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COVER SHEET

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Abstract:

This deliverable was intended as an input to the Access 5 Policy and Simulation Integrated Product Teams. This document contains high-level pilot functionality for operations in the National Airspace System above FL430. Based on the derived pilot functions the associated pilot information and control requirements are given.

Status:

Document Status SEIT Approved

Limitations on use:

This document represents thoughts and ideas of the Human System Integration Work Package team. It has not been reviewed or approved as an Access 5 project position on this subject; the information needs substantiation through simulation/flight demonstrations. Analysis was limited to enroute operations above FL430. Operations below FL430 and terminal operations have not been addressed in this document.

Human Systems Integration Requirements and Functional Decomposition



Access 5
Technology Integrated Product Team
Human Systems Integration

February 2005



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Foreword

The Human System Integration (HSI) tasks that were performed in FY04 contributed to the development of functional requirements and design guidelines for High Altitude Long Endurance (HALE) Remotely Operated Aircraft (ROA) operation at or above FL400 in the National Airspace (NAS). The Access 5 intent is to provide file and fly access to the NAS for HALE ROAs, identically to that available to manned aircraft.

The HSI FY04 work package prepared the following deliverable to contribute to the Step 1 program objectives:

- HSI Concepts Requirements and Definition Report, dated September 2004

The Access 5 Systems Engineering Integration Team (SEIT) reviewed the above document and requested that it be divided into four component reports in order that content be more readily assimilated by users of the material. These component parts are:

- HSI Regulatory Analysis, dated February 2005
- HSI ROA Comparisons, dated February 2005
- HSI Functional Decomposition, dated February 2005
- HSI Top Level Requirements, dated February 2005

The Concept Requirements and Definition Report was written in an integrated fashion and as a result breaking the material into stand-alone parts could not always be done with clear distinctions. The reader is encouraged to consult the integrated document if additional clarifications are needed.

Other FY04 deliverables for the HSI Work Package were:

- Human Engineering Program Plan
- HSI ROA Guidelines Outline (Annex A)
- HSI Functional Requirements- ROA C3 and CCA Subsystems (Annex B)

HSI Work Package Acknowledgements

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This deliverable is intended as an input to the Policy and Simulation IPTs. It aimed to answer the following questions:

- 1) What are pilot functionality requirements that correspond to required vehicle functionality? These were derived only at a high level and will be decomposed into greater detail by the end of Step 1.
- 2) What are the derived high-level pilot information and control requirements associated with required ROA functionality?

ROA Pilot and Air Traffic Controller Functional and Task Requirements¹- A set of a high-level, preliminary functions required of the ROA pilot was defined. Requirements specified in ROA-specific paragraphs of FAR Part 91 and AIM dictate functions required of the pilot. Requirements in ROA-specific paragraphs of FAA Order 7110.65 dictate the functions for the air traffic controller. Functions and task data are necessary for the derivation of crew information and control requirements, and follow-on workload and timeline analyses. *See Table 1.*

ROA Pilot and Air Traffic Controller Information and Control Requirements²- A set of a high-level, preliminary information and control requirements for the ROA pilot was defined. These data are derived from the functions and task analysis results that were produced in the previous analysis. These data are the basis for the derivation of crew workload and timeline analyses, and follow-on analyses for human-machine function allocations and material produced for the Human Systems Integration Design Guide. *See Table 2.*

¹ Air traffic controller functions will be provided in an update to this report.

² Air traffic controller information and control will be provided in an update to this report.

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1 Overall Problem: Unrestricted ROA Flight in the ATM System

ROA operations and, hence, sales are not meeting their full potential because of ATM-induced penalties. Currently, each ROA flight is handled as a special case, which is time-consuming, complex, and expensive. ROA operators are unable to operate efficiently due to ATM-mandated restrictions. As a result, potential ROA buyers and operators are reluctant to make large purchases due to ATM-related issues.

There is a large variety of existing and planned ROAs, each with its own unique in-flight capability. Some are very-high performance turbojets, some are piston-driven low-performance aircraft, and some are akin to model aircraft in size and performance.

None of these, however, currently possesses the functionality for unrestricted flight in the ATM system. They lack the requisite functionality by design; operate as military-unique vehicles employing special handling within civil or military airspace; or simply have not been designed with an eye toward flight in commercial airspace.

Access 5 efforts now underway aim to allow ROAs unrestricted access to the NAS for normal flight operations. This implies new concepts, rules, and regulations for both ROAs and the ATM system.

1.1 HSI Issues: Unrestricted ROA Flight in the ATM System

There are very few HSI issues unique to ROA operation in the NAS. This is because, for the most part, ROAs are similar to inhabited aircraft and are expected to be able to comply with most existing regulations.

However, the issues that do exist are significant and have, to date, disallowed unrestricted ROA flight in the NAS.

The Primary Issues for the ROA pilot are:

- Pilot ability to obtain required information on ROA performance and status in a timely fashion while operating on the ground and in flight
- Pilot ability to affect control of the ROA as required and in a timely fashion while operating on the ground and in flight
- Pilot ability to operate the ROA safely while operating on the ground and in flight
- Pilot ability to operate the ROA in compliance with Federal Aviation Regulations while operating on the ground and in flight

The Primary Issues for the air traffic management (ATM) system are:

- Air traffic controller ability to obtain required information on ROA performance and status in a timely fashion
- Air traffic controller ability to control the ROA as part of the overall traffic flow

In addition, there are Secondary Issues that must be resolved to satisfy the issues above:

- Satisfactory performance of ROA automation and autonomy including pilot override capability
- Pilot-directed or autonomous design to accomplish hazard avoidance
- Satisfactory performance of the pilot-ATM communications link
- Satisfactory performance of the pilot-ROA communications link
- Development of procedures and plans for specific non-normal and emergencies operations

The 2004 HSI effort is aimed at examining these and other issues to define HSI concepts and requirements for the pilot and air traffic controller that allow unrestricted ROA flight above FL400 in the NAS.

2 Objectives

Regulatory analysis documented in a separate FY04 HSI report submitted to the Access 5 SEIT, defines probable requirements in FARs, AIM, and Order 7110.65, a complete definition of functions and task provides allows performance of an analysis of pilot and air traffic controller information requirements and control functions. These define the information that must be presented to the pilot and air traffic controller and the control actions they must be able to affect. This functional decomposition is reported in this document.

2.1 Summarize Potential Concepts, Requirements, and Regulations.

This objective is concerned with summarizing the results from the analyses of FARs, AIM, and FAA Order 7110.65. The summary indicates those regulations and practices that an ROA is expected to comply with. These lead to the definition of requirements for pilot and air traffic controller functions, tasks, and information and control requirements. In addition, this task outlines regulations and practices that are expected to require change because of certain, basic ROA capabilities and limitations.

2.2 Identify Pilot and Air Traffic Controller Functional and Task Requirements.

This objective is concerned with identifying a high-level, preliminary set of functions required of the ROA pilot. Requirements specified in ROA-specific paragraphs of FAR Part 91 and AIM dictate functions required of the pilot. Requirements in ROA-specific paragraphs of FAA Order 7110.65 dictate the functions for the air traffic controller.

2.3 Determine Pilot and Air Traffic Controller Information and Control Requirements.

This objective is concerned with identifying a preliminary set of high-level pilot and air traffic controller information and control requirements. These are derived from the functions and task analysis in the previous Objective.

2.4 For the Objective: Summary of Potential Concepts, Requirements, and Regulations.

Findings from previous analyses of the FARs, AIM, and FAA Order 7110.65 were combined. The total of this information was analyzed in light of expected ROA capabilities to yield an indication of probable ROA compliance. This led to a definition of requirements that an ROA is expected to comply with and those it would not. Changes required to the documents were described. Rationales were given for each.

The summary of these findings led to definition of a concept for ROA flight in the NAS, where most regulations and requirements for inhabited aircraft are adhered to by an ROA, but with some exceptions. The exceptions are described as irregularities to the current concept of flight for inhabited aircraft in the NAS.

Safety was selected as the most critical topic. After reviewing the literature, ROA requirements were categorized according to safety-related criteria:

- Communications
- Emergencies
- Automation and autonomy

For each area, a requirement or concept was defined with an associated rationale for its applicability to a HALE ROA.

2.5 For the Objective: Identify Pilot and Air Traffic Controller Functional and Task Requirements.

Pilot functions were identified through a decomposition of potential concepts, requirements, and regulations. Functions were derived from these concepts, in concert with standard functions required of a pilot in an inhabited aircraft, to yield a set of ROA pilot functions for flight above FL400. Pilot task analysis and air traffic controller functions and task analyses were not performed; these will be conducted in FY05.

2.6 For the Objective: Determine Pilot and Air Traffic Controller Information and Control Requirements.

Pilot information requirements were identified through a decomposition of pilot functions. These requirements were derived from the functions analysis, in concert with standard information required of a pilot in an inhabited aircraft, to yield a set of ROA pilot information requirements for flight above FL400. Pilot control requirements and air traffic controller information and control analyses were not performed; these will be conducted in FY05.

2.7 Collaborative and Coordinating Efforts

The Access 5 Human Systems Integration (HSI) team interacted with relevant Access 5 Integrated Product Teams (IPTs), manufacturers, and operators to analyze ROA-ATM issues. In support of formal objectives, analytic, interview, and literature search methods were employed to gather all relevant data regarding the interface between these ROAs and their pilots, and ATM. Manufacturer representatives and ROA pilots provided data describing their respective ROAs through interviews and questionnaires. The general HSI areas emphasized include:

- Functions and Task Analysis – Analysis for identification of HSI functions required of the crew-ROA systems and ROA-ATC integration
- Information and Control Capability Analysis – Analysis for identification of the information required of the ROA pilot and air traffic controller and required control functions for each.
- Procedures Definition - Definition of standard HSI operational procedures for ROAs in the NAS
- Coordination with Other IPTs - Delivery of information necessary Policy, ROA Impact, Technology, and Simulation IPTs

3 Results and Discussion

3.1 Summary of Potential Concepts, Requirements, and Regulations.

3.2 Pilot and Air Traffic Controller Functional Requirements.

This objective is concerned with identifying a high-level, preliminary set of functions required of the ROA pilot. Requirements specified in ROA-specific paragraphs of FAR Part 91 and AIM dictate functions required of the pilot. Requirements in ROA-specific paragraphs of FAA Order 7110.65 dictate the functions for the air traffic controller (These air traffic controller functions will be defined in an update to this document.).

An analysis of FAR Part 91 and the AIM allowed translation of regulatory and recommended practices for pilots into pilot functional requirements. The pilot functional requirements shown in Table 1 are those for flight above FL400. They have been developed only at a high level and will be decomposed into greater detail by the end of Step 1.

Table 1. Pilot Functional Requirements

ID	Vehicle Functionality Description	Pilot Functionality Requirement
FLIGHT		
1	Pitch, Roll, Yaw ³	Monitor and control in response to aircraft requirements and ATC clearance
4	Indicated/Calibrated/Equivalent Airspeed	Monitor and control in response to aircraft requirements and ATC clearance
5	Mach Number ⁴	Monitor and control in response to aircraft requirements and ATC clearance
6	Altitude	Monitor and control in response to aircraft requirements and ATC clearance
7	Barometric Altimeter Setting	Set and monitor 29.92 in. Hg
9	Vertical Speed	Monitor and control in response to aircraft requirements and ATC clearance
12	Pilot-ATC Communication	Select assigned ATC frequency; Receive and comply with ATC clearances; Acknowledge ATC clearances;

³ Requirement dictated by aircraft design.

⁴ Only as required by airspeed/Mach envelope.

		Make requests to ATC
13	Pilot-ROA Communication	Monitor and control uplinks and downlinks and command aircraft in response to ATC clearance
16	Heading	Monitor and control in response to ATC clearance
18	Track (Magnetic/True)	Monitor and control in response to ATC clearance
21	Vertical Profile Deviation	Monitor and control in response to ATC clearance
23	Lateral Profile Deviation	Monitor and control in response to ATC clearance
30	Interactive Flight Plan Revising	Perform as necessary changes to 4D flight plan in response to ATC clearance or own need to revise flight plan
32	RNAV Capability (via GPS, INS, or equivalent) ⁵	Monitor and control all aspects of navigation in response to ATC clearance
33	Radio (VHF/UHF) ⁵	
34	DME ⁵	
41	Distance to Go	Monitor or calculate and control in response to navigation requirements and ATC clearance
42	Time to Go	
43	Wind Speed and Direction	Monitor or calculate in response to navigation requirements and ATC clearance
44	Estimated Time of Arrival at Waypoint	Monitor or calculate and control in response to navigation requirements and ATC clearance
46	Aircraft Position	Monitor and control in response to ATC clearance
SURVEILLANCE		
59	Permit ATC Secondary Surveillance Radar Identification via Transponder or Datalink	Set transponder to code assigned by ATC
HAZARD AVOIDANCE – SURVEILLANCE ⁶		
60	Weather (Direct View)	(1) Search for, (2) identify, (3) determine nature, (4) evaluate severity and magnitude, (5) determine lateral and vertical movement, and (6) determine if necessary to avoid
61	Weather (Radar)	
62	Precipitation (Direct View)	
63	Precipitation (Electronic)	
64	Turbulence (Direct View)	
65	Turbulence (Electronic)	
66	Lightning (Direct View)	(1) Search for, (2) identify, (3) determine nature, (4) evaluate severity and magnitude, (5) determine lateral and vertical movement, and (6) take action to avoid
67	Lightning (Electronic)	
68	Volcanic Ash (Direct View)	
74	Flight Traffic (Direct View)	(1) Search for, (2) detect, (3) identify, determine lateral and vertical movement, (4) decide if threat exists, (6) determine if necessary to avoid - If necessary to avoid, (7) determine avoidance maneuver, (8) maneuver to avoid threat, (9) advise ATC
75	Flight Traffic (Electronically)	
MISCELLANEOUS		

⁵ Navigation capability may be satisfied by use of self-contained navigation capability or via NAVAIDS.

⁶ Hazards may be identified by direct view or electronic display.

84	Identify Visual Flight Rules Conditions	Observe flight visibility and distances to clouds and apply VFR visibility standards to determine if in VFR conditions
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3.3 Pilot and Air Traffic Controller Information and Control Requirements.

This objective is concerned with identifying a preliminary set of high-level pilot information and control requirements. Requirements specified in FAR Part 91 and AIM dictate functions and tasks required of the pilot. These functions and tasks may be interpreted as required human control functions. In addition, specific requirements in Part 91 require the pilot to know or obtain certain information, Hence, the Part is a basis for defining pilot information and control requirements.

An analysis of FAR Part 91 and the AIM allowed translation of regulatory and recommended practices for pilots into pilot functional requirements. Decomposition of functional requirements led to identification of pilot information requirements. The pilot information requirements shown in Table 2 are those for flight above FL400. They have been developed only at a high level and will be decomposed into greater detail in the next update to this section. Control requirements will also be defined in the next update.

Table 2. Pilot Information Requirements

ID	Vehicle Functionality Description	Pilot Information Requirement
FLIGHT		
1	Pitch, Roll, Yaw ⁷	Pitch, Roll, and Yaw, in degrees, from local vertical
4	Indicated/Calibrated/Equivalent Airspeed	Display – Speed, in knots
5	Mach Number ⁸	Display – Speed, in Mach Number
6	Altitude	Display – Altitude, in feet, above mean sea level
7	Barometric Altimeter Setting	Display – Barometric altimeter setting, inches of Hg
9	Vertical Speed	Display – Vertical speed, in 10s, 100s, and/or 1000s ft/min, appropriate to aircraft performance
12	Pilot-ATC Communication	Display – Radio frequency, radio on/off
13	Pilot-ROA Communication	Display -Status of available uplinks and downlinks; identification of uplink and downlink currently in use

⁷ Requirement dictated by aircraft design.

⁸ Only as required by airspeed/Mach envelope.

NAVIGATION		
16	Heading	Display – Heading, in degrees, measured from magnetic and/or true north
18	Track (Magnetic/True)	Display – Track, in degrees, measured from magnetic and/or true north
21	Vertical Profile Deviation	Display – Deviation, in feet, from assigned altitude
23	Lateral Profile Deviation	Display – Deviation, in units appropriate to the method of navigation, from assigned track
30	Interactive Flight Plan Revising	All information relevant to the flight plan including lateral and vertical information, times, and speeds
32	RNAV Capability (via GPS, INS, or equivalent)	Display - All information relevant to navigation including lateral and vertical information, times, and speeds
33	Radio (VHF/UHF) ⁹	
34	DME ⁹	
41	Distance to Go	Display – Distance, in nm, to next fix, WP, or other lateral point and to point at which an altitude is reached OR Calculated by pilot
42	Time to Go	Display – Time, in hh:mm:ss, to next fix, WP, or other lateral point and to point at which an altitude is reached OR Calculated by pilot
43	Wind Speed and Direction	Display – Wind speed and direction OR Calculated by pilot
44	Estimated Time of Arrival at Waypoint	Display – ETA at WP OR Calculated by pilot
46	Aircraft Position	Display – Aircraft icon on navigation map
SURVEILLANCE		
59	Permit ATC Secondary Surveillance Radar Identification via Transponder or Datalink	Display - Transponder modes and code
HAZARD AVOIDANCE – SURVEILLANCE ¹⁰		
60	Weather (Direct View)	Display - Sensor image showing weather
61	Weather (Radar)	Display - Electronic representation showing weather and its intensity in relation to own aircraft
62	Precipitation (Direct View)	Display - Sensor image showing weather
63	Precipitation (Electronic)	Display - Electronic representation showing weather and its intensity in relation to own aircraft
64	Turbulence (Direct View)	Display - Sensor image showing weather from which turbulence may be inferred by the pilot

⁹ Navigation capability may be satisfied by use of self-contained navigation capability or via NAVAIDS.

¹⁰ Hazards may be identified by direct view or electronic display.

65	Turbulence (Electronic)	Display - Electronic representation showing weather and its intensity in relation to own aircraft weather from which turbulence may be inferred by the pilot
66	Lightning (Direct View)	Display - Sensor image showing weather
67	Lightning (Electronic)	Display - Electronic representation showing weather and its intensity in relation to own aircraft
68	Volcanic Ash (Direct View)	Display - Sensor image showing weather
74	Flight Traffic (Direct View)	Display - Sensor image showing traffic
75	Flight Traffic (Electronically)	Display - Electronic representation showing traffic in relation to own aircraft
MISCELLANEOUS		
84	Identify Visual Flight Rules Conditions	Actual flight visibility, in sm, and distances, in sm and feet, above, below, and laterally from clouds

4 Major HSI Issues for Step 1

This section identifies major HSI issues only for Step 1 of the Program (limited to flight above FL400). In addition to the Primary and Secondary Objectives described in section 1.1, HSI Issues: Unrestricted ROA Flight in the ATM System, the following are more detailed issues that require an approach including direct HSI involvement with specific functionalities provided by hardware, software, and procedures.

- HSI pilot-GCS functionality requirements and guidelines (e.g., layout and anthropometry options)
- Displays and controls functionality (e.g., numbers and types of displays, information content requirements)
- Pilot-ROA function allocation guidelines (e.g., automation and autonomy)
- Time-critical communications with ATC functionality (e.g., contingency management; determination of maximum acceptable lag between ATC communication and ROA response)
- Mission planning functionality and design (e.g., navigation)
- Pilot interface requirements and guidelines to traffic and weather data
- Guidelines and options for contingency management including requirements for pilot situation awareness and control capability
- Pilot qualification requirements, crew complement, and crew resource management
- Operator-computer interface functionality and design guidelines (e.g., methods of information display)
- Human error mitigation in design (e.g., designs for low workload and high situation awareness)

HSI Research Recommendations and Plans for FY05

5 HSI Research Recommendations and Plans for FY05

Research recommendation and plans for Step 1, FY 05, are contained in separate HSI planning documents:

Work Package 7, Human Systems Integration, FY-05 Moshpit,
September 2004.

Work Package 7, Human Engineering Program Plan, Step 1 HEPP, August 2004.

The topics for FY05 research described in these documents are:

- Initial HSI Requirements and Guidelines for Experimental Certification of the ROA System.
- Initial HSI Requirements for Technology Solutions.
- HSI ATC Requirements and Design Guidelines.
- HSI Functional Requirements for ROA Flight in the NAS Requirements, Design Guidelines, and Scenario Definitions.
- HSI Design Requirements and Guidelines.
- HSI Support for Simulation and Flight Test

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Organizations

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<http://www.aero.usyd.edu.au/wwwROA/ROAsig.html> (Australian special interest group on ROAs)
<http://www.auvsi.org/faa/mission.cfm> (AUVSI)
<http://www.euro-uvs.org/> (European Unmanned Systems Association)
<http://www.ROAnet.com/links.php> (links to ROA organizations and companies)
<http://www.ucare-network.org/> European Unmanned Vehicle Systems Association

Avionics and Systems Capabilities

Honeywell. ACAS II/TCAS – Enhanced airborne collision avoidance system II, Honeywell, Inc., Phoenix, AZ, 1999.
<http://www.defensedaily.com/reports/avionics/previous/0901/0901ROA.htm> (avionics)
<http://www.raytheon.com/products/> (avionics)

User-Systems Interface

- ICAO, Human factors in CNS/ATM systems, human factors digest no. 11, ICAO, Montreal, 1994.
- Hilburn, B., Bakker, M., and Pekela. Free flight and the air traffic controller: an exploratory analysis of human factors, NLR, Amsterdam, The Netherlands, June 1998.
- <http://acb220.tc.faa.gov/hfdg/index.html> (FAA Human Factors Design Standard)
- <http://airsafe.com/journal/asj.htm> (articles)
- <http://catless.ncl.ac.uk/Risks> (risk and error in computer systems)
- <http://flightdeck.ie.orst.edu/FDAI/issues.html> (flight deck automation issues)
- <http://human-factors.arc.nasa.gov/> (NASA human factors)
- http://www.caa.co.uk/forums/forums_hfstg/default.asp (The Joint Aviation Authorities (JAA) Human Factors Steering Group (HFStG))
- <http://www.eurocontrol.int/hmi/community/HmiMain> (Eurocontrol: human factors in air traffic control)
- <http://www.hf.faa.gov/> (FAA human factors)
- <http://www.rvs.uni-bielefeld.de/publications/Incidents/> (Ladkin, P. "Computer-Related Incidents with Commercial Aircraft: A Compendium of Resources, Reports, Research, Discussion and Commentary")
- <http://www.volpe.dot.gov/opsad/pubs.html> (operator performance and safety analysis)

Aviation Safety

- http://www.fas.org/irp/doddir/usaf/conops_ROA/part03.htm (Australian safety links)
- <http://www.flightsafety.org/home.html> (aviation safety)
- <http://www.rotor.com/Safety/links.htm> (Helicopter Association International safety links)