Heavy Payload and Versatility Using Tailsitter with Cyclic and Collective Controls

CONTESTANT: HEUROBOTICS CORPORATION

TECHNICAL POC:
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ABSTRACT: Unlike typical fixed-pitch blades used on quad and octocopters, Heurobotics' unique approach employs cyclic and collective control of proprietary rotor blades optimized for increased endurance. The collective control can create over 150 lbs of static thrust enabling heavy payload carrying capacity. Vehicle dynamics integrates twenty control degrees-of-freedom using surfaces, split surfaces and prop-rotors to provide a kinematic flight solution. This approach lends itself to a twin-engine tailsitter configuration, a mechanically-simple design for ease of use.

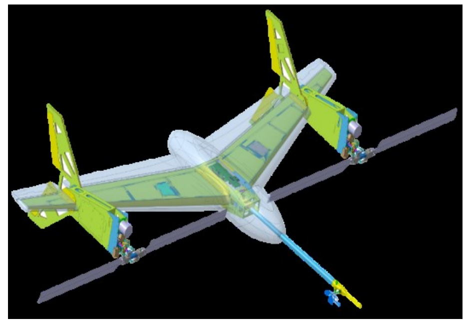
The impact of this approach is a platform capable of VTOL that still can travel over 70 knots optimized for efficiency on a fixed-wing. This conserves critical energy that can be used to hover longer over areas of interest.

TARGET FLIGHT TIME: 45 minutes with 20 lbs on battery

The Unmanned Aerial Systems Flight and Payload Challenge
January 26, 2018

PROJECT DESCRIPTION

Heurobotics Corporation is a spin-off from Embry-Riddle Aeronautical University in Daytona Beach, Florida. With support of this top aviation and aerospace school, Heurobotics has been researching and developing a twin-engine tailsitter UAV using cyclic and collective control for several years, making us uniquely qualified to employ this approach.

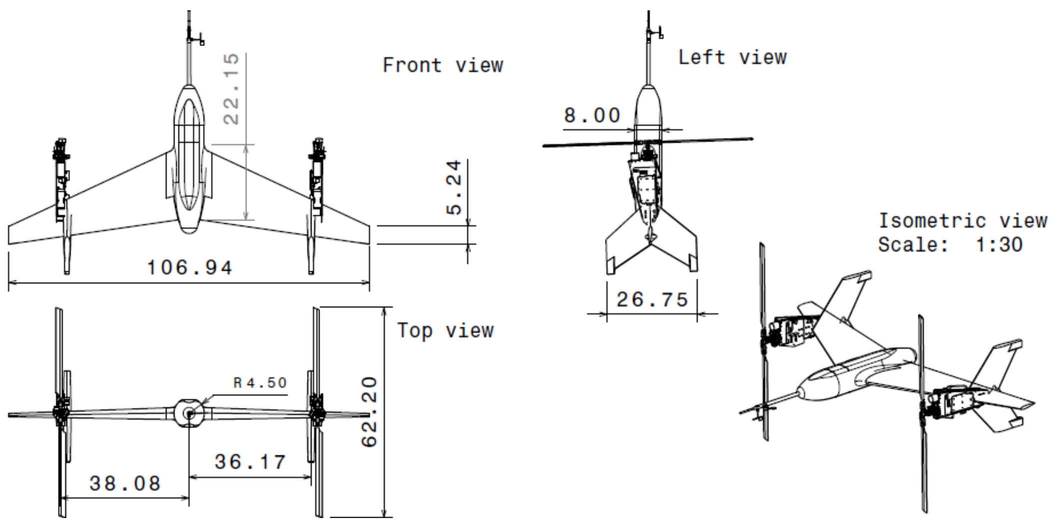
Heurobotics flagship vehicle the Mk II

Three all-electric prototypes have successfully flown a variety of mission profiles and payloads including a beta test for a local county government. The operation required antennae of varying strength (5 DB – 20 DB) to be hoisted into the air and held at specific altitudes to obtain radio strength readings. Heurobotics' tailsitter configuration made it the optimal shape for this payload. Similarly, the 10x10 base plate with 8-inch extended payload for this Challenge can be mounted to the airframe while maintaining a stable center of gravity (primarily due to the control power found from cyclic capabilities).

Close-up of prop-rotor head with cyclic and collective

The vehicles have been capable of flight from hover to its maximum speed and any speed in between using the full sphere of wind angles, angle of attack and angle of sideslip. This is done with a mix of movable aerodynamic controls and the generation of controlling forces and moments from the propulsors, in this case prop-rotors with active cyclic and collective controls used during all phases of flight. To maximize the versatility of the aircraft, the control power designed into the prop-rotors is substantial. This not only allows the vehicle to operate in the entire sphere of wind angle, but also provides the capability of generating large path or velocity changing accelerations (g-loadings). For example, the vehicle can reverse direction from maximum forward speed to its maximum forward speed *in the opposite direction* by executing a 180-degree pitch rotation with zero angular change to the flight path angle. During this maneuver, only the direction of the flight path angle changes, which results in a momentary high-speed backward, but completely controllable flight. In addition, the control power on the vehicle allows the vehicle to go from maximum speed to a stationary hover with no pull-up maneuver. It can be done in the same way that a humming bird stops from a traveling motion. It is the case that the flight path angle can be controlled independently of the vehicle speed from stationary to maximum speed.

The maneuverability of this vehicle allows for near all-weather vertical takeoff and landing capabilities. By turning the wing away from a landing surface wind, the vehicle can land in extremely strong winds.



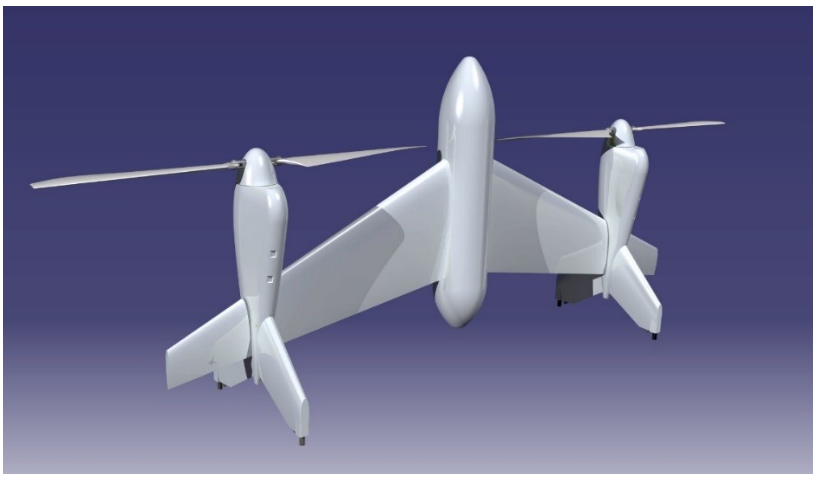
A helicopter also uses cyclic and collective control, however, its airframe is minus a fixed-wing making it not aerodynamically efficient. Tailsitters combine the attributes of VTOL with fixed-wing aircraft; however, other tailsitter UAVs on the market have simply used fixed-pitch blades, which makes them less wind-tolerant. In emergency management situations, weather should not prohibit employing UAV technology. These UAVs are also unable to carry heavy payloads.

Wingtra with fixed-pitch blades Max Payload 1.8 lbs

Aerovironment Quantix with fixed pitch blades

In terms of safety, Heurobotics cyclic and collective control means unlike quad/octocopters, the vehicle can perform one engine-out flight in cruise and can perform controlled autorotation from hovering flight. The two off-nominal cases can be combined to fly the vehicle some distance in the event of a single-engine failure then transition to an autorotation in a confined area. The vehicle can still maneuver at nearly full-control power in an autorotative state even with a loss of all propulsive power.

Therefore, Heurobotics intends to develop a version of its flagship vehicle fitting the requirements laid out for this Challenge. The vehicle will be a twin-engine tailsitter UAV using cyclic and collective control of proprietary rotors designed for efficiency and strength.



Rendering of optimized rotors

This will require fabrication of a wingbox in which Catia drawings are created and a carbon fiber supplier has already been identified. In-house mechanics will assemble the carbon fiber plates (which are cut to specification by the same material supplier). Existing electric propulsive pods can be mounted to this wingbox and aerodynamic surfaces applied.

The challenge to overcome with this approach is not the hardware design of the vehicle, rather it is the software required for flight control. The controllability challenges associated with this class of aircraft are mainly due to the unique flight profile of tailsitters, particularly the transitions required for the takeoff and landing maneuvers, and the complex, nonlinear aerodynamics encountered throughout this diverse flight profile. Heurobotics has defined the necessary control laws to fly this type of vehicle with full stability. Additionally, the Company holds a provisional patent on an attitude-control algorithm which can also be applied to this vehicle. Autonomous position-hold has been developed to ensure the UAV maintains its location with a 5 ft variance on the x,y,z axis per the Challenge Rules.

PERFORMANCE METRICS

Heurobotics has been flight testing its prototypes for years with an emphasis on safety. The successful commercialization of UAVs for civil and commercial applications depends on safely operating them especially in populated areas. Therefore, the flight testing to obtain performance metrics will follow a specific interval starting with hovering at 50 ft altitude for 35-minutes with zero payload. As in past tests, battery power readings are taken in order to estimate remaining flight time.

Subsequent flights will swap-out batteries for fully-charged ones and payload will be increased by 5 lbs until reaching 20 lbs. With successful completion of a 35-minute flight, the test will increase flight time by 5 minutes going through the same payload weight from 0 lbs to 20 lbs. Remaining battery power will be calculated based on this baseline information. Flight test will continue with flight durations increasing by 5 minutes each interval until the target time of 45 minutes with 20 lbs is (or is not) met. Battery power thresholds will be established once baseline is understood.

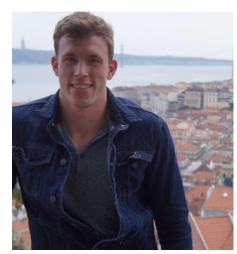
BATTERY READINGS TO POPULATE THE BELOW:

	0 lbs	5 lbs	10 lbs	15 lbs	20 lbs
35 Minutes					
40 Minutes					
45 Minutes					

KEY TEAM MEMBERS

Dr. Richard "Pat" Anderson is the technical point of contact for this Challenge and is also the Chief Scientist for Heurobotics. As a Professor of Aerospace Engineering at Embry-Riddle Aeronautical Engineering and Director of the Eagle Flight Research Center, Dr. Anderson has guided companies and students through diverse aerospace and aviation challenges. Dr. Anderson is a past Carnegie/CASE Florida University Professor of the Year. He holds a Ph.D. in Mechanical Engineering, a Master's and Bachelor's degree in Aerospace Engineering, an Airline Transport Pilot certificate, a Certified Flight Instructor certificate in multiple categories and classes, an Airframe and Powerplant certificate and an Inspection Authorization. Dr. Anderson has been awarded the Researcher of the Year and Faculty Advisor of the Year. Dr. Anderson's research has focused on interdisciplinary topics that span aviation and engineering. He was recently the advisor to ERAU's entry in the NASA Green Flight Challenge, which resulted in the development and flight of the world's first gas/electric direct drive hybrid airplane. Dr. Anderson has worked in the area of flight controls on both manned and unmanned aircraft. He has performed research on Boeing Phantom Work's X-45 and the Boeing ScanEagle UAV.

- Doctor of Philosophy — University of Central Florida
  Mechanical, Materials and Aerospace Engineering
- Master of Science — Pennsylvania State University
  Aerospace Engineering
- Bachelor of Science — Pennsylvania State University
  Aerospace Engineering



Mr. Zachery A. Kern is the business point of contact for this Challenge and is also the Chief Operating Officer of Heurobotics who spends his time directly working on the flagship vehicle. Mr. Kern has earned his Master's and Bachelor's degrees in Aerospace Engineering from Embry-Riddle Aeronautical University. He has experience with flight controls and sensor fusion including the development of a nine state Kalman filter for a small autonomous system. Technically skilled, Mr. Kern also has a passion for the business economics of these technologies to keep the project on task while remaining focused on the end goal of commercialization. Mr. Kern has been responsible to build the original tailsitter UAV for the company from the ground-up. He has three years of extensive knowledge in Catia and Matlab in order to develop the necessary hardware. He has also been the Director of Flight Testing spending time in the field developing flight test plans and obtaining and analyzing flight test data. Mr. Kern will lead the prototype development for this UAS Challenge.

- Master of Science — Embry-Riddle Aeronautical University
  Aerospace Engineering
- Bachelor of Science — Embry-Riddle Aeronautical University
  Aerospace Engineering

Mr. Patric Hruswicki is the flight test pilot for Heurobotics. Mr. Hruswicki was first introduced to the hobby of aeromodeling at a young age by his father. He caught his first taste of flight at age six—learning how to fly a .46-size trainer, and soon flying solo and moving up to large scale aerobatics planes. In 2012, Mr. Hruswicki placed well in the Nats that year, and in October, won the Micro Heli Cup at the iHobby Expo. Winning the Micro Heli Cup began his team sponsorship with Empire Hobby and Gaui and opened the door to many new opportunities in the helicopter realm of the hobby. In recent years, Mr. Hruswicki has focused mainly on his helicopter skills. He was invited to compete in the 2016 Extreme Flight Championship (XFC). In addition to practicing helicopter flying, he has recently been introduced to the popular world of drone racing and enjoys building and racing quadcopters.

He attends Embry Riddle Aeronautical University where he is a sophomore with a major in aerospace engineering and minor in unmanned aircraft systems.

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Heurobotics operates at a University-owned facility in which there are (2) ATP Mechanics who provide fabrication work of the UAV platform. These individuals will be retained for this Challenge.

Additional support has come from various faculty members and doctorates of mechanical engineering; engineering physics; and aerodynamics. These same individuals can be retained for this Challenge.

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Project Summary

- The aim of the project is to develop a tailsitter UAV using cyclic and collective control for longer endurance and more payload carrying capacity similar to the Company’s flagship vehicle (shown below). Proposed tools include Catia for design of new vehicle platform with the Challenge Requirements.

Participant Summary

- Heurobotics has been developing a tailsitter UAV with cyclic and collective control for the past several years with three working prototypes. Key team members include Dr. Richard “Pat” Anderson a PhD in aerospace engineering and Mr. Zachery Kern a Masters in Aerospace Engineering.

Technical Outcome

- Commercially available technology employs fixed-pitch control which does not allow for scaling up in size nor heavy payload carrying capacity. The technical outcome should prove a more robust flight control system and approach for long endurance and heavy payloads.

EMBRY-RIDDLE
Aeronautical University
Office of the Senior Vice President and Chief Financial Officer
Randall B. Howard, Ph.D.

January 25, 2018

To Whom It May Concern,

Embry-Riddle Aeronautical University is proud of its reputation as the world's largest and most respected university specializing in aviation and aerospace. Embry-Riddle is dedicated to providing applied research solutions to the challenges facing our nation's aerospace, aviation, and related industries. One of our signature areas of research is the emerging area of unmanned aerial systems (UAS).

I write this letter in support of the concept paper by Heurobotics Corporation for their Vertical takeoff and landing (VTOL) UAS which they are entering in the NIST Unmanned Aerial Systems Flight and Payload Challenge. Their tail-sitter concept offers many advantages to traditional VTOL vehicles and its ability has already been demonstrated over a significant period of time with three working prototypes. Therefore, I believe a version specific to this competition's requirements can be prototyped and operated with relative certainty.

I believe any prize money provided to Heurobotics will likely lead to an accelerated commercialization of their cutting edge technology. Embry-Riddle has a vested stake in Heurobotics and therefore has allowed Heurobotics to utilize certain University facilities, equipment, and resources. Our hope is for the company to be one of the first of many successful spin-offs to join our burgeoning Aerospace Research and Technology Park adjacent to the University's worldwide campus in Daytona Beach.

Sincerely,

Randall B. Howard, Ph.D.
Senior Vice President and CFO

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