Unmanned Aerial Systems Flight and Payload Challenge

Challenge application submission by:

esc Aerospace

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Cover Page and Abstract

Introduction

The benefits VTOL UAS in public safety applications are enormous. There are endless applications including data collection, surveillance, delivery/pickup, etc. The use of a UAS may greatly reduce the time associated with these functions which leads to higher mission success (saving lives). Many times, use of UAS may avoid the need for operational personnel to be placed in harmful/life-threatening situations. In addition to the time considerations, small UAS can go where it may be extremely difficult, if not impossible for an individual or other conventional equipment to go.

The overall utility of UAS in these applications is highly dependent on payload capacity, and flight time. These are dependent on a number of UAS systems design characteristics as well as external environmental conditions. By far, the largest contributor to payload capacity and flight time is the ***Power System (Battery(s)).***

UAS Systems

- Propulsion (motors, propellers, etc.)
- Frame/body
- Flight Controller
- Communications
- Navigation
- Gimbal
- Sensors
- Power System (Battery(s))

Most UAS manufacturers include estimated flight time in the product specifications. However, this estimate may not be reliable because actual flight time depends on payload (sensors, gimble, etc.), and environmental conditions (wind, altitude, etc.). These factors may be measured pre-mission and continuously during mission flight in order to give mission operators the ability to plan and execute the most efficient (and longest) missions.

Battery technology is improving rapidly. The typical sUAS battery is Lithium Ploymer (LiPo) and has an energy density between 150 and 200 watt-hours per kilogram (Wh/kg). Newer battery technology promises significant increases, but most of these technologies are not practical for sUAS use due to price, mass or other parameters. esc Aerospace has access to disruptive battery technology (graphene and carbon nanotube battery) ready for use in sUAS and that will provide energy density ***>400 Wh/kg (> 2X improvements).***

Our unique approach:

Our approach to challenge success is three-fold:

- **Exceptionally Qualified Team:** Our team has decades of experience in all technical, management and public safety application necessary to address all aspects of the challenge.
- **Optimized Power System:** Integrate a new technology battery that is significantly smaller, lighter, and provides > 2X more power density than traditional UAS batteries.
    - **Real-Time Mission Management System (MSS):** Our MMS will provide enhances Power Management and take into consideration such as load (sensors, gimble, etc.), environmental conditions (wind, altitude, etc.) and operational conditions (speed, acceleration, etc.)

This provides mission planners and operators the ability to plan and execute optimal public safety missions that ultimately … ***save lives.***

Target flight time for each payload and fuel / energy source of your UAV

In actual public safety application, flight time for a UAS will vary greatly depending on the payload, environmental conditions, and operational characteristics. For these reasons, we propose defining flight time improvements as a multiple improvement over existing commercial sUAS. We will create a test environment where an "off-the-shelf" sUAS is tested with the same (similar) payload, fly the same test mission and flight time measurements will be taken to calculate the actual flight time differences.

It is our objective to improve flight time by greater than 2X.

Project Description

The following is a description of our proposed project intended to improve the viability of use of Vertical takeoff and landing (VTOL) Unmanned Aircraft Systems (UAS) in public safety applications.

Overall Objective: develop a VTOL UAS with 2X longer flight time as measured against other commercially available, off-the-shelf UAS with same payload, flying same operational mission, in same environmental conditions.

To achieve this objective, the esc Aerospace Team will implement the following technical capabilities:

- **Optimized Power System:** Integrate a new technology battery that is significantly smaller, lighter, and provides 2X more power than traditional UAS batteries.
- **Real-Time Mission Management System (MSS):** Enhance current MMS that:
  - Manages power consumption
  - Factors in load (sensors, gimble, etc.), environmental conditions (wind, altitude, etc.) and real-time power consumption

This will provide mission planners and operators the ability to plan and execute optimal public safety missions that ultimately … ***save lives.***

Project Plan

esc Aerospace has more than 16 years of experience in designing on-board systems – the core element of an unmanned aerial vehicle - and integration of UAS for specific customer needs. We draw on a large pool of the best suppliers in the market and aim for providing the best available systems for our customers. We are not bound to certain suppliers but select the best parts and concentrate our effort on optimizing integration and the overall system.

Through a new partnership with HyCarb, we are able to use batteries with a much higher capacity compared with any other product on the market. Considering the short time frame of this challenge, we will re-use and upgrade our existing MMS battery/power management module and software to maximum flight time.

The combination of system design/integration, a vast network of the best suppliers in the market and our decades of experience in on-board design of unmanned system (aerial and space systems) is a unique combination that will ensure project success. To run this project efficiently, we will establish an Integrated Product Team (IPT) with our partners.

Lars Weimer is the NIST challenge project manager. He has more than 18 years of experience managing aviation and aerospace projects. Each team partner will nominate a primary point of contact for the IPT and will have a minimum of weekly meetings to discuss progress, issues, next steps and resolve issues and take action if needed. We will follow an iterative development methodology based on integration of enhanced capabilities of existing subsystems/technologies. This methodology is based on Agile development principles:

- Focused on individuals and interactions rather than on processes and tools.
- Focused on development rather than comprehensive documentation.
- Focused on customer collaboration rather than on contract negotiation.
- Focused on responding to change rather than following a plan.

The lifecycle pattern of an agile development model is made of five phases depicted in the figure above. This approach enables us to deliver results in the time frame given by the NIST challenge.

Additionally, the esc Aerospace team will leverage the capabilities of Florida's aerospace community, manufacturing and development resources, and academia to build upon esc's extensive expertise in the UAS market.

Below is a high level graphical representation of the overall project plan.

Subsystem Development

Three subsystems will be developed and integrated to provide a modified VTOL UAS that will meet all of the goals of the challenge.

Power Subsystem

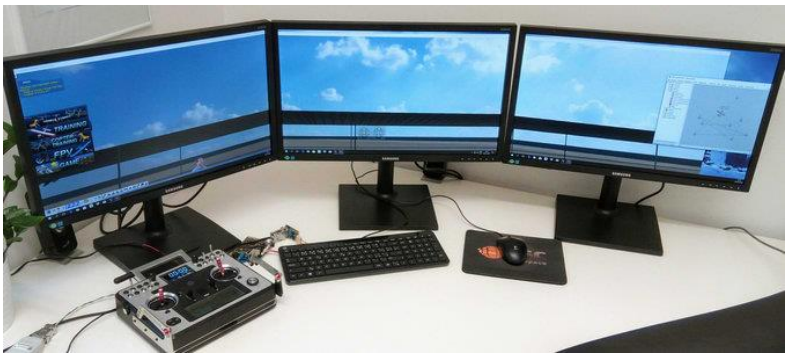
The Power Subsystem is an energy dense battery that will be implemented by our teammate, HyCarb. HyCarb's advanced graphene and carbon nanotube battery will be utilized and integrated into the UAS platform. To insure proper fit/function, custom mounting/connections may be required to be fabricated.

HyCarb is utilizing the superior capacity and resiliency of advanced carbon nano-technology to reduce the weight of batteries in order to improve payload capacity and extend the range of UAS.

Testing of the HyCarb battery has shown greater than 2X increase in power density over current UAS batteries (150 - 200 watt-hours per kilogram (Wh/kg)). It is our objective to utilize a HyCarb battery with: > **485 Wh/kg.**

Management System (MSS)

The Real-Time MMS will be based on esc Aerospace years of experience in development of UAS avionics/flight controls. The MMS will be based on previously developed product and be enhanced for power consumption optimization while taking into account factors in load (sensors, gimble, etc.), environmental conditions (wind, altitude, etc.) and operational factors.



The figure above shows an esc Aerospace MMS development setup. The development setup includes an ability to integrate with a small UAS flight simulator. Developing an MMS is easier when the flight tests are done in a simulator. This is called Hardware in the Loop (HIL). (1) The MMS hardware is fed with flight data generated by the simulator (lat/long, altitude, velocity, power consumption, etc.) (2) the MMS computes the new control values (i.e. servo positions) which are sent back to the simulator. The MMS also calculates estimated flight time utilizing load information (sensors, gimble, etc.), and environmental conditions (wind, altitude, etc.). This information is made available to the operator. (3) The simulated aircraft performs the flight as commanded by the autopilot, closing the loop. (4) The mission planned in the Ground Control Station is executed by the simulator and the MMS.

UAS Platform Subsystem

We will procure an VTOL sUAS that is inexpensive and easily customizable. This platform will be modified, as needed, to enable integration with our enhanced MMS and power subsystems. The UAS platform will also be modified, as needed, to meet the requirements of the challenge:

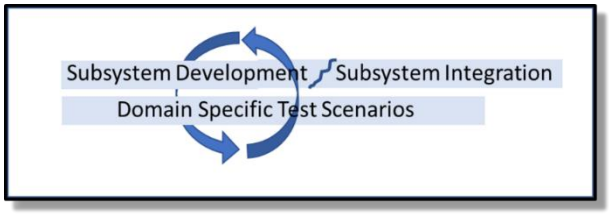
- Autonomous and human controlled flight;
- Vertical take-off and landing (VTOL) UAS with the ability to hover in place;
- Free flying, no tethers;
- Provide an interchangeable payload adapter (per specification to be provided);
    - Allow for the different weight payloads
    - 10 inch x 10 inch plate with 8020 aluminum extrusion rails attached to two opposite sides of the plate to attach the payload.
    - at least four points of connection to the 8020 rails
    - T-Slotted Aluminum Extrusions 10 inch long, with a 1 inch x 1 inch cross-section
    - support payload volume will be approximately 8 x 8 x 6 inches

Entire prototype UAS will fit within the specified 6 ft. x 4ft. x3 ft., and weigh no more than 55 pounds (UAS + payload).

Integration and Test

As shown in **Resume Information for Key Team Members** section, we have access to integration and test resources, not only from our named teammates, but through our team's affiliations, throughout the academic community (including Embrey-Riddle Aeronautical University (ERAU), and University of Central Florida (UCF)) and UAS community at large (Association of Unmanned Vehicle Systems International (AUVSI)).

Our team functions as an Integrated Product Team (IPT) and will iterate the development of test scenarios, subsystems development and subsystems integration to achieve all objectives. There is a constant feed-back loop between test/integration and development to ensure all issues identified are resolved and that all objectives are obtained.



Our team has extensive experience in support to UAS in public safety application. They will assist in the development of test scenarios that depict various real-world applications.

As stated previously, flight time for a UAS will vary greatly depending on payload, environmental conditions and operational characteristics. Many commercially available UAS will advertise extensive flight times. For this challenge to be successful, all test results ***must be "normalized"*** for specific payload, environmental and operational factors.

Our overall test approach consists of three steps:

1. Development of real-world test scenarios relative to use of UAS in Public Safety
2. Baseline of commercially available (un-modified) UAS against these scenarios, taking into consideration factors of payload, environmental, and operations)
3. Evaluation of esc Aerospace UAS against these test scenarios and comparison against commercially available UAS to show normalized flight time improvements.

The overall test and evaluation process will be supported by Embry-Riddle Aeronautical University (ERAU) and the ERAU MicaPlex. Through the esc Aerospace team, we have access to engineering resources as well as a state-of-the-art R&D complex with ability to test UAS systems in controlled environments (indoor and outdoor).

It is our objective to improve flight time by greater than 2X.

Additionally, through our relationships with AUVSI, ERAU and UCF we plan to host UAS in Public Safety awareness days, including educational sessions and demonstrations. It is anticipated that these events will take place at ERAU (Daytona Beach), UCF (Orlando) and other locations throughout the state.

Resume Information for Key Team Members

The esc Aerospace team consists of companies and subject matter experts to provide all the requisite capability and experience to meet the objectives of this project.

esc Aerospace

The esc group of companies is over sixteen-years old, and highly respected as a leader in the field of on-board flight software and instruments, on-board computers and GNC/AOCS products for unmanned systems. esc Aerospace has offices in Munich Germany, Prague Czech Republic, and Orlando Florida. Areas of business include Aerospace, IT systems, Communications, Defense, Transportation Systems and Control and Automation and Unmanned Systems.

esc Aerospace line of business (escDRONES™) offers affordable, robust, UAS platforms (multi-copter, helicopter, fixed wing) that may be configured to carry an almost limitless number of payloads (controlled autonomously or manually) to meet an enterprise's needs.

Our customers take advantage of our unique know-how gained through R&D projects funded by customers like the European Space Agency (ESA). esc Aerospace is an early adopter of high precision positioning and satellite communication solutions for UAS.

Safety features built into our drones are a prerequisite for many law enforcement and firefighting use cases. These features include: parachute, optical & acoustical warning signals, mini transponder (ADS-B), geofencing, LED lights.

esc Aerospace offers on-board systems for integration into a variety of UAS airframes. Our brand-new sixth generation of on-board systems / avionics for UAS features:

IMA - Integrated Modular Avionics - Standardized communication interfaces and software for maximum compatibility with other systems and avionics

- Time and Space Partitioning - Operational flexibility and online updating of deployed software, specific applications or configuration
- Hosting of Prototype Applications - 3rd party applications can be hosted in the operational environment – no need for additional avionics or devices
- Multicore Capability & Performance - Scalability to new CPU cores and evolving hardware facilitates customized and complex software algorithms
- Independent Levels of Security - Multiple levels of criticality ensure high level fault tolerance and prioritization for security/reliability

We integrate the usage of UAS and other technologies into a branded offering, esc Multi-Service Aerial Platform (escMSAP™). We also work with enterprises that are faced with a growing threat associated with the use of UAS for espionage, sabotage, or simply from accidents related to hobbyist drones (esc Counter UAS (escCUAS™)). For any of our offerings we enable integration into an enterprises Risk Management Systems and/or operational systems.

esc Aerospace specific responsibilities on this project include:

- Project management
- Systems engineering
- Controller board (MMS) development
- Test

Lars Weimer – Project Lead

Highly experienced and dynamic aerospace manager, with vast background of skills and experience leading technical and non-technical international teams. Strategic business development and successful delivery of new projects, focal point towards industrial and institutional partners. More than 18 years of demonstrated achievements in all space and aviation system life cycle phases. Successful technical/financial management of 10 subcontractors and customers from 8 different nations in parallel. Dipl.-Ing. (German degree, equivalent to M. Sc.) in Aviation and Aerospace Engineering.

Lorenzo Forzini – Systems Engineer

Senior System Engineer and UAS on-board system expert with more than 10-years of experience in architectural design and integration of SW/SW and SW/HW components for unmanned systems. He has been managing teams in UAS future concepts and technology programs with reference to power management and power subsystem integration. Master of Research (MRes) in Advanced Navigation and Communication Satellite Systems. As well as a Master of Science (M.S.) in Electronics Engineering.

Dr. Vitaliy Velychko – Systems Engineer

With a Ph.D. in Macromolecular Physics and over 20-years of R&D experience in electronics development and related fields, Dr. Velychko is one of esc's most senior experts in OBC (on-board computer) and GNC (guidance, navigation and control) development for UAS. Recently he was head of all on-board systems development for a 9ft fixed-wing VTOL drone. Dr. Velychko is supported by esc Aerospace software engineers with decades of experience in aviation, space, defense and UAS projects.

ASEC – Public Safety UAS Subject Matter Expertise

Aviation Systems Engineering Company, Inc. (ASEC) is a veteran-owned small business headquartered in Lexington Park, Maryland, with offices in Anacostia, DC; Jacksonville, FL; Dallas, TX; and Seattle, WA. ASEC has the required corporate capability, and proven aviation processes, tools, and knowledge drawn from thirteen years of systems engineering, test conduct, training, consulting, regulatory compliance, and operational experience while supporting public safety. ASEC maintains a diversified technical staff that includes over 200 engineers, analysts, and operators, including former military personnel who boast decades of engineering, operational, and test experience.

ASEC pilots fly company owned manned, and unmanned aircraft for sensor testing, mapping, inspection, research, surveillance, defense, security, and training. ASEC staff has extensive sensor experience, to include: LiDAR, multispectral, thermal, magnetometer, and optical. They are proficient in autonomous operations, regulatory processes, complex operations, package delivery, classified security programs, and incident management.

ASEC's Flight Department is certified by the International Standard for Business Aircraft Operations (IS-BAO) Level 2, and offers a high degree of safety and professional flight services. ASEC's best practices include domestic and international elements that supplement our UAS Safety Management System (SMS).

As an expert for the U.S. delegation for the International Organization of Standards (ISO) Technical Advisory Group for ISO/TC 20/SC 16 for UAS, ASEC participates in the development of international standards. ASEC regularly participates in the NASA UAS Traffic Management (UTM) efforts and is a member of the Sense and Avoid, and Communication / Navigation Working Groups. ASEC is designated as an Aviation Safety Officer for one of the six FAA UAS Test Sites. ASEC is a voting member for ASTM International as a F38 UAS committee member. ASEC is a member of the State Emergency Response Team for Florida as the small UAS director, and a founder and board member for the Florida Emergency Management Unmanned Consortium, setting standards for the safe integration of UAS in disaster management. ASEC sits on the national board of directors for Association of Unmanned Vehicle Systems International (AUVSI) and is a Co-chair for its Trusted Operator Program for UAS.

ASEC is the only company in the United States to obtain approval to operate sUAS in the Washington DC Special Flight Rules Area for Seat Pleasant Police Department. ASEC is the only company to have UAS courseware approved for training by the Maryland Police and Correctional Training Commissions. ASEC staff are graduates of the Airborne Law Enforcement Association (ALEA) Small UAS Operations Course and have lectured at Regional ALEA Safety Seminars on UAS. ASEC wrote the UAS auditing process for Local Government Insurance Trust (LGIT) to assess risk before awarding coverage to public safety member organizations. ASEC has developed turn-key programs for local municipalities and police departments, to include manual development, safety and training program creation, regulatory coordination, and acquisition support. ASEC coordinated small UAS activities during Hurricane Irma in the State Emergency Operations Center. ASEC provides safety reviews and field monitor support for all UAS operations conducted at the Shuttle Landing Facility (KTTS) at NASA Kennedy Space Center (KSC).

ASEC has over 240,000 manned flight hours, greater than 14,000 unmanned flight hours, flying over 100 type/model aircraft. ASEC's commercial sUAS operations perform under 14 CFR Part 107 authority, using its broad spectrum of certificated pilots, ranging from Part 61 pilots to Remote Pilots.

Brent Kelovan – Subject Matter Expert

Brent is the Director of Commercial Drones at Aviation Systems Engineering Company (ASEC). Prior to entering private industry, Brent logged 3,000 pilot flight hours while serving 20 years in the U.S. Navy, including ground breaking efforts to develop its two largest drone programs. He currently represents the United State as a drone expert to the International Organization of Standards (ISO), serves on the National Board of Directors for the Association of Unmanned Vehicle Systems International (AUVSI), is a voting member of American Society for Testing and Materials (ASTM) International Committee for Unmanned Aircraft Systems (UAS), participates in several NASA UAS-related research projects, is the President of the AUVSI Florida Peninsula Chapter, and a founding board member of Florida Emergency Management Unmanned Consortium. Brent holds Federal Aviation Administration (FAA) airman certificates as a Commercial Pilot and Remote Pilot. Mr. Klavon has over 29 years of aviation training, project management, and operational flight experience. He is an aviation and technical professional whose experience includes policy formulation and implementation, program and budget management, and team collaboration. He has a B.S., Business Logistics, Pennsylvania State University, 1988

HyCarb – Battery Engineering and Development

HyCarb, Inc. is a Florida-based, for-profit, woman-owned small business, headquartered at the University of Central Florida Business Incubator. HyCarb is developing leading-edge batteries, super-capacitors, fuel cells, solar panels, sensors, catalysts, filters and transistors.

There is a global need to move beyond polluting energy and integrate renewable

energy technologies into everyday life. HyCarb, Inc. is creating the next-generation energy harvesting, energy storage, and efficient energy end-use products for today and tomorrow. Technologies utilize the innovative, functional benefits of nanotechnologies (graphene and carbon nanotubes) to make devices that scale into any size product from microchips to utility-scale renewable energy systems. Micro-scale energy generation and storage capabilities are necessary for the emerging markets such as wearable electronics, Internet of Things (IoT) sensor, and unmanned systems markets.

Imagine a battery…
That's 5x lighter
That lasts 5x longer
That charges 5x faster
That's 90% recyclable

Light weight, powerful, long-lasting and quickly rechargeable power is essential to realizing the potential of UAS and other unmanned systems!

Yang Yang, Ph.D. - Chief Technical Officer

In addition to leading the HyCarb development, Dr. Yang is the Assistant Professor, Nanoscience Technology Center at the University of Central Florida (UCF). Dr. Yang's research interests include advanced materials and their applications in renewable energy devices, environmental science and smart electronics. Our research focuses on design and synthesis of highly ordered porous films with precisely controlled chemical composition and morphology; fundamental investigation of new electrochemical, electronic and optical properties; and exploration of novel cutting-edge technologies arising in these advanced materials. His educational credentials include Peter M. and Ruth L. Nicholas Post-Doctoral Fellow — Rice University, USA (Advisor: Dr. James M. Tour); Alexander von Humboldt Fellow — University of Erlangen-Nuremberg, Germany (Advisor: Dr. Patrik Schmuki); Ph.D. — Tsinghua University, China (Advisor: Dr. Longtu Li & Xiaohui Wang)

Brent A. Terwilliger, Ph.D.

Dr. Brent Terwilliger is a full-time faculty member of the Embry-Riddle Aeronautical University (ERAU) Worldwide campus where he serves as an Assistant Professor of Aeronautics and Program Chair for the Master of Science in Unmanned Systems (MSUS) degree in the College of Aeronautics. Dr. Terwilliger currently chairs the National Business Aviation Association (NBAA)-Business Aviation Management Committee (BAMC) UAS subcommittee, sits on the editorial board for the Journal of Unmanned Aerial Systems, and is working on several research publications detailing his work on application of UAS for emergency response, human/machine-interface (HMI), modeling and simulation, and situational awareness. He has more than 10 years' experience working in the aviation/aerospace industry leading integration testing, simulation and training development, and documentation at Rockwell Collins Simulation and Training Solutions (STS, formerly NLX Corp and Evans & Sullivan) and ENSCO (subcontractor to Lockheed Martin-Owego). His research includes UAS development and application, teleoperation, situational awareness, human-machine interfaces (HMI), and modeling and simulation, with results presented and published at multiple international industry and academic forums, including Association for Unmanned Vehicle Systems International (AUVSI), Inter-service/Industry, Training, Simulation and Training Conference (I/ITSEC), the Midwest UAS Conference, and Unmanned Systems Canada.