HYBRID QUADROTOR UAS SHIPBOARD OPERATION VIABILITY TESTING – LATITUDE ENGINEERING / NOAA

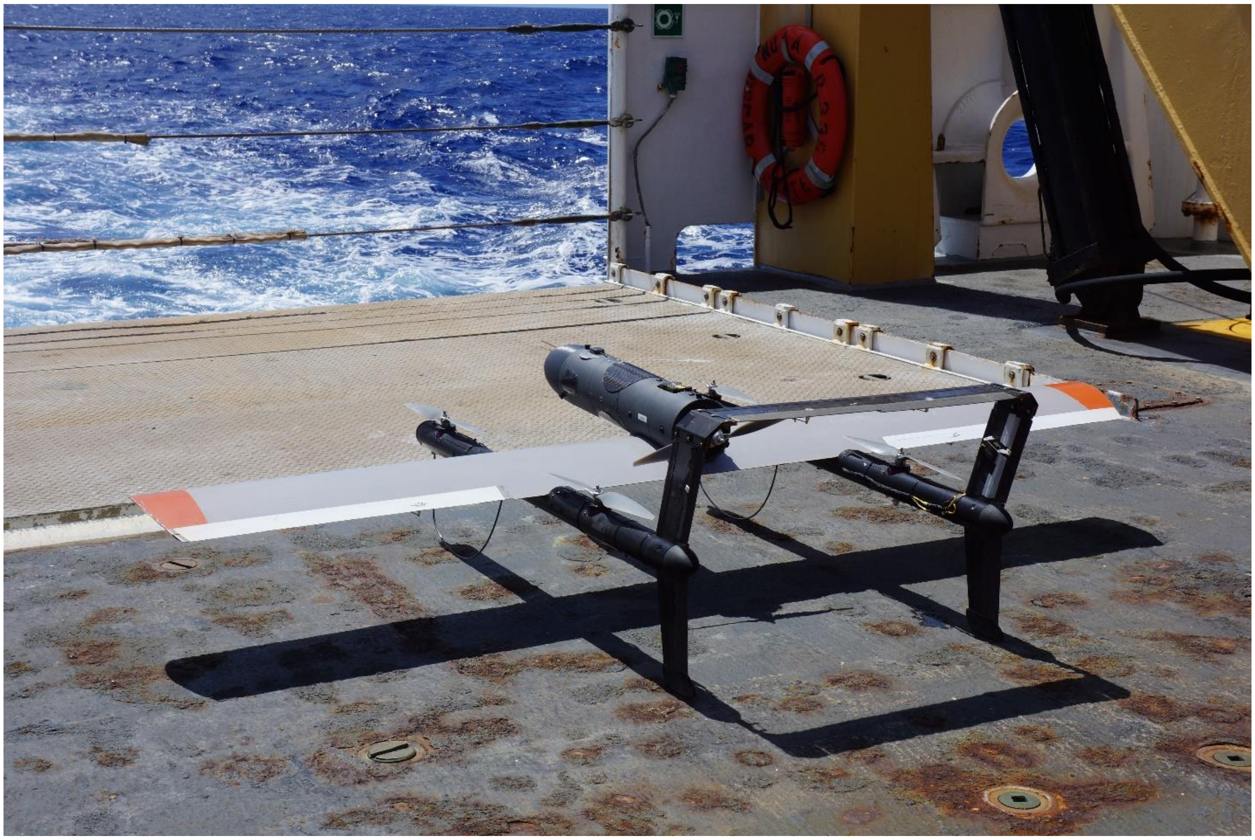
Latitude Engineering, LLC J. ARMER 21 June 2016

Synopsis

Beginning on June 17th, Latitude Engineering in collaboration with National Oceanic and Atmospheric Administration conducted the first shipboard launch and recovery of a new type of unmanned aircraft system known as a Hybrid Quadrotor aboard the R/V Oscar Elton Sette. This feasibility testing was designed to explore technical as well as logistical issues associated with the operation of an HQ style unmanned aircraft from the deck of a research vessel. This new technology offers atmospheric research groups the potential to utilize airborne sensors which are normally restricted to operating exclusively from land based launch and recovery locations.

NOAA R/V Oscar Elton Sette

The flight tests were scheduled to be conducted over a three day period off the southwest coast of Oahu, Hawaii. The required flight clearances were secured by NOAA from both the AOC and the FAA which allowed free flight testing to be conducted 30 nm. from Honolulu. The aircraft used during this flight test campaign was HQ-20 Hybrid Quadrotor aircraft. The HQ-20 is a 25lb, all electric VTOL fixed wing UAV. The HQ-20 is capable of ten minutes of vertical mode flight and ten minutes of fixed wing flight. It is designed to be an inexpensive, highly ruggedized test vehicle to be utilized for flight control software development and high risk testing. For this test event, two HQ-20 aircraft were supplied by Latitude Engineering.



Latitude Engineering HQ-20

The test campaign comprised three main phases. The first phase was intended to explore VTOL controllability and handling near the ships deck. This test was conducted in manual control and sought to obtain qualitative handling characteristics of the HQ-20 in VTOL mode. These flights were to be conducted while operating in the wind shadow of the ships super structure and other deck mounted heavy equipment. The second phase was to verify handoff from manual control to fully autonomous control. In this phase, the aircraft would transition into forward flight via a fully autonomous fixed wing mode of operation. The third phase was designed to expand upon the second phase by testing the launch and recovery process from multiple relative wind states as well as various ship speeds. This phase was an envelope expansion flight profile designed to find the operational limits of the HQ-20 aircraft.

Test Report

- Day 1 – Setup
    - Checkout of all ground equipment. Assembly and checkout of aircraft number one. All equipment verified to be fully functional.
- Day 2 – Hover test flights

  - Flight 1 - First hover test of aircraft number one. Ship positioned stern into the wind. Pitch, roll and heave of the deck analyzed by flight crew.
  - Flight 2- First fixed wing transition flight of aircraft number one. Ship positioned with wind on the stern. Winds steady at 15 kts. Aircraft experiences underdamped pitch oscillations. Pitch control diverges and aircraft experiences departure from controlled flight. Aircraft impacts water 50 ft. aft of the rear deck. Aircraft recovered by boat.
    - Aircraft is mechanically inspected and found to be damaged by contact of electrical components with salt water. Flight test engineers analyze telemetry. Uncorrected gain set found to be the cause of the underdamped pitching behavior. Gain set recalculated and autopilot file updated.
    - Aircraft number two assembled. Preflight checks conducted and completed by flight crew.
- Day 3 – Fixed wing transition flights
  - Flight 3 -Aircraft number two completes hover test flight. Flight test engineers analyze flight telemetry. Updated gain set is shown to have corrected the underdamped pitch control issue. Flight testing cleared to proceed.
  - Flight 4 - Ship positioned with wind on the stern. Winds steady at 15 kts. Aircraft is launched and performs autonomous transition to fixed wing flight. Aircraft recovered after approximately 3 minutes fixed wing flight. Aircraft lands on deck normally. Aircraft mechanically inspected and found to be in good condition. Flight test engineers analyze telemetry. Analysis produces suggested autopilot setting changes. Autopilot file setting changes implemented.
  - Flight 5 - Third fixed wing transition flight. Ship positioned with wind on the bow. Winds 15 kts. gusting 20 kts. Aircraft is launched and performs autonomous transition to fixed wing flight. Aircraft is recovered after approximately 7 minutes fixed wing flight. Aircraft encounters turbulence from wind flowing over the ships superstructure. Pilot encounters heavily degraded control performance and contacts deck mounted heavy equipment. Aircraft experiences departure from controlled flight and impacts water surface approximately 35 aft of the rear deck of the ship. Aircraft recovered by boat.
    - Aircraft is mechanically inspected and found to be damaged by contact of electrical components with salt water. Flight test engineers analyze telemetry. Uncorrected gain set found to be the cause of the underdamped pitching behavior. Gain set recalculated and autopilot file updated.
    - Aircraft number two repaired. All contaminated components inspected. Failed components replaced with new units. Preflight checks conducted and completed by flight crew.
- Day 4 – Envelope expansion
  - Flight 6 - Aircraft number two completes hover test flight. Flight test engineers analyze flight telemetry. All systems shown to be performing normally.
    - Magnetometer anomaly detected during preflight checks. Basic trouble shooting was inconclusive. Flight procedures were revised to accommodate possible magnetometer discrepancy.
  - Flight 7 - Fixed wing transition flight. Ship positioned with wind on the stern. Wind 15 kts. gusting 20 kts. Aircraft is launched and performs autonomous transition to fixed wing flight. Aircraft recovered

after approximately 3 minutes fixed wing flight. Aircraft lands on deck normally. Aircraft mechanically inspected and found to be in good condition. Flight test engineers analyze telemetry. Analysis produces suggested autopilot setting changes. Autopilot file setting changes implemented.

- Flight 8 - Fixed wing transition flight. Ship positioned with wind on the stern. Wind 15 kts. gusting 20 kts. Aircraft is launched and performs autonomous transition to fixed wing flight. Aircraft recovered after approximately 3 minutes fixed wing flight. Aircraft lands on deck normally. Aircraft mechanically inspected and found to be in good condition. Flight test engineers analyze telemetry. Analysis produces suggested autopilot setting changes. Autopilot file setting changes implemented.
- Flight 9- Fixed wing transition flight. Ship positioned with wind on the stern. Wind 15 kts. gusting 20 kts. Aircraft is launched and performs autonomous transition to fixed wing flight. Aircraft recovered after approximately 3 minutes fixed wing flight. Aircraft lands on deck normally. Aircraft mechanically inspected and found to be in good condition. Flight test engineers analyze telemetry. Analysis produces suggested autopilot setting changes. Autopilot file setting changes implemented.
- Flight 10 – Cancelled. Winds exceed 25 kt. limit.

Summary

A total of nine flights were conducted over the four day flight test period. Five of those flights were conducted with wind and sea states approaching or exceeding the 90th percentile of maximum limits. Following the test flights, a review of the ships motion during launch and recovery determined that pitch and roll of the deck posed a much less significant challenge than originally anticipated. The heave component of motion was considered to have provided the anticipated level of complication during the launch and recovery process.

Magnetometer performance during the testing period appeared to be very good initially. Following additional review and testing however the magnetometer performance proved to be inconsistent. It is believed that the large steel structure of the ship is significant enough to cause a large amount of interference. This theory was tested by taking magnetometer readings at different distances above the ship while the aircraft was flying. Test results seemed to indicate that the ship is indeed adversely affecting the magnetometer. Further analysis is required in order to determine the severity of the magnetometer disturbance created by the ship.

Observation following the loss of control during the flight when superstructure turbulence was encountered suggested that this specific ship orientation should be avoided for this specific vessel. It is anticipated by the flight crew that a wind quartering off the bow may provide adequate turbulence mitigation for launch and recovery in winds up to 20 kts. Alternatively, increased VTOL system control authority is expected to expand the operational limitations of the HQ aircraft in turbulent conditions. Latitude Engineering is eager to explore these scenarios during the next round of testing.

Tests regarding condition inspection of the hardware following the test concluded that no discernable corrosion or other damage was incurred during the four day test period. It is therefore not known what service life of the ground or airborne equipment can be expected in a maritime environment based on these tests. A prolonged test of six months or greater is expected to provide better understanding of the anticipated service life if this equipment in corrosive environment.

In conclusion, we are very pleased with the results of the test campaign. All objectives were met and all essential data was collected to allow the next phase of fully autonomous ship testing to take place.

Going forward

Suggested modifications to the flight control logic specific to shipboard operations were also noted.

- The flight control logic should be updated to automatically track the landing waypoint during an aborted launch. Currently, the logic dictates that the aircraft proceed to a launch abort waypoint some distance from the actual launch point during an aborted launch. Although this is suitable for land base operations, ship based operations will dictate that an autonomous abort command must return the aircraft to the ship.
- Following the observation of the flight deck motion during the launch and recovery operations as well as feedback from the manual pilot, it has been suggested that the flight control logic be updated to predict the optimal time to initiate launch and touchdown. This modification is relatively straight forward and is expected to provide a significant improvement in launch and landing repeatability.
- An alternate method of precision guidance utilizing machine vision has been under development for a short time. This method will utilize a down looking camera and a calibrated target fixed to the deck in order to guide the HQ aircraft while it's in VTOL mode near the flight deck. This method of navigation does away with the need for heavy and expensive differential GPS and aids the magnetometer while in close proximity to the vessel. Latitude Engineering is expecting to begin testing of this system by the end of 2016.

A special thanks to the crew of the R/V Oscar Elton Sette for supporting the shipboard test flight series of the HQ-20 UAS. The professionalism and dedication of the entire crew created an environment which allowed for a high level of testing to be accomplished at a very high rate. The success of this test event could not have been realized without their support.