Grand Challenge
UNIVERSITY OF COLORADO **BOULDER**
INTEGRATED REMOTE AND IN SITU SENSING

Integrated Remote and In Situ Sensing
College of Engineering and Applied Sciences
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Variable-Pitch Heavy Lift Quad – A Configurable Long-Endurance UAS for Public Safety Applications

a submission to

The Unmanned Aerial Systems Flight and Payload Challenge
Public Safety Communications Innovation Accelerator
National Institute of Standards and Technology

presented by

University of Colorado Boulder
Integrated Remote and In Situ Sensing Initiative

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Abstract

Over the past few years, unmanned aircraft systems (UAS) have become pervasive in their applications and utilities. Specifically, UAS with vertical take-off and landing (VTOL) capabilities have seen wide spread application due to their ease of use, ability to operate in restrictive and difficult environments, and their ability to hover in place. Due to their mechanical simplicity, the most widely deployed type of VTOL aircraft are electric quadrotors (a.k.a. mutli-rotors) that use direct-drive motors spinning fixed-pitch propellers. However, their use by first responders, fire fighters, and search and rescue teams has been limited due to their limited payload capacity (typically less than 5 lb) and limited flight times (less than 30 minutes). In support of providing a new capability for public safety uses, the University of Colorado at Boulder is proposing the development of the Variable Pitch Heavy Lift Quad (VP-HLQ) in response to the Unmanned Aerial Systems Flight and Payload Challenge sponsored by Public Safety Communications Innovation Accelerator. Instead of using multiple electric motors directly driving fixed-pitch propellers, the proposed solution utilizes a quadrotor configuration, using variable-pitch propellers, driven by a single gasoline-fueled internal combustion (IC) engine. The quadrotor configuration of the vehicle maintains the ease of operations in difficult environments, while the use of an IC engine will dramatically increase flight time and payload capacity. Because the proposed design is scalable and highly configurable, it will enable a family of configurations to be utilized and deployed by first responders. In addition, because the proposed design is based on commercial off-the-shelf parts, the airframe will be low-cost and highly maintainable with readily available components. For the Prize Challenge Competition, the VP-HLQ is expected to provide a maximum flight time of 2 hours with a 20-lb payload, 3.2 hours with a 15-lb payload, and 4.4 hours with a 10-lb payload, at a 10,000-ft density altitude, all while remaining under an all-up takeoff weight (AUW) of 55 lb. For the competition, the proposed aircraft is predicted to achieve a final combined score of 1,575 points and repeatedly land within a 3-ft radius from its launch point. Due to the onboard clutch mechanism, and variable pitch rotors, the VP-HLQ will be capable of autorotation for enhanced safety of operations.

Project Description

The application and use of small unmanned aerial systems (sUAS) below 55 lb continue to grow at unprecedented rates because of their ability to significantly enhance many different mission areas. For first responders, sUAS provide a new and enhanced ability to provide aerial imagery for situational awareness, act as communication relays for disjoint units in tough RF environments, and with remote and in situ sensing capabilities enhance measurements of weather aloft as well as the conditions on the ground. However, current design trends of commercial systems below 55 lb have limited their wide spread application to first responders due to their limited payload capacity and restrictive flight times.

In response to the Unmanned Aerial Systems Flight and Payload Challenge sponsored by the Public Safety Communications Innovation Accelerator, and in support of developing a new platform to enhance the utility of sUAS aircraft with VTOL capabilities for first responders, the Integrated Remote and In Situ Sensing (IRISS) initiative at University of Colorado Boulder is proposing the design and development of the Variable Pitch Heavy Lift Quad (VP-HLQ), shown in Figure 1. In addition to being specifically designed to meet the stated goal of the prize competition of maximizing flight time while providing a significant payload capability, the proposed solution is technically aligned with the stated objectives of the prize competition by being scalable and highly configurable, and thus adaptable to the unique mission requirements of firefighter and law enforcement scenarios. To maximize the ability of the project to lead to a technical outcome that demonstrates considerable progress towards the challenge goals, the proposed design reduces project schedule and cost risks by basing the design on readily available commercial off-the-shelf parts.

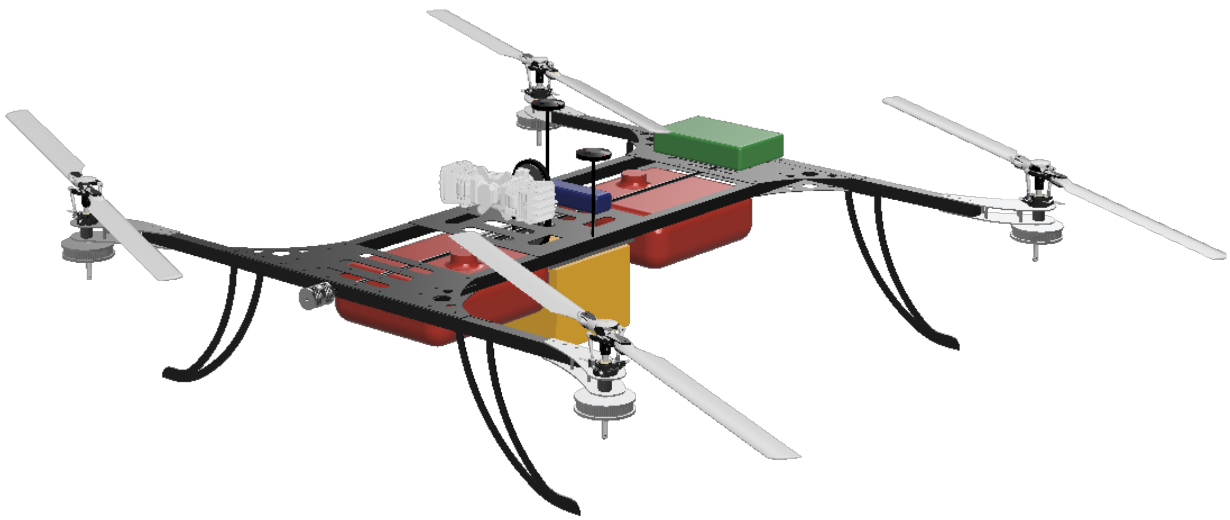

Figure 1: 3D Rendering of the Proposed VP-HLQ Concept

Solution

There are two well-known principles that the VP-HLQ design utilizes to significantly increase payload capacity and flight time: a low disc loading (thrust per disc area) greatly increases the efficiency of a rotary-wing design[1]; and that the energy density of gasoline is almost a factor of 100 times more than a standard LiPo battery[2]. Instead of using multiple electric motors directly driving fixed-pitch propellers, the proposed solution utilizes a quadrotor configuration of large variable-pitch propellers driven by a single gasoline-fueled internal combustion (IC) engine. The quadrotor configuration of the vehicle maintains the ease of operations in difficult environments, while the use of an IC engine will dramatically increase flight time and payload capacity. In essence, the VP-HLQ tries to combine the efficiency of a traditional helicopter while benefiting from the control simplicity of a direct-drive quadrotor. As such, the competitive advantage of the VP-HLQ design is the use of large efficient rotors, driven by a fuel-injected gas IC engine, based on a simplified drive train and control mechanisms that maintains agile and precise position control.

[1] Wieslaw Zenon Stepniewski, C. N. Keys. **Rotary-wing aerodynamics**, *Courier Dover Publications*, 1979. ISBN 0-486-64647-5

[2] https://www.aps.org/publications/apsnews/201208/backpage.cfm

The use of variable-pitch propellers is the key design feature that enables the use of large rotors driven by a centrally located IC motor. With direct-drive propellers, the electric motor changes speed at a very high rate, typically greater than 100 Hz, to maintain attitude and position control of the vehicle. However, IC engines do not have the instant torque and responsiveness of electric motors, and thus cannot adjust their speed at the frequency required to maintain control of a quadrotor configuration. A variable-pitch rotor overcomes this problem by utilizing servos mechanisms to control the pitch, and thus thrust, of the rotors while being spun at a constant rotational rate. Because the rotors can all be spun at the same constant rate, with small electric servos used to control the thrust (pitch) of individual rotors at a high rate (~300 Hz), a centrally located motor can be used with a simple drive train to distribute power. Because all rotors can be spun at the same constant rate, the drivetrain can be designed to operate the engine at its most efficient operating condition where specific fuel consumption is minimized.

In addition to maximizing flight time and payload capacity while remaining below 55 lb AUW, the design of the VP-HLQ is based on the design requirements to: utilize commercial off-the-shelf (COTS) components to reduce costs and increase component availability for long-term maintenance; and to minimize design complexity to reduce design, program, and cost risks. For an effective helicopter design that meets the requirements of the competition, a rotor diameter on the order of 6 to 10 ft would be required. However, there are very few known helicopter systems[3][4][5] that have significant flight time above 1-hour for a 20-lb payload while remaining below the 55 lb AUW limit. In general, there is lack of COTS components that enable a cost-effective helicopter solution in the size category required by the competition. Thus, to increase the lift capacity and decrease the disc loading (to increase efficiency) utilizing widely available COTS components, a quadrotor configuration using medium-sized RC helicopter rotor blades was chosen.

Design

The conceptual design of the VP-HLQ utilizes a DA-100 electric fuel injected engine[6], centrally mounted on a carbon fiber frame, spinning 520 mm rotors[7]. The IC engine is connected to a clutch mechanism, driving a centrally mounted drive shaft. The drive shaft is then connected to the rotors through a timing-belt and pulley mechanism that provides the required counter-rotation propeller motion. To minimize vibration of the system, a twin-cylinder motor is selected and all systems, including rotors, motor, and payload will be soft mounted to the frame. The required payload adapter is centrally located below the motor for weight balance. The overall dimensions of the vehicle in a flight ready configuration is shown in Figure 2. To facilitate the rapid deployment by first responders, the vehicle was designed to fit within the maximal dimensions of the 6 x 4 x 3 ft box by simply folding the rotors, and thus is flight ready out of the box with no tools or assembly.

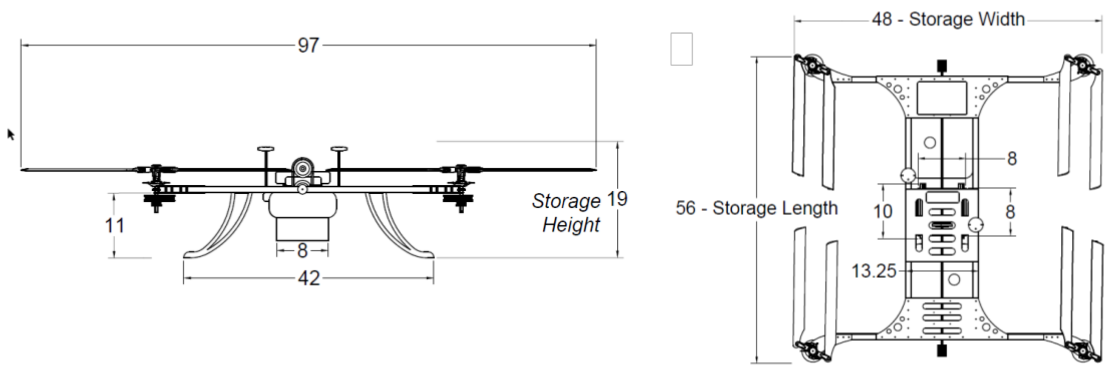

Figure 2: Dimensional Drawing of VP-HLQ in Flight Ready Condition (Left) and in the Storage Configuration (Right)

[3] www.bergenrc.com
[4] https://en.wikipedia.org/wiki/Yamaha_R-MAX
[5] http://www.leptron.com/leptron_avenger_uas_helicopter.html
[6] http://www.hfeinternational.com/shop/engines/da100efi
[7] https://hobbyking.com/en_us/520mm-carbon-fiber-helicopter-main-blades-1pair.html: rotors are commonly referred to in the individual blade size such that a 520 mm rotor blade has a total diameter of 1.1 m.

A detailed weight budget of the conceptual design was performed to analyze performance, select rotor size, and validate compliance to the 55 lb maximum weight, and is summarized in Table 1. The total empty weight of the airframe, without fuel and payload, is estimated to be 24 lb. With a 10-lb payload, the remaining weight for fuel is 21 lb, and with a 20-lb payload the fuel budget is 11 lb. Given a density of 6.3 lb/gal for gasoline, a 3-gallon fuel volume will provide a usable fuel load while minimizing size and weight of the fuel tanks. To balance the weight of the fuel, two 1.5-gal fuel tanks, seen on the bottom of the frame on either side of the payload box, will be utilized.

The budget estimate of the proposed solution is presented in Table 2 and shows the estimated system cost, including command and control, is under the competition requirement of $20,000. From the table it is clear that the most expensive component of the vehicle is the electric fuel injected (EFI) motor. Though there is a significant cost increase with an EFI system, the increase in efficiency and robustness in varying atmospheric conditions will be beneficial to the competition and first responders.

Table 1: Total Weight and Fuel Budget

System	Weight
Engine / Muffler / ECM	6.5 lb
Frame	5 lb
Drivetrain / Belt / Clutch	4 lb
Rotors / Heads	3.5 lb
Fuel Tanks / Lines / Connectors	2 lb
Avionics / GPS	1.5 lb
Battery System	0.75 lb
Misc Hardware	0.75 lb
Airframe Total	**24 lb**
Maximum Fuel Load	3 gal
Maximum Takeoff Weight	**55 lb**

Table 2: Budget Estimate

System	Budget Est
EFI Motor	$ 7,000
Frame	$ 2,000
Rotors and heads	$ 1,500
Fuel system	$ 500
Flight Control System	$ 1,500
Ground Station	$ 1,500
Comunication System	$ 1,000
Battery and Electrical System	$ 500
Misc	$ 500
Shipping Container	$ 1,500
Payload System	$ 100
Total =	**$ 17,600**

Performance Evaluation

To evaluate the expected performance of the VP-HLQ, a preliminary power analysis was done to estimate the flight time of the vehicle with the different payload weights. The power required for a given thrust value in a hover condition can be estimated using:

$$P_{req} = \sqrt{\frac{T_{req}/T_{eff}}{2\rho A}} \Big/ P_{eff}$$

where P_{req} is the power required per rotor, T_{req} is the thrust required per rotor, T_{eff} is the efficiency of the propeller, ρ is the density of the air, A is the disc area of the rotor, and P_{eff} is the efficiency of the transmission system. Given the total power requirement for hover, the specific fuel consumption of the motor can be used to estimate a fuel burn rate. From the equation, a total power of 5.6 hp (4.1 kW) is estimated for level flight with an all up weight of 55 lb (25 kg). In calculating the performance, the density of a hot, semi-humid day in Boulder, CO was assumed giving a density of the air of 0.9 kg/m^3[8], the thrust efficiency was estimated to be 0.8, and a transmission efficiency of 0.5 was used. The selected motor is expected to provide a specific fuel consumption of 0.97 lb/hp-Hr (0.6 kg/kW-Hr) at 6 hp (4.4 kW)[9].

[8] Density estimated using these conditions: 35 deg C, 50% relative humidity, at an altitude of 1850 m
[9] Specific fuel consumption provided by HFE over technical phone call

By integrating the fuel consumption over time as fuel is depleted, a prediction of the total estimated flight time can be made. However, this does not account for maneuvering and motor idling time during the competition. Thus, to estimate the achievable hovering time for the competition, the total estimated hovering time is given by:

$$t_{est} = t_{max} * 0.9 - 10$$

where t_{est} is the estimated hovering time for the competition, and t_{max} is the maximum theoretical flight time, in units of minutes. Essentially, a 10% safety factor is taken off the total flight time and then 10 minutes of maneuvering time is expected.

From the above equations, the VP-HLQ is expected to provide a maximum flight time of 2 hours with a 20-lb payload, 3.2 hours with a 15-lb payload, and 4.4 hours with a 10-lb payload, all while remaining under a 55-lb AUW. Thus, for the competition, the proposed aircraft is predicted to achieve a final combined score of 1,575 points as shown in Table 3. To enable precision landing within a 3-ft radius from its launch point, a precision landing system[10] will be installed.

Table 3: Predicted Competition Score

Payload [lb]	Fuel Load [lb]	All-up Weight [lb]	Hover Time Est [min]	Score Factor	Score
20	11	55	120	6	720
15	16	55	196	3	588
10	18.9	52.9	267	1	267
				Total Score =	**1575**

Project Plan

To ensure the proposed solution can deliver a high-quality technical outcome in pursuit of the challenge goals within the limited schedule and resources during the competition, the VP-HLQ is designed to utilize as many COTS as possible. The design objective to utilize readily available COTS also reduces project design and cost risks as many of the performance metrics and capabilities have been previously validated, reducing the amount of required verification and validation testing of custom systems. To minimize schedule risks, long-lead items such as the EFI engine and clutch mechanism will be purchased as early as possible. In addition, an agile and iterative program management mantra of *Fail Early, Fail Fast, Learn Cheaply* will be followed that focuses on testing as a critical part of every phase of development. To prototype and test as often as possible IRISS will utilize its available infrastructure of fabrication labs (that includes rapid prototyping capabilities such as 3D printers, access to machine shop, and composite fabrication capabilities), our systems integration lab for electronic testing and simulation capabilities, as well as our indoor and outdoor testing facilities. A project plan with milestones for the project is shown in Figure 3.

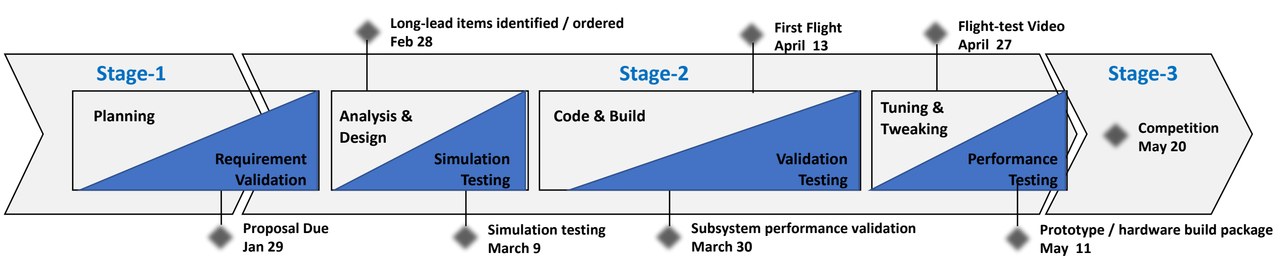

Figure 3: Project Plan with Milestones

[10] https://irlock.readme.io/v2.0/docs

Resume Information for Key Team Members

Brian Argrow, Ph.D.
Chair, Ann and H.J. Smead Aerospace Engineering Sciences
Director, Integrated Remote and In Situ Sensing, University of Colorado at Boulder
Curriculum Vitae: https://experts.colorado.edu//vitas/102860.pdf
LinkedIn: https://www.linkedin.com/in/brian-argrow-9b83461a/

Brian Argrow (Ph.D. 1989 Aerospace Engineering, University of Oklahoma) is Professor of Aerospace Engineering Sciences, founding RECUV director (emeritus), and former Associate Dean for Education for the College of Engineering and Applied Science. His current research includes small UAS airframe design and sensor integration, and integration into the National Airspace System, with other research including aero/gas dynamics, and engineering education. His teaching awards include the W.M. Keck Foundation Award for Excellence in Engineering Education, and he is a University of Colorado President's Teaching Scholar (a lifetime appointment) and an inaugural fellow of the CU Center for STEM Learning. Professor Argrow co-chaired the first Symposium for Civilian Applications of Unmanned Aircraft Systems (CAUAS) in 2007 and chaired the 2nd CAUAS in 2014. He is a fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a past chair of the AIAA UAS Committee. In 2009 he completed four years of service on the USAF Scientific Advisory Board, and he recently served on the NASA Advisory Council's Unmanned Aircraft Systems Subcommittee. He is currently a member of the Aeronautics and Space Engineering Board of the National Academies of Sciences, Engineering, and Medicine, and he serves on the ASTM Committee F38 on UAS, F38.02 Flight Operations.

Relevant Publications:

- Argrow, B., "Chap. 9: Unmanned Aircraft System Design," in *Introduction to Unmanned Aircraft Systems*, 2nd Ed., Douglas M. Marshall, Richard K. Barnhart, Stephen B. Hottman, Eric Shappee, and Michael T. Most, Eds. CRC Press (2016).
- Stachura, M., Elston, J., Argrow, B., Frew, E.W., and Dixon, C., "Chap. 90: Certification Strategy for Small Unmanned Aircraft Performing Nomadic Missions in the U.S. National Airspace System," in *Handbook of Unmanned Aerial Vehicles*, Kimon P. Valavanis and George J. Vachtsevanos, Eds. Springer-Verlag, (2013).
- Argrow, B., "Unmanned Aircraft Systems Operations in US Airspace," in *Encyclopedia of Aerospace Engineering,* Eds. R. Blockley and W. Shyy, John Wiley: Chichester. DOI: 10.1002/9780470686652.eae460, Dec (2012).

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Cory Dixon (Ph.D. Aerospace Engineering 2010, M.S. Aerospace Engineering 2003, B.S. Computer Science 2001, B.S. Aerospace Engineering 2001) has been involved with the design, development, and testing of autonomous robotic systems for over sixteen years ranging from small unmanned aircraft systems (sUAS) to explosive ordinance disposal (EOD) ground robotic systems. Dr. Dixon's Ph.D. research focused on using unmanned aircraft as airborne communication relays in ad hoc wireless networks. Dr. Dixon started flying model aircraft when he was ten years old and has been involved in the ground-up design of seven different unmanned aircraft systems that have been successfully deployed in commercial and academic field experiments. In total, he has worked with or flown over thirteen different unmanned aircraft systems, with commercial and open source autopilot systems, ranging in field deployments from artic climate research in Alaska, to photogrammetry of the beaches of Vieques, Puerto Rico, and tornado chasing across the Central Great Plains. Dr. Dixon returned to CU Boulder after spending seven years in industry designing and deploying commercial robotic systems. While at Stratom, Inc. Dr. Dixon focused his research on ground robotic systems and was a Principal Investigator for a Phase I, and two Phase II DoD SBIRs, managing over $3M in total research budget. He ultimately departed the company as the Director of R&D to become a founding partner of Black Swift Technologies, a small business focused on designing and deploying custom sUAS solutions for commercial and government clients.

- Experienced Program Manager and UAS Engineer
- Deployed on 6 major UAS field campaigns from the artic to the Caribbean
- Lead engineer on ground-up design of 7 commercial and academic UAS platforms
- 20+ Years RC Piloting Experience

Relevant Publications:

- Cory Dixon and Eric W. Frew, "Decentralized Extremum-Seeking Control of Nonholonomic Vehicles to Form a Communication Chain," in Advances in Cooperative Control and Optimization, Lecture Notes in Computer Science, Vol. 369, Michael J. Hirsch, Panos Pardalos, Robert Murphey, and Don Grundel, Eds. Springer-Verlag, Nov. 2007, ISBN: 978-3-540-74354-5.
- Timothy X. Brown, Brian M. Argrow, Eric W. Frew, Cory Dixon, Daniel Henkel, Jack Elston, and Harvey Gates, "Experiments Using Small Unmanned Aircraft to Augment a Mobile Ad Hoc Network," in Emerging Technologies in Wireless LANs: Theory, Design, and Deployment, Benny Bing, Ed. 2007, Chp. 28, pp. 123–145, ISBN-13: 9780521895842.
- Cory Dixon and Eric W. Frew, "Maintaining Optimal Communication Chains in Robotic Sensor Networks using Mobility Control," ACM/Springer Mobile Networks and Applications Journal, Special Issues on Mobility of Systems, Users, Data and Computing, 14(3):281–291, June 2009

<u>Steve Borenstein</u>

Senior Engineer, Integrated Remote and In Situ Sensing, University of Colorado at Boulder
LinkedIn: https://www.linkedin.com/in/sborenstein/

Steve Borenstein is the Chief Engineer of Unmanned Aircraft Systems at IRISS. Steve graduated with a BS in Computer Science and Electrical Engineering in 1999, and a Master of Science in Electrical Engineering in 2017, both from the Colorado School of Mines. Steve leads IRISS engineering of custom unmanned aircraft autopilot integrations, sensor packages, telemetry systems, onboard computing systems, and rapid 3D prototyping. Major project achievements at CU include redesigning and deploying the avionics stack in high performance storm chasing aircraft; implemented a real-time operations web application for operations remote monitoring; designed the operational control system and networked telemetry system for the operation of multiple simultaneous aircraft; custom sensor, payload, telemetry and integrated deployment mechanism design for UAS deployed weather balloons; heavy lift fixed wing and rotary aircraft design; vehicle mounted communications and computing systems. Prior to starting at IRISS, Steve has held positions as a Senior Measurement Engineer at an oil and gas pipeline, Controls Engineer specializing in water measurement, Airfield Lighting and Controls Engineer, and as a Field Engineer specializing in remote high precision GPS installations for geophysical research. In graduate school, Steve focused on Robotics and Computer Vision. In his free time, Steve flies RC fixed wing airplanes and helicopters, builds custom electronics, and designs custom CNC machines.

- Experienced Electronics and Integration Engineer, with extensive communication systems experience
- 30+ Years RC Piloting Experience
- FAA Private Pilot Certificate
- FAA Remote Pilot Certificate

Daniel Hesselius
Senior Pilot, Integrated Remote and In Situ Sensing, University of Colorado at Boulder

Dan Hesselius is a lifelong aerial enthusiast: he has designed and flown unmanned aircraft since 1979. His fascination with aircraft led him to the University of Oklahoma, where he studied Aerospace Engineering and Aviation, graduating in 1995 with a Bachelor's degree. After college, he continued to build his flight experience by flight instructing and operating charter flights on the east coast. In 1998 he became an Air Force Pilot. In the Air Force he served two tours in Bosnia, two tours in Iraq and one tour in Afghanistan as a combat pilot. He has been an airline pilot since 2001 and has accumulated over 11,000 total hours as a pilot in over 50 different aircraft types. He served as an aircraft accident investigator with the Air Force and has assisted the NTSB on accident investigations. Dan is highly decorated as a pilot, holding accolades for piloting both manned and unmanned aircraft, including being a three-time US National Champion Radio Control Pilot. At CU, he is a UAS Engineer and Pilot that deploys on field missions with multiple IRISS projects. In the summer of 2016 he became Director of Flight Operations for the CU Boulder campus.

- 38+ Years as competition level RC pilot
- FAA Airline Transport Pilot, Certified Flight Instructor, Flight Engineer and Ground Instructor
- Director of Flight Operations for the CU Boulder campus

Constantin Diehl
Business Development Manager, Integrated Remote and In Situ Sensing, University of Colorado at Boulder
LinkedIn: https://www.linkedin.com/in/constantin-diehl-13723612/

15 years of International Automotive Industry experience, focusing on highly technical products. Extensive product development experience including R&D, Design, Engineering, Manufacturing Planning, Product Launch and Quality. 10 Years International Program Management and Sales Experience. Proven ability to manage complex multinational, technically challenging programs. Proven ability to manage key account relationships and large-scale projects. Engineering Expertise: Validation Testing, Design for Manufacturing, Design for Plastic Injection Molding, Advanced Plastics Engineering, Advanced Quality Planning and Quality Assurance.

- President/CEO of UAS Colorado, Colorado's Unmanned Aircraft Systems Industry Business League
- Leads Rocky Mountain UAS Professionals Meetup Group with 500+ Professional Members
- FAA Private Pilot Certificate, 450 flight hours
- FAA Remote Pilot Certificate

Students
Undergraduate Students, Integrated Remote and In Situ Sensing, University of Colorado at Boulder

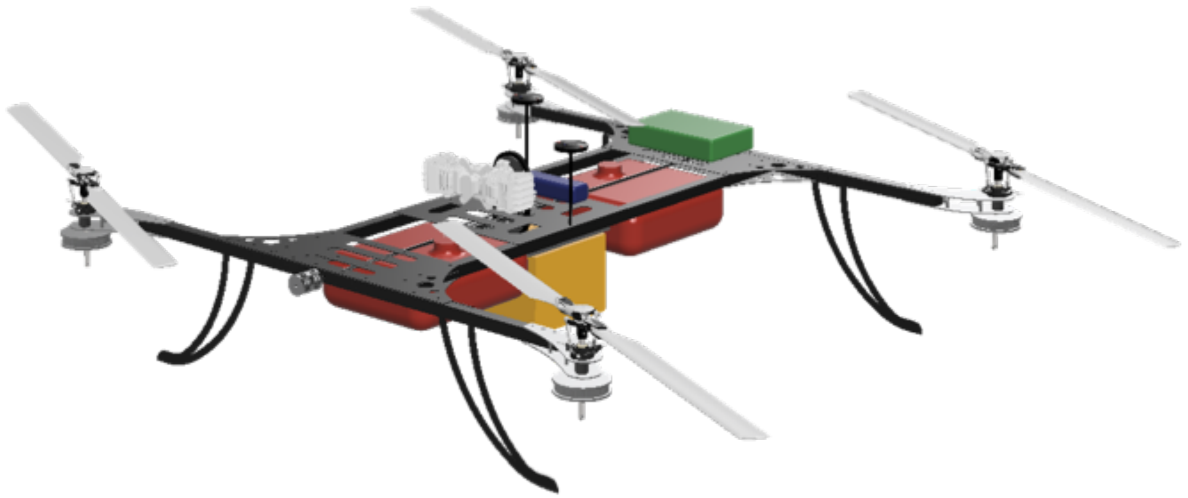
IRISS maintains an experienced team of engineering undergraduate students as part of our core capabilities. The students are instrumental in support the IRISS mission to design, develop, and deploy advanced UAS systems that support the numerous applications areas of CU Boulder researchers. The student's capabilities and experience include certified flight instructors for CU Boulder, FAA remote pilot certified pilots, FAA Private Pilots, machinists, 3D print experts, as well as being skilled and knowledge aerospace engineers with extensive RC modeling and flight experience.

Variable-Pitch Heavy Lift Quad –
A Configurable Long-Endurance UAS for Public Safety Applications

University of Colorado Boulder – Integrated Remote and In Situ Sensing Program
POC: Cory Dixon, Ph.D. – Cory.Dixon@Colorado.edu

Project Summary

The proposed solution utilizes a quadrotor configuration with variable-pitch propellers, driven by a gasoline-fueled internal combustion (IC) engine. The quadrotor configuration of the vehicle maintains the ease of operations in difficult environments, while the use of an IC engine and large rotors will dramatically increase flight time and payload capacity. Because the proposed design is scalable and highly configurable, it will enable a family of configurations to be utilized and deployed by first responders.



Participant Summary

The faculty, staff, and students in the Integrated Remote and In Situ Sensing Initiative represents over 110 years of combined experience in designing, developing, and deploying small unmanned aircraft systems. The team has facilities for fabrication, engineering, indoor flight testing, and three outdoor flight testing locations.

Technical Outcome

The VP-HLQ is expected to provide a maximum flight time of 2 hours with a 20-lb payload, 3.2 hours with a 15-lb payload, and 4.4 hours with a 10-lb payload at a 10,000-ft density altitude, all while remaining under an all-up takeoff weight of 55 lb. The aircraft is predicted to achieve a final combined score of 1575 points and land within a 3 ft radius from its launch point.

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INTEGRATED REMOTE AND IN SITU SENSING

Letter of Support

Letter of support From Leptron Unmanned Aircraft Systems

TO: Whom it May Concern

RE: The Unmanned Aerial Systems Flight and Payload Challenge
Public Safety Communications Innovation Accelerator
National Institute of Standards and Technology

As presented by:
University of Colorado Boulder
Integrated Remote and In Situ Sensing Initiative [IRISS]

Leptron Unmanned Aircraft Systems is prepared to support the IRISS team as manufacturer and deploy services for the systems described in their: Variable-Pitch Heavy Lift Quad – A Configurable Long-Endurance UAS for Public Safety Applications.

Description of support services, for example:

- Metal, plastic, composite fabrication and assembly of system hardware components
- Fleet operations and logistics support of service systems deployment

Sincerely,

Jeff Popiel

President & CEO

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