ANALYSIS OF ALTERNATIVES (AoA)

This Analysis of Alternatives will: (1) identify and evaluate various methods of obtaining needed goods and services, (2) determine which alternative is the most advantageous to the government, (3) document the value analysis, and (4) (For Economy Act Assisted Acquisitions,) attest that the work required to be performed is not an inherently governmental function.

To be completed by the USCG Program Manager or Requesting Unit Point of Contact:

Requesting Agency: United States Coast Guard (USCG)

Project Description: The purpose of the UAV capstone research project is to design a low cost, open architecture, and cooperative autonomous quadcopter. This drone should be capable of taking-off and landing from an autonomous surface vessel, transporting small cargo, and using computer vision to detect targets and landing zones. Together, these tasks support the objectives of an autonomous surface vessel in the Roboboat competition. All tasks should be completed autonomously, and the quadcopter should have the ability to coordinate objectives with the autonomous surface vessel.

To complete these objectives, the quadcopter must be capable utilizing positioning information from a multitude of sensors, including a satellite navigation receiver, lidar, barometer, accelerometer, gyroscope, compass, and digital camera, to maintain stabilized flight. Further, the quadcopter must respond safely to a variety of emergency conditions, such as loss of signal. Commercial and open-source quadcopters traditionally utilize autopilot software paired with a physical flight controller to process sensor data and control motor outputs. The flight controller hardware and autopilot software serve as the brains of the quadcopter and their reliable operation is responsible for the quadcopter's stable flight.

Analysis of Alternative Solutions:

USCG In-House Resources: CG-9313, the USCG's unmanned aircraft system program, has deployed fixed wing, unmanned ScanEagle drones onto several CG cutters. The CG Research and Development Center (RDC) has conducted research with independent contractors to test the deployment of vertical take off and landing drones from cutters. However, the USCG is not publicly dedicating in-house resources for quadcopter flight control.

Commercial Off-the-Shelf Software:

1. PX4: PX4 is a free, open-source quadcopter flight control software. PX4 software is covered under a permissive license, which allows it and its modifications to be incorporated into proprietary products. PX4 is highly compatible with software in the loop (SITL) technology and is configurable to suit a variety of airframes. PX4 includes modes for manual and GPS controlled flight, as well as an offboard command mode that is designed for integration into autonomous, computer-vision flight. PX4 offers extensive data logging that records all onboard sensor measurements and system states for the duration of each flight.

2. Ardupilot: Ardupilot is a free, open-source quadcopter autopilot software. Ardupilot's software license makes it free to use and it may be incorporated into final products, but all source code must be made available to the consumer. Much like PX4, it offers flight modes for manual and GPS controlled flight and is tunable to fit numerous airframes. Ardupilot extensively logs all sensor measurements and system states for the duration of each flight. Ardupilot does not natively offer an offboard command mode or SITL compatibility.

Commercial Off-the-Shelf Hardware:

1. Pixhawk 2.4.8: The Pixhawk is dedicated flight controller capable of running both PX4 and Ardupilot. The board contains an internal gyroscope and accelerometer and has five UART serial connections, in addition to SPI, I2C, and two CAN interfaces. It provides 168 MHz processing power with 256 KB RAM and 2MB flash memory. This is suitable for flight control, but the Pixhawk is not capable of performing computationally intensive tasks, such as computer vision-controlled flight. A serial port may be used to connect the Pixhawk to a separate processing unit.

The UAV Capstone group does not own a Pixhawk flight controller; however, the group's advisors have loaned the group two Pixhawk flight controllers for testing until new controllers can be acquired. A Pixhawk 2.4.8 flight controller costs approximately $120.

2. Emlid Navio2 with Raspberry Pi: The Emlid Navio2 is an extension board designed to fit on top of a Raspberry Pi 3. It is a physical flight controller that contains an onboard inertial measurement unit and barometer and has one of each UART, I2C, and ADC serial ports. The Navio2 is fully supported by Ardupilot but only offers experimental support for PX4. In preliminary testing, PX4 will compile on the Navio2, but it lacks the drivers needed to connect necessary additional sensors. The Navio2's physical connection with a Raspberry Pi makes the flight controller well equipped for computationally intensive tasks, such as computer vision-controlled flight. When used with the Raspberry Pi 3b, the Navio2 provides 1.4GHz processing power and 1GB RAM.

The UAV Capstone group already possesses four Navio2 flight controllers and three Raspberry Pi 3b's.

<u>Rationale for Selecting a specific solution</u>: USCG resources could be used to develop a proprietary flight controller to fit our mission needs; however, the goal of our research project to produce a low cost, open architecture solution makes open source, preexisting software a more appropriate solution. For our research, PX4 and Ardupilot have several key differences. PX4 natively supports an offboard command mode that is designed for computer-vision controlled flight., and PX4 supports SITL applications. Ardupilot does not offer this same level of compatibility. Both PX4 and Ardupilot are free, open-source software and, thus, PX4 is the most appropriate solution for our research.

The Navio2 flight controllers previously acquired by the UAV capstone group do not support PX4. The PX4-compatible Pixhawk flight controllers come with an acquisition cost of $120, but we believe the aforementioned benefits of PX4 justify this cost. The availability of loaned Pixhawk flight controllers mitigates the consequence of acquisition time by allowing testing to continue without delay.

In contrast to the Navio2, the Pixhawk flight controller cannot be used for computer-vision computations. However, an existing Raspberry Pi 3b can be connected to the Pixhawk flight controller over serial connection for computationally intensive tasks.

Therefore, our group plans to utilize PX4 with the Pixhawk flight controller to control our quadcopter. While this option yields an acquisition cost of $120, all other concerns can be mitigated with existing hardware and the capabilities to perform SITL testing and perform computer vision-controlled flight are essential to our research objectives.

<u>References:</u>

PX4 Overview: https://px4.io/software/software-overview/

Ardupilot Overview: https://ardupilot.org/index.php/about

CG VTOL: https://www.dcms.uscg.mil/Our-Organization/Assistant-Commandant-for-Acquisitions-CG-9/Newsroom/Latest-Acquisition-News/Article/2329061/coast-guard-evaluates-new-technology-for-unmanned-aircraft-system-operations/RDU

CG UAS: https://www.dcms.uscg.mil/Our-Organization/Assistant-Commandant-for-Acquisitions-CG-9/Newsroom/Latest-Acquisition-News/Article/1613588/acquisition-update-coast-guard-members-complete-small-unmanned-aircraft-system/

Navio2 Overview: https://navio2.emlid.com/

Pixhawk Overview: https://ardupilot.org/copter/docs/common-pixhawk-overview.html

Raspberry Pi 3b Overview: https://static.raspberrypi.org/files/product-briefs/Raspberry-Pi-Model-Bplus-Product-Brief.pdf

Pixhawk Cost: https://www.amazon.com/Readytosky-Pixhawk-Controller-Autopilot-Splitter/dp/B07CHQ7SZ4/ref=sr_1_4?dchild=1&keywords=Pixhawk+Flight+Controller&qid=1635818875&sr=8-4