplished to ensure COA compliance, assess any adverse impact on ATC or airspace, and ensure this COA is not burdensome or ineffective. Deviations, accidents/incidents/mishaps, complaints, etc., will prompt a COA review or site visit to address the issue. Refusal to allow a site safety evaluation/visit may result in cancellation of the COA. Note: This section does not pertain to agencies that have other existing agreements in place with the FAA.
6. Frequency spectrum approval is independent of the COA process and requires the proponent to obtain certification and frequency assignments (licenses) from the National Telecommunications and Information Administration (NTIA) (47 CFR Part 300) or

Federal Communications Commission (47 CFR Part 2, Subpart J and 47 CFR Part 87, Subpart D) and frequency licenses (47 CFR Part 87) when applicable for the control link, ATC radios, transponders, detect and avoid systems, and navigation systems used to support this COA. Equipment licensed under 47 CFR Part 5 (Experimental) or 47 CFR Part 15 (Radio Frequency Devices) does not provide the protection necessary for NAS operations.

B. Airworthiness Certification.

The Unmanned Aircraft System will be maintained in a condition for safe operation while conducting operations in the NAS. The proponent has made its own determination that the unmanned aircraft is airworthy. The unmanned aircraft system must be operated in strict compliance with all provisions and conditions contained in the Airworthiness Safety Release, including all documents and provisions referenced in the COA application.

C. Operations.

1. Unless otherwise authorized as a special provision, a maximum of one unmanned aircraft will be controlled:
   a. From a single control station, and
   b. By one pilot at a time.
2. A Pilot-in-Command (PIC) is the person who has final authority and responsibility for the operation and safety of flight, has been designated as PIC before or during the flight, and holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight. The responsibility and authority of the PIC as described by 14 CFR §91.3, Responsibility and Authority of the Pilot-in-Command, apply to the unmanned aircraft PIC. The PIC position may rotate duties as necessary with equally qualified pilots. The individual designated as PIC may change during flight.

Note: Flight Crew Member (UAS). In addition to the flight crew members identified in 14 CFR Part 1, Definitions and Abbreviations, an Unmanned Aircraft System flight crew members include pilots, sensor/payload operators, and visual observers and may include other persons as appropriate or required to ensure safe operation of the aircraft.

3. Operations (including lost link procedures) should not be conducted over populated areas, heavily trafficked roads, or an open-air assembly of people, unless the Airworthiness Certification does not restrict these operations.
4. When necessary, transit of airways and routes must be conducted as expeditiously as possible. The unmanned aircraft should not plan to loiter on Victor airways, jet routes, Q and T routes, IR routes, or VR routes.
5. For flights operating on an IFR clearance, the PIC must ensure positional information in reference to established National Airspace System (NAS) fixes, NAVAIDs, and/or waypoints are provided to ATC. The use of latitude/longitude positions is not authorized, except oceanic flight operations.
6. UAS operations at night, unmanned aircraft must operate with:
   a. Unless stipulated in the special provisions, an operational mode 3/A transponder with altitude encoding, or mode S transponder (preferred) set to an ATC assigned squawk

b. Position/navigation and anti-collision lights on at all times during flight unless stipulated in the special provisions or the proponent has a specific exemption from 14 CFR §91.209.

7. Unless installed as part of a Detect and Avoid (DAA) system, the use of a Traffic Collision Avoidance System (TCAS) in Traffic Advisory (TA) or Traffic Advisory/Resolution Advisory (TA/RA) modes while operating an unmanned aircraft is prohibited.

D. Safety of Flight.

1. The operator or delegated representative is responsible for halting or canceling activity in the COA area if, at any time, the safety of persons or property on the ground or in the air is in jeopardy, or if there is a failure to comply with the terms or conditions of this authorization.

2. See-and-Avoid.

   Unmanned aircraft have no on-board pilot to perform see-and-avoid responsibilities; therefore, when operating in the National Airspace System provisions must be made to provide an alternate means of compliance to 14 CFR §91.113.

   a. The operator and/or delegated representatives are responsible at all times for collision avoidance with all aviation activities and the safety of persons or property on the surface with respect to the UAS.

   b. UAS pilots will ensure there is a safe operating distance between other aviation activities and the unmanned aircraft at all times.

   c. Any crew member responsible for performing see-and-avoid requirements for the UA must have and maintain instantaneous communication with the PIC.

   d. Except when using an on-board detect and avoid system for 14 CFR 91.113(b) compliance, visual observers must be used at all times except in Class A airspace, active restricted areas, and warning areas designated for aviation activities or as authorized in the Special Provisions. Observers may either be ground-based or airborne in a chase plane.

      (1) Visual Observers:

         (a) Must be able to communicate clearly to the pilot any instructions required to remain clear of conflicting traffic, using standard phraseology as listed in the Aeronautical Information Manual when practical.

         (b) The PIC is responsible to ensure visual observers are able to see the aircraft and the surrounding airspace throughout the entire flight, and

         (c) The PIC is responsible to ensure visual observers are able to provide the PIC with the UA’s flight path, and proximity to all aviation activities and other hazards (e.g., terrain, weather, structures) sufficiently to exercise effective control of the UA to:

         - Comply with 14 CFR § 91.111, §91.113 and § 91.115, and
         - Prevent the UA from creating a collision hazard, and
         - Comply with all conditions of this COA.

(2) Chase Aircraft

(a) If the chase aircraft is operating more than 100 feet above/below and/or more than ½ NM laterally of the unmanned aircraft, the chase aircraft PIC will advise the controlling ATC facility.

(b) Must remain at a safe distance from the UA to ensure collision avoidance if a malfunction occurs.

(c) Must remain close enough to the UA to provide visual detection of any conflicting aircraft and advise the PIC of the situation.

(d) Must remain within radio control range of the UA to maintain appropriate signal coverage for flight control or activation of the Flight Termination System, for all operations when the UA is being flown by a pilot in the chase aircraft.

(e) May be required to have communication with appropriate ATC facilities based on the operator's application or mission profile.

(f) Must maintain 5 sm in-flight visibility restrictions.

(g) Pilot/observer:

- Will not concurrently perform either observer or UAS pilot duties along with chase pilot duties unless otherwise authorized.
- Must maintain direct voice communication with the UAS pilot.

(h) Pilots operating as a formation flight will immediately notify ATC if they are using a nonstandard formation. Nonstandard formations must be preapproved by ATC. Operators will adhere to the current edition of FAA Order JO 7610.4, Special Operations, as applicable. See Volume 16, Chapter 1, Section 2, for definitions of standard and nonstandard formations.

(i) Operations will not be conducted in instrument meteorological conditions (IMC).

(j) Operations will be thoroughly planned and briefed.

(k) During a lost link situation, the pilot must be notified immediately along with ATC. The chase pilot will report to ATC that the UA is performing lost link procedures as planned or if deviations are occurring.

(l) Pilot will ensure safe separation with the UA, and immediately notify ATC and the UA PIC during loss of visual contact with the UA by both the chase pilot and observer, when such contact cannot be promptly reestablished. The UA PIC will either execute lost link procedures to facilitate a rejoin, recover the UA, or terminate the flight as appropriate.

E. Notice to Airmen (NOTAM).

1. A Distant (D) NOTAM must be issued prior to conducting UAS operations not more than 72 hours in advance, but not less than 24 hours for UAS operations prior to the operation for routine operations unless operations are contained within Class A airspace, active restricted or warning areas that are designated on the appropriate aeronautical chart or airport directory. This requirement may be accomplished:
   a. Through the operator's local base operations or (D) NOTAM issuing authority, or
   b. By contacting the NOTAM Flight Service Station at 1-877-4-US-NTMS (1-877-487- 6867). The issuing agency will require:
      (1) Name and contact information of the pilot filing the NOTAM request
      (2) Location, altitude, or operating area
      (3) Time and nature of the activity.
2. The area of operation defined in the (D) NOTAM must only be for the actual area to be flown for each day defined by a point and the minimum radius required to conduct the operation.
3. Operator must cancel (D) NOTAMs when UAS operations are completed or will not be conducted.
4. <u>For first responders only.</u> Due to the immediacy of some emergency management operations, the (D) NOTAM notification requirement may be issued as soon as practical before flight and if the issuance of a (D) NOTAM may endanger the safety of persons on the ground, it may be excluded. If the (D) NOTAM is not issued, the proponent must be prepared to provide justification to the FAA upon request.

F. Reporting Requirements

1. Documentation of all operations associated with UAS activities is required regardless of the airspace in which the UAS operates. NOTE: Negative (zero flights) reports are required.
2. The Proponent must submit the following information on a monthly basis through the COA Application Processing System (CAPS):
   a. Name of Proponent, and aircraft registration number,
   b. UAS type and model,
   c. All operating locations, to include city name and latitude/longitude,
   d. Number of flights (per location, per aircraft),
   e. Total aircraft operation hours,
   f. Takeoff or landing damage, and
   g. Equipment malfunction. Required reports include, but are not limited to, failures or malfunctions to the:
      (1) Control station
      (2) Electrical system

(3) Fuel system

(4) Navigation system

(5) On-board flight control system

(6) Powerplant

h. The number and duration of lost link events (control, performance and health monitoring, or communications) per UAS, per flight.

3. Incident/Accident/Mishap Reporting

a. The proponent must provide initial notification to the FAA via email at mail at 9-AJV-115-UASOrganization@faa.gov and via the CAPS forms (Incident/Accident) within 24 hours of an incident or accident that meets the following criteria:

(1) All accidents/mishaps involving UAS operations where any of the following occurs:

(a) Fatal injury, where the operation of a UAS results in a death occurring within 30 days of the accident/mishap

(b) Serious injury, where the operation of a UAS results in:

- Hospitalization for more than 48 hours, commencing within 7 days from the date of the injury was received;
- A fracture of any bone (except simple fractures of fingers, toes, or nose);
- Severe hemorrhages, nerve, muscle, or tendon damage;
- Involving any internal organ; or
- Involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

(c) Total unmanned aircraft loss

(d) Substantial damage to the unmanned aircraft system where there is damage to the airframe, power plant, or onboard systems that must be repaired prior to further flight

(e) Damage to property, other than the unmanned aircraft.

(2) Any incident/mishap that results in an unsafe/abnormal operation including but not limited to

(a) A malfunction or failure of the unmanned aircraft's on-board flight control system (including navigation)

(b) A malfunction or failure of ground control station flight control hardware or software (other than loss of control link)

(c) A power plant failure or malfunction

(d) An in-flight fire

(e) An aircraft collision involving another aircraft.

(f) Any in-flight failure of the unmanned aircraft's electrical system requiring use of alternate or emergency power to complete the flight

(g) A deviation from any provision contained in the COA

(h) A deviation from an ATC clearance and/or Letter(s) of Agreement/Procedures

(i) A lost control link event resulting in

- Fly-away, or
- Execution of a pre-planned/unplanned lost link procedure.

b. Initial reports must contain the information identified in the CAPS Accident/Incident Report.

c. Follow-on reports describing the accident/incident/mishap(s) must be submitted by providing copies of proponent aviation accident/incident reports upon completion of safety investigations.

d. The above procedures are not a substitute for separate accident/incident reporting required by the National Transportation Safety Board under 49 CFR §830.5.

e. For other than Department of Defense operations, this COA is issued with the provision that the FAA be permitted involvement in the proponent's incident/accident/mishap investigation as prescribed by FAA Order 8020.11, Aircraft Accident and Incident Notification, Investigation, and Reporting.

G. Registration

The proponent must comply with the aircraft registration and marking requirements set forth in 14 CFR Parts 47 and 45, or Part 48, prior to conducting flight operations authorized by this COA. Title 49 United States Code (49 USC) sections 44101 through 44104 contain the laws requiring aircraft registration in the United States.

H. Special Use Airspace

1. Coordination and de-confliction between Military Training Routes (MTR) and Special Use Airspace (SUA) is the operator's responsibility. When identifying an operational area the operator must evaluate whether an MTR or SUA will be affected. In the event the UAS operational area overlaps an MTR or SUA, the operator will contact the scheduling agency as soon as practicable in advance to coordinate and de-conflict. Approval from the scheduling agency is required for regulatory SUA, but not for MTR's and non-regulatory SUA. If no response to coordination efforts, the operator must exercise extreme caution and remain vigilant of all MTRs and/ or non-regulatory SUAs.
2. Scheduling agencies for MTRs are listed in the Area Planning AP/1B Military Planning Routes North and South America. If unable to gain access to AP/1B contact the FAA at email address mailto:9-AJV-115-UASOrganization@faa.gov with the IR/VR routes affected and the FAA will provide the scheduling agency information. Scheduling agencies for SUAs are listed in the FAA JO 7400.10.

AIR TRAFFIC CONTROL SPECIAL PROVISIONS

A. **Coordination Requirements.**

1. UAS Operations outside of the R-2508 complex will be conducted during daylight hours in Visual Meteorological Conditions (VMC). Each flight will be coordinated in advance with Los Angeles ARTCC, Oakland ARTCC, Joshua Control Facility, and Victorville ATCT.
2. Proponent must ensure that multiple UAS in the operations area (i.e. lost link emergency profiles, spectrum, etc.) are deconflicted and separated from other UA operators that use the same operations area.
3. Proponent must ensure the completed FAA coordination checklist (see attachment 2) with route of flight depiction is emailed to air traffic facilities NLT one business day prior to UAS operations.
4. For IFR flights outside of restricted airspace that will enter Los Angeles Air Route Traffic Control Center (ZLA) airspace, coordination shall be accomplished a minimum of one business day prior , 9-awp-zla-mos@faa.gov with Military Operations Specialist (MOS) at (661) 265-8249.
5. For IFR flights outside of restricted airspace that will enter Oakland Air Route Traffic Control Center (ZOA) airspace, coordination shall be accomplished a minimum of one business day prior with ZOA Military Operations Specialist (MOS) at 9-awp-zoa-mos@faa.gov or 510-745-3334.
6. For IFR flights outside of restricted airspace that will enter Joshua Control Facility (JCF) airspace, coordination shall be accomplished a minimum of one business day prior with JCF, 9-awp-e10-tmu@faa.gov 661-277-3843.
7. For IFR flights within Victorville (VCV) Class D airspace, coordinate with VCV Tower at 760-246-0817, wtaylor@serco-na.com one business day prior to flight.
8. For IFR flights in the vicinity of Hunter, Roberts and Lemoore MOAs, proponent must coordinate deconfliction with Hunter, Roberts and Lemoore MOA respective scheduling agencies.
9. Proponent must coordinate and deconflict all SUA with appropriate scheduling agencies, ATC will not coordinate SUA.

B. **Communication Requirements.**

The UA PIC will maintain direct two-way communications with ATC, and comply with all ATC instructions and procedures.

C. **Flight Planning Requirements.**

1. All UAS operations conducted under this COA be on an IFR flight plan.
2. Unless otherwise authorized by ATC, pilots shall maintain FL200 from route Way Point (WP) 1 until within 5 minutes of WP4.
3. UA Pilot shall not request descent in ZOA airspace until after established on the southbound leg after WP6.

4. Unless otherwise authorized by ATC, UAS must maintain at or above 17,000 ft MSL while in Oakland ARTCC (ZOA) airspace**.**

5. The UA must operate an altitude encoding transponder with Mode C capability below 10,000 feet MSL.In the event of transponder failure on either the UA or the chase aircraft (if used), the UA must conclude all flight operations and expeditiously return to its base of operations within the prescribed limitations of this authorization.

6. If a chase aircraft is used, the chase aircraft transponders must be on standby while performing chase operations flight with the UA unless otherwise directed by ATC.

7. In the event of UA transponder failure, a chase aircraft (if used) will operate its transponder in Mode C.

8. When chase aircraft is utilized, the chase aircraft pilot shall maintain two-way radio communication with the UA PIC and an active listening watch on the assigned ATC frequency. Should the UAS experience communication difficulty or failure, the chase aircraft will assume responsibility for two-way radio communication with ATC.

9. The UA shall be level at the ATC assigned altitude for transit of Class A airspace prior to exiting Restricted Airspace.

D. **Procedural Requirements.**

1. UAS must maintain at or above 17,000 ft MSL while in ZOA airspace.

2. UAS DAA maneuvers must not enter active Hunter, Roberts or Lemoore MOAs.

3. For Victorville Class D operations, VCV ATCT must be open and providing Class D services.

4. All operations in Victorville Class D airspace must be under daytime, VMC conditions.

5. Minimum Vectoring Altitude for IFR aircraft over Victorville (Eastbound) is 7000 feet MSL.

E. **Emergency/Contingency Procedures.**

1. Lost Link Procedures:

   a. In the event of a lost link, the UAS pilot will immediately notify the controlling air traffic facility via telephone numbers below, state pilot intentions, squawk 7400, and comply with the following provisions:

   ZLA: (661) 265-8205

   ZOA: 510-745-3438

   JCF: 661-277-3843

   VCV ATCT: 760-246-0817

   b. Specific Lost Link Procedure for No Chase COA Route:

   (1) UAS will maintain last altitude assigned by ATC.

   (2) In the event of a lost link, after exiting R-2515 and 5 minutes prior to waypoint 4 the UA will continue to waypoint 4, then execute a right turn direct CHADS to return to R2508/R2515.

(3) If lost link within (inside) 5 minutes of WP4, the aircraft will continue the route to WP09, then return to R2515 via WP01.

(4) If link is lost between WP09 and WP10, the UAS will continue to WP10 then return to R2515 via Direct WP01.

(5) If link is lost after WP10, the UAS will continue the route to WP12, then execute a left turn Direct VEGAS (WP18) to return to R2515.

(6) If link is lost after WP12, the UAS will continue the route to WP18 (VEGAS) then return to R2515.

(7) If lost link occurs within a restricted or warning area, or the lost link procedure above takes the UA into the restricted or warning area – the aircraft will not exit the restricted or warning areas until the link is re-established or coordination via procedures above with ATC has occurred.

c. The unmanned aircraft lost link mission should minimize transit or orbit over populated areas.

d. Lost link programmed procedures will avoid unexpected turn-around and/or altitude changes and will provide sufficient time to communicate and coordinate with ATC.

e. Lost link orbit points shall not coincide with the centerline of Victor airways.

2. Emergency/Fly-Away Procedure:

   a. In the event of an emergency, the PIC will immediately contact the ATC facility having jurisdiction of the airspace, state the nature of the emergency and pilot intentions, and squawk 7700.

   b. In the event of a UA fly-away, advise ATC of the following:

      (1) Direction of flight

      (2) Last known altitude

      (3) Maximum remaining flight time

3. Loss of Detect And Avoid (DAA) system will constitute an emergency. The PIC must immediately contact ATC, state pilot intentions, and comply with all ATC instructions.

4. Loss of communications: Squawk 7600, the PIC must contact ATC facility by phone, and advise of intentions.

AUTHORIZATION

This Certificate of Waiver or Authorization does not, in itself, waive any Title 14 Code of Federal Regulations not specifically stated, nor any state law or local ordinance. Should the proposed operation conflict with any state law or local ordinance, or require permission of local authorities or property owners, it is the responsibility of the proponent to resolve the matter. This COA does not authorize flight within Temporary Flight Restrictions, Special Flight Rule Areas, regulatory Special Use Airspace or the Washington DC Federal Restricted Zone (FRZ) without pre-approval. The proponent is hereby authorized to operate the Ikhana Unmanned Aircraft System in the NAS within the areas defined in the Operations Authorized section of the cover page.

Attachment 1

NASA No Chase COA Route Graphic

Note: Altitudes for Planning Purposes Only

Detail of Victorville Overflight Box Route

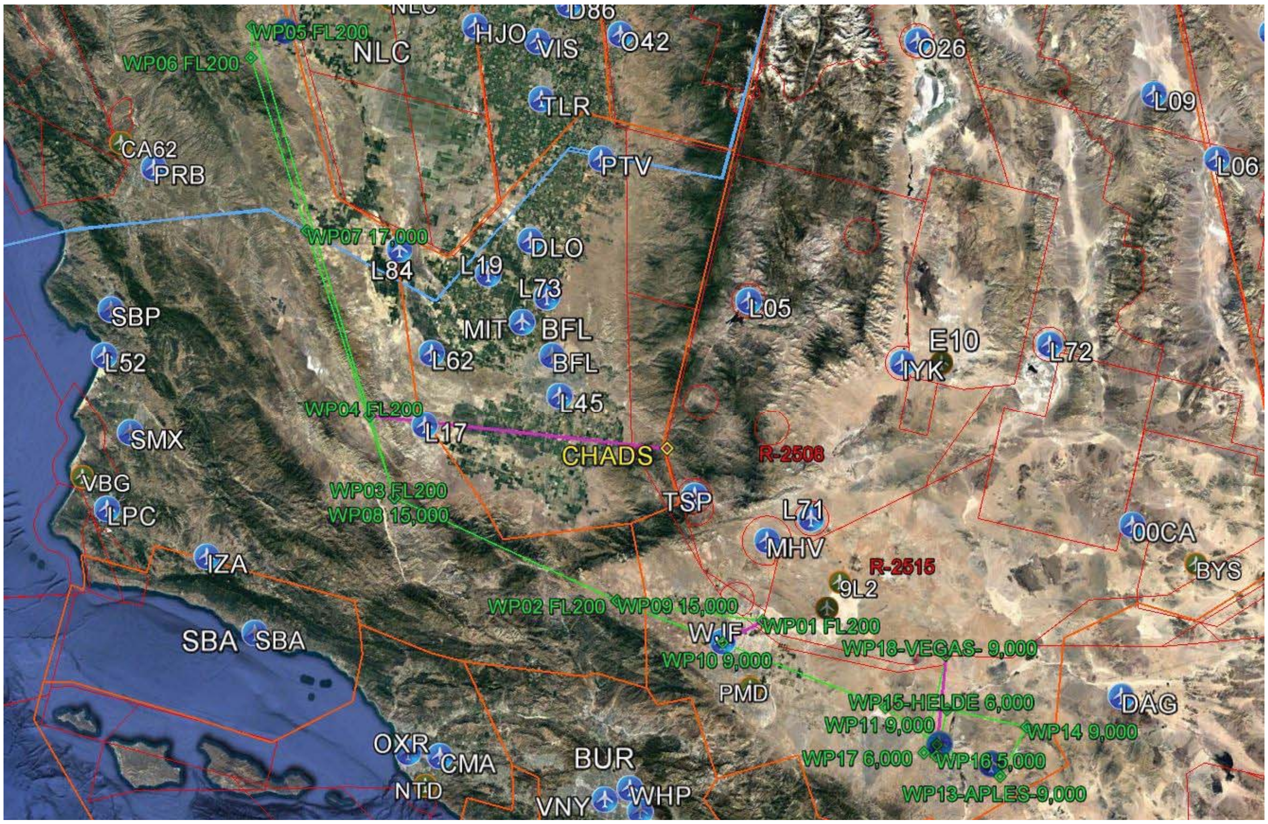
Note: Altitudes for Planning Purposes Only

2017-WSA-148 No Chase Route Coordinates

WP	LATITUDE (N)	LONGITUDE (W)	Comments
1	34° 49' 40.00"	118° 05' 48.00"	FL200
2	34° 47' 00.00"	118° 37' 00.00"	FL200
3	34° 54' 54.00"	119° 28' 34.00"	FL200
4	35° 07' 41.38"	119° 38' 09.42"	FL200
5	36° 09' 00.00"	120° 25' 0.00"	FL200
6	36° 03' 35.73"	120° 23' 25.22"	FL200
7	35° 36' 31.31"	120° 01' 36.78"	17,000
8	34° 54' 54.00"	119° 28' 34.00"	15,000
9	34° 47' 00.00"	118° 37' 00.00"	15,000
10	34°44'19.00"	118° 13' 0.00"	9,000
11	34° 40' 00.00"	117° 36' 00.00"	9,000
12	34° 35' 39.00"	117° 23' 24.00"	9,000
13 (APLES)	34° 32' 54.48"	117° 08' 58.14"	9,000
14	34° 42' 20.35"	117° 05' 34.95"	9,000
15 (HELDE)	34° 42' 16.29"	117° 22' 57.18"	6,000
16	34° 33' 43.03"	117°23' 00.88"	5,000
17	34° 33' 47.96"	117° 25' 43.42"	6,000
18 (VEGAS)	34°51' 19.00"	117° 26' 03.00"	9,000

Note: Altitudes for Planning Purposes Only

NASA No Chase Route with Lost Link Overview



Lost Link routes shown in Magenta
Note: Altitudes for Planning Purposes Only

NASA No Chase Route Lost Link VCV Detail

Lost Link routes shown in Magenta
Note: Altitudes for Planning Purposes Only

Attachment 2

UAS Flight Coordination Checklist

NOTES:

a. Coordination to Air Traffic facilities shall be completed **NLT** one business day prior to mission departure/TO time.
b. Facilities must be notified within two hours of the proposed departure time if there is a weather or maintenance delay and what the new planned departure time will be.
c. If two hours is exceeded, of proposed departure time, the facilities may require resubmitting mission plan with one business day notice requirement.
d. When mission is cancelled email all facilities, within two hours.

1. Mission Number - use also in email coordination subject line
2. Call Sign and Type:
3. Departure: Airport, Local time and date/ Zulu and date
4. Land : Airport, Local and date/ Zulu and date
5. Filed Flight plan: 34° 49' 40.00"N, 118° 05' 48.00"W; 34° 47' 00.00"N, 118° 37' 00.00"W; 34° 54' 54.00"N, 119° 28' 34.00"W; 35° 07' 41.38"N, 119° 38' 09.42"W; 36° 09' 00.00"N, 120° 25' 0.00"W; 36° 03' 35.73", 120° 23' 25.22"W; 35° 36' 31.31", 120° 01' 36.78"W; 34° 54' 54.00"N, 119° 28' 34.00"W; 34° 47' 00.00"N, 118° 37' 00.00"W; 34°44'19.00"N, 118° 13' 0.00"W; 34° 40' 00.00"N, 117° 36' 00.00"W; 34° 35' 39.00"N, 117° 23' 24.00"W; 34° 32' 54.48"N, 117° 08' 58.14"W; 34° 42' 20.35"N, 117° 05' 34.95"W; 34° 42' 16.29"N, 117° 22' 57.18"W; 34° 33' 43.03"N, 117°23' 00.88"W; 34° 33' 47.96"N, 117° 25' 43.42"W; 34°51' 19.00"N, 117° 26' 03.00"
6. Altitude information :
7. Duration of flight:
8. Pilot Contact information: POC telephone numbers, provide Ground Station phone numbers for this mission. Alternate contact numbers as appropriate.
9. WX alternate/Mission Slippage - Date and time of flight. If none state none.
10. Restricted/ Warning Areas/ ATCAA's - List all SUA including ATCAA's that the mission will transit or delay in. **NOTE:** ATC will not obtain permission for transit or delays in SUA for missions. Mission planning, filing into or through an SUA or ATCAA indicates to ATC that prior permission has been obtained from the using agency.
11. List all delays for flight – Restricted, Warning Areas, ATCAA, in FRD - Format: (Departure + ETE (hrs and minutes)
12. Lost link Procedures:
    a. Pilot will contact air traffic facility/ center via land line immediately upon losing link and coordinate expected actions/routing/altitude of the aircraft.
    b. State lost link procedures.
13. Email these attachments to all FAA facilities:
    (see Air Traffic Special Provisions, A. coordination Requirements).
    a. Ikhana coordination checklist.
    b. Route of flight power point/s – flight overview and sectional scale (2-3 per ARTCC), FRD's along route.
14. FAA Air Traffic facility contact numbers that the pilot will call are:
    1. JCF 661-277-3843
    2. ZLA OMIC (661) 265-8205
    3. ZOA MOS 510-745-3334
    4. VCV ATCT 760-246-0817

6.5 SCO Test Cards

The following are the redlined flight cards from the SCO flights performed with encounters.

- Flight 2 – 15 February 2018
- Flight 3 Attempt 2 – 28 March 2018

2018-02-15 Mike Sign Red Binder A

No Chase COA (NCC) System Checkout

SCO #2

Ver 1.0

Ikhana Crew	Comm:	Ops #	Intruder(s)	Intruder Crew

Card Count	Encounter	Priority	Configuration	Ownship Maneuver	Intruder(s)	Notes
X	Altimeter Calibration/Time Hack:				NASA856	
1	SQK-6 (no VID) ✓		Intruder Squawk **ON**	*None*	NASA856	Build-down encounter
2	SQK-6 ✓	1	Intruder Squawk OFF	CPDS	NASA856	
3	SQK-7 ✓	1	Intruder Squawk OFF	CPDS	NASA856	
4	SQK-8 ✓ Repeat	1	Intruder Squawk OFF	CPDS	NASA856	
5	LALT-24 ✓	1	Intruder Squawk OFF	*None*	NASA856	
6	LALT-25 ✓	1	Intruder Squawk ~~OFF~~ OFF	CPDS	NASA856	
X	Altimeter Calibration/Time Hack:				NASA808	
7	ATCAS-22 (no VID) ✓			*None*	NASA808	Build-down encounter
8	ATCAS-22 ✓	3	Advisory	Follow TCAS Manual	NASA808	
~~9~~ 3	ATCAS-23 ✓	3	AUTO	Follow TCAS AUTO	NASA808	
10	HDR-16 ✓	2		CPDS	NASA808	
11	NUIS-13 ✓	2		CPDS	NASA808	
12	NUIS-14 ✓	2		CPDS	NASA808	
13	DB-15 ✓	2		CPDS	NASA808	
14	HS-11 ✓	3		*None*	NASA808	
15	HS-12	3		CPDS	NASA808	
16	TM-1 ✓	1		*None*	NASA808	get Quad Vid 1942 comed
17	LOB-9	3	Advisory	Follow TCAS Manual	NASA808	
18	LOB-10	3	AUTO	Follow TCAS AUTO	NASA808	

142B100

06B22

Runway 4

1200 15620

123.225 – primary

121.95 – B/u

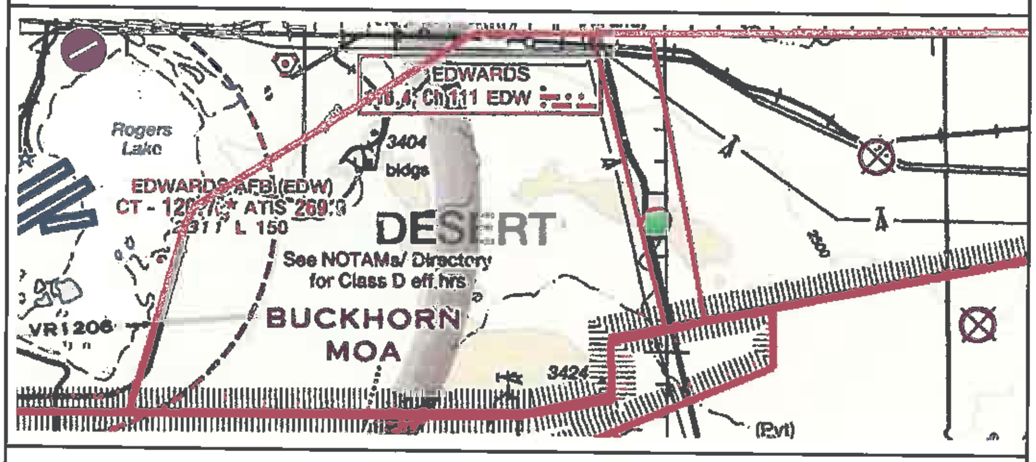
UHF – 347.1

"MCC3 UHF-1"

Single runway ops

6→715 20+ Aircraft

NCC SCO ALTIMETER CALIBRATION (LOW SPEED)



REJOIN AND ALTITUDE CALIBRATION:

Start conditions ALL AIRCRAFT

- Joined, straight and level, 90 KIAS, heading as required
- 29.92

Note: Ikhana maintains minimum Vstall +~~5~~kt +20kts

1. HOLD - left hand turns, at altitude
2. JOIN & SET - INTRUDER
   - Maintain 500 ft alt/sep until visual
   - INTRUDER "Joined, rollout heading AS/REQ"
3. REPORT - "29.92 set showing 9,###" - OWNSHIP / INTRUDER
4. ADJUST - altimeter to 9,000 - INTRUDER
   - Call "29.## showing 9,000"
   - Maintain new altimeter setting for encounters
5. COMPLETE - "Complete, [callsign] cleared off <dir> <alt>"

PT	LATITUDE	LONGITUDE	OWNSHIP ALTITUDE	CHASE ALTITUDE	A/S
CPA2	N34° 54.14'	W117° 30.29'	9000		90 KIAS
	N34° 54' 08.2"	W117° 30' 17.4"			

0712
time hack

870 29.92 - 9000

856 - 29.92 8950

29.95 - 9000

808
SQK - 0037

NCC SCO	A/C: NASA870	Squawk On - No Visual Required		
CARD# 1	SQK-6-NoVID			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	120	IP3	None	NO

Fly through

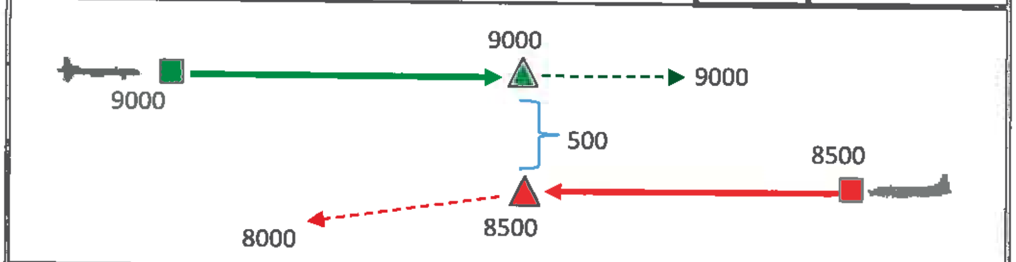
LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: 0726 IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP3	N34° 54.14'	W117° 35.17'	9000	4.0	120	2+00
	N34° 54' 08.2"	W117° 35' 10.0"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	9000	0.0	120	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Ownship Flythrough

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	NO DESCENT		

TOLERANCE: N/A

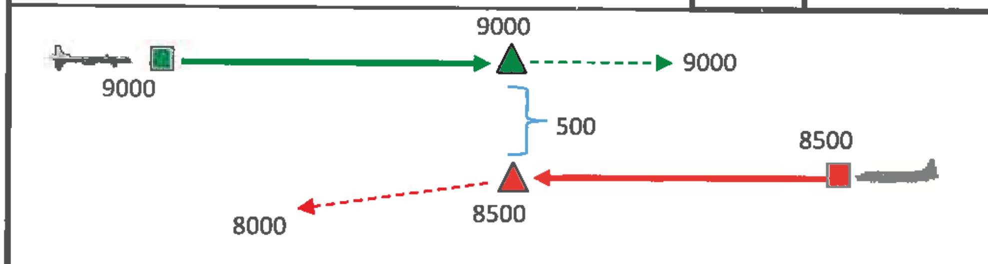
NCC SCO	A/C: NASA 856	Squawk On - No Visual Req		
CARD# 1	SQK-6-NoVID			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8500	100	IP14	None	NO

Squawk on - No Visual Required

DECONFLICTION ALT:
8000

ABORT PROCEDURE

8000	RIGHT



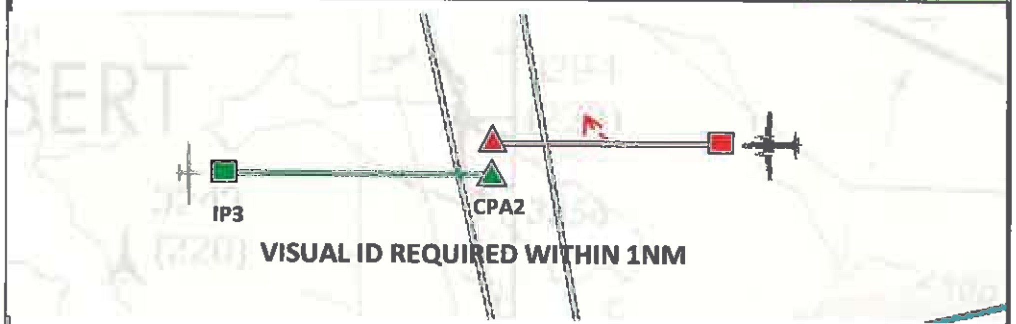
COMEX TIME: IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP14	N34° 54.60'	W117° 26.17'	8500	3.3	100	2+00
	N34° 54' 35.8"	W117° 26' 10.1"	0	258		
CPA10	N34° 54.61'	W117° 30.19'	8500	0.0	100	
	N34° 54' 36.7"	W117° 30' 11.5"	0	258		

NOTES: Non-maneuvering Ownship

TOLERANCE: N/A

NCC SCO	A/C: NASA870			Squawk Off
CARD# 2	SQK-6			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	120	IP3	CPDS	YES



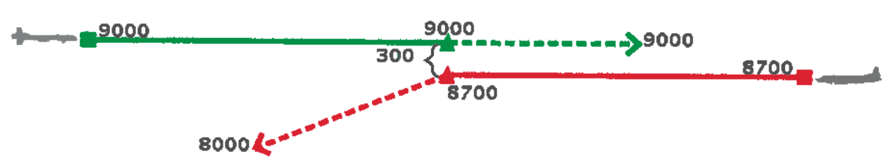
Follow Heading Bands

LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
9000	NAV TO LL WPT



COMEX TIME: 0738

IP WIND:

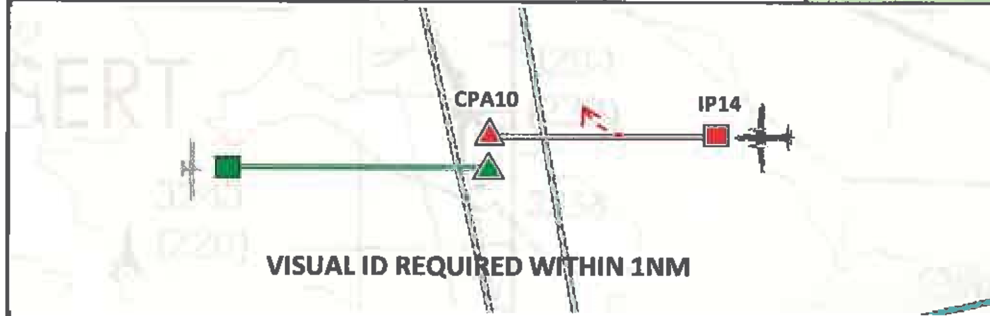
WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP3	N34° 54.14'	W117° 35.17'	9000	4.0	120	2+00
	N34° 54' 08.2"	W117° 35' 10.0"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	9000	0.0	120	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Ownship maneuver. Follow CPDS Guidance.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: N/A

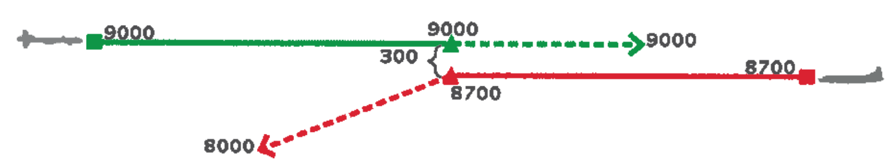
NCC SCO	A/C: NASA 856			Squawk Off
CARD# 2	SQK-6			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8700	100	IP14	None	YES



Squawk off

DECONFLICTION ALT:
8000

ABORT PROCEDURE	
8000	RIGHT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP14	N34° 54.60'	W117° 26.17'	8700	3.3	100	2+00
	N34° 54' 35.8"	W117° 26' 10.1"	0	258		
CPA10	N34° 54.61'	W117° 30.19'	8700	0.0	100	
	N34° 54' 36.7"	W117° 30' 11.5"	0	258		

NOTES: Expect Ownship maneuver.

TOLERANCE: N/A

NCC SCO	A/C: NASA870	Squawk Off

CARD# 3	SQK-7			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	120	IP3	CPDS	YES

Follow Heading Bands

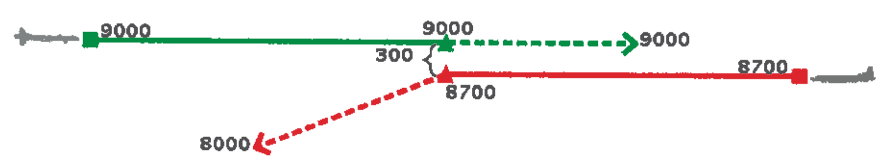
LOST LINK WAYPOINT: LL WPT 7

DECONFLICTION ALT: 9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: 0148

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP3	N34° 54.14'	W117° 35.17'	9000	4.0	120	2+00
	N34° 54' 08.2"	W117° 35' 10.0"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	9000	0.0	120	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Ownship maneuver. Follow CPDS Guidance.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 856	Squawk Off

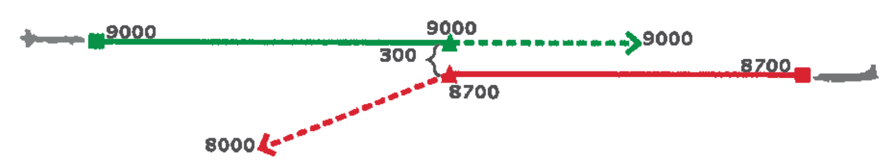
CARD# 3	SQK-7			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8700	100	IP15	None	YES

Squawk off

DECONFLICTION ALT: 8000

ABORT PROCEDURE

8000	RIGHT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP15	N34° 56.72'	W117° 27.64'	8700	3.3	100	2+00
	N34° 56' 43.4"	W117° 27' 38.5"	0	213		
CPA11	N34° 54.48'	W117° 30.66'	8700	0.0	100	
	N34° 54' 29.0"	W117° 30' 39.8"	0	213		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870			Squawk Off
CARD# 4	SQK-8			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	120	IP3	CPDS	YES

Follow Heading Bands

aborted lost KU

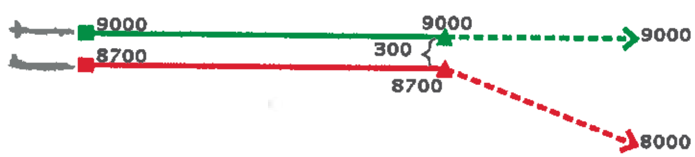
LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: 0801/0804 repeat

IP WIND:

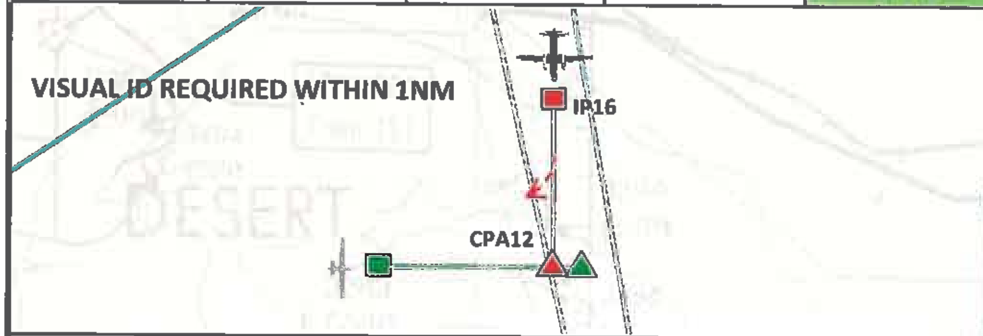
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP3	N34° 54.14'	W117° 35.17'	9000	4.0	120	2+00
	N34° 54' 08.2"	W117° 35' 10.0"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	9000	0.0	120	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Ownship maneuver. Follow CPDS Guidance.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 856			Squawk Off
CARD# 4	SQK-8			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8700	100	IP16	None	YES



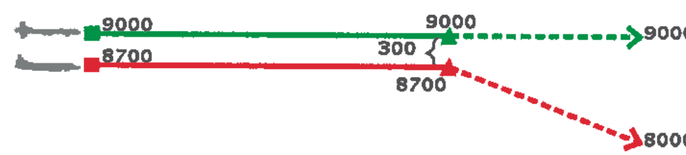
Squawk off

~~Squawk off~~ Mode C Squawk 0023

DECONFLICTION ALT:
8000

ABORT PROCEDURE

8000	RIGHT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP16	N3° 57.47' N34	W117° 30.88'	8700	3.3	100	2+00
	~~N3°~~ N34 57' 28.4"	W117° 30' 52.7"	0	168		
CPA12	N34° 54.13'	W117° 30.84'	8700	0.0	100	
	N34° 54' 07.8"	W117° 30' 50.3"	0	168		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870		Low Altitude - Squawk Off	
CARD# 5	LALT-24			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
6200	150	IP2	None	YES

High terrain within test area (3400 MSL)
Low altitude. 3000 ft AGL
Demonstrate representative NAS encounter
Class D Airspace

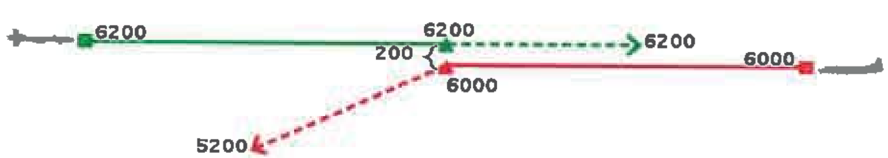
LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
6200

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

6200	NAV TO LL WPT



COMEX TIME: 0820

IP WIND:

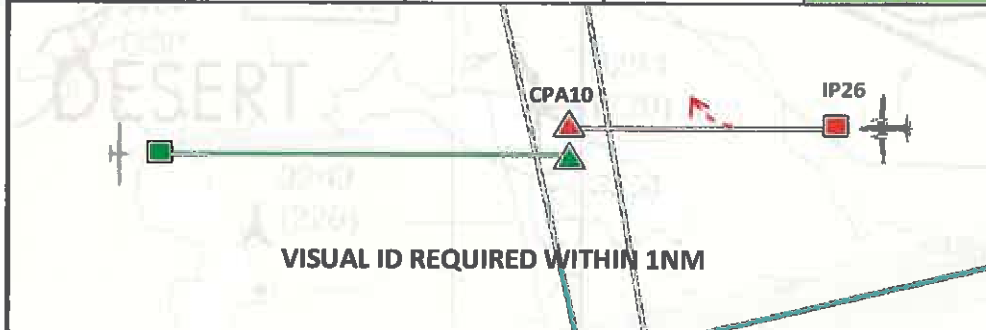
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP2	N34° 54.14'	W117° 39.44'	6200	7.5	150	3+00
	N34° 54' 08.2"	W117° 39' 26.1"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	6200	0.0	150	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Low altitude 3000ft AGL. Fly through

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	NO DESCENT		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 856		Low Altitude - Squawk Off	
CARD# 5	LALT-24			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
6000	100	IP26	None	YES

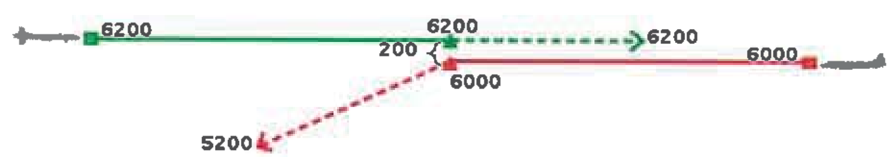


High terrain within test area (3400 MSL)
Squawk Off
Low altitude. 3000 ft AGL
Demonstrate representative NAS encounter

DECONFLICTION ALT:
5200

ABORT PROCEDURE

5200	RIGHT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP26	N34° 54.61'	W117° 24.13'	6000	9.0	100	3+00
	N34° 54' 36.7"	W117° 24' 08.0"	0	258		
CPA10	N34° 54.61'	W117° 30.19'	6000	0.0	100	
	N34° 54' 36.7"	W117° 30' 11.5"	0	258		

NOTES: Non maneuvering Ownship

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Low Altitude - SQK Off

CARD# 6	LALT-25			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
6200	150	IP2	~~TCAS~~ CPDS	YES

High terrain within test area (3400 MSL)
Low altitude. 3000 ft AGL
Demonstrate representative NAS encounter
Class D Airspace

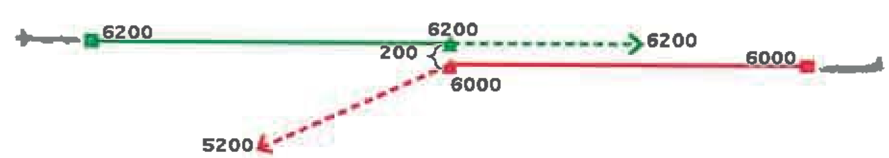
LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
6200

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

6200	NAV TO LL WPT



COMEX TIME: 0830

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP2	N34° 54.14'	W117° 39.44'	6200	7.5	150	3+00
	N34° 54' 08.2"	W117° 39' 26.1"	0	078		
CPA2	N34° 54.14'	W117° 30.29'	6200	0.0	150	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

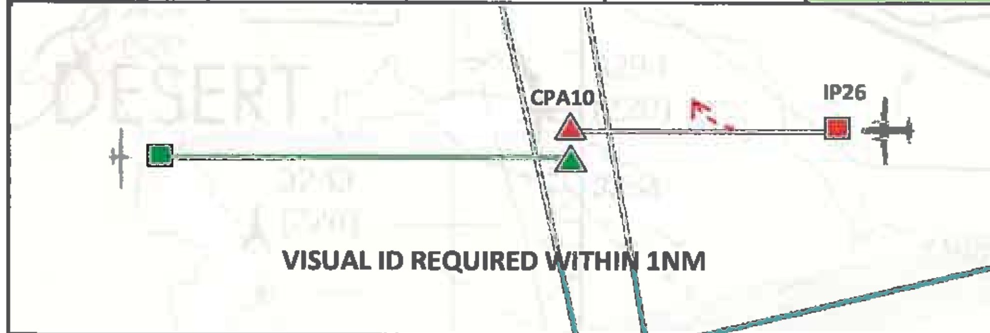
NOTES: Low altitude 3000ft AGL. Follow ~~TCAS~~ CPDS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	~~TCAS~~
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: N/A

NCC SCO	A/C: NASA 856	Low Altitude - SQK Off

CARD# 6	LALT-25			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
6000	100	IP26	None	YES



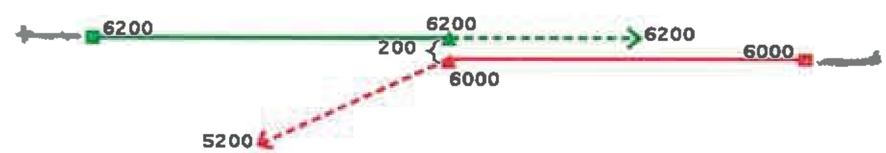
High terrain within test area (3400 MSL)
Low altitude. 3000 ft AGL
Demonstrate representative NAS encounter
Class D Airspace

SQK Off

DECONFLICTION ALT:
5200

ABORT PROCEDURE

5200	RIGHT



COMEX TIME:

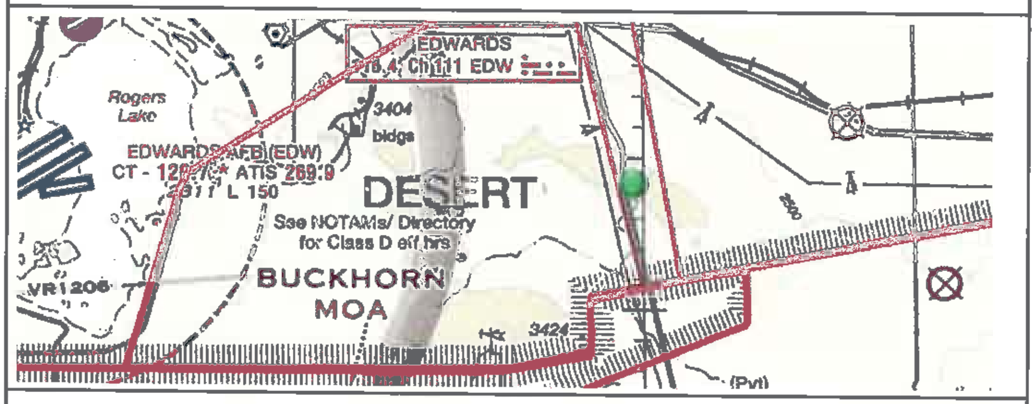
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP26	N34° 54.61'	W117° 24.13'	6000	5.0	100	3+00
	N34° 54' 36.7"	W117° 24' 08.0"	0	258		
CPA10	N34° 54.61'	W117° 30.19'	6000	0.0	100	
	N34° 54' 36.7"	W117° 30' 11.5"	0	258		

NOTES: Expect Ownship Maneuver

TOLERANCE: N/A

NCC SCO ALTIMETER CALIBRATION (HIGH SPEED)



REJOIN AND ALTITUDE CALIBRATION:

Start conditions ALL AIRCRAFT
- Joined, straight and level, 180 KIAS, heading as required
- 29.92

1. HOLD - left hand turns, at altitude
2. JOIN & SET - INTRUDER
   - Maintain 500 ft alt/sep until visual
   - INTRUDER **"Joined, rollout heading AS/REQ"**
3. REPORT - **"29.92 set showing 15,###" - OWNSHIP / INTRUDER**
4. ADJUST - altimeter to 15,000 - INTRUDER
   - Call **"29.## showing 15,000"**
   - Maintain new altimeter setting for encounters
   - Note and record GPS altitude
5. Intruder clears off ownship & accelerates to 250 KIAS
   - Note and record GPS altitude to baro at airspeed points
6. COMPLETE - "Complete, [callsign]"

PT	LATITUDE	LONGITUDE	OWNSHIP ALTITUDE	CHASE ALTITUDE	A/S
CPA2	N34° 54.14'	W117° 30.29'	15000		180 KIAS
	N34° 54' 08.2"	W117° 30' 17.4"			

at or below 220

Vis 3.5 nm

Ø time hack w/808 = 08:~~8~~4700

810/808 TA

808 RA

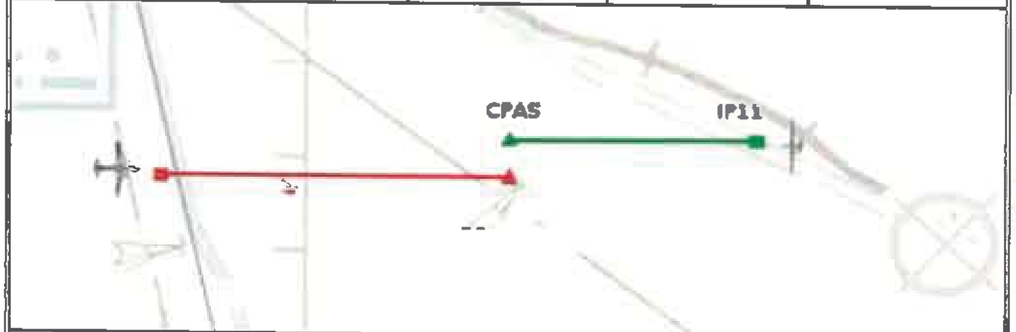
870 29.92 15000 180

808 – 29.92 15040 186 kgs

808 – 29.86 15000 180 windspeed

NCC SCO	A/C: NASA870	Advisory TCAS
CARD# 7	ATCAS-22-NoVID	OWNSHIP

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
21000	150	IP11	None	NO



Fly through in Advisory
Increased alerting above 20k ft

RA before IP

Climb RA

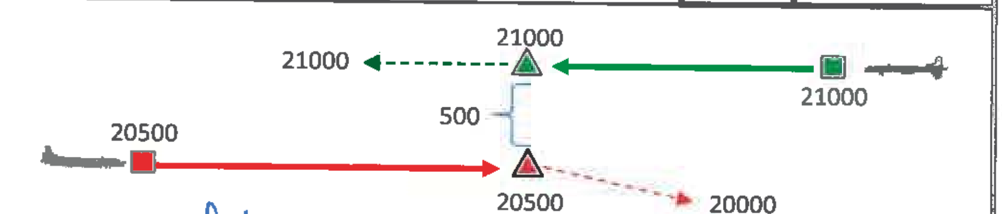
LOST LINK WAYPOINT: LL WPT 10

DECONFLICTION ALT: 21000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

21000	NAV TO LL WPT



Folex

COMEX TIME: ~~0854~~ 0859

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP11	N34° 57.09'	W117° 24.57'	21000	2.5	150	1+00
	N34° 57' 05.4"	W117° 24' 34.2"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	21000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

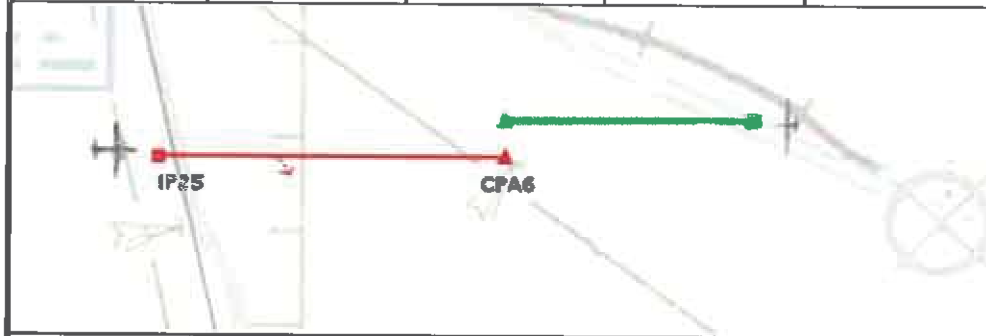
NOTES: Non-maneuvering Ownship

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	NO CLIMB		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	Advisory TCAS - No VID
CARD# 7	ATCAS-22-NoVID	INTRUDER 1

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
20500	210	IP25	None	NO



Ikhana flythrough

25 seconds early RA

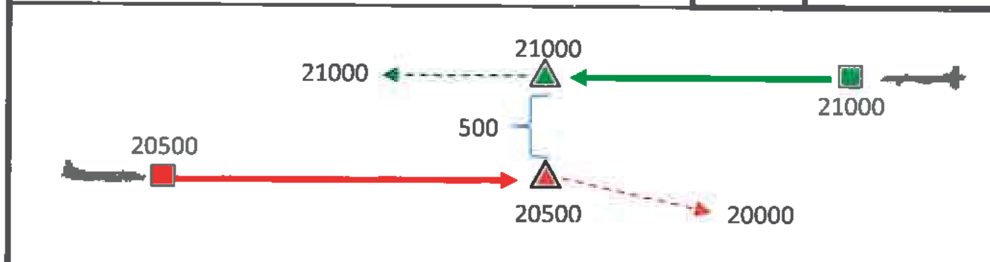
.5nm VID

275 Kgs

DECONFLICTION ALT: 20000

ABORT PROCEDURE

20000	RIGHT



COMEX TIME:

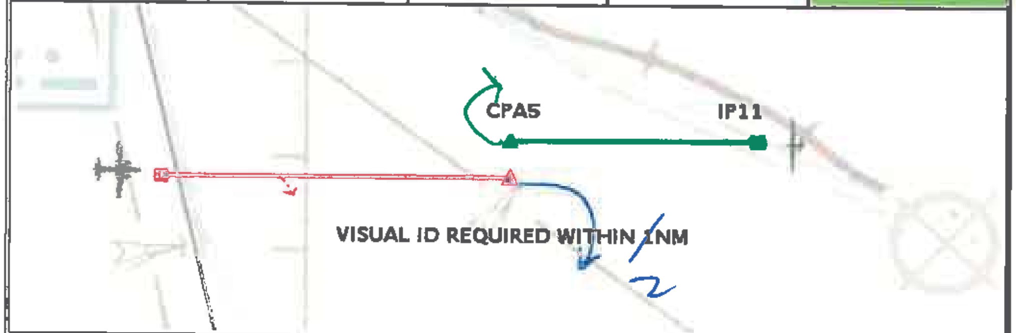
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP25	N34° 56.69'	W117° 31.89'	20500	3.5	210	1+00
	N34° 56' 41.4"	W117° 31' 53.4"	0	078		
CPA6	N34° 56.69'	W117° 27.62'	20500	0.0	210	
	N34° 56' 41.4"	W117° 27' 37.2"	0	078		

NOTES: Non-maneuvering Ownship.

TOLERANCE: N/A

NCC SCO	A/C: NASA870		Advisory TCAS		
CARD# 8	ATCAS-22				OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE		VID
21000	150	IP11	TCAS		YES



Maneuver ~~Fly through~~ in Advisory
Increased alerting above 20k ft
Follow

no increased alert for TCAS

244/46

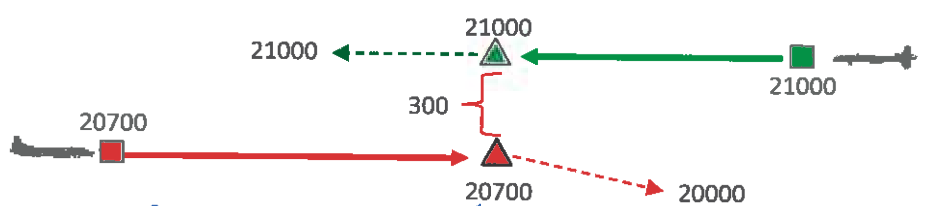
LOST LINK WAYPOINT:
LL WPT 10

DECONFLICTION ALT:
21000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

21000	NAV TO LL WPT



Folex Folex 0915

COMEX TIME: ~~0910~~ ~~0913~~ 0915 IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP11	N34° 57.09'	W117° 24.57'	21000	2.5	150	1+00
	N34° 57' 05.4"	W117° 24' 34.2"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	21000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

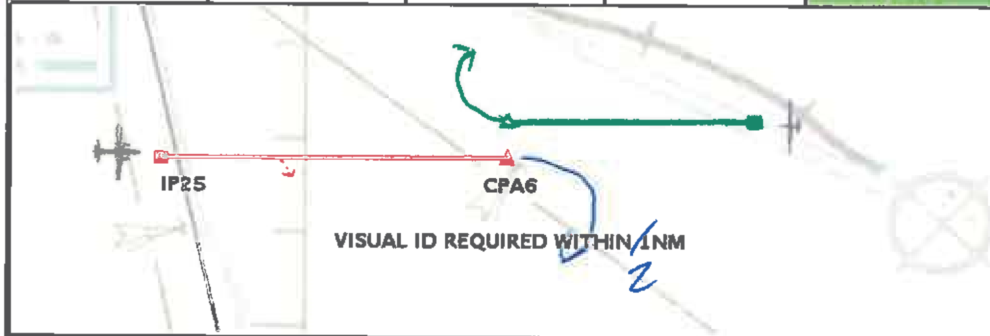
NOTES: Maneuvering Ownship. Follow ^Increased TCAS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	~~NO CLIMB~~ no descend		

[illegible] redline

TOLERANCE: N/A

NCC SCO	A/C: NASA 808		Advisory TCAS		
CARD# 8	ATCAS-22				INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE		VID
20700	210	IP25	None		YES



Ikhana ~~flythrough~~ Maneuver in Advisory

watch visual

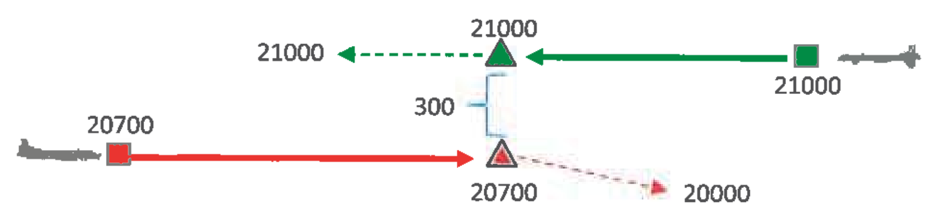
wnds 295@53

+10 2.5nm vis

DECONFLICTION ALT:
20000

ABORT PROCEDURE

20000	RIGHT



COMEX TIME: IP WIND:

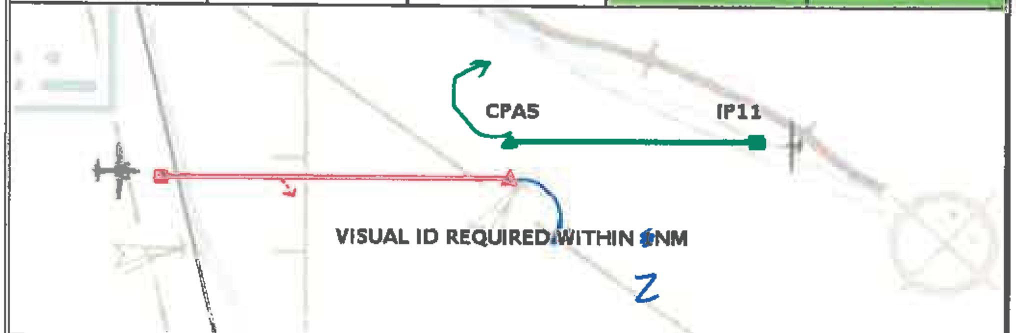
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP25	N34° 56.69'	W117° 31.89'	20700	3.5	210	Saw 260 160 IAS 1+00
	N34° 56' 41.4"	W117° 31' 53.4"	0	078		
CPA6	N34° 56.69'	W117° 27.62'	20700	0.0	210	
	N34° 56' 41.4"	W117° 27' 37.2"	0	078		

NOTES: Expect Ownship Maneuver

TOLERANCE: N/A

$\cancel{8}$ expect altitude swap after this card $\cancel{8}$

NCC SCO	A/C: NASA870	AUTO TCAS		
CARD# 9	ATCAS-23			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
21000	150	IPA11	AUTO	YES



Ownship Auto maneuver

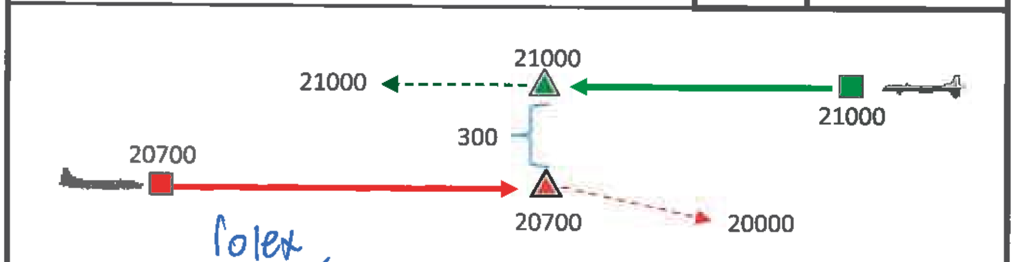
TA Climb fa Climbing

LOST LINK WAYPOINT: LL WPT 10

DECONFLICTION ALT: 21000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
21000	NAV TO LL WPT



Folex

COMEX TIME: ~~0925~~ 0929

IP WIND:

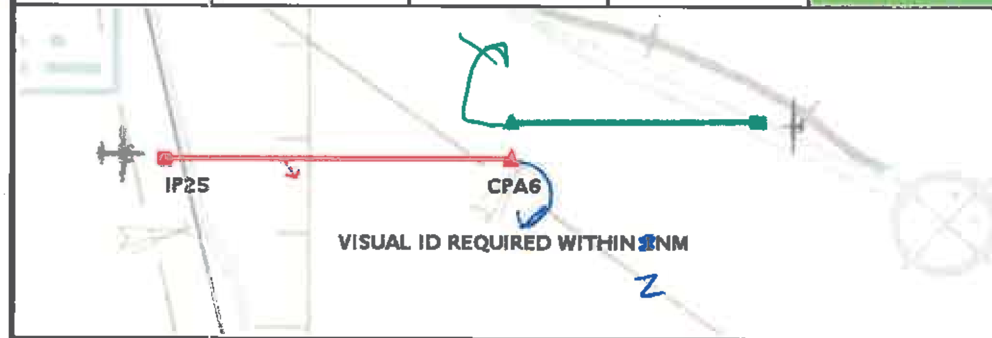
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP11	N34° 57.09'	W117° 24.57'	21000	2.5	150	100 1+00
	N34° 57' 05.4"	W117° 24' 34.2"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	21000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

NOTES: Ownship maneuver / Auto

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	AUTO TCAS		
CARD# 9	ATCAS-23			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
20700	210	IP25	None	YES

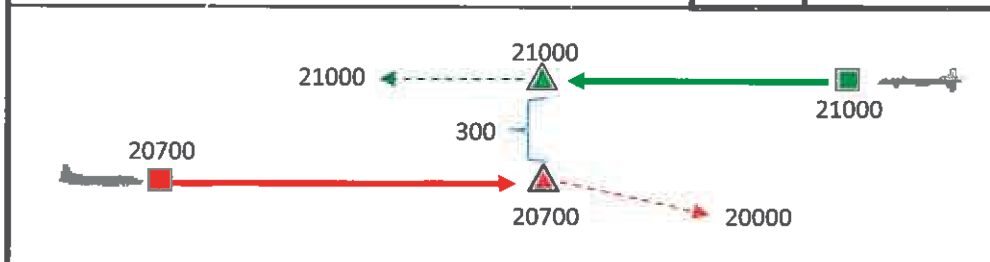


Ownship Auto maneuver

Spotty! 160 B 220 2.5 VIS

DECONFLICTION ALT: 20000

ABORT PROCEDURE	
20000	RIGHT



COMEX TIME:

IP WIND:

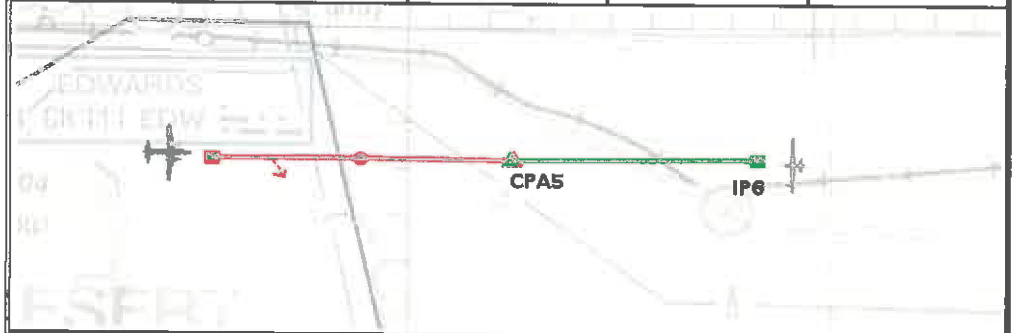
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP25	N34° 56.69'	W117° 31.89'	20700	3.5	210	270 1+00
	N34° 56' 41.4"	W117° 31' 53.4"	0	078		
CPA6	N34° 56.69'	W117° 27.62'	20700	0.0	210	
	N34° 56' 41.4"	W117° 27' 37.2"	0	078		

NOTES: Expect Ownship Maneuver

TOLERANCE: N/A

Watch guidance of high descent

NCC SCO	A/C: NASA870	Nuisance		
CARD# 11	NUIS-13			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	150	IP6	CPDS	NO



Demonstrate System will provide preventative, but not corrective alerting.

SQK: 0024

TA left turn 190

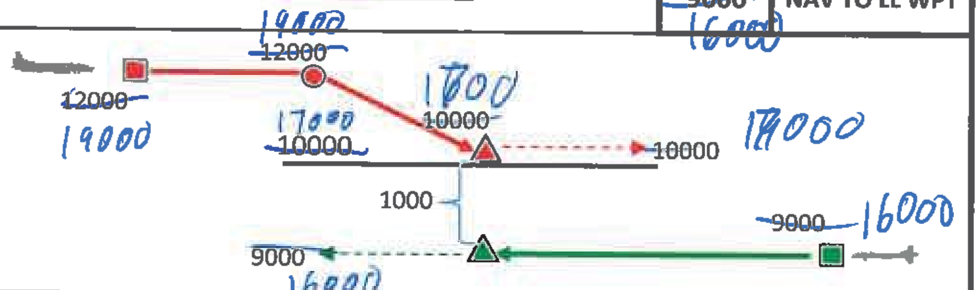
LOST LINK WAYPOINT: LL WPT 10

DECONFLICTION ALT: ~~9000~~ 16000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

~~9000~~ 16000	NAV TO LL WPT



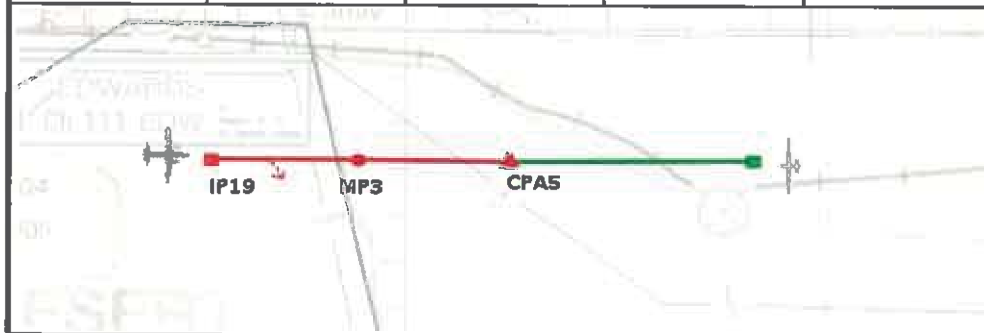
COMEX TIME: 0945			IP WIND:			
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP6	N34° 57.09'	W117° 21.52'	9000	5.0	150	2+00
	N34° 57' 05.4"	W117° 21' 31.2"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	9000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

NOTES: Follow guidance if triggered.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	Nuisance		
CARD# 11	NUIS-13			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	180	IP19	None	NO



-2000 fpm descent rate at MP3

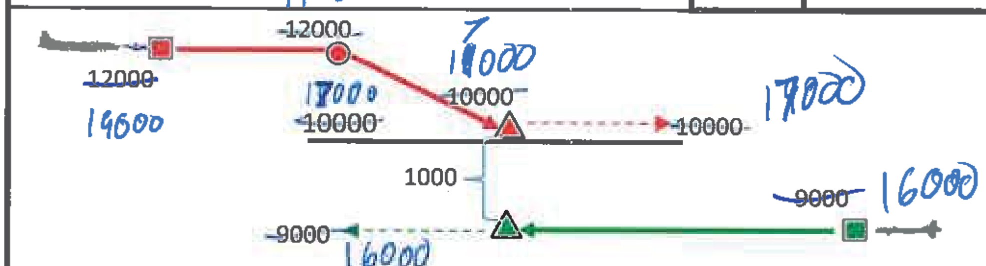
946 ssec Begin descent

30 sec

DECONFLICTION ALT: ~~10000~~ 17000

ABORT PROCEDURE

19000 ~~10000~~	RIGHT



COMEX TIME:			IP WIND:			
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP19	N34° 57.09'	W117° 34.94'	12000	6.0	180	2+00
	N34° 57' 05.4"	W117° 34' 56.4"	0	078		
MP3	N34° 57.09'	W117° 31.28'	12000	3.0	180	1+00
	N34° 57' 05.4"	W117° 31' 16.8"	-2000	078		
CPA5	N34° 57.09'	W117° 27.62'	10000	0.0	180	
	N34° 57' 05.4"	W117° 27' 37.2"	0	078		

NOTES: Expect Ownship maneuver. Intruder begin descent at MP. Level at target altitude.

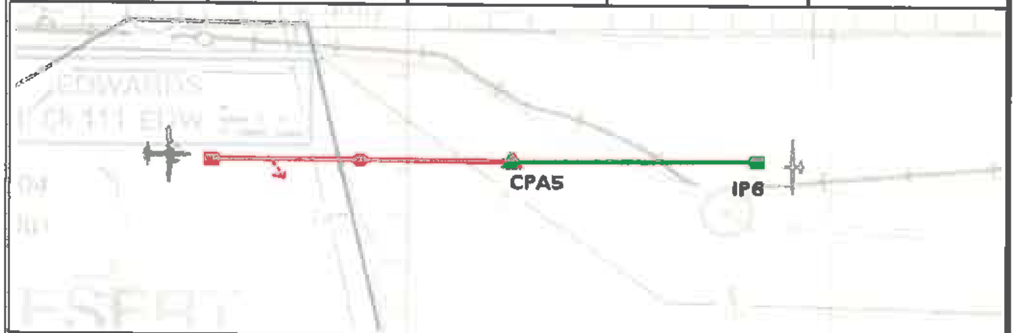
226

TOLERANCE: N/A

watch guidance ~~&~~

NCC SCO	A/C: NASA870	Nuisance

CARD# 12	NUIS-14			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	150	IP6	CPDS	NO



Demonstrate System will provide preventative, but not corrective alerting.

TA descent

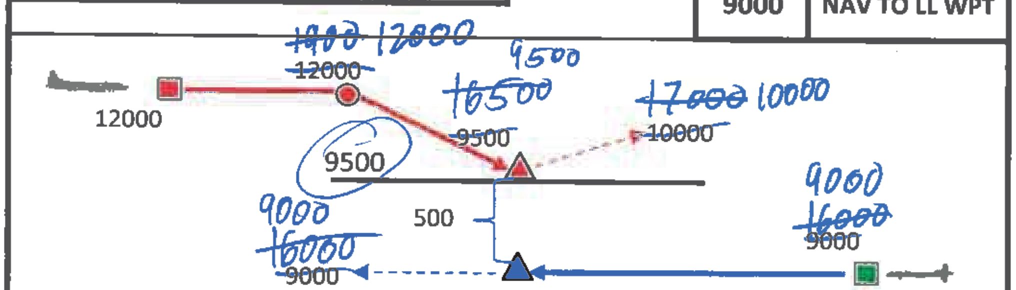
LOST LINK WAYPOINT: LL WPT 10

DECONFLICTION ALT: 9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: 0456 — IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP6	N34° 57.09'	W117° 21.52'	9000	5.0	150 160	2+00
	N34° 57' 05.4"	W117° 21' 31.2"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	9000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

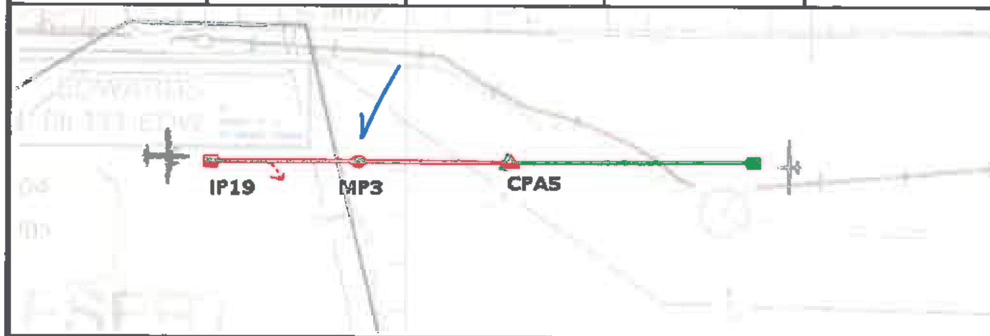
NOTES: Follow guidance if triggered.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	Nuisance

CARD# 12	NUIS-14			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	180	IP19	None	NO



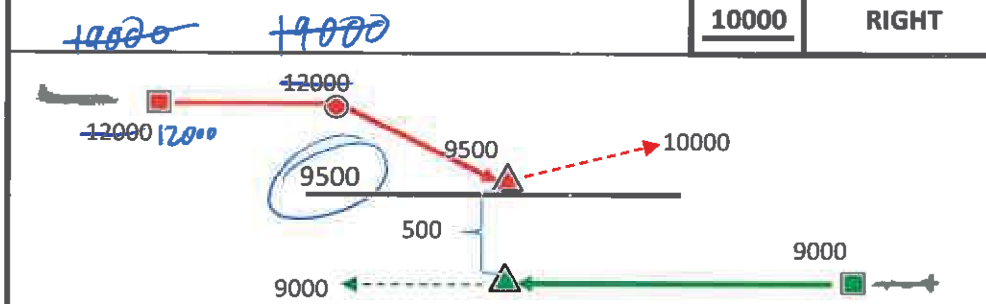
-2500 fpm descent rate at MP3

~~Go back~~ 12→16 then go back
2nm Vis

DECONFLICTION ALT: 10000

ABORT PROCEDURE

10000	RIGHT



COMEX TIME: — IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP19	N34° 57.09'	W117° 34.94'	12000	6.0	180 140	2+00
	N34° 57' 05.4"	W117° 34' 56.4"	0	078		
MP3	N34° 57.09'	W117° 31.28'	12000	3.0	180	1+00
	N34° 57' 05.4"	W117° 31' 16.8"	-2500	078		
CPA5	N34° 57.09'	W117° 27.62'	9500	0.0	180	
	N34° 57' 05.4"	W117° 27' 37.2"	0	078		

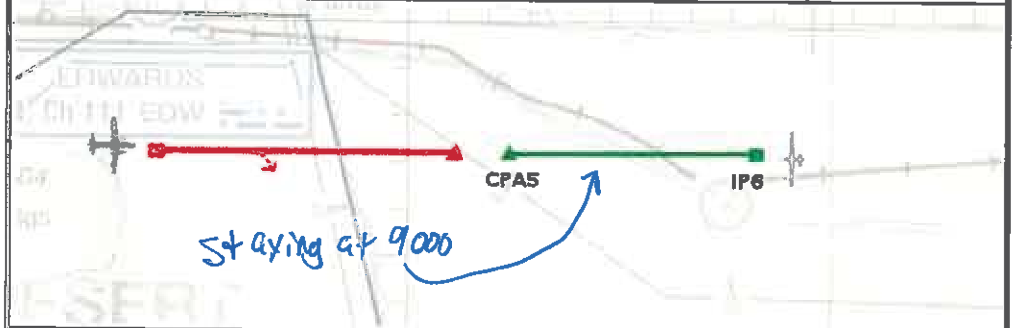
NOTES: Expect Ownship maneuver. Intruder begin descent at MP. Level at target altitude.

TOLERANCE: N/A

✱ Expect altitude swap

Ownship card

NCC SCO	A/C: NASA870		Double Blunder	
CARD# 13	DB-15			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
7000	150	IP6	CPDS	NO



Climb at 1000fpm at IP. Level off at 9000ft

left turn
leveling at 8000

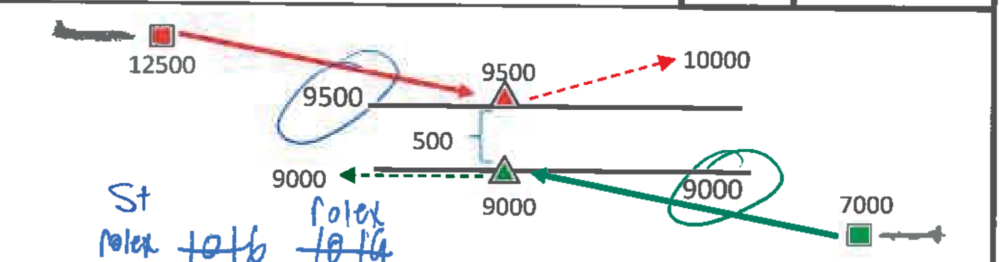
LOST LINK WAYPOINT: LL WPT ~~5~~ 10

DECONFLICTION ALT: 9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: ~~1006~~ 1020

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP6	N34° 57.09'	W117° 21.52'	7000	5.0	137 150	2+00
	N34° 57' 05.4"	W117° 21' 31.2"	1000	258		
CPA5	N34° 57.09'	W117° 27.62'	9000	0.0	150	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

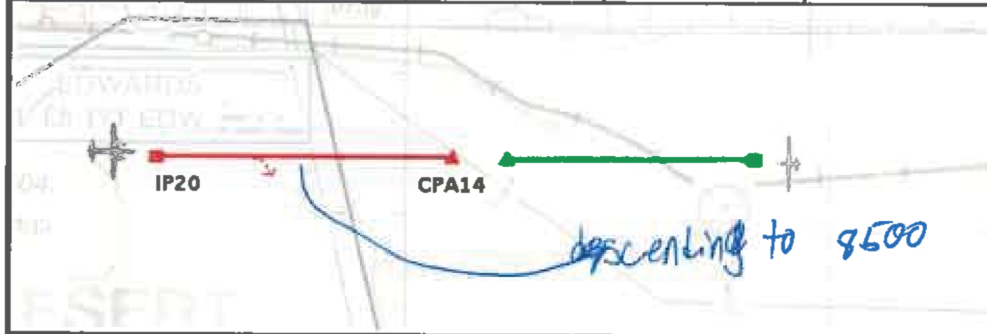
NOTES: Ownship maneuver, Follow CPDS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: ± 8 sec

Intruder 1 card

NCC SCO	A/C: NASA 808		Double Blunder	
CARD# 13	DB-15			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12500	180	IP20	None	NO



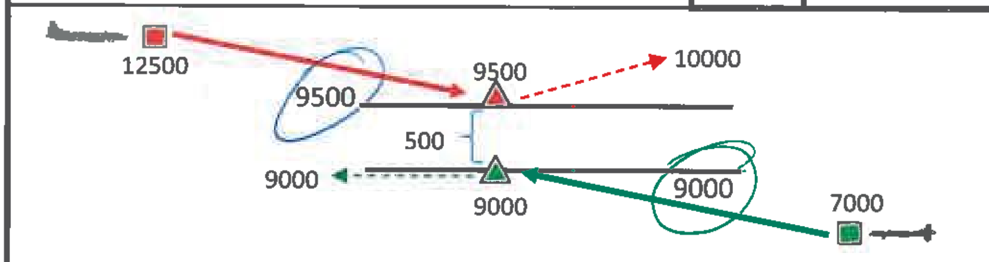
Descend at -1500fpm. Level off at 9500

Bad SAAP Okay 2hr
resetting radar

DECONFLICTION ALT: 10000

ABORT PROCEDURE

10000	RIGHT



COMEX TIME:

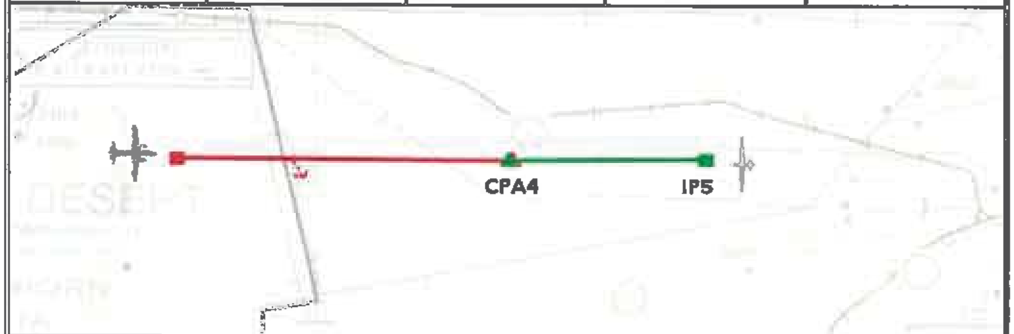
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP20	N34° 57.09'	W117° 36.28'	12500	6.0	180	up 197 descent 2+00
	N34° 57' 05.4"	W117° 36' 16.9"	-1500	078		
CPA14	N34° 57.09'	W117° 28.96'	9500	0.0	180	
	N34° 57' 05.4"	W117° 28' 57.7"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	High Speed		
CARD# 14	HS-11			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	180	IP5	None	NO



High Speed Intruder

TA/RA
6.8

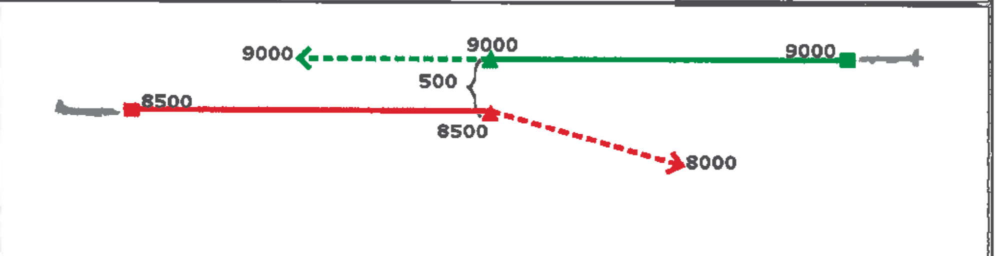
LOST LINK WAYPOINT:
LL WPT 6

DECONFLICTION ALT:
9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

9000	NAV TO LL WPT



COMEX TIME: +030 1033

IP WIND:

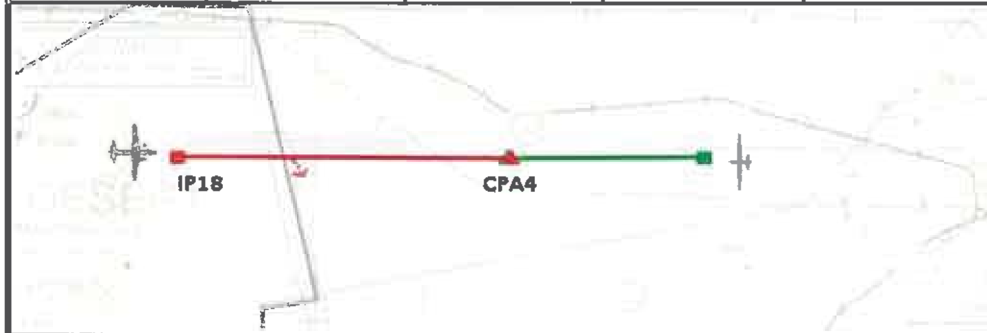
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP5	N34° 55.20'	W117° 15.71'	9000	6.0	180	2+00
	N34° 55' 11.7"	W117° 15' 42.3"	0	258		
CPA4	N34° 55.20'	W117° 23.02'	9000	0.0	180	
	N34° 55' 11.7"	W117° 23' 01.3"	0	258		

NOTES: Ownship fly through/non-maneuvering.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	NO DESCENT		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	High Speed		
CARD# 14	HS-11			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8500	300	IP18	None	NO



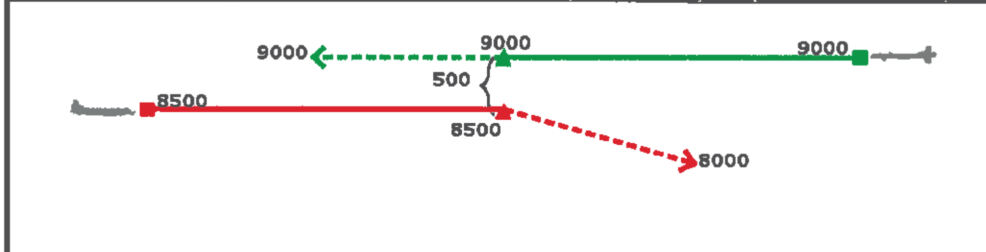
High Speed Intruder

May need Airspace to the North
TA 4.8 RA 2.8
Yes
+10 sec
1.7

DECONFLICTION ALT:
8000

ABORT PROCEDURE

8000	RIGHT



COMEX TIME:

IP WIND:

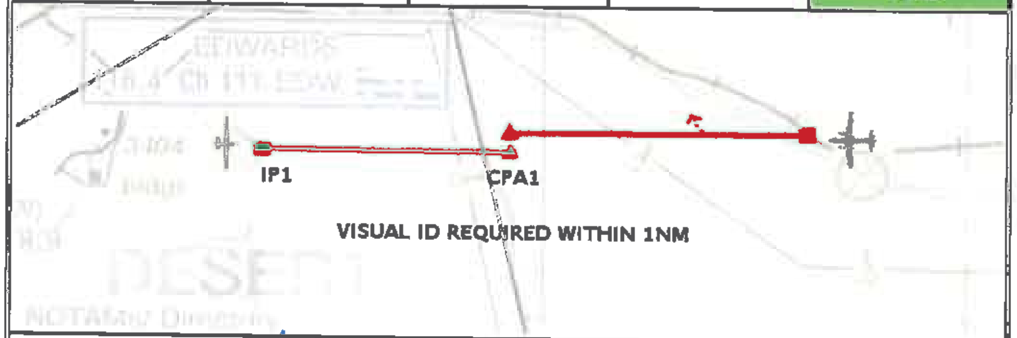
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP18	N34° 55.20'	W117° 35.22'	8500	10.0	300	2+00
	N34° 55' 11.7"	W117° 35' 13.1"	0	078		
CPA4	N34° 55.20'	W117° 23.02'	8500	0.0	300	
	N34° 55' 11.7"	W117° 23' 01.3"	0	078		

NOTES: Non-maneuvering Ownship.

TOLERANCE: N/A

expect altitude swap

NCC SCO	A/C: NASA870		Test Mode	
CARD# 16	TM-1			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	160	IP1	None	YES



Test Mode set to 253 ✓ TA 4nm

LOST LINK WAYPOINT: LL WPT 4

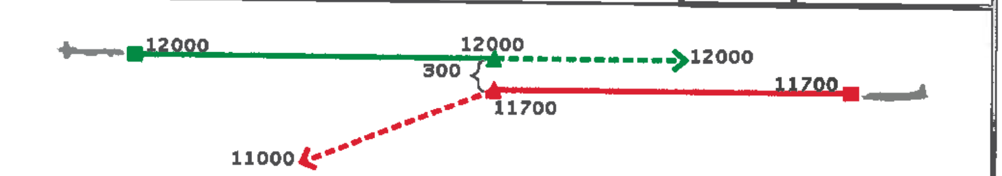
Abort Abort Abort no V/S

DECONFLICTION ALT: 12000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

12000	NAV TO LL WPT



1041

COMEX TIME: ~~1042~~

IP WIND:

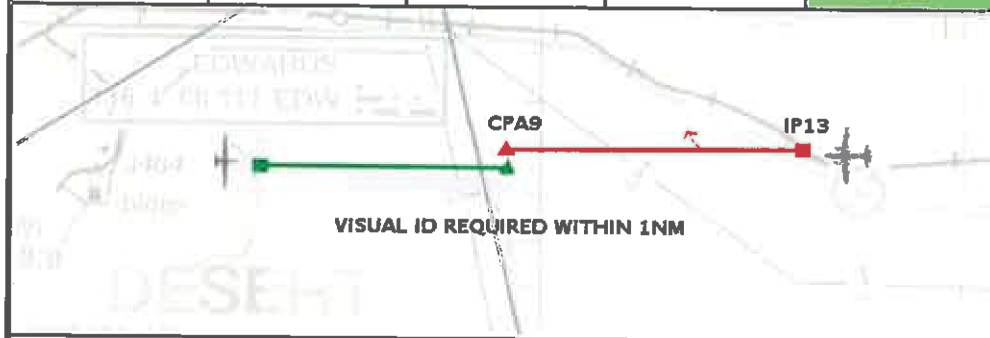
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP1	N34° 56.43'	W117° 37.07'	12000	5.0	160 177	2+00
	N34° 56' 26.0"	W117° 37' 04.1"	0	078		
CPA1	N34° 56.43'	W117° 30.97'	12000	0.0	160	
	N34° 56' 26.0"	W117° 30' 57.9"	0	078		

NOTES: Test mode Set to 253, fused targests will drop. Only Mode C tracks left

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	NONE		
Limit:	NO DESCENT		

TOLERANCE: N/A

NCC SCO	A/C: NASA 7		Test Mode	
CARD# 16	TM-1			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
11700	180	IP13	None	YES



go back to card 10

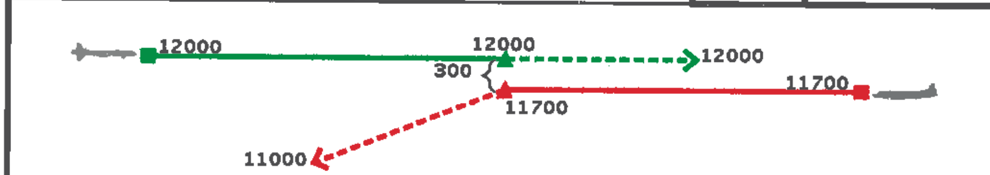
.5nm V/S

Abort

DECONFLICTION ALT: 11000

ABORT PROCEDURE

11000	RIGHT



COMEX TIME:

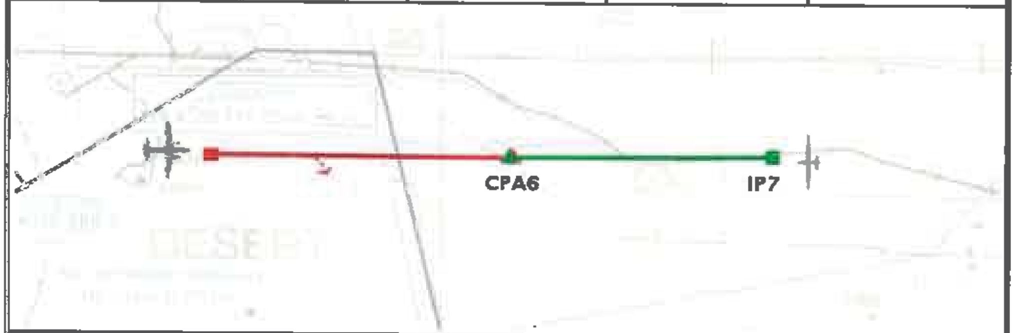
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP13	N34° 56.85'	W117° 23.64'	11700	6.0	180 200	2+00
	N34° 56' 50.9"	W117° 23' 38.6"	0	258		
CPA9	N34° 56.84'	W117° 30.98'	11700	0.0	180	
	N34° 56' 50.3"	W117° 30' 58.7"	0	258		

NOTES: Non-maneuvering Ownship.

TOLERANCE: N/A

NCC SCO	A/C: NASA870		High Descent Rate	
CARD# 10	HDR-16			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
10500	160	IP7	CPDS	NO



High Descent Rate (intruder) 3000fpm
Demonstrate representative NAS encounter

test mode 0

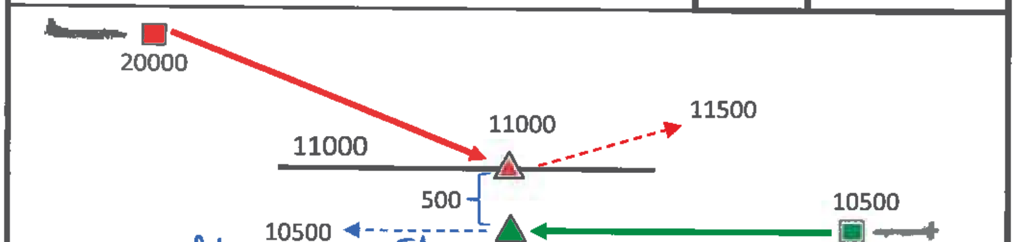
LOST LINK WAYPOINT: LL WPT 11

DECONFLICTION ALT: 10500

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

10500	NAV TO LL WPT



Holex ~~1050~~ 1051

COMEX TIME: 1052

IP WIND:

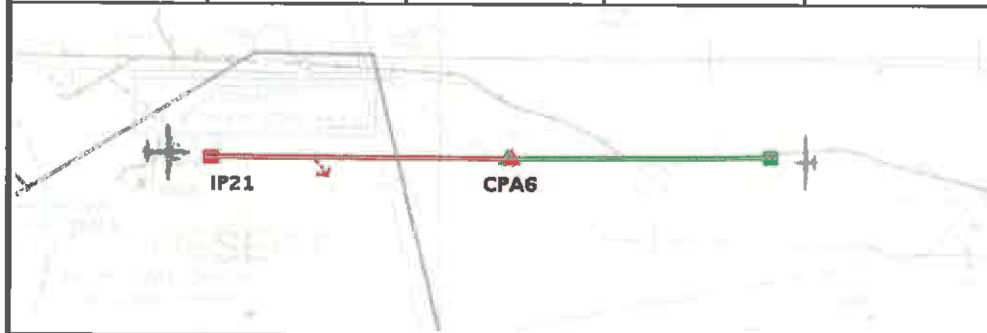
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP7	N34° 56.70'	W117° 17.87'	10500	8.0	160	3+00
	N34° 56' 42.1"	W117° 17' 52.1"	0	258		
CPA6	N34° 56.69'	W117° 27.62'	10500	0.0	160	
	N34° 56' 41.4"	W117° 27' 37.2"	0	258		

NOTES: Ownship maneuver. Follow CPDS Guidance.

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: ± 8 sec ± 100 fpm

NCC SCO	A/C: NASA 808		High Descent Rate	
CARD# 10	HDR-16			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
20000	180	IP21	None	NO



High Descent Rate (intruder) 3000fpm
Demonstrate representative NAS encounter

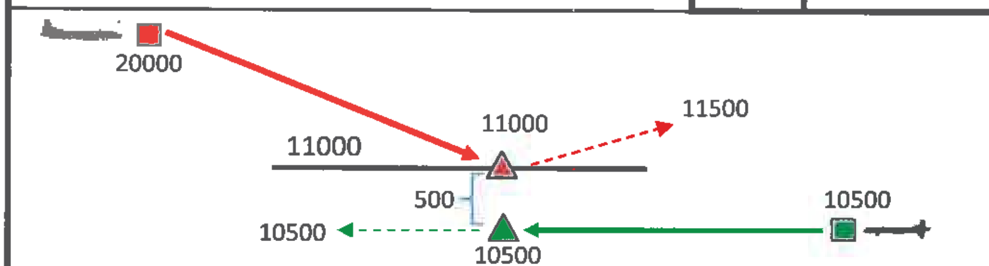
Skipped to Card 11

DECONFLICTION ALT: 11500

*5

ABORT PROCEDURE

11500	RIGHT



COMEX TIME:

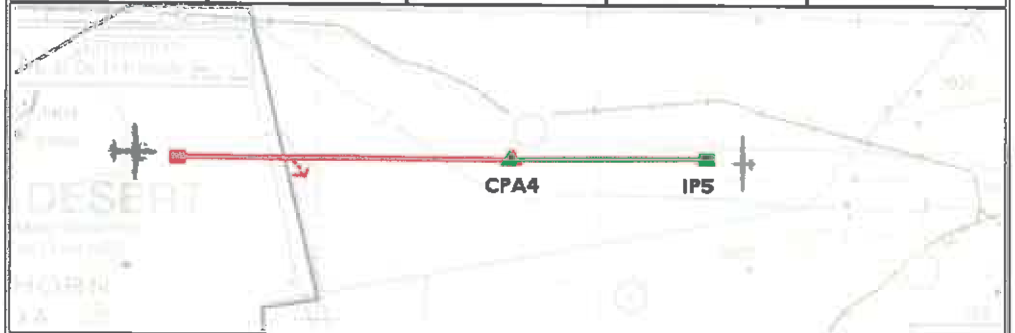
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP21	N34° 56.69'	W117° 38.60'	20000	9.0	180	250 3+00
	N34° 56' 41.4"	W117° 38' 36.0"	-3000	078		
CPA6	N34° 56.69'	W117° 27.62'	11000	0.0	180	
	N34° 56' 41.4"	W117° 27' 37.2"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec ± 100 fpm

NCC SCO	A/C: NASA870	High Speed		
CARD# 15	HS-12			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
9000	180	IP5	CPDS	NO



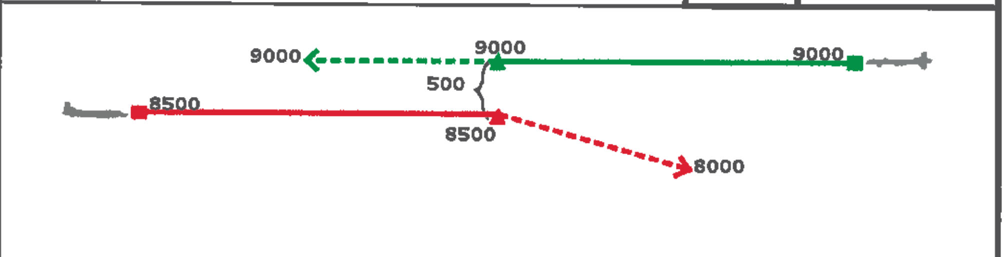
High Speed Intruder

LOST LINK WAYPOINT:
LL WPT 6

DECONFLICTION ALT:
9000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
9000	NAV TO LL WPT



COMEX TIME: IP WIND:

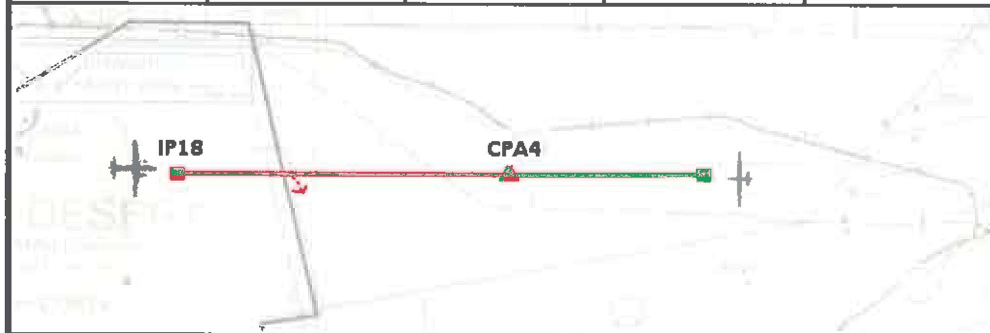
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP5	N34° 55.20'	W117° 15.71'	9000	6.0	180	2+00
	N34° 55' 11.7"	W117° 15' 42.3"	0	258		
CPA4	N34° 55.20'	W117° 23.02'	9000	0.0	180	
	N34° 55' 11.7"	W117° 23' 01.3"	0	258		

NOTES: Ownship maneuver. Follow CPDS Guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCEND		

TOLERANCE: N/A

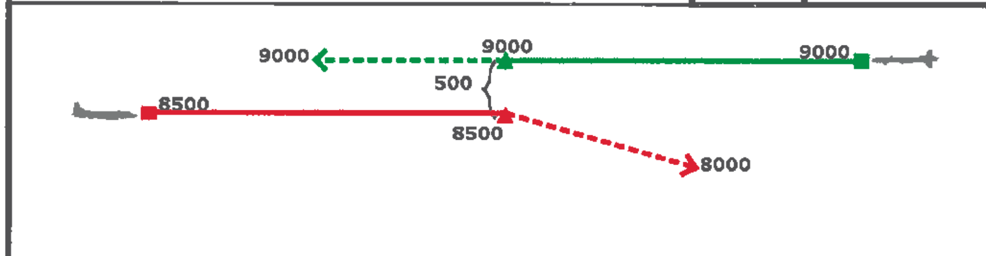
NCC SCO	A/C: NASA 808	High Speed		
CARD# 16	HS-12			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
8500	300	IP18	None	NO



High Speed Intruder

DECONFLICTION ALT:
8000

ABORT PROCEDURE	
8000	RIGHT



COMEX TIME: IP WIND:

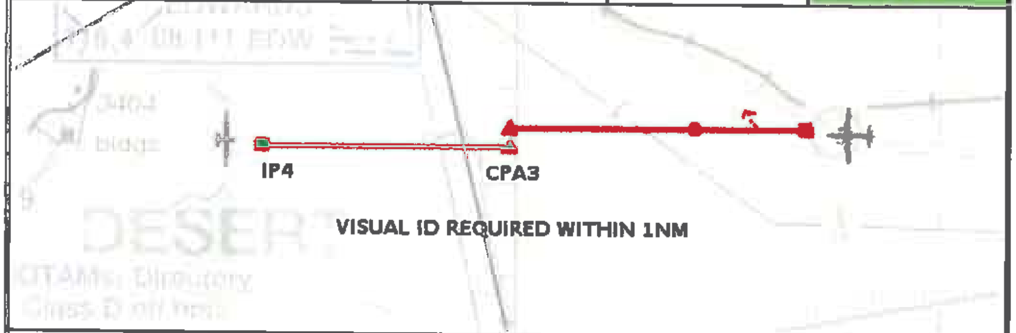
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP18	N34° 55.20'	W117° 35.22'	8500	10.0	300	2+00
	N34° 55' 11.7"	W117° 35' 13.1"	0	078		
CPA4	N34° 55.20'	W117° 23.02'	8500	0.0	300	
	N34° 55' 11.7"	W117° 23' 01.3"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: N/A

NCC SCO	A/C: NASA870	Level Off Blunder

CARD# 17	LOB-9			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
10000	150	IP4	TCAS	YES



Intruder Level Off Blunder
~~TCAS II Reversal~~

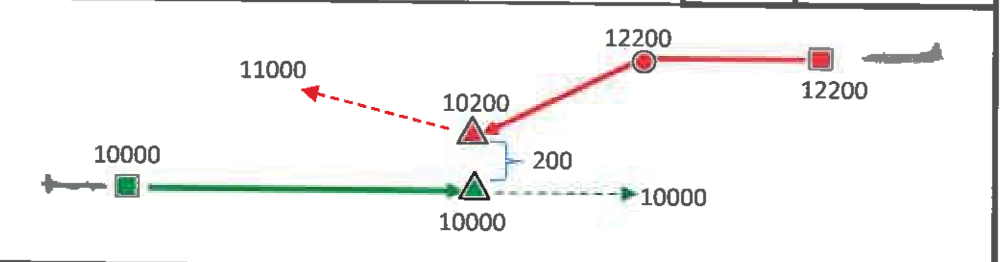
Return Mode to 0
Follow TCAS alert

LOST LINK WAYPOINT:
LL WPT 5

DECONFLICTION ALT:
10000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
10000	NAV TO LL WPT



COMEX TIME: IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP4	N34° 55.64'	W117° 36.37'	10000	5.0	150	2+00
	N34° 55' 38.4"	W117° 36' 22.1"	0	078		
CPA3	N34° 55.64'	W117° 30.29'	10000	0.0	150	
	N34° 55' 38.5"	W117° 30' 17.4"	0	078		

NOTES: Level Off Blunder
~~TCAS II Reversal~~

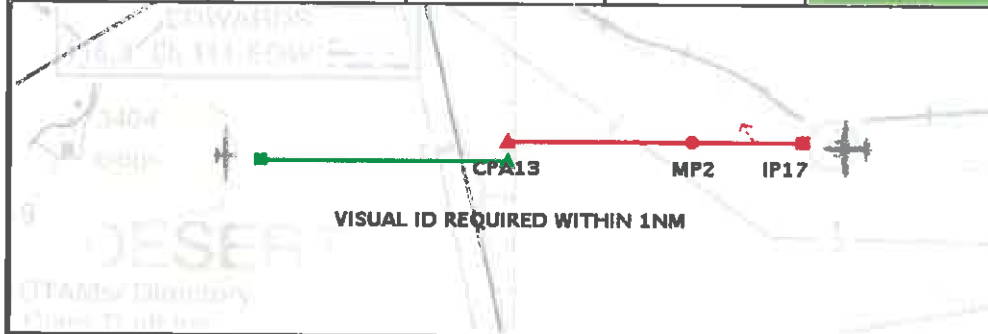
Follow TCAS in Manual

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808	Level Off Blunder

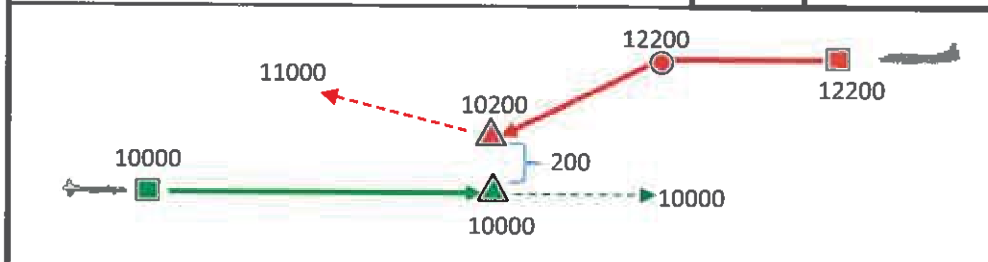
CARD# 17	LOB-9			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12200	180	IP17	None	YES



Intruder Level Off Blunder
Begin Descent at MP2
~~TCAS II Reversal~~

DECONFLICTION ALT:
11000

ABORT PROCEDURE	
11000	RIGHT



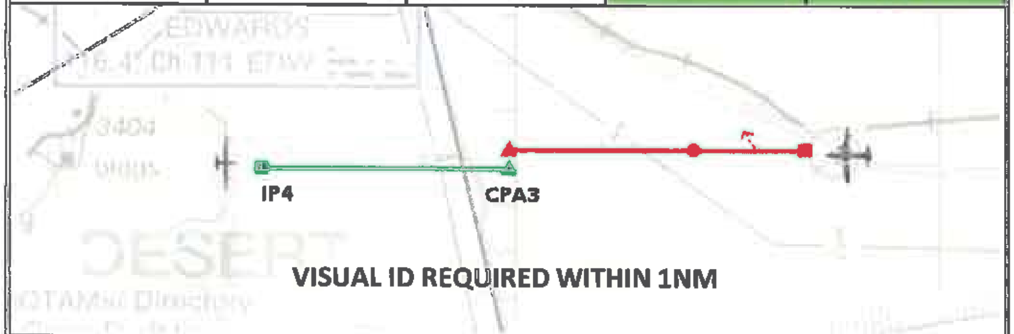
COMEX TIME: IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP17	N34° 56.04'	W117° 23.00'	12200	6.0	180	2+00
	N34° 56' 02.4"	W117° 22' 59.7"	0	078		
MP2	N34° 56.04'	W117° 25.73'	12200	4.5	180	1+00
	N34° 56' 02.5"	W117° 25' 43.7"	-2000	078		
CPA13	N34° 56.04'	W117° 30.29'	10200	0.0	180	
	N34° 56' 02.6"	W117° 30' 17.4"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: N/A

NCC SCO	A/C: NASA870		Level Off Blunder	
CARD# 18	LOB-10			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
10000	150	IP4	AUTO	YES



Intruder Level Off Blunder
~~TCAS II Reversal~~

Follow TCAS Alrt
Auto

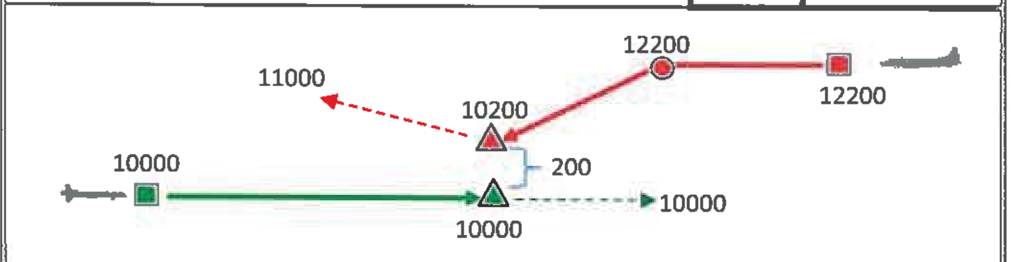
LOST LINK WAYPOINT:
LL WPT 5

DECONFLICTION ALT:
10000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

10000	NAV TO LL WPT



COMEX TIME: IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP4	N34° 55.64'	W117° 36.37'	10000	5.0	150	2+00
	N34° 55' 38.4"	W117° 36' 22.1"	0	078		
CPA3	N34° 55.64'	W117° 30.29'	10000	0.0	150	
	N34° 55' 38.5"	W117° 30' 17.4"	0	078		

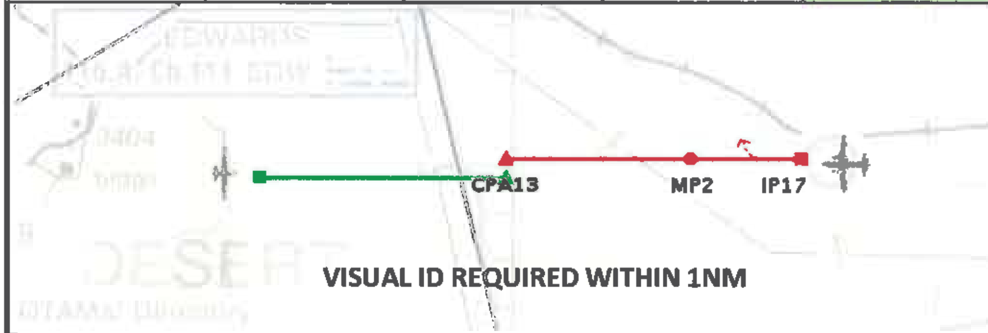
NOTES: Level Off Blunder
~~TCAS II Reversal~~

Follow TCAS
Auto

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: N/A

NCC SCO	A/C: NASA 808		Level Off Blunder	
CARD# 18	LOB-10			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12200	180	IP17	None	YES

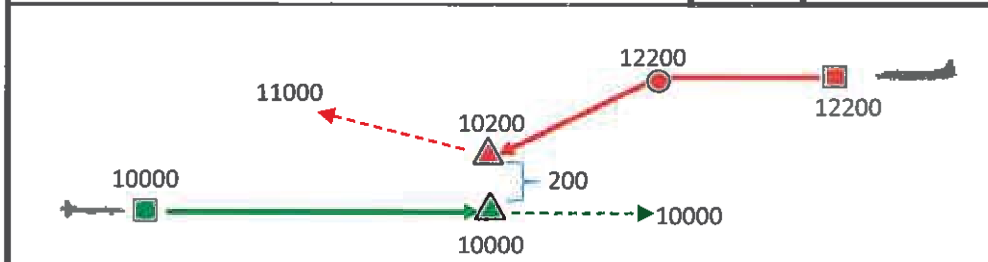


Intruder Level Off Blunder
Begin Descent at MP2
~~TCAS II Reversal~~

DECONFLICTION ALT:
11000

ABORT PROCEDURE

11000	RIGHT



COMEX TIME: IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP17	N34° 56.04'	W117° 23.00'	12200	6.0	180	2+00
	N34° 56' 02.4"	W117° 22' 59.7"	0	078		
MP2	N34° 56.04'	W117° 25.73'	12200	4.5	180	1+00
	N34° 56' 02.5"	W117° 25' 43.7"	-2000	078		
CPA13	N34° 56.04'	W117° 30.29'	10200	0.0	180	
	N34° 56' 02.6"	W117° 30' 17.4"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: N/A

SOF – Steve Schmidt

2018-03-27 — No Chase COA (NCC) System Checkout — Version 3

SCO #3

Ikhana Crew	Comm:	Ops #	Intruder(s)	Intruder Crew
Jelly	123.225	Ikhana -4332-1	NASA 7	Frank Batteas
Hernan	121.95	NASA 7 -4332-2		Manny Antimisiaris

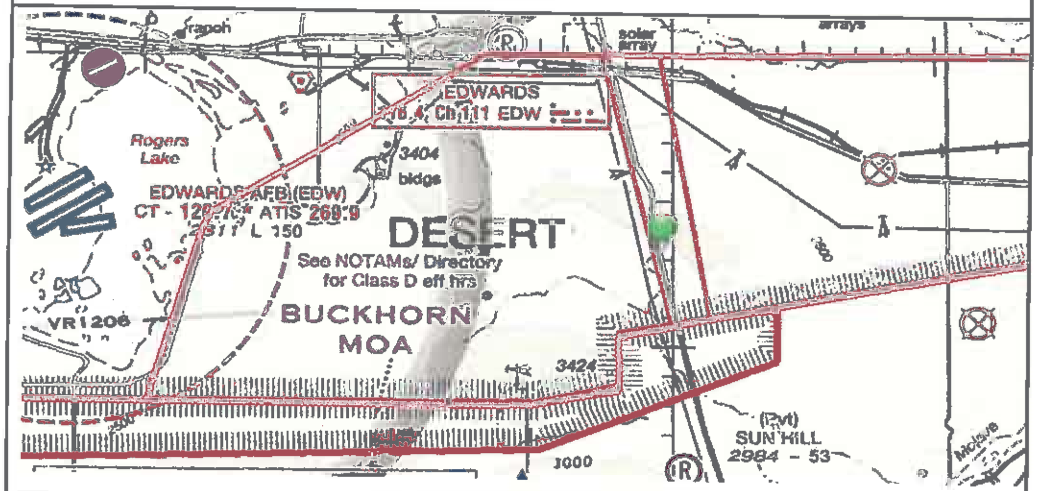
Card Count	Encounter	Priority	Configuration	Ownship Maneuver	Intruder(s)	Notes
X	Altimeter Calibration/Time Hack:				NASA7	
1	KU-1	1	Advisory / KU Only	*None*	NASA7	Build-down encounter
2	KU-2	1	Advisory / KU Only	CPDS	NASA7	
3	OTD-25	2	Advisory	CPDS	NASA7	
4	UC-2	1	Advisory	CPDS	NASA7	
5	IOT-17	2	Advisory	*None*	NASA7	
6	IOT-18	2	Advisory	CPDS	NASA7	
7	OOT-19	2	Advisory	CPDS	NASA7	expect alt swap
8	LT-20	2	Advisory	CPDS	NASA7	
9	LT-21	2	Advisory	CPDS	NASA7	
10	LOB-9	3	Advisory	Advisory	NASA7	
11	LOB-10	3	AUTO	TCAS - AUTO	NASA7	

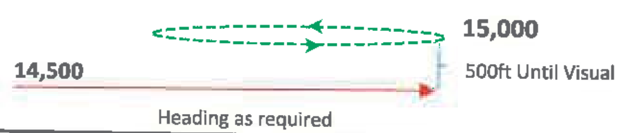
#GCS-1 — 090B165 — possibly runway 04 landing

MD

apocolipse now 870 1 NASA 7

NCC SCO ALTIMETER CALIBRATION (MEDIUM SPEED)





vis 3.7nm

Joined 0642

2992 set 15000 29.92 15050

29.86 15000

MR day VMC conditions

altimeter check when climbing above 20 K

give next call number during setup

REJOIN AND ALTITUDE CALIBRATION:

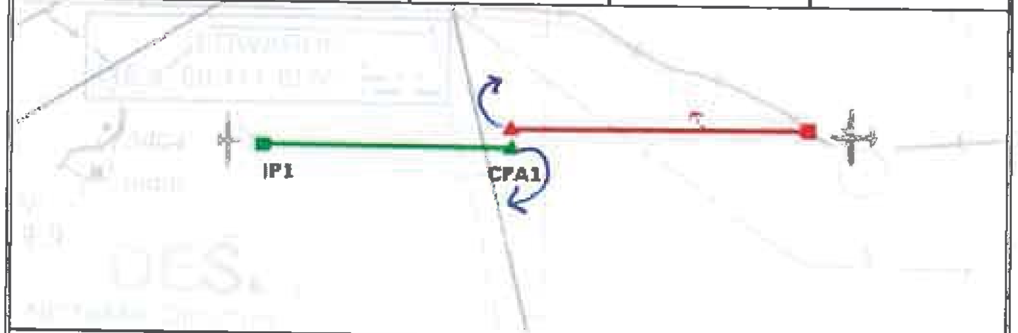
Start conditions ALL AIRCRAFT

- Joined, straight and level, 140 KIAS, heading as required
- 29.92

1. HOLD - left hand turns, at altitude
2. JOIN & SET - INTRUDER
   - Maintain 500 ft alt/sep until visual
   - INTRUDER "Joined, rollout heading AS/REQ"
3. REPORT - "29.92 set showing 15,###" - OWNSHIP / INTRUDER
4. ADJUST - altimeter to 15,000 - INTRUDER
   - Call "29.## showing 15,000"
   - maintain new altimeter setting for encounters
5. COMPLETE - "Complete, [callsign] cleared off <dir> <alt>"

PT	LATITUDE	LONGITUDE	OWNSHIP ALTITUDE	CHASE ALTITUDE	A/S
CPA2	N34° 54.14'	W117° 30.29'	15000		140 KIAS
	N34° 54' 08.2"	W117° 30' 17.4"			

NCC SCO	A/C: NASA870	Ku Only		
CARD# 1	KU-1			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
15500	150	IP1	None	NO



Ku Only
NO DLOS
Identify latencies in C2

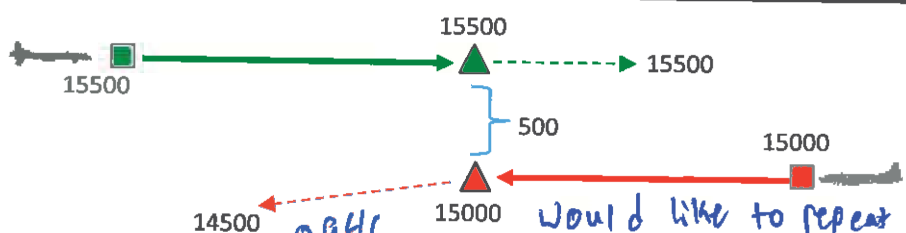
0653 in K.U

LOST LINK WAYPOINT:
LL WPT 4

DECONFLICTION ALT:
15500

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
15500	NAV TO LL WPT



0946

Would like to repeat ADS-B deselected

COMEX TIME: ~~0653~~ ~~0655~~

IP WIND:

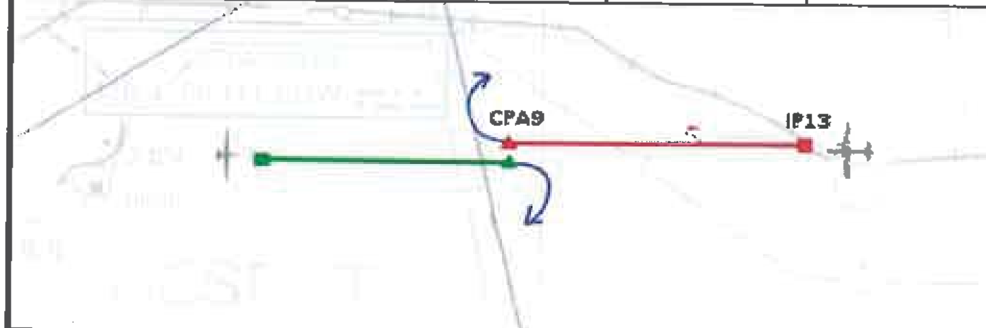
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP1	N34° 56.43'	W117° 37.07'	15500	5.0	150	2+00
	N34° 56' 26.0"	W117° 37' 04.1"	0	078		
CPA1	N34° 56.43'	W117° 30.97'	15500	0.0	150	
	N34° 56' 26.0"	W117° 30' 57.9"	0	078		

NOTES: Ownship will be in Ku Only. No DLOS

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	NONE		
Limit:	NO DESCENT		

TOLERANCE: ±10 sec

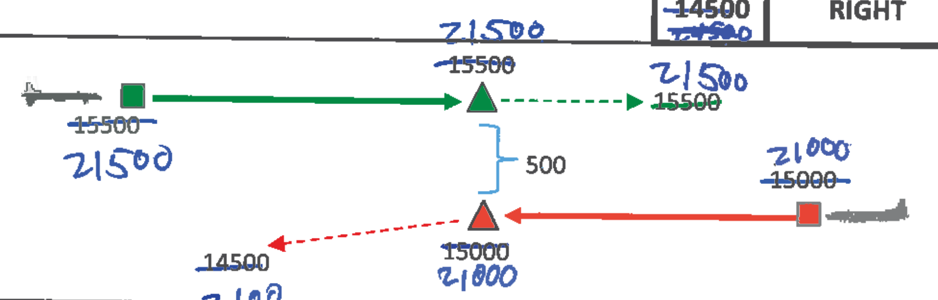
NCC SCO	A/C: NASA 7	Ku Only		
CARD# 1	KU-1			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
15000	180	IP13	None	NO



1.1nm U/S
2.2nm

DECONFLICTION ALT:
~~14500~~ ~~21500~~

ABORT PROCEDURE	
~~14500~~ ~~21500~~	RIGHT



COMEX TIME:

IP WIND:

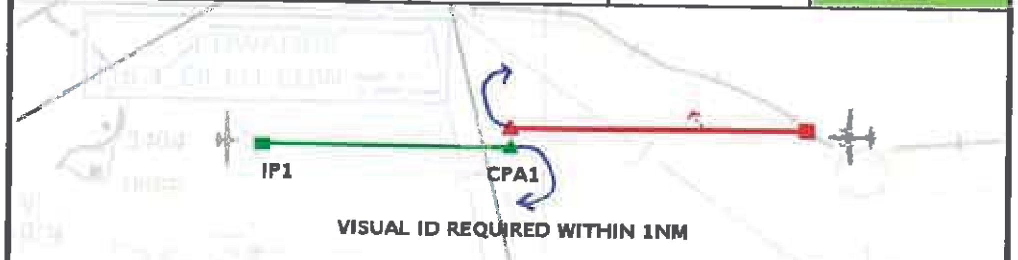
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP13	N34° 56.85'	W117° 23.64'	15000	6.0	180	2+00
	N34° 56' 50.9"	W117° 23' 38.6"	0	258		
CPA9	N34° 56.84'	W117° 30.98'	15000	0.0	180	
	N34° 56' 50.3"	W117° 30' 58.7"	0	258		

NOTES: Ownship flythrough

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA870	Ku Only
CARD# 2	KU-2	OWNSHIP

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
15300	150	IP1	CPDS	YES



Ku Only
NO DLOS
Identify latencies in C2

0703 KU only
lose nose cam in mc3

LOST LINK WAYPOINT:
LL WPT 4

DECONFLICTION ALT:
15300

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
15300	NAV TO LL WPT

left turn heading 007

COMEX TIME: 0705

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP1	N34° 56.43'	W117° 37.07'	15300	5.0	150	2+00
	N34° 56' 26.0"	W117° 37' 04.1"	0	078		
CPA1	N34° 56.43'	W117° 30.97'	15300	0.0	150	
	N34° 56' 26.0"	W117° 30' 57.9"	0	078		

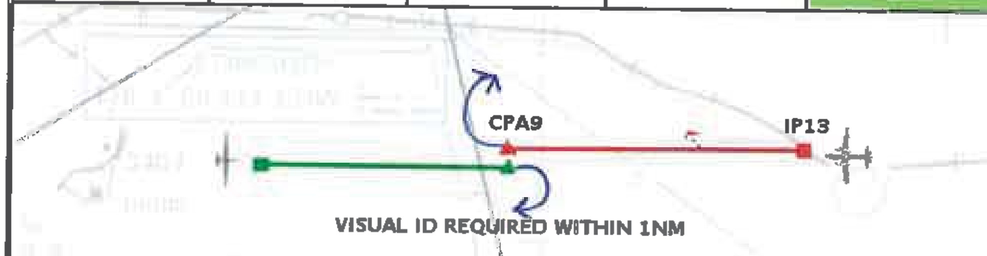
NOTES: Ownship will be in Ku Only. No DLOS

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT		

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA 7	Ku Only
CARD# 2	KU-2	INTRUDER 1

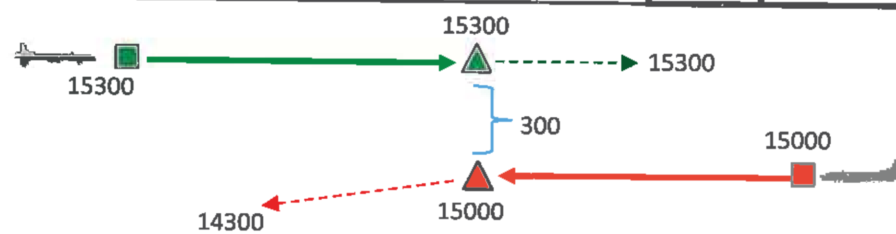
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
15000	180	IP13	None	YES



5.5nm vis

DECONFLICTION ALT:
14300

ABORT PROCEDURE	
14300	RIGHT



COMEX TIME:

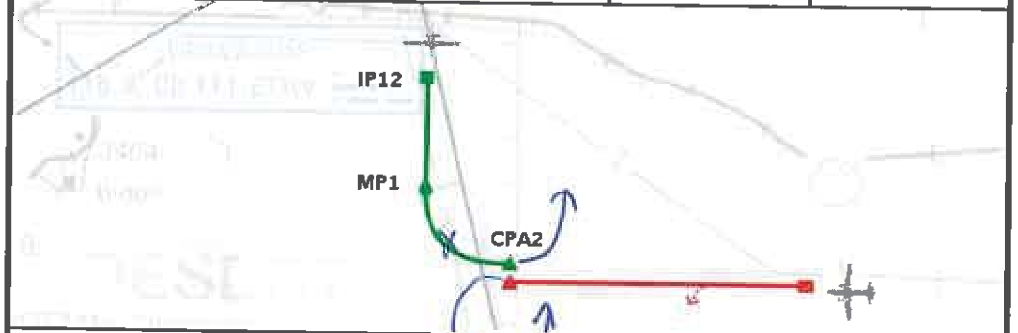
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP13	N34° 56.85'	W117° 23.64'	15000	6.0	180	2+00
	N34° 56' 50.9"	W117° 23' 38.6"	0	258		
CPA9	N34° 56.84'	W117° 30.98'	15000	0.0	180	
	N34° 56' 50.3"	W117° 30' 58.7"	0	258		

NOTES: Expect Ownship maneuver.

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA870		Ownship Turn and Descend	
CARD# 3	OTD-25			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
14000	150	IP12	CPDS	NO



Ownship Turn and Descend

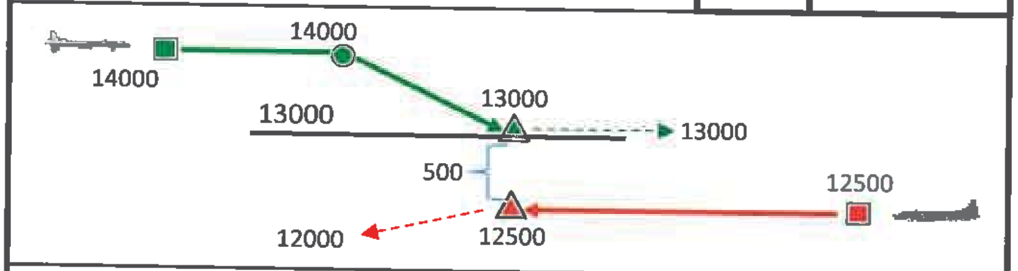
right turn

LOST LINK WAYPOINT:
LL WPT 8

DECONFLICTION ALT:
13000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
13000	NAV TO LL WPT



COMEX TIME: 0716

IP WIND:

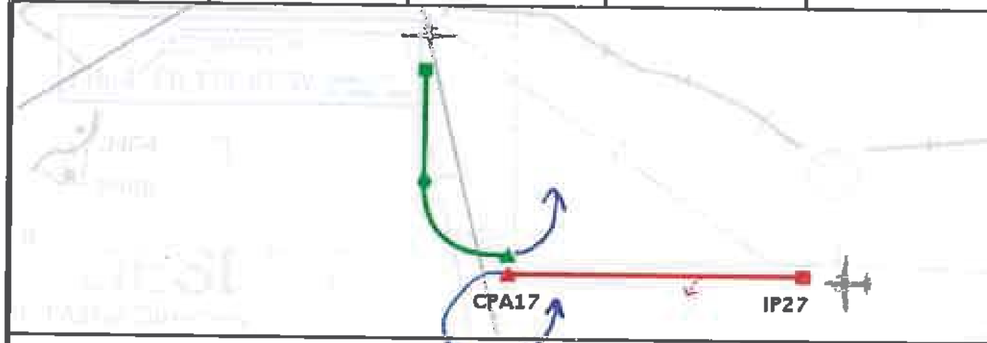
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP12	N34° 58.12'	W117° 32.36'	14000	4.8	150	2+00
	N34° 58' 07.2"	W117° 32' 21.8"	0	168		
MP1	N34° 55.73'	W117° 32.36'	14000	2.3	150	1+00
	N34° 55' 43.7"	W117° 32' 21.8"	-1000	168		
CPA2	N34° 54.14'	W117° 30.29'	13000	0.0	150	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Ownship Turn and Descend

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or lateral		
Limit:	NO DESCENT PAST FLOOR		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7		Ownship Turn and Descend	
CARD# 3	OTD-25			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12500	180	IP27	None	NO

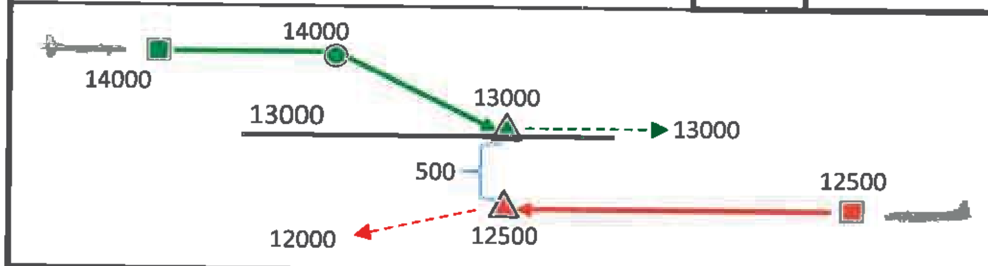


Ownship Turn and Descend

2.5nm

DECONFLICTION ALT:
12000

ABORT PROCEDURE	
12000	LEFT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP27	N34° 53.74'	W117° 22.98'	12500	6.0	180	2+00
	N34° 53' 44.2"	W117° 22' 58.5"	0	258		
CPA17	N34° 53.74'	W117° 30.29'	12500	0.0	180	
	N34° 53' 44.2"	W117° 30' 17.4"	0	258		

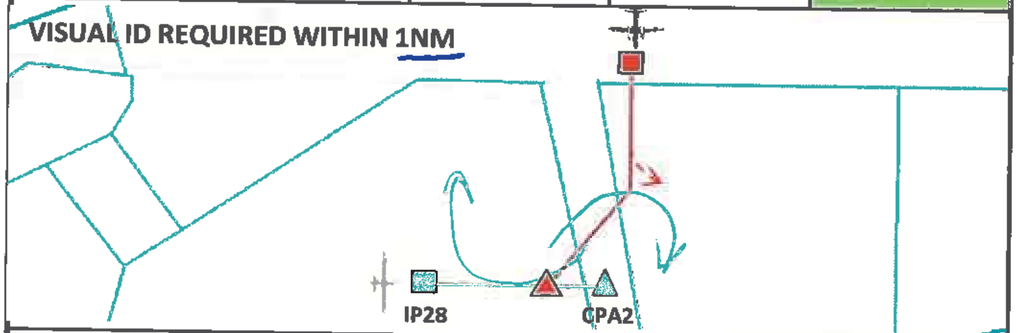
NOTES: Expect Ownship Maneuver

TOLERANCE: ± 8 sec

ADS-B - off

NCC SCO	A/C: NASA870		Use Case	
CARD# 4	UC-2			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
15000	150	IP28	CPDS	YES

VISUAL ID REQUIRED WITHIN 1NM



TC acts as ATC
Ownship descend at IP
During first corrective alert, follow guidance (left 30-40 deg)
Follow secondary DAA alert after intruder maneuver (level off)

left 030

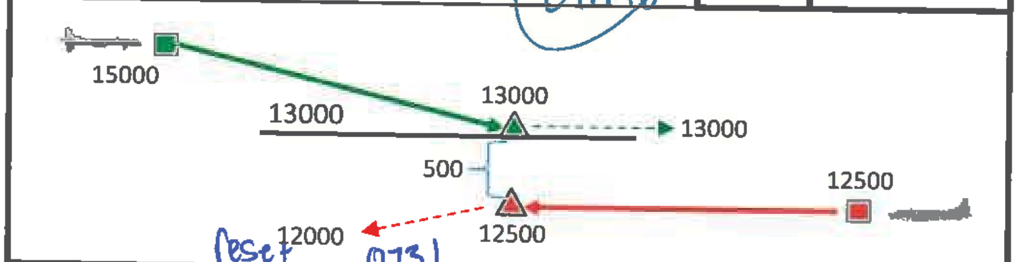
LOST LINK WAYPOINT:
LL WPT 7

DECONFLICTION ALT:
13000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

RA climb

ABORT PROCEDURE	
13000	NAV TO LL WPT



Reset ~~0726~~ ~~0729~~ 0731

COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP28	N34° 54.14'	W117° 36.40'	15000	5.0	150	2+00
	N34° 54' 08.2"	W117° 36' 24.1"	-1200	078		
CPA2	N34° 54.14'	W117° 30.29'	13000	0.0	150	
	N34° 54' 08.2"	W117° 30' 17.4"	0	078		

NOTES: Intruder maneuvers after ownship DWC maneuver. Causes change in secondary ownship DWC maneuver

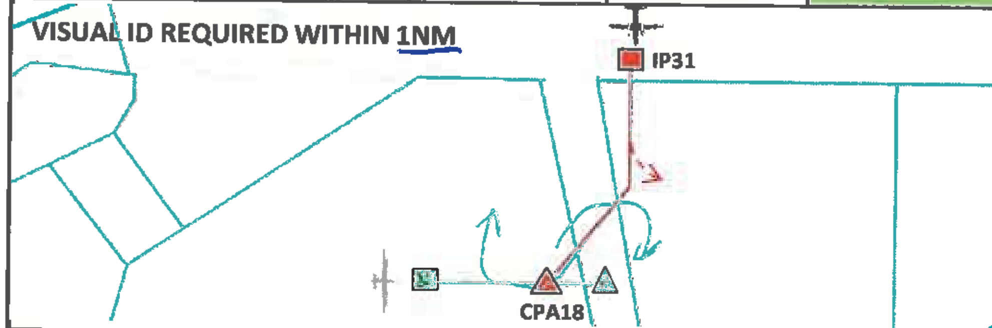
TOLERANCE: Not Required

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Lateral and/or Level off		
Limit:	NO DESCENT PAST FLOOR		

ADS-B - on

NCC SCO	A/C: NASA 7		Use Case	
CARD# 4	UC-2			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12500	180	IP31	None	YES

VISUAL ID REQUIRED WITHIN 1NM



TC acts as ATC
TC will call Intruder maneuver right 40 deg (heading 208)
following Ownship maneuver
Causes change in Ownship maneuver (expect ownship level off)

15Sec early + turning right 218

1.4nm vis

DECONFLICTION ALT:
12000

ABORT PROCEDURE	
12000	LEFT

COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP31	N35° 00.68'	W117° 29.34'	12500	7.5	180	2+00
	N35° 00' 40.7"	W117° 29' 20.1"	0	168		
CPA18	N34° 54.14'	W117° 32.31'	12500	0.0	180	
	N34° 54' 08.2"	W117° 32' 18.4"	0	208		

NOTES: Expect Ownship Maneuver. Follow direction from TC, expect additional Ownship maneuver

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870		Intruder Over Take	
CARD# 5	IOT-17			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	160	IP8	None	YES

Intruder Overtake.

~~VISUAL ID REQUIRED WITHIN 1NM~~

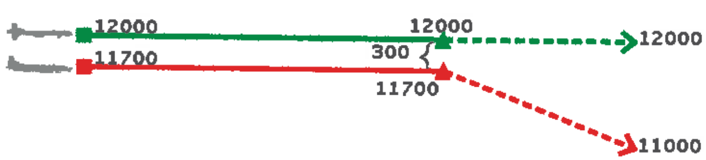
LOST LINK WAYPOINT: LL WPT 1

DECONFLICTION ALT: 12000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

12000	NAV TO LL WPT



COMEX TIME: 0741

IP WIND:

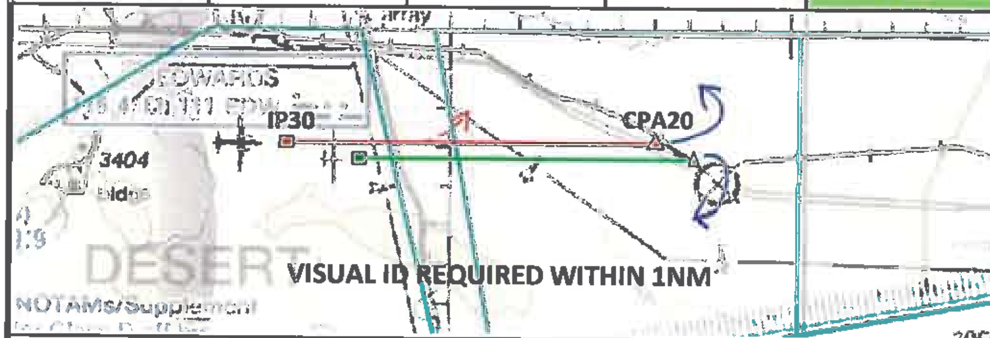
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP8	N34° 56.69'	W117° 32.78'	12000	8.0	160	3+00
	N34° 56' 41.4"	W117° 32' 46.9"	0	078		
CPA7	N34° 56.69'	W117° 23.02'	12000	0.0	160	
	N34° 56' 41.4"	W117° 23' 01.3"	0	078		

NOTES: Ownship Fly through

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	None		
Limit:	None		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7		Intruder Over Take	
CARD# 5	IOT-17			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
11700	180	IP30	None	YES



Intruder Overtake.
Remain 500ft Vertical Seperation until visual

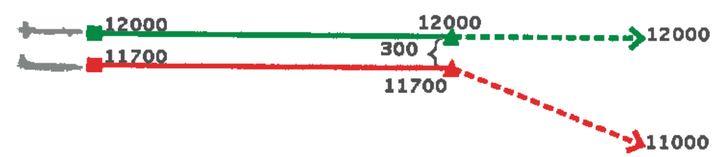
11500

DECONFLICTION ALT: 11000

4,5 nm

ABORT PROCEDURE

11000	LEFT



COMEX TIME:

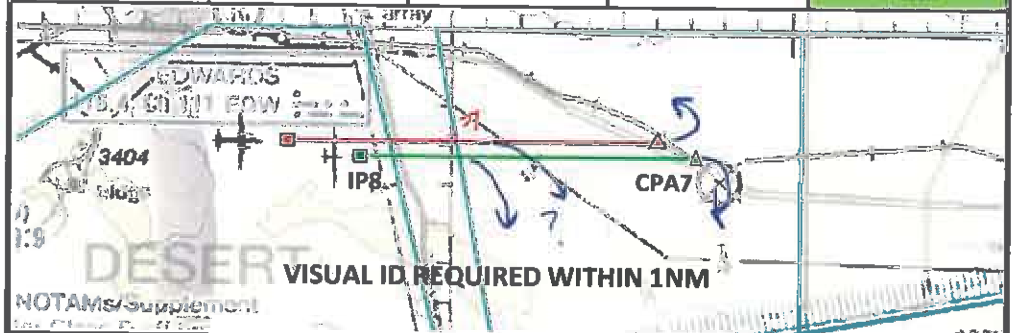
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP30	N34° 57.09'	W117° 34.87'	11700	9.0	180	-20 Kts +30 Kts 3+00
	N34° 57' 05.4"	W117° 34' 52.1"	0	078		
CPA20	N34° 57.09'	W117° 23.97'	11700	0.0	180	
	N34° 57' 05.4"	W117° 23' 58.2"	0	078		

NOTES: Ownship Fly through

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Intruder Over Take		
CARD# 6	IOT-18			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	160	IP8	CPDS	YES



Intruder Overtake. RA at IP - reset

right turn

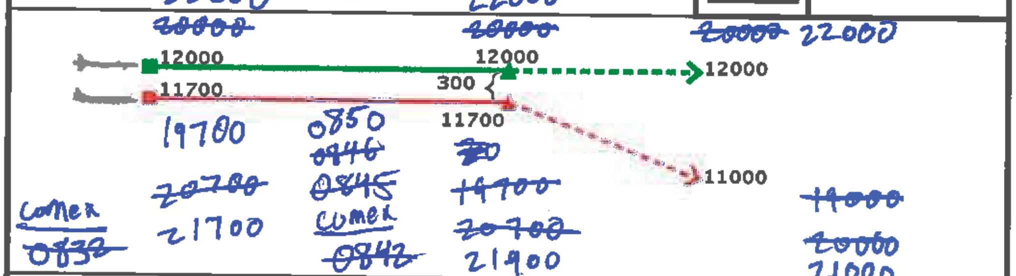
LOST LINK WAYPOINT: LL WPT 1

DECONFLICTION ALT: ~~12000~~ 22000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

22000 ABORT PROCEDURE

~~12000~~	NAV TO LL WPT



COMEX TIME: ~~0751~~ ~~0754~~

IP WIND:

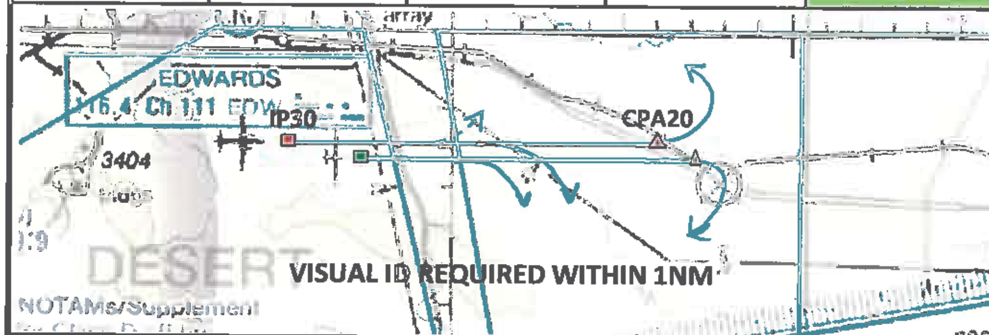
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP8	N34° 56.69'	W117° 32.78'	12000	8.0	160	3+00
	N34° 56' 41.4"	W117° 32' 46.9"	0	078		
CPA7	N34° 56.69'	W117° 23.02'	12000	0.0	160	
	N34° 56' 41.4"	W117° 23' 01.3"	0	078		

NOTES: Ownship Maneuver, Follow CPDS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or Right		
Limit:	NO DESCENT / NO LEFT		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7	Intruder Over Take		
CARD# 6	IOT-18			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
11700	180	IP30	None	YES



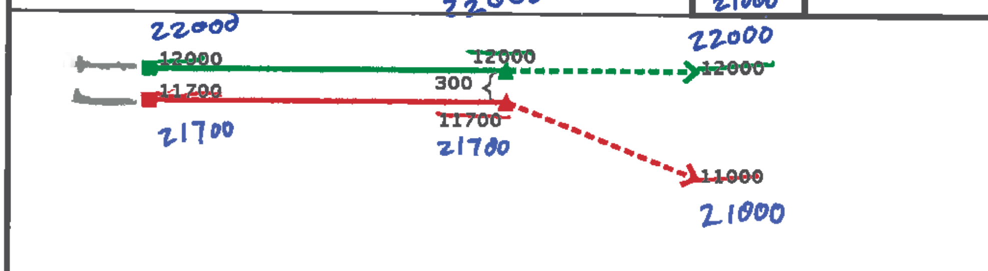
Intruder Overtake.
Remain 500ft Vertical Seperation until visual

21500 before

DECONFLICTION ALT: ~~11000~~ 21000

3.4nm vis, 2nm vis, 1.8nm vis 2.7nm vis ABORT PROCEDURE

~~11000~~ 21000	LEFT



COMEX TIME:

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP30	N34° 57.09'	W117° 34.87'	11700	9.0	180	3+00
	N34° 57' 05.4"	W117° 34' 52.1"	0	078		
CPA20	N34° 57.09'	W117° 23.97'	11700	0.0	180	
	N34° 57' 05.4"	W117° 23' 58.2"	0	078		

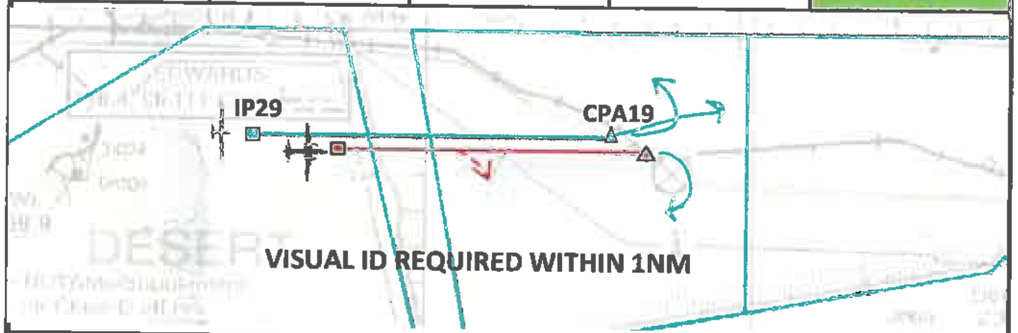
NOTES: Maneuvering Ownship

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Ownship Over Take

CARD# 7 — **OOT-19** — **OWNSHIP**

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	180	IP29	CPDS	YES



Ownship Overtake

May need to nearest airspace north

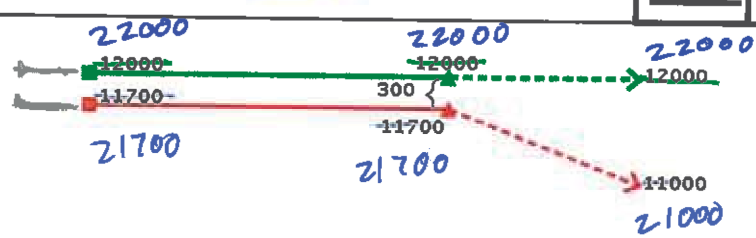
left turn

LOST LINK WAYPOINT:
LL WPT 2

DECONFLICTION ALT:
~~12000~~ 22000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
22000 ~~12000~~	NAV TO LL WPT



~~0900~~ 0906

COMEX TIME: ~~0902~~ ~~0903~~

IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP29	N34° 57.09'	W117° 35.24'	12000	9.5	180	3+00
	N34° 57' 05.4"	W117° 35' 14.6"	0	078		
CPA19	N34° 57.09'	W117° 24.30'	12000	0.0	180	
	N34° 57' 05.4"	W117° 24' 18.2"	0	078		

NOTES: Ownship maneuver, Follow CPDS guidance.

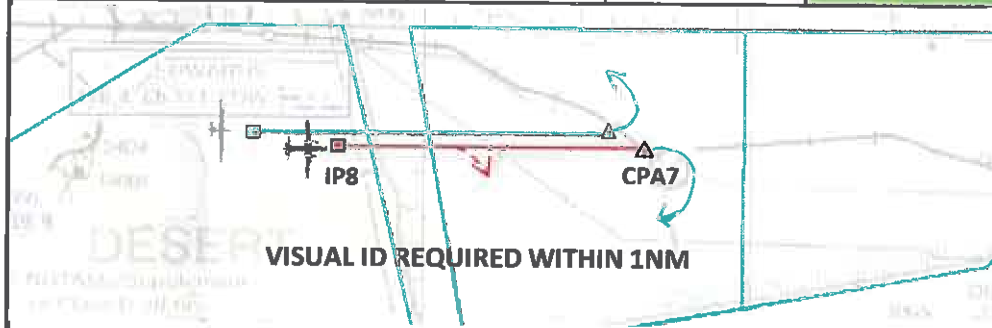
Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Up and/or Left		
Limit:	NO DESCENT / NO RIGHT		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7	Ownship Over Take

CARD# 7 — **OOT-19** — **INTRUDER 1**

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
11700	160	IP8	None	YES



Ownship Overtake

Remain 500ft Vertical Seperation until visual

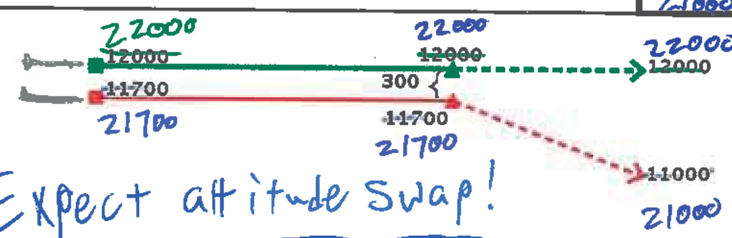
21500 until visual

DECONFLICTION ALT:
~~11000~~

21000

2.x.A.M.

ABORT PROCEDURE	
~~11000~~ 21000	RIGHT



Expect altitude swap!

COMEX TIME:

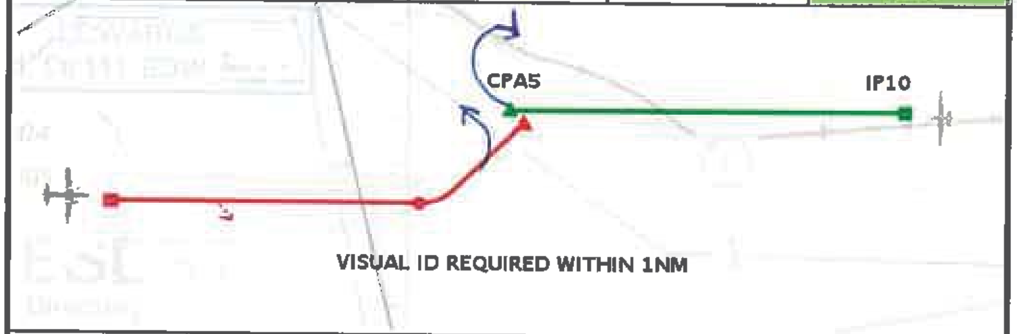
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP8	N34° 56.69'	W117° 32.78'	11700	8.0	160	3+00
	N34° 56' 41.4"	W117° 32' 46.9"	0	078		
CPA7	N34° 56.69'	W117° 23.02'	11700	0.0	160	
	N34° 56' 41.4"	W117° 23' 01.3"	0	078		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Intruder Left 45		
CARD# 8	LT-20			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	160	IP10	CPDS	YES



Intruder Left 45 deg turn.

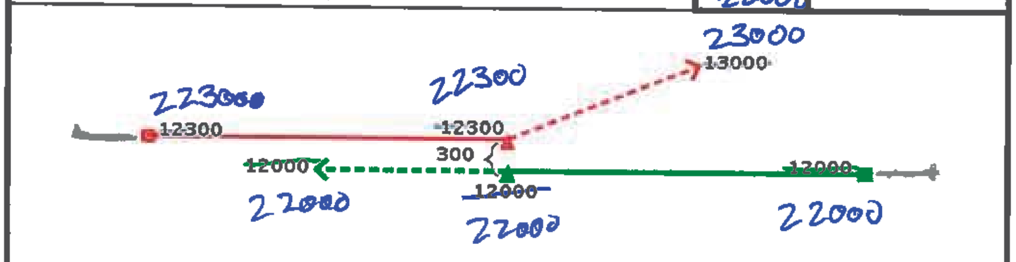
right turn

LOST LINK WAYPOINT: LL WPT 10

DECONFLICTION ALT: ~~12000~~ 22000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
~~12000~~ 22000	NAV TO LL WPT



COMEX TIME: 0615

IP WIND:

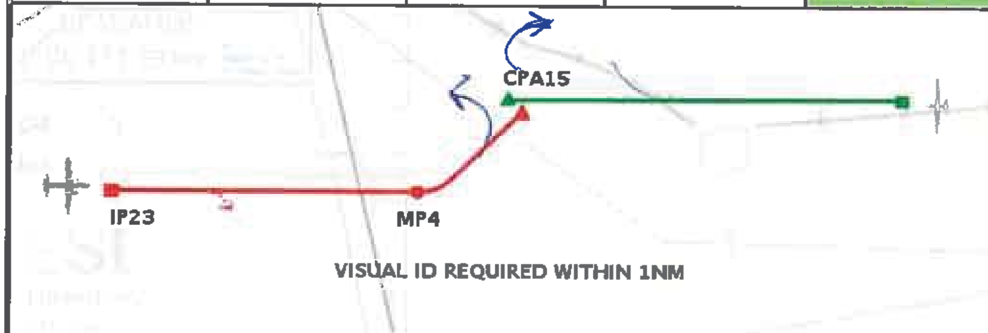
WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP10	N34° 57.09'	W117° 17.86'	12000	8.0	160	3+00
	N34° 57' 05.4"	W117° 17' 51.6"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	12000	0.0	160	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

NOTES: Ownship maneuver, Follow CPDS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7	Intruder Left 45		
CARD# 8	LT-20			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12300	180	IP23	None	YES



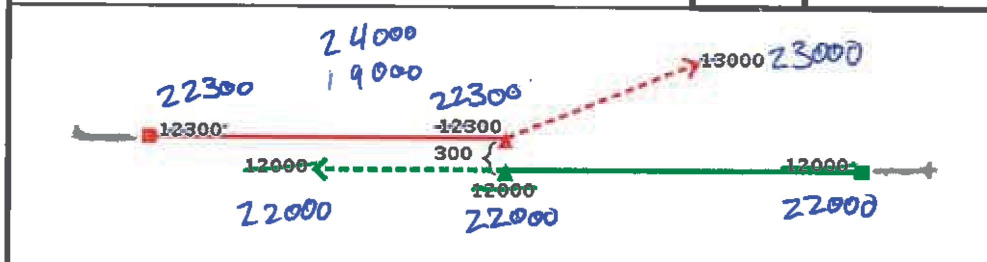
Intruder Left 45 deg turn.

fly over mp4

DECONFLICTION ALT: ~~13000~~ 23000

3nm vis

ABORT PROCEDURE	
~~13000~~ 23000	RIGHT



COMEX TIME:

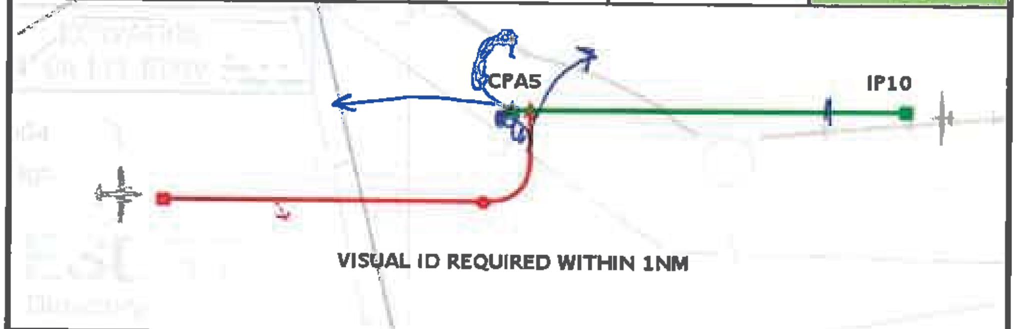
IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP23	N34° 55.09'	W117° 37.44'	12300	9.0	180	2+06
	N34° 55' 05.4"	W117° 37' 26.1"	0	078		
MP4	N34° 55.09'	W117° 29.85'	12300	2.7	180	0+54 7
	N34° 55' 05.4"	W117° 29' 51.1"	0	078		
CPA15	N34° 56.81'	W117° 27.28'	12300	0.0	180	
	N34° 56' 48.4"	W117° 27' 16.5"	0	033		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Intruder Left 90		
CARD# 9	LT-21			OWNSHIP
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12000	160	IP10	CPDS	YES



Intruder Left 90 deg turn

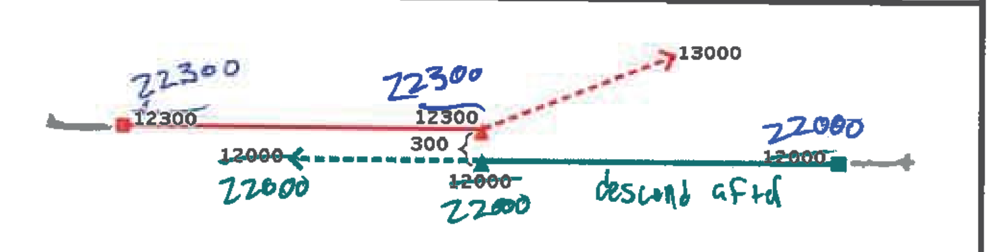
LOST LINK WAYPOINT:
LL WPT 10

DECONFLICTION ALT:
~~12000~~ 22000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

~~12000~~ 22000	NAV TO LL WPT



COMEX TIME: 0925 0935

IP WIND:

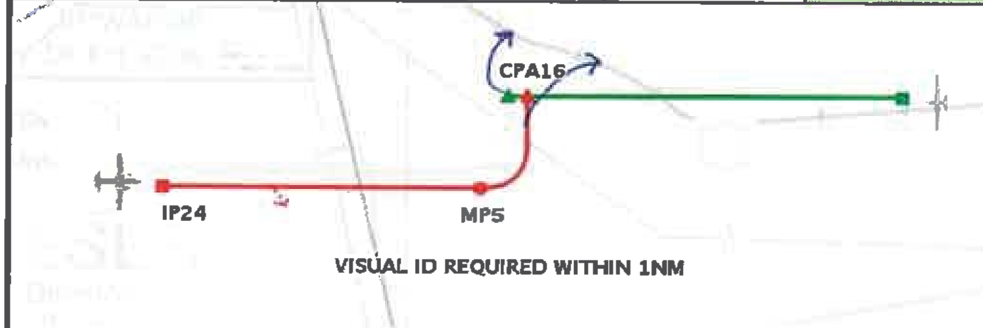
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP10	N34° 57.09'	W117° 17.86'	12000	8.0	160	3+00
	N34° 57' 05.4"	W117° 17' 51.6"	0	258		
CPA5	N34° 57.09'	W117° 27.62'	12000	0.0	160	
	N34° 57' 05.4"	W117° 27' 37.2"	0	258		

NOTES: Ownship maneuver, Follow CPDS guidance

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down and/or lateral		
Limit:	NO CLIMB		

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA 7	Intruder Left 90		
CARD# 9	LT-21			INTRUDER 1
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12300	180	IP24	None	YES



Intruder Left 90 deg turn

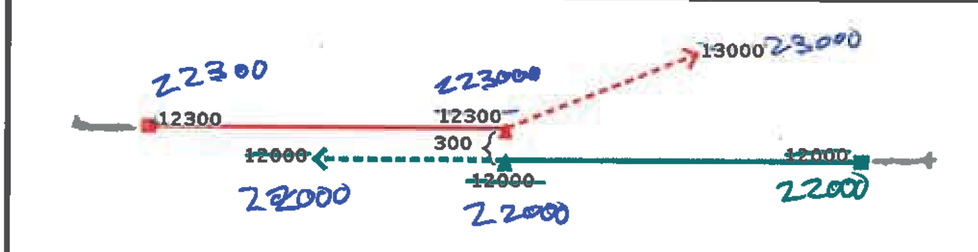
fly over mp5 1.2nm

DECONFLICTION ALT:
~~13000~~ 23000

2.4nm v/s

ABORT PROCEDURE

~~13000~~ 23000	RIGHT



COMEX TIME:

IP WIND:

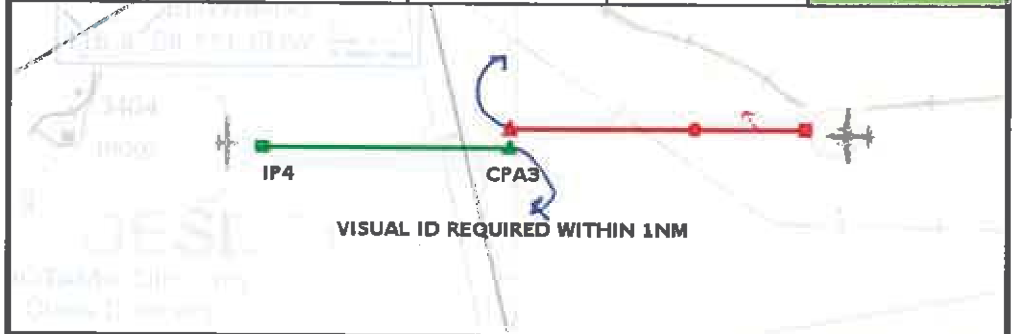
WPT	LATITUDE	LONGITUDE	ALT V/V	DIST MC	KGS	LEG TIME
IP24	N34° 55.09'	W117° 36.17'	12300	6.5	180	2+10
	N34° 55' 05.4"	W117° 36' 10.1"	0	078		
MP5	N34° 55.09'	W117° 28.30'	12300	2.5	180	0+50
	N34° 55' 05.4"	W117° 28' 17.8"	0	078		
CPA16	N34° 57.09'	W117° 27.13'	12300	0.0	180	
	N34° 57' 05.4"	W117° 27' 07.9"	0	348		

NOTES: Expect Ownship maneuver.

TOLERANCE: ± 8 sec

NCC SCO	A/C: NASA870	Level Off Blunder
CARD# 10	LOB-9	OWNSHIP

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
10000	150	IP4	TCAS	YES



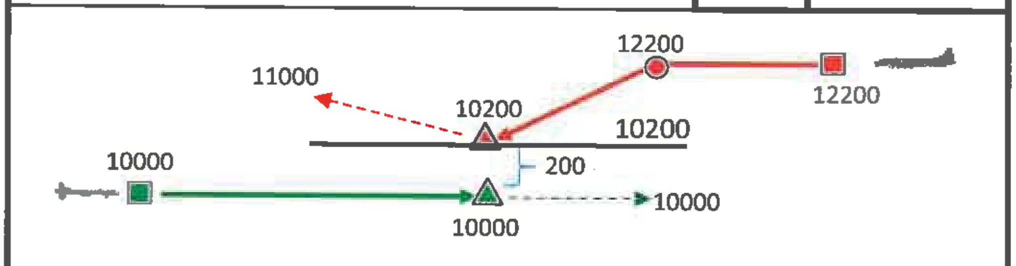
Intruder Level Off Blunder
Follow TCAS Alert
include more detail

LOST LINK WAYPOINT:
LL WPT 5

DECONFLICTION ALT:
10000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE	
10000	NAV TO LL WPT



COMEX TIME: ~~0954~~ 0956 | IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP4	N34° 55.64'	W117° 36.37'	10000	5.0	150	2+00
	N34° 55' 38.4"	W117° 36' 22.1"	0	078		
CPA3	N34° 55.64'	W117° 30.29'	10000	0.0	150	
	N34° 55' 38.5"	W117° 30' 17.4"	0	078		

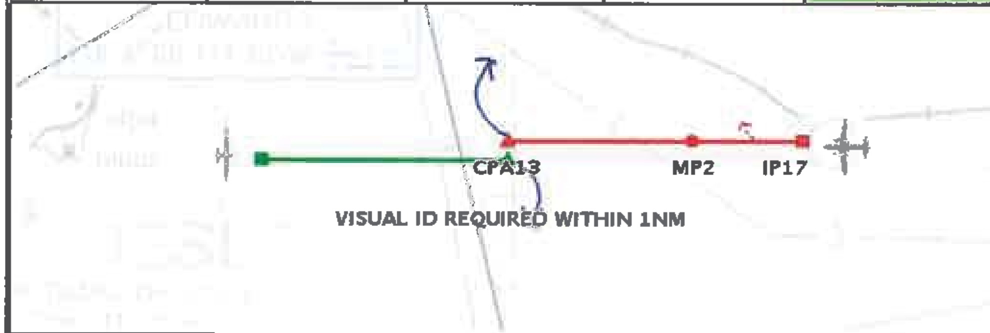
NOTES: Level Off Blunder

Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down ~~and/or lateral~~		
Limit:	NO CLIMB		

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA 7	Level Off Blunder
CARD# 10	LOB-9	INTRUDER 1

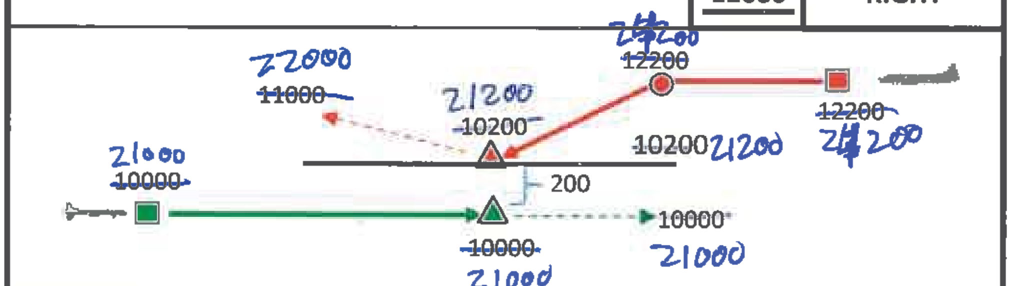
INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12200	180	IP17	None	YES



Intruder Level Off Blunder
Begin Descent at MP2 1.7nm

DECONFLICTION ALT:
11000

ABORT PROCEDURE	
11000	RIGHT



COMEX TIME: | IP WIND:

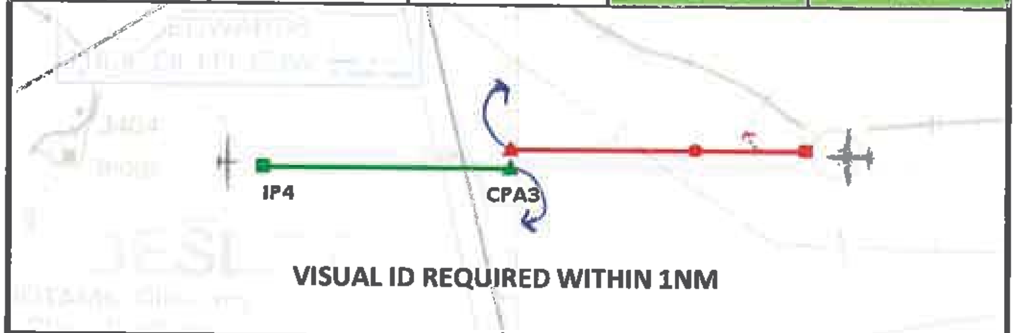
WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP17	N34° 56.04'	W117° 23.00'	12200	6.0	180	2+00
	N34° 56' 02.4"	W117° 22' 59.7"	0	258		
MP2	N34° 56.04'	W117° 25.73'	12200	4.5	180	1+00
	N34° 56' 02.5"	W117° 25' 43.7"	-2000	258		
CPA13	N34° 56.04'	W117° 30.29'	10200	0.0	180	
	N34° 56' 02.6"	W117° 30' 17.4"	0	258		

NOTES: Expect Ownship maneuver.

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA870	Level Off Blunder	
CARD# 11	LOB-10		OWNSHIP

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
10000	150	IP4	AUTO	YES



Intruder Level Off Blunder
Follow TCAS Alert in AUTO

~25sec

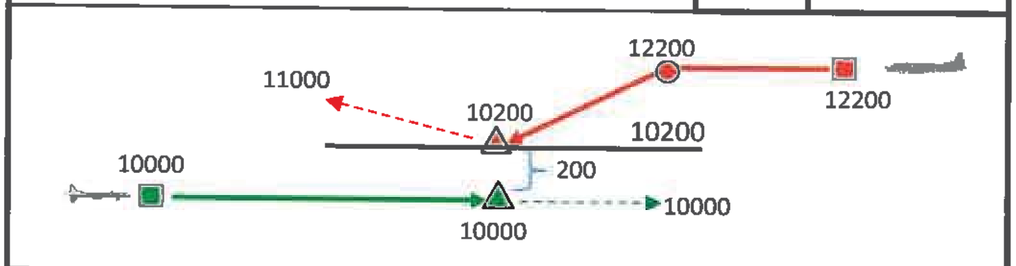
LOST LINK WAYPOINT: LL WPT 5

DECONFLICTION ALT: 10000

Sensor:	ACTIVE	ADS-B	ATAR
MANEUVER:	OFF	Advisory	AUTO

ABORT PROCEDURE

10000	NAV TO LL WPT



COMEX TIME: 1006 | IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP4	N34° 55.64'	W117° 36.37'	10000	5.0	150	2+00
	N34° 55' 38.4"	W117° 36' 22.1"	0	078		
CPA3	N34° 55.64'	W117° 30.29'	10000	0.0	150	
	N34° 55' 38.5"	W117° 30' 17.4"	0	078		

NOTES: Level Off Blunder

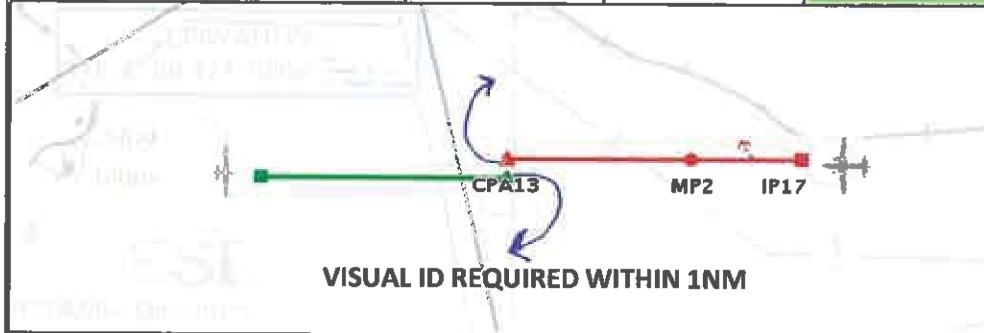
Maneuver:	YES	NO	
Guidance:	NONE	CPDS	TCAS
Direction:	Down ~~and/or lateral~~		
Limit:	NO CLIMB ~~/ no left~~		

~~Down and lat~~

TOLERANCE: ±10 sec

NCC SCO	A/C: NASA 7	Level Off Blunder	
CARD# 11	LOB-10		INTRUDER 1

INITIAL ALT	INITIAL SPEED	INITIAL WPT	RESPONSE	VID
12200	180	IP17	None	YES



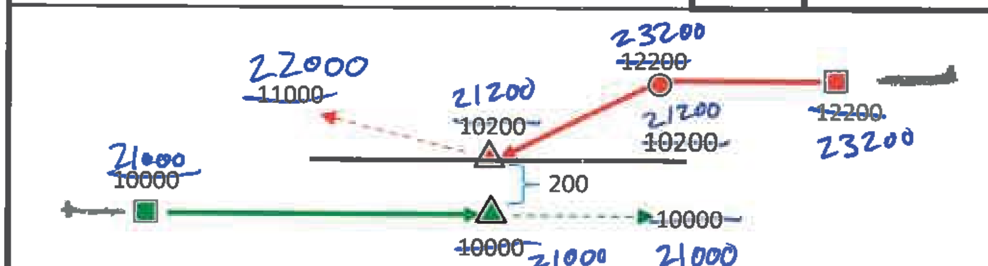
Intruder Level Off Blunder
Begin Descent at MP2

3nm

DECONFLICTION ALT: 11000

ABORT PROCEDURE

11000	RIGHT



COMEX TIME: | IP WIND:

WPT	LATITUDE	LONGITUDE	ALT / V/V	DIST / MC	KGS	LEG TIME
IP17	N34° 56.04'	W117° 23.00'	12200	6.0	180	2+00
	N34° 56' 02.4"	W117° 22' 59.7"	0	258		
MP2	N34° 56.04'	W117° 25.73'	12200	4.5	180	1+00
	N34° 56' 02.5"	W117° 25' 43.7"	-2000	258		
CPA13	N34° 56.04'	W117° 30.29'	10200	0.0	180	
	N34° 56' 02.6"	W117° 30' 17.4"	0	258		

NOTES: Expect Ownship maneuver.

TOLERANCE: ±10 sec

6.6 TCOR Notes

Below are the raw TCOR notes from SCO 2 and 3 where data was collected.

Table 22. No Chase COA System Checkout Flight 2 Data and Observation Notes.

	Ikhana	NASA 856	NASA 808
Take Off	7:06	6:58	8:15
RTB	10:54	8:33	10:54
Land	11:18	8:47	11:22
Squawk	0403 / 0024	0426 / 0023	0037
ALT	29.92		

MCC3	Zeus Nominal // Complete			
LVC	Nominal			
GCS	All systems under test are up and nominal			
Admin	Time Hack 1	7:12	Time Hack 2	8:47
Other	Sport // Mercury Spin and Four Corners 060B100 //			

Number of Repeats	1
Number of Resets	1
Number of Rolexs	7

Alt Cal	Intruder	Ownship Altitude	Ownship Pressure	Altitude at Ownship's Pressure	Pressure at Ownship's Altitude	Corrective Altitude
	856	9000	29.92	8950	29.95	9000
	808	15000	29.92	15040	29.86	15000

Run #	Name or S/N	Sign	COMEX	Start or tol. (sec)	VID (NM)	FL Init (M3)	IP KGS (Zeus)	IP Wind	Termination Time	TA	RA	Maneuver	Results/Notes	
1	SQK-6 - No VID	870	0726	0		090	on	325/11	7:28:43	Yes	Yes	Fly Through	RA Monitor V/S	This is an example
		856		0	1.1	085	-60						STRATUS not picking up ADS-B	
1	SQK-6 - No VID	870	0726	0		090	on	325/11	7:28:43	Yes	Yes	Fly Through	RA Monitor V/S	
		856		0	1.1	085	on						STRATUS not picking up ADS-B	
2	SQK-6	870	0738	0		090	on		7:39:40			Left Turn	Left turn to the north	
		856		0	4.5	085	+5						A bit high; diving into IP for speed	Not receiving STRATUS
3	SQK-7	870	0748	0		090	on		7:49:14	Yes		Right Turn		
		856		0	Yes	085	0						Track 856 off Zeus; maintain 085	Light chop at 8500
4	SQK-8 - abort	870	0801	0		090	on		abort				abort abort abort; lost KU; DAA system went down	Turning on mode C
		856		-5		087	-5							7 gallons remaining
5	SQK-8	870	0809	-2		090	on		8:10:45			Right Turn		
		856		10	2.6	086	on							
6	LALT-24	870	0820	0		062	on		8:23:15	Yes	Yes	Fly Through	Receiving RA, Red banding at 2.4 nm Climb 1000 fpm	
		856		+5	1	060	+10						Continued in mode C	NASA 808 Taxing 0819
7	LALT-25	870	0830	0:00:00		062	on		8:32:24	Yes		Right Turn	Right turn, yellow banding	020/13
		856		-5		057							Squawk off; joker; still dropping 856 track on Zeus; running encounter at 057	
8	ATCAS-22 NoVID	856	0859	+5		210	on		8:59:46	Yes	Yes	Fly Through	RA before IP - Fly Through	ALT Cal with 808 at 15000
		808		-20	0.5	205	+60						Called ROLEX; had RA - followed it	
9	ATCASS-22	856	0915	0		on	on	870:244@46	9:16:12	Yes	Yes		No increased alert for TCAS	Red line: No decent; 09:05:00; winds 245/53
		808		-15	0.5		+50	245:53@20.5					ROLEX	
10	ATCAS-23	870	0928			on			9:29:30	Yes	Yes		Climb; Auto to clear of conflict	Visual required 2 miles
		808		+5	2.5	on	+60						ROLEX	Sport 16000 22000
11	NUIS-13	870	0945	0		160	on		9:47:03	Yes		Left Turn; heading 190	16000 IP	Sport 160-220 7000 across board; moved to card 11 due to altitude restriction; abort deconfliction 17000
		808		+10			+60						Decent to 19000	
12	NUIS-14	870	0956	0		090	+40		9:58:20	Yes			Decent at 09:57:08	Run card as is
		808		0	2	120	+6							
13	DB-15	870	1020	0		070	-5		10:22:00	Yes	Yes	Left Turn; leveling at 8000	Bad SAAP; reset SAAP and radar	ROLEX
		808		0		125	+17							
14	HS-11	870	1033	0		090	+2		10:35:24	Yes	Yes	Fly Through	TA monitor Vertical Speed; RA at 6.8 nm	ROLEX
		808		+5	1.7	086	-6		0	Yes	Yes		808 RA at 2.6 nm	
15	TM-1	870	1041	+5		120	+20		10:42:47	Yes	Yes	Fly Through	Test mode set to 253; TA at 4 nm	ROLEX; abort abort abort - no visual
		808		-15	0.7	118	-3						0.75 nm visual	
16	HDR-16	870	1051	0		105	+22		10:53:39			Fly Through		Test mode is 0
		808		-5		201	+70							ROLEX

Table 23. No Chase COA System Checkout Flight 3 Attempt 2 Data and Observation Notes.

	Ikhana	NASA7
Take Off	0605	0630
RTB	10:00	10:00
Land	10:25	10:24
Squawk	0477	0401
ALT		

MCC3	Zeus Nominal // Complete			
LVC	Nominal			
GCS	All systems under test are up and nominal			
Admin	Time Hack 1		Time Hack 2	
Other	Sport // Mercury Spin and Four Corners 060B100 //			

Number of Repeats	1
Number of Resets	4
Number of Aborts	1
ROLEX Count	6

Alt Cal	Intruder	Ownship Altitude	Ownship Pressure	Altitude at Ownship's Pressure	Pressure at Ownship's Altitude	Corrective Altitude
	NASA7	15000	29.92	15050	29.86	15000

Intruder Initial altitude (in the "FL Init (M3)" column) read from Zeus

Run #	Name or S/N	Sign	COMEX	Start or tol. (sec)	VID (NM)	FL Init (M3)	IP KGS (Zeus)	IP Wind	Termination Time	TA	RA	Maneuver	Quality	Results/Notes	
1	KU-01	870	0655	-20		155	on		6:57:00	Yes	Yes	Fly Through			No C-Band (up/down); C-Band back up after terminate
	KU-01	7		+7	1	152	on			Yes					
2	KU-02	870	0705	+3		150	on		7:06:43	Yes		Left			No C-Bank up/down; C-Band between cards
	KU-02	7		-23	5.5	152	-5								
3	OTD-25	870	0716	+10		150	+15		7:18:11	Yes		Right			GDT back on; ADS-B off
	OTD-25	7		+15	2.5	180	+26								
4	UC-02	870	0731	+2		149	+3		7:32:57	Yes	Yes	Climb		ADS-B on	initial COMEX: 0726 > ROLEX, 0729 > Reset: 0731; target it 218 (late start)
	UC-02	7		-10	1.4	127	on			Yes				Reset - intruder 40 seconds early	
5	IOT-17	870	0741	+10		120	+13		7:45:08	Yes	Yes	Fly Through			HDIV Fusion; initially 4 NM ADS-B Only; Need 60 Sec to 3 NM;; No active surveillance until 1.2 NM
	IOT-17	7		+60	4.5	119	+45							Visual before IP	Only ADS-B from intruder
6	IOT-18	870	0850	-10		220	+2		8:52:30	Yes		Right		All alt +10000 (including abort and deconfliction)	COMEX: 0751 > ROLEX, new COMEX: 0752 > Reset: bad approach. Both aircraft were angled incorrectly (course wasn't parallel), timing was off, early RA altering due to bad set up Adding 10000 ft altitude to all encounters (intruder and ownship). SPORT placed an 18000 ft restriction in Mercury Spin (move to 4C) , so to continue flight testing (to not wait an hour), we moved above this restricted area second attempt (after settling SPORT issue; encounter still hasn't been completed), COMEX: 0832 > abort abort abort: sensors feedback went off on its own. Sensors turned back on (on its own) (reason unknown) third attempt: COMEX: 0842 > Reset > forth attempt: new COMEX: 0845 > ROLEX, new COMEX: 0846: Reset: bad intruder approach fifth attempt: COMEX: 0850
	IOT-18	7		+6	2.4	220	+60							All alt +10000 (including abort and deconfliction) (MS+4C) (870/220)	~0756 Sport order to wait at least an hour (traffic in the west and east). Intruder alt down to 11k for 1000ft separation during 1 hour wait PIRA 0810 180
7	OOT-19	870	0906	+5		220	-40		9:08:10	Yes	Yes	Left		All alt +10000 (including abort and deconfliction)	Position Swap 870 N 7S; adjusting for run in line reposition
	OOT-19	7		+18	2	217	+29							All alt +10000 (including abort and deconfliction)	ROLEX from 0900 to 0902; ROLEX from 0902 to 0903; ROLEX from 0903 to 0906; PIRA open in +25 0905
8	LT-20	870	0915	on		220	+4		9:17:34	Yes	Yes	Right		All alt +10000 (including abort and deconfliction)	TC switch from Steffi to Alex (TC in training)
	LT-20	7		-60	2.5	225	-16			Yes				All alt +10000 (including abort and deconfliction)	
9	LT-21	870	0925	+6		220	+27		9:27:57	Yes	Yes	Descent		All alt +10000 (including abort and deconfliction)	No TA due to 1300ft separation - repeat: Early TA at beginning of encounter, since advisory of 1000ft descent was taken, which was the cause of the 1300ft sep.
	LT-21	7		-25	2.1	225	+48							All alt +10000 (including abort and deconfliction)	
10	LT-21 - Repeat	870	0935	+2		220	+20		9:31:06	Yes	Yes	Descent		All alt +10000 (including abort and deconfliction)	
	LT-21 - Repeat	7		-30	1.1	226	+10							All alt +10000 (including abort and deconfliction)	
11	KU-01 - Repeat	870	0946	+7		215	+40		9:48:32	Yes	Yes	Fly Through		New Altitudes: IP: 21500 CPA: 21500 Abort: 21500 Deconfliction: 21500	ADS-B sensor deselected
	KU-01 - Repeat	7		+40	2.1	212	-7			Yes				New Altitudes: IP: 21000 CPA: 21000 Abort: 14500 Deconfliction: 14500	
12	LOB-9	870	0956	+3		210	+20		9:58:00	Yes	Yes	Descent		New Altitudes: IP: 21000 CPA: 21000 Abort: 21000 Deconfliction: 21000	TC called wrong ALT initially, corrected. Audio response
	LOB-9	7		+17	1.5	234	+57			Yes				New Altitudes: IP: 24200 MP: 24200 CPA: 21200 Abort: 22000 Deconfliction: 22000	
13	LOB-10	870	1006	on		210	+2		10:08:09	Yes	Yes	Descent		New Altitudes: IP: 21000 CPA: 21000 Abort: 21000 Deconfliction: 21000	
	LOB-10	7		+22	2.8	235	+13			Yes				New Altitudes: IP: 23200 MP: 23200 CPA: 21200 Abort: 22000 Deconfliction: 22000	