COVER SHEET
Access 5 Project Deliverable

Deliverable Number: *SIM001*

Title: *Detailed Airspace Operations Simulation Plan*

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Abstract:
Initial Definition of AOS simulator requirements, analysis methodology and schedule. Provides details regarding implementation of high-altitude air traffic services in the laboratory environment for evaluation of routine UAS operations above FL400 (since adjusted to above FL430 to avoid RVSM issues). This document provides the initial plan for Access 5 Step 1 AOS activities, and provides and overview of simulation capabilities.

Status:

SEIT-Approved

Limitations on use:
This document was intended as an Access 5 internal document for aligning simulation capabilities with inter-IPT needs. It usefulness proved limited, as direct communication and evolving requirements proved the only adequate means of meeting IPT needs. For that reason, this document was not officially updated. Deliverable SIM005 (preliminary findings report) documents the relationships and processes that developed for managing simulation requirements, and further documents the capabilities that were actually utilized in the first two series of Airspace Operations Simulations.

High Altitude Long Endurance Remotely Operated Aircraft

- National Airspace System Integration -

Simulation IPT

Detailed AOS Plan
Version 1.0
30 September 2004

Executive Summary

The Access 5 Detailed Step 1 Airspace Operations Simulation Plan provides the template for the Simulation IPT to follow in conducting simulations activities, and the project infrastructure within which the simulation tasks must be performed. The Simulation IPT role, its goals and assumptions are stated, and the relationships employed to communicate information among Access 5 entities and external parties are defined as well. The method of simulation conduct is described and includes the following: participants and qualifications, facilities employed, simulation procedures, scenario generation, data collection and analyses methods, and a tentative schedule.

Through comprehensive simulation, the Simulation IPT is to compliment a Flight Demonstration program in the evaluation of technologies, policies and procedures needed to achieve the Access 5 goals of safe, reliable and routine operation of HALE ROAs in the NAS. In coordination with the Flight Demonstration IPT, the Simulation IPT is to provide the supportive evidence to convince NAS stakeholders that the policy, procedure and technology recommendations resulting from Access 5 will achieve the project vision if implemented. In support of this effort, a series of key relationships have developed.

A strong relationship is required with the Access 5 Policy Integrated Product Team (IPT) to coordinate efforts with the FAA; this relationship is essential in guiding simulation efforts toward meeting Access 5 goals and FAA expectations of Access 5. A member of the Policy IPT from the FAA will be assigned to the Simulation IPT and will participate in simulation activities: serving as a domain expert in air traffic control procedures for planning and evaluation purposes. Further, The Policy IPT NATCA representative will assist the Simulation IPT in arranging for participation of air traffic controllers in the simulation, as well as observe (and participate where appropriate) in the simulation activities. The Policy IPT will serve as the primary conduit of information between the Simulation IPT and the FAA Access 5 consultants; the Access 5 Strategic Communication group will serve to communicate Simulation IPT activities to external NAS Stakeholders (non Access 5 participants). Significant input from the Human Systems Interface (HSI) work package (Technology IPT) is also required. Substantial tasks relating to controller and ROA operator interface performed by the HSI work package (e.g. mission decomposition) concern both Simulation and Flight Demonstration activities, and are best coordinated through HSI participation in simulation activities. A member of the HSI team will serve as a domain expert to the Simulation IPT and assist in developing simulation scenarios that leverage the

activities of the HSI and Flight Demonstration activities. Lastly, the Simulation IPT lead will serve (along with other IPT leads and domain experts) on the System Engineering and Integration Team (SEIT). This will allow for rapid integration of new procedures and technologies into the simulation environment, and provide a mechanism for tracking schedule and cost of simulation activities. SEIT participation further serves as the primary means of coordination with the Flight Demonstration, Technology and Implementation IPTs; resulting in a coordinated Demonstration/Simulation effort, and integrating recommended NAS infrastructure changes into the simulation environment at an early stage.

These relationships direct the simulation effort toward accomplishing the goals of the Simulation IPT for Step 1 AOS activities. There are four high-level goals of the Step 1 Simulation activities:

- Evaluate controller and ROA operator workload and situational awareness

- Evaluate HALE ROA operations and procedures above FL400

- Evaluate recommended technology insertions and requirements

- Assess Flight Demonstration Mission Profile(s)

These high-level goals can only be achieved through the inclusion of a wide variety of traffic conditions: varying traffic density, varying ROA density, varying scenario complexity, varying weather conditions, and a representative mix of manned air traffic. Procedures and technologies will be assessed across the range of traffic conditions; controller and operator workload and situational awareness, as well as operational data (efficiency, errors) will be collected for each scenario. Technology recommendations to be evaluated include: Command, Control and Communications (C3), Cooperative Collision Avoidance (CCA), Weather Awareness (WA), Human Systems Interface (HSI), and Contingency Management (CM, e.g. loss link, engine out). The Flight Demonstration mission profile will be evaluated to determine the suitability of the proposed mission to accomplish the goals of the demonstration.

The following list details the key assumptions made for the Step 1 effort:

- Access to/from FL400 through restricted airspace

- Multiple ARTCCs/Sectors required

- HALE ROAs will be operated with procedures specified for the ROA and controlled according to established ATC procedures for flight above FL400

- HALE ROA C3 latencies are expected and are considered an aspect of normal operations (a range of latencies need to be evaluated)

- HALE ROA C3 losses are not considered normal (will be considered as a contingency)

- HALE ROA collision avoidance functionality is limited to cooperative aircraft only

The simulations will be conducted at NASA Ames Research Center's ATC Laboratory utilizing the Aeronautical Datalink and Radar Simulator (ADRS) software for managing simulation data flow, and the Multi Aircraft Control System (MACS) software for emulating the Display System Replacement (DSR). MACS will further control the underlying target generation software (Pseudo Aircraft Systems, or PAS). PAS will generate the tracks for all aircraft in the simulation, including HALE ROA aircraft when not integrated with the AVCS simulator. A representative mix of manned aircraft for the simulated airspace will be employed, and HALE ROAs will be introduced to the simulation on a per-aircraft replacement basis. Three performance classes (by speed) of HALE ROAs will be simulated. Low performance HALE ROAs cruise at speeds well below other traffic above FL400 (i.e. TAS 50-120 Kts); these aircraft may present unique conflict scenarios for high altitude sectors. Medium performance ROAs cruise at speeds significantly below other aircraft at FL400 (120-250 KTAS), and high performance HALE ROAs achieve cruise and climb performance to approaching other traffic above FL400 (250+ KTAS). Four HALE ROAs are modeled to an appropriate level of fidelity: Northrop Grumman's Global Hawk (High Performance), General Atomics Aeronatical Systems' Altair (Medium), Aurora Flight Sciences' Perseus B (Medium), and AeroVironment's Pathfinder Plus (Low). HALE ROAs in Step 1 AOS Simulations will be flown by pseudo-pilots, with the exception of integrated AVCS/AOS simulation activities, where some ROAs will be flown by the AVCS operator. All HALE ROAs in controlled sectors will be directed by ARTCC controllers with standard air traffic control procedures.

ARTCC radar controllers (R-Side) will control aircraft (within his/her sector) verbally through a communications system to pseudo-pilots operating the PAS interface. The MACS DSR emulation will serve as the primary means of data input and surveillance for the controller

(as the DSR does in operational Centers). The R-side controller will be required to have current qualifications to control traffic in the airspace being simulated (tentatively Cleveland ARTCC, or ZOB). The pseudo-pilots require proficiency in operating the PAS interface and a working knowledge of air traffic phraseology (transparency to the controller). Three to four R-Side controllers will be required for each series of simulations; it is anticipated that one of these sectors can act as a feeder sector to the simulation (possibly in an adjacent ARTCC), and not necessarily be a subject of the simulation. This feeder sector could be manned by either the Policy IPT NATCA representative, or the controller member of the Simulation IPT; thus requiring three ZOB controllers to conduct a simulation. The number of pseudo pilots required will generally range from 4 to 6. Each simulation series will follow a pattern that includes necessary briefings, training, simulation conduct, metrics collection, and debriefing.

A number of HALE ROA mission profiles have been produced to initiate the scenario generation process. Each mission profile was produced with cooperation from operators of each HALE ROA system. The mission profiles were produced for simulation in the ZFW airspace, but are easily migrated to the eventual simulation airspace. Each mission profile serves a specific purpose (e.g. speed-differential conflict geometries, multiple close-proximity ROAs, ultra-long endurance, etc.). A mission profile has been created for each of the modeled HALE ROAs, thus covering the spectrum of performance capabilities of current HALE ROAs. These mission profiles will be overlaid on baseline scenarios on a per-aircraft replacement basis to keep sector count constant for baseline comparisons. Baseline scenarios will include a representative mix of traffic for the simulation airspace, and include the effects of weather (temperature, pressure, winds aloft, and dynamic convective cells). Baseline traffic levels will vary from 110% to 125% of current levels for the simulation airspace; prior experience has shown increased traffic is necessary to approach the mental demand experienced in actual ARTCC operations.

Data to be recorded during each simulation include all simulation parameters (aircraft tracks, weather data, controller inputs, pseudo-pilot inputs, traffic counts, sector transition times, route deviations, operational errors, etc.). All simulation data will be archived to allow for review of each scenario by the participants in debrief sessions, and for later analysis by the Simulation IPT. Additionally, a series of metrics will be collected to evaluate controller and AVCS operator workload and situational awareness. Initially, only the R-Side controller will be a subject from which metrics are collected, and the measures employed may include both objective (task completion times) and subjective (NASA-TLX, WAK, SAGAT). Non-intrusive metrics will be employed where possible. The data obtained during

Step 1 simulations will contribute to the NAS-wide fast-time simulations in Step2, as well as to subsequent Step 1 and Step 2 real-time simulations (modifications to the simulation environment will be made where necessary).

Ongoing simulation activities are focused on scenario generation and training preparations; this effort will continue into March of 2005. In March, practice sessions and training of pseudo-pilots will be conducted as 'normal' operations scenarios are finalized. Simulation of normal of normal HALE ROA operations will be conducted in April, as well as baseline scenario simulations (absence of HALE ROAs). This series of simulations will last one week (including travel days), and include approximately 12 one-hour simulation sessions. Subsequent activities will include generation of contingency scenarios, coordination with the Flight Demonstration IPT for forming the demonstration mission profile scenario, and integration of new policy, procedure and technology recommendations into the simulation environment. Parallel to this effort, preparations for FY06 AVCS simulations and integrated AOS/AVCS simulations are ongoing. Full-mission simulations that include recommended contingency management procedures and technology requirements will occur at a roughly six-week interval following the initial round of simulations; each consisting of a similar one-week series of 10-12 sessions including 3 active controllers from the simulation airspace (tentatively ZOB).

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1.0   Introduction

The primary goal of Access 5 is to allow safe, reliable and routine operations of High Altitude-Long Endurance Remotely Operated Aircraft (HALE ROAs) within the National Airspace System (NAS). Step 1 of Access 5 addresses the policies, procedures, technologies and implementation issues of introducing such operations into the NAS above pressure altitude 40,000 ft (Flight Level 400 or FL400). Routine HALE ROA activity within the NAS represents a potentially significant change to the tasks and concerns of NAS users, service providers and other stakeholders. Due to the complexity of the NAS, and the importance of maintaining current high levels of safety in the NAS, any significant changes must be thoroughly evaluated prior to implementation. The Access 5 community has been tasked with performing this detailed evaluation of routine HALE-ROA activities in the NAS, and providing to key NAS stakeholders a set of recommended policies and procedures to achieve this goal. Extensive simulation, in concert with a directed flight demonstration program are intended to provide the required supporting evidence that these recommendations are based on sound methods and offer a clear roadmap to achieving safe, reliable and routine HALE ROA operations in the NAS. Through coordination with NAS service providers and policymakers, and with significant input from HALE-ROA manufacturers, operators and pilots, this document presents the detailed simulation plan for Step 1 of Access 5.

A brief background of the Access 5 project will be presented with focus on Steps 1 and 2, concerning HALE-ROA operations above FL400 and FL180 respectively. An overview of project management structure follows with particular emphasis on the role of the Simulation IPT and its relationships to other project entities. This discussion will include a description of work packages assigned to the Simulation IPT, and present the specific goals to be achieved for each simulation work package, along with the associated deliverables necessary to achieve these goals and the needs of other Access 5 IPTs. The simulation environment chosen for this task is then outlined. This section includes a description of the system architecture, a list of the necessary assumptions made by the Simulation IPT, and the roles, responsibilities and interactions of simulation participants. The method of simulation conduct is presented in the next section with particular emphasis on scenario development and applicability to evaluation of Step 1 HALE-ROA operations. Following, data collection and analysis methods are discussed for air traffic specialists and air vehicle control station operators. Lastly, a schedule of Step 1 simulation activities is presented for reference.

2.0   Background

The Access 5 vision statement reads:

> *Within 5 years, to operate High Altitude Long Endurance Remotely Operated Aircraft routinely, safely, and reliably in the National Airspace System.*[1]

The mission statement reads:

> *Through a Strategic Government/Industry Alliance, accomplish the Access 5 vision by developing standards, regulations, and procedures; demonstrating the technologies; and implementing infrastructure necessary to meet national priorities.*[1]

The ultimate goal is to have HALE ROAs operate in all relevant categories of airspace, with the aircraft viewed by air traffic management and other NAS users as an integral member of the aviation community.

Step 1 of the program (see Figure 1) proposes "routine operations above FL400 through restricted airspace." Step 2 of the program proposes "routine operations above FL180 through restricted airspace."[2] Steps 3 and 4 are as yet, unfunded.
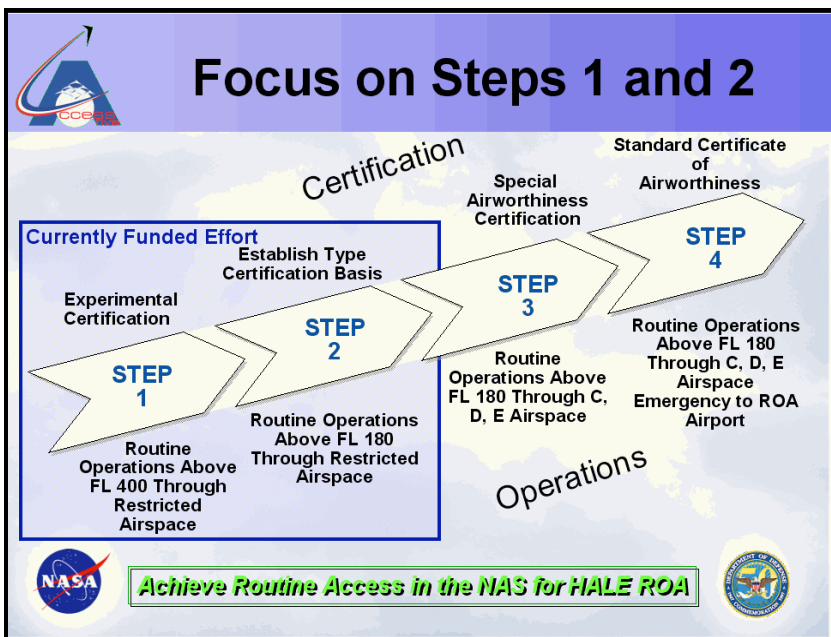

Figure 1 HALE ROA Steps

Routine ROA Operations Above FL400

The step 1 concept envisages ROAs climbing to at least 40,000 feet (see Figure 2), via a secure corridor of restricted airspace. Presumably, upon reaching the designated 'minimum' operating altitude of 40,000 feet, the ROA enters into the NAS and is treated in a manner similar to the typical traffic that would otherwise be present.

ROA descent is via a secure corridor of restricted airspace.

Figure 2 Routine ROA operations above FL400

Routine ROA Operations Above FL180

The step 2 concept envisages ROAs climbing to at least 18,000 feet (see Figure 3), via a secure corridor of restricted airspace. Presumably, upon reaching the designated 'minimum' operating altitude of 18,000 feet, the ROA enters into the NAS and is treated in a manner similar to the typical traffic that would otherwise be present.

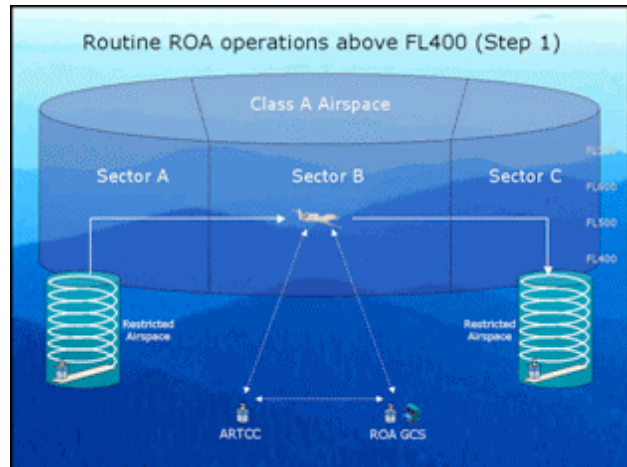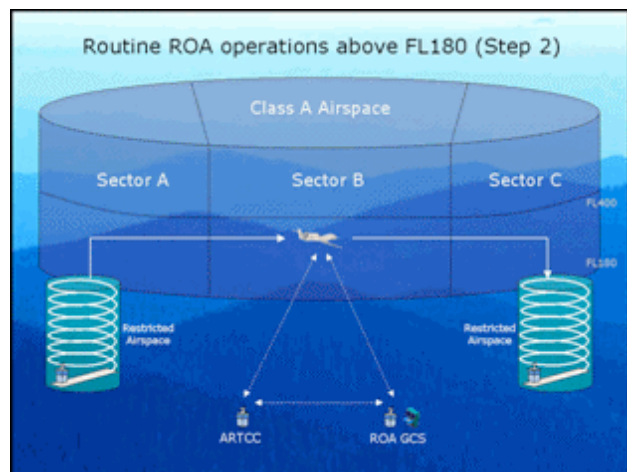ROA descent is via a secure corridor of restricted airspace.

Figure 3 Routine ROA operations above FL180

3.0   Organizational Structure and Relationships

This section provides an overview of the project management structure of Access 5, and details the relationships, roles and responsibilities of the Simulation Integrated Product Team (Sim IPT) within the Access 5 community. The Access 5 organization is structured to delineate high-level tasks into focused groups with the expertise required to complete well-defined tasks and meet well-defined goals that integrate to the higher-level project goals. This section describes the project management structure, outlines the focused goals of the simulation IPT, details the relationship of these goals to project level goals and defines the key interfaces within the project management structure designed to facilitate task integration. This section concludes with an overview of the Simulation IPT work packages for Step 1.

3.1   Project Management Structure

Figure 4 shows the hierarchy of project management within Access 5. The Integrated Product Teams (IPTs) are each responsible for managing tasks and integrating work packages to meet IPT goals. The IPT leaders (as well as a collection of technical experts) collectively form the System Engineering and Integration Team (SEIT). The SEIT is responsible for integrating the work among the different IPTs to meet project-level goals. The SEIT also provides

Figure 4 Project Management Structure
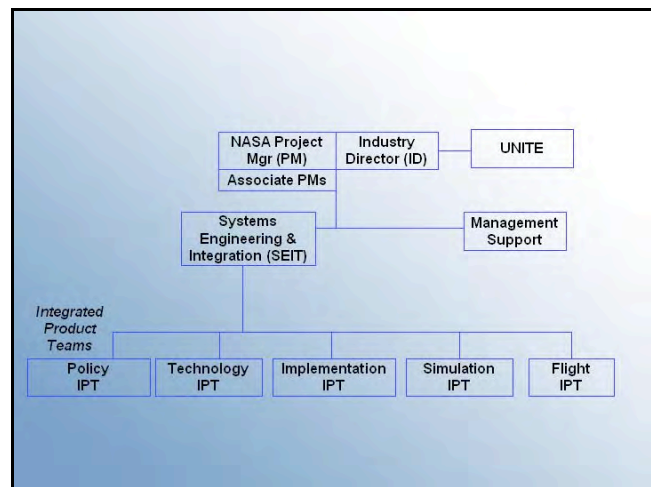
guidance to the NASA Project Manager and the Industry Director in forming annual work packages to meet these project goals. The Simulation IPT is responsible for all airspace operations and air vehicle control station simulations; the following sub-section details the role of the Simulation IPT and describes the relationships necessary to accomplish the higher-level project goals.

3.2   Simulation IPT Charter, Relationships and Task Integration

The Simulation IPT charter reads as follows:

> Through comprehensive simulation, compliment a Flight Demonstration program in the evaluation of technologies, policies and procedures needed to achieve the Access 5 goals of safe, efficient and routine operation of HALE ROAs in the NAS.

The role of simulation within the project is to provide the proof required to convince NAS stakeholders that the recommendations resulting from Access 5 activities would achieve the project vision if implemented. To fill this role, a few key relationships have developed that will assist the simulation IPT in presenting a more appealing body of evidence to support the Access 5 recommendations.

First, and foremost, the Policy IPT is utilized as a conduit of communication and cooperation with key personnel within the Federal Aviation Administration (FAA), namely individuals within the FAA's Air Traffic, Flight Standards and Certification organizations. A process utilizing standard forms is employed to receive guidance and feedback on simulation activities to meet the specific needs of these groups. The Policy IPT is also tasked with coordinating the routine communication between domain experts within the FAA and the simulation principal investigators required to achieve the highest practical level of simulation realism and value.   Where appropriate the Policy IPT will arrange for domain experts to participate in Simulation IPT activities (e.g. Controllers, Traffic Management Coordinators or NATCA representatives).   Communicating Access 5 activities (including simulation) to other NAS stakeholders (commercial operators, private pilots, community groups, etc.)   is managed by the Strategic Communication group.

Second, Human Systems Interface (HSI) activities within the Technology IPT and simulation development and analysis require similar inputs for evaluation (e.g. mission decomposition, task analysis). Tight integration with the HSI work package participants in the form of teleconference participation and coordination of common tasks eliminates duplication of efforts. Furthermore, by involving HSI participants in the simulation planning process, the risk of needing to repeat studies due to inadequate Human Factors (HF) consideration is greatly reduced.

Lastly, participation of the Simulation IPT lead in regular SEIT meetings (along with other IPT leads and technical experts) allows tracking of work package and task progress to ensure schedule compliance and to recognize new requirements at an early stage. SEIT participation also fosters rapid integration of simulation requirements derived from ROA Impact and Flight Demonstration IPTs: leading to coordinated flight demonstration activities, and early adoption of infrastructure changes needed to routinely operate HALE ROAs in the NAS. Together, these relationships serve to minimize the inefficiencies that often arise with complex projects, and to ultimately increase the likelihood of success in achieving the simulation goals.

3.3   Step 1 Airspace Operations Simulation Goals

The goals of the Step 1 simulation are to evaluate "routine ROA operations" in the NAS above FL400 with access through restricted airspace. This includes evaluating workload and situational awareness of ROA and ATC operators, evaluating the effectiveness and impact of an integrated system incorporating HALE ROAs into the NAS, and testing and validating various policy and technological recommendations and requirements flowing down from the various IPTs comprising Access 5.

More specifically these goals consist of:

- Using simulation, evaluate workload and situational awareness of ROA operators and controllers with regard to:
  - Standard operations (ATC commands, handoffs, and airspace transitions in consideration of varying traffic density and ROA performance capabilities)
  - Contingency operations (Lost Link, Engine Out, etc.)
  - Cooperative conflict avoidance (at varying levels of traffic density, and varying levels of airspace complexity)

- Evaluate routine ROA operations and procedures (and some TBD level/extent of "contingency" events) in the NAS above FL400 at:
  - Varying levels of traffic density
  - Potential range of ROA operations (complexity, performance, endurance, level of autonomy)

- Evaluate technology insertions, recommendations, and requirements stemming from Access 5 IPTs to ensure safe ROA operations in the NAS including:
    - Contingency management
    - Cooperative conflict avoidance
    - HSI factors
    - Communication
    - Weather issues

- Evaluate the mission plan of the proposed graduation flight exercise
    - Same or equivalent mission plan
    - Same or equivalent airspace
    - High fidelity ROA performance model
    - High equivalence AVCS
    - Realistic ATC Operations

3.4   Work-package Details

The work performed by the simulation IPT is authorized by the approval of work packages by the SEIT and Project Office. The FY04 work package consisted of planning for Step 1 Airspace Operations Simulations (AOS), and development of the capabilities to support the planned simulations. This document represents the planning efforts undertaken in the FY04 work package. The simulation capability to support the plans outlined in this document and the capabilities dictated in the simulator requirements document have been developed concurrently with the planning effort as part of the FY04 work package.

The FY05 work package continues the plan outlined herein and initiates AVCS simulation planning. The details of the AVCS simulation will be added to this document as they evolve. Concurrently with this planning effort, the AVCS simulation capability will be developed from an existing AVCS capability at NASA Ames Research Center. Furthermore, the interface between the AVCS and the AOS capabilities will be developed as part of this effort.

The FY05 work package will initiate conduct of airspace operations simulations. Four week-long sessions of simulation are planned: one week for 'normal' operations and 3 weeks for 'full-mission' simulations. The normal operations simulations will investigate routine operations of HALE ROAs within the NAS, including ATC communications, airspace

boundary transitions, and various mission profile execution under varying traffic loading scenarios. Full-mission simulations will include contingencies on these mission profiles, and the recommended procedures to manage these contingencies. Full-mission simulations will also include evaluation of technology functional requirement recommendations (e.g. CCA). FY05 AOS activities will result in a report summarizing the controller workload, controller situational awareness and operational impact of HALE ROA integration into the NAS above FL400; FY05 AVCS simulation activities will begin investigation of these same measures on the AVCS operator.

The FY06 activities of the Sim IPT work package will include part-task and full-mission AVCS simulations, as well as integrated AVCS/AOS simulations. A final report on the findings of all Step 1 simulations will document the conclusions and recommendations resulting from analyses based on metrics collected and feedback received from the subjects in these simulations. This report will support the recommendations made by the Access 5 community, and will serve to compliment the flight demonstration program in forming these recommendations.

For detailed documentation of the tasks involved in executing the Simulation IPT work package, please refer to the Work Package proposals archived on the Access 5 website.

4.0   Simulation Environment

This section describes the simulation environment.

4.1   Air Vehicles

This section describes the vehicles involved in Step 1 simulations. Two types of air vehicles will be considered: manned and remotely operated aircraft.

Manned Aircraft

The manned aircraft modeled in Step 1 simulation activities represent the spectrum of aircraft currently operating in ARTCC airspace during En Route and terminal phases of flight (initial descent and climb to cruise). Representative aircraft include those operated by commercial air carriers, air cargo companies and air taxi operators. Simulation of these aircraft is based on airframe drag and engine thrust models provided (in most cases) by the aircraft manufacturer. Point mass equations of motion are solved to provide aircraft state information during a simulation [7]. The extent to which manned aircraft are simulated is to that level necessary to model the behavior of manned aircraft operating within the NAS to a sufficient level of fidelity to evaluate the workload and situational awareness of the air traffic specialist and air vehicle control station operator of any remotely operated aircraft.

Remotely Operated Aircraft

Remotely operated aircraft will be simulated by three methods in Step 1. The first method is to simulate ROAs in the same manner as manned aircraft; using point mass equations of motion, simplified airframe and thrust models and 'piloted' from a workstation interface not dedicated to the specific vehicle being simulated and making no effort to mimic the air vehicle control station operator interface. This first method will be employed in the most basic simulations where only response to air traffic commands, hand-offs and impact of ROA performance characteristics within the NAS are being investigated. These simulations will be focused solely on the air traffic specialist. The second method will include state generation using the same point-mass equations of motion and integrating an Air Vehicle Control Station (AVCS) and piloted by an AVCS operator. These simulations will focus on the interactions between the air traffic specialist and the AVCS operator; workload and situational awareness of the air traffic specialist and AVCS operator will be investigated, and the duties of the AVCS operator will be at a higher level of fidelity. The third method of simulation of ROAs will be similar to the second method, with the notable exception of the state information of the ROA will be provided by an integrated simulation module provided

by the ROA manufacturer. This third method will allow for highly accurate simulation of ROAs within the airspace simulation, inclusion of proprietary simulation models and detailed analysis of component technologies (e.g. conflict avoidance) within an airspace simulation. Additionally, any of the three methods of operation are assumed to be capable of an 'autopilot' mode that can be used to populate the simulation with additional ROAs that are not the primary focus of investigation, but are needed to achieve the goals of a specific scenario.

To fully investigate the potential impact of HALE ROAs on air traffic specialist workload and situational awareness, a representative spectrum of ROAs need to be modeled. Three levels of vehicle performance capabilities are considered for Step 1: High, Medium and Low. These capability classes nominally refer to ROA cruise speed. High capability vehicles cruise at speeds similar to commercial airliners (>300 KTAS). Medium capability ROAs cruise at speeds similar to regional turboprop air taxi service (~ 200-300 KTAS). Low capability ROAs cruise at speeds below 200 KTAS, and at altitude differ significantly from the performance capabilities of commercial air carriers and corporate jet aircraft. One vehicle representative of each performance class has been selected for inclusion in Step 1 simulations; following is a brief overview of the performance capabilities of each of the selected aircraft.

Global Hawk (High)

Speeds	Runway Requirements	Max. Gross Takeoff Weight
Stall – 95 kts	Paved	25,600 lbs
Cruise – 340 to 350 kts	5000+ x 150+ feet	
Maximum – XXX kts		
Aircraft Weather Limits	Ceiling (Operational up to)	Endurance / Range
Not disclosed.	65,000 feet	42 hours
	Cruise not disclosed.	13,500 nm

Altair (Medium)

Speeds	Runway Requirements	Max. Gross Takeoff Weight
Stall – XXX kts	Paved	7,000 lbs
Cruise – XXX kts	5000 x 125 feet	
Maximum – 220+ kts		
Aircraft Weather Limits	Ceiling (Operational up to)	Endurance / Range
Not disclosed.	52,000 feet	32 hours
		4,200 nm

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

Cruise not disclosed.

Helios-class (Low)

Speeds	Runway Requirements	Max. Gross Takeoff Weight
19 – 27 mph Up to 170 mph GS at altitude	Not disclosed.	Approx. 2,700 lbs
Aircraft Weather Limits	Ceiling (Operational up to)	Endurance / Range
Not disclosed.	100,000 feet 50,000 – 70,000 feet cruise	Not disclosed.

A Helios-class vehicle was selected as the 'Low' performance ROA for simulation, but may not be modeled to a high level of fidelity. Accurate simulation of Helios-like operations require a level of mission planning fidelity and vehicle performance model fidelity that would require a significant level of development. For airspace operations simulation, the vehicle speed and maneuverability capabilities will be accurately reflected, but such factors as available power dependence on cloud cover and sun incidence angle will not be considered. However, if Helios' manufacturer (AeroVironment) chooses to supply an integrated module to provide high fidelity Helios simulation, this will certainly be employed. A Helios-class vehicle with a power source other than solar cells, will be modeled to the same level of fidelity as the other performance class vehicles.

4.2 Weather

Weather could affect the ability of the NAS to accommodate ROAs. Alternatively, the ability of ROAs to comply with ATM instructions may be affected by weather events. Many of the candidate ROAs do not come equipped with weather detection or de-icing mechanisms, whereas standard manned aircraft equipped for Class A airspace can withstand more adverse conditions (are equipped with these systems). Furthermore, the varied performance capabilities of HALE ROAs may necessitate new procedures for responding to convective weather events in densely populated airspace. Therefore, it is relevant to measure the effects of these equipages on current operations in the NAS. Weather events will be simulated to include a representative set of possible occurrences affecting ATC's ability to direct traffic. The simulation of weather will need to include the ability to visually represent weather elements that can grow and or diminish in size and intensity, and can move within the airspace in pre-programmed routines that resemble actual weather patterns in the area being modeled. The fidelity of the ATC's screen representation is (TBD). The ROA operator

should monitor the weather and weather advisories and request clearances as needed from ATC to deviate from the current flight path to avoid weather. It will be the job of the ATC controller to properly divert traffic away from these weather situations based on the current traffic picture to ensure that a conflict with another aircraft or an emergency situation does not arise and issue clearances accordingly. Measures of situational awareness and workload will be taken from both the ROA operator and ATC controller in these events.

4.3   Participant Roles

ROA Operators

The AVCS operator will perform only those duties of an HALE-ROA operator that are required to sufficiently model ATC interaction from the controller's perspective. These duties shall include (at a minimum):

- Verbal response to ATC directives and inquiries
- Execution of ATC clearances
- Execution of HALE-ROA mission profile (flight path)
- Appropriate response to mission contingencies

The AVCS operator is a secondary subject of the AOS Step 1 activities, with the exception of integrated simulation activities with the AVCS simulations. The AVCS operator shall have a working knowledge of the capabilities and mission profiles of the system they are operating; it is not required that the AVCS operator in AOS Step 1 be certified as a vehicle operator for that system (this is assumed beyond the requirements of fidelity for AOS simulations, but may well be necessary for AVCS simulation). Requirements for the AVCS operator will be further developed by the AVCS Simulation Work Package, and integrated into the Step 1 AOS Simulation Plan.

Air Traffic Controllers

The controller in the AOS simulation will be the primary subject of workload and SA analyses. The controller will have a working knowledge of the airspace, and depending on scenario fidelity, may need an active certification as an air traffic specialist for the airspace environment being simulated. The controller will attend an introductory training session to educate the controller on the objectives of the simulation, simulation conduct, and data collection methods to be used (questionnaires, SA procedures, NASA-TLX, etc.). During simulations, the controller will perform the duties of his/her daily responsibilities in providing radar separation, responding to NAS user requests and coordinating with other

controllers in providing safe, expeditious traffic flow. The other simulation participants will rely heavily on the domain expertise of the controller throughout simulation conduct and post-run briefings.

Manned Aircraft Pilots

Pilots in the Access 5 simulation environment will have all the standard responsibilities of a pilot in the current operational environment. The pilot-in-command of an aircraft is directly responsible for, and is the final authority as to the safe operation of that aircraft. The pilot will perform the duty of verbally responding to ATC directives issued by the controller. The pilot will further respond to ATC directives by inputting the directives, as commands, to the aircraft via the target generator control interface (allowing each pilot to comand multiple aircraft within a simulation). Movements of the aircraft model will be controlled by the target generator; the target generator will serve to execute these commands such that the controller detects response to the issued directives on the controller interface. The pilot is not a subject of AOS analyses.

Other Participants

It is not anticipated, at this time, that Step 1 AOS simulations will require the inclusion of D-Side (planning) controllers or Traffic Management Coordinators (TMCs) as subjects for analyses. Inclusion of D-Side controllers and TMCs may become necessary in Step 2, as high-density airspace is evaluated, or due to feedback from participant subjects that TMC functions or planning could be significantly impacted due to the types of operations and procedures required for routine HALE ROA integration in the NAS.

4.4 Airspace

The simulation will be conducted in Class A airspace. All aircraft will operate under Instrumental Flight Rule (IFR) operations. No Visual Flight Rule (VFR) operations are permitted. The airspace will include a combination of ultra high and high altitude sectors; low altitude sectors will also be simulated, but will only
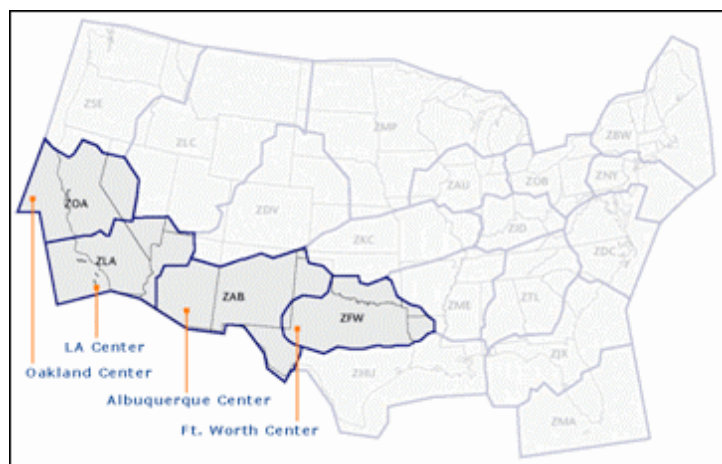

Figure 5 NAS Centers – lower 48.

be populated with automatically flown targets intended to create a sense of simulation realism to the high altitude controllers near congested terminal airspace. Simulation for Step 1 will use Centers along a nominal route from Edwards Airforce Base to Eglin Airforce Base, with particular focus on the Ft. Worth Center (ZFW). Traffic will be a combination of enroute, departures and arrivals over various populated areas.

Recent discussions with FAA personnel may lead to inclusion of another ARTCC as a focus Center (instead of ZFW). Familiarity with various upper airspace redesign efforts (e.g. DRVSM), ongoing training activities impacting subject availability, and suitability of facilities for evaluating high altitude operations (traffic density above FL400) may result in selection of a more practical and suitable airspace for simulation.

4.5   Assumptions

A consequence of the IPTs working concurrently is that important decisions regarding policy, procedures, technologies, and myriad other critical areas are not yet defined, or may not be codified prior to the Simulation IPT needing to advance with its testing schedule. With this in mind, it is necessary to proceed with a set of assumptions to build a foundation in order to complete the simulation task.

In Step 1, HALE ROAs will climb and descend through restricted airspace up to FL400: simulation operations will be limited to above FL400 in the NAS. This dictates that only ARTCC airspace need be modeled (in the NAS), with transition to and from restricted airspace. Therefore it is assumed that there is no need to model the restricted airspace or surface operations within the restricted airspace for Step 1 objectives. Furthermore, due to the length of time HALE ROAs are in flight, it is also assumed that several centers and sectors may need to be modeled in order to provide the level of fidelity of a true mission profile.

The principal ATM operational assumption is the "no (or nearly no) special handling" goal for controller interactions with ROAs. For the AOS, this would include standard clearance procedures, nominal ROA response capabilities, and operator-controller (and ROA) communications.

The next set of assumptions deals with communications between the elements involved in the simulation. Due to the remote operation of HALE-ROAs, communication transmission latency (excluding time for operator to respond) between the vehicle and the vehicle operator (pilot), and thus between the operator and air traffic control is unavoidable. While analog voice communication used in today's ATC environment typically exhibits from 95ms to 150ms of latency [8], over-the-horizon (OTH) communication with HALE-ROA operators can result in latency approaching 250 ms (when relayed through a geostationary satellite). Furthermore, there is additional latency involved in executing any flight maneuvers directed by ATC (transmission delay in C2 uplink from the AVCS), which could be perceived by controllers as a delayed response to a directive, and potentially require increased attentiveness and result in loss of situational awareness. It is assumed that communication latency is normal in reference to ROA operations and a range of latencies will be investigated for their impact on workload, situational awareness, and safety for controller operations.

Loss of communications that are contingencies will be modeled in Step 1 activities. In order for ROAs to meet the equivalent level of safety of manned aircraft, ROAs must meet the same demands with respect to communication reliability and accuracy. Current ATC procedures for manned aircraft call for immediate landing at the nearest suitable airport in the event of a communication loss as soon as VMC is reached. This has serious implications for ROA manufacturers as (the relatively frequent) event of communication loss is considered to be an insignificant event for these vehicles, and the usual protocol is to proceed as planned and wait for communications to be reestablished. This strategy is, at present, under scrutiny in Access 5 since success in integrating HALE ROAs into the NAS may well require viewing communication loss as a contingency.

5.0   Simulation Conduct

This section details the simulation conduct.

5.1   Participants and Support Personnel

ROA Operators

Participant ROA ground station operators will have had previous experience 'flying' an unmanned aerial vehicle. Where practical, the ROA operator will have experience executing the type of mission being simulated, even if the AVCS interface is a more generic model than the vehicle used for the mission. The number of operator-controlled ROAs in a scenario will vary from zero to some practicable maximum for the simulation airspace. ROA operations in background airspace (e.g. adjacent and uncontrolled sectors) may be automated prior to these ROAs entering 'active' sectors manned by controller subjects.

Air Traffic Controllers

Participant air traffic controllers will be drawn from a pool of experienced air traffic specialists provided by the FAA in coordination with the Access 5 NATCA representative

Pilots – Manned Aircraft

Personnel responsible for 'flying' multiple "traffic" aircraft will be knowledgeable in standard ATC phraseology for the management of IFR operations within the NAS. Furthermore, a proficiency with operating the target generation interface for multiple targets will be required to respond to air traffic directives in a timely manner (transparent to the air traffic controller).

Simulation Conductor

The simulation conductor is responsible for coordination and planning of all aspects of a simulation:

- Introductory Briefings & Training
- Simulation Initiation
- Monitoring Simulation Systems
- Simulation Termination
- Post-run Debriefings

The simulation conductor will be familiar with the operation of the simulation facility and have knowledge to troubleshoot issues relating to the primary components of the simulation environment. The simulation conductor will further coordinate for the timely availability of simulator subsystem experts.

Human Factors Specialist

The human factors specialist will be responsible for collecting and analyzing metrics related to controller workload and situational awareness. This will involve presentation of pre-run briefing materials and conduct of mid-run and post-run data collection. The human factors specialist will have knowledge of controller duties and an understanding of workload and situational awareness data collection and analysis methods as they apply to air traffic controllers. During simulation activities, he/she will monitor controller actions/comments for exceptional situations that necessitate discussion in post-run debriefings. The human factors specialist is responsible for administration of workload and SA questionnaires, and for appropriate selection of timing of data collection during a simulation.

5.2   Scenarios

The goals of Step 1 include evaluating operations in the NAS above FL 400 with HALE ROAs present, assessing workload and situational awareness of ATC and ROA operators, and testing various policy and technological recommendations and requirements coming from other Access 5 IPTs.

Nominal Operations

A representative set of HALE UAV mission profile sketches (varying in vehicle type and mission tasking) were constructed as candidates for Step 1 Airspace Operations Simulations. These are outlined in the Mission Profiles section below. These mission profiles will be combined to create fully detailed simulation scenarios over a common airspace, which will also include operations by manned aircraft. These scenarios will then be varied along a variety of research dimensions, including traffic density (number of manned aircraft in the airspace), weather, and the number and type of ROAs present. This more detailed development will come after technical, operational, and FAA policy review. These discussions will verify scenario element operational and policy utility and appropriateness, and will provide advice on specific airspace sectors, jet airways, traffic characteristics, etc., to ensure that Access 5 Step 1 simulation goals are robustly addressed to the maximum extent possible. For the sake of explication, these operations are initially assumed to be

conducted in and around the ZFW Center (and associated jet airways), but are designed to be readily migrated to a finalized airspace choice during early 2005 planning.

These mission profiles will be included in broader scenarios that include a representative mix of air traffic and weather in the chosen airspace. The airspace selection is necessary to further define the scenario traffic levels and mission profiles. Baseline traffic scenarios will be created with traffic levels above those of current NAS operations (110-125%); experience in past controller-in-the-loop simulations indicate an increased level of traffic is necessary to accurately represent the mental demand of daily tasks associated with their responsibilities. HALE ROAs will replace manned aircraft in baseline scenarios to maintain traffic count in comparison to the baseline.

Mission Profiles

Altair

The Altair scenario is a high-altitude reactive (on demand) observation of thunderstorm activity north and west of Dallas/Fort Worth (DFW). The goals of the mission are infrared observation of lightning behavior and possible Doppler radar observation of turbulence, winds and precipitation.

The Altair files a flight plan requesting a route from El Mirage to the Bowie (UKW) VORTAC, R-134, 30 nm DME fix at FL410. The Remarks section of the flight plans states that the Altair requests to hold west of this fix at FL410 using 4-minute legs. The Remarks section also describes the Altair weather mission and notes that it may request a departure from the holding pattern to observe significant weather. The area for observation is described as a square area, bounded on the south by the Ranger (FUZ) VORTAC R-264 from FUZ to a point 30 nm DME west of FUZ and bounded on the east by the FUZ R-354 from FUZ to a point 30 nm DME north of FUZ.

In keeping with the filed flight plan, the Altair departs El Mirage and goes to Edwards AFB (EDW) before setting off en route to DFW via the high-altitude jet airways. The Altair climbs to FL180 in the restricted area and/or while en route from El Mirage to EDW, then continues to climb at best rate en route to the first waypoint at Hector (HEC) VORTAC, where it enters the J6 airway. The aircraft should be able to reach its initial cruise altitude (FL410) at or before HEC, then continue via jet routes or great circle path to Wichita Falls (SPS) VORTAC, and onward to the UKW VORTAC. Once reaching the ZFW airspace, the Altair has clearance to monitor a square area defined in the flight plan (above). A detailed route plan can be

seen in Figure 6. This clearance incorporates a 30 nm square area located just west of DFW as shown in Figure 7. This area is assumed to have been pre-selected as a likely weather cell observation area by the National Weather Service, NASA and/or the FAA. The Altair will hold in the center of the mission area until weather cells develop using a standard racetrack holding pattern with 4 minute legs and standard rate turns, maintaining best endurance airspeed. Altair observes weather cells as directed by the sensor operator using pilot's discretion routing within the assigned boundaries and altitude. Once weather develops, the Altair will request a clearance from ATC to depart the holding pattern and proceed to its weather observation area which is defined by specific lat/long coordinates. Upon receipt of the clearance, Altair will proceed using its best dash speed from the holding pattern to the point of interest, then slow to best endurance speed while orbiting observed cells. After sufficient fuel has burned off, the Altair pilot will request clearance to climb to the next available higher IFR altitude for continued surveillance. The Altair finally returns to its departure base at conclusion of on-station time via the reverse of the inbound route. Approximately six hours are required each for ingress and egress from/to El Mirage, allowing approximately 12 hours on station.

Location	Mag Crs (deg)	Gnd Spd (kts)	Dist / Total (nm)	Time / Total (min)
El Mirage, CA; Depart & climb direct EDW Vortac to FL180				
	330	105	22.3	0:12
EDW [Edwards]; Climb direct HEC Vortac to FL410			22.3	0:12
	086	150	63.6	0:25
HEC [Hector]; Proceed en route via J6-J72 to SPS Vortac at FL410 [5 waypoints]			85.9	0:38
	085 (AVG)	180	890.0	4:56
SPS [Wichita Falls]; Proceed direct UKW Vortac at FL410			975.9	5:34
	119	180	47.1	0:15
UKW [Bowie]; Proceed via UKW R134 to holding anchor point at UKW R134 30 DME			1023.0	5:50
	134	180	30.0	0:09
Holding Pattern Anchor Point; Hold until sensor operator detects storm cell within clearance area, dash to cell location			1053.0	6:00
	As Reqd	As Reqd	As Reqd	As Reqd
Observation Waypoint; Orbit cell of interest for sensor observation, best loiter speed				
	As Reqd	As Reqd	As Reqd	As Reqd
[Repeat as reqd for duration of mission; Request higher FL when able]				
[At end of on-station period, return to El Mirage via reverse of ingress route]				

Figure 6 Altair important mission waypoints, Altitude FL410-FL510, no wind

In the figure, the following callouts appear:

- ARRIVAL ROUTE FROM EL MIRAGE, CA, VIA SPS-UKW, FL410
- TYPICAL AD HOC CELL OBSERVATION LEG, DASH SPEED TO CELL, ORBIT AT BEST ENDURANCE SPD
- TSTORM OBSERVATION CLEARANCE AREA 30 NM N & W OF FUZ VORTAC
- HOLD ON UKW R134 / 30 NM, LEFT TURNS, BEST ENDURANCE SPEED
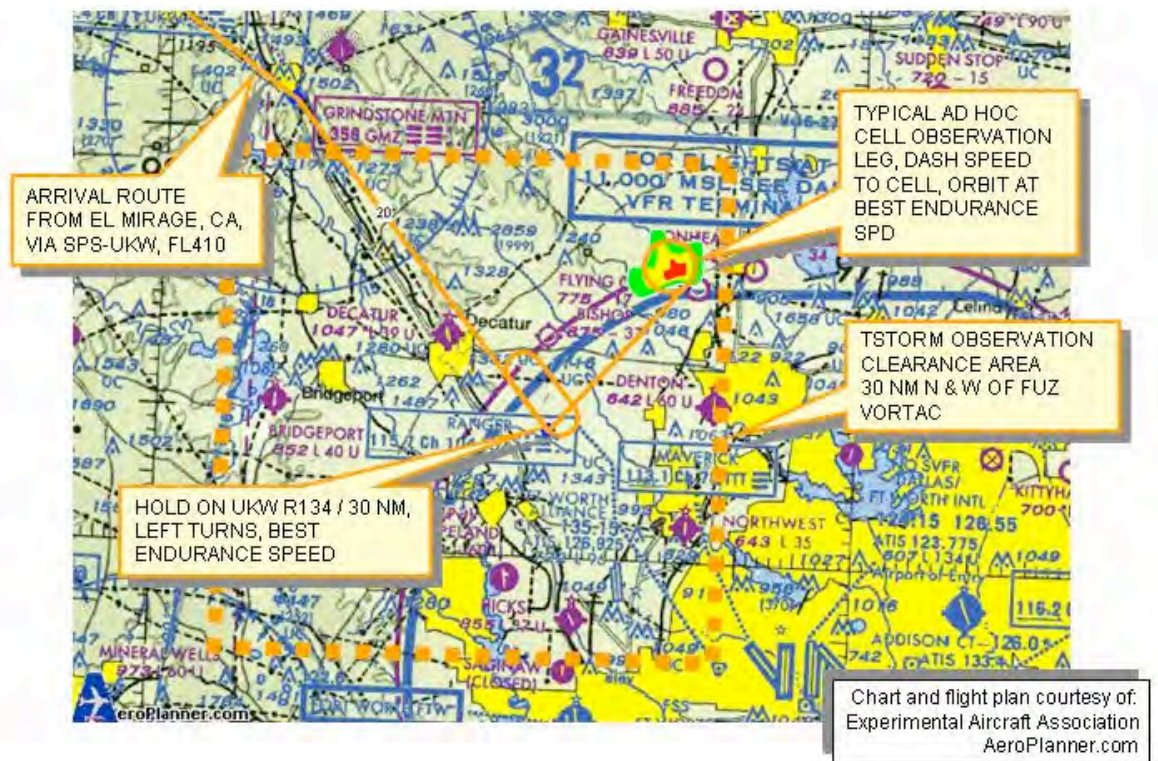- Chart and flight plan courtesy of: Experimental Aircraft Association AeroPlanner.com

Figure 7 Area of operations for Altair weather observation mission

Perseus

This scenario incorporates two Perseus B ROAs conducting a high altitude ozone concentration survey over the greater Dallas/Fort Worth area using differential absorption LIDAR sensors.   Samples will be taken every TBD nm on North/South and South/North paths at 4000 feet altitude intervals by each of the two aircraft.   This provides a grid of samples every 2000 ft for legal flight levels between FL410 and FL630 (see Figure 10 below).

Each Perseus files a flight plan requesting its route from takeoff to its enroute surveillance pattern which is defined by a set of lat/long coordinates. These coordinates define the entire lateral route to be flown during the mission. The first Perseus requests FL430 as its initial altitude and FL630 as its final altitude. Similarly, the second Perseus requests FL410 as its initial altitude and FL610 as its final altitude. The Remarks section of the flight plan states that upon reaching the final waypoint in the flight plan, the aircraft will request a turn to fly the same route in the reverse direction, as specified by a set of lat/long coordinates. Remarks also specify that the aircraft requests a 4000-ft higher altitude on each course reversal. (Because the filed altitudes do not comply with IFR altitudes for the Peruses'

direction of flight, ATC will exercise its authority to clear the aircraft at the requested altitudes.)

As described in the flight plan, the two aircraft will take off approximately 30 minutes apart and will be separated by 2,000 ft altitude over the same route. The aircraft will depart Fort Stockton Pecos County Airport in Southwest Texas, where they will climb to FL410 in the vicinity of the airport (designated as a temporary restricted area) using their best climb speed. The aircraft will then depart en route over the Fort Stockton (FST) VORTAC adjacent to the airport, from which they will fly a high-altitude route to the mission area via direct Glen Rose (JEN) VORTAC, then direct to the first pattern waypoint. A list of the waypoints can be seen in Figure 8. Using the best endurance cruise speed, the aircraft will conduct repeated south/north and north/south passes in a grid pattern over the Dallas/Fort Worth area. A map of the grid pattern may be seen in Figure 9. The first aircraft will enter its pattern at FL430; the second will start its pattern at the same waypoint but at FL410. The two aircraft will repeat this pattern at 4000 ft altitude intervals from FL410 through FL630. At the end of each traverse, the aircraft perform a course reversal and climb to the next pattern altitude. One pattern traversal takes approximately 2 hours and 20 minutes, with a total of six required traversals for a complete mission of 14 hours, not including initial climb, ingress, egress or descent. A conceptualization of this pattern can be seen in Figure 10. The two aircraft will finally return to Fort Stockton via the reverse of the arrival route. If either Perseus aircraft must be vectored for traffic, the route must be replanned to avoid missed sampling points. The optimum maneuver would depend on distance between sampling points. The preferred traffic avoidance maneuver might be a 360° turn.

Location	Mag Crs (deg)	Gnd Spd (kts)	Dist (nm)	Time (min)
Depart Fort Stockton Pecos County Airport, local climb to FL410 (no time recorded), Depart for JEN from directly over FST Vortac	065	124	40.8	19
JEN Vortac [Glen Rose]	038	124	47.1	22
Pattern Wpt 1 [32° 45' N, 97° 30' W]	355	124	44.9	21
Pattern Wpt 2 [33° 15' N, 97° 30' W]	085	124	12.7	6
Pattern Wpt 3 [33° 15' N, 97° 15' W]	175	124	44.9	21
Pattern Wpt 4 [32° 45' N, 97° 15' W]	085	124	12.6	6
Pattern Wpt 5 [32° 45' N, 97° 00' W]	355	124	44.9	21
Pattern Wpt 6 [33° 15' N, 97° 00' W]	085	124	12.7	6
Pattern Wpt 7 [33° 15' N, 96° 45' W]	175	124	44.9	21
Pattern Wpt 8 [32° 45' N, 96° 45' W]	085	124	12.6	6
Pattern Wpt 9 [32° 45' N, 96° 45' W]	355	124	44.9	21
Pattern Wpt 10 [33° 15' N, 96° 45' W]	355-175	120	16.0	8
Back to Wpt 10 and fly reverse pattern at next altitude; repeat patterns for six flight levels		Total Pattern Time:		2:17

Figure 8: Perseus B ozone monitor route waypoints. Patterns flown at 4000 ft intervals between FL410 and FL610.

Perseus B DFW Area Ozone Analysis Route
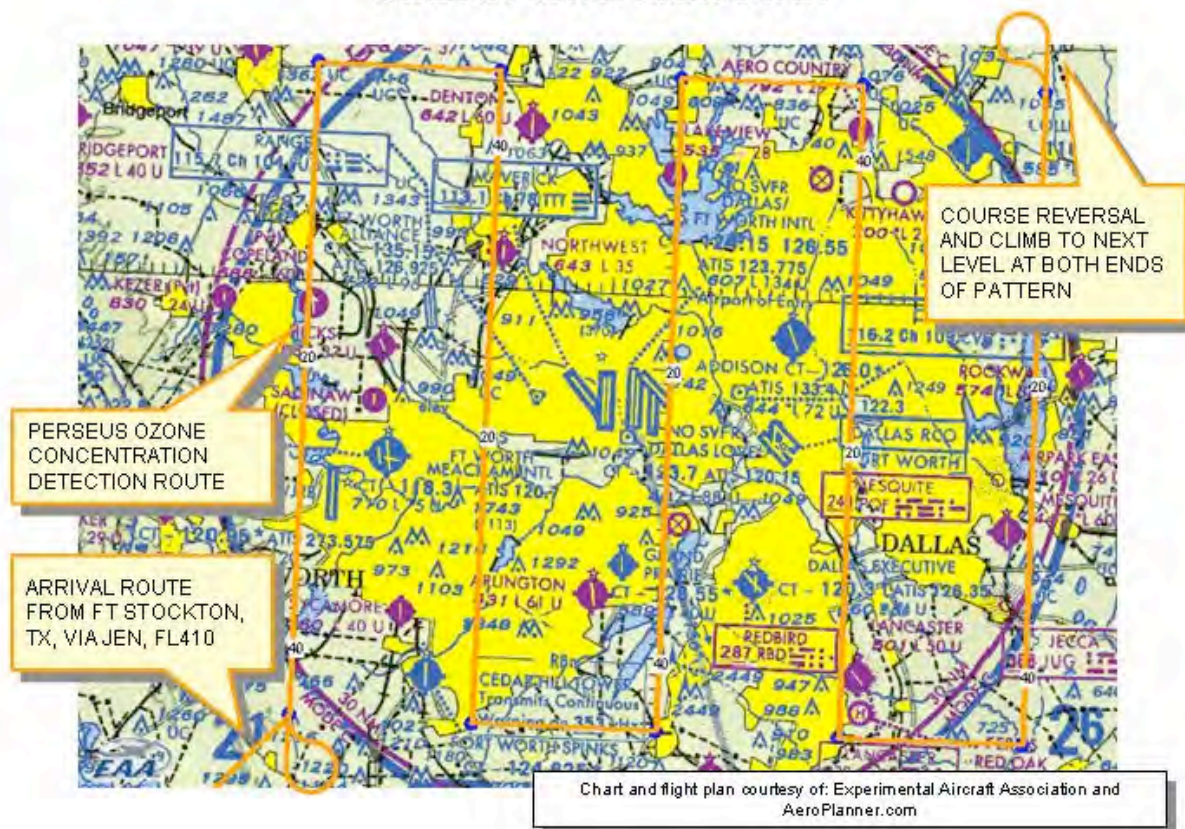### Identical Path for Each Aircraft

Figure 9 Perseus B DFW Area Ozone Analysis Route

FL630
FL610
FL590
FL570
FL550
FL530
FL510
FL490
FL470
FL450
FL430

FL410

North

Pattern Area Covers
Greater Dallas/Fort Worth
Corporate Limits

Egress, Return to
Base

Covered by Aircraft 1:
FL430-630, 4,000 ft Separation

Covered by Aircraft 2:
FL410-610, 4,000 ft Separation

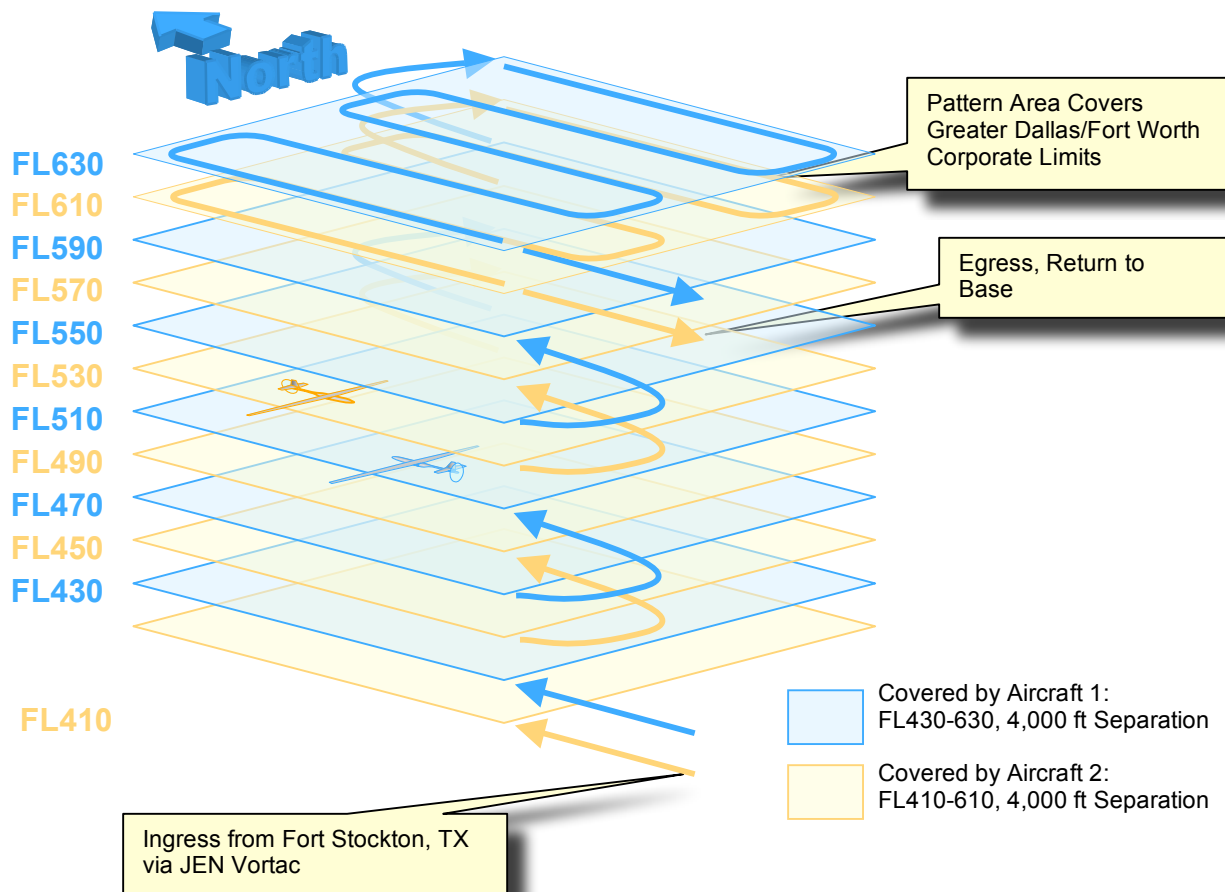Ingress from Fort Stockton, TX
via JEN Vortac

Figure 10 Dual Perseus B ozone concentration mapping flight levels. A course reversal and 4000 ft climb will be performed at the end of each traverse.

Helios

The Helios mission is a high altitude communications relay, possibly for telephone or high-definition television, over the greater Dallas/Fort Worth Area. The Helios will maintain a constrained holding pattern to ensure antenna coverage. A large factor in the Helios mission will be the winds aloft, as the wind velocity may exceed the aircraft airspeed. Another factor in the profile is that the aircraft is assumed not to be equipped with a fuel cell power unit for use during night hours when solar power is unavailable. For night operations, we therefore assume that Helios must rely on storage batteries, which are postulated to be sufficient to maintain FL510 for a period of 12 hours. The batteries are then recharged using surplus daylight solar cell power as Helios climbs to and maintains the higher altitude.

The aircraft will Depart Henry Post AAF at nearby Fort Sill, OK, and climb to FL400 in Restricted Area R6501. Figure 11 shows the mission waypoints and Figure 12 shows the course over the DFW area. The aircraft will climb en route to SPS VORTAC to FL490 heading south-southwest. The aircraft will then climb en route to the UKW VORTAC to FL510 heading southeast. After that, the aircraft will maintain FL510 at an orbit point over TTT VORTAC, where it will use battery power during the night hours until the dawn of day two. On day two, the Helios will climb to FL800 at an average climb rate of 333 feet per minute (fpm), where it will hold until sunset. At sunset, the aircraft will descend to FL510 using its best power-off sink rate of 300 fpm. Figure 12 shows the Helios mission time versus altitude profile and Figure 14 depicts the mission distance versus altitude profile. The aircraft will repeat this on-station daylight climb/night descent pattern until relieved by another Helios. During the handoff of one Helios to the relieving unit, the two aircraft may be in nearby orbits for as much as 12 or more hours.

Location	Mag Crs (deg)	Gnd Spd (kts)	Dist (nm)	Time (min)
Depart Henry Post AAF [Ft Sill, OK], Climb in R5601 to FL400 (no time recorded), Depart for SPS from directly over airport	188	39	40.8	1:02
SPS Vortac [Wichita Falls]				
	119	49	47.1	0:57
UKW Vortac [Bowie]				
	134	49	30.0	1:08
TTT Vortac [Maverick] Holding Pattern Anchor Point				
[Hold until dawn using battery power, Day 2; then climb to FL800, relieving current Helios if present]				
[Hold until sunset, Day2; then descend at lowest sink rate to FL510 and hold until dawn, Day 3, using battery power]	[See slides depicting altitude vs time, distance vs time, wind speed effects, and orbit patterns depending on wind speed]			
Repeat daylight climb/hold to FL800, night descend/hold to FL510 until relieved]				
[Return to Fort Sill via reverse of ingress route after handoff to relief Helios]				

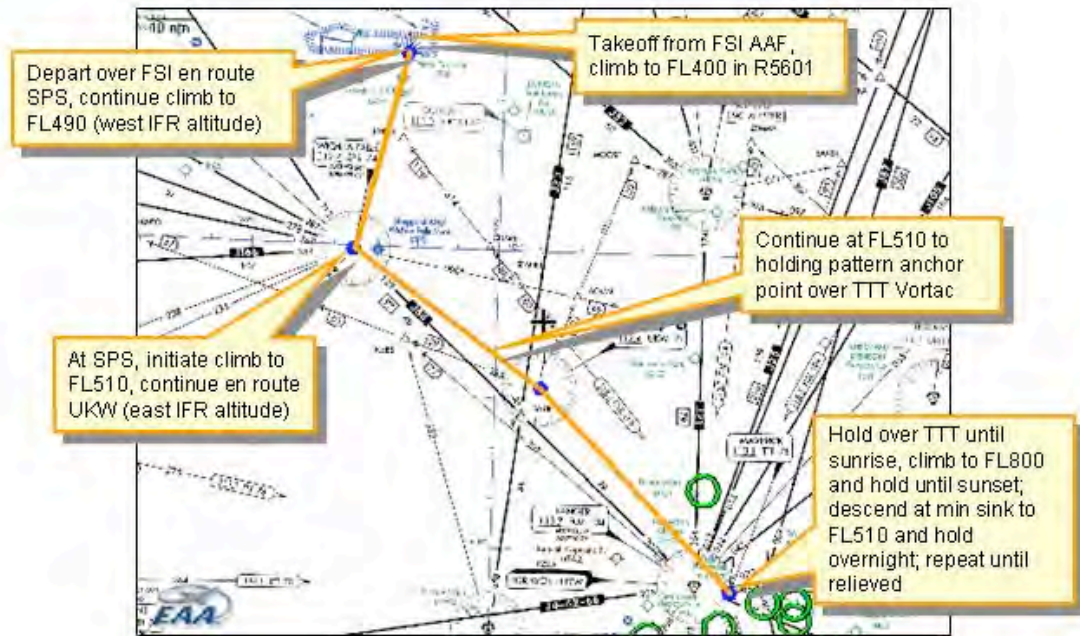Figure 11: Helios communication relay mission waypoints at FL400-FL800, no wind.

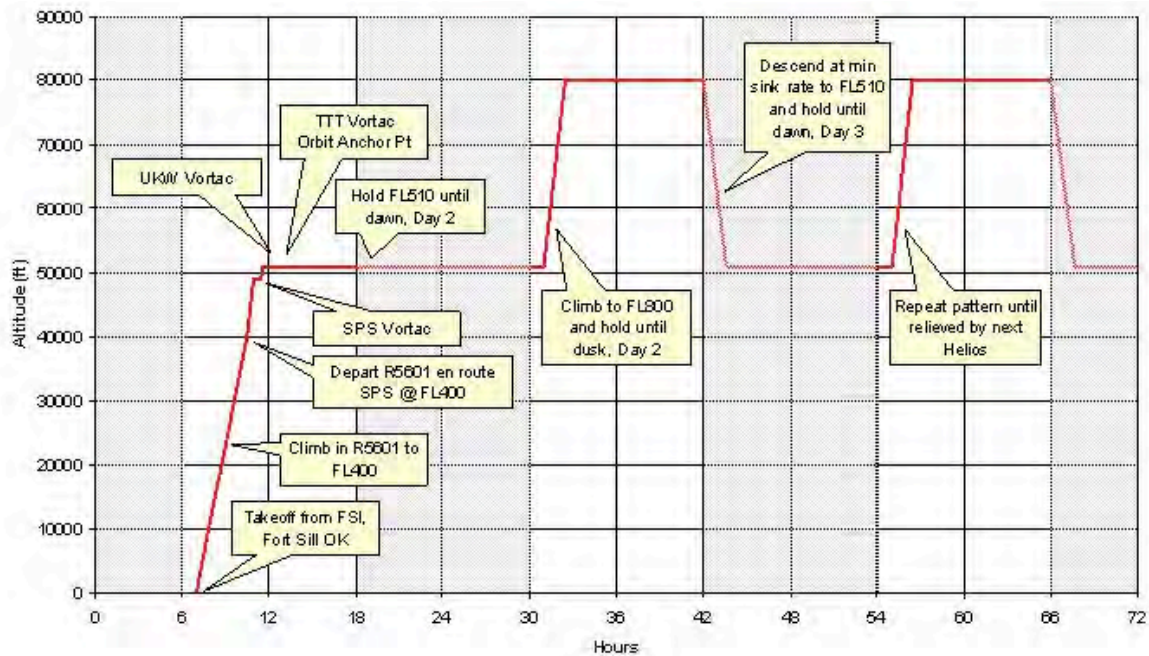Figure 12: Helios Route of Flight, ingress to hold point

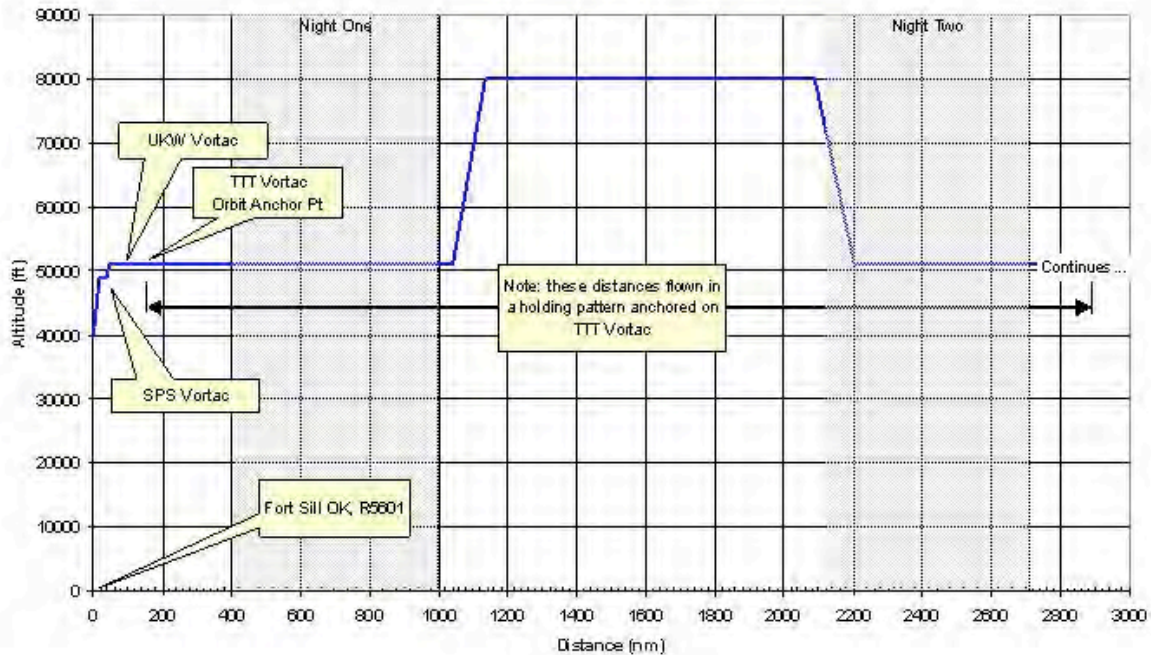Figure 13 Helios communication relay mission. Altitude profile vs. Time.

Figure 14 Helios communication relay mission. Distance vs. Altitude.

As mentioned previously, wind speed may play a large role in this mission. Figure 15 shows the effects of wind on notional Helios orbits, assuming the aircraft is flying at 50 KTAS. With no wind, the Helios executes a racetrack orbit on a heading optimized for the sun angle, with 2 minute turns at the end of each orbit and 2 minute legs at 2 nm per leg. With a 25 knot wind, the nominal racetrack is changed to a D-shaped pattern with a 1 nm/2 minute leg on a heading directly into the wind, followed by a continuous 4-minute turn to the base of the inbound leg. Wind speeds approaching the aircraft speed could preclude any downwind legs at all, instead requiring opposing "S" turns or perhaps a "Figure 8" type of on-station orbit. Of course, if the wind speed exceeds the aircraft speed (a not improbable event), it cannot maintain its position at all.
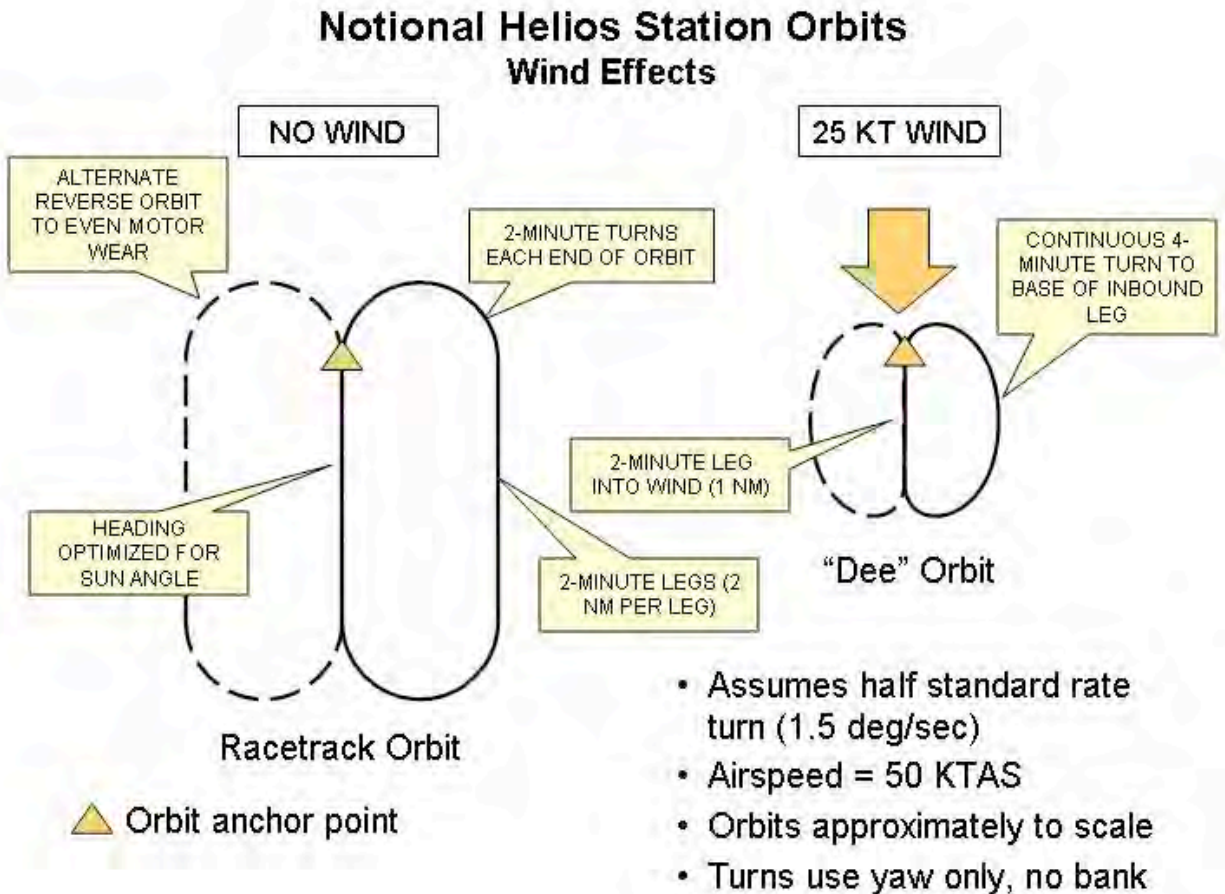
Figure 15 Notional Helios station orbits and wind effects

Global Hawk

The Global Hawk mission involves a repetitive high altitude/long duration surveillance of reservoirs north, south and west of the DFW area for Homeland Security purposes. This mission utilizes high-resolution IR/electro-optical cameras, high-resolution Doppler radar with moving target indication, and high-resolution Synthetic Aperture Radar.

The Global Hawk will depart Beale AFB. The mission waypoints can be seen in Figure 16. The aircraft will climb to FL400 en route at its best rate of climb, then accelerate to Mach 0.6 in level flight. The aircraft will ingress to the DFW airspace via a direct great circle route between the HEC and SPS VORTACs. Figure 17 shows the Global Hawk surveillance route in the DFW area. The aircraft will maintain a mission loop, at FL650 using its best endurance speed of 343 KTAS (Mach 0.6), with the UKW VORTAC as the starting point and passing over the MQP, JEN and FUZ VORTACs and back to UKW. The mission loop will occur for a

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

period of 24 hours, revisiting waypoints approximately every 30 minutes. The aircraft will then return to Beale via the reverse of the ingress route.

	Mag Crs (deg)	Gnd Spd (kts)	Dist (nm) FL410	Time (h:m)
Depart Beale AFB, CA				
	105	275	262.8	0:57
BTY Vortac [Beatty]				
	082	343	904.9	2:38
STS Vortac [Wichita Falls]				
	119	343	47.1	0:08
UKW Vortac [Bowie]				
	185	343	49.3	0:08
MQP Vortac [Milsap]				
	164	343	34.5	0:06
JEN Vortac [Glen Rose]				
	039	343	56.3	0:09
FUZ Vortac [Ranger]				
	315	343	50.4	0:08
UKW Revisited [Loop complete]				
	Loop Dist /		141.2	0:31

Figure 16 Global Hawk ZFW Surveillance Route Waypoints. Altitude FL650, no wind, 343 KTAS.
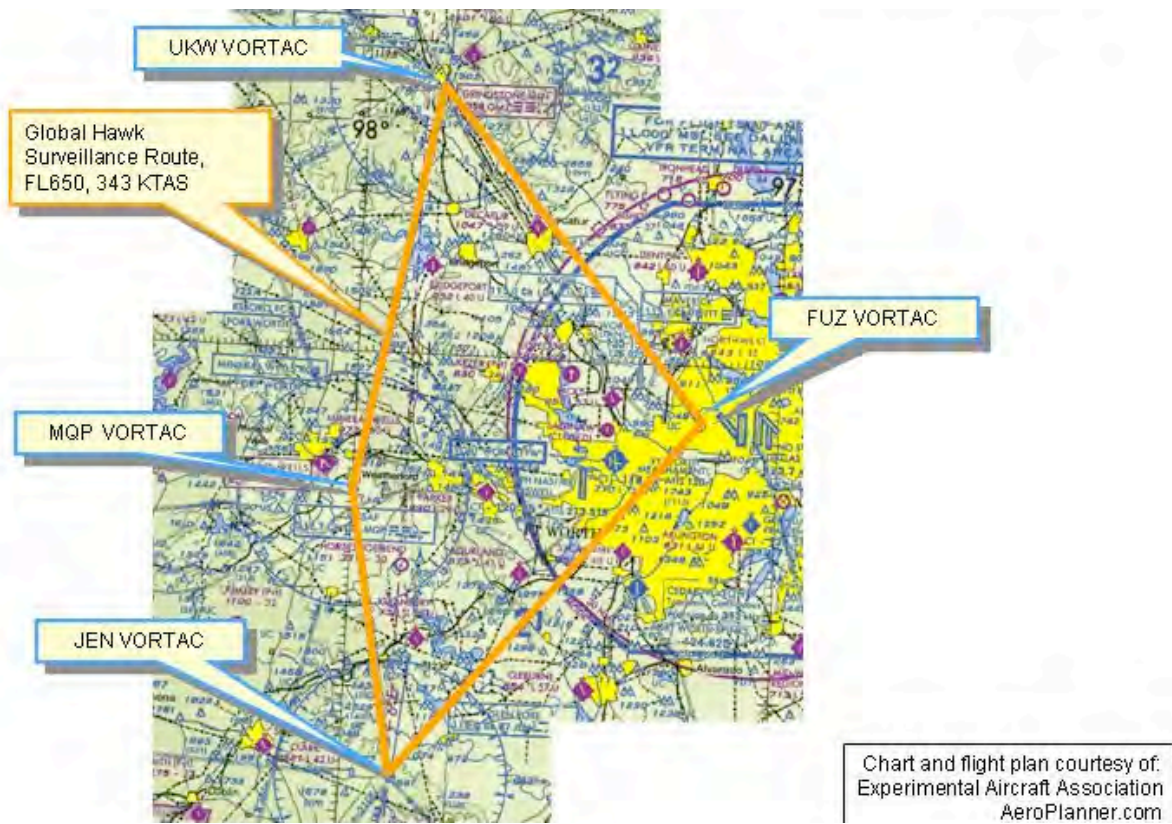
Figure 17 Global Hawk ZFW area lakes surveillance route.

Off Nominal Events

Simulation scenarios for off-nominal events will be based on contingencies encountered during the execution of the nominal mission profiles. These contingencies will be defined by the Contingency Management work package within the Technology IPT, and procedures to manage the contingencies will be evaluated in the simulation environment. Contingency scenario definition will occur with consideration for potential impact of management procedures on controller and operator workload and situational awareness, as well as airspace operational aspects such as complexity and efficiency. The Contingency Management Work Package, in coordination with the Policy IPT, will define 'emergency' procedures for critical contingencies, and coordinate which of the multitude of possible contingencies and combinations of contingencies require evaluation in the simulation environment.

5.3   Simulation Procedures

Each weekly session of simulations will follow a structured pattern of activities designed to minimize impact of process on the collected data. Pseudo pilot training will occur prior to simulation activities; this training is required to achieve a level of proficiency with operating the target generation facility necessary to be transparent to the air traffic controller subjects. A pre-briefing session will introduce the controller subjects to the purposes of the simulation, and to the ROA mission profiles that would require such briefing during routine ROA operations (assumed normally not required).   However, vehicle performance capabilities will be briefed to the controller subjects, as well as to the pseudo-pilot participants, as this is considered basic knowledge to performing required tasks for any type of vehicle in the NAS. Any recommended ATC procedures for managing contingencies or emergencies with ROAs will necessarily briefed prior to simulation. Where complexity of a procedure warrants practice sessions, such sessions will be performed prior to collecting any data. A day in the week-long session will consist of short daily briefing of the day's planned activities, a series of 3-5 simulation scenarios, each followed by (or interrupted by) metrics collection and a debrief session to document general feedback, and a closing summary of day's activities and comments on simulation conduct and any remaining issues. Each of the simulation scenarios and ROA missions will be designed to minimize similarities between runs. While unique scenarios will not be produced for each run, scenarios will be adjusted by shifting initial conditions and flight numbers such that each scenario appears unique to the controller subjects. It is anticipated that 2-4 controller subjects will be required for each simulation scenario, as well as 4-6 pseudo-pilots.

6.0   Data Collection and Analysis

The Aeronautical Datalink and Radar Simulator (ADRS) continuously collects state data on all aircraft in a simulation. The Multi Aircraft Control System (MACS) software collects data on controller inputs and various aircraft parameters. MACS data collection is configurable, see figure below for an example.
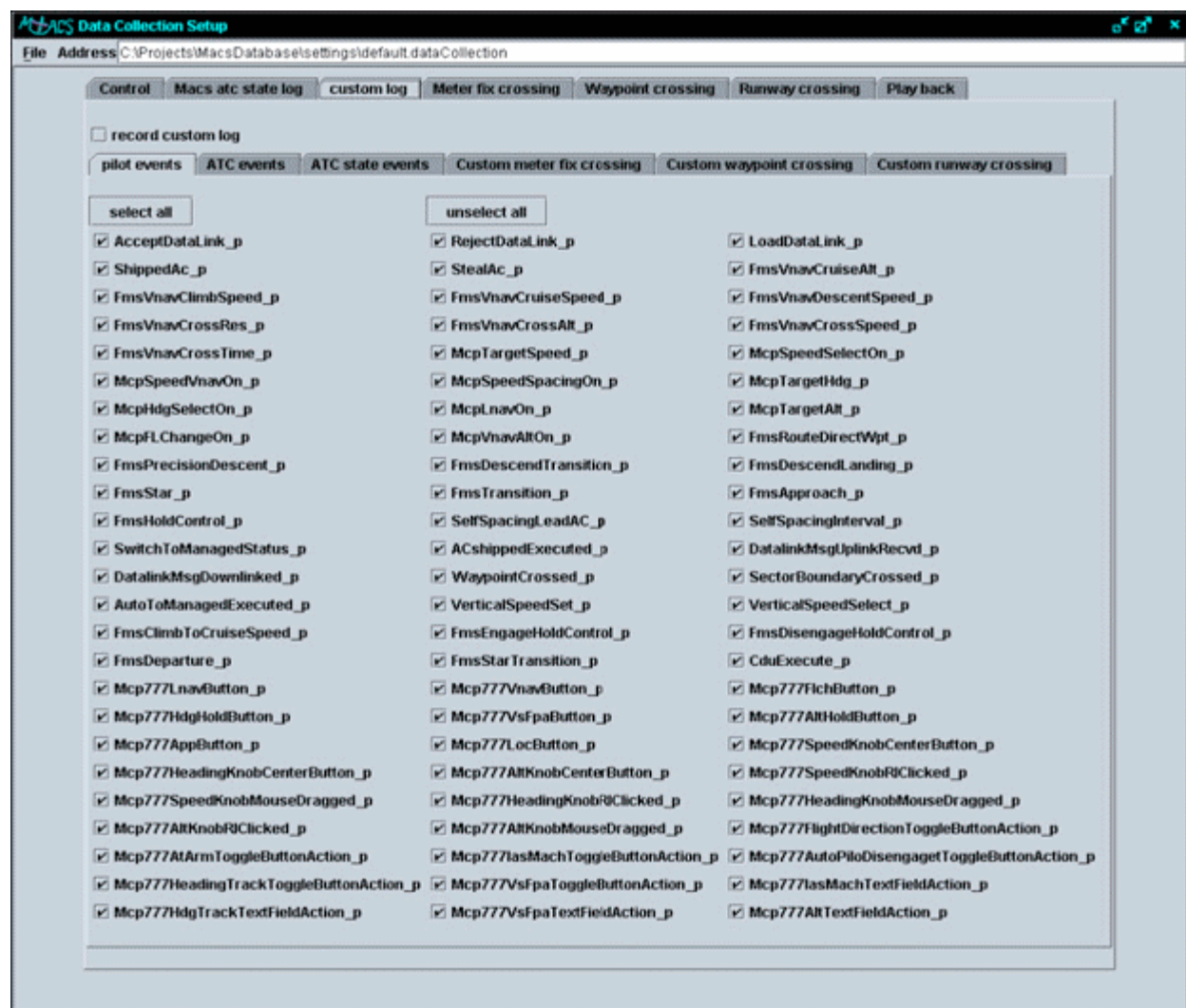

Figure 6 MACS data collection – pilot, ATC, and other variables can be selectively recorded.

6.1   Dependent Variables

Dependent variables collected during simulation include:

Aircraft Parameters

- Closest Point of Approach (CPA) between aircraft (that fall within a pre-specified radius of each other). Are CPAs more 'severe' with ROAs present?

- Sector transition times of manned aircraft. Are transition times adversely affected by the presence of one or more ROAs?

- Flight path deviations. Are manned aircraft deviated from optimal flight paths when ROAs are present?

Controller Parameters

- Number and duration of controller communications. Are communications more frequent, subject to repetition, of longer duration with ROAs present? How does ROA communication latency affect operations?

- Use of controller tools (trajectory predictors, etc), manned aircraft versus ROAs. Is tool use more frequent, longer in duration, when monitoring ROAs versus manned aircraft?

- Point Outs. Are "point outs" to manned aircraft more numerous with ROAs present in the airspace?

- Operational Errors. Is there an increase (or decrease) in the occurrence of operational errors (loss of separation) in the presence of HALE ROAs?

Other

- CTAS post simulation controller questionnaires. The Workload Assessment Keypad (WAK) may be used to collect workload ratings at regular intervals during a simulation. NASA's TLX may be used to collect subjective, post hoc ratings.

6.2   Data Analysis Tools

Objective Measures

Situation Awareness options:

- SAGAT – The Situation Awareness Global Assessment Technique [5] offers an objective measure of situation awareness (SA), under simulated conditions. The technique uses periodic, randomly-timed freezes of the simulation, during which

operator displays are blanked, and a series of questions posed, to assess his or her knowledge of what was occurring at the precise time the simulation was suspended.

The core advantage of SAGAT is its objectiveness. The resulting index of SA also encompasses a wide range of elements believed important to SA. The primary disadvantage of SAGAT is the intrusive nature of the measure on the tasks being performed; continuing a scenario after this intrusion is ill-advised.

Subjective Measures

Situation Awareness options:

- SART – The Situation Awareness Rating Technique [5] is used for rating situation awareness of operators of complex human-machine systems. It is an index of how well operators are able to acquire and integrate information.

  Operators rate their SA on a bi-polar scale to indicate how they perceive 1) demand for their attentional resources, 2) the supply of attentional resources, and 3) their understanding of the situation. A disadvantage of SART is that the resulting SA score is based on how well the operator thinks he/she did, as opposed to how good he/she actually did.

Workload Assessment options:

- NASA TLX – The NASA Task Load Index [3] is a subjective, post-hoc workload assessment tool. The multi-dimensional rating procedure that derives an overall workload score is based on a weighted average of ratings on six sub-scales – Mental Demand, Physical Demand, Temporal Demand, Own Performance, Effort, and Frustration.

- ATWIT – The Air Traffic Workload Input Technique [4] is the subjective workload ratings given by participants during a specific time interval. To ensure stable ratings, the average of three workload ratings made during the time interval comprises the period's score.

Data can be collected for ATWIT using Workload Assessment Keypads (WAKs). A WAK can be positioned adjacent to a controller's workstation, and set up to issue an audible alert at regular intervals, at which time the participant indicates their current workload on a scale of 1 to 7 (1 = very low, 4 = moderate, 7 = very high) on a simple keypad device.

By coordinating workload measures taken during a study, with post-hoc measures using a similar scale, comparisons can be made.

Other Measures:

- CARS – Controller Acceptance Rating Scale [6] is a subjective, post hoc system acceptability measure. CARS is based on the Cooper-Harper Scale for evaluating vehicle handling qualities, and modified for evaluation of air traffic systems by air traffic controllers. CARS may be employed to evaluate acceptability of the air traffic controller's environment once the multitude of technologies and procedures are integrated into simulation.

7.0   Upcoming Simulation Schedule

November/December - Implementation

- Detailed scenario description (at the level coders need for implementation)
- Data collection defined and implemented

December/January - Training

- Airspace definition and integration
- Weather defined and integrated
- Instructional training for:
    - Pseudo-pilot operators (MACS stations)
    - ROA pseudo-pilot operators (MACS stations)
    - Air Traffic Control participants
    - Experimenters / Support Personnel
- Test:
    - Data collection
    - Video monitoring
- Documentation Review
    - Rating forms (TLX, SART, etc)
    - Questionnaires (demographics, post-action, etc.)
    - Data sheets/coding forms
    - Flight plans/maps/training packages

February/March – Normal Operations Simulation

- Full dress rehearsal sim (1st week)
- Refine procedures
- Schedule:
    - People
    - Facilities
- Conduct simulation
- Demos/Documentation

May-August – Full Mission Simulations

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Acronyms

ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control (Controller)
ATM	Air Traffic Management
ATWIT	Air Traffic Workload Input Technique
HALE	High Altitude Long Endurance
LOS	Loss Of Signal
MACS	Multi-Aircraft Control Station
PTT	Push-To-Talk
ROA	Remotely Operated Aircraft
SA	Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SART	Situation Awareness Rating Technique
TRACON	Terminal Radar Approach Control (facility)
UAV	Unmanned Aerial Vehicle
WAK	Workload Assessment Keypad