ECHO Memo #052
24 March 2021

Evaluation of Drone Options for Beam Mapping

Versions
March 2021 – Initial Draft with bits from internal notes – D. Jacobs

With ECHO-2 we have the goal of improving shortcomings in the ECHO-1 design enabling routine measurements at operating arrays. Areas affecting the measurement quality included flight time and angular stability. We also needed a system robust enough for regular field use by the student team to make routine measurements at remote sites. Flight time, repairability, mounting are all strongly dependent on the drone technology we use. Off the shelf systems are lower risk but cost more and in-flexible. We selected a system by following a requirements definition and prototype evaluation process, evaluating six potential options and acquiring three (the Steadidrone Vader, the Yuneec octo, the Chiropter) for test. The Chiropter was our own design developed in collaboration with the ASU DREAMS robotics lab. A summary breakdown of these tests shown in Table 1. We initially expected the Vader, with its large frame and high performance propulsion system to have the best flight time and mounting performance, however its un-loaded hover time of 20 minutes was significantly below the Chiropter at 45 minutes. There were a number of other shortcomings of the off-the-shelf systems which made them unsuitable. Ultimately the Chiropter was the clear winner. The low cost is an important factor. At only $2k we can make several units and nicely package them for travel, for less than the cost of one off the shelf system. See the complete travel kit with 3 spare drones in Figure 1.

Table 1: This project places unique demands on drone systems. This table summarizes the results of field testing several options. The ``Chiropter" is a custom system designed and built the ECHO group with the help of the ASU DREAMS exploration robotics lab. A last item that should be listed here but isn't is "sparing". Having multiple drones dramatically mitigates flight risk during expensive on site operations.

Drone	3D-Robotics X8	Steadidrone Vader	Yuneec H520	Chiropter	Relevance
Payload Capacity	0.2 kg	6.6 kg	0.8 kg	>0.6kg	Critical
Mounting	Possible, but little space	Easy and accessible	No	Easy and accessible	
Scriptable Flight Path	Yes	Yes	No	Yes	
Time-Tagged GPS Data	Yes	Yes	No	Yes	
Availability	No	No	Yes	Yes	
Hover Time	15 min	25 min	25 min	45 min	Important
Price	$1,300.00	$15,000.00	$4,000.00	$2,800.00	
Repairable	Possible but difficult	Very difficult	No	Easy	
Faults	3/40	1/1	0/2	1/25	
Retractable Legs	No	Yes	Yes	No	Nice to have
Weight (with battery)	5.5 kg	15.0 kg	1.7 kg	3.9 kg	Safety
Year	2015	2017	2018	2019	

The Chiropter setup

The current flight system includes three spare drones, two spare transmitters, an independent receiver for RFI diagnostic, tools, spare parts, battery charging, and computers for ground control. Details about the drone build including build log, bill of materials and payload mount solid model files are on the project Github repo.

Figure 1: The ECHO-2 external calibration kit emphasizes redundancy with multiple drones (currently three), an independent spectrum monitor (collapsible bicone for <100MHz operation + Fieldfox spectrum analyzer), batteries chargers, independent ground station computer.

The Yuneec

Marketed as a turnkey system this product appears to offer a low cost off the shelf solution. Little information is available in marketing materials about hosting of external payloads. Inquiry to the company resulted in little new information. We obtained a Yuneec H520 in 2018. We flew it both locally and at a remote site. More importantly we evaluated the potential for hosting custom payloads. Ultimately it was judged to be unsuitable for the following reasons ordered by severity

1. Interface was difficult to program. The controller runs a custom fork of Qgroundcontrol. We were ultimately able to load in our desired flight path, but foresaw unnecessary difficulty solving typical problems like maintaining firmware versioning, keeping settings stable, and enforcing orientation and flight speed.
2. Requires custom batteries and charger. One ends up needing many batteries. They wear out. A single source supplier is risky to time and budget. Also, because airplane security restricts the number that can be carried, we often end up buying new and shipping to our site. For this reason it is important to have multiple suppliers.
3. The controller is has a large built-in computer and video display with a very short battery life (<40m typical). This is a safety risk.
4. It was <u>not possible to attach a custom payload</u> for several reasons.
    a. The drone data link radio is in the _payload_ camera. One cannot get live flight telemetry _without_ the camera attached, can't attach a payload _with_ the camera attached.
    b. The payload camera attaches via a slide-click type plastic fitting also passes power/data. We investigated the possibility of reverse engineering this interface. We took apart the gimballed camera that comes with it but the microelectronics were not labeled in such a way to make the process a simple matter of googling.
    c. The slide-click payload attachment would be challenging to mate on a mechanical level requiring mold-making and use of industrial plastic engineering at a level beyond our capability.

Figure 2: Testing the Yuneec. It is smaller than it looks on the internet.

Steadidrone Vader

The Vader was a high performance drone marketed for inspection and other commercial purposes by a company of that same name in South Africa. With 12” carbon fiber propellers, high performance motors, quad 5S batteries and carbon fiber frame it claimed a flight time of 40+ minutes with several kilo payload. We purchased one in 2017. Afterflight testing both locally and at a field site this system was also determined to be unsuitable. The following reasons in increasing order:

1. The system required 5S batteries which are an unusual voltage not available off the shelf. We had to have them custom made.
2. The though the size and the rigidity of the carbon fiber propellers enabled high efficiency they were a significant weak point for several reasons
    a. Each propeller assembly split into 7 parts including small screws and washers. Assembly was time consuming, and parts were easy to lose in the grass.
    b. Each propeller was custom made, difficult and expensive to obtain. We had few spares
    c. Carbon fiber is sharp, a 12” prop moving at speed is much more dangerous than a 7” plastic prop moving at the same speed
3. 5 minutes into our first flight, a power supply failed. This part was located inside the tubular arm and required a long difficult repair. During this repair an ESC failed, further lengthening the down time. Further risk reduction testing was needed.
4. Each flight took 4 batteries. This significantly lengthens flight turnaround and necessitates more charging equipment to keep up.
5. An unloaded hover test time of 20m.
6. The company went completely out of the multi-copter business just as the purchase was being completed. Further support was not possible.

Figure 3: The Steadidrone Vader met all requirements for mounting, flight time, and stability. But ultimately was not used because of repairability and safety.