**U.S. Coast Guard Academy; Department of Engineering**

**Electrical Engineering & Cyber Systems Section**

Capstone Projects in EE/CYS 1 F21

Unmanned Aerial Vehicle: Requirements Document

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**Mission Needs Statement**

The United States Coast Guard is responsible for protecting the country from adversaries on the high seas and rescuing those in peril. For decades, the Coast Guard has relied on either manned aircraft or remotely-piloted drones to detect vessels of interest and persons in distress. Manned flight requires years of expensive training, large amounts of fuel, and introduces the possibility for the loss of life should an accident occur. Further, remotely-piloted drones currently in use by the USCG also require expensive training to operate and specialized recovery equipment, as well as present the opportunity for user error. Both manned aircraft and current remotely-piloted drones require a flight deck to operate. Human error is the leading cause for aviation mishaps of U.S. military aviation assets, both manned and remotely piloted.[[1]](#footnote-2) To expand the capabilities and reduce costs for the USCG in drug/migrant interdiction and search and rescue (SAR) operations, the following must occur: a new flight system must be designed that makes drug/migrant/SAR operations inexpensive, requires little training, requires no dedicated pilot, and can be deployed from any Coast Guard cutter, small boat, or other asset.

**Concept of Operations**

The United States Military has used autonomous unmanned aerial vehicles for many years, and the idea of utilizing them for Coast Guard missions is incredibly exciting. Through computer vision, autonomous drones can be leveraged to execute Coast Guard missions from search and rescue to drug and migrant interdiction. Real-time image processing algorithms can be utilized to identify people, vessels, or other objects in the water without requiring a crew member to watch the video feed. The proposed system would have the capability to fly search patterns with no pilot or observer thereby reducing the time, cost, and effort required to use aircraft to support such missions. Additionally, autonomous unmanned drones are not limited to independent operation; unlike manned aircraft, these drones can be coordinated to fly in conjunction with others. The ability for multiple drones to simultaneously fly several overlapping patterns is incredibly valuable to the Coast Guard, as time is of the essence in most search and rescue cases. Increased search efficiency would better the chances of recovering distressed vessels and people. Small autonomous unmanned vehicles have the ability to be deployed from nearly any Coast Guard asset; therefore, these same target recognition techniques can also support law enforcement, fisheries enforcement, port security, and disaster response activities. The adoption of autonomous UAVs would offer the Coast Guard incredible value and relatively low operational costs while supporting a variety of existing missions.

**Operational Requirements**

**Key Performance Parameter 1:** Maneuverability and Transportability

**Operational Requirement 1:** The Vehicle Shall be Capable of Unassisted Flight.

Functional Requirements:

* 1. The UAV must be capable of controlled flight in the presence of wind.
     1. Objective: Minimal affects with respect to constant wind; turbulent flow accounted for.
     2. Threshold: UAV operable in 10 kt winds without regard to direction.

Non-Functional Requirements:

* 1. The UAV must be electronically powered.
     1. Threshold: No battery voltage may exceed 60Vdc.

**Operational Requirement 2:** The Vehicle Shall Meet Competition Size Guidelines.

Non-Functional Requirements:

* 1. The vehicle shall meet RoboBoat weight standards.
     1. Threshold: Total weight must be less than 10 pounds (including batteries).
  2. The vehicle shall meet RoboBoat dimension standards.
     1. Threshold: Together with the ASV, must not exceed 3ft by 3ft by 6 ft.

**Key Performance Parameter 2:** Primarily Autonomously Controlled

**Operational Requirement 3:** The Vehicle Shall be Capable of Autonomous Flight.

Functional Requirements:

* 1. The UAV must be able to be controlled manually and autonomously.

Non-Functional Requirements:

* 1. Aerial operations must be compliant with FAA regulations.
  2. Operators must have UAS pilot certificate from FAA.

**Operational Requirement 4:** The Vehicle Shall Communicate with the ASV.

Functional Requirements:

* 1. The vehicles must exchange information about takeoff and landing status.
  2. The vehicles must exchange information about locations and targets of interest.

Non-Functional Requirements:

* 1. Wireless communication must utilize public frequencies.

**Key Performance Parameter 3:** Computer Vision Enabled

**Operational Requirement 5:** The Vehicle Shall be Capable of Landing on an ASV Flight Deck.

Functional Requirements:

* 1. A detectable and agreed upon flight deck design must be on the ASV
  2. The UAV must be equipped with cameras/LIDAR/RTK in order to safely land on the target.

Non-Functional Requirements:

* 1. The flight deck must be a design that is preemptively established in the computer vision module.

**Operational Requirement 6:** The Vehicle Shall Enable Transportation of Small Objects.

Functional Requirements:

* 1. The UAV must be equipped with a claw capable of carrying and dropping objects.

Non-Functional Requirements:

* 1. UAV must be able to detect, move toward, and deliver objects to a designated target area design.

**Operational Requirement 7:** The vehicle shall deploy from the ASV’s flight deck.

Functional Requirements:

* 1. The UAV must have landing gear.
  2. The UAV must be able deploy while the ASV is moving or stationary.

Non-Functional Requirements:

* 1. Cannot deploy until a ‘flight ready’ status is given at the completion of safety inspections
     1. Test of all remote-control abilities and loss of communication situations.
     2. Test of remote kill functionality at range and near.
     3. Document review for design, construction and operation safety.
  2. Cannot deploy until a ‘safe for takeoff” status is given by the RoboBoat flight director.

**Key Performance Parameter 4:** Respond Safely to Casualty

**Operational Requirement 8:** The Vehicle Shall Have a Loss of Contact Instruction Set.

Functional Requirements:

* 1. Must initiate slow decent within 5 seconds of losing contact with remote control or remote kill.
     1. Slow decent must be <= 3ft/s
  2. A 100+dba siren with a 1+pulse/sec must be on during slow decent.
  3. Positively buoyant for at least 120 seconds.

**Operational Requirement 9:** The Vehicle Shall Allow for Manual Control.

Functional Requirements:

* 1. The UAV must have flight operations programmed into a wireless controller.

Non-Functional Requirements:

* 1. The override must be wirelessly capable.

**Operational Requirement 10:** The Vehicle Shall Allow for Immediate Shutdown.

Functional Requirements:

* 1. The vehicle shall have a kill switch onboard the UAV and the control station.
  2. Both must turn off all motors on UAV within 1 second of being pressed.

Non-Functional Requirements:

* 1. Range must be greater than 1000 ft.
  2. The remote stop function must be separate from the main controller.

**Requirements Matrix**

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| **KPP** | **Operational Requirement** | **Functional Requirement** | **Non-Functional Requirement** |
| Maneuverability and Transportability | The Vehicle Shall be Capable of Unassisted Flight. | The UAV must be capable of controlled flight in the presence of wind. |  |
| Maneuverability and Transportability | The Vehicle Shall be Capable of Unassisted Flight. |  | The UAV must be electronically powered: no battery voltage may exceed 60Vdc. |
| Maneuverability and Transportability | The Vehicle Shall Meet Competition Size Guidelines. |  | Together with the ASV, the dimensions must not exceed 3ft by 3ft by 6ft. |
| Maneuverability and Transportability | The Vehicle Shall Meet Competition Size Guideline. |  | The criteria include batteries, meaning the total weight must be less than 10 pounds. |
| Primarily Autonomously Controlled | The Vehicle Shall be Capable of Autonomous Flight. | The UAV must be able to be controlled manually and autonomously. |  |
| Primarily Autonomously Controlled | The Vehicle Shall be Capable of Autonomous Flight. |  | Operators must have UAS pilot certificate from FAA. Aerial operations must be compliant with FAA regulations. |
| Primarily Autonomously Controlled | The Vehicle Shall Communicate with the ASV. | The vehicles must exchange information about takeoff and landing status. |  |
| Primarily Autonomously Controlled | The Vehicle Shall Communicate with the ASV. | The vehicles must exchange information about locations and targets of interest. |  |
| Primarily Autonomously Controlled | The Vehicle Shall Communicate with the ASV. |  | Wireless communication must utilize public frequencies. |
| Computer Vision Enabled | The Vehicle Shall be Capable of Landing on an ASV Flight Deck. | A detectable and agreed upon flight deck design must be on the ASV. |  |
| Computer Vision Enabled | The Vehicle Shall be Capable of Landing on an ASV Flight Deck. | The UAV must be equipped with cameras/LIDAR/RTK in order to safely land on the target. |  |
| Computer Vision Enabled | The Vehicle Shall be Capable of Landing on an ASV Flight Deck. |  | The flight deck must be a design that is preemptively established in the computer vision module. |
| Computer Vision Enabled | The Vehicle Shall Enable Transportation of Small Objects. | The UAV must be equipped with a claw capable of carrying and dropping objects. |  |
| Computer Vision Enabled | The Vehicle Shall Enable Transportation of Small Objects. |  | UAV must be able to detect, move toward, and deliver objects to a designated target area design. |
| Computer Vision Enabled | The Vehicle Shall Deploy from the ASV’s flight deck. | The UAV must have landing gear. |  |
| Computer Vision Enabled | The Vehicle Shall Deploy from the ASV’s flight deck. | The UAV must be able deploy while the ASV is moving or stationary. |  |
| Computer Vision Enabled | The Vehicle Shall Deploy from the ASV’s flight deck. |  | Cannot deploy until a ‘flight ready’ status is given at the completion of safety inspections. |
| Computer Vision Enabled | The Vehicle Shall Deploy from the ASV’s flight deck. |  | Cannot deploy until a ‘safe for takeoff” status is given by the RoboBoat flight director. |
| Respond Safely to Casualty | The Vehicle Shall Have a Loss of Contact Instruction Set. | Must initiate slow decent within 5 seconds of losing contact with remote control or remote kill. |  |
| Respond Safely to Casualty | The Vehicle Shall Have a Loss of Contact Instruction Set. | A 100+dba siren with a 1+pulse/sec must be on during slow decent. |  |
| Respond Safely to Casualty | The Vehicle Shall Have a Loss of Contact Instruction Set. | Positively buoyant for at least 120 seconds. |  |
| Respond Safely to Casualty | The Vehicle Shall Allow for Manual Control. | The UAV must have flight operations programmed into a wireless controller. |  |
| Respond Safely to Casualty | The Vehicle Shall Allow for Manual Control. |  | The override must be wirelessly capable. |
| Respond Safely to Casualty | The Vehicle Shall Allow for Immediate Shutdown. | The vehicle shall have a local kill switch onboard the UAV. |  |
| Respond Safely to Casualty | The Vehicle Shall Allow for Immediate Shutdown. | The vehicle shall have a remote kill switch at the control station. |  |
| Respond Safely to Casualty | The Vehicle Shall Allow for Immediate Shutdown. | Both must turn off all motors on UAV within 1 second of being pressed. |  |
| Respond Safely to Casualty | The Vehicle Shall Allow for Immediate Shutdown. |  | Range must be greater than 1000 ft. |
| Respond Safely to Casualty | The Vehicle Shall Allow for Immediate Shutdown. |  | The remote stop function must be separate from the main controller. |

1. Statistic supported by https://pubmed.ncbi.nlm.nih.gov/16856358/ and https://pubmed.ncbi.nlm.nih.gov/1115737/. [↑](#footnote-ref-2)