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Autonomous Satellite Recovery Vehicle (ASRV) Final Report

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Research Question: Can you fit a quad-copter into a rocket and if so could it be deployed from that rocket and navigate autonomously back to the user?

Introduction

So what is the purpose behind this research? This project consists of building a quad-rotor that could fit in and be deployed from the space constraints of a rocket. A quad-rotor with this capability could be used for numerous applications including long range surveillance, weather observations, and low collateral damage attacks. Overall, this system would be able to get its users key information in less time than a conventional unmanned aircraft system, specifically because a rocket could get the ASRV to the necessary location faster without using any of the aircrafts power supply/fuel.

Approach/Methods

All of the research conducted for this project was acquired from the website ardupilot.com and tutorial videos on YouTube. We chose to acquire our information from ardupilot.com because they provided thorough websites and directions on how to construct a quad-rotor, which we had never done before. A suitable frame was selected and the quad was constructed with modifications to allow the arms to fold inwards. Electrical components of the quad-copter included an apm 2.6 Ardupilot flight controller, power distribution board, electronic speed controllers, electric motors, RC receiver and transmitter, and lithium polymer batteries.

There are a few things to consider when designing and choosing materials to build a quad copter. First its best to consider the frame including; what it will need to be capable of doing and overall frame durability (Willie). Ultimately, we decided to construct our quad-rotor from a carbon fiber kit with movable arms for durability and flexibility. This allows the arms to be pushed inwards to make the quad rotor slimmer on its horizontal axis. We used springs to provide tension between the arms and the body of the aircraft. Basically, when the arms do not have pressure applied to them they go back to their original “X” orientation. Another important part of the frame is some form of vibration dampening (Ershov). You can use gel, cushions, rubber, etc (Ershov). Overall, some form of vibration dampening is important because if you do not dampen vibrations they will create sensor errors in your autopilot and possibly your GPS as well (Ershov).

The next component to consider is an autopilot. Autopilots range from very easy to install to hard to install depending on the amount of programming that may be involved. Some autopilots also require intense parameter setting which can also make installation difficult. Within this project we researched and studied two different autopilots including an easy installation autopilot the Dji Naza V2, and a harder installation autopilot the ardupilot APM 2.6. The most important thing to remember when installing the autopilot is to place it directly in the middle of the frame (Developer). Also be aware of the front facing arrow on the autopilot; it is what the autopilot will consider forward during flight (Developer).

Another component that needs to be considered is a suitable battery (Willee). The battery is very essential to building a quad-rotor because the one chosen will determine the quad-rotors overall capabilities. More specifically the battery will determine flight duration, flight speed, and the ability to use external components. There are a few types of suitable batteries including NiCad, Lithium-ion, and Lithium-polymer. Batteries range from low to high capacity and discharge rate. Typically, the higher the capacity the longer the battery will last and the discharge rate provides you with the safe amount of electrical discharge at one time for the battery. So how long do you want your quad-rotor to be able to fly? In this category there is a big trade-off between flight-duration and weight. The more batteries you have on board the longer the flight time, but this also creates more weight which creates more power consumption. We choose to use one 4000 milliamp/hour (mAh) battery and restrict our aircrafts weight to under 10 lbs. to create a quad-rotor that had both good flight duration and minimal weight.

Other things to consider are power distribution, electronic speed controls (ESCs), motors, and a radio controller (RC) transmitter and receiver (Willee). Power distribution can be done a few ways. One way is by connecting the ESCs and autopilot directly to the battery, another way is to connect the ESCs and autopilot to a power distribution board (Willee). We decide to use the power distribution board for the battery power delivery to ensure none of the motors were drawing more power than the others and to prevent shorting out any of the components.

Electronic speed controllers are also a very important component of a quad-rotor build because they provide the correct voltage to the onboard motors and prevent the motors from receiving too much current. When installing the ESCs to the motors it is also important to remember the direction that you need each motor to spin (Willee). To make the motor spin counter-clockwise you would connect the wires from the ESC to the motor as usual i.e. positive wire to positive wire, signal wire to signal wire (Willee). When you want the motor to spin clockwise, the positive wire from the ESC should be switched with the signal wire (Willee). When selecting what motors to use be aware of the kilovolt (kV) usage, max amps, and thrust. The thrust is important obviously because the correct amount of thrust is necessary to counteract the weight of the aircraft and acquire flight.

The last component to consider is a good radio controller transmitter and receiver kit (Willee). The better the quality the better the signal which is very important in manual flight of RC aircraft. We also researched two radio controller receiver and transmitter kits within this project, the Turnigy 9X, and the Spektrum DX9. The Spektrum turned out to be significantly better than the Turnigy and it also provided more channels for external components and customizations. Overall, it is best to get a quality radio controller to guarantee safe control over your RC aircraft during manual flight.

Results

We ran into a few power problems with the first frame due to throttle setting malfunctions, but we eventually fixed the problem. Our first flight test was unsuccessful due to system pre-check errors, which basically turned out to be another parameter setting error. The second flight test with the first frame started out successful with controlled flight on all axes. Unfortunately, upon trying to land, the aircraft throttled itself high because of a parameter setting and crashed. We ran diagnostics on the second flight test and discovered that the autopilot and frame were experiencing excess amounts of vibrations, causing inertial momentum unit (IMU) errors. Ultimately, we decided to disassemble the original frame and construct a new one. The new frame was constructed completely from a carbon fiber kit for robustness, and we also decided to apply cushions under the autopilot to counteract vibrations. After reconstruction we conducted two additional flight tests, one inside and one outside and both proved to be very successful. The aircraft was able to fly in all modes (GPS, ATTITUDE, MANUAL), and we were no longer experiencing problems with vibrations. After installing both autopilots we found that the Naza V2 had better controllability while flying and also could hold its position at a point considerably better than the APM 2.6. We concluded from this information that the Naza had a better GPS module making it better for controlled flight conditions and autonomous flight conditions.

Drop tests were also conducted to test the parachute system and the parachutes worked two out of the three times that we tested them. All of the parachute tests were conducted in Embry-Riddle Aeronautical University's engineering build, from the third floor. We used a box and weighted items to simulate the weight of the aircraft. The parachute system essentially uses e-matches, gunpowder, and carbon dioxide (CO_2). A small amount of gunpowder is ignited pushing the CO_2 canister into a pin, which then releases the CO_2 causing the parachutes to deploy. Unfortunately, we were unsuccessful at fitting the quad-copter into EFRSEDs designated rocket, and testing the deployment of the quad-copter from a rocket has not been completed. The space requirements were just too small even with precise measuring. Overall, the entire research project is a concept until we can acquire a rocket large enough to deploy the qua-copter from.

Conclusion

As stated before, flight test have been conducted with the new frame and the quad-rotor is flying phenomenally. Although, we have not been able to test deploying the aircraft from a rocket and retrieving it we believe the endeavor is still feasible. The main problem is finding a rocket or rocket bay that can fit the aircraft precisely. Another issue is the thrust forces from the rocket. They could having an adverse effect on the aircraft and cause it to malfunction.

This project was started and conducted by members of the Society for Space club and it provided great first time hands on research, electrical, constructing, testing, and teamwork skill-building. Overall, we believe the ASRV has been a very interesting and unique project from the beginning and we will continue to improve on what we have started.

Works Cited

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