HAMR-XL a Hybrid Electric Multi-Rotor

Advanced Aircraft Company

Contestant: Advanced Aircraft Company (AAC)

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Abstract:

This approach is unique with the incorporation of two new technologies. The first are aerodynamic improvements to double the aerodynamic efficiency of a multi-rotor. The second is the incorporation of a hybrid electric propulsion system. The combination of these two technologies will increase the max flight time greater than 3 hours, while simultaneously maintaining the benefits of a conventional multi-rotor.

AAC is currently commercializing the HAMR UAS. HAMR is an acronym for hybrid advanced multi-rotor. The HAMR has a max flight time of 3.5 hours. The 4th prototype of the HAMR is flying and the 5th prototype is under construction currently. First delivery of a HAMR to a beta customer is planned for March 5th. For more information on HAMR, please visit: http://www.advancedaircraftcompany.com/hamr/

We understand that a requirement of this challenge is a newly designed and built aircraft. The existing HAMR has a max takeoff weight of 36 pounds. The proposed HAMR-XL (extra large) would be a clean sheet design of a larger aircraft with a 55 pound max takeoff weight utilizing the technologies developed with our 36 pound aircraft. It is interesting to note that two of our customers have asked us to develop a larger version at the 55 pound weight limit. We have previously considered developing a HAMR-XL. However, the timeline of this challenge is aggressive, and we are focused on a first production run of our HAMR UAS for Beta customers. Therefore, this proposal is being submitted mostly for notification purposes of AAC's R&D and to request to speak with the challenge organizers, because we will not be able to commit to a May 20th demonstration date. If there is adjustment to the timeline, please notify us.

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Background

Advanced Aircraft Company (AAC) is startup long endurance VTOL UAS manufacturer. Our first product, the HAMR UAS, is a hybrid electric multi-rotor with a 3.5 hr max endurance, targeting commercial and military markets. The HAMR achieves long endurance for two reasons. First, aerodynamic design improvements increase the aerodynamic efficiency of the aircraft. Second, the aircraft incorporates a hybrid electric propulsion system.

Figure 1. HAMR UAS Flying Over Charles City County, VA.

This long endurance serves our commercial customers (the UAS service providers) by enabling them to increase the utilization of their workforce, which lowers their cost per acre to acquire data by up to 45% relative to battery powered multi-rotors. Using FAA Part 107 operations, the HAMR can survey 1,500 acres in a 45 minute flight carrying 6 pounds of payload. For extended line of site operations, the HAMR can survey 3,500 acres in a 1 hour and 35 minute flight carrying 4 pounds of payload.

For our military customers, there are the hand launched Group 1 size, or the catapult launched Group 2 size, UAS. The HAMR spans the gap between the Group 1 and Group 2 UAS. Relative to today's Group 1 UAS, the HAMR provides dramatically increased capability for the same logistical footprint and price point.

Contestant's Knowledge, Skills, and Capabilities

As a startup UAS manufacturer, we have demonstrated the knowledge, skills and capabilities to commercialize a product. It also should be noted that our supplier base is a critical component of our team as well. The prepreg carbon fiber fabrication, electric machines (generator and motors) and power electronics are critical components that we acquire from our suppliers. For more information on our team's background and skill sets, please visit: http://www.advancedaircraftcompany.com/team/

Current State-of-the-Art

KEY SHORTCOMINGS, LIMITATIONS, COSTS, AND CHALLENGES CURRENT SOLUTIONS

BATTERY POWERED MULTI-ROTORS

There has been a recent proliferation of battery powered multi-rotor systems to serve the commercial and consumer markets. A limited number of demonstrator multi-rotor aircraft have used fuel cells, but so far none of these have achieved operational status. All multi-rotor UAS in production today are battery powered. Considering the specific energy of battery technology that achieve the C-rate required of aircraft, flight times are in the 15 to 30 minute time range depending on payload weight.

TAIL SITTERS

Many alternative VTOL systems take the form of open rotor or ducted fan tail-sitters. The primary advantage of tail-sitter solutions is their relative simplicity for the aircraft. No actuation is required to change the configuration of the aircraft; it simply changes its pitch angle to complete the transition. Unfortunately, there are three significant drawbacks to tail-sitters.

First, the payload has to rotate through 90 degrees as the aircraft pitches up to hover, which adversely affects the available field of view.

The second issue to be addressed is that of tip-over angles. An aircraft's center of gravity (CG) is located near the main wing quarter chord. A tail-sitter when at rest on the ground has its CG high above the ground. The angle of a line drawn from the feet of the aircraft to the CG is referred to as the tip over angle. If this angle is exceeded, the aircraft will tip over and may be damaged. Most tail-sitter VTOL aircraft can achieve a tip over angle of ~30 deg. The resulting effects are that they tend to tip over if they are landing on a sloped surface, on rocky terrain, or with some horizontal velocity. Further, it will be very difficult for a tail-sitter VTOL to land aboard ship without complex launch and recovery equipment, due to the turbulent wind environment and significant deck motion. By comparison, the AGL sits very low to the ground and has a very wide stance yielding a tip over angle of ~70 degrees. This large tip over angle will enable the aircraft to authoritatively land in a turbulent wind environment on a moving deck more robustly than other solutions.

The third limitation of tail sitters is that the transition from forward flight to hover for landing requires that the aircraft pitches up before descending tail first. This maneuver does not have easily controlled intermediate states that enable smooth go-arounds or accommodation of rapidly changing winds.

The AeroVel Flexrotor is a custom-designed high performance tail sitter VTOL system, but the price point of this system is prohibitively expensive.

MULTICOPTERS COMBINED WITH FIXED-WING AIRCRAFT (HYBRID QUADS)

Latitude Engineering has patented a simple option for retrofitting a conventional fuel-powered UAS with a multi-rotor system for VTOL operations. The general arrangement has been broadly applied to numerous systems such as the Arcturus Jump and Textron Aerosonde. This approach is appealing for many companies that have established fixed-wing UAS products and are looking for an expedient means of obtaining a VTOL capability with minimal investment. The primary limitation of this approach is that the technologies are applied in a non-synergistic fashion, such that the multi-rotor functionality adds weight and more importantly drag that adversely affects the useful load, range and endurance capability of the legacy aircraft. The resulting performance of these aircraft types is a compromise between that of a fixed wing and a multi-rotor. Additionally, these aircraft suffer from limited control authority in hover and therefore must be operated in calmer conditions.

HOW THE PROPOSED PROJECT WILL OVERCOME THE SHORTCOMINGS, LIMITATIONS, AND CHALLENGES

This proposed project will leverage all the development and lessons learned that has gone into AAC's HAMR UAS and scale the aircraft larger. A key differentiator of the HAMR (and the HAMR-XL) as compared to tail sitters and hybrid quads is price point. These systems cost in the range of $200,000 to $400,000, while a HAMR will sell for $60,000 in low production quantities. HAMR-XL pricing is to be determined.

The HAMR-XL would be an 8 prop configuration to generate the extra lift capacity to achieve the 55 pound takeoff weight. Additionally, a Desert Aircraft 70 cc engine (DA70) would be used to spin a larger generator. The hybrid electric propulsion system on HAMR generates 1.5 kw of electricity. The HAMR-XL will require 2.5 kw of electricity to hover at gross weight. This is well within the shaft power available of a DA70, thus an added benefit of the HAMR-XL would be greater altitude performance before the lapse rate of the engine drops to the power required to fly.

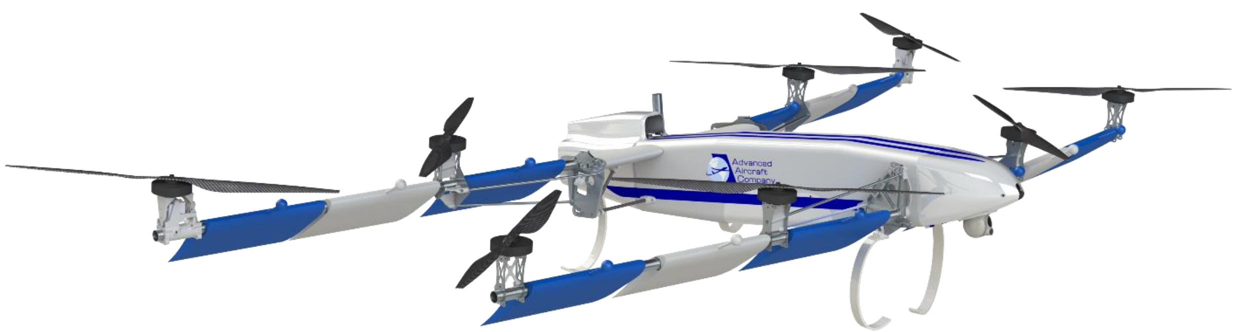

Figure 2. Proposed HAMR-XL Configuration with Aerodynamic Fairings.

The aerodynamic fairings are free to rotate about the motor booms via the aerodynamic forces acting on them. Careful design of the camber line of the airfoils causes them to trim to a five degree local angle of attack. In hover, they are pointed leading edge straight up. As the vehicle builds airspeed, they will rotate aft to whatever angle minimizes drag and generates some lift.

Competitive Advantage

The primary advantage of AAC relative to the other contestants is that we are already developing an aircraft that this challenge is seeking, although our aircraft is smaller than the requested aircraft. Additionally, our patent pending aerodynamic technologies along with hybrid electric propulsion increases the endurance performance by 6 to 10 times as compared to today's state of the art battery powered multi-rotors.

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High-Level Vision for Performance Metrics

Performance metric will be defined as the integral of the area under the curve of a payload vs. endurance diagram. Figure 3 is a payload vs. endurance diagram. Depending on the mission of the operator that day, they may want to tradeoff payload weight for fuel load. A payload vs. endurance curve shows the total performance of the vehicle as opposed to a point performance metric of max endurance.

As can be seen in Figure 3, increasing the size of battery powered multi-rotors does not significantly increase the endurance of the aircraft, but clearly the payload capacity on the lower end of the endurance curve is greater. Also plotted is the proposed HAMR-XL as compared to the existing HAMR. One will notice that the HAMR curves are made up of three line segments. The segment to the left, with zero slope, is a safety constraint on the minimum fuel quantity the operator should takeoff with. The middle segment is the max takeoff weight constraint. The rightmost segment, with the steepest slope, is the max fuel quantity constraint. Note, a HAMR fuel tank is 100 fluid ounces of volume. In the future, custom fuel tanks could be developed of the desired volume. The HAMR performance curves have been validated via flight test and the HAMR-XL curves are from a conceptual sizing analysis only. It also should be noted that Figure 3 assumes the aircraft is hovering the entire mission. If the aircraft is operating in edgewise flight with some forward speed, the endurance increases.

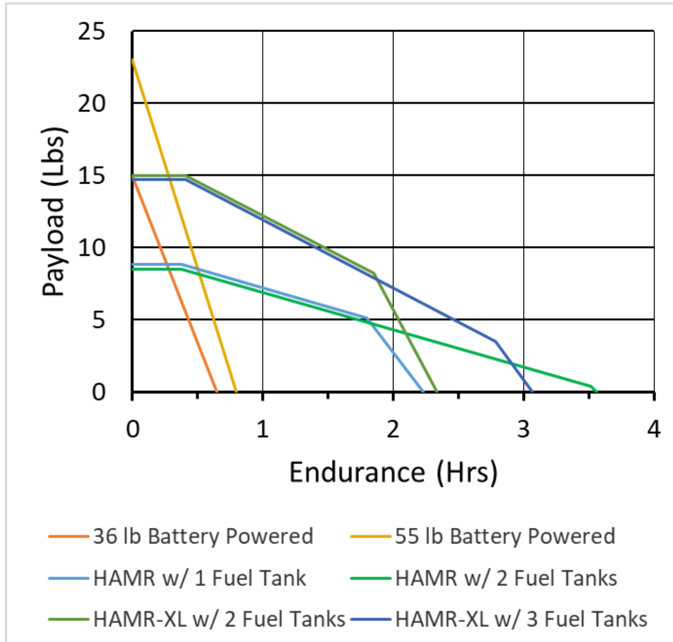

Figure 3. Payload vs. Endurance for Selected Multi-Rotors.

Conclusion

AAC finds this challenge as an exciting opportunity to start the development of our next product line, the HAMR-XL. Unfortunately, timing does not fit well with us. We will be unable to meet the timeline of the challenge because we are currently task saturated with prior commitments to deliver beta units to customers. However, AAC would still like to engage with this challenge and the end users it serves because we intend to commercialize UAS that serve this market. Please contact me at the contact info listed on the cover page. It is expected that a HAMR-XL, with a 55 pound max takeoff weight, will be in low rate production in Spring 2019.

Respectfully Submitted,

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