The Unmanned Aerial Systems Flight and Payload Challenge

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The use of Unmanned Aerial Vehicle (UAV) Systems in the public safety sector has been limited to live stream video, recorded video and thermography. In addition those systems used have been small hobbyist systems incapable of long duration flight carrying heavy payloads. One of the key challenges for multi-agency critical incident events is the ability to manage communications especially in remote locations or where security and privacy are required. The cut off point for a search is typically 51 hours and a large wildfire on average lasts 37 days. The challenges to provide communication support are duration effected by weight, deployment time, turn around time and repair time. A communication support UAV must be light weight, have a high energy density, be ready to deploy out of the box, be simple to check and repair and be cost effective.

The system proposed herein meets these challenges. It is simple in design having only 50 components of 20 types. No components are bonded and the system can be completely disassembled for repair and replacement. The structural components are carbon fiber and 6061 T6 aluminum and the power components are designed for professional UAV use in the agricultural sector. All software is open source allowing for modification to meet specific mission requirements at a minimum cost. The UAV fits in the storage container fully ready to deploy without assembly. The system uses COTS hardware which is readily available.

The system as currently designed weighs 34.5 pounds, is capable of hovering in winds up to 23 mph and has duration capabilities as follows:

Estimated Performance in Terms of Time				
Payload Weight	Maximum Thrust Time	Hover Thrust Time	Factor	Points
0	15	64	0	0
10	10.8	46	1	46
15	9.4	40	3	120
20	8.5	36	6	216
			Total	382

I am an electrical engineer with 35 years in the aerospace industry including 8 years working on the US Army Aquila remotely piloted vehicle and the Lockheed Altair International lightweight UAV and other covert vehicles. I have also been a volunteer firefighter for over 20 years and understand the rigors of on scene operations and the communication challenges related to Incident Command where multiple agencies are involved. I am also a private pilot an AMA member and have been modeling for over 50 years. I have developed processes to link risk management and model based engineering to help optimize design and applied these to the NASA and DOD programs. I have also developed critical incident simulation/training software for the public safety sector and petrochemical industries. USAF trained technician.

Project Description

Submittal

This proposal composes the required parts for an entry submission, for the National Institute of Standards and Technology (NIST) challenge, Unmanned Aerial Systems Flight and Payload Challenge. The work and design presented are the sole creation of the submitter, William R. Gleason. To the best of my knowledge the design presented does not infringe, misappropriate or otherwise violate any intellectual property rights, privacy rights, or any other rights of any person or entity. In addition this proposal is not defamatory or libelous to any person or entity. The design presented is composed of commercial off the shelf (COTS) components which were selected based on their suitability to fulfill the required mission, weight and cost requirements, as well as meet the challenge timeline requirements. The selection and arrangement of the components into the design presented is the submitters own work.

State of the Art

The use of Unmanned Aerial Vehicle (UAV) Systems in the public safety sector, specifically search and rescue has been limited to live stream video, recorded video and thermography. Very little use has occurred in the area of communication support where there are few available resources or privacy is a concern. The traditional means of support has been through helicopters and other manned aircraft. Helicopters enter a high risk environment when operating below 1500 feet. UAVs can operate at a lower risk in the realm of 400 feet and below while in visual line of sight (VLOS). In the realm of heavy lift UAVs the market has been dominated by medium and large aerospace companies repurposing their systems for civilian use. Smaller agencies have been limited to small UAVs that were intended for the sport and hobby market which have limited lift capability and are designed primarily for video and photography applications.

Heavy lift UAVs have had their initial development in the agricultural industry where they are used for precision spraying. Three examples of systems designed for spraying are: DJI Agras MG-1, Zerotech Guardian Z10 and the Yamaha RMAX. They are each designed to carry a load of 22-44 pounds (10-20 kg).

For most all of the current systems available the key challenge is weight versus flight time and energy storage. For vehicles weighing less than 55 pounds the use of battery storage versus gasoline is about equal due to the higher weight of the engines and their low energy conversion (~35%). Where one third of the vehicle weight is allocated to energy storage electric powered systems are limited to approximately 1 hour of flight time. For the public safety mission especially search and rescue and wild land fire fighting a four hour flight time would be more appropriate.

Vehicle Description

The proposed air vehicle is shown in Figure 1. It is configured in an inline format with two pairs of coaxial rotors at each end and an open three bay mounting platform in the center.

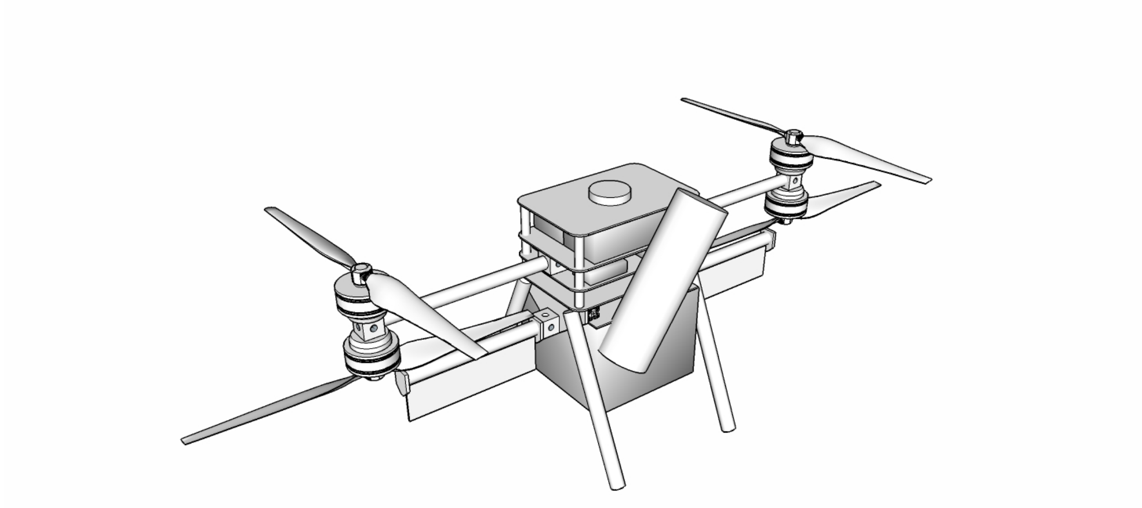

Figure 1: Air Vehicle

The top bay contains the primary batteries, the second bay contains the flight controller, electronic speed controllers (ESC), receiver, and power module. The third bay contains the optional parachute actuating system, servos and flight termination system. With the propellers extended the vehicle length is 66 inches in length. With the propellers folded the vehicle is 43 inches in length. The vehicle is 23 inches tall with the parachute installed and 20 inches tall without the parachute. The vehicle is 26 inches wide with the propellers extended and 19 inches wide with the propellers folded. The vehicle nominal weight is 34.5 pounds. Without the parachute the vehicle is symmetric along the x and z axes. With the payload installed the vehicle center of mass is below the motor supports. Actual center of mass has not yet been determined. The vehicle is constructed of carbon fiber plates and tubes which are connected using 6061 T6 aluminum components at the joints and held with mechanical fasteners. This will facilitate ease of assembly and repair. If the parachute is not used the third bay is used to carry additional batteries. If the parachute is used then the primary batteries are two 22 amp hour, 22.2 volt units connected in series (2S) for a nominal 44.4 volt output and a capacity of 44 amp hours. If the parachute is not used the batteries are replaced with four 16 amp hour, 22.2 volt units connected in a two parallel and 2 series (2P2S) configuration for a nominal 44.4 volts and 64 amp hour capacity.

The vehicle is intended to fly into the wind with the longitudinal axis in line with the wind direction. Forward motion is achieved by tilting the vehicle in pitch, The tilt is limited to 25 degrees fore and aft. This will provide for an estimated air speed of 23 mph. Further increase in pitch does not significantly increase air speed. The vehicle should be capable of hover in a 23 mph wind and will have sufficient maneuvering thrust available to maintain position. Yaw control is by differential torque applied to each motor pair. Lateral motion and roll are controlled by a pair of control surfaces located below the propeller disks along the x-axis. This method was selected to minimize vehicle width and weight, and to lessen the set up time.

The vehicle cost is estimated to be approximately $11,965 which includes the optional parachute. Spare parts for the vehicle are not included. The major components are summarized in Table 1 below.

Table 1: Major Component List and Cost

Item	Manufacturer	Model	Qty	Cost
Propellers	T-Motor	26 x 8.5 Carbon Fiber	4	$1,132.00
Motors	T-Motor	P80-120 KV	4	$800.00
ESC	T-Motor	Flame 100 Amp HV	4	$520.00
Batteries	Venom	3500 or 35001	4	$1,800.00
Receiver	Futaba	R3008SB FHSS	1	$60.00
Servos	Hitec	D951TW	2	$360.00
Flight Controller	3D Robotics	Pixhawk 2.1	1	$430.00
GPS	HERE	HERE GNSS	1	$720.00
Power Module	Home Made	Not Defined	1	$100.00
Flight Termination and Parachute	Fruity Chutes	Peregrine UAV 4	1	$2,950.00
Air Frame	Rock West	Multiple Components	1	$1,093.00
Computer/Tablet	Not Selected	Not Selected	1	$2,000.00
			Total	$11,965.00

The flight termination system (FTS) will have a power disconnect in the positive line going to each ESC. Arming the FTS will arm the vehicle. If the parachute is installed a second arming switch will arm the parachute so that it activates when the FTS is activated. The FTS will be activated through a separate and independent transmitter and receiver combination powered by a separate power source.

Performance Metrics

The vehicle performance was determined using the maximum weight of 55 pounds times a performance coefficient of 1.5 for a maximum required thrust of 82.5 pounds. The motor efficiency was set at 0.85 and the propeller thrust was reduced by 0.2 to account for propeller turbulence interaction. The electronic speed control loss was set at 0.2. Components were selected to have a safety factor of 1.4 where possible. The performance and design parameters are summarized in Tables 2 and 3 below.

Table 2: Performance in Terms of Time

Payload Weight	Maximum Thrust Time	Hover Thrust Time	Factor	Points
0	15	64	0	0
10	10.8	46	1	46
15	9.4	40	3	120
20	8.5	36	6	216
			Total	382

Table 3: System Operation Parameters

System Operation Parameters per Motor Metrics	Maximum Value	Hover Value	Units
Power Loading	0.73	0.29	hp/ft^2
Thrust Loading	8.61	12.70	lbf/hp
Lift per Motor	27.38	13.80	lbf
Power Input per Motor	2727	953	Watts
Motor Current	61.70	21.57	Amps
Power Out/Power In Ratio	0.87	0.87	Ratio
Required ESC Input Current	64.38	25.89	Amps
Vehicle Total Metrics	Value	Value	Units
Total Thrust	82.74	55.19	Pounds
Total Power Input	9485	3814	Watts
Total Motor Current	214.60	86.29	Amps
Total ESC Input Current	257.52	103.55	Amps

Ground Control Station

The ground control station (GCS) will consist of three parts; a hand held transmitter, flight termination transmitter and a laptop or tablet computer. The hand held transmitter will transmit using an FHSS protocol. The computer will use an open source mission planning and control software such as Mission Planner. It will provide the following basic functions as a minimum:

- Point-and-click waypoint entry, using Google Maps/Bing/Open street maps/Custom WMS.
- Select mission commands from drop-down menus
- Download mission log files and analyze them
- Configure APM settings for your airframe
- Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.
- See the output from APM's serial terminal

Verification and Time Allocation

The electronics systems will be assembled and tested on the bench to verify that all parameters and specifications are within the design specifications. The control software will be verified through a set of module tests and vehicle motion tests to verify the correct response. Individual motor thrust will also be determined.

It is anticipated that flight testing will be conducted at a 1000 acre site being developed as a county park in central Texas. The testing will be observed by the park development manager. Flight testing will be conducted with the parachute installed. Construction – 80 Hours, Software Modification – 160 Hours, Integration – 120 Hours, Test and Verification – 160 Hours.

Total Time: 520 Hours or 65 days.

Resume Summary

Education

M.A., Architecture, Sasakawa International Center for Space Architecture, University of Houston
B.S., Electrical and Computer Engineering, University of Wisconsin – Madison

Coursework

Aerospace Engineering, University of Texas, Austin TX
Neural Networks, Northeastern University, Boston MA

General Manager Houston Operations, Director of Houston Risk and Technology Services, Manager of System and Specialty Engineering, Senior Consultant
ARES CORPORATION, Houston, TX

- Established a System Analysis and Specialty Engineering consulting group within Risk and Technology Services to integrate Risk and System Analysis. Directed delivery of technology consulting engagements providing technical analysis for aerospace and petrochemical customers.
- Selected to provide **program organization and technical interface of government scientists** tasked to determine and specify the natural and induced environments for the Constellation Program launch vehicles, spacecraft, and support systems.
- Developed a proprietary, quantitative method, which combines Model Based Systems Engineering with Uncertainty based Risk Decision Principals to **optimize system performance, minimize cost and schedule impacts**, and provide program managers unbiased insight into the probability of program success while enhancing their decision-making capabilities.

Principal Engineer, LOCKHEED CORPORATION, Houston, TX

- Designed and provided analytical support for the upgrade of the Johnson Space Center System Engineering Simulator, which provides real time simulation of space vehicle dynamics.
- Established system requirements and performed conceptual and detailed hardware and software design for the development of covert electronic surveillance systems using both manned and unmanned aircraft. Security Clearance: Top Secret
- Developed Unmanned Air Vehicle technology for US Army, helped establish the design and manufacturing center and provided development test support. Security Clearance: Secret

Electrical Group Lead, TELEDYNE GURLEY, Troy, NY

Developed and implemented test methods for high resolution imaging satellite optical instruments. Generated system requirements, qualification, life, and acceptance test plans and procedures.

Public Safety

Klein Volunteer Fire Department, Spring TX
Pasadena Volunteer Fire Department, Pasadena TX

- Certified Texas Firefighter, Captain, Treasurer, Vice President, Certified Instructor
- ICS Coursework and Certification

Hobby

- Over 50 Years of free flight, control line, and radio control modeling including aircraft, helicopters, and multi-rotor
- AMA Member
- Private Pilot