

# MFA Bundle™ Datasheet and user Guide

The **MFA BUNDLE** is our basic developer kit targeted for precision small-payload designs. The kit features four HE400 Hover Engines™ and all the control logic and actuation systems needed for designers to evaluate MFA in their applications. The MFA BUNDLE is designed to demonstrate precise motion and control capability and is not designed to carry heavy payloads. The kit can be controlled via a 2.4 GHz RC system such as the one linked [here](#). The system can also be controlled using a microcontroller. Users would need to generate modules outputting PWM signals for the MFA BUNDLE ESC.

## MFA BUNDLE technical details

### **All data based on 6mm (1/4") Al-1100 Substrate**

#### **Estimated Hover height:**

10mm with 0.5 kg load/engine

6mm with 1.0 kg load/engine

**Run time:** Dependent on power system and substrate. Extended run times will increase the temperature of the components and substrate. Active cooling may be necessary.

**Max Payload Capacity:** 1.25 kg/engine including the weight of system

Note: Payload and runtime can be improved when operated on thicker and/or more conductive surfaces.

**Number of individual Hover engines:** 4 units, cylindrical in shape, approximately 1.75" tall, 2.75" in diameter

**Individual Mounting Brackets:** 4 units made from 1/16" Al 6061-T6, comes with mounting holes suitable for chassis and engine mounting. Approximately 4.25" long, 1.25" wide, 2" tall

**Motor Controller Spec Sheet:** [Q-Brain 4x25A Brushless Quadcopter ESC 2-4S 3A SBEC](#)

\*Please note that some versions of the MFA Bundle have come equipped with [4x20A version of the QBrain](#)

**ESC Specifications (Note: ESC is a QUAD device and all motor controller specs represent sum total output of all 4 controllers on board)**

Input Voltage: 7.4~14.8V (2~4S LiPo)

Cont. Current: 25A x 4 for 25A version (20A x 4 for 20A version)

Burst Current (10 sec): 30A x 4 for 25A version (25A x 4 for 20A version)

BEC Type: Switching

BEC Output: 5.25V@3A for 25A version (5V@3A for 20A version)

Motor Wire Length: 250mm

Dimensions: 69x62x11mm

**Motor(s):** HiMAX HC6310-0400

**The HiMAX HC6310-0400 is a custom version of this [motor](#) with the following differences:**

- No load current is 0.8A
- Rm is 93 m ohm
- Kv is 400

**Motor constant (Kv):** 400 RPM/Volt

**Motor connector:** [3.5mm MALE bullet connector](#)

**Servo(s):** HiTec [HS-5485HB](#)

**System controller:** [OpenPilot CC3D](#)

**System software:** [LibrePilot](#)

## Engine placement and organization

We recommend that designers place engines in pairs at least 3.5cm apart, or a half of a diameter of each engine. **For each horizontal pair**, we strongly recommend that each engine rotates in an opposite direction to its nearest neighbor. Also, be sure to place engines in such a manner that when fully actuated the engine does not extend past the width of the vehicle. This system is designed to lift the vehicle off the surface without standoffs or user assistance.

### Mounting

#### Mounting Scheme #1: Control

To optimize for vehicle control, mount engine pairs at a 45-degree angle to the forward direction of the vehicle, at opposite directions to each other, as described in Figure 1. This method allows for 3-axis omnidirectional control (forward-aft, left-right, yaw), at the expense of some degree of forward thrust.

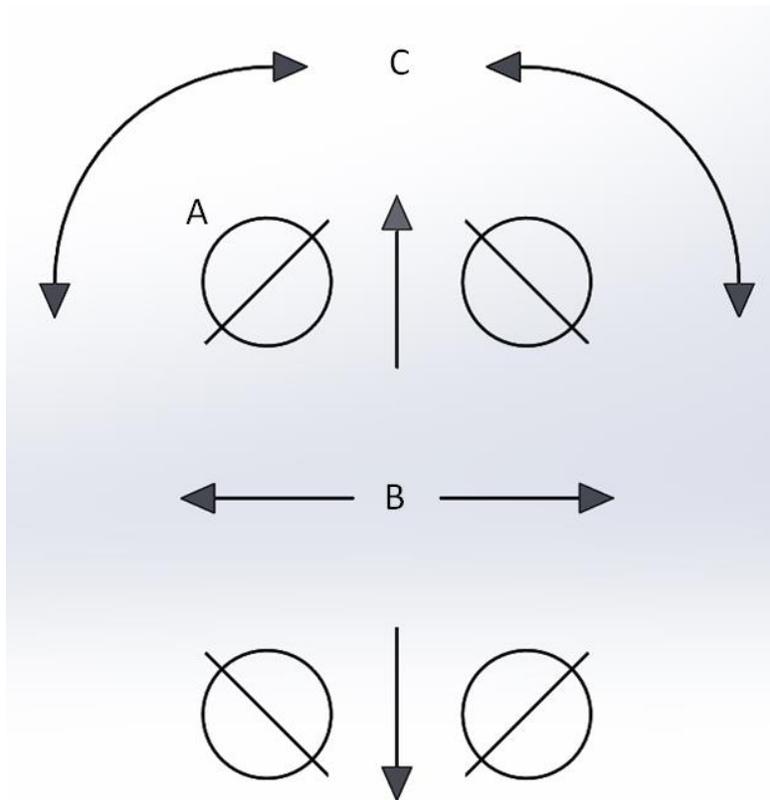


Figure 1

Figure 1 describes a topside view of the layout of the engines (A) in pairs at 45-degree angles, and in opposition to each other. Said position allows for both directional movement (B) and rotational movement (C).

## Mounting Scheme #2: Propulsion

To optimize for maximum propulsion, mount the engines parallel to the forward direction of the vehicle, as described in Figure 2. This method optimizes for forward and rear speed at the expense of any multi-axis control.

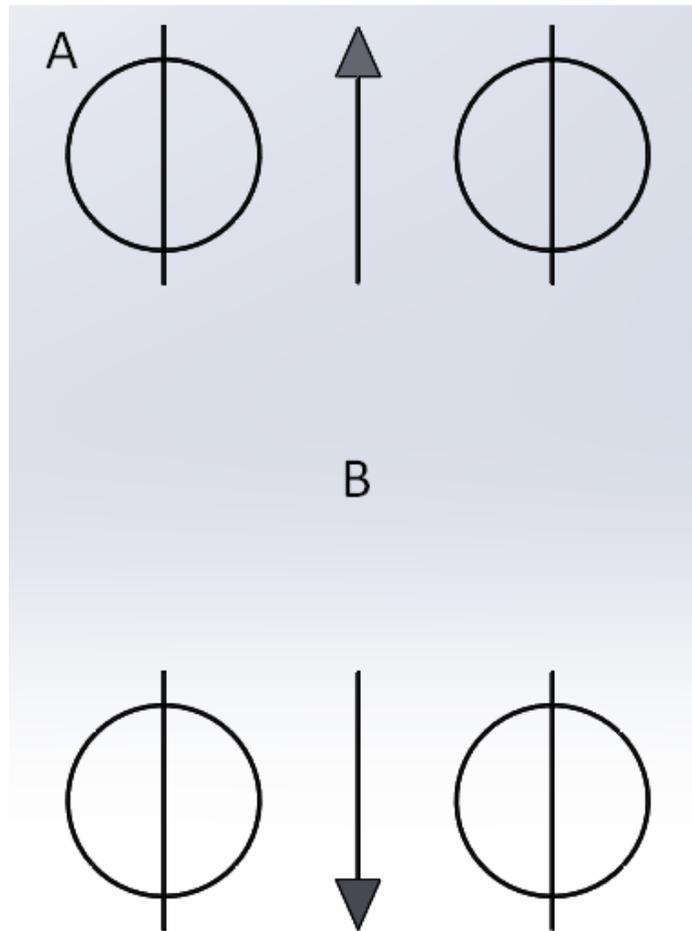


Figure 2

Figure 2 describes a topside view of the layout of the engines (A) in pairs with engines parallel to the direction of the vehicle.

### Example CAD files

To help users we have published example CAD files of existing hardware to our website. You can find that data on our website [here](#).

## Actuation

Actuation is provided through the servos, connected through the mounting brackets.

Hover height is measured from the bottom of the hover engine to the top of the conductive surface. Engines tend to find their own hover height, determined by payload, as a result of operating at their lowest-energy state. We recommend that designers try to optimize hover height only after testing a system under payload.

Generally speaking, actuation of the engine offers thrust at minimal expense of lift. Designers do NOT have to account for mm of engine actuation as a part of determining desired hover height – the system will tend to self-level even when engines are actuated.

We have found that relatively small degrees of angle provide significant thrust while still maintaining safe hover. With some of our small-scale demo systems using this technology we have needed less than 3 degrees of actuation in order to operate the system at speed.

Trimming of the servos and setting the total throw of the engines (degree of tilt) can be managed through LibrePilot GCS software, available [here](#). We also recommend a review of the LibrePilot [documentation](#) if you are new to the platform.

## Motion

Varying the patterns of actuation of each of the engines together enable controlled motion.

Several variables can affect controlled motion, including engine positioning, actuation type, degree of tilt, rotational speed, and type of conductive surface. Users should define their own actuation schema that are optimized for their own vehicle design. We have provided basic templates for users to refer to in their own system development.

**For all images, please note that this is a topside view and the vehicle front is located toward the top of the image.**

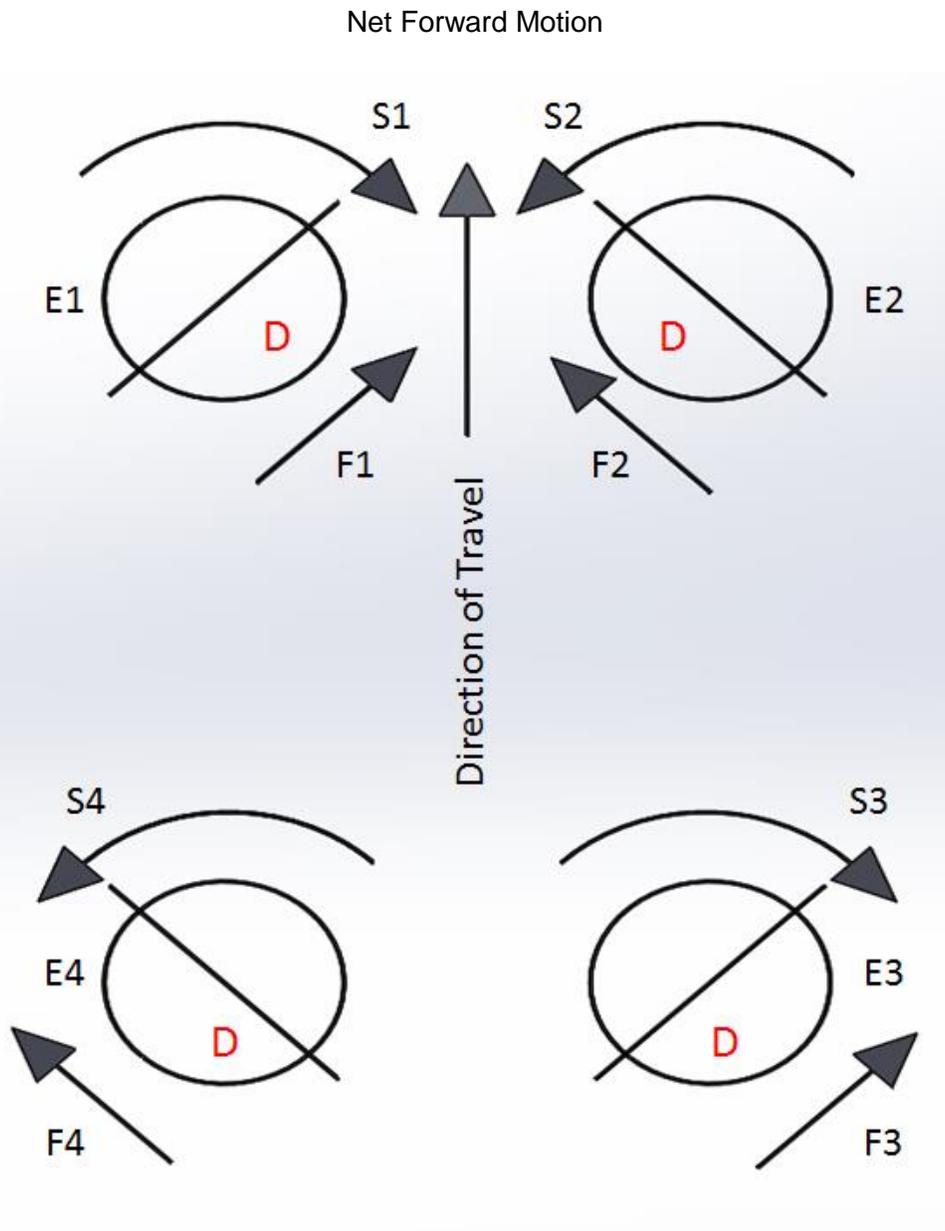


Figure 3

Figure 3 is a topside view describing forward motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle forward.

Net Rearward Motion

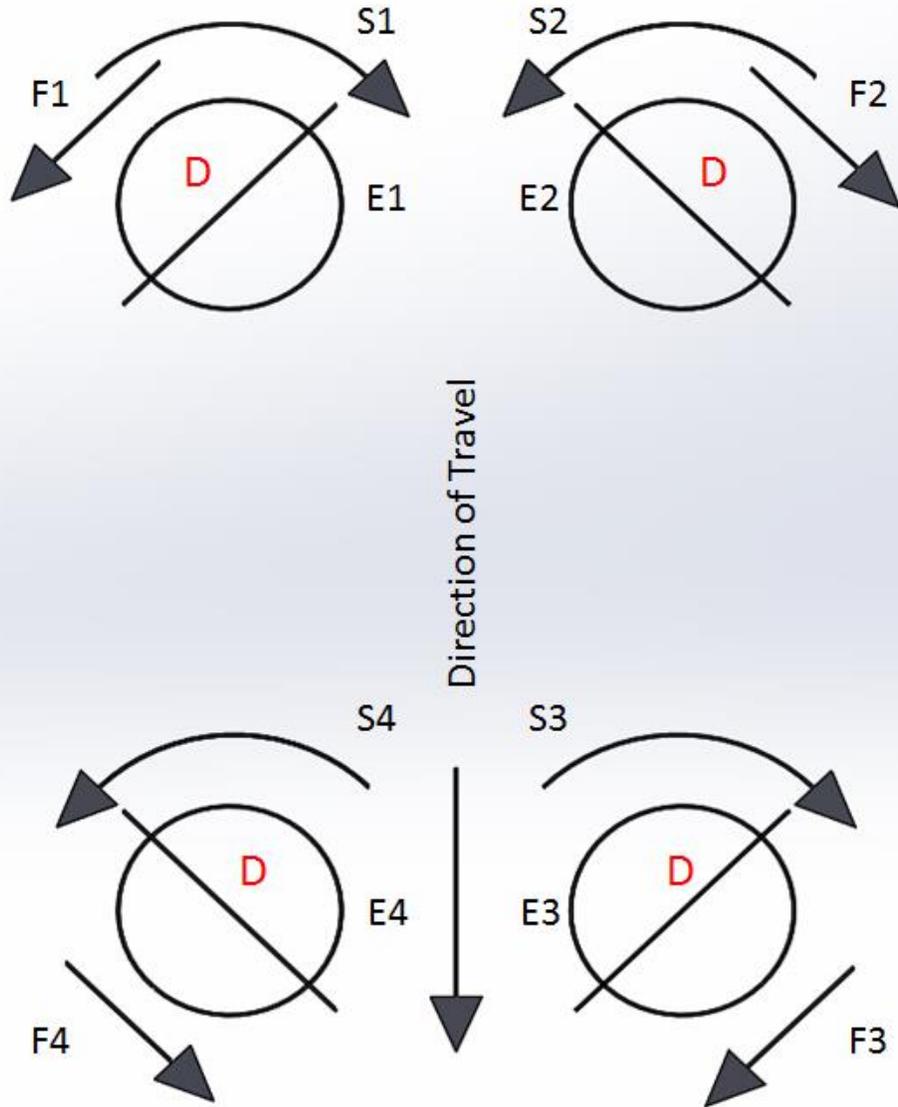


Figure 4

Figure 4 is a topside view describing rearward motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle aft.

Net Leftward Motion

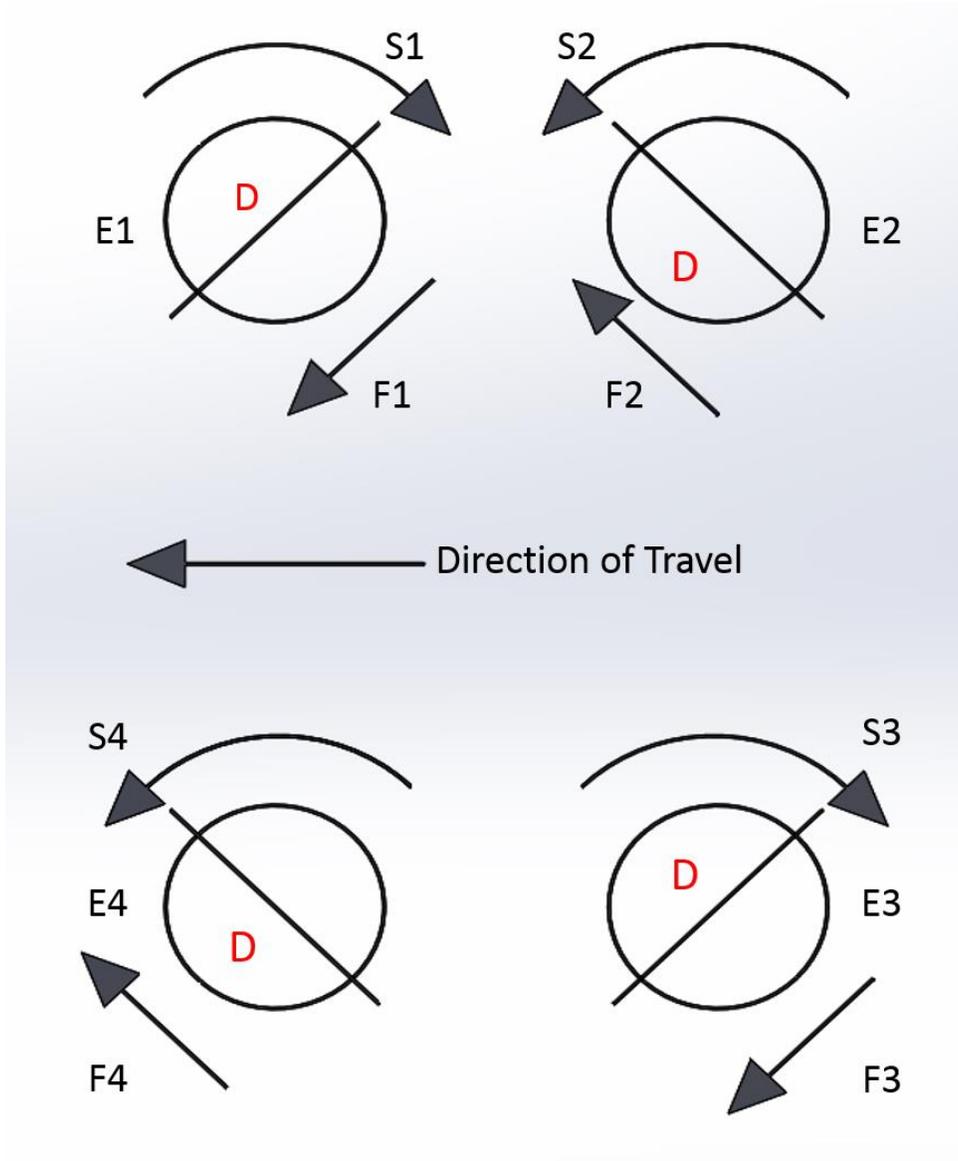


Figure 5

Figure 5 is a topside view describing leftward motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle to the left.

Net Rightward Motion

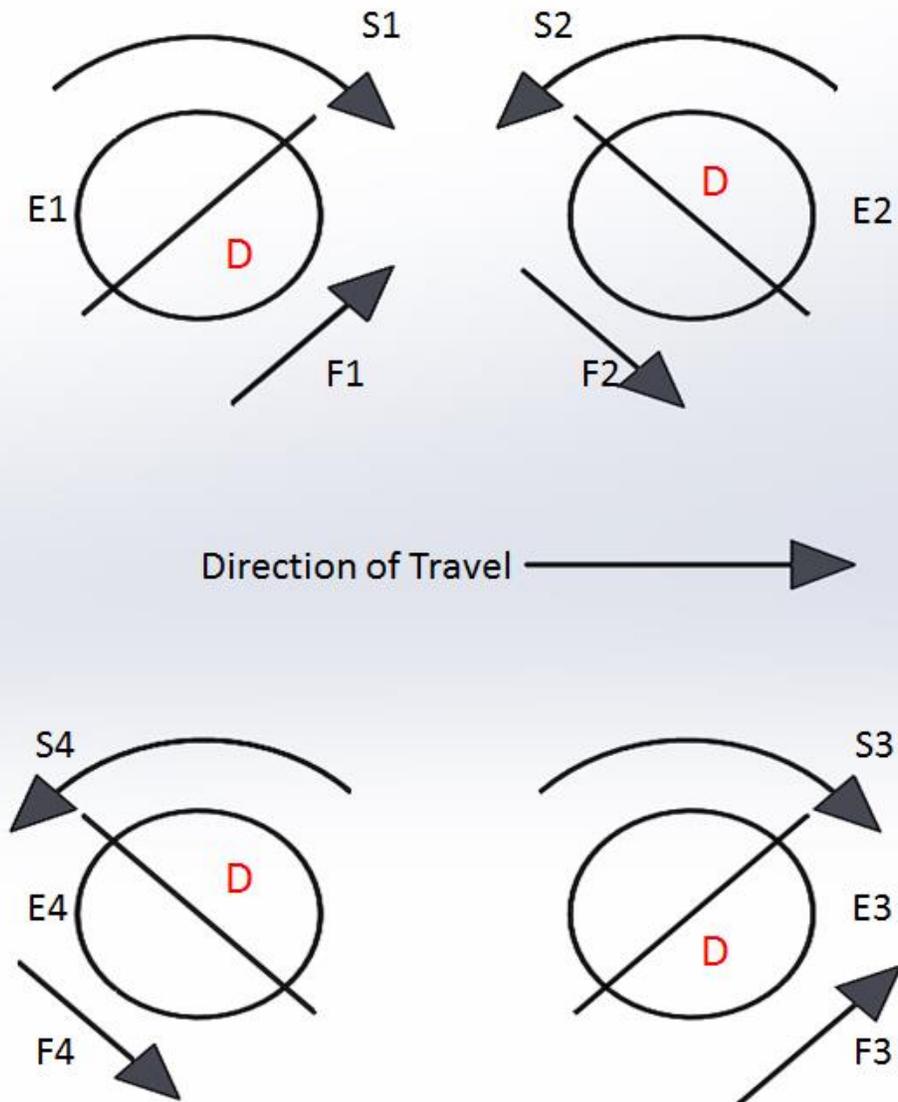


Figure 6

Figure 6 is a topside view describing rightward motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle to the right.

Net Clockwise Motion

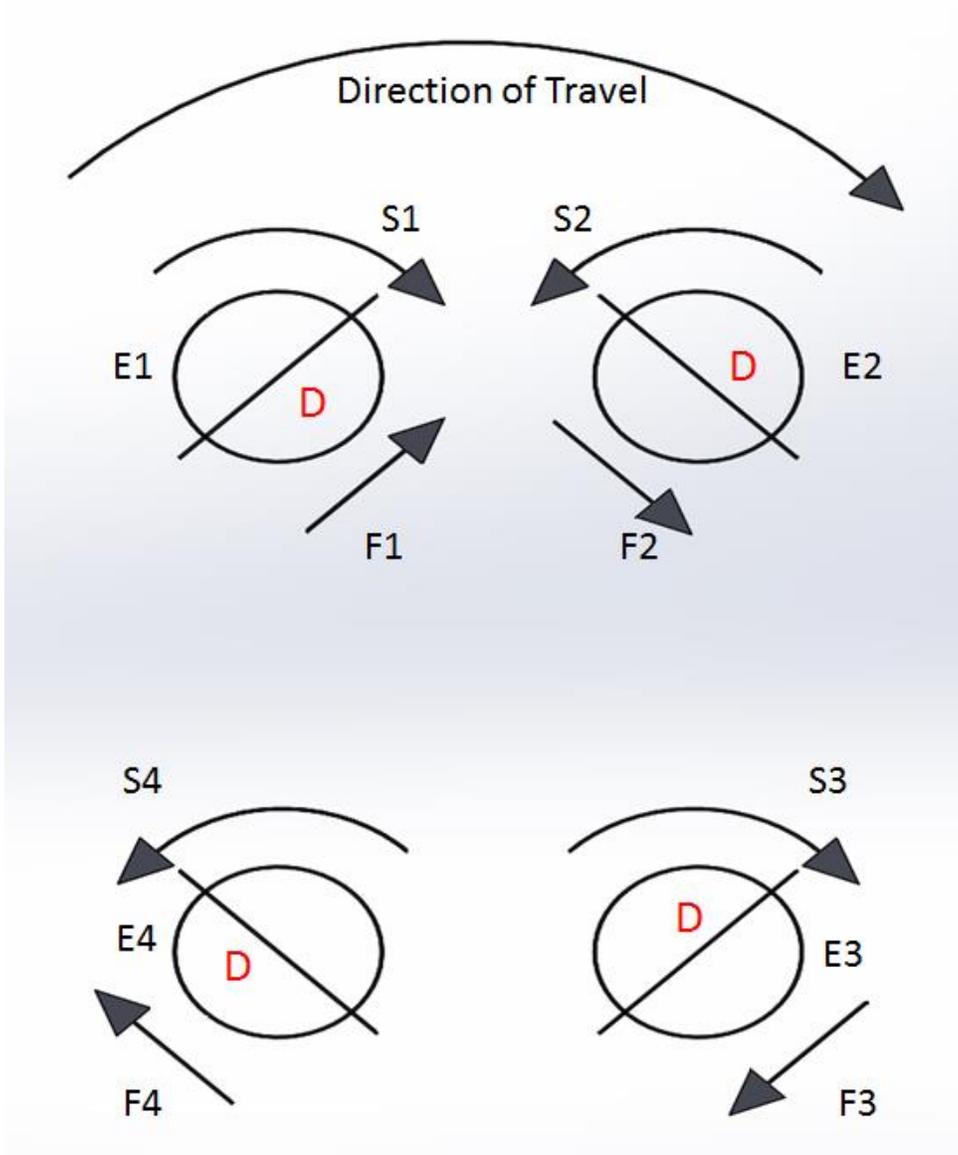


Figure 7

Figure 7 is a topside view describing clockwise motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle in a clockwise direction.

### Net Counterclockwise Motion

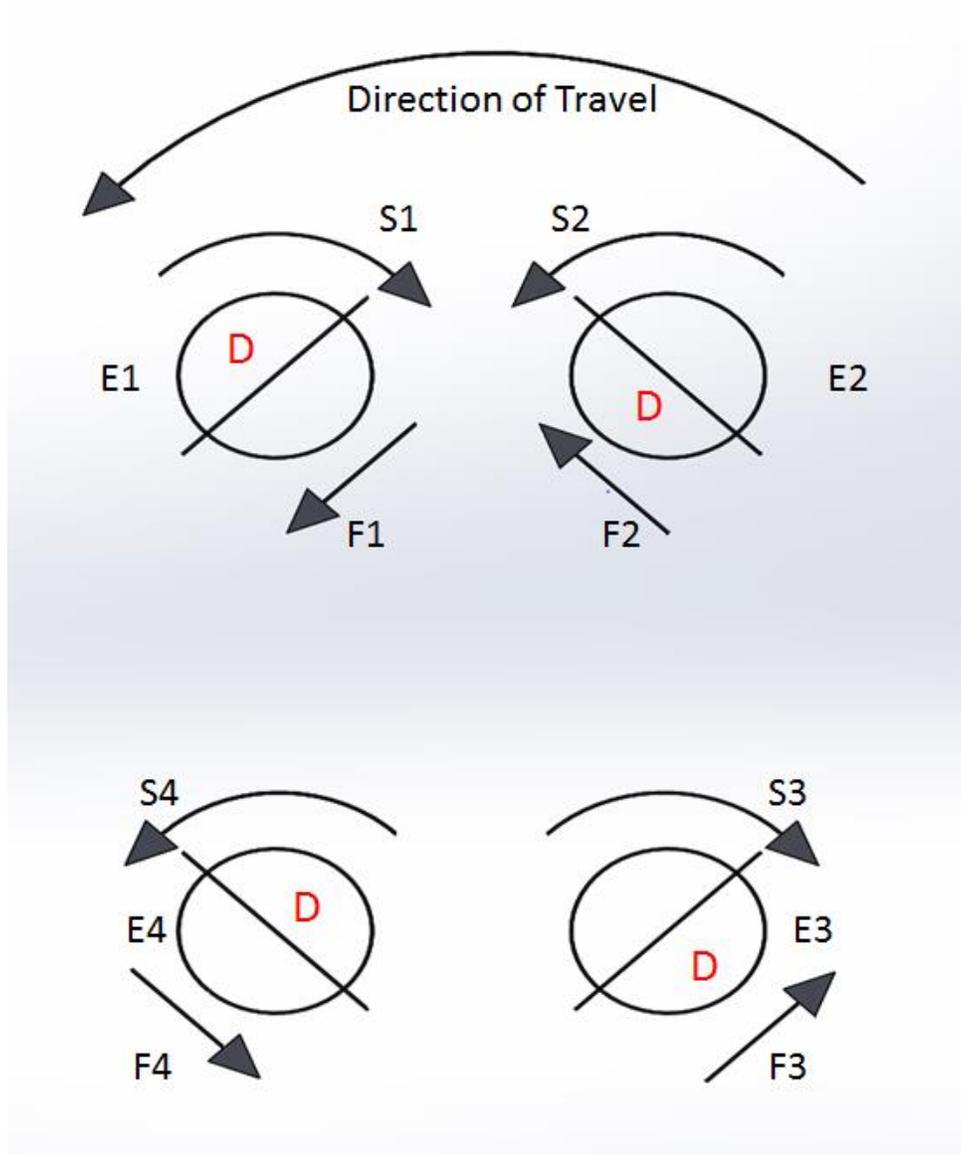


Figure 8

Figure 8 is a topside view describing counterclockwise motion of the vehicle given direction of rotation (S). Engines (E) are tilted downward toward side (D), which generates individual force (F). Net force of all engines moves the vehicle in a counterclockwise direction.

## **Braking**

Braking is possible within any mounting format. Braking is most effective through actuation, by tilting the engine to generate force in the opposite direction. Engines tilted to provide forward thrust will create braking force simply by reversing the tilt. Users can also generate braking force by reversing the rotation of the engine.

## **Engine RPM**

Systems are programmed to run at full-throttle on startup. Users can change this setting through the programming of the system controller via the OpenPilot GCS software. Users can also change the RPM through modulating the voltage to the system.

Generally, increasing RPM of the system will increase hover height. HOWEVER, this is only true up to a certain point (depending on system design and payload).

In our small-scale demo systems built with these hover engines, we have found that systems can operate well up to 4400 RPM, but additional rotational speed offers little improvement in system performance.

We strongly recommend that you adhere to the Vin MAX of 15V so as not to exceed 6,000 RPM as that may result in damage to the engine.

## **Power**

On previous demo systems built with four of these Hover Engines we have used a single 5000mAh 3S (11.1V) LiPo battery with 20C (100A) discharge current. Users can provide any power source suited to the application

Note that there is no over-current or under-current protection built in to the system as shipped, so pay attention to min-max current ratings as provided in the MFA BUNDLE Technical Details section above.

## **Recommended surfaces**

System testing was performed on 6mm (1/4") of Al-1100. Users can optimize performance by using thicker material or more conductive material.

In a lab environment we recommend a single-thickness piece of aluminum (as opposed to layered sheets), as aluminum typically develops an oxide layer which can act as an electrical insulator and will affect performance of the hover engine if such sheets are stacked to create the desired thickness.

We recommend the longest possible length of conductive material. Seams between metal sheets tend to disrupt the formation of eddy currents, and may cause slight instability in system performance. Instability can be minimized by driving your system over seams in a direction perpendicular to the seam itself. Also, we have found that the instability is more pronounced at slow speeds and tends to resolve itself at higher speeds as there is less disruption in the formation of eddy currents in that circumstance.

The system is robust and should perform well on surfaces that are slightly dirty or have imperfections. Even cracks or gouges should not affect performance much unless they are long enough to affect eddy current formation in all of the engines on a vehicle.

Other possible Hover surfaces for MFA BUNDLE that users can use in their lab environments:

- [110-grade Copper](#), 4mm thickness
- [6061-grade Aluminum](#), 10mm thickness

Refer to the International Annealed Copper Standard (IACS) for more information on conductivity of metals. You can find more information on metals and individual alloys [here](#). Users can experiment with any conductive material, while keeping in mind that the system will perform well on thinner surfaces of more conductive material or thicker surfaces of less conductive material. For the most part our testing has only been with materials of an IACS of 40% or above.

### Addendum I

**Example image of components in MFA BUNDLE**

