University of Ottawa

MCG4322

RE3 - Wildcat Engineering

Capstone Report

Volume x of y

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Sponsor: Dr. Eric Lanteigne

Abstract

i.Contents of each book (if applicable)

ii.Description of design

iii.Special considerations

iv.Illustration of the final design

half page, one paragraph

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Nomenclature

E_p Modulus of elasticity of considered plastic hub or boss $[N/mm^2]$

F_R Keel to assembly arm connector reaction, $[N]$

F_T Thruster force, $[N]$

F_g Force of gravity, $[N]$

F_{GR} Reaction force of gondola, $[N]$

F_{K1} Keel reaction force 1, $[N]$

F_{K2} Keel reaction force 2, $[N]$

F_{LA} Linear actuator force, $[N]$

F_{NB} Normal force applied to bearing, $[N]$

F_{RSF} Force of snap fit bearing $[N]$

F_α Force on fastener α (hinge to gondola), $[N]$

F_β Force on fastener β (hinge to gondola), $[N]$

F_a Force on fastener a (hinge to gondola), $[N]$

F_{bolt} Bolt pretension force, $[N]$

F_{brake} Normal braking force keel reaction, $[N]$

F_b Force on fastener b (hinge to gondola), $[N]$

F_{c1} Connector moment couple force 1, $[N]$

F_{c2} Connector moment couple force 2, $[N]$

F_{ffric} Friction force acting on friction wheel, $[N]$

F_{nfric} Normal force acting on friction wheel, $[N]$

F_{s1} Force on friction wheel motor fastener 1 , $[N]$

F_{s2} Force on friction wheel motor fastener 2 , $[N]$

F_{spring} Force applied by hinge spring, $[N]$

H_{keel} Height of the bearing arm contact point on the keel, $[m]$

L_G Width of gondola, $[m]$

L_a Length from pivot point of hinge to fastener a , $[m]$

L_b Length from pivot point of hinge to fastener b , $[m]$

L_m Length from side of gondola to gondola drive motor hinge, $[m]$

L_s Length from fastener to fastener of gondola motor to hinge, $[m]$

L_{SF} Length to snap fit bearing, $[m]$

L_{ac} Length from centerline of gondola to fastener a, $[m]$

L_{bc} Length from centerline of gondola to fastener b, $[m]$

L_{cm} Length from gondola wall to center of mass of gondola, $[m]$

$L_{contact}$ Length from contact to contact of bearings on keel, $[m]$

L_{drive} Length of gondola hinge to friction wheel contact, $[m]$

L_{hs} Distance from the pivot of the hinge to the gondola motor fastener, $[m]$

L_{hw} Distance from the gondola motor fastener to the contact point of the friction wheel, $[m]$

L_{rx} Friction wheel motors shaft length, $[m]$

M_1 Reaction moment on bearing arm, $[Nm]$

M_R Connector moment reaction, $[Nm]$

R Reaction force, $[N]$

$S_{compressive}$ Compressive strength of gondola material, $[Pa]$

T_w Friction wheel motor torque, $[Nm]$

T_{spring} Torque of hinge spring, $[Nm]$

W_A Weight of thruster assembly arm, $[N]$

W_E Weight of thruster enclosure, $[N]$

W_T Weight of thruster, $[N]$

W_c Weight of connection piece, $[N]$

W_{LA} Weight of linear actuator, $[N]$

η Safety Factor

μ Coefficient of friction

σ' Von Mises Stress, $[Pa]$

σ_{washer} Compressive force of washer, $[Pa]$

σ_x Principle stress, $[Pa]$

σ_a Hoop stress, $[N/mm^2]$

σ_s Allowable design stress for plastic, N/mm^2

$a_{airship}$ Acceleration of airship, $[m/s]$

$a_{gondola1}$ Acceleration of Gondola 1 , $[m/s^2]$

$a_{gondola2}$ Acceleration of Gondola 2 , $[m/s^2]$

c Distance from neutral axis to stress location, $[m]$

d_i Interference diameter, $[mm]$

d_s Hub outer diameter, $[mm]$

d_s Shaft diameter, $[mm]$

i_a Allowable interference, $[mm]$

$m_{airship}$ Mass of airship, $[kg]$

$m_{gondola1}$ Mass of Gondola 1, $[kg]$

$m_{gondola2}$ Mass of Gondola 2, $[kg]$

r_{fw} Radius of friction wheel, $[m]$

w_{armx} Width of the bearing arm in the x direction, $[m]$

w_{army} Width of the bearing arm in the y direction, $[m]$

Chapter 1: Introduction

1.1 Project Mandate

The goal of the project is to overcome the current limitations involved with the control and landing of unmanned airships in adverse outdoor conditions. The airship consists of a helium filled envelope, external keel, and gondola which will act as a ballast. The moving ballast will control the pitch by the controlled displacement of the centre of mass. Propulsion will be provided by propellers in the X-Y plane of the airship. The system will have vector thrusting to allow for altitude change independent of pitch change.

1.2 Group Problem Scope

The research project led by Dr. Eric Lanteigne involves designing a system to allow for the control of an unmanned airship. The goal of the project is to create a system that controls the airship by changing the position of the centre of mass to initiate pitch change. This pitch change, along with forward propulsion, will drive the airship in a given direction. The design team will be responsible for creating a system, where a gondola that acts as a ballast, will move along a nonlinear, diamond-shaped keel in order to initiate pitch change of an airship. Ideally, the system will be able to incur a pitch change of up to ninety degrees, allowing the airship to descend straight downwards. Currently, all designs must be scalable as specifications of the airship envelope have yet to be finalized. The unmanned airship must be capable of flying outdoors and be able to carry a payload of between 0.2kg and 0.5kg. The main components of the design can be split up into: Gondola Design, Gondola Movement, Securing Gondola to Keel, Gondola Position Measurement, Securing the Propellers, Thrust Vectoring, Batteries, and Wire Management.

1.3 Criteria and Restrictions

The propellers will be in the X-Y plane, in line with the centre of volume. This eliminates any moments from the propellers that lead to imbalance and unwanted pitch variations. The gondola will be able to move along the varying curvature of the keel using a hinged-gondola. The driving mechanism will be two friction wheels with the additional support of 4 driven bearings. The cross-section of the keel is diamond-shaped, however it is not torsionally constant, therefore the vertexes are not coincident on the curved section. Once the airship has been constructed, a Special Flight Operations Certificate (SFOC) issued by Transport Canada will be necessary in order to fly the airship lawfully.

1.4 Parameterization Overview

A high level overview of the system's parameterization is shown in Figure 1.1.

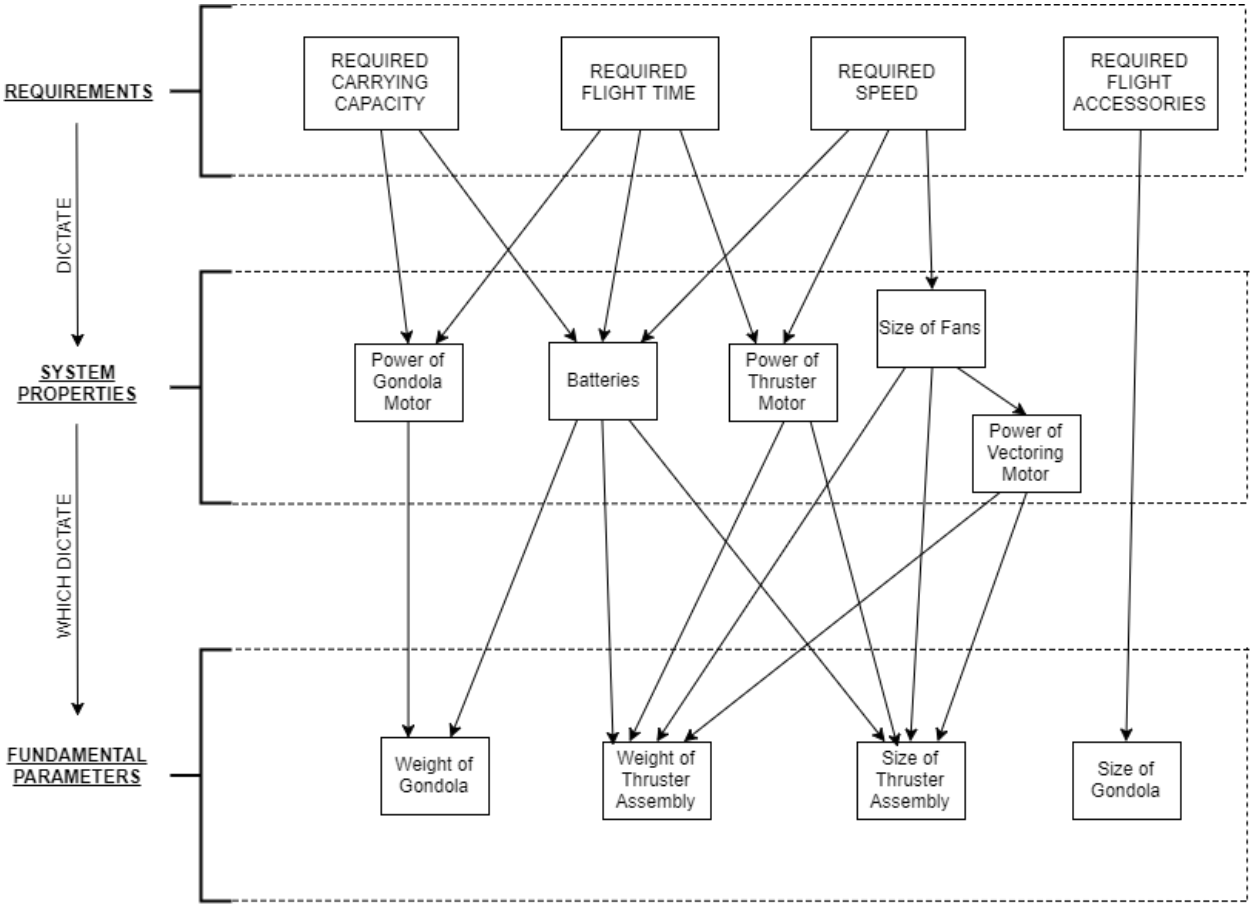

Figure 1.1: Overview of Modelling Paramaterization

Figure 1.2 is a more detailed parameterization outline, which shows how user inputs will be converted to forces using an iterative approach. This approach will be used to compute all forces shown in Section ADD HERE.

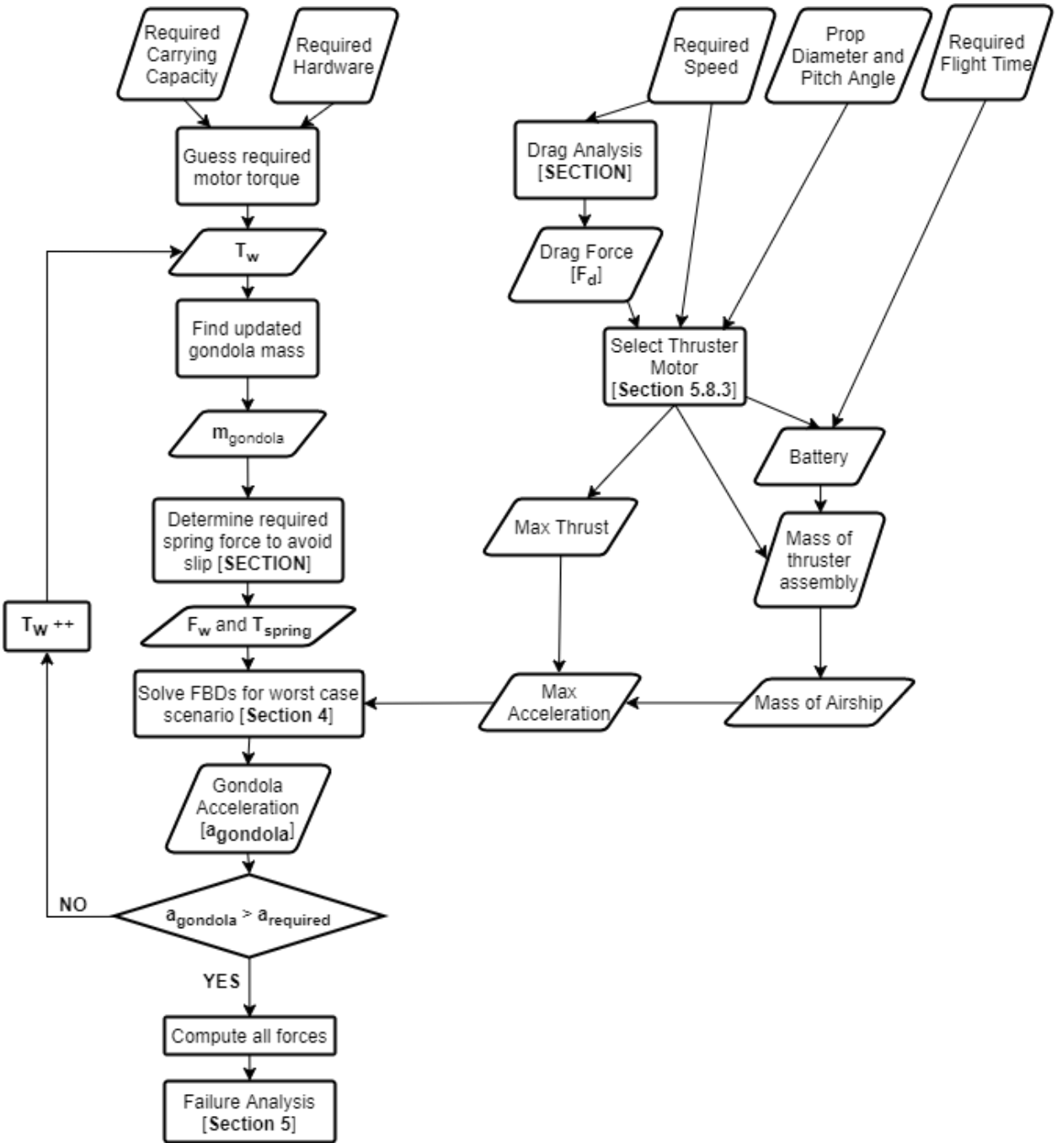

Figure 1.2: Detailed Modelling Paramaterization

Once all of the forces acting on the body are computed, failure analyses for each part are conducted in Section ADD HERE.

Chapter 2: Proposed Design

Text

Chapter 3: Analysis

Text

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Appendix A: Thrust Force

Test

Appendix B: Data Sheets

B.1 Linear Actuator [1]

100mm L12 Actuator
Actual Size

Miniature Linear Motion Series · L12

Actuonix Motion Devices unique line of Miniature Linear Actuators enables a new generation of motion-enabled product designs, with capabilities that have never before been combined in a device of this size. These small linear actuators are a superior alternative to designing with awkward gears, motors, servos, and linkages.

Actuonix's L series of micro linear actuators combine the best features of our existing micro actuator families into a highly flexible, configurable, and compact platform with an optional sophisticated on-board microcontroller. The first member of the L series, the L12, is an axial design with a powerful drive-train and a rectangular cross section for increased rigidity. But by far the most attractive feature of this actuator is the broad spectrum of available configurations.

L12 Specifications

Gearing Option	50:1	100:1	210:1
Peak Power Point	17N @ 14mm/s	31N @ 7mm/s	62N @ 3.2mm/s
Peak Efficiency Point	10N @ 19mm/s	17N @ 10mm/s	36N @ 4.5mm/s
Max Speed *(no load)*	25mm/s	13mm/s	6.5mm/s
Max Force *(lifted)*	22N	42N	80N
Back Drive Force *(static)*	12N	22N	45N

Stroke Option	10 mm	30mm	50mm	100mm
Mass	28 g	34 g	40 g	56 g
Repeatability *(-I,-R,-P&LAC)*	±0.1 mm	±0.2 mm	±0.3 mm	±0.5 mm
Max Side Load *(extended)*	50N	40N	30N	15N
Closed Length *(hole to hole)*	62mm	82mm	102mm	152mm
Potentiometer *(-I, -R, -P)*	1kΩ±50%	3kΩ±50%	6kΩ±50%	11kΩ±50%

Voltage Option	6VDC	12VDC
Max Input Voltage	7.5V	13.5V
Stall Current	460mA	185mA
Standby Current *(-I/-R)*	7.2mA	3.3mA

Operating Temperature	-10°C to +50°C
Potentiometer Linearity	Less than 2.00%
Max Duty Cycle	20 %
Audible Noise	55dB @ 45cm
Ingress Protection	IP-54
Mechanical Backlash	0.2mm
Limit Switches *(-S)*	Max. Current Leakage: 8uA
Maximum Static Force	200N

1 - Control Option Specific values are identified with -I, -R, -P, -S, and LAC
2 - 1 N (Newton) = 0.225 lbf (pound-force) & 25.4mm=1 Inch
3 - A powered-off actuator will statically hold a force up to the Backdrive Force
4 - Actuators should be tested in each specific application to determine their effective life under those loading conditions and environment.

Benefits
- → **Compact**
- → **Simple control**
- → **Low voltage**
- → **Equal push/pull**
- → **Easy mounting**

Applications
- → **Robotics**
- → **Appliances**
- → **Toys**
- → **RC vehicles**
- → **Automotive**
- → **Industrial Automation**

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Victoria, BC, V9E 2A9
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1 (888) 225-9198 *toll-free*
1 (206) 347-9684 *fax*
sales@actuonix.com
www.actuonix.com

B.2 Bearings [12]

McMASTER-CARR®

General Purpose Plastic Ball Bearing

with Stainless Steel Ball, for 1/4" Shaft Diameter, 5/8" OD

In stock
$6.03 Each
6455K2

Bearing Type	Ball
For Load Direction	Radial
Ball Bearing Type	Standard
Construction	Single Row
Seal Type	Open
For Shaft Shape	Round
Trade No.	R4
For Shaft Diameter	1/4"
ID	0.25"
ID Tolerance	0" to 0.003"
OD	5/8"
OD Tolerance	-0.003" to 0"
Width	0.196"
Width Tolerance	-0.005" to 0.005"
Material	Acetal
Cage Material	Plastic
Radial Load Capacity, lbs.	
Dynamic	25
Static	15
Maximum Speed	2,300 rpm
Shaft Mount Type	Press Fit
Lubrication	Not Required
Temperature Range	-40° to 180° F
ABEC Rating	Not Rated
Radial Clearance	0.001" to 0.008"
Ball Material	Stainless Steel
RoHS	Compliant

Choose these acetal bearings for their all-around corrosion and chemical resistance.

Stainless steel balls offer excellent corrosion resistance.

B.3 Friction Wheel Assembly

B.3.1 Friction Wheel [11]

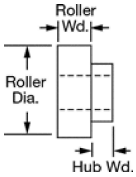
10/10/2017 McMaster-Carr - Neoprene Roller, Drive, Aluminum Hub, 5/8" Roller Diameter, 3/16" Roller Width

McMASTER-CARR

Neoprene Roller

Drive, Aluminum Hub, 5/8" Roller Diameter, 3/16" Roller Width

In stock
$16.70 Each
60885K31



Guide Roller Type	Drive
Roller Style	Shaft Mount
Roller Profile	Flat
Roller Material	Neoprene
Hub Material	Aluminum
Roller	
Diameter	5/8"
Width	3/16"
For Shaft Diameter	1/4"
Hub	
Diameter	1/2"
Width	1/4"
Shaft Mount Type	Set Screw
Set Screws	
Number Required	1
Included	No
Thread Size	8-32
Temperature Range	-40° to 170° F
Durometer (Hardness Rating)	55A (Medium) Black
RoHS	Compliant
Related Product	8-32 Stainless Steel Cup Point Set Screws (100/Pkg.)

Made of neoprene rubber, these rollers resist oil, flames, gasoline, and weather. Also known as contact wheels and feed rollers, they have tapped hubs that allow you to mount them onto a shaft or stud to transmit power.

https://www.mcmaster.com/#60885k31/=19r77pc 1/2

B.3.2 Friction Wheel Set Screw [13]

McMASTER-CARR®

Alloy Steel Cup-Point Set Screw

Black Oxide, 8-32 Thread, 1/4" Long

In stock
$10.65 per pack of 100
91375A190

Material	Black-Oxide Alloy Steel
Thread Size	8-32
Length	1/4"
Drive Size	5/64"
Screw Size Decimal Equivalent	0.164"
Hardness	Rockwell C45
Specifications Met	ASME B18.3, ASTM F912
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 3A
Thread Direction	Right Hand
Drive Style	Hex
Tip Type	Cup
Head Type	Headless
System of Measurement	Inch
RoHS	Compliant

Made from alloy steel, these set screws have a thin edge that digs into hard surfaces for a secure hold. Length listed is the overall length.

Black-oxide alloy steel set screws resist corrosion in dry environments.

'
''

B.3.3 Friction Wheel Motor [15]

50:1 Micro Metal Gearmotor HP 6V

Pololu item #: 998 **438** in stock

Price break	Unit price (US$)
1	15.95
10	13.55
50	11.96

Quantity: 1 Add to cart

backorders *allowed* Add to wish list

This gearmotor is a miniature **high-power, 6 V** brushed DC motor with a **51.45:1** metal gearbox. It has a cross section of 10 × 12 mm, and the D-shaped gearbox output shaft is 9 mm long and 3 mm in diameter.

Key specs at 6 V: 625 RPM and 120 mA with no load, 15 oz-in (1.1 kg-cm) and 1.6 A at stall.

Select options: 51.45 :1 | 1.6A stall @ 6V (HP 6V) | extended motor shaft? N

Go ►

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Description Specs (10) **Pictures (20)** **Resources (12)** **FAQs (1)** **On the blog (1)**

Dimensions

Size:	10 × 12 × 26 mm[1]
Weight:	9.5 g
Shaft diameter:	3 mm[2]

General specifications

Gear ratio:	51.45:1
Free-run speed @ 6V:	630 rpm
Free-run current @ 6V:	120 mA
Stall current @ 6V:	1600 mA
Stall torque @ 6V:	15 oz·in
Extended motor shaft?:	N

B.3.4 Friction Wheel Encoder [16]

Magnetic Encoder Pair Kit for Micro Metal Gearmotors, 12 CPR, 2.7-18V (HPCB compatible)

Pololu item #: 3081 **574** in stock

Price break	Unit price (US$)
1	8.95
10	7.95
50	6.95

Quantity: 1 Add to cart

backorders *allowed* Add to wish list

Add quadrature encoders to your micro metal gearmotors (extended back shaft version required) with this kit that uses a magnetic disc and hall effect sensors to provide 12 counts per revolution of the motor shaft. The sensors operate from 2.7 V to 18 V and provide digital outputs that can be connected directly to a microcontroller or other digital circuit. This module is compatible with **all** of the dual-shaft micro metal gearmotors we carry, including the HPCB versions.

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Description **Specs (6)** **Pictures (13)** **Resources (5)** FAQs (0) **On the blog (4)**

Overview

This kit includes two dual-channel Hall Effect sensor boards and two **6-pole magnetic discs** that can be used to add quadrature encoding to two **micro metal gearmotors with extended back shafts** (motors are not included with this kit). The encoder board senses the rotation of the magnetic disc and provides a resolution of 12 counts per revolution of the motor shaft when counting both edges of both channels. To compute the counts per revolution of the gearbox output shaft, multiply the gear ratio by 12.

B.4 Spring [14]

McMASTER-CARR®

Music-Wire Steel Torsion Spring

180 Degree Right-Hand Wound, 0.767" OD

In stock
$8.06 per pack of 6
9271K271

Spring Type	Torsion
Material	Music-Wire Steel
Deflection Angle	180°
Wind Direction	Right Hand
OD	0.767"
For Maximum Shaft Diameter	0.500"
Wire Diameter	0.063"
Leg Length	2.000"
Number of Coils	6.00
Spring Length @ Maximum Torque	0.475"
Maximum Torque	5.518 in.-lbs.
RoHS	Compliant

These music-wire steel springs are stronger than stainless steel springs. Commonly found in clothespins, spring clamps, mousetraps, motors, and spring-return mechanisms, torsion springs maintain pressure over a short distance in a rotational direction. They are often supported by a shaft, mandrel, or arbor.

Squeezing a torsion spring reduces its OD, which tightens the spring around a shaft and increases the spring length. Since the spring gets tighter as it is squeezed around the shaft, a maximum shaft diameter for each spring is listed. Using a shaft with a larger diameter will interfere with the spring motion.

Torsion springs should be used in the direction in which the coils are wound. Deflection angle represents the angle between the legs of the spring as well as the maximum spring rotation. All springs rotate until their legs are parallel. For example, a spring with a 90° deflection angle has a 90° angle between its legs, and it will rotate a maximum of 90°. Maximum torque is the torque required to rotate the spring legs to the parallel position.

B.5 Battery [2]

Rhino 2250mAh 3S 11.1v 40C Lipoly Pack

Specifications

SKU:	R2250-40-3	Brand:	N/A
Weight(g)	243.00	Length	109.00
Width:	26.00	Height:	36.00
Capacity (mAh)	2250.00	Discharge(c)	40.00
Length-A(mm):	107.00	Height-B(mm):	34.00
Width-C(mm)	26.00	Unit Weight (g)	191
Max Charge Rate(C):	5.00	Discharge Plug:	N/A

B.6 Thruster Assembly

B.6.1 Thruster Motor [9]

HobbyKing® ™ 2612 Brushless Outrunner 1900KV

Specifications

RPM/V: **1900Kv**
Cell Count: **2~3s Lipoly**
Max.efficiency: **78.0%**
Current at Max.eff: **6.3~8.7A**
Max.current: **14A**
No Load Current: **0.8A/7V**
Intemal Resistance: **165mOhm**
Diameter: **27mm**
Length: **23.4mm**
Mounting Hole Spacings: **32mm**
Mounting Hole Diameter: **2mm**
Shaft: **3mm**
Weight: **25g**

B.6.2 Propeller [7]

Aerostar Carbon Fibre Propeller 7x5

Specifications

SKU:	9445000180-0	Brand:	N/A
Weight(g)	14.00	Length	180.00
Width:	15.00	Height:	20.00
Pitch Y(Inch)	5.00	Material	Carbon Fiber
Rotation:	CCW	Unit Weight (g):	N/A
Type	Normal	Blade Count	2
Diameter X(Inch):	7.00		

B.6.3 BESC [3]

TURNIGY Plush 10amp Speed Controller w/BEC

Specifications

Cont Current: **10A**
Burst Current: **12A**
BEC Mode: **Linear**
BEC : **5v / 2A**
Lipo Cells: **2-4**
NiMH : **5-12**
Weight: **9g**
Size: **27x17x6mm**

SKU:	TR_P10A
Weight(g)	20.00
Width:	10.00
Brand:	No
Length	110.00
Height:	110.00

B.6.4 Servo Motor [17]

RB-Hit-128

HS-7950TH Ultra Torque HV Coreless Titanium Gear Servo

Hitec's strongest servo period, the "Ultra Torque" HS-7950TH is designed to operate on a two cell LiPo Pack. Featuring our high resolution "G2" second generation programmable digital circuit and our indestructible Titanium gears, the HS-7950TH has the performance and durability you've come to expect from a Hitec servo. Other features in the HS-7950TH include a 7.4V optimized coreless motor, integrated heat sink case, and a top case with two hardened steel gear pins supported by axial brass bushing.

The HS-7950TH has been designed for the most demanding hobby applications including the largest aircraft and monster trucks. Featuring a titanic 403 oz./in. of torque at 6.0 volts, while still maintaining a respectable 0.15 second transit time.

Features

- G2 Digital Circuit
- Titanium Gear Train (MK first gear)

- Ultra Performance Coreless Motor
- Heatsink Case
- (8) O-Rings for Water/Dust/Fuel protection
- Dual Ball Bearing Supported Output Shaft

Programmable Features Include:

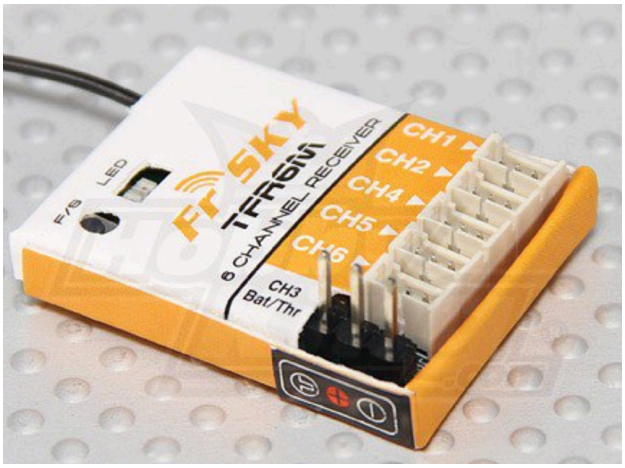
- Dead Band Width
- Direction of Rotation
- Speed of Rotation (slower)
- End Points
- Neutral Points
- Fail Safe On/Off
- Fail Safe Point
- Resolution* (default is high resolution)
- Overload Protection* (default is off)

Specifications

- Motor Type: Coreless
- Bearing Type: Dual Ball Bearing
- Speed (6.0V/7.4V): 0.15 / 0.13
- Torque oz./in. (6.0V/7.4V): 403 / 486
- Torque kg./cm. (6.0V/7.4V): 29.0 / 35.0
- Size in Inches: 1.57 x 0.79 x 1.50
- Size in Millimeters: 39.88 x 20.07 x 38.10
- Weight oz.: 2.40
- Weight g.: 68.04

B.6.5 Receiver [8]

FrSky TFR6M 2.4Ghz 6CH Micro Receiver FASST Compatible



Specification

SKU:	236000003	Brand:	FrSky
Weight(g)	34.00	Length	160.00
Width:	20.00	Height:	87.00

B.7 Flight Control Assembly

B.7.1 ESC [4]

Turnigy 20A BRUSHED ESC

Specifications

SKU:	TGY-20A	Brand:	No
Weight(g)	39.00	Length	150.00
Width:	10.00	Height:	110.00

B.7.2 GPS Module [6]

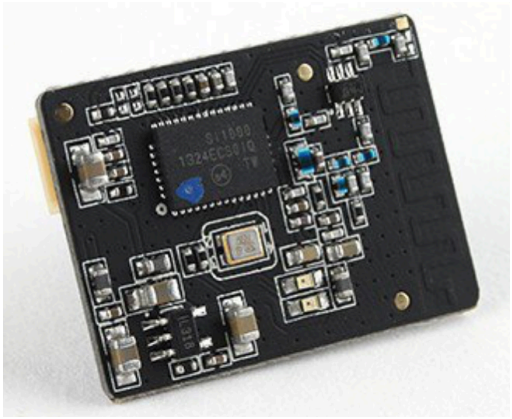
UBLOX Micro M8N GPS Compass Module

Specifications

SKU:	9387000083-0	Brand:	No
Weight(g)	29.00	Length	80.00
Width:	10.00	Height:	60.00

B.7.3 Transceiver [10]

Micro HKPilot Telemetry Radio Set with Integrated PCB Antenna 915Mhz



Specifications

Supply voltage: **3.7-6 VDC**
Transmit current: **100 mA at 20 dBm**
Receive current: **25 mA**
Serial interface: **3.3 V UART**
Size: **19x25x5mm (with antenna)**
Weight: **1.6g (with antenna)**
Specs Ground Transceiver:
Supply voltage: **3.7-6 VDC (from USB or DF13 connector)**
Transmit current: **100 mA at 20 dBm**
Receive current: **25 mA**
Serial interface: **3.3 V UART**
Size: **25.5x 53x11 mm (without antenna)**
Weight: **11.5g (without antenna)**

SKU:	387000067-0	Brand:	No
Weight(g)	44.00	Length	100.00
Width:	40.00	Height:	70.00

B.7.4 Flight Controller [5]

PixFalcon Micro PX4 Autopilot

Specifications

SKU:	9387000082-0	Brand:	N/A
Weight(g)	99.00	Length	107.00
Width:	40.00	Height:	74.00