Vertiq 12” Underactuated Propeller

1 Features

- 3 degrees of freedom with one actuator
- Generate thrust & vector torque in 2 axes
- Enables new vehicle designs
- Increases hover efficiency
- Rated to 50 hours of flight

2 Applications

- Aerial Robotics
- 2 actuator UAV (4dof flight)
- Sliding quadrotor (6dof flight)

3 Description

The Vertiq 12” Underactuated Propeller (UP12) is a propeller designed to allow the control of thrust, roll torque, and pitch torque. With this propeller, a hovering UAV can be built with just two actuators. A second actuator could be an additional underactuated propeller in a coaxial, tandem, or tilt rotor configuration. A standard anti-torque rotor similar to a helicopter can also be used. In this case the performance of a fixed-pitch helicopter can be acheived without the use of a swashplate, drastically reducing complexity.

On a standard quadrotor the UP12 can be used to allow for 6 degree of freedom control by vectoring the thrust of the rotors while using standard quadrotor roll and pitch controls to maintain attitude.

The UP12 is designed to interface with the Vertiq 23-06 2200Kv module. It can be controlled using the IQUART communication protocol. An Ardupilot implementation is available and a PX4 implementation is coming soon.

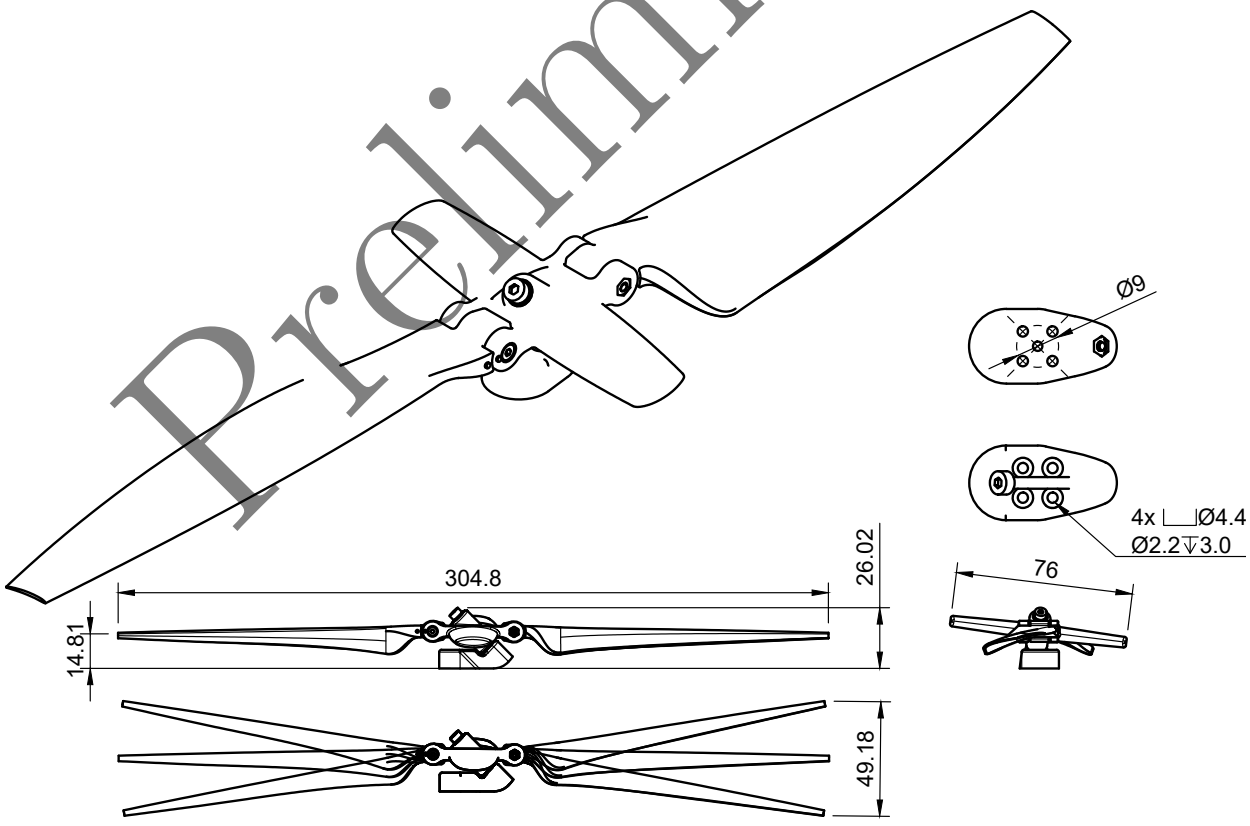
4 Technical Specifications

Table 1: Propeller Specifications

Description	Symbol	Value	Unit	Notes
Diameter	d	12	in	
Pitch	p	4	in	
Mass	m	32.6	g	
Nominal Thrust	$F_{z,nom}$	250	g	
Max Continuous Thrust	$F_{z,max}$	360	g	Thermally limited by Vertiq 23-06 continuous torque
Max Control Torque	$\tau_{xy,max}$	0.17	Nm	At nominal thrust of 250g

5 Mechanical Interface

The UP12 is composed of a motor adapter, a central hub, and two blades. The adapter interfaces directly with the Vertiq 23-06 2200Kv module via four M2 screws on a 9mm diameter circle. The hub is attached to the adapter via a single 2.5mm shoulder bolt. The blades are then attached with a single 2mm shoulder bolt each. A captive nut in the hub secures the blades when the bolt is tightened.



All measurements are in mm

6 Thrust Performance Data

Note: All data is collected using a Vertiq 23-06 2200Kv module.

Figure 1: Thrust vs Speed

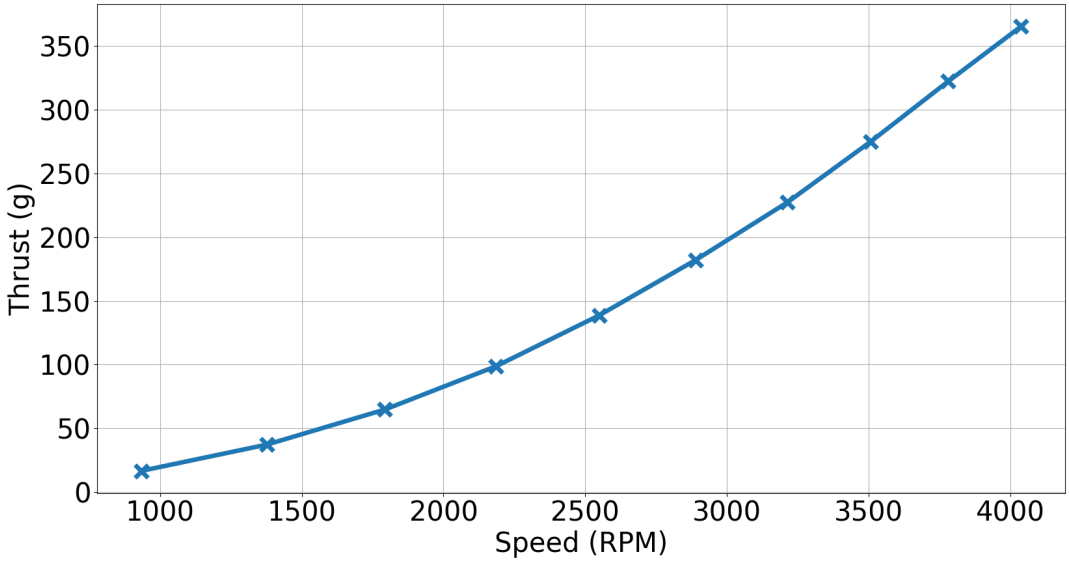


Figure 2: Torque vs Speed

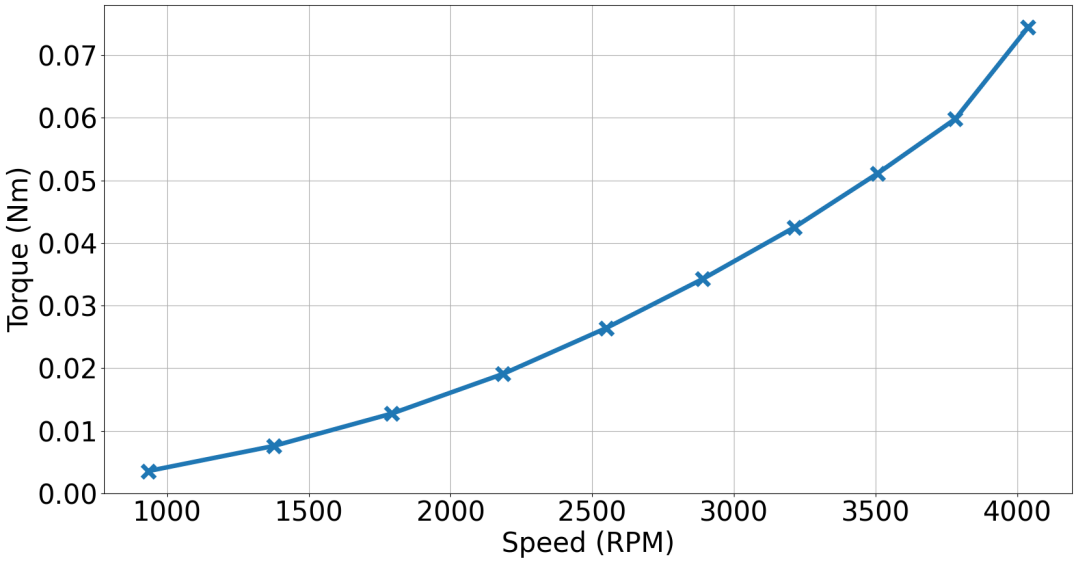
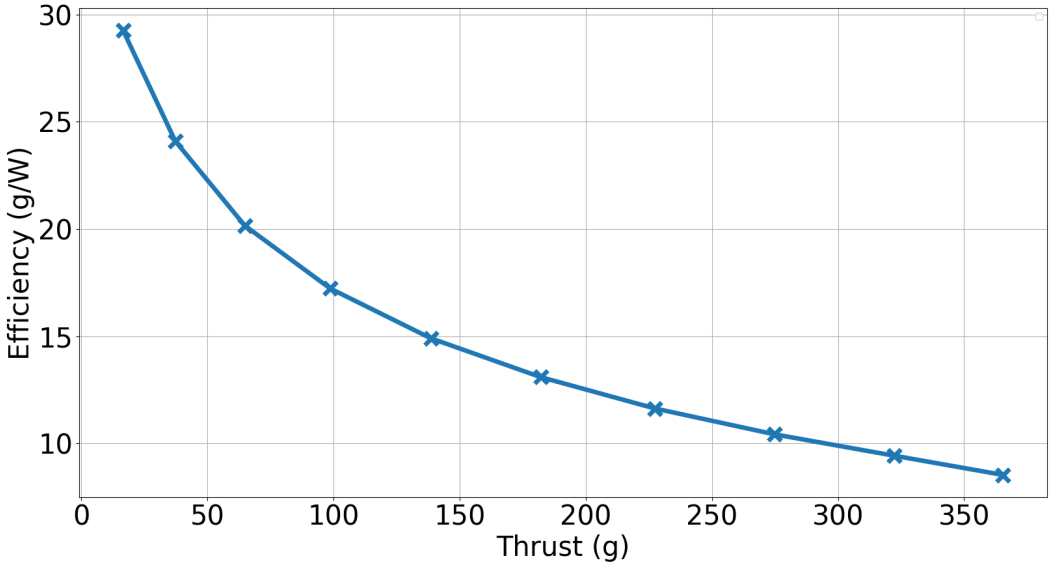


Figure 3: Grams/Watt Efficiency as measured with Vertiq 23-06 2200Kv module



7 Control Performance Data

Figure 4: Maximum Control Torque vs Speed

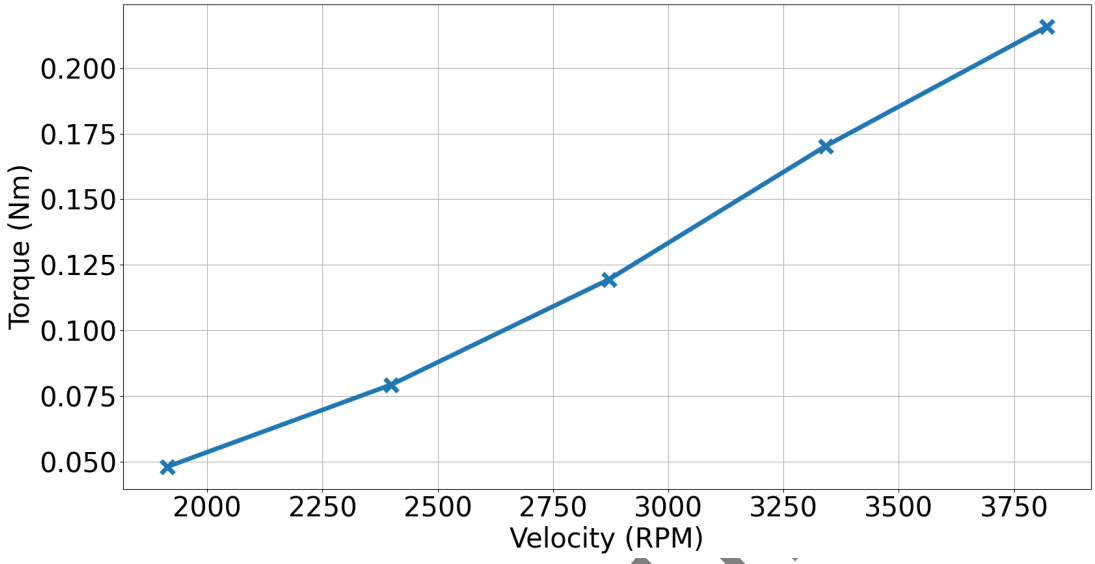
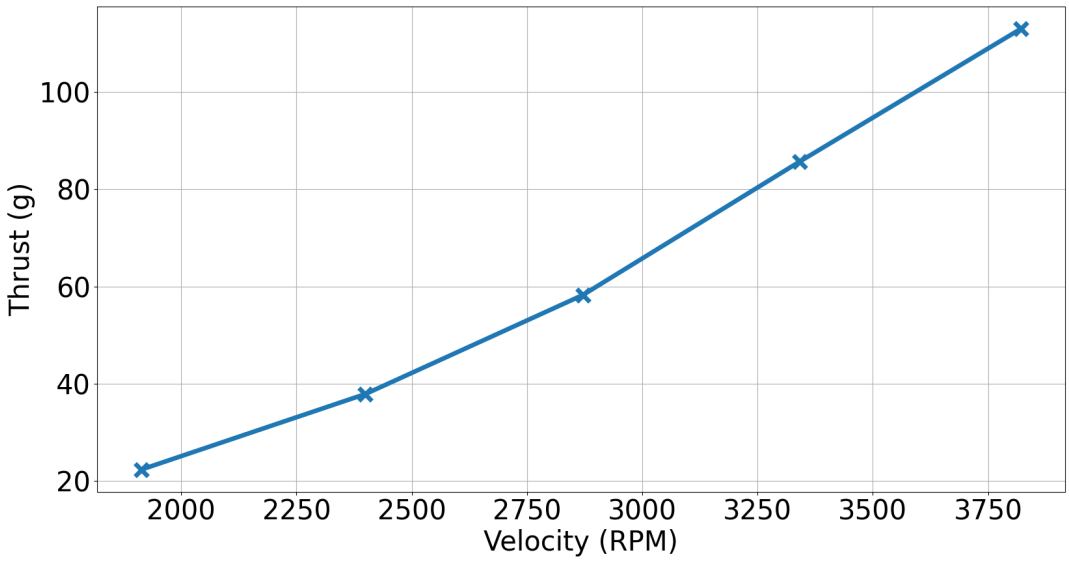


Figure 5: Maximum Control Force vs Speed



8 Torque vs Force Angle

Torque is generated both directly through the main shaft and through a force being offset from the Center of Gravity (CoG) of the aircraft. The direct torque and the torque generated by force appear at different angles approximately 81 degress apart from each other. The torque generated by force happens forward in rotation of the propeller. Some examples of a CCW propeller are shown below at different heights above CoG.

Figure 6: Torque Contribution and Force at 0.0mm Height

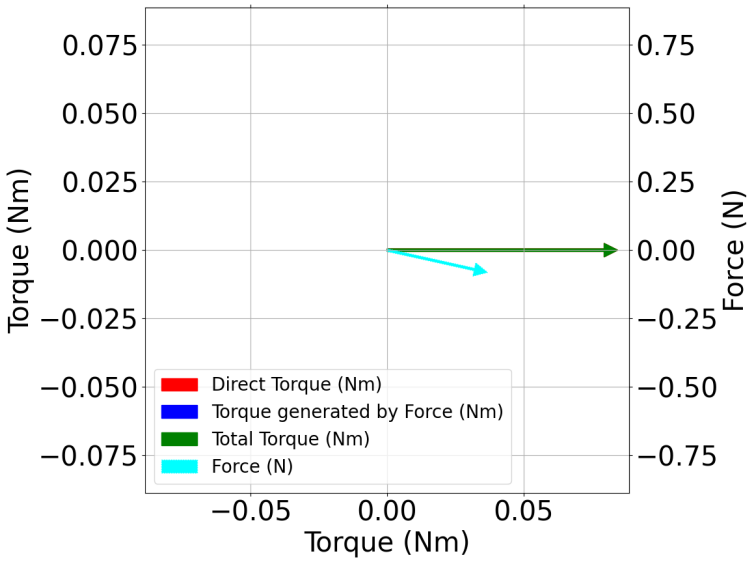


Figure 7: Torque Contribution and Force at 50.0mm Height

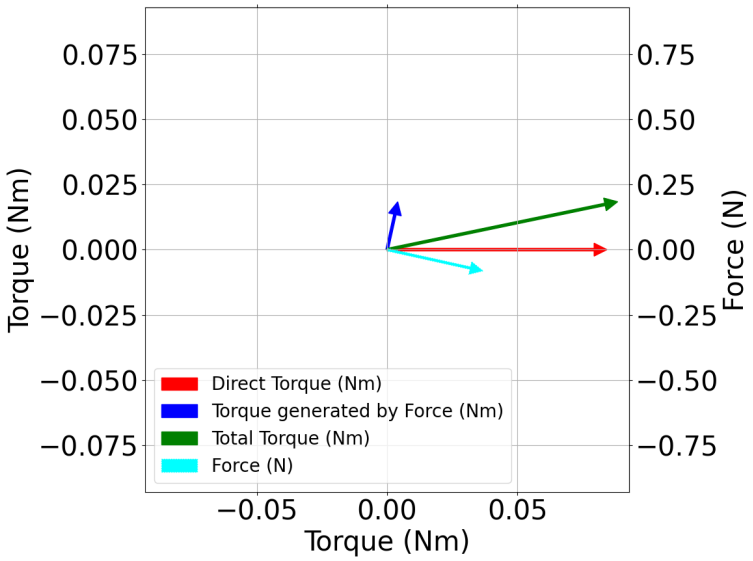
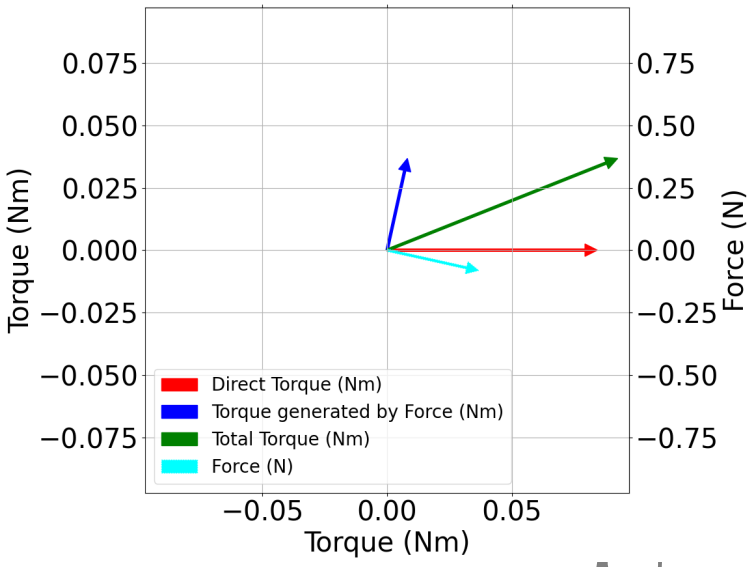


Figure 8: Torque Contribution and Force at 100.0mm Height



9 Revision History

Table 2: Revision History

Version	Date	Changes
0.1	2023-06-23	Preliminary Version