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COVER SHEET
Access 5 Project Deliverable

Deliverable Number: *HSI010*

Title: *Step 1: Human System Integration Simulation and Flight Test Progress Report*

Filename: HSI010_Step 1_Human System Integration Simulation and Flight Test Report_FINAL.doc

Abstract:
The Access 5 Human Systems Integration Work Package produced simulation and flight demonstration planning products for use throughout the program. These included:

- Test Objectives for Command, Control, Communications
- Pilot Questionnaire for Command, Control, Communications
- Air Traffic Controller Questionnaire for Command, Control, Communications
- Test Objectives for Collision Avoidance
- Pilot Questionnaire for Collision Avoidance
- Plans for Unmanned Aircraft Systems Control Station Simulations
- Flight Requirements for the Airspace Operations Demonstration

Status:

Document Status Work in Progress

Limitations on use:
This document is an interim deliverable. It represents the Human Systems Integration functions and performance requirements limited to enroute operations above FL430. Operations below FL430 and terminal operations have not been addressed in this document.

Step 1: Human System Integration Simulation and Flight Test Progress Report

Access 5

November 30, 2005

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EXECUTIVE SUMMARY

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective. In FY05, several HSI products were developed to contribute to overall program objectives.

Human-Systems Integration (HSI) Goals

The primary goal of HSI Work Package (WP) FY05 simulation and flight demonstration work was to collect human interface data to support validation of functional requirements for the HSI WP and other WPs. The HSI work performed in FY05 centered on development of plans for FY05 and FY06 simulations and flight demonstrations. In FY05, only the Airspace Operations Simulation (AOS) was conducted and, in this, HSI had a no role. Hence, no reports containing data analyses, conclusions, or recommendations were published to validate requirements. These will be produced in FY06.

Process

The process employed by the HSI WP to support simulation and flight demonstration planning required examination of the Functional Requirements Documents, Test Objective plans, and other relevant documents for four WPs, namely, Command, Control, and Communications (C3), Collision Avoidance (CA), Contingency Management (CM), and Weather Management (Wx). The HSI WP participated in regular, weekly telecons with these WPs and was represented at coordination meetings. In addition, the HSI WP attended weekly Simulation WP and Flight Test WP telecons. From information obtained from these sources, the HSI WP determined its own goals and goals to support the other WPs.

Results - Simulation

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Airspace Operations Simulation (AOS)

In support of Airspace Operations Simulation (AOS) planning, the HSI WP developed a workload questionnaire to be administered to Air Route Traffic Control Center (ARTCC) controllers in the AOS. Seven workload questions were developed, including a new rating scale, which was coordinated with the Simulation WP and the Policy IPT. In the end, the Simulation WP selected in-house performance evaluation tools instead of the HSI submission. The HSI WP-developed questionnaire may be used in future evaluations.

Aircraft Control Station (ACS) Simulation

The HSI WP developed seven simulation plans for the FY06 Aircraft Control Station (ACS) simulation effort, which will be conducted at the NASA Ames Human Systems Integration UAV Lab. The submission included two plans for Communications that focus on beyond-line-of-sight (BLOS) latency guideline validation issues for (1) pilot-air traffic controller voice communications and (2) the pilot-vehicle control loop; two plans for Contingency Management (CM) that are directed at pilot and air traffic controller human-in-the-loop performance validation issues for (1) lost pilot-air traffic controller voice communications and (2) lost pilot-unmanned aircraft (UA) datalink; one plan for Weather Management (WX) concerning the validation of guidelines for data content required for the UA pilot; and two plans for Collision Avoidance (CA) involving the CA concept validation of (1) information requirements for the pilot and (2) pilot response time to a CA system Traffic Alert (TA).

Results - Flight Tests and Demonstrations

National Oceanic and Atmospheric Administration (NOAA) Piggyback Opportunity

In early 2005, Access 5 learned of an unmanned aircraft system (UAS)-based science mission to be operated under the auspices of the National Oceanic and Atmospheric Administration (NOAA). Access 5 viewed this mission as a piggyback opportunity to observe and collect data for specific Access 5 requirement and concept validation purposes. The HSI WP performed a cost-benefit study and found that its UA pilot and air traffic controller BLOS voice communications flight demonstration goals for Step 1 could be completely satisfied with data collection from this operation. The HSI WP developed a test objectives document which was submitted to the Flight Test IPT. It contained four General Test Objectives (GTO), multiple Specific Test Objectives (STO), Measures of Performance (MOP), Success Criteria, Evaluation Criteria, definition of Final Data products, and Data

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Requirements. The air traffic controller questionnaire developed for the AOS was modified slightly to make it appropriate for use in evaluating in-the-ARTCC controller workload. In the end, the Program made the decision not to pursue the piggyback opportunity. However, in the planning process, HSI had developed a voice communications questionnaire for UA pilots that would be of use in later work.

Command, Control, and Communications (C3)

Command, Control, and Communications (C3) WP FY05 plans included a flight demonstration scheduled for September 2005 to evaluate Step 1 aspects of C3. The HSI WP evaluated the C3 test plan and determined the need to obtain requirements validation data for UA pilot-air traffic controller voice communications, and C2 pilot-UA datalink. As the scope of this flight demonstration was very close to that of the NOAA exercise, the HSI WP required little time or funding to modify its earlier NOAA test objectives and questionnaire documents to satisfy C3 HSI WP requirements.

In support of the development of voice communications quality evaluations for pilots and controllers, a literature survey was performed to identify methodologies to evaluate voice quality. A modified Mean Opinion Score (MOS) was developed, specific to Access 5 HSI requirements, and distributed within the Program. This was an integral part of the questionnaires.

As C3 plans matured, the C3 WP and program determined that it would be impractical to develop scenarios that involved beyond-line-of-sight C3 between the pilot and FAA ATC. As, the HSI WP had previously evaluated line-of-sight C3 (in the Alaska flight demonstration), the deletion of the beyond-line-of-sight goals eliminated the need for HSI involvement in the C3 demonstration.

Collision Avoidance (CA)

CA WP FY05 plans included a flight demonstration scheduled for September 2005 to evaluate Step 1 aspects of CA.

To support preparatory to Systems Integration Lab (SIL) simulation efforts and flight demonstration, the CA WP required CA display symbology and pilot procedures. This task was performed by the HSI WP, beginning with a literature review of existing CA concepts, symbology, and procedures. Thereafter the HSI WP developed a set of data tailored to the CA test plan to support CA flight demonstration goals. Symbology guidelines were developed for pilot alerting, avoidance maneuver command guidance, and traffic display formats. This information was used by Lockheed-Martin in Ft. Worth to develop CA symbology and CA concepts and, later, by the Northrop-

Grumman Corporation in their SIL. Output from the SIL is to be hosted in the ACS used in the September 2005 flight demonstration.

The HSI WP also developed a test objectives document that outlined flight demonstration goals for validation of pilot-in-the-loop aspects of the CA concept. The document contained two GTO, multiple STO, MOP, Success Criteria, Evaluation Criteria, definition of Final Data products, and Data Requirements. In addition, as required by the HSI test plan, collection was required of pilot performance data to support the requirements validation effort. A number of pilot questionnaires were developed, culminating in a four-question format. However, as the CA WP refined its test plans and objectives, its last revision eliminated requirements for HSI data collection. The CA WP had structured its demonstration to collect data on the performance of its CA hardware and software designs to verify its functional requirements. As such, the demonstration was not conducive to the evaluation of the interface between the pilot and CA system. Nevertheless, HSI WP planning led to the production of a number of documents that will facilitate future HSI-CA simulation and flight demonstration efforts.

Airspace Operations Demonstration (AOD)

Flight Test WP FY05 plans include a scheduled flight demonstration in early FY06 to demonstrate Step 1 aspects of UAS functional requirements. The HSI WP developed and submitted AOD Flight Requirements to the Flight Test WP to support demonstration of its high-level functional requirements. Included are four Flight Requirements for C3, one for CA, and one for CM.

Summary

In FY05, the HSI WP produced simulation and flight demonstration planning products that are available for future use.

- Test Objectives for C3
- Pilot Questionnaire for C3
- Air Traffic Controller Questionnaire for C3
- Test Objectives for CA
- Pilot Questionnaire for CA
- Plans for ACS
- Flight Requirements for AOD

As the ground work has been laid in FY05, modification and tailoring of planning documents for new efforts will require minimal time and funding. The bulk of HSI work for FY06 will be participation in simulations and flight demonstrations, data analyses,

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conclusions development, and formulation of recommendations leading to validation of HSI functional requirements.

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ACRONYMS

AOS	Airspace Operations Simulation
AOD	Airspace Operations Demonstration
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
C3	Command, Control, and Communications
CA	Collision Avoidance
CM	Contingency Management
BLOS	Beyond Line of Sight
DOD	Department of Defense
FAA	Federal Aviation Administration
FL	Flight Level
GTO	General Test Objective
HALE	High Altitude Long Endurance
HSI	Human Systems Integration
IFR	Instrument Flight Rules
IPT	Integrated Product Team
NOAA	National Oceanic and Atmospheric Administration
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
MOP	Measure of Performance
MOS	Mean Opinion Score
SIL	Systems Integration Lab
STO	Specific Test Objective
SWPCS	Situational Weather Product Classification & Selection
TA	Traffic Alert
WP	Work Package
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System

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1 INTRODUCTION

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

The Access 5 Project is taking an incremental approach for introducing UAS into the NAS. HALE was chosen as the focus because HALE aircraft are mature systems and can operate above most air traffic, making this class of UAS the safest for initial introduction into the NAS. It is believed, however, that Access 5 will also lay the groundwork for the future introduction of other classes of UAS. Access 5 will achieve its goals by systematically addressing access to the NAS in four discrete steps of increasing complexity and capability:

Step 1: Routine Operations above Flight Level (FL) 430 through Pre-Coordinated Airspace

Step 2: Routine Operations above FL 180 through Pre-coordinated Airspace with Emergency Landings at Pre-coordinated Airports

Step 3: Routine Operations above FL 180 through C, D, and E Airspace with Emergency Landing at Pre-coordinated Airports

Step 4: Routine Operations above FL 180 through C, D, and E Airspace with Emergency Landings at any UAS Designated Airport

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective. In FY05, several HSI products were developed to contribute to overall program objectives. The FY05 HSI effort followed a standard, HSI process methodology that produced the following deliverables (Figure 1):

Deliverable 1: Human System Integration Step 1 Functional Requirement Document (FRD)

Deliverable 2: Human System Integration (HSI) Step 1 Design Guidelines for the Unmanned Aircraft System (UAS) Ground Control Station

Deliverable 3: High Altitude Long Endurance (HALE) Unmanned Aircraft System (UAS) Pilot Rating Criteria (Draft)

Deliverable 4: HSI Requirements and Guidelines for Experimental Certification of the Unmanned Aircraft System

Deliverable 5: Human Systems Integration Step 1 Pilot-Technology Interface Requirements

Deliverable 5a: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Command, Control, and Communications (C3) in Unmanned Aircraft Systems

Deliverable 5b: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Collision Avoidance in Unmanned Aircraft Systems

Deliverable 5c: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Contingency Management System in Unmanned Aircraft Systems

Deliverable 5d: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for the Weather System in Unmanned Aircraft Systems

Deliverable 6: Human Systems Integration Support to Simulation and Flight Test for Step 1

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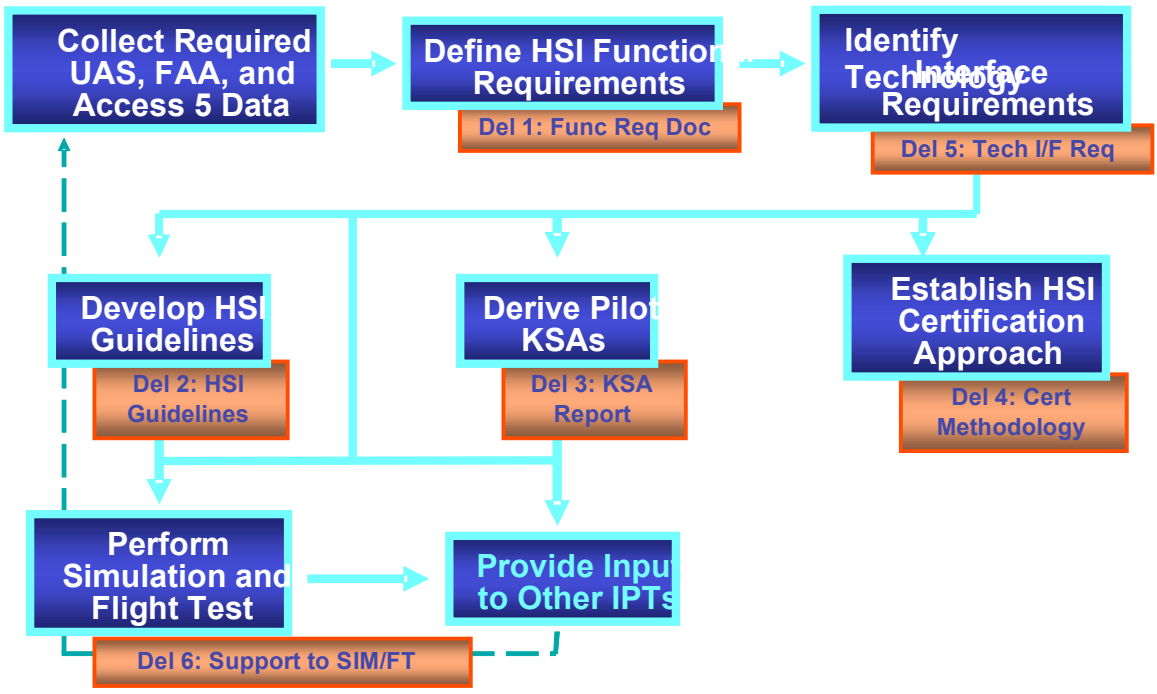

Figure 1. FY05 HSI Process and Deliverable Overview

1.1 METHOD

The method used in HSI WP efforts related to simulation and flight demonstration varied according to the specific goals and scope of individual evaluations.

Flight demonstration and simulation planning for Command, Control, and Communications (C3), Collision Avoidance (CA), Contingency Management (CM), and Weather Management (Wx) required examination of those WP's Functional Requirements Documents (FRD), Test Plans, and other relevant documents. Coordination meetings took place to further gain insight into the requirements for HSI flight demonstration and simulation planning. From this information, the HSI WP determined the goals and scope, thereby allowing it to define its own goals to support the other WPs. The output of this process typically included an HSI Test Objectives document, data collection tools (such as Pilot Questionnaire, Air Traffic Controller Questionnaire), and other relevant materials (such as display symobology guidelines for CA).

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The FY05 planning efforts were targeted at the simulation Aircraft Control Station) (ACS) slated to start in FY06. Similarly, flight demonstrations for C3, CM and Airspace Operations Demonstration (AOD) are also planned to take place in FY06.

In FY05, no simulations or flight demonstrations took place in which HSI had a role. Hence, no reports containing data analysis, conclusions, or recommendations were published. This will occur in FY06.

1.2 DOCUMENT ORGANIZATION

This document is organized into the following sections:

Section 1 - Introduction: States the purpose, scope, background, and methodology used for this requirements document, including its relationship to the Access 5 project.

Section 2 – Simulations: Describes FY05 HSI planning, documentation, and coordination within Access 5 for simulations.

Section 3 – Flight Tests and Demonstrations: Describes FY05 HSI planning, documentation, and coordination within Access 5 for flight tests and demonstrations.

Appendix A – Air Traffic Controller Questionnaire

Appendix B – Rating Scale for Use with the Air Traffic Controller Questionnaire

Appendix C – Human Systems Integration (HSI) Aircraft Control Station (ACS) Simulation Test Plans – FY06

Appendix D – Human Systems Integration (HSI) Test Objectives for NOAA C3 Demonstration

Appendix E – Human Systems Integration (HSI) Test Pilot Questionnaire for NOAA C3 Demonstration

Appendix F – Method to Evaluate Voice Communications Quality

Appendix G – Human Systems Integration (HSI) Test Objectives for Command, Control and Communications Flight Demonstration

Appendix H – Human Systems Integration (HSI) Access 5 C3 Technology Demonstration – Pilot Questionnaire

Appendix I – Human Systems Integration (HSI) HSI Display Symbology Guidelines for Simulation or Flight Test for Collision Avoidance

Appendix J – Human Systems Integration (HSI) Test Objectives – Collision Avoidance

Appendix K – Human Systems Integration (HSI) Test Pilot Questionnaire for CCA Flight Demonstration

Appendix L – Pilot Observation Log - Access 5 Collision Avoidance Flight Demonstration

Appendix M – Human Systems Integration (HSI) Airspace Operations Demonstration (AOD) Flight Requirements

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2 SIMULATION

2.1 AIRSPACE OPERATIONS SIMULATION (AOS)

2.1.1 AIR TRAFFIC CONTROLLER EVALUATION TOOLS

Part of the AOS effort at NASA Ames included plans for the evaluation of air traffic controller workload. While NASA Ames has performed this type of work for many years, Access 5 had requested HSI to develop a workload questionnaire for air traffic controllers. The product was to be compared to similar NASA Ames workload measures to determine whether to use one or both.

At this time, Access 5 was making plans for evaluation of air traffic controller workload for voice communications in flight demonstrations. Therefore, it was planned that the HSI workload questionnaire would be administered to Air Route Traffic Control Center (ARTCC) controllers that would be in communication with the unmanned aircraft (UA) pilot.

Seven workload questions were developed and coordinated with NASA Ames and the Policy IPT ["Access 5 – Questionnaire for Air Traffic Controllers Feb 16 05" (Appendix A)]. A new rating scale was developed that was a modification of the Cooper-Harper 10-point rating scale. The scale was documented in "Access 5 Rating Scale for Air Traffic Controllers Feb 16 05" (Appendix B).

After evaluation by Access 5, the Simulation WP selected an existing workload questionnaire rather than the one developed by HSI. Flight demonstrations aimed at evaluating air traffic controller workload were not realized and, hence, the questionnaire was not used. Nevertheless, the effort placed into developing the questionnaire and rating scale was worthwhile, for this tool is available for any future Access 5 voice communications flight demonstration or simulation involving air traffic controllers. No additional HSI costs will be incurred to develop another questionnaire.

2.2 AIRCRAFT CONTROL STATION (ACS)

2.2.1 HSI FY06 PLANNING

The HSI WP developed seven simulation plans for the FY06 ACS simulation effort. This effort is headed by the Simulation WP with the goal, over several years, of evaluating technology and procedures for the UA pilot and air traffic controllers using

human-in-the-loop simulation. The work will be conducted at the NASA Ames Human Systems Integration UAV Lab.

After a review of relevant documents from other WPs, HSI developed ACS simulation plans, which are documented in "HSI AVCS Simulation Test Plans for FY06 Jun 8 05" (Appendix C)[1]. The submission included two plans for Communications; two plans for Contingency Management (CM); one plan for Weather Management (WX); and two plans for Collision Avoidance (CA).

The plans for voice communications focus on beyond-line-of-sight (BLOS) latency issues. Line-of-sight issues are not included because they had been successfully evaluated in the 2004 Alaska Flight demonstration[2].

Simulation 1 will determine the operational effects of latency on voice communications between UA pilots and air traffic controllers and determine a latency or latencies below which acceptable voice communications are realized. Today, voice communications in the National Airspace System (NAS) have effectively zero latency. As a result, communications between two parties takes place unencumbered by delays in voice transmission. This leads to effective communications, subject to non-

[1] Command and Control Communications, Step 1, Functional Requirements Document, Access 5 WP6 Team, Version 3.01. June 10, 2005.

Contingency Management Requirements Document. (Preliminary Version) September 30, 2004 (Revision D – 03/31/2005)

HALE UAS Command and Control Communications Functional Requirements. May 31, 2005.

NASA Access 5 WP6 Team, HALE ROA ATC Communications Step 1 Functional and Performance Requirements. Report No. TR04045. September 30, 2004.

NASA Access 5 WP6 Team, HALE ROA Command and Control Communications Functional and Performance Requirements. Sep 2004.

NASA Access 5 WP1 and WP2 Teams, Sense and-Avoid Equivalent Level of Safety Definition for Unmanned Aircraft Systems, rev. 9, September 23, 2004.

NASA Access 5 WP6 Team, Cooperative Conflict Avoidance Functional Requirements for Step 1— HALE ROA Flight above FL400, Draft, Rev. 2, September 30, 2004.

Weather Requirements & Procedures for Step 1. March 2005.

[2] Access 5 Program Observations of the Alaska Mariner/Altair UAV System Concept Evaluation Operational Test and Evaluation of a Mariner (Modified Predator B) in the Alaska Area Of Responsibility. September 2004.

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latency issues. Research shows that there is an association between latency magnitude (in seconds) and acceptability of communications, flight safety, air traffic delay, and pilot and controller workload.

Simulation 2 plans focus on the BLOS datalink delay impact on manual control of a UA. It is expected that some UAs will be manually controlled, either as its primary flight control mode or as a backup mode. BLOS latencies are of a larger magnitude than that required for safe UA manual control[3]. This simulation will examine various latencies to determine the effect on the pilot-vehicle control loop.

Simulation 3 will evaluate contingency management (CM) for pilot loss of communications with air traffic control (ATC). Today, pilots who loss communication while on an Instrument Flight Rules (IFR) flight plan are bound by Federal Aviation Regulations (FAR) Section 91.185 to follow a specific course of action. Access 5 has not agreed that this is appropriate for UA operations. As a result, this simulation will examine procedural options for UA flight during loss of communications, observe pilot tasks and impact on ATC. Results will indicate the impact on UA safety, air traffic safety, air traffic controller workload, and safety of nearby aircraft.

Simulation 4 will assess CM for loss of datalink between the UA Aircraft Control station (ACS) and UA. Today, there is no analogy in inhabited aircraft for this type of failure. However, a parallel has been drawn by some that the procedure for lost voice communications may be applied here. Access 5 has not agreed that this is appropriate for UA operations. As a result, this simulation will examine procedural options for UA flight during loss of datalink, with the focus placed primarily on impact on ATC and safe operation of the UA. Results will indicate the impact on UA safety, air traffic safety, air traffic controller workload, and safety of nearby aircraft.

Simulation 5 will evaluate the HSI to the Access 5 concepts for CA. It will focus on CA performance as a function of information presented to the pilot. Information display options are (1) aural alert and plan view traffic display and (2) aural alert, plan view traffic display, and avoidance maneuver guidance display, and (3) plan view traffic display only. Analysis of the literature show that option 2 above is required[4]. However, the Access 5 program has not agreed this position and, hence, the simulation evaluation will provide objective data to evaluate the various information display and pilot decision-making options.

[3] National Research Council. Aviation Safety and Pilot Control. – Understanding and Preventing Unfavorable Pilot-Vehicle Interactions. 1997.
[4] Human Systems Integration Pilot-Technology Interface Requirements for Cooperative Conflict Avoidance. Access 5 Program. August 2005.

Simulation 6 will investigate the time required for a pilot to respond to a CA system Traffic Alert (TA).[5] Results will include a recommendation for maximum allowable pilot response time to a CA alert for en route flight above FL430.

The objective of Simulation 7 is to demonstrate the expected enhanced hazardous weather avoidance performance of pilots using the SWPCS concept at the ACS. The SWPCS concept utilizes a weather display capability that separates integrated, "nowcasted" weather products from other weather information, providing them to the pilot under a separate menu selection. These graphical products contain certain attributes that make them spatially/temporally more appropriate for operational planning decision-making. Operators that utilize these products, along with other sources of weather information, may make better hazardous weather avoidance decisions than operators utilizing other products with temporal latencies or spatial inaccuracies.

[5] An alert requiring an avoidance maneuver.

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3 FLIGHT TESTS AND DEMONSTRATIONS

3.1 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) PIGGYBACK FLIGHT DEMONSTRATION

3.1.1 HSI TEST OBJECTIVES AND PILOT EVALUATION TOOLS

In early 2005, Access 5 learned of a UAS-based science mission under the auspices of the National Oceanic and Atmospheric Administration (NOAA). This mission involved flight southwest of the Los Angeles area to distances of up to 1000 nautical miles (nm) for the purpose of collecting data on winds aloft and jet stream activity.

Access 5 viewed this mission as a piggyback opportunity to observe and collect data for specific Access 5 purposes. Part of the process the Program employed in determining the viability of performing the piggyback operation was a cost-benefit study. The HSI WP performed such a study and found that its UA pilot and air traffic controller BLOS voice communications flight demonstration goals for Step 1 could be completely satisfied through this operation. That is, there would be not a need for HSI to replicate the work in the future.

A test plan was developed and submitted to the Flight Test IPT that contained four General Test Objectives (GTO), multiple Specific Test Objectives (STO), Measures of Performance (MOP), Success Criteria, Evaluation Criteria, definition of Final Data products, and Data Requirements ("Human Systems Integration (HSI) Test Objectives for NOAA C3 Flight Demonstration Mar 2 05 rev 1") (Appendix D). The air traffic controller questionnaire developed for the AOS was modified slightly to make it appropriate for use in evaluating ARTCC controller workload. A new, unique UA pilot 14-question pilot questionnaire was also developed to assess voice communications, "Human Systems Integration (HSI) Test Pilot Questionnaire for the NOAA C3 Flight Demonstration Mar 7 05" (Appendix E). This questionnaire was based in part on an HSI analysis of methods for voice quality evaluation (see 3.2.1).

In the end, the Program made the decision not to pursue the piggyback opportunity. However, in the planning process, HSI had developed a voice communications questionnaire for UA pilots that would be of use in later work.

3.2 COMMAND, CONTROL, AND COMMUNICATIONS (C3) FLIGHT DEMONSTRATION

3.2.1 EVALUATION OF VOICE COMMUNICATIONS

C3 WP FY05 plans included a flight demonstration in September 2005 to evaluate Step 1 aspects of command, control, and communications. The HSI WP evaluated the scope of the C3 test plan and determined the need to examine the interface between the UA pilot and air traffic controller for voice communications. In addition, it was deemed necessary to examine the pilot interface to the uplink- and downlink-provided information, as this is the only source of command, control, and feedback available to the pilot to know vehicle status and affect its control.

In support of the development of voice communications quality evaluations by pilots and controllers, a literature survey was performed to identify methodologies to evaluate voice quality. The Mean Opinion Score (MOS) was found to be most commonly used and valid tool. Due to a number of technical factors, it was modified to tailor it to specific Access 5 HSI requirements. The analysis and rationale for modification are described in “Method to Evaluate Voice Communications Quality – Preliminary Analysis Jan 11 05” (Appendix F).

As C3 plans matured, the C3 WP and program determined that it would be impractical to develop scenarios that involved beyond-line-of-sight C3 between the pilot and FAA ATC. As, the HSI WP had previously evaluated line-of-sight C3 (in the Alaska flight demonstration), the deletion of the beyond-line-of-sight goals eliminated the need for HSI involvement in the C3 demonstration.

3.2.2 HSI TEST OBJECTIVES AND PILOT EVALUATION TOOLS

A test plan was developed and submitted to the Flight Test WP that contained four GTO, multiple STO, MOP, Success Criteria, Evaluation Criteria, definition of Final Data products, and Data Requirements (“Human Systems Integration (HSI) Test Objectives for C3 Flight Demonstration Apr 6 05”) (Appendix G). The air traffic controller questionnaire developed for the AOS was modified slightly to make it appropriate for use in evaluating ARTCC controller workload.

Results of the voice quality assessment analysis had provided a modified MOS for use in the NOAA (see 3.1) and C3 flight demonstrations. The modified MOS was combined with additional voice and datalink-related questions to form to complete

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HSI C3 pilot questionnaire. The pilot questionnaire developed for the AOS was reduced from 14 questions to 12 questions to make it appropriate for use in evaluating pilot controller workload ("Human Systems Integration (HSI) Test Pilot Questionnaire for C3 Flight Demonstration Jul 23 05") (Appendix H).

[The modified MOS was not applied to the air traffic controller questionnaire originally developed for the AOS (see 2.1), as it had been determined that Access 5 Program personnel would be unable to administer questionnaires to controllers.]

3.3 COLLISION AVOIDANCE (CA) FLIGHT DEMONSTRATION

3.3.1 SYMBOLOGY GUIDELINES DEFINITION

CA WP FY05 plans included a flight demonstration in September 2005 to evaluate Step 1 aspects of collision avoidance. The CA WP required CA display symbology and procedures to support its effort and requested the HSI WP to provide support.

The HSI WP performed a literature review of existing CA concepts, symbology, and procedures. Thereafter it developed a set of data tailored to the CA test plan to support CA flight demonstration goals. Guidelines include information on alerting, avoidance maneuver command guidance, and traffic display formats.

These data were communicated to the CA WP, and in particular, directly to the LMCO CA organization in Ft. Worth, TX, that had responsibility to convert these symbology guidelines into a working simulation. HSI symbology concepts are documented in a 37 Power Point slide presentation, "HSI Display Symbology Guidelines for Simulation or Flight Test for CA Mar 8 05" (Appendix I).

3.3.2 HSI TEST OBJECTIVES AND PILOT EVALUATION TOOLS

As part of the Flight Test and CA WP FY05 flight demonstration planning effort, the HSI WP evaluated the scope of the CA test plan and determined the need to examine the interface between the UA pilot and CA displays, controls, and procedures. A test plan was developed and submitted to the Flight Test and CA WP that contained two GTO, multiple STO, MOP, Success Criteria, Evaluation Criteria, definition of Final Data products, and Data Requirements ("Human Systems Integration (HSI) Test Objectives for CCA Flight Demonstration Apr 5 05") (Appendix J). In addition, as required by the HSI test plan, collection of pilot observation data of their CA experience was required. A four-question, pilot questionnaire was developed

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for this purpose entitled, “Human Systems Integration (HSI) Test Pilot Questionnaire for CCA Flight Demonstration May 10 05” (Appendix K).

The CA WP refined its test plans and objectives with the last revision eliminating HSI data collection. The CA WP had structured its demonstration to collect data on the performance of its CA hardware and software designs to verify its functional requirements. As such, the demonstration was not designed to evaluate the interface between the pilot and CA system.

3.3.3 FLIGHT DEMONSTRATION EVALUATION TOOLS

While no HSI evaluations were planned for the CA flight demonstration, the CA WP required a method for the pilot to log abnormal occurrences or note unusual observations. The purpose of this was to have a record that could be compared to recorded data and provide insight into the reasons for data collected. The HSI WP developed, and submitted to the CA WP, a short, four-question observation log form for this purpose, “Pilot Observation Log for CCA Flight Demonstration May 25 05” (Appendix L).

3.4 AIRSPACE OPERATIONS DEMONSTRATION (AOD)

3.4.1 HSI FY06 PLANNING

Flight Test WP FY05 plans included a flight demonstration in early 2006 to demonstrate Step 1 aspects of unmanned aircraft system (UAS) functional requirements. Each WP was assigned the task to submit AOD Flight Requirements for flight demonstration of its high-level functional requirements. The HSI WP provided several inputs to the Flight Test WP including, “Human Systems Integration (HSI) Flight Requirements for Airspace Operations Demonstration Jul 20 05” (Appendix M). Included are four Flight Requirements for C3, one for CA, and one for CM.

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

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

APPENDIX A: AIR TRAFFIC CONTROLLER QUESTIONNAIRE

AIR TRAFFIC CONTROLLER QUESTIONNAIRE

February 16, 2005

COMMUNICATIONS

For Communications questions, the controller should consider the following elements in providing an answer: volume of transmission, background noise heard through the headset, understandability of pilot, transmission quality, need to repeat transmissions, and time delays.

1. What was the ease or difficulty in receiving communication from the aircraft?
2. What was the ease or difficulty in transmitting acknowledgements and/or clearances to the aircraft?

TRAFFIC

For Traffic questions, the controller should consider the following elements in providing an answer: ability or inability of pilot to understand point out information, and limitations of the aircraft to find traffic (as explained by the pilot).

3. What was the ease or difficulty in pointing out traffic to the vehicle?
4. What was the ease or difficulty in the vehicle finding the traffic?

ATC CLEARANCE COMPLIANCE

For ATC Clearance Compliance questions, the controller should consider the following elements in providing an answer: level of compliance or non-compliance with clearance, timeliness of pilot readback, timeliness of aircraft response, impact on traffic of aircraft performance, and impact of aircraft movement (if any) on traffic flow.

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5. What was the ease or difficulty in getting the vehicle to change its flight path by issuing a clearance (altitude, heading, route, speed, etc.)?
6. What was the ease or difficulty in dealing continuously with the aircraft?

WEATHER

For the Weather question, the controller should consider the following elements in providing an answer: obtaining information on cloud bases and tops; icing location, level and severity; and turbulence location and intensity.

7. What was the ease or difficulty in obtaining PIREPS on weather?

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APPENDIX B: AIR TRAFFIC CONTROLLER QUESTIONNAIRE RATING SCALE

RATING SCALE FOR USE WITH AIR TRAFFIC CONTROLLER QUESTIONNAIRE

February 16, 2005

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No controller effort required
2	Good; Negligible deficiencies	Controller effort not a factor
3	Fair/Mild deficiencies	Minimal controller effort required for desired performance
4	Minor deficiencies	Moderate controller effort is required for desired performance
5	Objectionable deficiencies	Considerable controller effort required for desired performance
6	Very objectionable deficiency	Extensive controller effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Controller cannot complete task

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APPENDIX C: HUMAN SYSTEMS INTEGRATION (HSI) AIRCRAFT CONTROL STATION (ACS) SIMULATION TEST PLANS – FY06

HUMAN SYSTEMS INTEGRATION (HSI) AIRCRAFT CONTROL STATION (ACS) SIMULATION TEST PLANS – FY06

JULY 20, 2005

HSI AVCS Simulation Test Plans – FY06

Simulation 1:

Title – Human-Systems Integration Simulation Study of BLOS Voice Communications Latency: An Operational Assessment of Communications between an ROA Pilot and Air Traffic Control

Objective – Determine the operational impact threshold for BLOS voice communications latency between an ROA pilot and air traffic controller for operations above FL180.

Description – Examine various latencies to determine the effect(s) on communications. A threshold will be defined, above which, the communications delay will be unacceptably large and, below which, the delay will be acceptable.

Simulation 2:

Title - Human-Systems Integration Simulation Study of BLOS Data Communications Latency: An Operational Assessment of Data Link Latency in Manual Control of an ROA

Objective – Determine the operational impact threshold for BLOS data communications latency between an ROA pilot and ROA vehicle for operations above FL180.

Description – Examine various latencies to determine the effect on the pilot-vehicle control loop. A threshold or thresholds will be determined above which pilot ability to send flight control commands to the aircraft and receive feedback, will not allow for

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satisfactory aircraft control, and below which, satisfactory control can be achieved. This is specific to manual flying for specific ROAs.

Simulation 3:

Title – Human-Systems Integration Simulation Study of Loss of Communications: An Operational Assessment of ROA Operations, Pilot Tasks, and Air Traffic Control Impacts.

Objective – Examine options for loss of communications procedures between the ROA pilot and air traffic control for operations above FL180.

Description – Examine procedural options for ROA flight during loss of communications. Observe pilot tasks and impact on ATC. Procedural options include (1) diversion to nearest suitable airport, (2) return to origin, and (3) continuance to destination.

Simulation 4:

Title – Human-Systems Integration Simulation Study of Loss of Data Link: An Operational Assessment of ROA Operations, Pilot Tasks, and Air Traffic Control Impacts.

Objective – Examine options for loss of link procedures between the ROA pilot and ROA for operations above FL180.

Description – Examine procedural options for ROA flight during loss of link. Observe pilot tasks and impact on ATC. Procedural options include (1) diversion to nearest suitable airport, (2) return to origin, and (3) continuance to destination.

Simulation 5:

Title – Human-Systems Integration Simulation Study of Collision Avoidance: An Operational Assessment of Pilot Behavior for a Collision Avoidance Concept

Objective – Determine if avoidance maneuver guidance information is necessary for satisfactory collision avoidance performance for operations above FL180.

Description – For the Access 5 collision avoidance concept(s), evaluate collision avoidance performance as a function of information presented to the pilot.

Information display options are (1) aural alert and plan view display and (2) aural alert, plan view display, and avoidance maneuver guidance display.

Simulation 6:

Title – Human-Systems Integration Simulation Study of Pilot Reaction Time: An Operational Assessment of Required Pilot Reaction Time for a Collision Avoidance Concept

Objective – Determine the required pilot reaction time for the Access 5 concept(s) for collision avoidance for operations above FL180.

Description – For the Access 5 collision avoidance concept(s), measure pilot reaction time in an operational environment. Thereafter, determine if the observed reaction time data are compatible with collision avoidance concepts. If shorter reaction times are required, perform a second study to determine if the required reaction time is within pilot capabilities.

Simulation 7

Title: Hazardous weather avoidance decision-making using Situational Weather Product Classification & Selection (SWPCS) versus a standard cockpit weather information display format.

Objective: To demonstrate the expected enhanced hazardous weather avoidance performance of pilots using the SWPCS concept at the AVCS position.

Description: The SWPCS concept utilizes a weather display capability that separates integrated, “nowcasted” weather products from other weather information, providing them to the operator under a separate menu selection. These graphical products contain certain attributes that make them spatially/temporally more appropriate for operational planning decision-making. Operators that are trained to interpret and utilize these products, along with other sources of weather information (HIWAS, Dispatcher, AFSS, EFAS, ASOS, etc.) should make better hazardous weather avoidance decisions than operators utilizing other products with temporal latencies or spatial inaccuracies. One test run could use a standard set of weather products (excluding nowcasts) and another test run could include “nowcasted” weather

products (NCWF, CIP GTG) under a separate selection on the weather display. Pilots would be instructed in the interpretation of these “nowcasted” products, and how to use them when planning avoidance scenarios.

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APPENDIX D: HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES FOR NOAA C3 DEMONSTRATION

ACCESS 5 – NOAA TECHNOLOGY DEMONSTRATION HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES – COMMAND, CONTROL, & COMMUNICATION

FEBRUARY 5, 2005

1.0 Introduction

This technology demonstration flight supports the ACCESS 5 goal of providing routine access to the National Airspace System (NAS) for Remotely Operated Aircraft (ROA). These flights will provide the ACCESS 5 staff with flight test data on Human System Integration (HSI) of Command, Control, and Communications (C3) technologies that promise to enhance ROA capabilities to the level required for routine access to the NAS. These test objectives will be evaluated during a series of flights involving an ROA.

1.1 General Test Objectives (GTOs):

1. Evaluate HSI for ROA system status, for Beyond Line-of-Sight (BLOS) operations.
2. Evaluate HSI for command, control, and communications (C3) links between the ROA pilot and the ROA, and ROA pilot and Air Traffic Control (ATC), for BLOS operations.
3. Evaluate HSI for command and control (C2)-supported flight functions between the ROA pilot and ROA, for BLOS operations.
4. Evaluate HSI for command and control (C2)-supported navigation functions between the ROA pilot and ROA, for BLOS operations.

1.2 Discussion of Objectives:

For Step 1 of Access 5, the C3 subsystem shall reliably provide ROA status to the air vehicle control station (AVCS); command and control the ROA above FL400 and

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communicate with ATC; and support ROA flight and navigation functions. To successfully accomplish these objectives, the ROA system must be able to satisfy major test objectives in accordance with HSI functional requirements. The HSI top level functional requirements document[6] (developed by Work Package 7), the C3 Functional and Performance Requirements document[7], and the HALE ROA ATC Communications Step 1 Functional and Performance Requirements document[8] (developed by Work Package 6) defined the requirements for HSI with the C3 system. The general test objectives and specific test objectives were then derived from these combined HSI and C3 system requirements.

1.3 Assumptions

Certain assumptions were made concerning the flight test objectives for HSI.

- The test objectives are general and are not specific to a particular C3 line of sight (LOS) or BLOS technology solution or air vehicle control station (AVCS) design.
- Access 5 HSI observers will interface with the NOAA operation on a non-interference basis.
- Access 5 HSI observers will administer a questionnaire to pilots and conduct informal interviews to obtain data regarding HSI aspects of C3.
- Access 5 HSI observers will not obtain data from ATC controllers as insufficient time was available for coordination and approval.

[6] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005

[7] NASA Access 5 WP6 Team, *HALE ROA Command and Control Communications Functional and Performance Requirements.* 30 Sep 2004, pp. 12-20.

[8] NASA Access 5 WP6 Team, *HALE ROA ATC Communications Step 1 Functional and Performance Requirements.* Report No. TR04045. 30 Sep 2004.

2.0 General Test Objectives/Specific Test Objectives.

2.1 General Test Objective 1: Evaluate HSI for ROA system status, for BLOS operations.

2.1.1 Specific Test Objective 1-1: Evaluate C3 system capability to provide operator awareness of the health and status of the ROA System (FR1)[9].

2.1.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings[10].

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions from the ROA.

Evaluation Criteria: Transmission of health and status data will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.1.2 Specific Test Objective 1-2: Evaluate C3 system capability to provide operator ability to access C3 status and control the C3 system (FR1)[11].

2.1.2.1 Measure of Performance (MOP): Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of commanding and monitoring C3 system operation.

[9] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[10] Questionnaire rating scales are shown in Figures 1 and 2 at the end of the document.
[11] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005

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Evaluation Criteria: C3 system command and monitoring capability will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.2 General Test Objective 2: Evaluate HSI for command, control, and communications (C3) links between the ROA pilot and the ROA, and ROA pilot and ATC, for BLOS operations.

2.2.1 Specific Test Objective 2-1: Evaluate system capability to provide operator ability to communicate with ATC (FR2)[12].

2.2.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 25 individual transmissions from the ROA pilot and a minimum of 25 transmissions from ATC.

Evaluation Criteria: Communications capability and quality will be considered satisfactory when,

> For communications capability, the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale and,
> For communications voice quality, the mean questionnaire rating is 3 or higher using the modified Mean Opinion Score rating scale.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

[12] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005

2.3 General Test Objective 3: Evaluate the HSI for command and control (C2) - supported flight functions between the ROA pilot and ROA, for BLOS operations.

2.3.1 Specific Test Objective 3-1: Evaluate C2 system capability to provide operator ability to command flight maneuvers to comply with ATC instructions (FR3a)[13].

2.3.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of commanding flight maneuvers in response to a minimum of 10 different ATC clearances.

Evaluation Criteria: Flight maneuver command capability will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.3 2 Specific Test Objective 3-2: Evaluate C3 system capability to provide operator ability to command and monitor flight maneuvers to safely conduct flight (FR3b)[14].

2.3.2.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of commanding and monitoring flight maneuvers.

Evaluation Criteria: Flight maneuver command and monitoring capability will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

[13] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[14] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

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2.4. General Test Objective 4: Evaluate the HSI for command and control (C2) - supported navigation functions between the ROA pilot and ROA, for BLOS operations.

2.4.1 Specific Test Objective 4-1: Evaluate C2 system capability to provide operator ability to know actual vehicle position and heading, course, speed, altitude (FR4a)[15].

2.4.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions from the ROA.

Evaluation Criteria: Transmission of ROA navigation parameter data will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.4.2 Specific Test Objective 4-2: Evaluate C2 system capability to provide operator ability to control vehicle position and heading, course, speed, altitude (FR4b)[16].

2.4.2.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 minutes of commanding navigation maneuvers.

Evaluation Criteria: Navigation maneuver command capability will be considered satisfactory when the mean questionnaire rating is 4 or lower using the modified Cooper-Harper rating scale.

[15] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[16] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

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LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

Figure 1. Modified Cooper-Harper Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pilot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

Figure 2. Recommended Modified MOS Rating Scale

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APPENDIX E. HUMAN SYSTEMS INTEGRATION (HSI) TEST PILOT QUESTIONNAIRE FOR NOAA C3 DEMONSTRATION

ACCESS 5 C3 NOAA FLIGHT DEMONSTRATION - HUMAN SYSTEMS INTEGRATION PILOT QUESTIONNAIRE

MARCH 7, 2004

Pilot Background Information

Name: _____
Date:_____

Predator Pilot flight hours: _____

Totals ROA Pilot flight hours: _____

Manned aircraft flight hours: _____

Licenses and Ratings (circle choices): Private, Commercial, Airline Transport Pilot, Instrument, Airplane, Rotocraft, Single-Engine, Multi-Engine, Instructor, Other

Aircraft Flown_____

Mission Information

Flight Event: No./Description _____

Aircraft Call Sign: _____

Flight Plan Attached: Y N

Flight Planned Route and Altitude_____

Actual Departure Time_____ Actual Arrival Time_____

ROA Status Transmissions: Observation Time (min) _____
Command and Monitoring C3 System Operation: Observation Time (min) ___
Transmissions to ATC (number): _____
Receptions from ATC (number): _____
ATC Clearances Received (number): _____
Commanding and Monitoring Flight in Response to ATC Clearance:
Observation Time (min) _____

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Commanding and Monitoring Flight Maneuvers for Safe Flight: Observation Time (min) _____

Pilot Knowledge of Actual Navigation Position and Trajectory: Observation Time (min) _____

Pilot Control of Actual Navigation Position and Trajectory: Observation Time (min) _____

Pilot-ROA and Pilot-ATC Human/Systems Integration Questions

1. Rate C3 system performance as it affected your ABILITY TO OBTAIN AWARENESS OF THE HEALTH AND STATUS OF THE ROA SYSTEM (not including the C3 system).
   (In answering, consider: How did the C3 system work in supporting your performance of obtaining ROA health and status data? Did you have to control or change C3 system performance or configuration to allow you to perform the task?)
   Answer only for Beyond Line-of-Sight (BLOS) operations. Circle the number in the left column that represents your observations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

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

_____
_____
_____
_____

Note. This questionnaire has been modified from its original form to reduce the number of pages in this appendix. Original questionnaire pages appeared as seen on this page - including lines for pilot comments. Pilot comment lines have been deleted from succeeding questionnaire pages in this appendix in order to save space.

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2. Rate C3 system performance as it affected your ABILITY TO OBTAIN AWARENESS OF THE HEALTH AND STATUS OF THE C3 SYSTEM. (In answering, consider: Did you have to control or change C3 system performance or configuration to allow you to obtain status of the C3 system?) Answer only BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

3. Rate the ease or difficulty in OPERATING THE C3 SYSTEM. Answer only for BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

4. Rate C3 system performance as it affected your ability to command FLIGHT MANEUVERS TO COMPLY WITH ATC INSTRUCTIONS.
(In answering, consider: How did the C3 system work in supporting your performance of flight maneuvers? Did you have to control or change C3 system performance or configuration to allow you to perform the task?) Answer only for BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

5. Rate C3 system performance as it affected your ability TO COMMAND FLIGHT MANEUVERS TO SAFELY CONDUCT FLIGHT.
(In answering, consider: How did the C3 system work in supporting your performance of these flight maneuvers? Did you have to control or change C3 system performance or configuration to allow you to perform the task?) Answer only for BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired

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		performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

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

6. Rate C3 system performance as it affected your ability to MONITOR FLIGHT MANEUVERS TO SAFELY CONDUCT FLIGHT.
   (In answering, consider: How did the C3 system work in supporting your performance of monitoring these flight maneuvers? Did you have to control or change C3 system performance or configuration to allow you to perform the task?) Answer only for BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

7. Rate C3 system performance as it affected your ability to KNOW ACTUAL VEHICLE POSITION AND HEADING, COURSE, SPEED, ALTITUDE (FOR NAVIGATION PURPOSES).
   (In answering, consider: How did the C3 system work in supporting your performance of these navigation data? Did you have to control or change C3 system performance or configuration to allow you to perform the task?) Answer only for BLOS operations.

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with

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		maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

8. Rate C3 system performance as it affected your ability TO CONTROL VEHICLE POSITION AND HEADING, COURSE, SPEED, ALTITUDE (FOR NAVIGATION PURPOSES).
   (In answering, consider: How did the C3 system work in supporting your control of these navigation maneuvers? Did you have to control or change C3 system performance or configuration to allow you to perform the task?) Answer only for BLOS operations.

   LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

9. Rate the ease or difficulty in TRANSMITTING TO ATC.
   (In answering, consider: Did ATC receive your transmission on the first attempt? Did ATC make any comments about your transmission? Did ATC ask you to repeat your transmission? Did ATC describe any problem with your transmission? Did you have to repeat your transmission more than once until ATC understood you?)
   Answer only for BLOS operations. Circle the number in the left column that represents your observations.

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

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

10. Rate THE LOUDNESS/VOLUME OF THE ATC TRANSMISSION.
    (In answering, consider: Was the ATC transmission loud enough to hear? Was it necessary to increase reception volume to obtain adequate loudness or volume? How much effort was required for you to hear it? How did the loudness or volume compare to the loudness or volume you have experienced in an inhabited aircraft?) Answer only for BLOS operations.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

11. Rate the effect, if any, of a poor SIGNAL-TO-NOISE RATIO, MASKING, NOISE, AND /OR CLUTTER WITH THE ATC TRANSMISSION.
    (In answering, consider: Was there any kind of interference that you heard on the radio? Did any background noise, masking noise, side tones, static, clutter, etc., interfere with your hearing transmissions from ATC? How did these factors

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

compare to your experience in an inhabited aircraft?) Answer only for BLOS operations.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

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

12. Rate THE UNDERSTANDABILITY/INTELLIGIBILITY OF THE ATC TRANSMISSION.
(In answering, consider: Were you able to understand the words spoken by the controller?
Were the words intelligible? Did you have any difficulty in understanding every word the controller said? How did these factors compare to your experience in an inhabited aircraft?) Answer only for BLOS operations.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

13. Rate the VOICE DISTINCTNESS/CLARITY OF THE ATC TRANSMISSION.
(In answering, consider: Was the controller's voice clear and distinct? If there was any interference on the radio, was the controller's voice still clear and distinct against the background? How did these factors compare to your experience in an inhabited aircraft?) Answer for BLOS operations.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

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

14. Rate the effect on your tasks of LATENCY INVOLVED IN ATC COMMUNICATIONS
(In answering, consider: Did you sense that your transmissions were delayed in being received by ATC? Did you block the transmission of another aircraft or controller due to latency? Were you blocked by another aircraft or controller due to latency? Did you have difficulty in receiving ATC transmissions due to latency? Did ATC have difficulty receiving your transmissions due to latency?) Answer for BLOS operations.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

Pilot Opinion of C3 Performance, Operations, and Designs

Identify any C3 function, pilot task, workload aspect, operation, phase of flight, Air Vehicle Control Station feature, or vehicle design feature where changes to C3 functional capability is required (that is, mandatory) for you to comply with normal IFR flight operations? Additional capabilities include: (1) Controls or displays needed (if any) for C3 but not provided during the flight, (2) additional information (if any) that would have significantly improved your situation awareness and/or workload during critical phases of this mission, (3) hardware, software, and/or procedural changes (if any) that would improve your situation awareness and/or workload.

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

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

APPENDIX F: METHOD TO EVALUATE VOICE COMMUNICATIONS QUALITY

METHOD TO EVALUATE VOICE COMMUNICATIONS QUALITY

January 11, 2005

A brief survey was performed of methods historically used to evaluate voice quality in communications systems[17]. Most of these methods are designed for use in laboratory settings and employ standardized protocols. In most cases, methodologies use a standardized set of words, phrases, or sentences.

For the Access 5 voice communications quality evaluation, no such formalized methodology will be employed. Rather, evaluations will be made of actual air traffic control transmissions as heard by the pilot at a ground control station through a headset or loudspeaker. This unstructured environment requires a suitable methodology such as the Mean Opinion Score (MOS) (also known as Absolute Category Rating (ACR)), which is widely used for such assessments (Table 1).

Table 1. MOS (ACR) Rating Scale

5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

Using this scale, the ROA pilot would be asked a question such as, “Rate the quality of the voice transmission you received from ATC?” and respond with a rating of 1, 2, 3, 4, or 5.

However, there are three issues in the use of this scale for Access 5 purposes. First, pass/fail criteria are required. The results of ratings from pilots must be assessed to

[17] http://www.acoustics.hut.fi/~slemmett/dippa/chap10.html
http://www.meyersound.com/support/papers/speech/glossary.htm
http://www.dynastat.com/Testing%20&%20Evaluation.htm
http://www.cis.upenn.edu/~graphics/pelachaud/workshop_face/subsubsection3_8_6_6.html

determine if the communications quality is operationally acceptable or unacceptable. The MOS rating scale does not include such a metric. Pass/fail criteria could be applied to the MOS rating scale by informing the pilot subjects that a rating of 3 though 5 indicate acceptable quality and 1 and 2 do not. Second, the level of effort required by the pilot to understand the communication should be identified. Even though the pilot may understand the communication, the difficulty in understanding air traffic control communications increases workload and distracts the pilot from other tasks. It is also associated with misunderstanding. Third, a description voice quality problems associated with a given rating needs to be provided. A debriefing session could be employed to interview pilot subjects in order to understand why the rating was given and what corrective measures, if any, are required.

Overall, it is the preliminary opinion of Human Systems Integration that a modified MOS rating scale should be employed to include pass/fail criteria, level of effort required by the pilot to understand the communications content, and section for comments and explanations.

As a result, the following type of modified-MOS is suggested (Table 2).

Table 2. Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pilot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

In addition, rather than a single overall question about voice quality, it is suggested that more and pertinent questions are employed, each using the rating scale, such as:

1. Rate your ability to hear (i.e., loudness) the voice communication from ATC?
2. Rate your ability to understand (i.e., intelligibility) the voice communication from ATC?
3. Rate the distinctness (i.e., clarity) of the voice communication from ATC?
4. Others TBD

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In this way, a relatively simple questionnaire may be used that allows data collection describing voice communication performance to allow the program to determine if the results are acceptable or whether additional work is necessary.

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

APPENDIX G: HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES FOR COMMAND, CONTROL AND COMMUNICATIONS (C3) FLIGHT DEMONSTRATION

HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES FOR COMMAND, CONTROL AND COMMUNICATIONS (C3) FLIGHT DEMONSTRATION

JULY 23, 2005

ACCESS 5 – Technology Demonstration

Human Systems Integration (HSI) Test Objectives – Command, Control, & Communication

1.0 Introduction

This technology demonstration flight supports the ACCESS 5 goal of providing routine access to the National Airspace System (NAS) for Unmanned Aircraft (UA). These flights will provide the ACCESS 5 staff with flight test data on Human System Integration (HSI) of Command, Control, and Communications (C3) technologies that promise to enhance UA capabilities to the level required for routine access to the NAS. These test objectives will be evaluated during a series of flights involving an UA.

1.1 General Test Objectives (GTOs):

Evaluate HSI for the AVIATE function, for Beyond Line-of-Sight (BLOS) operations.

Evaluate HSI for the COMMUNICATE function between the UA pilot and UA, and UA pilot and Air Traffic Control (ATC), for BLOS operations.

Evaluate HSI for the NAVIGATE function between the UA pilot and UA, for BLOS operations.

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

Evaluate HSI for the AVOID HAZARDS function between the UA pilot and UA, for BLOS operations.

1.2 Discussion of Objectives:

For Step 1 of Access 5, the C3 subsystem shall reliably provide UA status to the air vehicle control station (AVCS); command and control the UA above FL400 and communicate with ATC; and support UA flight and navigation functions. To successfully accomplish these objectives, the UA system must be able to satisfy major test objectives in accordance with HSI functional requirements. The HSI top level functional requirements document[18] (developed by Work Package 7), the C2 and C3 Functional and Performance Requirements document[19] [20], and the HALE UA ATC Communications Step 1 Functional and Performance Requirements document[21] (developed by Work Package 6) defined the requirements for HSI with the C3 system. The general test objectives and specific test objectives were then derived from these combined HSI and C3 system requirements.

1.3 Assumptions

Certain assumptions were made concerning the flight test objectives for HSI.

- The test objectives are general and are not specific to a particular C3 line of sight (LOS) or BLOS technology solution or air vehicle control station (AVCS) design.
- Access 5 HSI observers will interface with the NOAA operation on a non-interference basis.
- Access 5 HSI observers will administer a questionnaire to pilots and conduct informal interviews to obtain data regarding HSI aspects of C3.
- Access 5 HSI observers will not obtain data from ATC controllers as insufficient time was available for coordination and approval.

1.4 Scope

The scope of the HSI effort is focused on BLOS operations only. This is because LOS C3 operations were evaluated in previous research where the findings indicated

[18] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005

[19] NASA Access 5 WP6 Team, HALE UA Command and Control Communications Functional and Performance Requirements. 30 Sep 2004, pp. 12-20.

[20] HALE ROA Command and Control Communications Functional Requirements. Access5 WP6 Team. Version 2.1. February 2005

[21] NASA Access 5 WP6 Team, *HALE UA ATC Communications Step 1 Functional and Performance Requirements.* Report No. TR04045. 30 Sep 2004.

that all HSI C3 LOS operations were satisfactory. As a result, the HSI Work Package believes that to evaluate LOS operations again is redundant.

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

2.0 General Test Objectives/Specific Test Objectives.

2.1 General Test Objective 1: Evaluate HSI for the AVIATE function, for BLOS operations.

2.1.1 Specific Test Objective 1-1: Evaluate C3 system capability to provide operator awareness and control of flight parameters (HSI AVIATE functional requirement)[22].

2.1.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings[23].

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions and receptions from the UA.

Evaluation Criteria: Transmission and reception of data will be considered satisfactory when the pilot completes the questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.1.2 Specific Test Objective 1-2: Evaluate C3 system capability to provide operator awareness and control of systems status (HSI AVIATE functional requirement)[24].

2.1.2.1 Measure of Performance (MOP): Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions and receptions from the UA.

[22] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005

[23] Questionnaire rating scales are shown in Figures 1 and 2 at the end of the document.

[24] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005

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

Evaluation Criteria: Transmission and reception of data will be considered satisfactory when the pilot completes the questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.2 General Test Objective 2: Evaluate HSI for the NAVIGATE function, for BLOS operations.

2.2.1 Specific Test Objective 2-1: Evaluate system capability to provide operator awareness and control of navigation (HSI NAVIGATE functional requirement)[25].

2.2.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions and receptions from the UA.

Evaluation Criteria: Transmission and reception of data will be considered satisfactory when the pilot completes the questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.3 General Test Objective 3: Evaluate the HSI for the COMMUNICATE function, for BLOS operations.

2.3.1 Specific Test Objective 3-1: Evaluate C2 system capability to provide operator awareness and control of the COMMUNICATE function (HSI COMMUNICATE functional requirement)[26].

[25] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005.

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

2.3.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions and receptions from the UA.

Evaluation Criteria: Transmission and reception of data will be considered satisfactory when the pilot completes the questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.3 2 Specific Test Objective 3-2: Evaluate Voice Communications system capability to provide operator awareness and control of the COMMUNICATE function (HSI COMMUNICATE functional requirement))[27].

2.3.2.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 60 total minutes (continuous or in segments) of data transmissions and receptions from the UA.

Evaluation Criteria: Transmission and reception of data will be considered satisfactory when the pilot completes the questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

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[26] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005.

[27] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005.

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

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

Figure 1. Pilot Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pilot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

Figure 2. Recommended Modified MOS Rating Scale

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

APPENDIX H: HUMAN SYSTEMS INTEGRATION (HSI) ACCESS 5 C3 TECHNOLOGY DEMONSTRATION – PILOT QUESTIONNAIRE

HUMAN SYSTEMS INTEGRATION (HSI) ACCESS 5 C3 TECHNOLOGY DEMONSTRATION – PILOT QUESTIONNAIRE JULY 23, 2005

Pilot Background Information

Name:

_____

Date: _____

Totals UA Pilot flight hours: _____

Manned aircraft flight hours: _____

Licenses and Ratings (circle choices): Private, Commercial, Airline Transport Pilot, Instrument, Airplane, Rotocraft, Single-Engine, Multi-Engine, Instructor, Other

Aircraft flown:

_____

Mission Information

Flight Event: No. or Description_____

Aircraft Call Sign: _____

Flight Plan Attached: Y N

Flight Planned Route and Altitude_____

Actual Departure Time_____ Actual Arrival Time_____

Transmissions to ATC (number): _____Receptions from ATC (number):_

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

ATC Clearances Received (number): _____

Commanding/Monitoring AVIATE: Observation Time (min) _____

Commanding/Monitoring NAVIGATE: Observation Time (min) _____

Commanding/Monitoring COMMUNICATE: Observation Time (min)_____

Total Observation Time (min):_____

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

Human-Systems Integration AVIATE Questions

1. Rate C3 system performance as it affected your ABILITY TO OBTAIN AWARENESS OF THE HEALTH AND STATUS OF THE UAS.

Answer only for Beyond Line-of-Sight (BLOS) operations.

Circle the number that corresponds to your ability to obtain required data.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

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

Note. This questionnaire has been modified from its original form to reduce the number of pages in this appendix. Original questionnaire pages appeared as seen on this page - including lines for pilot comments. Pilot comment lines have been deleted from succeeding questionnaire pages in this appendix in order to save space.

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

2. Rate C3 system performance as it affected your ability TO COMMAND FLIGHT MANEUVERS TO SAFELY CONDUCT FLIGHT.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

3. Rate C3 system performance as it affected your ability to MONITOR FLIGHT MANEUVERS TO SAFELY CONDUCT FLIGHT.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to obtain required data.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.

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

5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

Human-Systems Integration COMMUNICATE Questions

4. Rate the ease or difficulty in OPERATING THE C3 SYSTEM.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

5. Rate the ease or difficulty in TRANSMITTING TO ATC.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors

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

2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

6. Rate THE LOUDNESS/VOLUME OF THE ATC TRANSMISSION.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

7. Rate the effect on your tasks of SIGNAL-TO-NOISE RATIO, MASKING, NOISE, AND /OR CLUTTER WITH THE ATC TRANSMISSION.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

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

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

8. Rate THE UNDERSTANDABILITY/INTELLIGIBILITY OF THE ATC TRANSMISSION.

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

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

9. Rate the VOICE DISTINCTNESS/CLARITY OF THE ATC TRANSMISSION.

Answer for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

10. Rate the effect on your tasks of LATENCY INVOLVED IN ATC COMMUNICATIONS

Answer for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

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

Recommended Modified MOS Rating Scale

5	Excellent – No Pilot Effort Required to Perform Task
4	Good – Minimal Pilot Effort Required to Perform Task
3	Fair – Moderate Pilot Effort Required to Perform Task
2	Unacceptable – Very High Pi lot Effort Required to Perform Task
1	Unacceptable – Pilot Unable to Perform Task

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

Human-Systems Integration NAVIGATE Questions

11. Rate C3 system performance as it affected your ability TO CONTROL VEHICLE POSITION AND HEADING, COURSE, SPEED, AND ALTITUDE to follow the flight plan/ comply with ATC clearance (NAVIGATION PURPOSES).

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.
5 Significant Deficiencies	Significant difficulty with some errors.
6 Major Deficiencies	Major difficulty with many errors.
7 Unsatisfactory	Cannot perform task. Unsafe.

12. Rate C3 system performance as it affected your ability TO KNOW VEHICLE POSITION AND HEADING, COURSE, SPEED, ALTITUDE as it related to your flight plan or ATC clearance (FOR NAVIGATION PURPOSES).

Answer only for BLOS operations.

Circle the number that corresponds to your ability to affect system control.

Information Presented	Pilot Task Performance
1 No Deficiencies	Easy with no errors
2 Minor Deficiencies	Minor difficulty with no errors.
3 Moderate Deficiencies	Moderate difficulty with no errors.
4 Very Objectionable Deficiencies	Very objectionable difficulty with no errors.

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

5	Significant Deficiencies	Significant difficulty with some errors.
6	Major Deficiencies	Major difficulty with many errors.
7	Unsatisfactory	Cannot perform task. Unsafe.

Pilot Opinion of C3 Performance, Operations, Information Displayed, and/or Control Capability

Identify any C3 functional capability, displayed information, control capability, pilot task, workload aspect, operation, phase of flight, or feature where changes are required (that is, mandatory) for you to comply with normal IFR flight operations above FL430?

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

APPENDIX I: HSI DISPLAY SYMBOLOGY GUIDELINES FOR SIMULATION OR FLIGHT TEST FOR COLLISION AVOIDANCE

HUMAN SYSTEMS INTEGRATION (HSI) HSI DISPLAY SYMBOLOGY GUIDELINES FOR SIMULATION OR FLIGHT TEST FORCOLLISION AVOIDANCE MARCH 16, 2005

The briefing charts presented on the following pages were submitted to LMCO – Ft. Worth as guidance in their development of CA displays for CA WP simulation and flight demonstration purposes. The document represents a revision to an earlier submission.

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

Slide 1

HSI Display Guidelines for Simulation or Flight Test: CA

03/03/05

Gary Gershzohn
HSI WP

DRAFT

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

Slide 2

Revision Mar 3, 2005

- Changes are marked in blue
- Tables will be supplied when requested
  - Tables will contain information specific to each simulation or flight test

DRAFT

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

Slide 3

CA

- HSI requirements for cockpit display of traffic information (CDTI) to be submitted to LMCO -Ft. Worth
- Symbology requirements were derived from CA WP, HSI WP analyses, and test objectives
- Additional information was obtained from FAA and RTCA documents

DRAFT

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

Slide 4

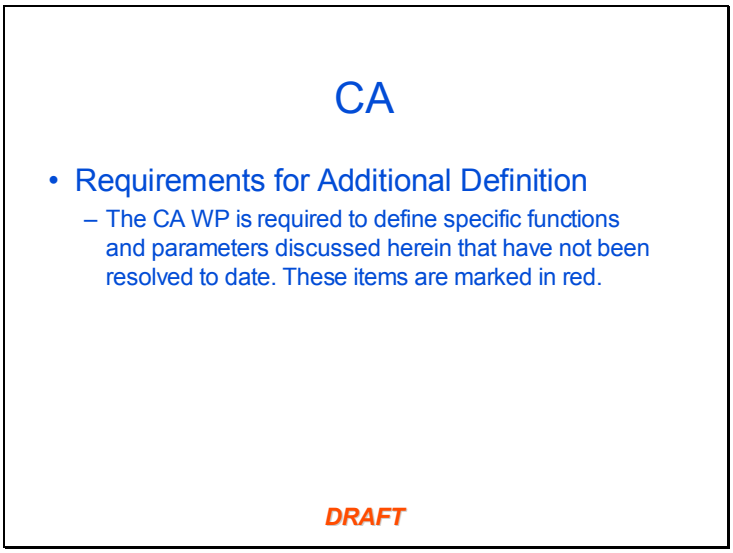
CA

- Requirements herein define
  1. Cockpit display of traffic information (CDTI)
     a. with threat identification features
     b. without threat identification features
  2. Vertical Speed Indicator (VSI) including pilot commanding features
  3. Aural alerting
- Combinations may be used for test and evaluation
  - 1a or 1b only
  - 1a, 2 and 3
  - 1a and 3
  - 2 and 3

DRAFT

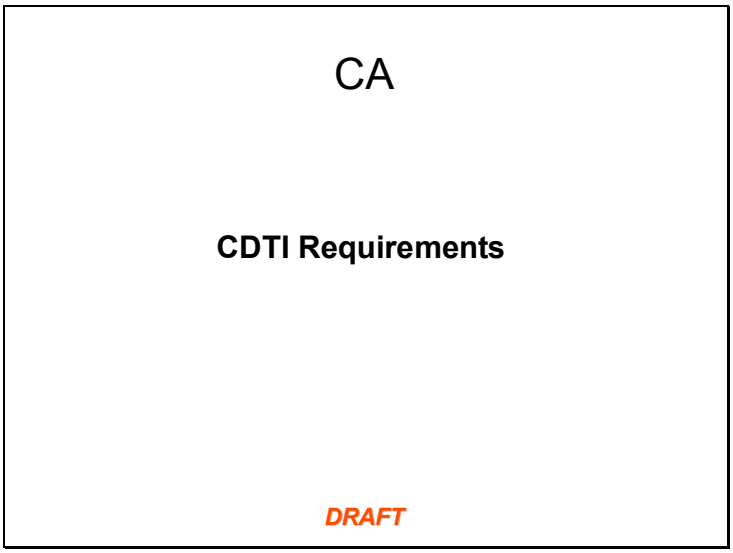
The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

Slide 5



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

Slide 6



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

Slide 7

CA

- Requirements are for a dedicated CA plan view display.
  - When CA information is displayed on a shared display (e.g., on a NAV display), additional requirements shall be defined. Details TBS if requested.

DRAFT

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Slide 8

CA

- Symbology requirements
  - Own Aircraft Symbol and Location
    - The traffic display shall contain a symbol representing the location of the own aircraft. The color of the symbol shall be either white or cyan and different than that used to display proximate or other traffic.
    - The own aircraft symbol shall be centered horizontally on the display and approximately 1/3 of the height from the bottom of the display

DRAFT

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Slide 9

CA

- Range Rings
  - One or more range rings shall be placed at specified radii from the own aircraft symbol. The inner range ring shall not be solid and shall be comprised of only discrete markings at each of the twelve clock positions. The markings shall be the same color as the own aircraft symbol and of a size and shape that will not clutter the display. If CA information is shown on a shared display which does not provide range rings (or markings), range rings shall be provided when the CA information is selected.

DRAFT

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Slide 10

CA

- Threat Symbology
  - When traffic is classified according to threat level
    - The symbol for a Traffic Alarm shall be a red filled square. (Traffic Alarm Definition: Display information provided by the CA subsystem to the ROA Pilot advising that a particular maneuver should, or should not, be performed to attain or maintain safe separation distance from an intruder aircraft.)
    - The symbol for a Traffic Alert shall be an amber or yellow filled circle. (Traffic Alert Definition: Display information provided by the CA subsystem to the ROA Pilot in a timely manner, identifying the location of a converging aircraft of a potential collision.

DRAFT

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CA

- The symbol for Proximate Traffic shall be a white or cyan filled diamond. The color of the Proximate Traffic symbol should be different than that used for the own aircraft symbol to ensure the symbol is readable.
- The symbol for Other Traffic shall be a white or cyan diamond, outline only. The color of the Other Traffic symbol should be different than that used for the own aircraft symbol to ensure the symbol is readable.

DRAFT

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CA

- When traffic is not classified according to threat level
  - The symbol for traffic shall be a white or cyan diamond, outline only. The color of the Traffic symbol should be different than that used for the own aircraft symbol to ensure the symbol is readable.

DRAFT

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Slide 13

CA

– Altitude Data Tag

- A data tag shall indicate the relative altitude, if available, of the intruder aircraft and shall consist of two digits indicating the altitude difference in hundreds of feet. For an intruder above own aircraft, the tag shall be placed above the traffic symbol and preceded by a “+” sign; for one below own aircraft, the tag shall be place below the traffic symbol and preceded by a “ -” sign. It is recommended that the “+” or “ -” character be emphasized by using a slightly larger character set than that used for the digits.

DRAFT

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Slide 14

CA

- The tag for co -altitude traffic shall be displayed as the digits “00”. The “00” characters should be placed above the symbol if the intruder aircraft closed from above; below the symbol if the intruder aircraft closed from below. If no trend information is available, the co -altitude “00” symbol should be placed below the traffic symbol.
- The color of the data tag shall be the same as the symbol.
- The display shall be capable of displaying relative altitudes of up to a maximum of ±9900 feet.

DRAFT

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Slide 15

CA

– Intruder Vertical Speed Arrow

- A vertical arrow shall be placed to the immediate right of the traffic symbol if the vertical speed of the intruder (as determined by the CA system) is equal to or greater than 500 fpm, with the arrow pointing up for climbing traffic and down for descending traffic. The color of the arrow shall be the same as the traffic symbol.

DRAFT

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Slide 16

CA

– Non-Altitude Reporting Intruders

- Neither a data tag nor a trend arrow shall be associated with the traffic symbol for an that is not reporting altitude. The colors described for various threat levels shall be used for the display of non - altitude reporting intruders.

DRAFT

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Slide 17

CA

– No-Bearing Advisories

- Advisories issued against an intruder for which bearing information is not available (No -Bearing advisories) shall be presented for traffic generating either a Traffic Alarm or Traffic Alert .
- Details for display of No -Bearing aircraft TBS if required.

DRAFT

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Slide 18

CA

– Display of Traffic

- Whenever a Traffic Alarm or Traffic Alert is displayed, all intruders causing a Traffic Alarm or Traffic Alert and all Proximate Traffic within the selected display range, subject to any limitations to the maximum number of intruders that can be shown on the display, shall be displayed. It is recommended that other traffic within the selected display range also be displayed whenever a Traffic Alarm or Traffic Alert is displayed to maximize the probability of the pilot visually acquiring the intruder causing the Traffic Alarm or Traffic Alert .

DRAFT

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CA

- When traffic is classified according to threat level, the traffic display shall have the capability to display a minimum of eight (TBV) intruder aircraft. All intruders being tracked by the CA system are ranked by the CA logic and the intruder information is sent to the display in a prioritized order. The display shall present the intruders in the order received from CA logic to ensure the intruders most relevant to collision avoidance are displayed. The number of intruders to be displayed shall be fixed or variable.

DRAFT

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Slide 20

CA

– Altitude Band for the Display

- The normal altitude band for the display of traffic having an established surveillance track shall be ±2700 feet (TBV) from the own aircraft.
- If an intruder causing a Traffic Alarm or Traffic Alert is outside this altitude band, it shall be displayed with the appropriate relative altitude displayed. Proximate and Other traffic outside the normal altitude band may also be displayed while a Traffic Alarm or Traffic Alert is displayed.
- As an option, a pilot selectable mode may be provided to permit the expansion of the normal altitude band. Details TBS if required.

DRAFT

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CA

– CA Operating Modes and Selected Display Range Annunciations

- The selected modes (TBD) of the CA system operation shall be annunciated on the traffic display. The operating mode may be manually selected by the pilot using the CA Control Panel or automatically by the CA logic (TBV). In addition, the selected display range shall be annunciated on the traffic display.

DRAFT

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Slide 22

CA

– Status and Failure Annunciations
  - Whenever status and failure annunciations are written in text on the traffic display, the annunciations shall have a single meaning for all available display modes.
  - The display shall be capable of annunciating the following CA operating modes and failure conditions:
    – TBD

DRAFT

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Slide 23

CA

– Display Range

- It is recommended that the scale of the display area be between 5.0 and 7.0 nm (TBV) to the front and at least 2.5 nm (TBV) to the rear of the ownship aircraft symbol.
- A 2.0 nm (TBV) range ring shall be provided.
- If available, a range selector control shall provide for the setting of different full range scales.

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CA

- A range reference (ring or markings) shall be provided at either 2.0 or 3.0 nm for scales of 12 nm or less. For display ranges greater than 12 nm, at least one range reference (ring or markings) shall be provided.

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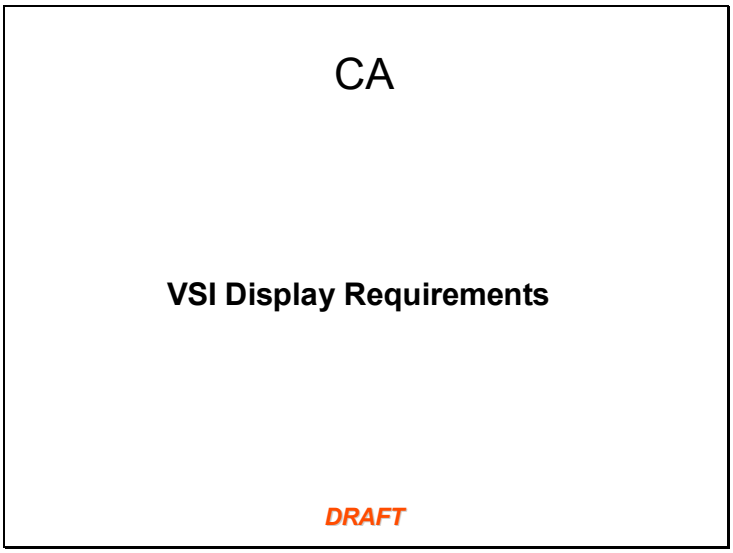
Slide 25



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CA

– MR/VSI (Round dial VSI) Display
- (Requirements for non -round dial VSIs can be provided if requested)
- This implementation shall indicate the vertical speeds to be flown and avoided using a series of red, green, and black arcs displayed around the periphery of the VSI. The term “black arcs” refers to the area of the VSI scale, usually the background of the scale, that is not illuminated by the lighted red and green arcs .
- The scale of the VSI shall have sufficient range to display the required red and green arcs for all Traffic Alarms which can be generated by the CA logic. This will require a range of ±6000 fpm.

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CA

– Red Arcs
  - The red arcs shall indicate the vertical speed range that must be avoided to maintain or attain the desired vertical miss distance from one or more intruders. The red arcs shall have the capability of displaying a resolution no larger than 500 fpm (TBV) for maintain rate Traffic Alarms issued by the CA logic. If the display is capable of displaying a finer resolution, it shall be used. The red arcs shall be able to accurately depict all vertical speed limit (VSL) Traffic Alarms shown in Table 1 (TBS). The red arcs shall be readily discernible and distinguishable. The length of the red arc shall be adjusted as appropriate when the Traffic Alarm is strengthened or weakened by CA logic.

DRAFT

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CA

– Green Arcs

- A green “fly -to” arc shall be used to provide a target vertical speed whenever a change in the existing vertical speed is desired or when an existing vertical speed (not less than 1500 fpm) must be maintained. The nominal size of the green arc shall be approximately that defined by the distance between the 1500 and 2000 fpm marks on the VSI scale. The size of the green arc shall remain constant no matter where the arc is placed on the display, with the exception of multi -aircraft encounters.

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CA

- The green arcs shall be readily discernible and distinguishable. In addition, the green arc shall either be wider than the red arc or offset from the red arc to assist in visually differentiating between the red and green arcs. The green arc shall remain displayed for the entire duration of the Traffic Alarm . Its position shall move to the appropriate position when a Traffic Alarm is strengthened or weakened by the CA logic.

DRAFT

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CA

– Black Arcs
  - The portions of the VSI scale not covered by either a red or green arc shall remain black.

DRAFT

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CA

– Multi-aircraft Encounters

- For the special situation where a multi -aircraft encounter results in an Traffic Alarm where neither a climb nor descent is permitted, a green arc shall be displayed from approximately -250 fpm to +250 fpm (TBV). The remainder of the VSI scale shall be illuminated with red arcs.

DRAFT

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CA

– Lighting Control

- The lighting intensity of the red and green arcs shall either be automatic or connected to an adjustable lighting control similar to alerting indicators.

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CA

Alerting Requirements

DRAFT

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CA

- Aural Annunciations
  - Aural alerts shall be presented by voice announcements only (TBV).
  - An aural annunciation shall be generated when the first Traffic Alarm of an encounter is displayed and each time a subsequent change in the advisory is displayed (strengthened or weakened). An aural annunciation shall also be provided to indicate that the ownship aircraft is clear of conflict with all threatening aircraft.

DRAFT

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CA

- The aural annunciations used shall conform with the content and duration (repetitions) shown in Table 2 (TBS). An annunciation shall be interrupted before it is completed if the CA logic determines that a higher priority aural annunciation should be announced.
- Quality
  - Aural alerts shall be announced in a high fidelity, distinguishable voice that is audible in all expected AVCS ambient noise conditions.

DRAFT

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CA

- Traffic Alerts
  - When a Traffic Alert is initially issued, the aural annunciation “TBD” shall be spoken once. The annunciation shall be pre -empted by any annunciation associated with a Traffic Alert.
- Traffic Alarms
  - The annunciations shown in Table 3 (TBS) are spoken when the indicated Traffic Alarm is issued by the CA system. The annunciations for a Traffic Alarm reversal and for an increase rate Traffic Alarm indicates the previously annunciated Traffic Alarm has reversed or been increased in strength. These aural annunciations shall be spoken with a sense of urgency.

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CA

- Visual Alerts
  - Traffic Alert
    - An independent amber or yellow visual alert, i.e., a dedicated glare shield or instrument panel light, for Traffic Alerts is optional.
  - Traffic Alarm
    - A red visual alert shall be provided in the primary field of view for each pilot. The red arcs on an Traffic Alarm/VSI display fulfill this requirement.

DRAFT

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APPENDIX J: HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES – COLLISION AVOIDANCE

HUMAN SYSTEMS INTEGRATION (HSI) TEST OBJECTIVES – COLLISION AVOIDANCE MARCH 16, 2005

1.0 Introduction

These technology demonstration flights support the ACCESS 5 goal of providing routine access to the National Airspace System (NAS) for Remotely Operated Aircraft (ROA). These flights will provide the ACCESS 5 staff with flight test data on Human System Integration (HSI) of Collision Avoidance (CA) technologies that promise to enhance ROA capabilities to the level required for routine access to the NAS. These test objectives will be evaluated during a series of flights involving ROA. These test objectives will be conducted in piggyback efforts on other work packages' (WP) flight tests.

1.1 General Test Objectives (GTOs):

Assess HSI for CA system capability to provide operator awareness of the health and status of the CA System (FR1)[28].

Assess HSI for CA system capability to provide the pilot with the capability to avoid cooperative traffic (FR5a)[29].

1.2 Discussion of Objectives:

For Step 1 of Access 5, the CA subsystem shall provide the ROA pilot with the ability to reliably provide CA system status to the air vehicle control station (AVCS). It shall also provide the pilot the ability to avoid cooperative traffic. To successfully accomplish these objectives, the ROA system must be able to satisfy major test objectives in accordance with HSI standards. The HSI top level functional requirements document[30] (developed by WP7), the *CA Sense-and-Avoid Equivalent Level of Safety Definition for Unmanned Aircraft Systems*[31] (developed by WP1 and

[28] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[29] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005.
[30] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[31] *NASA Access 5 WP1 and WP2 Teams, Sense and-Avoid Equivalent Level of Safety Definition for Unmanned Aircraft Systems, rev. 9, September 23, 2004.*

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

2), and the *Cooperative Conflict Avoidance Functional Requirements for Step 1 - HALE ROA Flight above FL400*,[32] (developed by Work Package 2) defined the requirements for HSI with the CA system. The general test objectives and specific test objectives were then derived from these combined HSI and CA system requirements.

1.3 Assumptions

Certain assumptions were made concerning the flight test objectives for HSI.

The test objectives are general and are not specific to a particular CA technology solution or nor AVCS design.

The pilot may or may not be provided with alerts to aid in the performance of the CA function. As the requirement for such alerts has been established by analysis, alerting evaluation is not required in this demonstration.

The pilot may or may not be provided with guidance to aid in the performance of the CA function. If guidance is provided, its evaluation will be required in this demonstration.

Access 5 HSI observers will administer a questionnaire to pilots and conduct informal interviews to obtain data regarding HSI aspects of CA.

[32] NASA Access 5 WP6 Team, *Cooperative Conflict Avoidance Functional Requirements for Step 1— HALE ROA Flight above FL400, Draft, Rev. 2*, September 30, 2004.

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2.0 General Test Objectives/Specific Test Objectives.

2.1 General Test Objective 1: Assess pilot ability to obtain awareness of CA system health and status (FR1)[33].

2.1.1 Specific Test Objective 1-1: Assess HSI for ROA CA system status.

2.1.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 30 total minutes (continuous or in segments) of health and status data transmissions from the ROA and displayed in the AVCS to the pilot.

Evaluation Criteria: Assessment of data for CA system health and status will be considered satisfactory when each pilot completes the HSI CA questionnaire[34].

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.1.2 Specific Test Objective 1-2: Assess pilot ability to control the CA system.

2.1.2.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 30 total minutes (continuous or in segments) of commanding CA system operation.

Evaluation Criteria: Assessment of data for pilot control of the CA system will be considered satisfactory when each pilot completes the HSI CA questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

[33] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005
[34] Each pilot questionnaire employs a modified Cooper-Harper rating scale (Figure 1).

Data Requirements: Pilot questionnaires.

2.2 General Test Objective 2: General Test Objective: Assess HSI for CA system capability to provide the pilot with the capability to avoid cooperative traffic (FR5a)[35].

2.2.1 Specific Test Objective 2-1: Assess pilot ability to perceive (observe) traffic shown on CA display.

2.2.1.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 20 CA events of pilot observing traffic targets shown on the CA display.

Evaluation Criteria: Assessment of data for pilot ability to perceive (observe) traffic on CA display will be considered satisfactory when each pilot completes the HSI CA questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.2.2 Specific Test Objective 2-2: Assess pilot ability to make a decision (determine a response) for collision avoidance. (Applicable to CA scenarios that do or do not present maneuvering guidance information to the pilot.)

2.2.2.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 20 CA events of pilot decision-making responses to traffic targets shown on the CA display.

Evaluation Criteria: Assessment of data for pilot decision-making capability will be considered satisfactory when each pilot completes the HSI CA questionnaire.

[35] Access 5 HSI Top Level Functional Requirements SEIT Review, January 7, 2005.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.2.3 Specific Test Objective 2-3: Assess pilot ability to affect a control response to avoid cooperative traffic.

2.2.3.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 20 CA events of pilot affecting responses to avoid cooperative traffic.

Evaluation Criteria: Assessment of data for pilot control response capability will be considered satisfactory when each pilot completes the HSI CA questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires.

2.2.4 Specific Test Objective 2-4: Assess CA guidance presented to pilot (Applicable only to CA scenarios that present maneuvering guidance to the pilot.).

2.2.4.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 20 CA events with guidance presentations.

Evaluation Criteria: Assessment of data for guidance presentations will be considered satisfactory when each pilot completes the HSI CA questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires and observer log.

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

2.2.5 Specific Test Objective 2-5: Evaluate alerts presented to pilot.

2.2.5.1 Measure of Performance: Data provided in pilot questionnaire containing pilot observations and ratings, and data entered in experimenter's log containing observations of pilot performance.

Success Criteria: Acquire HSI pilot questionnaire data based on a minimum of 20 CA events with guidance presentations.

Evaluation Criteria: Assessment of data for guidance presentations will be considered satisfactory when each pilot completes the HSI CA questionnaire.

Final Data Products: Results summary, discussion, and recommendations based on pilot questionnaire data.

Data Requirements: Pilot questionnaires and observer log.

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LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

Figure 1. Modified Cooper-Harper Rating Scale

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APPENDIX K: HUMAN SYSTEMS INTEGRATION (HSI) TEST PILOT QUESTIONNAIRE FOR THE COOPERATIVE CONFLICT AVOIDANCE FLIGHT DEMONSTRATION

HUMAN SYSTEMS INTEGRATION (HSI) TEST PILOT QUESTIONNAIRE FOR THE COOPERATIVE CONFLICT AVOIDANCE FLIGHT DEMONSTRATION
MAY 10, 2005

Pilot Background Information

Name: _____ Date: _____

Pilot flight hours in this ROA: _____

Totals ROA pilot flight hours: _____

Manned aircraft flight hours: _____

Licenses and Ratings (circle choices): Private, Commercial, Airline Transport Pilot, Instrument, Airplane, Rotocraft, Single-Engine, Multi-Engine, Instructor, Other

Aircraft flown:

_____

Mission Information

Flight Event: No./Description _____

Aircraft Call Sign: _____

Flight Plan Attached: Y N

Test Card Data Attached: Y N

CA Status Transmissions: Observation Time (min) _____
Commanding CA System Operation: Observation Time (min) _____
Assessment of Pilot Ability to Perceive (Observe) Traffic on Display: Events (Number) _____

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Assessment of Pilot Ability to Make a Decision to Avoid Traffic: Events (Number) _____

Assessment of Pilot Ability to Affect a Control Response to Avoid Traffic: Events (Number) _____

Assessment of CA Guidance Presented to Pilot: Events (Number) _____

1. Rate the ease or difficulty in determining THE MEANING OF THE TRAFFIC ICONS.

(In answering, consider: How did these icons affect your ability to identify traffic position, trajectory, and proximity to your aircraft? Was the meaning of the icon clear and unambiguous in all conditions? Did the icon give you a clear understanding of the threat status of the traffic? Was the amount of time required to perform this task satisfactory or unsatisfactory?)

LEGEND:

Rating	**Ease/Difficulty**	**Demand Level**
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

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

_____
_____
_____
_____
_____
_____

Note. This questionnaire has been modified from its original form to reduce the number of pages in this appendix. Original questionnaire pages appeared as seen on this page - including lines for pilot comments. Pilot comment lines have been deleted from succeeding questionnaire pages in this appendix in order to save space.

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

2. Rate the ease or difficulty in using the AURAL ALERT to inform you that there was a collision threat.

(In answering, consider: Was the alert timely, that is, did it warn you in time to initiate the maneuver to avoid traffic?)

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

3. Rate the ease or difficulty in using the CA display to MAKE A CORRECT DECISION TO AVOID TRAFFIC.

(In answering, consider: How confident were you that your decision was correct? How long did it take to make the decision: short, moderate, long, etc.? Please describe the steps you went through and the factors you considered in making the decision, for example, use of traffic icons, data tags, movement of icons, etc. Was the amount of time required to perform this task satisfactory or unsatisfactory?)

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired

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		performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

4. For trials where guidance was presented on the display that provided an evasive maneuver, rate the ease or difficulty in using THE GUIDANCE COMMAND display to avoid the traffic.

(In answering, consider: How confident were you that the guidance was correct? How long did it take to make this decision: short, moderate, long, etc.? Did the guidance symbols appear in a timely manner, that is, did it inform you in time to initiate the maneuver to avoid traffic?)

LEGEND:

Rating	Ease/Difficulty	Demand Level
1	Excellent	No pilot effort required
2	Good; Negligible deficiencies	Pilot effort not a factor
3	Fair/Mild deficiencies	Minimal pilot effort required for desired performance
4	Minor deficiencies	Moderate pilot effort is required for desired performance
5	Objectionable deficiencies	Considerable pilot effort required for desired performance
6	Very objectionable deficiency	Extensive pilot effort required for desired performance
7	Major deficiencies	Adequate performance not attainable with maximum effort
8	Major deficiencies	Minor errors experienced with maximum effort
9	Major deficiencies	Major errors experienced with maximum effort
10	Impossible/Unacceptable	Pilot cannot complete task

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

APPENDIX L: PILOT OBSERVATION LOG - ACCESS 5 COLLISION AVOIDANCE FLIGHT DEMONSTRATION

PILOT OBSERVATION LOG - ACCESS 5 COLLISION AVOIDANCE FLIGHT DEMONSTRATION JUNE 28, 2005

1. Did the aural alert operate correctly and warn you of a RA? YES NO
2. Did the VSI operate correctly and did it have an impact on your reaction time? YES NO
3. Did the VSI provide a clear indication of the required response? YES NO
4. Did the plan view display operate correctly and provide you with traffic situation awareness? YES NO

If you answered “NO” to any question, provide a description of your observation. Describe what did not appear to work correctly. This information will be used in data analysis so engineers can compare recorded data to your observations.

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HUMAN SYSTEMS INTEGRATION (HSI) AIRSPACE OPERATIONS DEMONSTRATION (AOD) FLIGHT REQUIREMENTS

JUNE 28, 2005

Overarching HSI Flight Requirement – Demonstrate the pilot interface for unmanned aircraft system (UAS) operation in the National Airspace System (NAS).

Function	HSI Flight Requirement	WP	Success Criteria	Measures of Performance	Priority
Aviate	Demonstrate the pilot interface to aircraft trajectory above FL430	C3	• ACS provides trajectory control • ACS displays trajectory data	• Aircraft pitch/yaw/roll/speed changes in response to ACS input • Documentation of displayed pitch/yaw/roll/speed data	Required
Aviate	Demonstrate the pilot interface to aircraft system failure / status data	CM	• ACS provides aircraft systems control in response to system failure • ACS displays system failure data	• Observation/ documentation of pilot control of systems in response to failure • System reconfiguration data • Documentation of displayed failure data	Required
Communicate	Demonstrate the	C3	• ACS provides voice	• Observation/ documentation of	Required

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	pilot interface to voice communications to and from ATC above FL430		communication to/from ATC • ACS displays voice communication system data	pilot-ATC communications • Documentation of displayed communication system data	
Communicate	Demonstrate the pilot interface to datalink system above FL430	C3	• ACS provides datalink control • ACS displays datalink system data	• Datalink operation • Documentation of datalink status, channel in use	Required
Navigate	Demonstrate the pilot interface to navigation above FL430	C3	• ACS provides navigation control • ACS displays navigation data	• Aircraft navigation changes in response to ACS input • Documentation of displayed navigation data	Required
Avoid Hazards	Demonstrate the pilot interface to hazard avoidance above FL430	CA	• ACS provides for hazard avoidance • ACS displays hazards	• Documentation/ description of displayed cooperative traffic (i.e., audio alert, command guidance, and traffic depiction on CCA display)	Required
Avoid Hazards	Demonstrate the pilot-system interface to weather information above FL430.	WX	• ACS provides for access to and control of weather information • ACS displays weather information	• Documentation/ description of displayed weather information • Documentation/ description of displayed weather information	Required

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