**Project SKY NET**

**Futuristic Innovative Technologies**

**Artificial Intelligence (AI) Sub-system**

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# ***Scope***

****This preliminary system specification has been created as an addendum to the primary UAV System Specification document and is to be used for educational purposes. It does not capture the full system specifications, nor does it include system requirements outside of this system unless a modification has been identified to those systems for this system to be fully integrated.

The scope of this document is to establish the sub-system level requirements from a performance, design, development and system level test perspective to integrate upgraded Artificial Intelligence (AI) technology into existing AUAVs, to make use of the latest technology to provide AI-based decision-making for station-keeping, threat-aversion, “search and find” maneuvers and Object of Interest (OoI) tracking. ~~While allowing for continuous navigation information even in an electronic warfare (EW) jamming environment.~~

Today’s encounters with agents of foreign governments may include such operations to confuse, destroy or otherwise compromise the mission of identification of illegal activity at the border.

Specifically, the project is to provide an add-on upgraded AI (the system) that is to provide position, flight data, location of the sub ordinate AUAV and altitude to mother ship to the existing flight computer sub-system.

During the flight, the AI sub-system provides a continuous stream of data to the flight computer to allow autonomous decision algorithms to properly calculate the AUAV position relative to programmed boundaries. This data is also fed to the mission control computers to allow AUAV command and control operators to see what is happening with the AUAV and to make real time mission decisions.

# ***Applicable Documents***

The processes and standard operating procedures referenced within this specifications document:

* 1. Military Standards

MIL-STD-499 for SYSTEM ENGINEERING MANAGEMENT (17 JUL 1969).

* 1. Federal Aviation Administration (FAA) Standards

FAA part 107 Unmanned Aircraft Systems (UAS)

* 1. Defense Innovation Board (DIB) guidelines

AI Principles: Recommendations on the Ethical Use of Artificial Intelligence by the Department of Defense

# ***System Requirements***

This section covers all functional, non-functional, human-centered, and applicable system life-cycle requirements.

## ***Sub-System Definition***

The AI Sub-system is mainly made of hardware and software components with logistics and maintenance support. The fully operational system can stream data about the AUAV position even in an critical environment. This system takes advantage of the latest AI software package to provide the AUAV with a robust information stream to allow for confident mission decisions.

### ***General Description***

The AI unit of the AUAV provides real time data to the flight computer to allow autonomous decisions about movement of the aircraft. This data allows the AUAV system to maneuver autonomously or manually directed and to maintain visibility of the target with onboard optical systems.

### ***Operational Requirements***

(Need, Mission, Use Profile, Distribution, Life Cycle)

The AI sub-system is required for the following stakeholder requirements:

S.R. 04 The AUAV shall have a flexible control scheme through either a remote mission control center, local mobile command center, or independent AI-based decision-making system; with the ability to exchange authority over the AUAV between all control methods.

S.R. 05 The AUAV shall be adaptable for other features/capabilities/sensor packages/upgrades including a natural language, AI-based decision-making/mission reconfiguration.

S.R. 06 The AUAV should utilize commercial off the shelf products (COTS) where possible to reduce risk and cost.

S.R. 07 The AUAV shall be capable of supporting 24/7 operations worldwide.

S.R. 13 The AUAV shall be capable of performing solo missions with the aid of the onboard AI system.

S.R. 14 The AUAV shall be capable of flying as a part of an integrated swarm of AUAVs with adaptive, AI-based decision-making/mission reconfiguration.

S.R. 15 The integrated swarm of AUAVs shall be able to cooperatively intercept and geolocate Objects of Interest (OoI).

S.R. 16 The AUAV shall be capable of sending critical information to the Mission Command Center in less than 5 seconds.

Stakeholder requirements S.R. 04, S.R. 05, S.R. 13, and S.R. 14 are directly impacted by the AI sub-system, while requirement S.R. 15 is indirectly coupled because the navigation sub-system input is needed for the flight computer to make effective decisions about the AUAV position. The requirements S.R. 06 and S.R. 07 are indirectly related as well since they need to be taken into account when selecting the AI component.

The AI sub-system is part of the larger AUAV system, and all these pieces work together to successfully accomplish the mission needs.

### ***Maintenance Concept***

The AI subsystem shall support the function of updating firmware via transmission link with its mission control center. The supplier will train onsite maintenance technicians to perform any required maintenance and upgrade functions.

The supplier has a 24/7 customer support center available with trained engineers ready to assist in troubleshooting any issues that the customer may encounter. This option is available up to 120 hours of time covered under contract. Additional time shall be billable to the U.S. Department of Defense.

If the AI Sub-system cannot be repaired on-site, the supplier maintains a full repair capability down to component level at their corporate headquarters. Hardware can be returned to that facility if necessary. This service is without cost during the stated warranty period. After that time, the return evaluation and repair shall be billable to the U.S. Department of Defense.

### ***Functional Analysis and System Definition***

The AUAV control scheme needs to be able to function independently using AI-based decision-making system. This subsystem receives command instructions from the user, which can be voice interactive including the position to where the AUAV should go and the mission to be performed. The AI piece interprets real time data from the navigation subsystem about the position, altitude and latitude of the AUAV, and the new position it needs to go in order to determine the appropriate flight control action necessary and send it to the navigation subsystem. Along with this information, the parameters of the mission set by the user will be shared with the appropriate sub-systems. The AI Sub-system interfaces with the Master Control Function in order to gather any data necessary and uses it to fulfill its list of tasks. The AI Sub-system is capable of receiving instructions in the form of natural language and converts this to a Mission Plan and executes the mission plan based on the instructions given.

The AI sub-system is divided into several distinct functions. These functions are depicted in the figure below:

1.1 Power Distribution

1.2 Processor

1.2.1 Speech Recognition

1.2.2 Machine Vision

1.2.3 Natural Language Processing

1.3 Memory

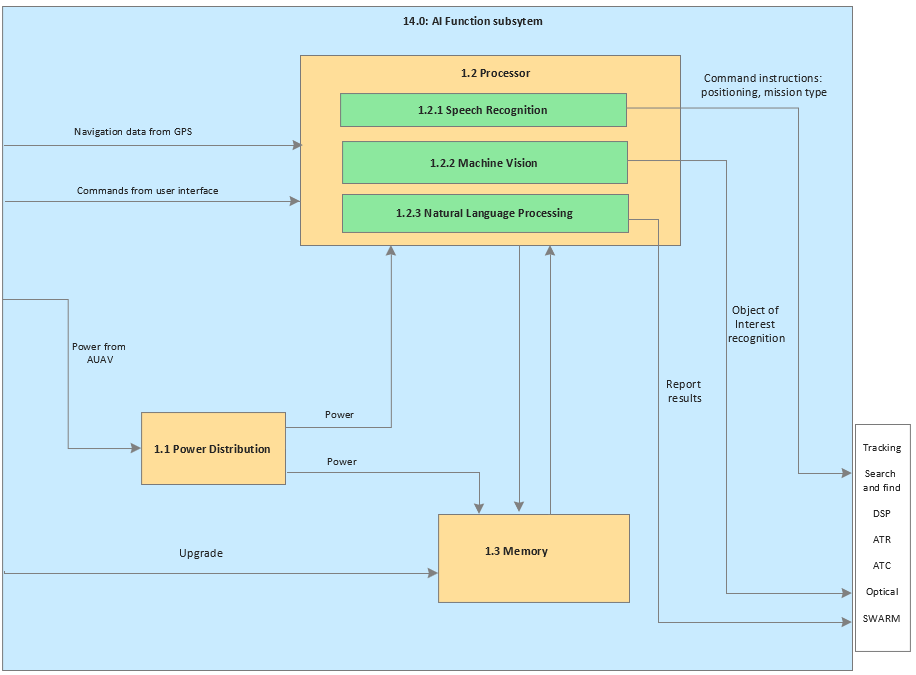


Figure 1 System Functional Block Diagram

The hardware consists of an AI processor (1.2) which converts the instructions received into commands for the correspondent subsystems, using the preprogrammed AI rules stored in the memory (1.3). The AI processor has three main functions, the first one is Speech Recognition (1.2.1), which translates the oral instructions (voice commands) into written words. Thus, they will be converted into input commands for the subsystems related. For example, the navigation subsystem will receive the position coordinates, the search and find subsystem will receive an instruction to activate if the mission selected requires it. The second function is Machine vision (1.2.2), it performs image recognition which will be an input for the search and find subsystem. The third function is Natural language processing (1.2.3), which is capable of receiving instructions in the form of natural language and converting it to an actionable mission plan, it also is cable of providing an answer to a question posed by the user, such as a request to report back the results of a voice command given by the user.

This subsystem also contains power distribution functions (1.1) that prepares and converts the voltages necessary for each of the subsystem components. These pieces make up the AI subsystem for the AUAV system.

Requirements

* + - 1. The AI Sub-system shall be capable of changing the AUAVs pitch, roll, and heading using AI based-decision making as required by the mission or command.
      2. The AI Sub-system shall be capable of changing the AUAVs elevation using AI based-decision making as required by the mission or command.
      3. The AI Sub-system shall be capable of changing the AUAVs position relative to the ground using AI based-decision making as required by the mission or command.
      4. The AI Sub-system shall be capable of autonomously avoiding collisions.
      5. The AI Sub-system shall be capable of determining and capturing critical information using the AI as deemed by the mission/command.
      6. The AI Sub-system shall regulate the incoming power voltage to prevent power surges.
      7. The AI Sub-system shall transform the incoming power voltage to suit components.
      8. The AI Sub-system shall translate voice commands into executable instructions understandable for the sub-system related through Speech recognition.
      9. The AI Sub-system shall answer to user questions through the Natural language processing.
      10. The AI Sub-system shall recognize Objects of Interest through the use of Machine vision.
      11. The AI Sub-system shall be capable of changing from a fly-to location mission to an observe on station mission autonomously.
      12. The AI Sub-system shall be capable of changing from an observe on station mission to a fly-to location mission autonomously.
      13. The AI Sub-system shall be capable of changing from a fly-to location mission to a return to base mission autonomously.
      14. The AI Sub-system shall be capable of changing from an observe on station mission to a return to base mission autonomously.
      15. The AI Sub-system shall be capable of controlling the optical sub-system autonomously to set a detection scan pattern.
      16. The AI Sub-system shall be capable of controlling the optical subsystem automatically to set detection locations.
      17. The AI Sub-system shall be capable of adjusting the AUAV’s flight parameters autonomously to maneuver the AUAV while on the ground.
      18. The AI Sub-system shall be capable of adjusting the AUAV’s flight parameters autonomously to maneuver the AUAV from takeoff through landing.
      19. The AI Sub-system shall be capable of flying independently or as part of a SWARM of multiple AUAVs with adaptive, AI-based decision-making/mission reconfiguration.
      20. The AUAV shall be able to share information with other AUAVs based on the Information Exchange Requirement (IER) including position above the ground and altitude as well as imagery data.
      21. The AUAV shall be adaptable for other features/capabilities/sensor package/upgrade including a natural language, AI-based decision-making/mission reconfiguration.
      22. The integrated swarm of AUAVs shall be able to cooperatively intercept and geolocate Objects of Interest (OoI).
      23. The AUAV shall be able to automatically takeoff and land, queue, and route using AI Sub-system and have environment surrounding of other AUAVs including SWARM capability.

Requirements derivation:

All requirements not stated here are directly from the Functional Definition section of the Subsystem Specification.

Requirements 3.1.4.1-5 have been derived from requirements 3.1.4.1,2,3,6 (02 subsystem spec.)

### ***Allocation of Requirements***

* + 1. Power
       - 1. The AI Sub-system shall consume a maximum of 2 Amperes
         2. The AI Sub-system shall operate with a 12 VDC input
         3. The AI Sub-system shall provide internal filtering and conditioning for the subsystem components.
    2. Composition
       - 1. The AI Sub-system shall include an AI processor.
         2. The AI Sub-system shall include a memory.
         3. The AI Sub-system shall include a processing unit.
         4. The AI Sub-system shall include a power conditioning and distribution unit.

### ***Functional Interfaces and Criteria***

Discussion

The AI subsystem interfaces with the following subsystems:

* + Navigation
  + Search and Find
  + Tracking
  + DSP
  + ATC Imaging
  + ATR
  + Optical
  + SWARM

The AI sub-system data is critical to proper AUAV operations. The AI sub-system will take data from the GPS of the navigation system and user commands to make autonomous flight decisions. The AI sub-system will interact with the navigation and optical subsystems to allow the AI to make necessary calculations to perform the following functions: search and find, tracking, and ATR. In order for these functions to be performed properly The AI Sub-system must interact with the optical sub-system as to perform both DSP and ATC as to apply necessary corrections to long range imagery. The AI will interact with the SWARM as to perform the above functions seamlessly and simultaneously. By interacting with all of the above subsystems The AI sub-system will fulfil the operational requirements listed in section 3.1.2.

Requirements

* + - 1. The AI Sub-system shall interface with, provide data, and receive data from the flight computer subsystem.
      2. The AI Sub-system shall interface with, provide data, and receive data to and from the Communication subsystem.
      3. The AI Sub-system shall interface with, provide data, and receive data to and from the Search and Find Maneuvers subsystem.
      4. The AI Sub-system shall interface with, provide data, and receive data to and from the Navigation subsystem.
      5. The AI Sub-system shall interface with, provide data, and receive data to and from the Tracking subsystem.
      6. The AI Sub-system shall interface with, provide data, and receive data to and from the Optical subsystem.
      7. The AI Sub-system shall interface with, provide data, and receive data to and from the SWARM subsystem.
      8. The AI Sub-system shall interface with, provide data, and receive data to and from the DSP subsystem.
      9. The AI Sub-system shall interface with, provide data, and receive data to and from the ATC Imaging subsystem.
      10. The AI Sub-system shall interface with, provide data, and receive data to and from the ATR subsystem.
      11. The AI Sub-system shall interface with and accept commands from the user interface. t~~he flight computer sub-system~~.
      12. The AI Sub-system shall receive Global Positioning System (GPS) Data.
      13. The AI Sub-system shall provide altitude data to the flight computer sub-system
      14. The AI Sub-system shall provide speed data to the flight computer sub-system
      15. The AI Sub-system shall provide altitude data (roll, pitch and yaw) to the flight computer sub-system
      16. The AI Sub-system shall allow firmware updates via transmission link with its mission control center or mobile control center.
      17. The AI Sub-system shall be able to receive and respond to vocal commands via the mission control center or mobile control center.
      18. The Master Control System shall be able to override the AI decision matrix as necessary.

Justification for 3.1.9.18: Based on need for manual control, and updating parameters, avoid dangerous decisions/situations.

* + 1. ***Environmental Conditions***
       1. Not applicable—reserved for future use

## ***System Characteristics***

### ***Performance Characteristics***

* + - 1. The AI Sub-system shall operate at full performance for all temperatures ranging from -40.0 degrees Fahrenheit [-40 degrees Celsius] and +120.0 degrees Fahrenheit [+48.9 degrees Celsius], inclusively.
      2. The AI Sub-system shall operate at full performance for all atmospheric pressures ranging from -9.0 pounds per square inch absolute [-62.1 kilopascals absolute] and 0.0 pounds per square inch absolute [0.0 kilopascals absolute], inclusively.
      3. The AI Sub-system shall be able to measure the UAV flight speed from 0.0 miles per hour [0.0 kilometers per hour] to 158.45 miles per hour [255.00 kilometers per hour], inclusively, within a tolerance of +/- 5 miles per hour [8 kilometers per hour].
      4. The AI Sub-system shall be able to measure the UAV flight altitudes from ground level to a maximum of 25,000 feet above mean sea level [7.62 kilometers], inclusively, with a tolerance of +/- 3.0 feet [0.914 meters].
      5. The AI Sub-system shall be able to measure the UAV flight spatial position (latitude and longitude) with a tolerance of 1/25th of a second [3.6 feet].
      6. The AI Sub-system shall operate with the UAV experiencing g-forces 0 and 0.5 in the negative direction.
      7. The AI Sub-system shall operate with the UAV experiencing a bank angle between 0 and 40 degrees.
      8. The AI Sub-system will have at least 16GB of RAM.
      9. The AI Sub-system shall calculate and direct the position the optical sensors at its target location within a tolerance of +/- 0.610 meters.
      10. The AI Sub-system shall be able to calculate the required magnification of the electro-optical sensor from 1 time to 25 times magnification, inclusively, with a tolerance of +/- 0.5 millidegrees.
      11. The AI Sub-system shall be able to assess an image for a target / no-target decision within a maximum time of 1 second from receiving the image.
      12. The AI Sub-system shall have a 90% positive target detection rate.
      13. The AI Sub-system shall determine optimal flight control settings within a maximum time of 200 milliseconds.
      14. The AI Sub-system shall determine optimal optical control settings within a maximum time of 200 milliseconds.
      15. The AI Sub-system shall detect a ground-based obstacle entering its sphere of influence within of 0.5 seconds.
      16. The AI Sub-system shall detect human Target of Interest (TOI) with a slant range of 9.543km during daytime.
      17. The AI Sub-system shall detect human Target of Interest (TOI) with a slant range of 1.5 km during nighttime.
      18. The AI Sub-system shall identify human Target of Interest (TOI) with a slant of 1.5 km during daytime.
      19. The AI Sub-system shall identify human Target of Interest (TOI) with a slant range of 250 m during nighttime (with slipstream sensors).
      20. The AI Sub-system shall identify human Target of Interest (TOI) within a slant range of 1.5km (with slipstream sensor).
      21. The AI Sub-system shall also be able to calculate a search area large grid within a 256 km by 256 km range associated with each hot spot.

### ***Physical Characteristics***

* + - 1. The AI Sub-system shall be contained within an 17 ft3 [ 0.481 m3] space inside the UAV.
      2. The AI Sub-system weight shall not exceed 45 pounds [20.41 kilograms].
      3. The AI Sub-system shall be self-contained regarding component packaging.

### ***Effectiveness Requirements***

* + - 1. The AI Sub-system shall provide detection 24 hours per day / 7 days per week with a 98% operational availability during on-station time.

### ***Reliability***

* + - 1. The AI Sub-system shall have an Instantaneous Reliability of at least 70%.
      2. The AI Sub-system system shall have a Mean Time Between Failure (MTBF) of at least 20 years.
      3. The mean time to repair (MTTR) shall be less than 8 hours.

### ***Maintainability***

* + - 1. The AI Sub-system shall not result in down time of more than 16 hours due to regular system maintenance.
      2. The AI Sub-system shall require complete system inspection after every 1000 hours of flight time.
      3. The AI Sub-system shall have the ability to self-check and perform software updates within 4 hours prior to operation time.
      4. The AI Sub-system shall allow for quick updating of software by maintenance personnel with an intermediate skill level.
      5. The AI Sub-system shall have a built-in-test (BIT) protocol incorporated into the controller to allow for easier maintenance.
      6. The AI Sub-system BIT function shall store BIT error files onto onboard memory.
      7. The AI Sub-system shall transmit BIT error files to the mission control center within 30 seconds of receipt of error.
      8. The company shall maintain the capability of repairing individual modules. That is if a module fails, it should be replaced with a spare at the customer site and the failed module transported to the factory where it can be repaired by personnel with high skill levels.
      9. All documentation for the maintenance schedules and procedures shall be provided for the AI Sub-system as part of the contractual deliverables.
      10. The AI Sub-system should be maintained with existing tools and equipment.
      11. Supplier shall provide all specialty tools required for routine maintenance.

### ***Usability (Human Factors)***

* + - 1. The AI Sub-system shall be designed so that it can be operated by a single operator with intermediate skills. Intermediate skills in this case is defined as High School Graduate with 9th grade reading/writing level with no prior work experience and around 40 hours of training plus some on-the-job training.
      2. The AI Sub-system shall understand voice commands in English (default language).
      3. The AI Sub-system shall provide a capability to modify the language.

### ***Supportability***

* + - 1. The AI Sub-system shall support different data transfer protocols.

### ***Transportability / Mobility***

* + - 1. The AI Sub-system shall accommodate ease of transport during AI Sub-system integration and maintenance.
      2. The AI Sub-system shall be easily deployable and transported when not under any operational mode.
      3. The AI Sub-system shall be capable of being transported safely by commercial air cargo or common carrier.
      4. The AI Sub-system should not sustain damage while being transported.

### ***Flexibility***

* + - 1. The AI Sub-system shall be designed to be flexible by making use of functional modularity that will allow for cost effective modification or repair.

### ***Availability***

* + - 1. Not applicable—Reserved for future use

### ***Sustainability***

* + - 1. The AI Sub-system shall be designed with AI Sub-system recycling in consideration.
      2. The AI Sub-system shall have the minimal infrared heat signature and acoustic emission to support environmental sustainability.

### ***Security***

* + - 1. The AI Sub-system shall incorporate secure data encryption for all stored data (mission planning files, logs, AI rules).
      2. The AI Sub-system shall incorporate a special security token to modify or upload new software to the controller modules.
      3. The AI Sub-system shall continue to operate properly while climbing to 20,000 feet of altitude at a climb rate of 30 feet per second while UAV is being actively attacked.
      4. The AI Sub-system shall report BIT status on command as requested to determine state of health in the event of an attack.

## ***Design and Construction***

### ***CAD/CAM Requirements***

* + - 1. All dimensioning shall be presented as imperial units with metric units presented in brackets after the imperial units.
      2. Electrical design drawings shall be modeled on software compatible with Autodesk AutoCAD.
      3. Mechanical design drawing shall be modelled on software compatible with PTC Creo Parametric.
      4. Mechanical failure analysis shall be modelled on software compatible with ANSYS Workbench.
      5. Logical simulations shall be modelled on software compatible with MATLAB.
      6. Testing software scripts shall be generated on software compatible with MATLAB.

### ***Materials, Processes, and Parts***

* + - 1. The AI Sub-system shall incorporate standard hardware fasteners to maintain uniformity with the preexisting hardware.
      2. The AI Sub-system shall incorporate materials that resist corrosion during all operational modes.
      3. The AI Sub-system shall use approved processes dictated by the FAA for aerospace application.
      4. AI Sub-system hardware shall be compatible with USG System Integration Labs standards and procedures.

### ***Mounting and Labelling***

* + - 1. Electrical components shall be labeled with regulatory classification statements.
      2. Electrical component input and output pinouts shall be identified with identification labels.
      3. Electrical components shall be labeled with safety warnings.

### ***Electromagnetic Radiation***

Electromagnetic radiation or EMF will be present in small amounts due to the inherent nature of the electronics within the housing. To retain full control and reliability of the controller and its constituent parts, this requirement is necessary.

* + - 1. No element of the AI Sub-system shall emit electromagnetic radiation levels of more than 5 milligauss.

### ***Safety***

* + - 1. The AI Sub-system shall not present any safety hazards to maintenance personnel.
      2. The AI Sub-system shall not present safety hazards to the user during operation under either autonomous, or non-autonomous flight modes.
      3. The AI Sub-system shall not interfere with the transponder of the AUAV.

### ***Interchangeability***

* + - 1. The AI Sub-AI Sub-system shall be designed using interchangeable parts that can be easily switched when repairs arise.

### ***Workmanship***

* + - 1. Workmanship standards for material selection and manufacturing processes shall conform to the quality standards of the client.

### ***Economic Feasibility***

* + - 1. The AI Sub-system shall have an installed cost of a maximum of USD $TBD for 22 UAVs.

## ***Documentation / Data***

* + 1. Maintenance schedules and procedures shall be included as part of the contractual deliverables to the Client in the final acceptance documentation.

## ***Logistics***

### ***Maintenance Requirements***

To Be Determined.

### ***Supply Support***

* + - 1. All vendors shall support the supplied product for the life of the AUAV program.
      2. All contractor shall support the product for the life of the AUAV program.

### ***Test and Support Equipment***

* + - 1. Software support utilities shall be developed for unit testing and verification and for debugging procedures.
      2. The developed AI Sub-system shall be capable of being tested by the Supplier and Client software engineering teams.

### ***Personnel and Training***

* + - 1. A user interface document shall be developed for the training of AUAV operators.
      2. A user interface document shall be developed for the training of maintenance personnel.

### ***Facilities and Equipment***

* + - 1. The AI Sub-system shall conform to all AUAV facility and applicable equipment standards.

### ***Packaging, Handling, Storage and Transportation***

The entirety of the AI Sub-system is very fragile and susceptible to damage from vibration, heat and electromagnetic discharge while not housed in AUAV system infrastructure. Care should be exercised when unit is being transported from within the facility or to other remote locations.

* + - 1. Loose electrical components shall be packaged in ESD protected packaging.
      2. Loose components shall be placed in temporary frames that are guarded from shock.
      3. All transportation personnel shall receive sufficient training on handling of the components.
      4. Components shall be stored in a climate-controlled environment.

### ***Computer Resources***

* + - 1. The AI Sub-system utilities, test and support equipment, and all other tools shall be compatible with Windows 10 OS or later.

### ***Technical Data***

* + - 1. A quality control dossier shall be created per AUAV.
      2. An Operation Manual shall be created per site.
      3. A Maintenance Manual shall be created per site.
      4. One (1) copy of software test results shall be included in the handover Quality Control documentation.
      5. One (1) copy of mechanical test result data shall be included in the handover Quality Control documentation.
      6. Four (4) copies of the Operation Manual shall be included in the handover documentation.
      7. Four (4) copies of the Maintenance Manual shall be included in the handover documentation.
      8. One (1) copy of the AI Sub-system design dossier shall be included in the handover documentation.
      9. One (1) copy of the As-installed Software shall be included in the handover documentation.

### ***Customer Service***

* + - 1. The Supplier shall provide a customer support contact number which shall be staffed 24 hours a day to respond to queries.

## ***Producibility***

The AI Sub-system is a custom design unique to this specific UAV configuration. There are no instances where mass production would be warranted.

* + 1. The AI Sub-system shall be producible using manufacturing documents.
    2. The software shall be downloadable.
    3. The software shall be able to be installed by a trained user.

## ***Disposability***

The proper disposal of the AI Sub-system and its component parts is important to ensure data security and that no substances are released that are harmful to human health and the environment.

* + 1. Components shall be properly sanitized prior to disposal.
    2. All data storing hardware shall be re-formatted prior to disposal.

## ***Affordability***

* + 1. The AI Sub-system shall be cost competitive when compared to its peer group.

# ***Test and Evaluation***

Sub-system testing and evaluation shall be conducted during each phase of the sub-system life cycle. The sub-system shall be tested in a tiered approach, verifying selected sub-system requirements of the sub-system requirements described in Section 3, while also validating the functionality of the sub-system. The following types of testing shall be performed:

Analytical and Simulation Evaluation: This involves evaluation and analysis of computer simulations for various AI Sub-system components.

Type 1 Testing: Evaluation of initial models and development builds for the component software. Testing shall be performed at the Supplier’s facilities using Supplier’s test tools and resources.

Type 2 Testing: Evaluation of the AI Sub-system prototype and initial integration of the AI Sub-system components. Testing shall be performed at the Supplier’s facilities using the Supplier’s test tools and resources.

Type 3 Testing: Evaluation of the final implementation of the AI Sub-system. Testing shall be conducted at the Supplier’s facilities and Client’s base of operations using the Supplier’s test tools and resources.

Qualification by Analysis: Full testing is not needed due to legacy hardware/software uses and Technology readiness level (TRL), but analysis is needed to verify specific use case of this program and integration architecture allows HW/SW to still perform to spec.

Qualification by Similarity: Lower-level, less intensive analysis is needed to show legacy hardware/software has meet these requirements in the past and is currently employed in a way that allows identical functionality.

Methods for Verification: Test, Analysis, Demonstration, Simulation, or Inspection

|  |  |  |
| --- | --- | --- |
| Requirement | Method for Verification | Reasoning |
| 3.1.4.8 The AI Sub-system shall translate voice commands into executable instructions understandable for the sub-system related through Speech recognition. | Simulation and Testing | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.1.4.9 The AI Sub-system shall answer to user questions through the Natural language processing. | Simulation and Testing | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.1.4.10 The AI Sub-system shall recognize Objects of Interest through the use of Machine vision. | Simulation and Testing | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.1.8.17 The AI Sub-system shall be able to receive and respond to vocal commands via the mission control center or mobile control center. | Demonstration, Analysis, and Testing. | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.2.6.2 The AI Sub-system shall understand voice commands in English (default language). | Demonstration, Analysis, and Testing. | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.2.6.3 The AI Sub-system shall provide a capability to modify the language. | Demonstration, Analysis, and Testing. | Voice commands are open to interpretation based on phrases used, accents, articulation, and language used. |
| 3.5.5.1 The AI Sub-system shall conform to all AUAV facility and applicable equipment standards. | Inspection | Needs to comply with safety specifications to ensure reliability. |

# ***Quality Assurance Provisions***

All AI Sub-system level tests will be witnessed by representatives of the Supplier’s Quality Assurance discipline along with the software engineering and systems engineering teams to ensure the test procedures are conducted as documented.

All inspection and testing documentation shall be provided to the Client in the final acceptance documentation.

# ***Distribution and Customer Service***

The AI Sub-system shall be installed within, and integrated into, the UAVs existing sub-systems at Supplier’s workshop by Supplier’s personnel. The Client’s technicians shall be invited to witness all applicable Type 1, 2 and 3 testing. Aerial acceptance testing and hand-over shall be performed at the original base of operations.

Supplier shall provide 2-days of onsite training for the technicians and operators as each UAV location. Operation and Maintenance manuals shall be provided for each UAV. Supplier shall provide a 1-year warranty on parts and workmanship. Additionally, the Supplier shall provide a customer support contact number which shall be staffed 24 hours a day to respond to queries.

# ***Acronyms***

|  |  |
| --- | --- |
| AI | Artificial Intelligence |
| ATC | Atmospheric Turbulence Compensation |
| ATR | Atmospheric Target Recognition |
| AUAV | Autonomous Unmanned Aerial Vehicle |
| BIT | Built-In-Test |
| CRPA | Controlled Radiation Pattern Antenna |
| DSP | Digital Signal Processing |
| FAA | Federal Aviation Administration |
| GPS | Global Positioning System |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time to Repair |
| OEM | Original Equipment Manufacturer |
| OoI | Object of Interest |
| RF | Radio Frequency |
| SAE | Society of Automotive Engineers |
| SOH | State of Health |
| TCU | Turbocharger Control Unit |
| TOI | Target of Interest |
| UAV | Unmanned Aerial Vehicle |
| VDC | Volts Direct-Current |

1. Feasibility Study

Several AI options were evaluated for use and installation with integration into the UAUV itself. General Atomics just won a contract in 2020 to use Metis software but is not feasible yet. Other software will need to be integrated. The main AI software likely to be implemented will be similar to the United States Air Force’s Skyborg new technology publicly in use in 2018.

Additionally, the company GA-ASI has been contracted to install Skyborg Software onto Avenger RPA for U.S.A.F, which is the same parent company of the General Atomics M1-Q Predator used a basis for the AUAV system. The first proof of flight with Skyborg ACS on April 21, 2021, debuted on a Kratos UTAP-22 Mako. There is a potential high budget risk as budgets have been exceeded but so far, the software is on track, and General Atomics, Boeing, and Kratos have 5 months to build Skyborg Prototypes as of December 2020.

8.1 Skyborg Features

|  |  |
| --- | --- |
| Type of Feature | List of Features |
| General | * OMS Based Scalable Architecture * Agile, Modular Payloads * Separated Vehicle/Mission Systems * Third-Party Autonomy Integration * Common Core Heterogeneous Family * Assured Prioritized Comm * Assured Navigation * Assured Autonomy * Low Cost * Untethered * Auto Takeoff/Land * Auto Queuing * Auto Routing * Multi-Ship Teaming * Dynamic Autonomy * Objective Based Tasking |
| Software | * Autonomy architecture * Collaborative operations * Mission Planning * Manned/Unmanned teaming * Mission Skills * Transferable Autonomy Apps * Software Development Kits |
| Hardware | * Open Architecture Standards * USG System Integration Labs * Hardware-in-the-Loop Testing |
| Operations | * CONOPS/CONEMPS Validation * Launch and Recover Operations * DOTML |
| Potential Features for New Stakeholders | * Next-Gen ISR/Strike * Munitions Delivery * CAS * Interdiction * OCA/DCA * ABMS |
| Other | * Potential Stakeholders/Collaborative Partners Above * Low-Cost attributable aircraft tech * Shared digital care * Digital platform engineering |

8.1 Reliability

The AI is a software-based sub-system and so can be assumed to have a software-based reliability model. With periodic debugging efforts and use of a reliable software system like Linux that is also compatible with Windows 10 as per System Requirement, we can assume that the reliability is 0.97 as per the feasibility study.

1. FMECA – Work in excel sheets for formatting

Mitigation of AI Sub-system through digital engineering, agile software development, and open systems architecture, increasing dependence on U.S. sources of raw materials and microelectronics, and building of new partnerships.



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