ECHO Drone Requirements

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Description

The ECHO drone is a large, custom-built drone designed with the purpose of calibrating wide-field radio telescope arrays by broadcasting a known radio signal at precise locations above the array. Most drones on the market do not meet all of our design specifications, so we deemed it necessary to begin work on building our own drone from the ground-up.

Requirements

- *30 Minute Flight Time*
  - A typical flight time for drones that are on the market is around 15-20 minutes. Increasing this flight time to 30 minutes allows us to halve the amount of flights per calibration, drastically increasing efficiency. It also allows for the possibility of running slower, but extra precise flights should we choose to do so.
- *Positional and Angular Stability*
  - The calibration is sensitive to slight alterations in the position of the radio transmitter attached to the drone. Therefore, it is important to minimize any excessive movement caused by wind, vibration, or the drone momentum. Data analysis has determined that a <10cm stability along the x, y, and z axes and a <1° angular stability are ideal.
- *Able to Carry 600g Payload*
  - The ECHO experiment includes a 600g payload that must fly with the drone during its path over the telescope. The drone must be able to lift this payload while still meeting the other flight requirements. The payload consists of a radio antenna, a transmitter in a black box, an Anker battery, and a couple of cables.
- *Vibrationally Sound*
  - With dual blade propellers, the frame should be expected to withstand twice the rotation frequency of the motors. With the U8 Pro 100 KV motors, the frame needs to be able to handle 250 Hz vibrations.
- *Slow Flight Speed*
  - Flying slowly is ideal for our scenario as it increases the stability of the drone, regardless of any other factors. Minimizing any extra movement from momentum shifts, vibration, and wind resistance can be easily achieved by keeping flight speeds between 0.5 and 1 m/s.
- *100m Flight Ceiling*
  - The ECHO drone flies in a semi-spherical path with a radius of 100m. Therefore, the drone needs to be able to fly at least 100m above the ground. Not only must the drone itself be able to withstand the physical conditions 100m in the air, but the radios need to be able to communicate from this far away as well.

- *Programmable Flight Path*
  - Calibration of the array requires the drone to follow an extremely precise semi-spherical path that is nearly impossible to replicate by hand. The best way to do this is by creating a script that sends the drone along a predefined path using waypoints. Not all flight controllers offer this feature.
- *Time-Tagged GPS Information*
  - In order to calibrate the array, we need to be able to know the time and position of the drone for the entire path. The most efficient way to do this is to download time-tagged data straight from the GPS on the drone.
- *Open Mounting Space for Transmitter*
  - The radio transmitter needs to hang below the drone and away from any electronics or metal, as they can distort the beam pattern observed by the array. Therefore, there needs to be an accessible area for mounting on the bottom of the drone. A region that is about 10cmx10cm is large enough.
- *Retractable Legs and Foldable Arms*
  - The legs are a common problem for the transmitter, as any metal in them can distort the beam pattern. It would be ideal for the legs to fold up and out of the way of the bottom of the drone during flight, and then fold back down before landing. Also, due to the large size of the drone, folding the arms and legs for more compact storage would be beneficial.
- *$5000-$15000 Price Range*
  - As with any project, it is important to keep the price as low as possible. Based on observations from the market, a maximum price of $15k seems reasonable. It may be possible to build the drone ourselves with a price as low as $5000, but would rather pay more for a professional build.

Flight Components

- *Propellers*
  - Greater than 15” propellers for 30 minute flight time
  - Lowest pitch possible is most stable
  - Carbon fiber is likely the best option for its strength, but is expensive to replace
  - Vader: 28x9.2” carbon fiber
- *Motors*
  - 300KV or less for 15” or greater propellers
  - High manufacturer quality (SunnySide were bad)
  - Vader: T-Motor U8 100KV
- *ESCs*
  - Recommended from motors
  - 30-40A
- *Battery*
  - Flight time determined from mAH
  - Have 10k mAH 4s 25c in lab
  - Vader uses 10k mAH 5s 40c (4 total, 1 per arm)

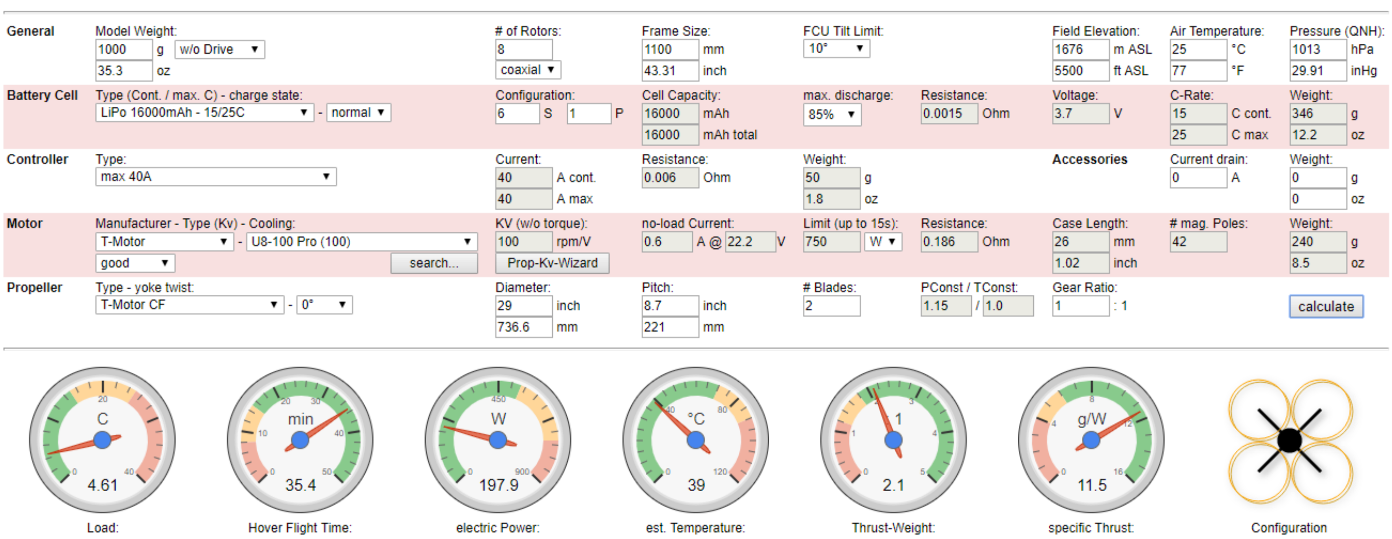
- *Frame*
  - Coaxial Octocopter configuration for stability and minimal weight (4 arms, 8 props)
  - Target weight <1kg
  - Central hub must have room for components and ECHO payload
  - Carbon fiber, Windform SP, help from PADT

Communications Components

- *Flight Controller*
  - Pixhawk does waypoint-based flight (on X8)
- *Controller Radios*
  - Allows pilot to talk to drone
  - Currently using FrSKY D4R-II receiver and FS-TH9X transmitter
- *Ground Station Radios*
  - Currently using 3DR radios with APM planner

eCalc Model #1 (11/2/17)

- 1kg Model Weight
- Pulse 16000mAH 6s 15c LiPo Battery
  - https://www.pulsebattery.com/plu15-160006-pulse-lipo-16000mah-6s1p-22-2v-15c.html
- T-Motor Air 40A ESCs
  - http://store-en.tmotor.com/goods.php?id=368
- T-Motor U8 Pro 100KV Motors
  - http://store-en.tmotor.com/goods.php?id=325
- T-Motor 29x8.7” Carbon Fiber Props
  - http://store-en.tmotor.com/goods.php?id=503



Propellers

- Increasing diameter increases flight time and thrust
  - At least 15” seems to be necessary for our flight time
- Decreasing pitch increases stability
  - Usually only a couple options per prop diameter, can pick lowest available
- Plastic vs Carbon Fiber
  - Plastic is cheaper and easier to replace, but carbon fiber is stronger and creates more stable flight
- Vader uses 28x9.2” carbon fiber

Motors

- Use lower KV for bigger props
  - 15” prop diameter seems to work best with ~300KV motors
- Quality of motor manufacturer is important
  - SunnySide on the X8 were not good
- Vader uses Tiger Motor U8-100KV

ESCs

- Motors have recommended ESCs
- Around the 30-40A range for our size
- Vader’s motors recommended 30-40A

Battery

- Increasing mAH increases flight time
- Have 10k mAH 4s 25c in lab
- Vader uses 10k mAH 5s 40c (4 total, 1 per arm?)

Flight Controller

- Needs to work with waypoint-based flight
- Pixhawk works, can either salvage from an X8 or get a new one

Ground Station Radios

- 1 radio on drone, 1 radio with ground station
- Currently using 3DR radios with APM Planner
- Salvage or new

Controller Radios

- Receiver on drone pairs with transmitter (controller)
- Currently using FrSKY D4R-II receiver and FS-TH9X transmitter
- Salvage or new

Frame

- Needs to be light enough for 30 minutes of flight (< 1 kg)
- Have long enough arms for the propellers
- Big enough hub for radios, battery, flight controller, ECHO transmitter, etc.
- Coaxial octocopter (4 arms, 8 props) is the best configuration
    - Less arms minimizes weight
    - Less arms also allows them to be closer together, further reducing weight
    - Very stable configuration as well
- Windform SP
    - 3D printed carbon fiber
    - High stiffness, excellent strength, reduced weight, excellent resistance to vibration/damage/deformation
    - Resistant to high temperatures and waterproof
    - Use for hub
- Can use simple carbon fiber rods for arms/legs