

UNIVERSITY OF OTTAWA

MCG4322

RE3 - WILDCAT ENGINEERING

Capstone Report

Volume x of y

Joey Kane - 7386330

Isaak Goldenberg - 7395188

Sawyer Woodside - 7158568

Alex Pennell - 7334789

December 8, 2017



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

Contents

1 Problem Statement	1
1.1 Project Mandate	1
1.2 Group Problem Scope	1
1.3 Criteria and Restrictions	1
2 Test 2	3
2.1 what	3
3 Test 3	5
A Thrust Force	7
B Data Sheets	9
B.1 Linear Actuator [?]	10
B.2 Bearings [?]	11
B.3 Friction Wheel Assembly	12
B.3.1 Friction Wheel [?]	12
B.3.2 Friction Wheel Set Screw [?]	13
B.3.3 Friction Wheel Motor [?]	14
B.3.4 Friction Wheel Encoder [?]	15
B.4 Spring [?]	16
B.5 Battery [?]	17
B.6 Thruster Assembly	18
B.6.1 Thruster Motor [?]	18
B.6.2 Propeller [?]	19
B.6.3 BESC [?]	20
B.6.4 Servo Motor [?]	21
B.6.5 Receiver [?]	23
B.7 Flight Control Assembly	24
B.7.1 ESC [?]	24
B.7.2 GPS Module [?]	25
B.7.3 Transceiver [?]	26
B.7.4 Flight Controller [?]	27

List of Figures

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: Problem Statement

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.

Chapter 2: Test 2

2.1 what

Chapter 3: Test 3

[?]

Appendix A: Thrust Force

Test

Appendix B: Data Sheets

B.1 Linear Actuator [?]



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
Mass	28 g	34 g	40 g
Repeatability (-I, -R, -P&LAC)	±0.1 mm	±0.2 mm	±0.3 mm
Max Side Load (extended)	50N	40N	30N
Closed Length (hole to hole)	62mm	82mm	102mm
Potentiometer (-I, -R, -P)	1kΩ±50%	3kΩ±50%	6kΩ±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.

All information provided on this datasheet is subject to change. Purchase or use of Actuonix actuators is subject to acceptance of our terms and conditions as posted here: <http://www.actuonix.com/terms.asp>



Actuonix Motion Devices Inc

580 Starling Lane

Victoria, BC, V9E 2A9

Canada

1(206) 347-9684 phone

1(888) 225-9198 toll-free

1(206) 347-9684 fax

sales@actuonix.com

www.actuonix.com

B.2 Bearings [?]

10/10/2017

McMaster-Carr - General Purpose Plastic Ball Bearing, with Stainless Steel Ball, for 1/4" Shaft Diameter, 5/8" OD



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 [?]

10/10/2017

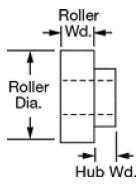
McMaster-Carr - Neoprene Roller, Drive, Aluminum Hub, 5/8" Roller Diameter, 3/16" Roller Width



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.

B.3.2 Friction Wheel Set Screw [?]

10/10/2017

McMaster-Carr - Alloy Steel Cup-Point Set Screw, Black Oxide, 8-32 Thread, 1/4" Long



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 [?]

10/10/2017

Pololu - 50:1 Micro Metal Gearmotor HP 6V

50:1 Micro Metal Gearmotor HP 6V



www.pololu.com

Pololu item #: 998 438 in stock

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

Quantity: 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:

[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

<https://www.pololu.com/product/998/specs>

1/2

B.3.4 Friction Wheel Encoder [?]

10/10/2017

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

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: **Add to cart**

backorders allowed **Add to wish list**

Navigation icons: back, forward, first, last.

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.

[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 [?]

10/10/2017

McMaster-Carr - Music-Wire Steel Torsion Spring, 180 Degree Right-Hand Wound, 0.767" OD



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 [?]

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 [?]

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**

Internal Resistance: **165mOhm**

Diameter: **27mm**

Length: **23.4mm**

Mounting Hole Spacings: **32mm**

Mounting Hole Diameter: **2mm**

Shaft: **3mm**

Weight: **25g**

B.6.2 Propeller [?]

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 BEC [?]

TURNIGY Plush 10amp Speed Controller w/BEC



Specifications

Cont Current: 10A	SKU:	TR_P10A
Burst Current: 12A	Weight(g)	20.00
BEC Mode: Linear	Width:	10.00
BEC : 5v / 2A	Brand:	No
Lipo Cells: 2-4	Length	110.00
NiMH : 5-12	Height:	110.00
Weight: 9g		
Size: 27x17x6mm		

B.6.4 Servo Motor [?]

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 [?]

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 [?]

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 [?]

UBLOX Micro M8N GPS Compass Module

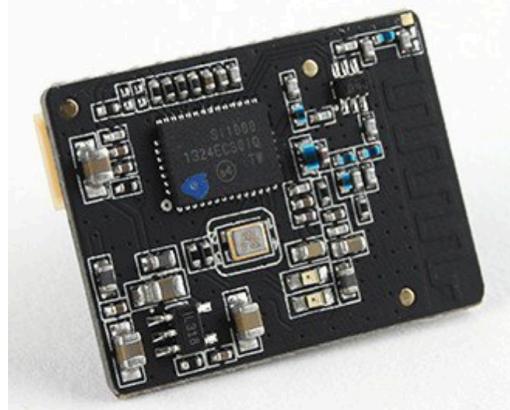


Specifications

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

B.7.3 Transceiver [?]

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 [?]

PixFalcon Micro PX4 Autopilot



Specifications

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