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Abstract:
The purpose of this Functional Requirements Document (FRD) is to compile the functional requirements needed to achieve the Access 5 Vision of "operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the national airspace system (NAS)" for Step 1. These functional requirements could support the development of a minimum set of policies, procedures and standards by the Federal Aviation Administration (FAA) and various standards organizations. It is envisioned that this comprehensive body of work will enable the FAA to establish and approve regulations to govern safe operation of UAS in the NAS on a routine or daily "file and fly" basis.

The approach used to derive the functional requirements found within this FRD was to decompose the operational requirements and objectives identified within the Access 5 Concept of Operations (CONOPS) into the functions needed to routinely and safely operate a HALE UAS in the NAS. As a result, four major functional areas evolved to enable routine and safe UAS operations for an on-demand basis in the NAS. These four major functions are: Aviate, Navigate, Communicate, and Avoid Hazards. All of the functional requirements within this document can be directly traceable to one of these four major functions. Some functions, however, are traceable to several, or even all, of these four major functions. These cross-cutting functional requirements support the "Command / Control" function as well as the "Manage Contingencies" function. The requirements associated to these high-level functions and all of their supporting low-level functions are addressed in subsequent sections of this document.

Status:

Access 5 - Approved

Limitations on use:
This document is an approved Access 5 Project position on the functional requirements for HALE UAS operations in the NAS for Step 1 (operations above FL430).

Functional Requirements Document For HALE UAS Operations in the NAS Step 1

Version 3, January 2006

Prepared by:

Access 5 Systems Engineering and Integration Team

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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UAV NATIONAL INDUSTRY TEAM

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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RECORD OF CHANGES

Revision	Date	Change Description
Version 1	Sept 2003	Initial release of document.
Version 2 1st Draft	May 2005	Made substantial changes to Version 1. - Defined the approach used to develop the UAS functions, - Established a functional architecture for a UAS, - Updated the requirements in accordance with the established functional architecture, and - Incorporated Work Package specific requirements developed for Step 1
Version 2 2nd Draft	Sept. 2005	Refined the May 2005 draft. - Incorporated numerous changes based on comments received against the May 2005 draft document, - Added an Executive Summary, - Added a List of Figures & Tables, References, Acronyms, and Definitions, - Updated the Operational Requirements Table based upon revised CONOPs, - Added a HALE UAS Description Section, - Added a Verification/Validation Section, - Developed and incorporated an Operational/Functional Traceability Matrix, and - Developed and incorporated a requirements traceability wiring diagram for the four high-level functions (Aviate, Navigate, Communicate, and Avoid Hazards)
Version 3 3rd Draft	Jan. 2006	Minor changes were made in preparation for release to RTCA.

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EXECUTIVE SUMMARY

The purpose of this Functional Requirements Document (FRD) is to compile the functional requirements needed to achieve the Access 5 Vision of "*operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the national airspace system (NAS)*" for Step 1. These functional requirements will be used by Access 5 to develop a minimum set of policies, procedures and standards that can be proposed to the Federal Aviation Administration (FAA) and various standards organizations for consideration. It is envisioned that this comprehensive body of work will enable the FAA to establish and approve regulations to govern safe operation of UAS in the NAS on a routine or daily "file and fly" basis.

The approach used to derive the functional requirements found within this FRD was to decompose the operational requirements and objectives identified within the Access 5 Concept of Operations (CONOPs) into the functions needed to routinely and safely operate a HALE UAS in the NAS. Once these functions were identified, a functional architecture was developed to accommodate these functions. As a result, four major functional areas evolved to enable routine and safe UAS operations for an on-demand basis in the NAS. These four major functions are: Aviate, Navigate, Communicate, and Avoid Hazards. All of the functional requirements within this document can be directly traceable to one of these four major functions. Some functions, however, are traceable to several, or even all, of these four major functions. These cross-cutting functional requirements support the "Command / Control" function as well as the "Manage Contingencies" function. The requirements associated to these high-level functions and all of their supporting low-level functions are addressed in subsequent sections of this document. Where appropriate, rationale and justification has been provided to support each of the functional requirements within this FRD.

To ensure the requirements are necessary and sufficient, validation and verification processes will be used throughout the Access 5 project. The validation process will ensure each of these requirements is unambiguous, correct, complete, consistent, operationally and technically feasible, and verifiable. The verification process will demonstrate that a potential solution can meet the low-level functional and performance requirements demonstrating that the system is ready for use in the operational environment.

Several appendices are included at the end of this FRD to identify requirement traceability throughout the requirements hierarchy. Both tabular and graphic depictions of this traceability are provided.

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this Functional Requirements Document (FRD) is to compile the necessary functional requirements to achieve the Access 5 Vision of "*operating High Altitude, Long Endurance (HALE) Unmanned Aircraft Systems (UAS) routinely, safely, and reliably in the National Airspace System (NAS)*"[1]. These requirements will then be used by Access 5 to develop the recommended policies, procedures and standards necessary for HALE UAS to have same-day "file and fly" access to the NAS.

The scope of this FRD is focused on capturing the functional requirements specifically needed to meet the Access 5 Step 1 objective of routine operations within the NAS above 43,000 feet. These functional requirements were identified by performing a thorough functional analysis of a UAS, whereby the major functions of a UAS were identified and then organized into a functional architecture. To assist in this process, several work packages were created to develop the low-level functional requirements related to several of these major functional areas. Although Step 1 of Access 5 may not have a specific Work Package associated with each functional area, those areas unique to unmanned aircraft have been the initial focus.

1.2 ACCESS 5 OVERVIEW

Access 5 is a national project sponsored by the National Aeronautics and Space Administration (NASA) and Industry with participation by the Federal Aviation Administration (FAA), Department of Defense (DoD) and Department of Homeland Security (DHS) promoting the safe and reliable operation of HALE UAS within the NAS for civil and commercial applications. This team of government and industry partners are focusing their resources on developing the necessary policies, procedures, and standards to enable companies to apply for FAA certification and approval to operate their civil/commercial UAS in the NAS.

The goal of Access 5 is to enable what government and industry leaders believe will ultimately be a robust civil and commercial market for HALE UAS. While Access 5's primary focus is to address airspace access of unmanned aircraft within the domestic NAS, it is also working with the international community to ensure what is done in the United States will not inhibit the introduction of UAS into the global airspace in the future.

Access 5 is taking an incremental approach for introducing HALE UAS into the NAS. HALE was chosen as the focus because HALE aircraft are more mature systems and can operate above most air traffic, making this class of UAS a good candidate 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 goal by systematically addressing access to the NAS in four discrete steps of increasing complexity and capability:

[1] Access 5 Project Readiness Review (PRR) Presentation Dallas, TX; February 10 – 11, 2004.

Step 1: Routine operations above Flight Level (FL) 430 through pre-coordinated airspace with emergency landings at pre-coordinated airports; and recommendations for obtaining an experimental certification

Step 2: Routine operations above FL 180 through pre-coordinated airspace with emergency landings at pre-coordinated airports; and recommendations for obtaining a type certification

Step 3: Routine operations above FL 180 through C, D, and E airspace with emergency landing at pre-coordinated airports; and recommendations for obtaining a special airworthiness certification

Step 4: Routine operations above FL 180 through C, D, and E airspace with emergency landings at any UAS designated airport; and recommendations for obtaining a standard airworthiness certification

1.3 DOCUMENT ORGANIZATION

This document is organized into the following sections:

Section 1 – Introduction: States the background, purpose and scope of this requirements document, including its relationship to the Access 5 project.

Section 2 – Access 5 Requirements Analysis Process: Identifies the hierarchical structure of requirements adopted by Access 5 and describes the approach used to develop the Operational, Functional, and Performance Requirements for a UAS.

Section 3 – HALE UAS Description: Defines what comprises a HALE UAS and identifies the operational requirements needed for safe and routine UAS operations within the NAS.

Section 4 – UAS Functional Analysis: Identifies the functional architecture used to capture the major functions of an unmanned aircraft system.

Section 5 – UAS Functional Requirements: Specifies the functional requirements for a UAS in accordance with the Functional Architecture established in Section 4.

Section 6 – Requirements Validation / Verification: Specifies the rationale for conducting verification of the functional requirements identified under this project and the different methods to be used.

Section 7 – References: Provides the references used in the creation of this FRD.

Appendix A – Acronyms: Provides a list of the acronyms used within this document.

Appendix B – Definitions: Provides definitions for the unique words found within.

Appendix C – UAS Requirements Wiring Diagram: Provides a wiring diagram of the UAS Functional Requirements showing traceability throughout every level of our UAS requirements.

Appendix D – Operational/Functional Traceability Matrix: Provides a traceability Matrix between the Operational and Functional Requirements.

2 ACCESS 5 REQUIREMENTS ANALYSIS PROCESS

2.1 REQUIREMENTS ANALYSIS

Requirements Analysis involves defining the needs and objectives of a particular system in the context of how the system is employed, what type of environment it will be used within, and what type of system characteristics it is intended to possess[2]. The purpose of performing requirements analysis is extensive. First and foremost, requirements analysis should result in a clear understanding of the functions (*what the system has to do*), their interfaces (*environment in which the system will perform*) and their necessary level of performance (*how well the system should perform*) in order to meet the intended operational concept of the system.

2.2 REQUIREMENTS PERSPECTIVE

The requirements that result from performing requirements analysis can be expressed in three different perspectives or views. These three views are: Operational, Functional, and Physical. The Operational View addresses how the system will serve its users and is useful when establishing requirements of "how well" and "under what condition." The Functional View focuses on "what" the system must do to produce the required operational behavior. Lastly, the Physical View focuses on "how" the system is constructed and establishes the physical interfaces among operators and equipment as well as technology requirements[3].

Although all three views are essential to fully understand the customer's needs and objectives for a system, Access 5 will only be considering the Operational and Functional perspectives. The Physical perspective is not being considered because Access 5 is not developing or certifying any specific unmanned aircraft system. Therefore, the physical components and interfaces are considered design specific and therefore outside the scope of Access 5. The Access 5 Concept of Operations (CONOPs) is intended to provide the Operational View, while the Access 5 Functional Requirements Documents will provide the Functional View.

2.3 REQUIREMENTS HIERARCHY

There are several different levels or categories of requirements. The highest-level requirements are Operational Requirements. Functional, Performance, and Design requirements then flow from these. Functional requirements are derived from the Operational ones; Performance requirements are derived from the Functional ones; and Design requirements are derived from the Performance requirements; as shown in Figure 1. For added clarity, each of these different levels of requirements is defined in the subsequent sections. In addition, Figure 2 articulates what Access 5 deliverable will contain these different levels of requirements.

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[2] Systems Engineering Fundamentals, Defense Acquisition University Press. Requirements Analysis, Pg. 36. January 2001.

[3] Ibid. Pg. 38-39.

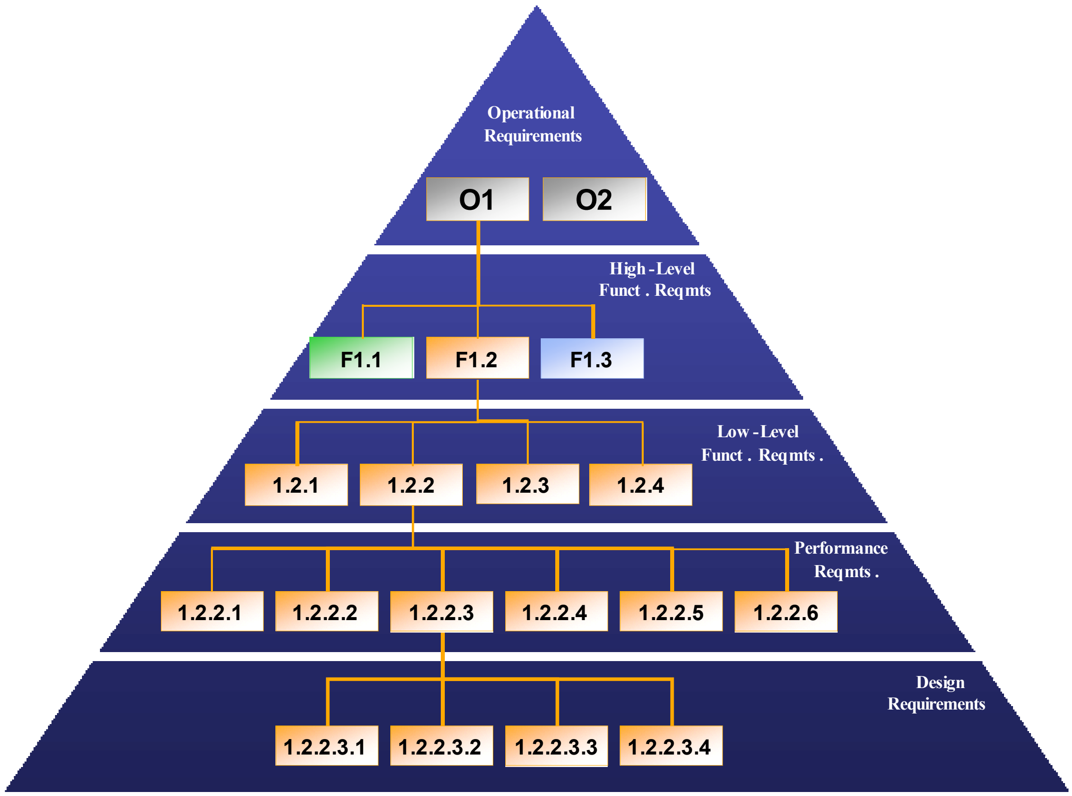

Figure 1: Example of a Requirements Hierarchy

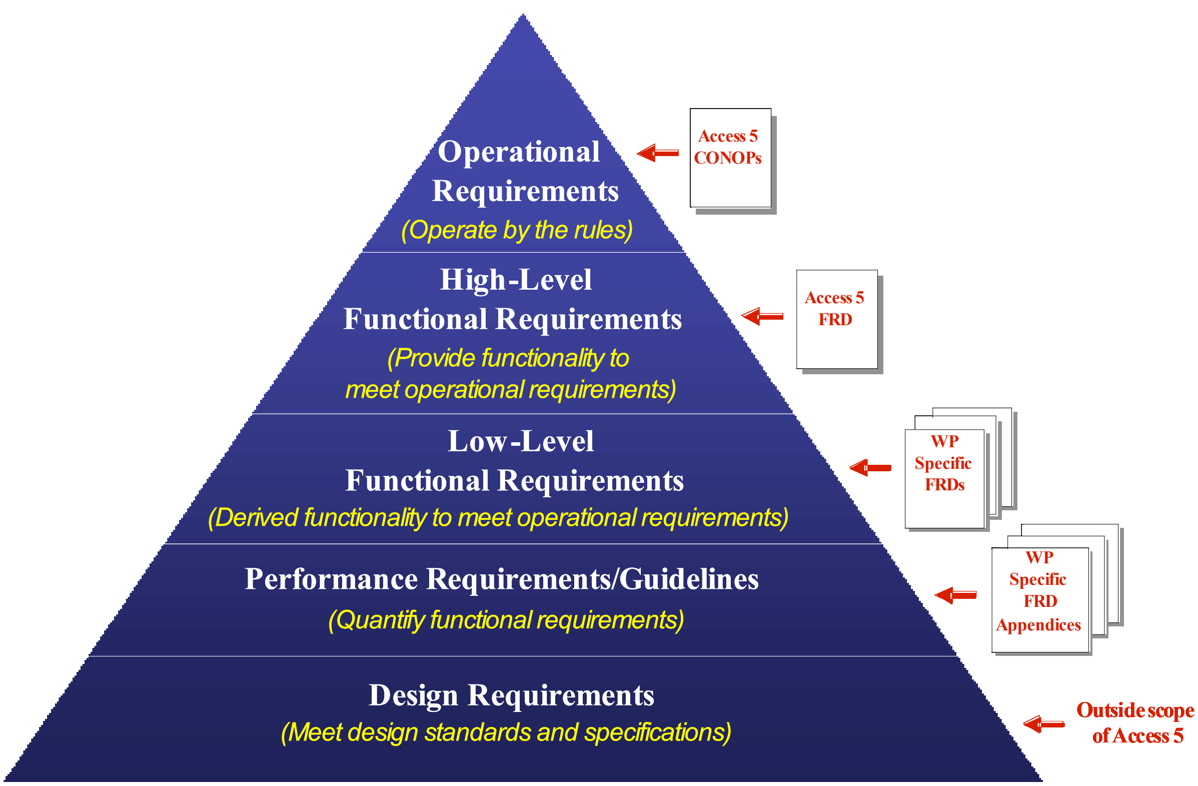

Figure 2: Correlation Between Requirements Hierarchy & the Access 5 Deliverables

2.3.1 OPERATIONAL REQUIREMENTS

Operational requirements define what is necessary for the system to operate within the existing rules and constraints (see the top tier of Figures 1 and 2). Since these rules and constraints do not currently exist for UAS, Access 5 is working very closely with the FAA and various standards organizations to help establish what policies, procedures, and standards UAS will be required to meet in the future. Specifically, the Access 5 operational requirements should identify where the system will be used, how the system will accomplish its mission objectives, and what environment the system will be expected to operate within[4]. This level of requirements is captured within the Access 5 CONOPs document.

2.3.2 FUNCTIONAL REQUIREMENTS

Functional requirements state the necessary task, action, or activity that must be accomplished. Regarding the requirements analysis process, functional requirements (what has to be done) should be used when performing functional analysis[5]. There may also be different levels of functional requirements. The high-level functional requirements provide the necessary functionality to meet the operational requirements, while the low-level functional requirements are functional requirements that are derived from the high-level functional requirements to provide further clarification. With respect to Access 5, the high-level functional requirements are captured within the Access 5 FRD (this document) and the low-level Functional Requirements are captured within the Work Package specific FRDs (see the 2nd and 3rd tiers of Figures 1 and 2).

2.3.3 PERFORMANCE REQUIREMENTS

Performance requirements define how well the system must perform its intended function (e.g. accuracy, fidelity, range, resolution, and response times)[6]. During requirements analysis, performance requirements are defined such that the functional requirement they relate to can be verified using a quantified performance value. The Access 5 Work Package specific FRDs will capture Performance "Guidelines" within the documents appendices as opposed to Performance Requirements. The reason for this distinction between requirements and guidelines is due to the nature of the requirements Access 5 is developing. Since Access 5 is not focused on any particular UAS architecture or platform it is very difficult to specify performance requirements that will accommodate all UAS. Therefore, performance guidelines are being suggested as the notional requirements that should be adequate for most platforms but may not satisfy all possible cases at different ends of the spectrum (see the 4th tier from the top in Figures 1 and 2).

2.3.4 DESIGN REQUIREMENTS

Design requirements are the "build to" or "code to" requirements[7] for products and are very design and implementation specific. Since Access 5 is not certifying any platforms or designing any specific solutions, no Access 5 resources are being spent at this level of the requirements chain (see the bottom tier of Figures 1 and 2).

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[4] Systems Engineering Fundamentals, Defense Acquisition University Press. Requirements Analysis, Pg. 36. January 2001.
[5] Ibid.
[6] Ibid.
[7] Ibid.

3 HALE UAS DESCRIPTION

3.1 HALE UAS DEFINITION

An Unmanned Aircraft System is an unmanned aircraft that is remotely operated from a control station by a pilot that issues command and control instructions to the aircraft, which are executed by an onboard flight management control system. A HALE UAS is an unmanned aircraft capable of performing mission objectives at an altitude above 18,000-feet mean sea level (MSL) with sufficient cruise capability to transit the NAS.

Any UAS is comprised of three major elements as portrayed in Figure 3 below. These elements are: 1) the Control Station, 2) the Unmanned Aircraft, and 3) the Command/Control Links.

- The Control Station (CS) is a site configured to allow the pilot in command of the UAS to operate and monitor all UAS operations conducted under his/her authority. The UAS pilot is considered to be an integral part of the Control Station.

- The Unmanned Aircraft (UA) is the unmanned platform capable of flight in the air. This could include a fixed wing airplane, a helicopter, or a balloon.

- The Command/Control (C2) Link is the two-way data link between the Control Station and the Unmanned Aircraft that is used to control the UA and monitor the health/status of onboard systems.

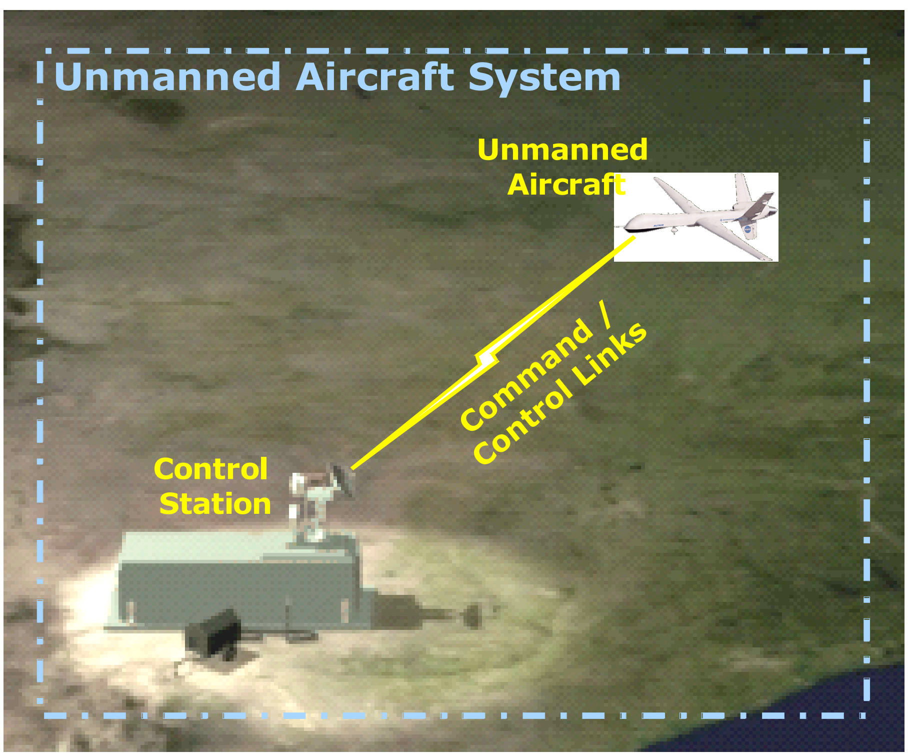

Figure 3: Notional Unmanned Aircraft System

3.2 ACCESS 5 OPERATIONAL REQUIREMENTS

As discussed in Section 2, the very top level in the requirements hierarchy is the operational requirements level. These operational requirements should identify where the system will be used, how the system will accomplish its mission objectives, and what environment the system will be expected to operate within. The following table identifies the HALE UAS operational requirements. These requirements specify the operational capabilities needed by a HALE UAS to enable it to operate routinely and safely in the NAS. Table 1 captures these Operational Requirements as identified in the Access 5 CONOPs[8].

Table 1: Access 5 Operational Requirements

Requirement Number	Operational Requirement
Overall Operational Requirement	**UAS shall operate routinely and safely in the NAS.**
O1	**UAS shall be airworthy.**
O1.1	The UAS shall be registered with the FAA.
O1.2	The UAS shall obtain and maintain a standard airworthiness certificate.
O1.3	The UAS shall meet an equivalent level of safety to that of a manned general aviation aircraft.
O2	**UAS shall be operated safely in the NAS.**
O2.1	UAS operations shall comply with all applicable 14 CFR Part 91 requirements.
O2.2	The UAS shall obtain and maintain the necessary operating certificates for 14 CFR Part 91 commercial operations (maintenance, training, etc).
O2.3	UAS flight operations shall be conducted under Instrument Flight Rules (IFR).
O2.4	The UAS shall operate under the same separation standards required for manned aircraft per FAA 7110.65.
O2.5	An authorized and qualified pilot shall be responsible for the safe flight of each UA.
O2.6	The UAS shall operate in a predictable manner similar to that of manned aircraft in the event of an emergency or other contingency situation.
O2.7	UAS shall utilize authorized frequency spectrum for command, control, communications and payloads.

These operational requirements are captured in this FRD because the UAS Functional Requirements discussed later within this document are directly related to one or more of these operational requirements. It is essential that each functional requirement be traceable to at least one of these Access 5 Operational Requirements. Appendix D provides a traceability matrix between these operational and functional requirements.

[8] Access 5 Concept of Operations, Version 2.0, Pg. TBD. Aug 2005. (This document is also being revised at the present time.)

4 UAS FUNCTIONAL ANALYSIS

This section describes the framework used to perform the functional analysis on a UAS as well as the rationale used for utilizing this architecture.

4.1 FUNCTIONAL ANALYSIS

The purpose of functional analysis is to transform the functional, performance, and interface requirements that were identified through requirements analysis into a coherent description of system functions that the system must be capable of doing. These functions should be discrete actions (using action verbs) necessary to achieve system objectives[9].

In order to develop functional requirements for any system, a functional analysis of the system should be performed. Functional analysis provides a system description that becomes a framework for developing requirements and architectures. The Access 5 functional analysis examines the UAS functions and sub-functions necessary to accomplish the operational concept identified in the Access 5 CONOPs. This process is iterated until the system is completely decomposed into basic sub-functions, and each sub-function at the lowest level is completely, simply, and uniquely defined by its requirements. The result of this process is a functional architecture where system requirements can be identified, decomposed, and derived.[10]

4.2 FUNCTIONAL VS PHYSICAL ARCHITECTURE

The previous version of the Access 5 FRD[11] separated each of the initial UAS functional requirements according to a physical architecture that was comprised of three major elements: (1) Air Vehicle Element, (2) Control Element and (3) Communications Element. It was determined that many of these functional requirements could actually pertain to more than one of these physical elements. For example, one manufacturer may assign a collision avoidance function to the control station while another may prefer to implement that same function onboard the unmanned aircraft. Furthermore, assigning a functional requirement to one of the physical elements inadvertently promotes a particular design or implementation to the UAS industry. To prevent this from occurring, it was decided that a functional architecture would much better meet the needs of Access 5; particularly since Access 5 does not intend to certify any specific unmanned aircraft system. A functional architecture should therefore provide the necessary flexibility to the manufacturers by allowing each one the ability to decide where best to implement each function within their specific UAS.

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[9] Systems Engineering Fundamentals, Defense Acquisition University Press. Requirements Analysis, Pg. 45. January 2001.
[10] "Section 4.4: Functional Analysis" NAS System Engineering Manual. Version 3.0, 30 September 2004
[11] Access 5 Functional Requirements Document, Revision 1, 5 September 2003.

4.3 UAS HIGH-LEVEL FUNCTIONS

To determine what high-level functions Access 5 would use to capture the essence of an unmanned aircraft system, several different methods were proposed. The different methods considered included: Phases of Flight; Access 5 Work Packages (how the Access 5 Technology IPT is organized); NAS Functions of Communication, Navigation, and Surveillance (CNS); and Airworthiness & Operational Functions.

While many of these proposed approaches could have been used, a concerted effort was made to select the best approach for meeting the various needs of Access 5. After several meetings between various Work Package representatives, it was determined that the best approach for meeting the needs of Access 5 was to decompose the UAS into 4 major functions: ***Aviate, Navigate, Communicate, and Avoid Hazards***. A depiction of this high-level functional breakout is shown in Figure 4.

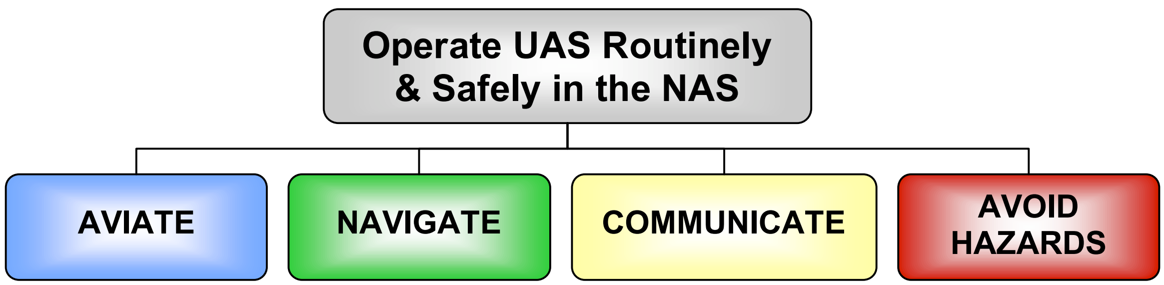

Figure 4: UAS High-Level Functions

The "Aviate, Navigate, Communicate, and Avoid Hazards" functions were chosen for several reasons. The most basic reason stems from a principle that every pilot is trained to adhere to. For anyone that has ever taken flying lessons, the first critical piece of information taught to any new trainee is the 3 major responsibilities of a pilot and the order (priority) in which these responsibilities should be performed. The first responsibility is to fly the plane (*aviate*), then fly it in the right direction (*navigate*), and finally state your intentions to others (*communicate*). Since the operational concept for a UAS is to operate in the NAS as any other type of aircraft, this paradigm makes sense for routine operations. In addition, the UAS also needs to be able to perform a function ensuring that no person or property in the air or on the surface is placed in danger. The function "Avoid Hazards" was therefore added to Aviate, Navigate and Communicate due to the necessity to ensure safety when introducing UAS into the NAS. This function is normally performed by the pilot on-board a manned aircraft. However, the separation of the pilot from the aircraft in a UAS places additional emphasis on this function. The success or failure of integrating UAS into the NAS may very well be dependent upon how well they can perform this particular function.

4.4 UAS LOW-LEVEL FUNCTIONS

Once the high-level functions of the UAS were determined, a functional analysis was performed to decompose these into their respective low-level functions. These lower level functions are the focus of the remainder of this FRD (see Section 5), which attempts to capture the HALE UAS functional requirements and ensures they are traceable back to one of these high-level functions and at least one of the operational requirements listed in Table 1.

While performing the functional analysis of a UAS, it became apparent that some functions were common to all four of the high-level functions. These cross-cutting functional areas included command/control, human systems interface, and contingency management. While the functional requirements pertaining to command/control and contingency management are discussed in Section 5.5 (Cross-Cutting Functional Requirements), the HSI functional requirements have been integrated into the appropriate sections under the Aviate, Navigate, Communicate and Avoid Hazards Functions. The rationale for keeping the HSI functional requirements together with the relevant functional area is because the human system interface is considered to be part of the function itself. If the function were implemented in a fully autonomous manner, then the human system interface requirement would not be necessary to support the higher level function.

The figure on the following page depicts the UAS low-level functions subordinate to Aviate, Navigate, Communicate, and Avoid Hazards. In addition, the command/control and contingency management low level functions are shown as the large purple and orange blocks, respectively, that span the breadth of the functional architecture. The numbers within each block correspond to the corresponding paragraph numbers in Section 5.

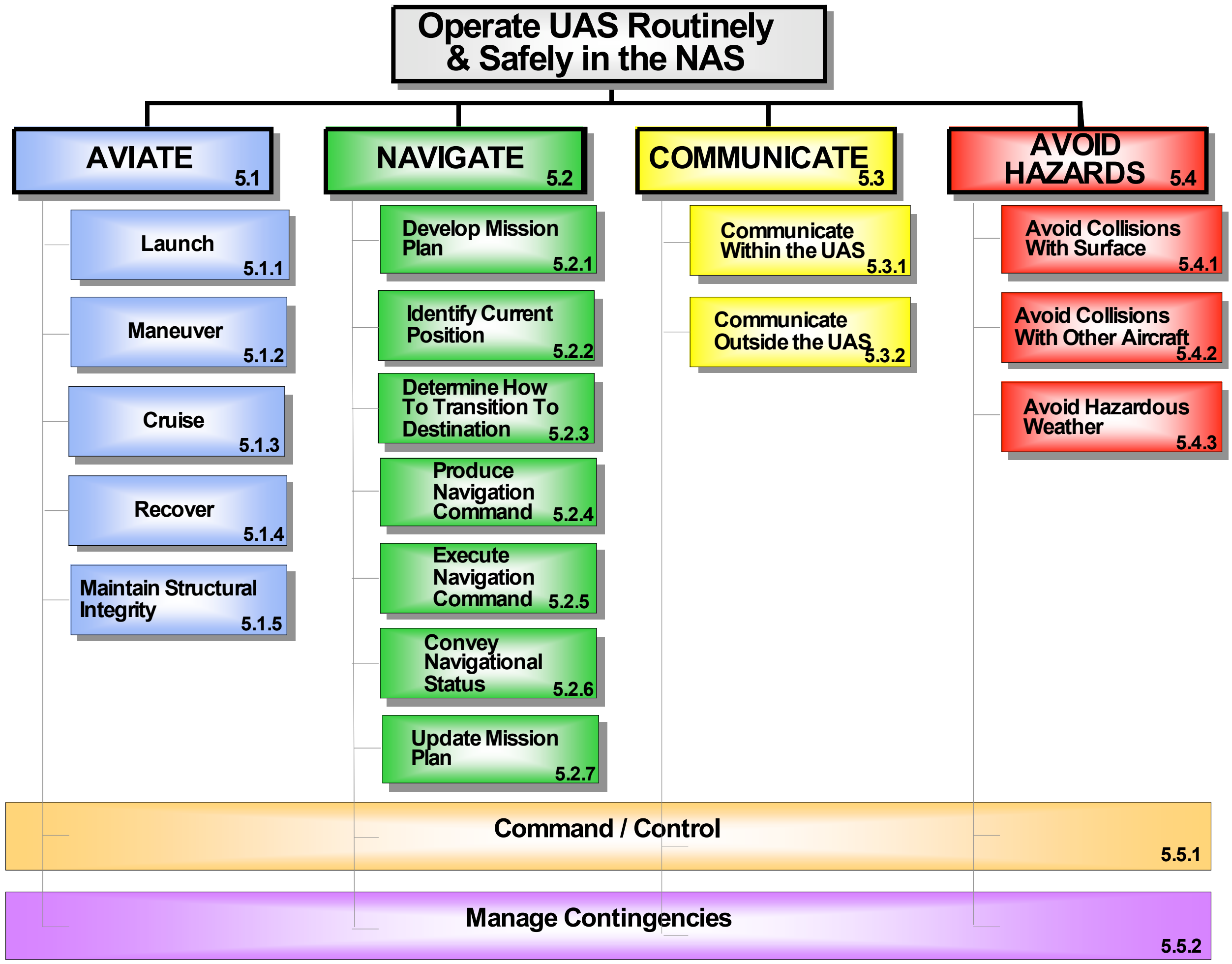

Figure 5: UAS Low-Level Functions

5 UAS FUNCTIONAL REQUIREMENTS

This section attempts to capture the functional requirements needed to operate HALE UAS safely and routinely in the NAS in accordance with the limitations established under the Access 5 Step 1 objectives. Each of these functional requirements has been allocated to one or more of the high-level functions (Aviate, Navigate, Communicate, Avoid Hazards) used in developing the framework for the UAS functional architecture.

At the highest level of this functional architecture, the UAS is identified as the object needing to perform the required function (i.e. "The UAS shall…"). However, as one looks deeper into the functional architecture, specific systems responsible for performing the function are identified as the object of the requirement (i.e. "The Communications System shall…" or "The Collision Avoidance System shall …"). As it is used in this context, the word "System" could comprise functional elements from anywhere within the UAS. The word "System" should therefore be thought of in the broadest context possible, as it does not imply a single "black box". The UAS pilot could even be part of any one of these Systems.

5.1 AVIATE FUNCTIONAL REQUIREMENTS

The UAS shall be able to aviate within the NAS. Aviating includes both controlling and monitoring the aircraft and all of its systems necessary for launch, climb, maneuver, cruise, descent, and recovery. Since Step 1 of Access 5 only addresses flight operations above FL 430 the requirements for operating on the surface is reserved for future study. Figure 6 depicts the functional requirements comprising the overall Aviate Function of a UAS.

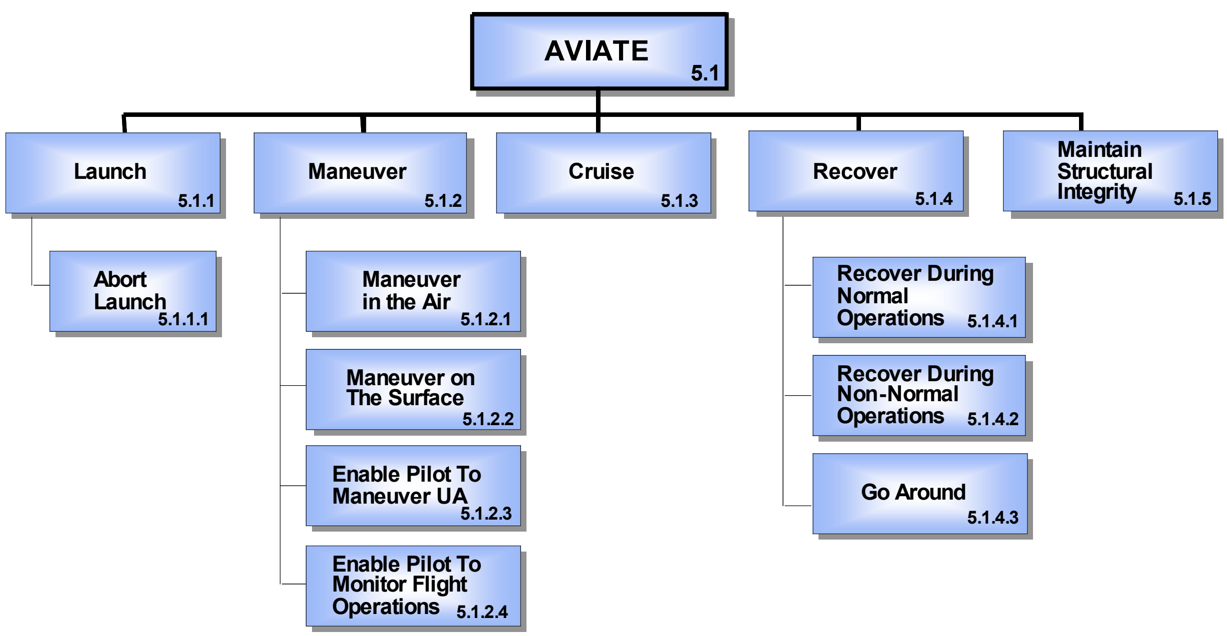

Figure 6: Aviate Functions

5.1.1 LAUNCH

The UAS Aviate System shall be able to initiate flight within the NAS. The specific method used to initiate flight (such as taking off from a runway, being catapulted into the air, dropped from another aircraft, or being launched from a rocket) is considered a design decision and is not applicable at this level.

5.1.1.1 Abort Launch

The UAS Aviate System shall be able to abort a launch. Just prior to launch, the UAS should be able to determine when less than optimal conditions exist for launching the UA. If so, the UAS should have the capability to cancel the launch and try again at a later time. This ensures last minute changes in weather or obstructions near the launch area do not cause an accident or incident.

5.1.2 MANEUVER

The UAS Aviate System shall be able to maneuver the UA within the NAS. In order to aviate within the NAS, the UA may be required to change its flight path, ground path, or speed.

5.1.2.1 Maneuver in the Air

The UAS Aviate System shall be able to maneuver the UA through the air. In order to aviate within the air, the UA may be required to change its flight path or speed. The typical method used to maneuver through the air involves controlling the aircraft's flight controls and propulsion system.

5.1.2.1.1 Change Altitude

The UAS Aviate System shall be able to climb or descend to its intended altitude of operation.

5.1.2.1.2 Change Heading

The UAS Aviate System shall be able to turn left and right to specific headings.

5.1.2.1.3 Change Speed

The UAS Aviate System shall be able to change its airspeed.

5.1.2.2 Maneuver on the Surface

The UAS Aviate System shall be able to maneuver the UA on the surface. In order to aviate along the surface, the UA may be required to change its ground path, or speed. The typical method used to maneuver on the surface involves ground steering, manipulating the flight controls and adjusting the propulsion system. Even such items as a tow truck or ground crew could be used to maneuver the UA on the surface.

5.1.2.2.1 Change Ground Path

The UAS Aviate System shall be able to change the direction of its ground path.

5.1.2.2.2 Change Speed

The UAS Aviate System shall be able to change the speed of its ground path.

5.1.2.3 Enable Pilot to Maneuver UA (HSI F1)

The Human System Interface shall enable the pilot to command flight maneuvers. Flight maneuvers can include, but are not limited to changing the aircraft's attitude, altitude, heading, velocity, and vertical velocity.

5.1.2.4 Enable Pilot to Monitor Flight Operations (HSI F2)

The Human System Interface shall convey information to the pilot to monitor flight operations. This requirement enables the pilot to determine if the aircraft is following the intended flight or ground path. This applies regardless of whether the UAS is autonomously flying to the next waypoint or the pilot is the one inputting specific commands.

5.1.3 CRUISE

The UAS Aviate System shall be able to conduct steady-state (non-accelerating) flight within the NAS. Since Step 1 of Access 5 assumes UA will operate under instrument flight rules (IFR), they will need to be able to comply with ATC instructions that may include being told to hold altitude or maintain heading. This requirement, as worded, includes cruise-climb as a type of steady state, non-accelerating flight.

5.1.4 RECOVER

The UAS Aviate System shall be able to safely conclude flight operations within the NAS. The specific method used to conclude flight (such as landing on a runway/landing pad, being caught by a net, or controlled flight into terrain) is considered a design decision and is not applicable at this level.

5.1.4.1 Recover During Normal Operations

The UAS Aviate System shall be able to land/recover during normal operations. Normal operations include all cases that don't involve dealing with a contingency or anomalous condition.

5.1.4.2 Recover During Non-normal Operations

The UAS Aviate System shall be able to land/recover during non-normal operations. Recovery during non-normal operations my include a variety of techniques to include using parachutes, pre-programmed commands, flight termination systems, or controlled flight into terrain.

5.1.4.3 Go Around

The UAS Aviate System shall be able to perform a go around maneuver when landing/recovery operations warrant it. Just prior to recovery, the UAS should be able to determine when less than optimal conditions exist for recovering the UA. If so, the UAS should have the capability to cancel the recovery and try again. This ensures last minute changes in weather or obstructions to the recovery area do not cause an accident or incident.

5.1.5 MAINTAIN STRUCTURAL INTEGRITY

The UAS Aviate System shall maintain structural integrity as it transits the NAS. Although further details related to this subject area are reserved for future study, it is still an essential element for ensuring airworthiness.

5.2 NAVIGATE FUNCTIONAL REQUIREMENTS

The UAS shall be able to navigate within the NAS. The ability to navigate infers the UAS is capable of maintaining navigational control, which involves maintaining knowledge of the current position, the destination, and the four dimensional path (latitude, longitude, altitude, time) to the destination. Navigation can be accomplished both strategically and tactically. While a traditional flight plan requires more time to complete and would be considered strategic, in-flight maneuvering would be considered a form of tactical navigation. Figure 7 depicts the functional requirements comprising the overall Navigate Function of a UAS.

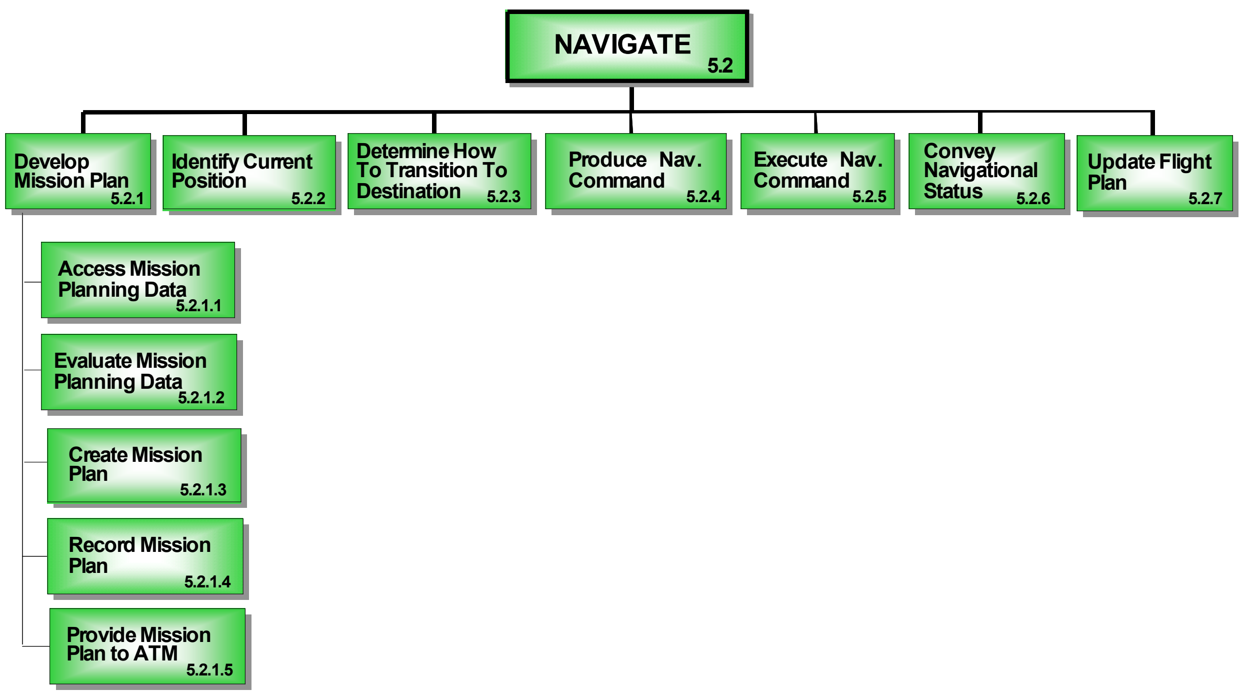

Figure 7: Navigate Functions

5.2.1 DEVELOP MISSION PLAN

The UAS Navigation System shall develop a mission plan to cover normal operations and contingencies. This requirement ensures the UAS can develop a strategic plan for getting to its intended destination.

5.2.1.1 Access Mission Planning Data (MP F1)

The UAS Mission Planning System shall access information needed to conduct a flight.

5.2.1.2 Evaluate Mission Planning Data (MP F2)

The UAS Mission Planning System shall evaluate information needed to conduct a flight.

5.2.1.3 Create a Mission Plan (MP F3)

The UAS Mission Planning System shall create a mission plan to include contingency routes or route segments.

5.2.1.4 Record Mission Plan (MP F4)

The UAS Mission Planning System shall record the mission plan in a manner required by the unmanned aircraft before flight.

5.2.1.5 Provide Required Information to the ATM System (MP F5)

The UAS Mission Planning System shall submit a flight plan to the air traffic management (ATM) System.

5.2.2 IDENTIFY CURRENT POSITION

The UAS Navigation System shall be able to identify the current three-dimensional position (i.e. latitude, longitude, altitude) of the UA with enough accuracy to fly under instrument flight rules (IFR). It is critical for the navigation system to be able to identify its current position so it may determine how to get to where ever it needs to go.

5.2.3 DETERMINE HOW TO TRANSITION TO DESTINATION

The UAS Navigation System shall be able to determine how to transition to its desired destination. This is necessary to ensure the UA can determine the next waypoint in accordance with the current flight plan.

5.2.4 PRODUCE NAVIGATION COMMAND

The UAS Navigation System shall be able to produce navigation commands in accordance with the current flight plan. The navigation command is used by the Aviate Function to actually fly the UA along the flight plan to the desired destination in accordance with the current flight plan.

5.2.5 EXECUTE NAVIGATION COMMAND

The UAS shall execute the navigation command. This requirement involves the physical change in state necessary to implement the navigation command (moving control surfaces, adjusting speed, etc.). This navigation functional requirement is actually performed by other functions within the UAS functional architecture such as the Aviate / Maneuver function.

5.2.6 CONVEY NAVIGATIONAL STATUS

The UAS Navigation System shall convey the navigational status of the executed command. This requirement is the foundation for the navigate function in that it identifies where the aircraft is flying in relation to the airspace around it. After this information is conveyed, other functions within the UAS can determine if the aircraft is following the flight plan or if a correction is needed.

5.2.6.1 Convey Navigational Information to the Pilot (HSI F4)

The UAS Human System Interface shall convey navigational information to the pilot to determine position, heading, course, speed, and altitude.

5.2.7 UPDATE FLIGHT PLAN

The UAS Navigation System shall allow the flight plan to be updated in real time throughout the mission. This requirement is necessary because many HALE UAS missions are able to last for several days or even weeks. During these extended missions, the Mission Planning System needs to have a capability to modify the original flight plan as necessary.

5.2.7.1 Pilot Updates to Flight Plan (HSI F5)

The UAS Human System Interface shall enable the pilot to update the UAS's flight plan. This requirement is necessary because it allows the pilot to change the course, speed, and/or altitude of the unmanned aircraft for a number of reasons that include following an Air Traffic Control (ATC) directive, a change in its mission/destination, bad weather along the flight path, or based upon the pilot's or system's assessment of a possible collision.

5.3 COMMUNICATE FUNCTIONAL REQUIREMENTS

The UAS shall be able to communicate (data or voice) with all entities needed to maintain safe and reliable UAS operations. These entities could be both internal and external to the UAS. While external entities would typically include ATC and other aircraft, internal entities could include ground support, maintenance, mission control, other control stations (hand-off), etc. Figure 8 depicts the functional requirements comprising the overall Communicate Function of a UAS.

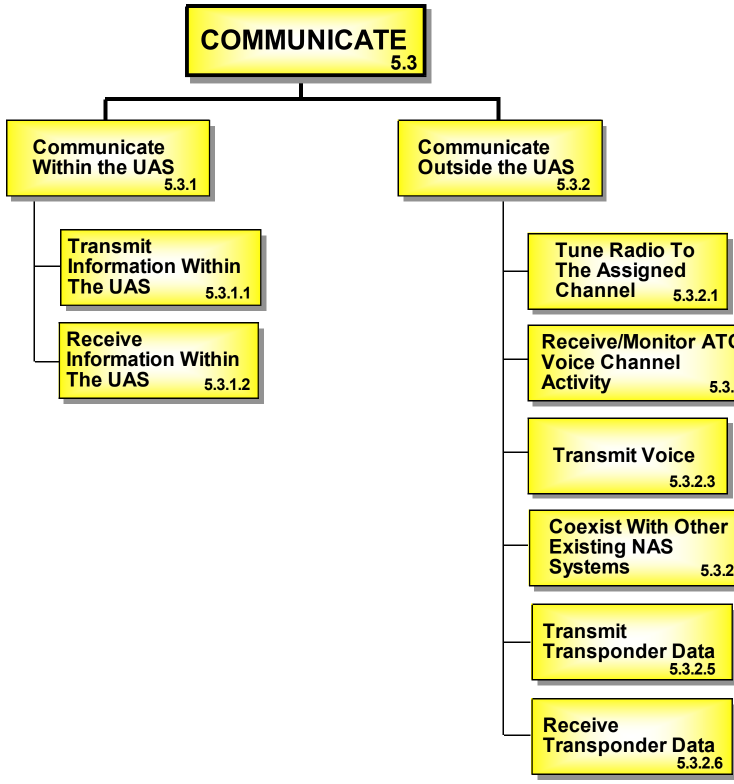

Figure 8: Communicate Functions

5.3.1 COMMUNICATE WITHIN THE UAS

The UAS Communication System shall provide internal communications connectivity between functions within the UAS. As mentioned above, this communications could be between the pilot and ground support, maintenance, mission control, or other control stations (hand-off).

5.3.1.1 Transmit Information within the UAS

The UAS Communication System shall be able to transmit voice/data communications to entities within the UAS.

5.3.1.2 Receive Information within the UAS

The UAS Communication System shall be able to receive voice/data communications from entities within the UAS.

5.3.2 COMMUNICATE OUTSIDE THE UAS

The UAS Communication System shall provide external communications connectivity with entities outside the UAS. To ensure the necessary information is conveyed between the UAS pilot and ATC or some other aircraft, some means of communications is needed to ensure this function can occur throughout the entire flight profile.

5.3.2.1 Tune Radio to the Assigned Channel (C3-ATC F1)

The UAS ATC Communication System shall be able to tune to an assigned ATC voice channel corresponding to the ATC sector the UA is flying within. Depending on the particular Link Type implemented, this may involve remotely tuning a VHF radio on the UA or switching connectivity to a particular ATC facility.

5.3.2.2 Receive/Monitor ATC Voice Channel Activity (C3-ATC F2)

The UAS ATC Communication System shall be able to continuously monitor voice channel activity, including controller and other pilot voice activity, on its assigned channel. This sets the requirement for "party line" for ATC air to ground (A/G) radio talk groups and augments 14 CFR 91 regulations. The requirement to be able to hear other pilots and to be able to talk to other pilots on the same assigned channel (i.e. within the "talk group") is not explicitly specified in the Federal Air Regulations nor in FAA standards, but is common practice and promotes situational awareness. The Step 1 HALE UAS ATC Communication System should not preclude this capability.

5.3.2.2.1 Receive Using Human Systems Interface (HSI F6)

The Human System Interface shall enable the pilot to receive communications from ATC.

5.3.2.3 Transmit Voice (C3-ATC F4)

The UAS ATC Communication System shall be able to transmit pilot voice communications on an assigned ATC channel. This requirement is necessary because it meets 14 CFR Part 91.135, "Each pilot must maintain two-way radio communications with ATC while operating in Class A airspace."[12] While transmitting voice traffic to other aircraft in the area is not a hard requirement, it is strongly recommended that the voice being transmitted to ATC should not be precluded from being heard by other pilots on the assigned channel.

5.3.2.3.1 Transmit Signal Indication (C3-ATC F3)

The UAS ATC Communication System shall be able to generate a Transmit Signal Indication to initiate ATC communications. For configurations employing VHF subsystems this corresponds to the Push to Talk (PTT) signal, which the voice switch and/or VHF transmitter needs to initiate communications. For a satellite channel, link initiation and channel signaling are different from the VHF case; however a PTT indication still has to be sent by the pilot microphone/headset to the UAS VHF subsystem by way of the pilot – Satellite Subsystem link.

5.3.2.3.2 Transmit Only During Transmit Signal Indication (C3-ATC F5)

The UAS ATC Communication System shall be able to transmit ATC voice communications only for the duration of a pilot PTT (transmit indication signal) event. This is necessary because this is how existing simplex VHF A/G radios work today to access the channel.

[12] "Part 91.135: Operations in Class A Airspace" FAR/AIM 2005. 2005

5.3.2.3.3 Entry Into a Talk Group (C3-ATC F6)

The UAS ATC Communication System shall allow any UAS/pilot, operating in the correct mode, entry into any Talk Group within the Talk Group's service volume. This is to ensure that the pilot can enter a Talk Group regardless of whether or not the pilot was instructed to do so by the air traffic controller. For example, in the case where the pilot has lost communication with its own Talk Group, it should still be able to access another Talk Group.

5.3.2.3.4 Transmit Using Human Systems Interface (HSI F6)

The Human System Interface shall enable the pilot to transmit communications to ATC.

5.3.2.4 Coexist With Other Existing NAS Systems (C3-ATC F7)

The UAS ATC Communication System shall cooperatively coexist w/ other existing NAS systems. The UAS ATC Communication System must not introduce any harmful radio frequency interference (RFI) to compromise the current NAS performance.

5.3.2.4.1 Limit Interference (C3-ATC F7a)

The UAS ATC Communication System shall not generate harmful interference to other NAS systems (e.g., navigation, landing, and surveillance)

5.3.2.4.2 Use Allocated Spectrum (C3-ATC F7b)

The UAS ATC Communication System shall operate under the existing RFI environments.

5.3.2.5 Transmit Transponder Data

The UAS Communication System shall be able to transmit altitude encoded transponder data. This requirement is necessary because it meets 14 CFR Part 91.215, "No person may operate an aircraft in Class A, B, or C airspace unless that aircraft is equipped with an operable coded radar beacon transponder".[13] This is also necessary to execute the Avoid Hazard requirement for being detectable to other NAS users (see requirement 5.4.2.1)

5.3.2.5.1 Select / Modify Transponder Code

The UAS Communication System shall allow the pilot to select/modify the transponder code.

5.3.2.5.2 Enable / Disable Reporting Capability

The UAS Communication System shall allow the pilot to enable/disable the altitude reporting capability.

5.3.2.6 Receive Transponder Data

The UAS Communication System shall be able to receive altitude encoded transponder data. This is necessary to execute the Avoid Hazard requirement to detect cooperative traffic (see requirement 5.4.2.3)

[13] "Part 91.215: ATC Transponder and altitude reporting equipment and use" FAR/AIM 2005. 2005

5.4 AVOID HAZARDS FUNCTIONAL REQUIREMENTS

The UAS shall avoid hazards while operating in the NAS. These hazards include obstacles on the surface, other traffic (both airborne and on the ground), and severe weather. Figure 9 depicts the functional requirements comprising the overall Avoid Hazards Function of a UAS.

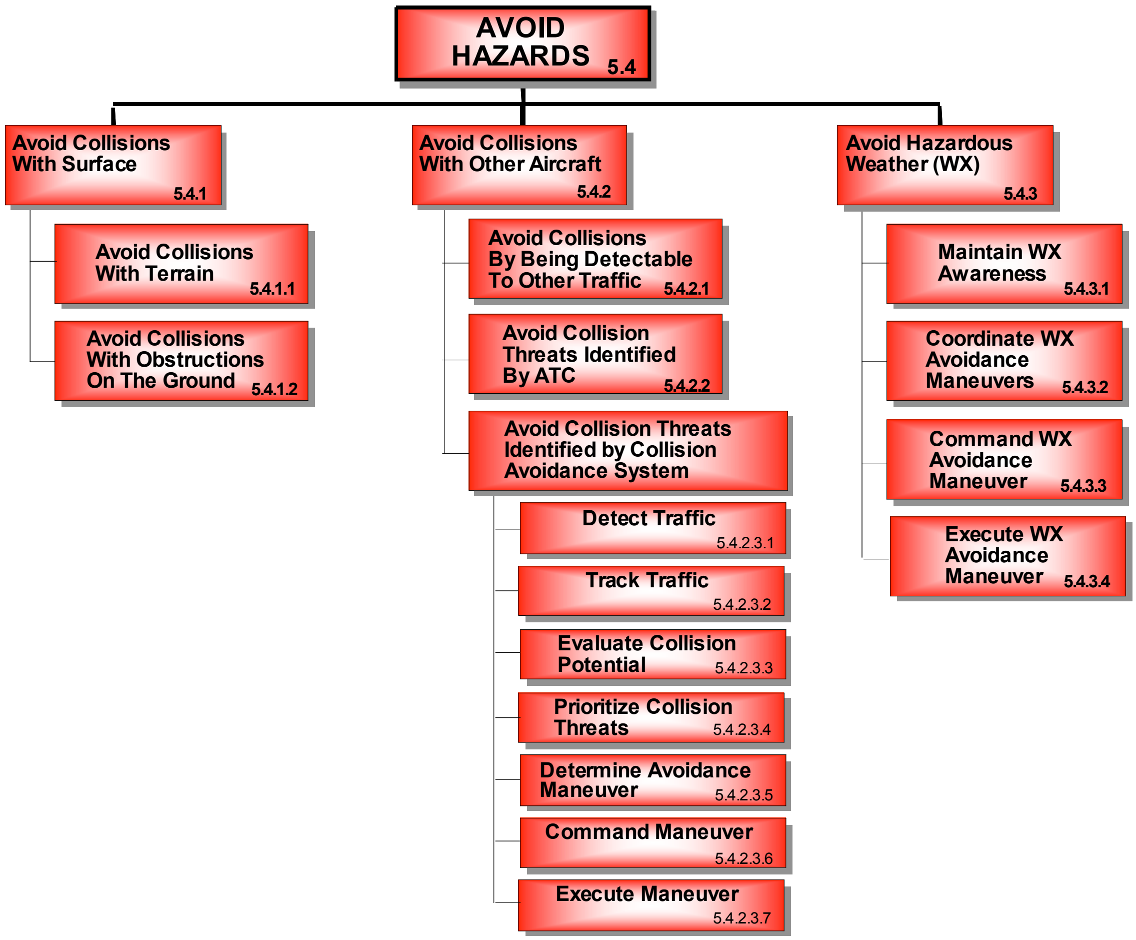

Figure 9: Avoid Hazards Functions

5.4.1 AVOID COLLISIONS WITH THE SURFACE

The UAS Avoid Hazards System shall be able to avoid collisions with the surface of the earth. Surface not only includes the ground itself, but also bodies of water and obstacles on the surface. Step 1 of Access 5 only addresses collision avoidance with other aircraft above Flight Level FL 430 and reserves defining the requirements for collisions with the surface and obstacles on the surface for a future Step.

5.4.1.1 Avoid Collisions with Terrain

The UAS Avoid Hazards System shall be able to avoid unplanned impact with terrain. Terrain includes the ground itself, natural land formations, bodies of water, and trees.

5.4.1.2 Avoid Collisions with Obstructions on the Ground

The UAS Avoid Hazards System shall be able to avoid unplanned collisions with obstructions while transiting the NAS. Obstructions include vehicles, humans, animals, and man-made structures such as buildings or towers.

5.4.2 AVOID COLLISIONS WITH OTHER AIRCRAFT

The UAS Avoid Hazards System shall be able to avoid collisions with other aircraft. Step 1 of Access 5 has established several constraints on the collision avoidance function. First and foremost, Step 1 assumes that the pilot will initiate all avoidance maneuvers, thereby prohibiting autonomous maneuvers. Autonomous collision avoidance maneuvers will be addressed in a future Step. In addition, since Step 1 only involves flight above FL430, airborne collision avoidance is all that was addressed. The detailed requirements dealing with collisions on the surface have been postponed for a future Step.

5.4.2.1 Avoid Collisions by Being Detectable to Other Traffic

The UAS Avoid Hazards System shall avoid collisions with other aircraft by being detectible to other traffic in its proximate area. The UAS being detectible is essential in situations where the other aircraft is the one maneuvering to avoid the potential collision. Examples of this may include the UAS employing special coloring, markings, lights, active transmissions, and/or other means to enhance visibility/detectability of the UA to other traffic.

5.4.2.2 Avoid Collision Threats Identified by ATC

The UAS Avoid Hazards System shall be able to avoid collisions with other aircraft by maneuvering the UA in accordance with separation guidance provided by ATC. This requirement ensures the UAS is able to respond in accordance to traffic advisories provided by the appropriate air traffic authorities.

5.4.2.3 Avoid Collision Threats Identified by Collision Avoidance System

The UAS Avoid Hazards System shall be able to avoid collisions with other aircraft by utilizing sense and avoid information. This requirement ensures the UAS is able to sense and avoid aircraft posing a potential collision threat. Although Step 1 of Access 5 only deals with avoiding cooperative aircraft using a pilot to initiate the maneuver, these functional requirements are worded broad enough such that they can accommodate the cooperative/non-cooperative case as well as man-in-the-loop/autonomous initiated maneuvers.

5.4.2.3.1 Detect Traffic (CA F1)

The UAS Collision Avoidance System shall detect traffic within its surveillance volume. The size of the surveillance volume is defined in accordance to the UA's flight performance characteristics (airspeed, climb/descent rate, turn rate, etc.) as well as the flight characteristics of the potential traffic found within the UA's operating environment. For Step 1, this refers only to cooperative traffic, which is defined as other aircraft that broadcast positional information using an altitude-encoding transponder. In the very near future, this may also include technologies such as Automatic Dependent Surveillance - Broadcast (ADS-B).

5.4.2.3.2 Track Traffic (CA F2)

The UAS Collision Avoidance System shall track the detected traffic. A "track" is established when a state estimate is developed with sufficient confidence. This estimate includes the traffic element's position and velocity vector.

5.4.2.3.3 Evaluate Collision Potential (CA F3)

The UAS Collision Avoidance System shall evaluate the potential for collision with each traffic element being tracked, including the assessment of existing collision threats. This requirement ensures all traffic being tracked is evaluated against some set of criteria enabling the system to determine collision potential.

5.4.2.3.4 Prioritize Collision Threats (CA F4)

The UAS Collision Avoidance System shall prioritize the traffic posing the most immediate collision threat. Traffic elements that have been deemed collision threats should be ranked based on time to collision, or some other similar criteria.

5.4.2.3.5 Determine Avoidance Maneuver (CA F5)

The UAS Collision Avoidance System shall determine an avoidance maneuver that prevents a collision. The role of the pilot in CA F5 may vary depending on policy or design decisions:

A) The pilot may determine the maneuver without assistance from any collision avoidance logic.

B) The pilot may take into consideration the information provided by collision avoidance logic to help make a determination.

C) The pilot may solely rely upon the maneuver determined by the collision avoidance logic.

D) The pilot may have no interaction with the maneuver decision whatsoever. In Access 5, Step 1, option D is removed from consideration since autonomous maneuvers have been assumed to be out of scope.

5.4.2.3.5.1 Convey threat information to the Pilot (HSI F7a)

The UAS Human System Interface shall convey threat information to the pilot to avoid collisions with other aircraft. Since Step 1 of Access 5 assumes the pilot is responsible for initiating any avoidance maneuver, the pilot must have the necessary information needed to properly assess the collision situation and determine an appropriate avoidance maneuver.

5.4.2.3.6 Command Maneuver (CA F6)

The UAS Collision Avoidance System shall command an appropriate avoidance maneuver. For Step 1 it is assumed that the pilot is part of the UAS CA function and will initiate the maneuver, since autonomous maneuvers are outside the scope of Step 1. The commanded maneuver can include initiating a new maneuver, continuing an ongoing maneuver, or terminating an avoidance maneuver if a collision threat no longer exists.

5.4.2.3.6.1 Control the Collision Avoidance System (HSI F7b)

The UAS Human System Interface shall enable the pilot to control the Collision Avoidance System. Since Step 1 of Access 5 assumes the pilot is responsible for initiating any avoidance maneuver, the pilot must have the ability to configure the collision avoidance system settings as well as initiate/modify/discontinue an avoidance maneuver.

5.4.2.3.7 Execute Maneuver (CA F7)

The UAS shall perform the commanded maneuver. This CA functional requirement is performed by the maneuver function located within the "Aviate" portion of the UAS functional architecture.

5.4.3 AVOID HAZARDOUS WEATHER

The UAS shall be able to avoid hazardous weather while flying in the NAS. Hazardous weather is defined as any atmospheric or space environment phenomena that could be detrimental to the UAS mission. Hazardous aviation weather for the purposes of Step 1 typically includes thunderstorms, icing conditions, turbulence, or massive solar ejections. However, this may vary based on the structural characteristics of the UA being flown. It is important to note that the primary need for the UAS avoiding hazardous weather is to prevent the UA from harming people or property, not for self preservation of the UA.

5.4.3.1 Maintain Weather Awareness

The UAS Weather Awareness System shall maintain awareness of hazardous weather along the entire route of flight. The UAS should be able to routinely access pertinent aviation weather information to include atmospheric and space weather data. This requirement ensures the UAS pilot has access to the necessary weather information resources such as ATC and/or packaged weather products, throughout the entire route of the flight.

5.4.3.1.1 Gather Weather Information

The UAS Weather Awareness System shall gather all necessary weather information for the entire route of flight. This information should be gathered for the altitude at which the UAS will be operating as well as the area below the UAS in case descent through the lower airspace is required. It is assumed that the UAS pilot is part of the UAS Weather Awareness System.

5.4.3.1.1.1 Request weather information (HSI F8b)

The UAS Human System Interface shall enable the pilot to request weather specific to a current or future flight plan.

5.4.3.1.1.2 Convey weather information to the UAS Pilot (HSI F8a)

The UAS Human System Interface shall convey weather information to the pilot.

5.4.3.1.2 Evaluate Potential for Weather Conflicts

The UAS Weather Awareness System shall evaluate the potential for flying into hazardous weather situations. This requirement enables the UAS pilot to plan for hazardous weather along the route of flight utilizing all available weather resources.

5.4.3.2 Coordinate Weather Avoidance Maneuver

The UAS Weather Awareness System shall coordinate with ATC the appropriate avoidance maneuver that prevents the UA from flying through the hazardous weather. The UA will always be flying under Instrument Flight Rules and, therefore must coordinate any deviation of the current flight path with ATC.

5.4.3.3 Command Weather Avoidance Maneuver

The UAS Weather Awareness System shall be capable of commanding an appropriate maneuver to avoid the hazardous weather. It is assumed that the UAS pilot, as part of the UAS Weather Awareness System, will initiate the maneuver since autonomous maneuvers are outside the scope of Step 1. The commanded maneuver can include initiating a new maneuver, continuing an ongoing maneuver, or terminating an avoidance maneuver if hazardous weather no longer exists.

5.4.3.3.1 Control the Weather Awareness System (HSI F8c)

The UAS Human System Interface shall enable the pilot to control the Weather Awareness System. The pilot must have the ability to configure the Weather Awareness System settings as well as initiate, modify, or discontinue and avoidance maneuver.

5.4.3.4 Execute Weather Avoidance Maneuver

The UAS shall perform the commanded weather avoidance maneuver. This functional requirement is actually performed by the maneuver function located within the "Aviate" portion of the UAS functional architecture.

5.5 CROSS-CUTTING FUNCTIONAL REQUIREMENTS

As previously discussed and as displayed in Figure 5 above, there are several functions that cross-cut through the major 4 functions (Aviate, Navigate, Communicate, Avoid Hazards) that establish the backbone of the UAS functional architecture. These cross-cutting functional areas pertain to Command/Control (C2) and Contingency Management (CM). Figure 10 depicts the functional requirements comprising the cross-cutting functions for C2 and CM.

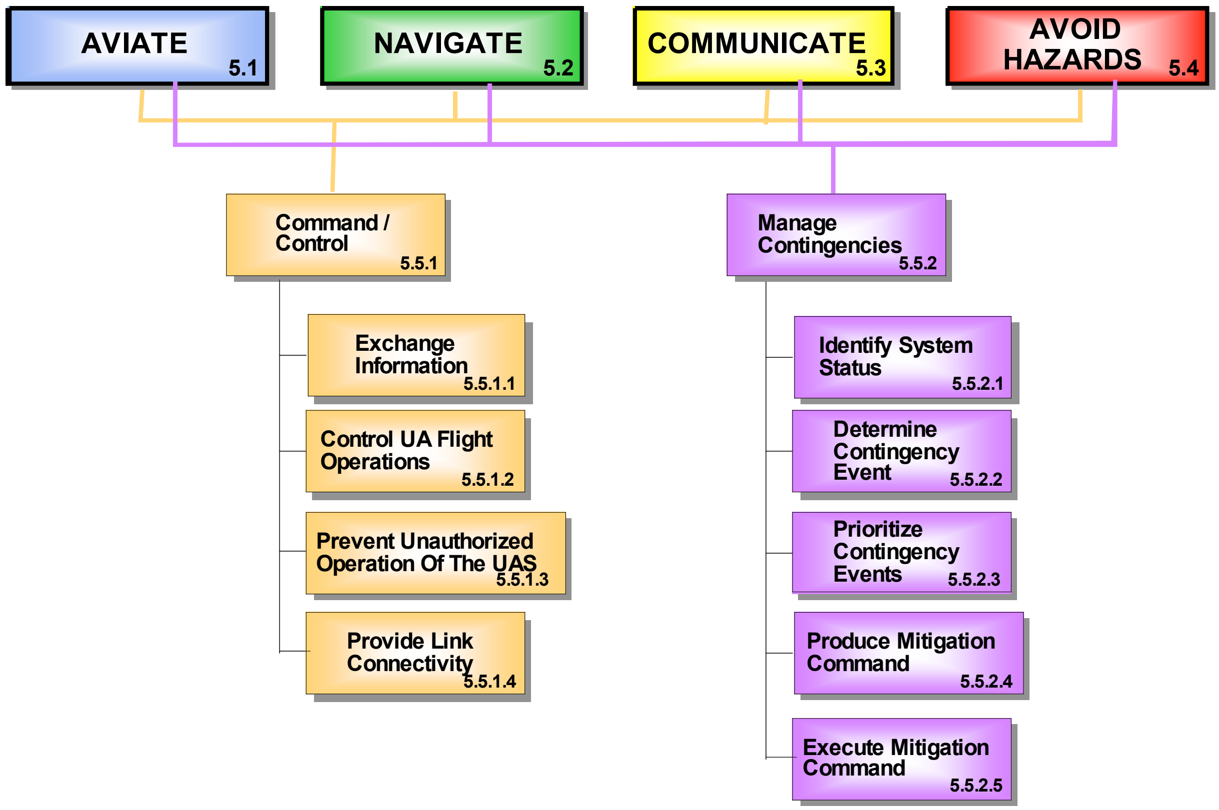

Figure 10: Cross-Cutting Functions

5.5.1 COMMAND / CONTROL

The UAS shall be able to command / control the UA as it transits the NAS. This requirement is intended to ensure the UAS provides a 2-way command and control (C2) link between the UA and the Control Station for the purpose of maintaining safe UAS operations. Being able to command/control the UA from a remote location is one of the major differences between manned and unmanned aircraft

5.5.1.1 Exchange Information (C2 F1)

The UAS Command/Control System shall perform information exchanges for UAS operations. The C2 Communications System is the conduit for exchanging information between the Control Station and UA. The C2 links are typically implemented with, but not limited to, modern digital communications via LOS or BLOS links. The UAS provides a 2-way C2 communication link between the UA and the Control Station.

5.5.1.1.1 Uplink Information (C2 F1.1)

The UAS Command/Control System shall provide an uplink between the UA and Control Station. The uplink is the data transmission from the Control Station to the UA. The transmissions provide directives and information to the UA and include commands, messages, and related data. These transmissions must be achieved in a timely manner to ensure safety of flight.

5.5.1.1.2 Downlink Information (C2 F1.2)

The UAS Command/Control System shall provide a downlink between the UA and Control Station. The downlink is the data transmission from the UA to the Control Station. The transmissions provide necessary and timely data for the pilot to conduct safe flight operations. The data may contain telemetry, situation awareness, health and status, and other data as needed.

5.5.1.1.3 Consistent Operations (C2 F1.3)

The UAS Command/Control System shall ensure cohesive and consistent uplink and downlink operations. It is critical that messages that are initiated for sending are received undamaged and within enough time to be useful. The uplink and downlink operations must work together smoothly to achieve these goals.

5.5.1.2 Control UA Flight Operations (C2 F2)

The UAS Command/Control System shall control the UA during flight operations. Since UA do not have an onboard pilot, the C2 Communications System is vital to transmit information that enables the pilot to direct UA operations and ensure flight safety in the NAS

5.5.1.2.1 Provide Situational Awareness and Health & Status (C2 F2.1)

The UAS Command/Control System shall provide situational awareness and health & status of the UA to the Control Station. Since the UA pilot is off board the aircraft at all times and "flies" the aircraft from the Control Station, the UA must transfer onboard information to the pilot. The transferred data includes health and status of the aircraft along with in-flight situation awareness information from onboard sensors and systems.

5.5.1.2.2 Provide C2 Directives (C2 F2.2)

The UAS Command/Control System shall provide C2 directives to the UA. Since the UA pilot is off board the aircraft at all times and "flies" the aircraft from the Control Station, the pilot must transfer directives to the UA. The directives include flight commands and requests for data.

5.5.1.2.3 Prioritize Information Exchanges (C2 F2.3)

The UAS Command/Control System shall provide the capability to prioritize C2 information exchanges. There are several kinds of messages conveyed in the C2 link. Some of the messages and information will be more critical than others to control safe flight, depending on the operational environment and events. It is crucial that the C2 Communications System transfer higher priority messages before transferring lower priority messages. In effect, higher priority messages will usually be transferred with less delay than lower priority messages.

5.5.1.2.4 Coexist Within the NAS (C2 F2.4)

The UAS Command/Control System shall provide protection means for the C2 communications to coexist with current NAS systems and operations. The C2 link is new to the NAS infrastructure and thus must not introduce any harmful radio frequency interference (RFI) to compromise the current NAS performance.

5.5.1.2.5 Distinguish Between UA's (C2 F2.5)

The UAS Command/Control System shall provide the ability to distinguish each UA. It is paramount to flight safety and task success to be able to identify, communicate, and control each UA without any ambiguity.

5.5.1.3 Prevent Unauthorized Operation of the UAS (C2 F3)

The UAS Command/Control System shall ensure no un-authorized person(s) or system(s) assume control of the UAS. Security of the C2 link is important to the safety of the UA and other aircraft and personnel in the NAS. Only authorized users should have access to the C2 link to perform message transfers. The transmissions themselves must not be corrupted, changed, or denied; to do so could jeopardize safety as well as task success.

5.5.1.3.1 Physical Security

The UAS Command/Control System shall prevent physical interruption or interference with the pilot.

5.5.1.3.2 Link Security (C2 F3.2)

The UAS Command/Control System shall prevent un-authorized person(s) or systems(s) from assuming control of the UAS command/control link.

5.5.1.3.3 Link Interference (C2 F3.3)

The UAS Command/Control System shall prevent un-authorized person(s) or systems(s) from interfering with the UAS command/control link.

5.5.1.4 Provide Link Connectivity (C2 F4)

The UAS Command/Control System shall provide C2 link connectivity. The overall safety of the UAS depends greatly upon the ability of the UAS to maintain connectivity between the UA and Control Station.

5.5.1.4.1 Transitioning Between LOS/BLOS (C2 F4.1)

The UAS Command/Control System shall provide C2 Communications while transitioning between LOS and BLOS operations. Typically, the UA flies away from LOS and to BLOS with respect to the Control Station. The C2 Communications System must be capable of providing communications for both LOS and BLOS conditions, including the transition between them. Due to physical constraints that may exist, such as during transitions between satellites or at the edge of a satellite footprint, scheduled and/or predictable link dropouts may be acceptable as long as the dropouts do not compromise the UAS's ability to comply with other functional requirements.

5.5.1.4.2 Transitioning Between Control Stations (C2 F4.2)

The UAS Command/Control System shall provide C2 Communications while transitioning between different Control Stations. It is possible that more than one Control Station is employed during the course of UA flight, though there is no requirement to have more than one Control Station. The C2 Communications System must be capable of providing communications between the UA and the Control Station in control, including the transition from one Control Station to another.

5.5.2 MANAGE CONTINGENCIES

The UAS shall manage contingencies to reduce the likelihood of loss of life or damage to personal property. Contingencies include failures of avionics and other equipment within the UAS, loss of communications both internal and external to the UAS, and failure of pilot or operators to respond to critical events within the UAS. Contingency management involves evaluating non-normal events, deciding on the proper course of action (plan) and successfully executing the mitigation plan.

5.5.2.1 Identify System Status

The UAS Contingency Management System shall be able to identify the health and status of all flight critical systems within the UAS. Flight critical systems are those systems deemed necessary to the safe operation of the UAS for routine operations in the NAS.

5.5.2.1.1 Convey System Status to the Pilot (HSI F3)

The UAS Human System Interface shall convey information to the pilot to determine the health and status of the UAS. This requirement is necessary because it provides essential information to the pilot to determine if systems on board the unmanned aircraft are accepting updates and functioning properly. Any degradation of a system that could decrease the UAS's ability to fly safely in the NAS should be brought to the pilot's attention.

5.5.2.2 Determine Contingency Event

The UAS Contingency Management System shall be able to determine the contingency event that took place. This requirement ensures the non-normal event can be evaluated and assessed.

5.5.2.3 Prioritize Contingency Events

The UAS Contingency Management System shall be capable of prioritizing simultaneous contingencies so the most critical one can be addressed first. Although unlikely, the UAS must be able to handle simultaneous contingencies and address the most critical on first.

5.5.2.4 Produce Mitigation Command

The UAS Contingency Management System shall produce the command necessary for mitigating the contingency. This mitigation command is intended to re-establish an improved operational condition. Once safe operational conditions are established the UA could continue on its original flight path or transition to a location where it may be recovered.

5.5.2.4.1 Enable Pilot to Manage Contingencies (HSI-F9)

The UAS Human System Interface shall enable the pilot to manage contingencies. Each contingency that arises will require the appropriate information be conveyed to the pilot, thereby enabling the pilot to respond to contingencies in a predictable manner.

5.5.2.5 Execute Mitigation Command

The UAS Contingency Management System shall support execution of the command produced for mitigating the contingency. This mitigation command will most likely be performed by some other system or function within the UAS.

6 REQUIREMENTS VALIDATION / VERIFICATION

Validation and verification is the System Engineering process that confirms whether the system requirements are correct and satisfied. According to the NAS Systems Engineering Manual, the validation process confirms that the system requirements are unambiguous, correct, complete, consistent, operationally and technically feasible, and verifiable; while the verification process ensures that the solution under test can meet the lower-level functional and performance requirements demonstrating that the system is ready for use in the operational environment for which it is intended[14]. This section describes how Access 5 intends to use both of these processes for validating and verifying our HALE UAS requirements.

6.1 WHY VALIDATION IS IMPORTANT TO ACCESS 5

The primary objective of the validation process is to ensure that requirements are correct and complete. Correctness of a requirements statement means the absence of ambiguity or error in its attributes. Completeness of a requirements statement means that no attributes have been omitted and those stated are essential and traceable[15]. Successful validation confirms that the identified requirements are justified, relevant, and logically correct in terms of the stake holder's needs and operating environment.

The validation process should be repeated incrementally at all stages of requirements development to ensure that the requirements at all levels are consistent with the intended mission. Since these requirements are hierarchical in nature and developed in increasing detail, validation is a staged process. Thus, as each level of requirements is developed, the requirements at that level undergo validation, after which each validated requirement undergoes verification.

Access 5 intends to conduct validation in order to demonstrate that the requirements for a UAS are clearly understood and that it is operationally and technically feasible (i.e. not beyond the laws of physics). Before any requirement gets verified, it must first be validated as being: unambiguous, correct, complete, traceable, and verifiable (measurable).

6.2 WHY VERIFICATION IS IMPORTANT TO ACCESS 5

All requirements, if well written, are verifiable (measurable). Without being verifiable, there would be no way to prove to the key stakeholders that the requirements specified in this document could ever be met. While functional analysis is a top-down process whereby the high level functions are decomposed into lower level functions; requirements verification is a bottom-up process. In other words, to verify that a higher level requirement was met, the supporting lower level requirements must first be verified. Only after the supporting lower level requirements have been verified can it be determined that the higher level requirement was met.

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[14] "Validation and Verification", NAS Systems Engineering Manual, Version 3.0, 30 September 2004. Page 4.12-1
[15] Ibid. Page 4.12-5

Because verification is a bottom-up process, it can be difficult to determine what verification methodology should be used to verify an operational requirement, or even a functional requirement. It is therefore necessary to develop and verify performance level requirements, which by definition provide a quantifiable value that is measurable. It is for this reason, that verification of requirements begins at the performance level and then proceeds further up the requirements hierarchy until all of the functional and operational requirements have been verified.

6.2.1 METHODS OF VERIFICATION

The following verification methods can be used in determining compliance of the individual requirements identified in this document[16]. The four verification methods, listed in decreasing order of complexity, are defined as:

- **Test:** This method is accomplished through systematic exercising of the application item under appropriate conditions, with or without instrumentation, and the collection, analysis, and evaluation of quantitative data.

- **Demonstration**: This method includes verification accomplished by operation, adjustment, or reconfiguration of items performing their design functions under specific scenarios. The items may be instrumented and quantitative limits of performance monitored; however, only check sheets are required rather than recordings of actual performance data. This method is used when actual demonstration techniques may be used to verify compliance with a requirement. Observations made by engineers or instrumentation are compared with predetermined responses based on the requirements. Demonstration is often used to verify compliance with requirements in *servicing, reliability, maintainability, transportability, and human factors engineering*.

- **Analysis:** This method is accomplished by technical or mathematical evaluation, mathematical models or simulation, algorithms, charts, circuit diagrams, and representative data.

- **Inspection:** This method is accomplished by visually examining the item, reviewing descriptive documentation, and comparing the appropriate characteristics with predetermined standards to determine conformance to requirements without the use of laboratory equipment or procedures. Inspection is generally nondestructive and uses the senses of sight, hearing, smell, touch, and taste; simple physical manipulation; mechanical and electrical gauging and measurement; and other means of investigation. Inspection often verifies the physical design features of a system as well as construction features, workmanship, dimensions, quality, and physical conditions, such as cleanliness, installation, and finishing. Inspection may include reviews of documentation, system descriptions, and other materials to compare the actual system with predetermined standards.

[16] "Validation and Verification", NAS Systems Engineering Manual, Version 3.0, 30 September 2004. Page 4.12-19

6.2.2 ACCESS 5 VERIFICATION APPROACH

Since Access 5 is not going to certify any particular UAS, specific requirements for any one UAS are not being developed. As such, generating performance requirements is a challenge because the performance requirements need to apply to all, or at least most, UAS. Therefore, Access 5 is generating performance guidelines as opposed to performance requirements. These guidelines are intended to capture the key performance parameters and provide a way to quantify the parameters for a variety of UAS. In many cases these performance guidelines may not capture every end of the spectrum, but should capture the majority of cases. Several of the work packages developing functional requirements have gone to the next layer of functional analysis and have begun developing these supporting performance guidelines. These performance guidelines can be found in the appendix of the relevant work package specific FRD.

In addition to including the functional requirements and supporting performance guidelines, several of the work-package-specific FRDs include a verification matrix identifying the suggested methodology intended to be used for verifying the requirement. While verification by flight test is not feasible for all of our requirements, flight testing could be used to verify key characteristics and assumptions used in developing the requirements. Validated models and simulation tools are also analytical verification methods that are being widely used to verify many of the requirements developed under Access 5.

The method of verification identified in these verification matrices are intended for use within Access 5 as a way to plan what requirements should be demonstrated by different integrated product teams (IPT) within Access 5. For example, those requirements needing demonstration or test would be assumed by the Flight IPT and those requirements needing simulation would be assumed by the Simulation IPT. By verifying each of our functional requirements, Access 5 hopes to gain confidence in their final proposed recommendations as well as build the necessary supporting body of evidence that supports these recommendations. While these verification methodologies could also be used by companies wishing to certify a UAS that is not the intent or purpose of these matrices.

7 REFERENCES

1. Access 5 Project Readiness Review (PRR) Presentation Dallas, TX; February 10 – 11, 2004.
2. Access 5 Concept of Operations. Version 2.0, Aug 2005.
3. Access 5 Functional Requirements Document. Revision 1, 5 September 2003.
4. Collision Avoidance Functional Requirements for Step 1 – HALE UAS Flight Above FL 430. Version 4, July 2005.
5. Contingency Management Requirements Document. Revision D, 31 March 2005.
6. HALE UAS Mission Planning Requirements Document. Preliminary Version, March 2005.
7. HALE UAS Command and Control Communications Step 1 Functional Requirements Document. Version 3.01, June 2005
8. HALE ROA ATC Communications Step 1 Requirements Document. Version 3.0, May 2005.
9. "Validation and Verification", NAS Systems Engineering Manual, Version 3.0. September 2004.
10. "Part 91.135: Operations in Class A Airspace," FAR/AIM 2005. 2005
11. "Part 91.215: ATC Transponder and Altitude Reporting Equipment and Use," FAR/AIM 2005. 2005
12. Step 1: Human System Integration Functional Requirements Document. Version 1.1, July 2005.
13. Systems Engineering Fundamentals. Defense Acquisition University Press. January 2001.
14. Weather Requirements & Procedures for Step 1. 9 March 2005.

APPENDIX A: ACRONYMS

ADS-B	Automatic Dependent Surveillance - Broadcast
A/G	Air to Ground
AIM	Aeronautical Information Manual
ATC	Air Traffic Control
ATM	Air Traffic Management
BLOS	Beyond-Line-of-Sight
C2	Command and Control
C3	Command, Control, and Communications
CA	Collision Avoidance
CFR	Code of Federal Regulations
CM	Contingency Management
CNS	Communications, Navigation, Surveillance
CONOPs	Concept of Operations
CS	Control Station
ELOS	Equivalent Level of Safety
F#	Functional Requirement #
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FHA	Functional Hazard Assessment
FL	Flight Level
FMCS	Flight Management Control System
FRD	Functional Requirements Document
FRS	Flight Recovery System
HALE	High Altitude Long Endurance
HSI	Human Systems Integration
IFR	Instrument Flight Rules
IPT	Integrated Product Team
LOS	Line-of-Sight
MP	Mission Planning
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
PTT	Push to Talk
RFI	Radio Frequency Interference
ROA	Remotely Operated Aircraft
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules
VHF	Very High Frequency
WX	Weather

APPENDIX B: DEFINITIONS

ATC Communication Link – Two-way data and/or voice link between the UAS system and Air Traffic Control and/or other aircraft.

Autonomous– Operations that do not require direct pilot control. There are numerous levels of autonomy based upon how much the UAS pilot is involved in flying the UA.

Civil Aircraft – Aircraft other than public aircraft. See Public Aircraft.

Command and Control (C2) Link – The two-way data link between the Control Element and the UA that is used to control the UA and monitor the health/status of onboard systems.

Concept of Operation (CONOP) – A detailed description of the means for implementing an operational concept that is necessary to integrate UAS into the NAS in order to accommodate a "file and fly" capability.

Control Station (CS) – A site configured to allow the pilot in command of an UAS to operate and monitor all UAS operations conducted under his/her authority. The UAS pilot is considered to be an integral part of the Control Station.

Cooperative Traffic – Traffic that broadcasts position or other information, which assists in detecting and assessing conflict potential.

Sense and Avoid – The ability to sense traffic, which may be a conflict, evaluate flight paths, determine traffic right-of-way, and maneuver to avoid other traffic.

Equivalent Level of Safety (ELOS) – An evaluation of any applicable airworthiness requirement that cannot be literally complied with, and a determination that alternative requirements or other compensating factors can be substituted for that requirement. The evaluation is often subjective, and looks at the system and/or operation to determine the risk to other users of the NAS and people/property on the ground. It is the intent of Access 5 to specify the ELOS requirements for a UAS using functional terms (i.e. functional requirements) and not specific design requirements.

File and Fly – The ability of UAS pilot to file an IFR flight plan and operate in all classes of airspace, consistent with the regulatory criteria and operational requirements for manned aircraft. The flights require no pre-coordination with ATC. As with manned aircraft, UAS flights requiring special ATC handling in order to achieve mission objectives are not 'file and fly' and would be pre-coordinated with ATC.

Flight Management Control System (FMCS) – An operable system onboard a UA that performs the flight control actions from input received from the pilot via the C2 link or that automatically operates the HALE UAS from data previously installed.

Flight Path - The 3-dimensional track along which an aircraft is flying or intended to be flown.

High Altitude, Long Endurance (HALE) UAS – An unmanned aircraft capable of performing mission objectives at an altitude above 18,000-foot mean sea level (MSL) with sufficient cruise capability to transit the NAS.

Line-of-Sight (LOS) – The condition where the control element and the UAS are within electronic point-to-point link.

Manned Aircraft – Aircraft piloted by a human onboard.

Mission Area – Airspace of defined horizontal and vertical dimensions and a defined duration within which the UA will operate during a specified mission. The mission area is not associated with the flight route from/to the departure/arrival airports (see Route).

Mission Route – The flight path to be taken within the Mission Area where sensors or other applications will be exercised. Changes to the Mission Route during the mission could adversely affect the mission objectives.

Non-Cooperative Traffic – Traffic that does not broadcast position or other information.

Operational Concept – A high level description of Air Traffic Management (ATM) services necessary to integrate UAS into the NAS by a given time horizon.

Beyond Line of Sight (BLOS) – The condition where the control element and the UAS are not within electronic point-to-point link of each other.

Pilot – The individual that monitors and controls the UAS through issuance of command and control input to the aircraft and that posses the applicable FAA pilot certifications and ratings.

Route – The flight path of HALE UAS from the departure airport to the arrival airport, excluding any mission route and mission area. Course changes to the route have no impact on the mission objectives.

Routine Operations – See "File and Fly".

UAS Designated Airport – An airport that is capable of handling UAS operations.

Unmanned Aircraft System (UAS) – An unmanned aircraft that is operated from a remote location by a pilot/operator that issues command and control instructions to the aircraft, which are executed by an onboard flight management control system. The UAS is comprised of three major elements: 1) UA, 2) Control Station and 3) Command/Control Link.

Validation – The determination that the requirements for a system are sufficiently correct and complete. Correctness of a requirements statement means the absence of ambiguity or error in its attributes. Completeness of a requirements statement means that no attributes have been omitted and those stated are essential and traceable.

Verification – The evaluation of a system to determine that applicable requirements are met. The major objectives of the verification process are to confirm that: (1) the intended functions are correctly implemented and that the system is operationally ready and acceptable to the users; and (2) the requirements are satisfied.

APPENDIX C: UAS REQUIREMENTS WIRING DIAGRAM

This appendix provides a wiring diagram of the UAS Functional Requirements showing traceability throughout every level of our UAS requirements. *Analyst Pro* software was used to generate this diagram and is currently being used to manage and track all of the Access 5 functional requirements. This requirements management software tool provides effective tracking, importing, exporting, base lining, reporting, diagramming, graphing and requirements traceability. While not as powerful as some of its industrial counterparts, *Analyst Pro* has the capability to directly link requirements from one level to requirements at another level, providing easy traceability of each requirement.

With one click of the mouse, a systems engineer can instantly see all the requirements attached to a single requirement. The traceability output can be in the form of tables or even diagrams which make it easier and quicker to analyze. The importing and exporting features make transferring requirements from other documents such as Word and Excel faster and quicker without having to cut and paste between applications. Reports are extremely flexible and adaptable with many choices including number and titles of columns, table or text formats and many field indicators. The requirements can be tightly grouped into a table or spelled out in great detail individually with many attributes. The diagram feature allows easier and faster understanding of a tree of functions, systems, or operations by graphically representing a tree from beginning to end.

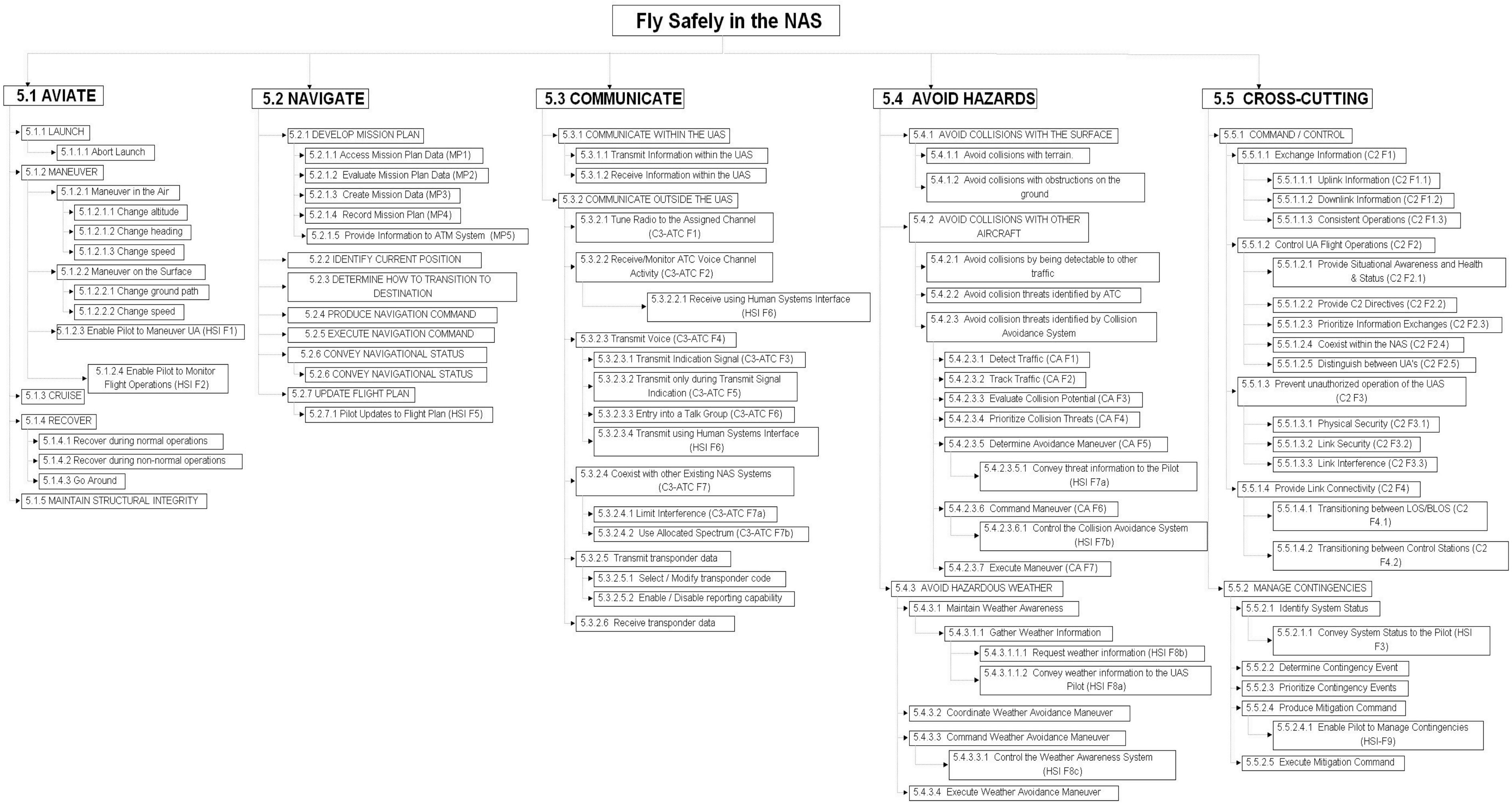

Figure C.1: UAS Functional Requirements Wiring Diagram

APPENDIX D: OPERATIONAL/FUNCTIONAL TRACEABILITY MATRIX

This Appendix provides a traceability matrix between the Operational Requirements found in the Access 5 CONOPs and the Functional Requirements found within the Access 5 FRD. Columns 1 and 2 of the table list all of the Functional Requirements and column 3 provides those operational requirements that are supported by the functional requirement listed in that row.

Table D.1: Operational / Functional Traceability Matrix

Functional Requirement Number	Functional Requirement	Operational Requirement Number
5.1	**AVIATE FUNCTIONAL REQUIREMENTS**	
5.1.1	LAUNCH	O1.1, O1.2, O1.3, O2.2
5.1.1.1	Abort Launch	O1.3
5.1.2	MANEUVER	O1.1, O1.2, O1.3, O2.2
5.1.2.1	Maneuver in the Air	O1.1, O1.2, O1.3, O2.1, O2.3
5.1.2.1.1	Change altitude	O1.2
5.1.2.1.2	Change speed	O1.2
5.1.2.1.3	Change heading	O1.2
5.1.2.2	Maneuver on the Surface	O1.1, O1.2, O1.3, O2.1, O2.3
5.1.2.2.1	Change ground path	O1.2
5.1.2.2.2	Change speed	O1.2
5.1.2.3	Enable Pilot to Maneuver UA (HSI F1)	O1.2, O2.5
5.1.2.4	Enable Pilot to Monitor Flight Operations (HSI F2)	O1.2, O2.5
5.1.3	CRUISE	O1.1, O1.2, O2.2, O2.3
5.1.4	RECOVER	O1.1, O1.2, O2.2, O2.3
5.1.4.1	Recover during normal operations	O1.2, O1.3
5.1.4.2	Recover during non-normal operations	O1.2, O1.3
5.1.4.3	Go Around	O1.3
5.1.5	MAINTAIN STRUCTURAL INTEGRITY	O1.1, O1.2, 01.3
5.2	**NAVIGATE FUNCTIONAL REQUIREMENTS**	
5.2.1	DEVELOP FLIGHT PLAN	O2.1, O2.3
5.2.1.1	Gather Information (MP1)	O2.3
5.2.1.2	Create a Mission Profile (MP2)	O2.3
5.2.1.3	Provide Mission Information to the UA (MP3)	O2.3
5.2.1.4	Provide Flight Information to the NAS (MP4)	O2.3
5.2.2	IDENTIFY CURRENT POSITION	O2.1, O2.3, O2.4
5.2.3	DETERMINE HOW TO TRANSITION TO DESTINATION	O2.1, O2.3, O2.4
5.2.4	PRODUCE NAVIGATION COMMAND	O2.1, O2.3, O2.4

5.2.5	EXECUTE NAVIGATION COMMAND	O1.2, O1.3, O2.1
5.2.6	CONVEY NAVIGATIONAL STATUS	O2.1, O2.3
5.2.6.1	Convey Navigational Information to the Pilot (HSI F4)	O2.5
5.2.7	UPDATE FLIGHT PLAN (HSI F5)	O2.1, O2.3
5.2.7.1	Pilot Updates to Flight Plan (HSI F5)	O2.5
5.3	**COMMUNICATE FUNCTIONAL REQUIREMENTS**	
5.3.1	COMMUNICATE WITHIN THE UAS	O1.2, O1.3, O2.7
5.3.1.1	Transmit Information within the UAS	O1.2, O1.3
5.3.1.2	Receive Information within the UAS	O1.2, O1.3
5.3.2	COMMUNICATE OUTSIDE THE UAS	O2.1, O2.4, O2.7
5.3.2.1	Tune Radio to the Assigned Channel (C3-ATC F1)	O2.1, O2.4
5.3.2.2	Receive/Monitor ATC Voice Channel Activity (C3-ATC F2)	O2.1, O2.4
5.3.2.2.1	Receive using Human Systems Interface (HSI F6)	O2.1, O2.4, 02.5
5.3.2.3	Transmit Voice (C3-ATC F4)	O2.1, O2.4, O2.7
5.3.2.3.1	Transmit Indication Signal (C3-ATC F3)	O2.1, O2.4
5.3.2.3.2	Transmit only during Transmit Signal Indication (C3-ATC F5)	O2.1, O2.4
5.3.2.3.3	Entry into a Talk Group (C3-ATC F6)	O2.1, O2.4
5.3.2.3.4	Transmit using Human Systems Interface (HSI F6)	O2.1, O2.4, O2.5
5.3.2.4	Coexist with other Existing NAS Systems (C3-ATC F7)	O1.3, O2.7
5.3.2.4.1	Limit Interference (C3-ATC F7a)	O1.3, O2.7
5.3.2.4.2	Use Allocated Spectrum (C3-ATC F7b)	O1.3, O2.7
5.3.2.5	Transmit transponder data	O2.1, O2.4, O2.7
5.3.2.5.1	Select / Modify transponder code	O2.1, O2.4
5.3.2.5.2	Enable / Disable reporting capability	O2.1, O2.4
5.3.2.6	Receive transponder data	O2.4
5.4	**AVOID HAZARDS FUNCTIONAL REQUIREMENTS**	
5.4.1	AVOID COLLISIONS WITH THE SURFACE	O1.3
5.4.1.1	Avoid collisions with terrain.	O1.3
5.4.1.2	Avoid collisions with obstructions on the ground	O1.3
5.4.2	AVOID COLLISIONS WITH OTHER AIRCRAFT	O1.3
5.4.2.1	Avoid collisions by being detectable to other traffic	O1.3, O2.4
5.4.2.2	Avoid collision threats identified by ATC	O1.3, 02.4
5.4.2.3	Avoid collision threats identified by Collision Avoidance System	O1.3, O2.4, O2.7
5.4.2.3.1	Detect Traffic (CA F1)	O1.3, O2.4
5.4.2.3.2	Track Traffic (CA F2)	O1.3, O2.4
5.4.2.3.3	Evaluate Collision Potential (CA F3)	O1.3, O2.4
5.4.2.3.4	Prioritize Collision Threats (CA F4)	O1.3, O2.4
5.4.2.3.5	Determine Avoidance Maneuver (CA F5)	O1.3, O2.4
5.4.2.3.6	Command Maneuver (CA F6)	O1.3, O2.4
5.4.2.3.7	Execute Maneuver (CA F7)	O1.2, O1.3, O2.1, O2.4
5.4.3	AVOID SEVERE WEATHER	O1.3, O2.1
5.4.3.1	Maintain Weather Awareness	O1.3, O2.1
5.4.3.1.1	Gather Weather Information	O1.3, O2.1
5.4.3.1.2	Evaluate Potential for Weather Conflicts	O1.3, O2.1
5.4.3.2	Coordinate Weather Avoidance Maneuver	O1.3, O2.1

5.4.3.3	Command Weather Avoidance Maneuver	O1.3, O2.1
5.4.3.3.1	Control the Weather Awareness System	O1.3, O2.1, O2.5
5.4.3.4	Execute Weather Avoidance Maneuver	O1.2, O1.3, O2.1
5.5	**CROSS-CUTTING FUNCTIONAL REQUIREMENTS**	
5.5.1	COMMAND / CONTROL	O1.3, O2.5, O2.7
5.5.1.1	Exchange Information (C2 F1)	O2.7
5.5.1.1.1	Uplink Information (C2 F1.1)	O2.7
5.5.1.1.2	Downlink Information (C2 F1.2)	O2.7
5.5.1.1.3	Consistent Operations (C2 F1.3)	O2.7
5.5.1.2	Control UA Flight Operations (C2 F2)	O1.3, O2.5, O2.7
5.5.1.2.1	Provide Situational Awareness and Health & Status (C2 F2.1)	O1.3
5.5.1.2.2	Provide C2 Directives (C2 F2.2)	O2.5
5.5.1.2.3	Prioritize Information Exchanges (C2 F2.3)	O1.3
5.5.1.2.4	Coexist within the NAS (C2 F2.4)	O2.7
5.5.1.2.5	Distinguish between UA's (C2 F2.5)	O1.3
5.5.1.3	Prevent unauthorized operation of the UAS (C2 F3)	O1.3
5.5.1.3.1	Physical Security	O1.3
5.5.1.3.2	Link Security (C2 F3.2)	O1.3
5.5.1.3.3	Link Interference (C2 F3.3)	O1.3
5.5.1.4	Provide Link Connectivity (C2 F4)	O1.3, O2.7
5.5.1.4.1	Transitioning between LOS/BLOS (C2 F4.1)	O1.3, O2.7
5.5.1.4.2	Transitioning between Control Stations (C2 F4.2)	O1.3, O2.7
5.5.2	MANAGE CONTINGENCIES	O1.3, O2.6
5.5.2.1	Identify System Status	O1.3, O2.6
5.5.2.1.1	Convey System Status to the Pilot (HSI F3)	O1.3, O2.5, O2.6
5.5.2.2	Determine Contingency Event	O1.3, O2.6
5.5.2.3	Prioritize Contingency Events	O1.3, O2.6
5.5.2.4	Produce Mitigation Command	O1.3, O2.6
5.5.2.4.1	Enable Pilot to Manage Contingencies (HSI-F9)	O1.3, O2.5, O2.6
5.5.2.5	Execute Mitigation Command	O1.2, O1.3, O2.6