Balloon Deployment System

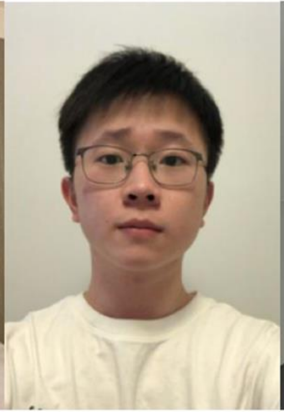
Preliminary Design Review

Customer: Dr. Dale Lawrence
Advisor: Matt Rhode


Jake McGrath
Command and Control


Sebastian Urrunaga
Structures


Kyler Stirewalt
Release Mechanism


Chenshuo Yang
Structures


Patrick Paluszek
Release Mechanism


Grant Norman
Command and Control


Jack Soltys
Structures


Aufa Amirullah
Command and Control


Matthew Konnath
Release Mechanism


Peter Hurst
Structures

Presentation Overview

- Project Description
    - Project Definition
    - Objectives
    - Critical Project Elements
- Evidence of Baseline Feasibility
    - Structures analysis
    - Release Mechanism analysis
    - Command/Control
- Current Status
    - Further development of the wind model
    - Cost analysis

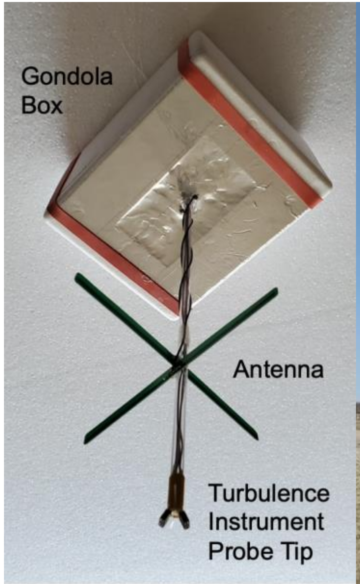
Mission Statement

The team shall design, build and test a high altitude balloon launcher for use in heavy winds supporting the Hypersonic Flight in the Turbulent Stratosphere (HYFLITS) program. The launcher will stand 3m high when fully extended, pose no risk for balloon puncture, be operable by a single user hands free and be easy to set up and transport.

Project Description: Project Definition

- Need: High wind weather balloon launching system
- Program: Hypersonic Flight in the Turbulent Stratosphere (HYFLITS) program
    - Study how future hypersonic vehicles can account for turbulence and particles in stratosphere
    - U of Colorado, Embry-Riddle, U of Minnesota
- Customer: Professor Dale Lawrence at CU-Boulder Smead Aerospace Engineering

Payload:



Balloon:

Current Process

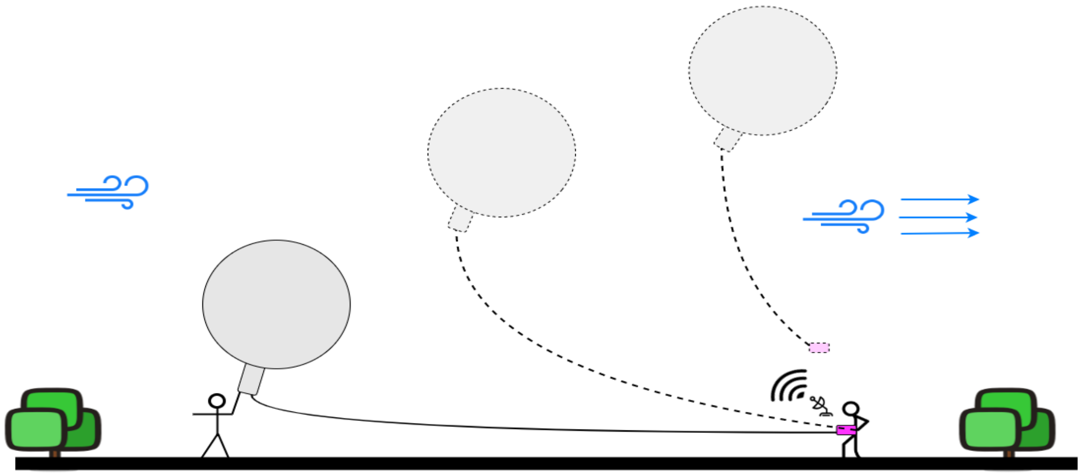
Naive Approach: Second Person

Pros:

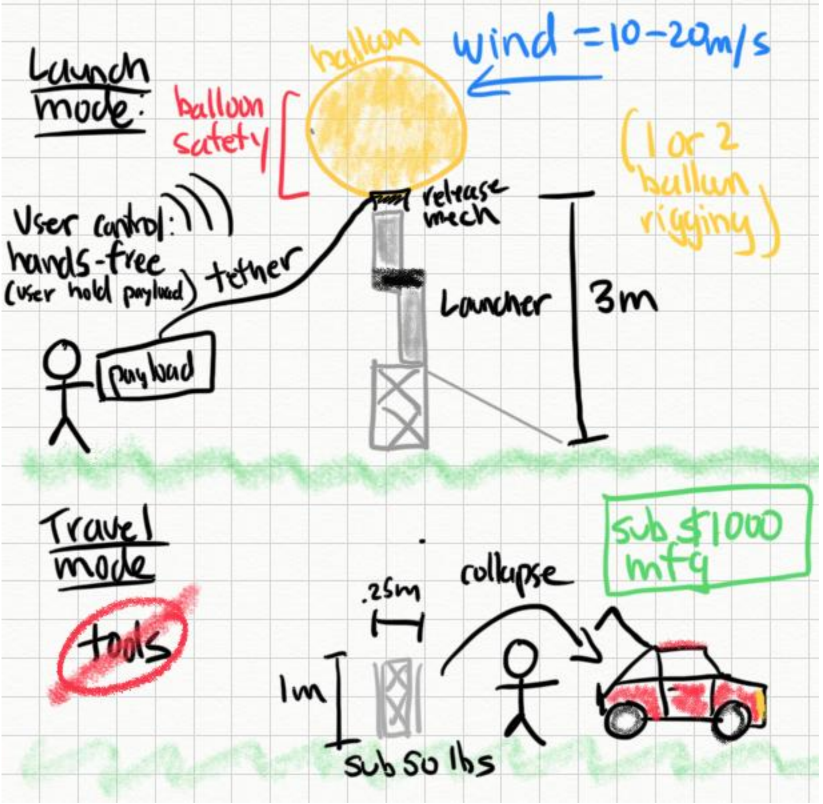
- Solves the issue of the payload swinging into the ground

Cons:

- Expensive
- Difficulty scheduling
- Still difficult to hold the balloon
- Not very high off of the ground



Project Description: Objectives

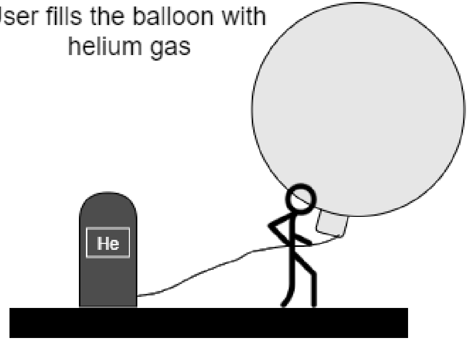


Use Case One:
Single Balloon Launch

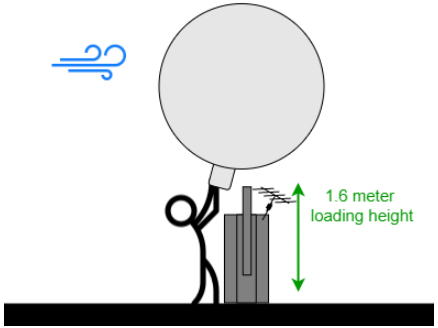
Project Description: CONOPS

1 User arrives at launch site and assembles the BDS in under 5 minutes

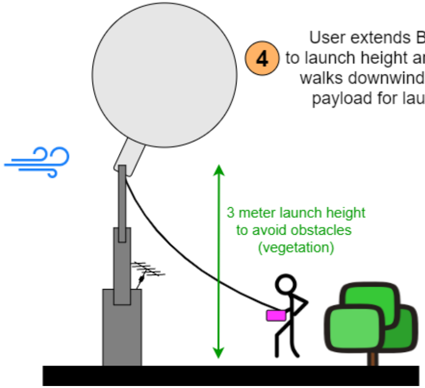
2 User fills the balloon with helium gas



3 User loads the balloon while the BDS is configured at launch height then attaches payload to the balloon



4 User extends BDS to launch height and then walks downwind with payload for launch



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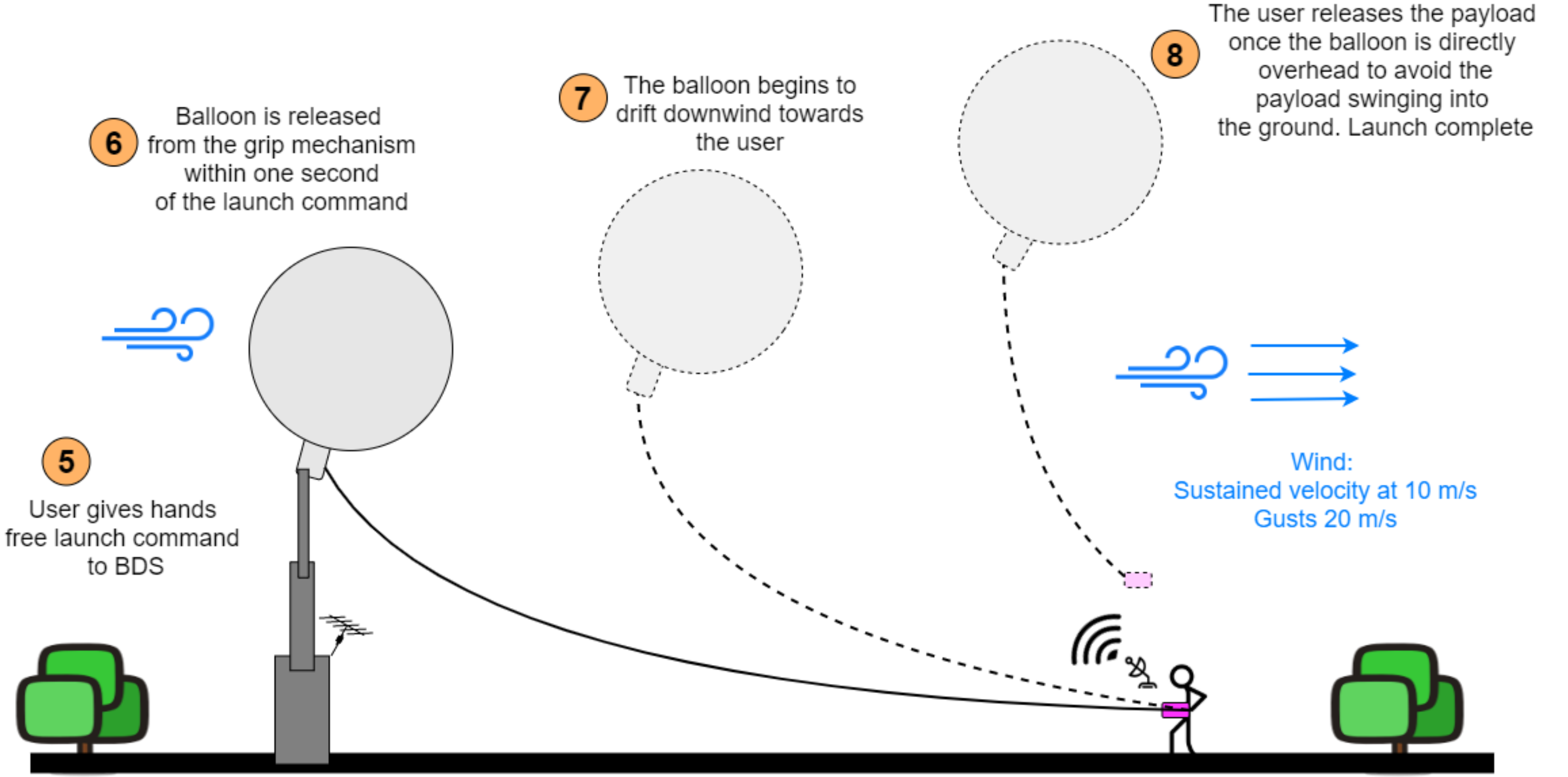
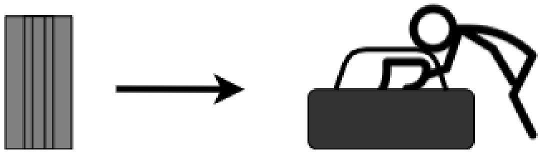


Project Description: CONOPS

9 After confirmation of a successful launch, the user disassembles BDS and stores the system in the carrying case for departure



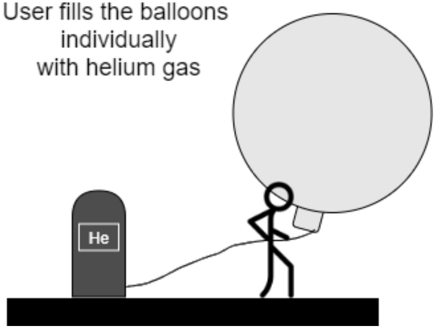
10 The user departs the launch site and is ableto repeat this process for another launch when needed

Use Case Two:
Two Balloon Launch

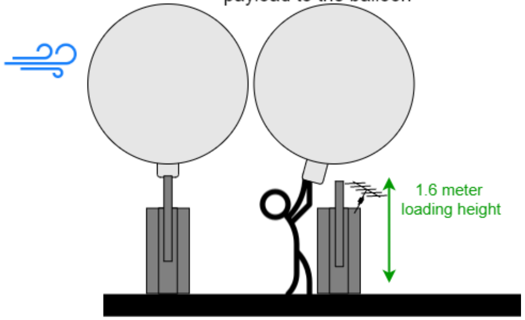
Project Description: CONOPS

1 User arrives at launch site and assembles the BDS in under 5 minutes

2 User fills the balloons individually with helium gas



3 User loads the balloons individually while the BDS is configured at launch height then attaches payload to the balloon



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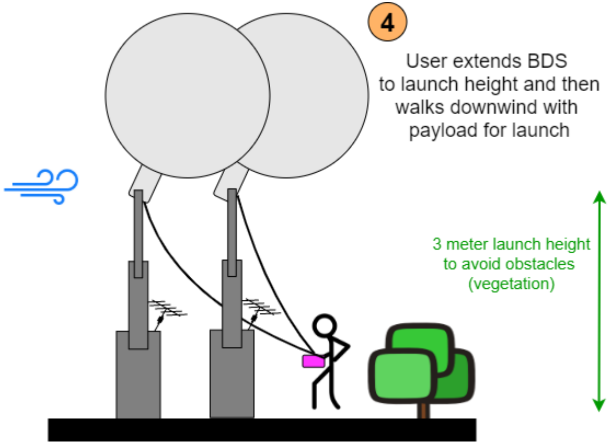
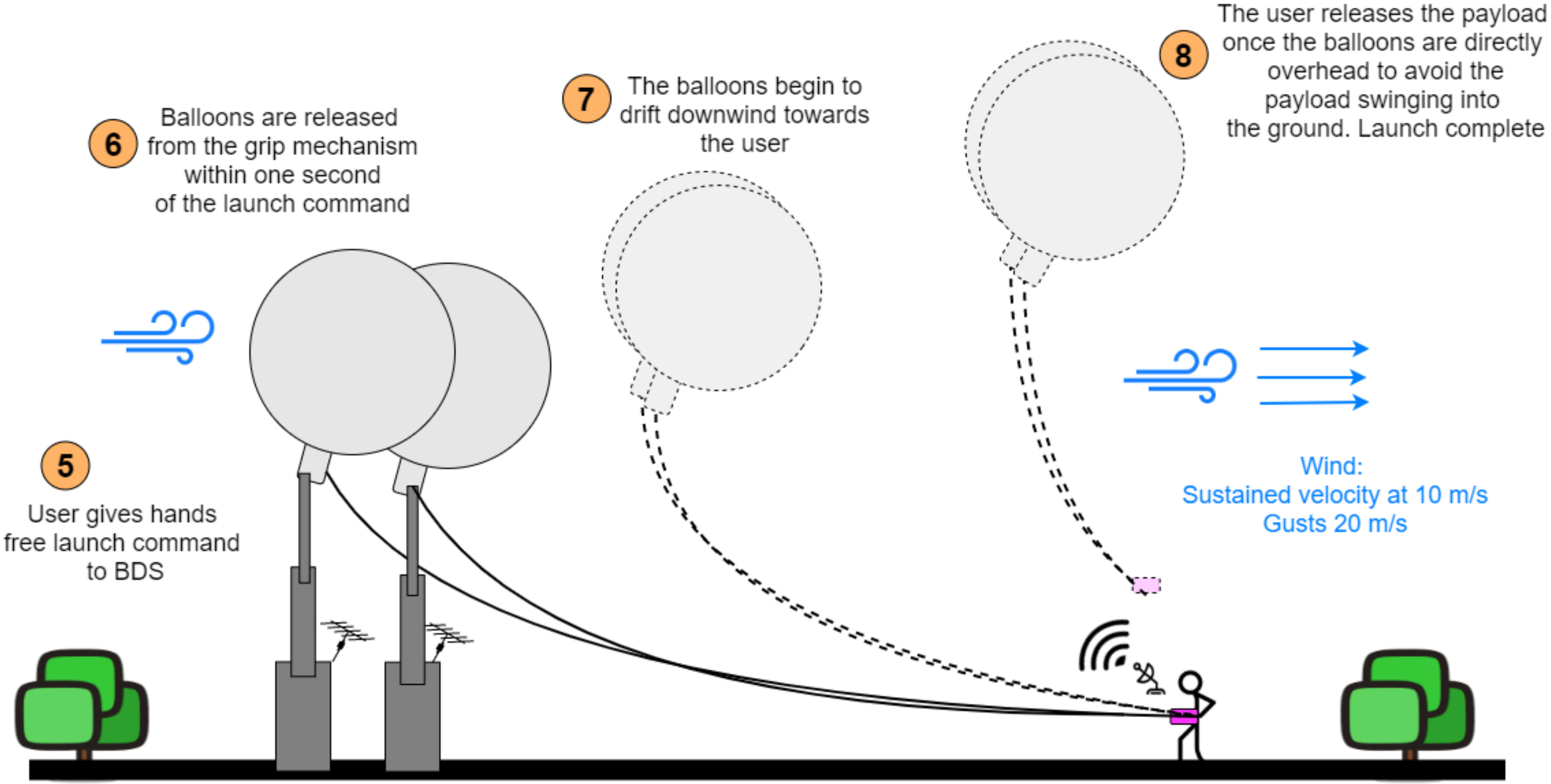


Project Description: CONOPS



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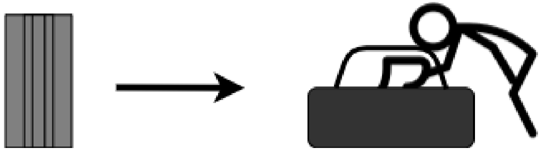

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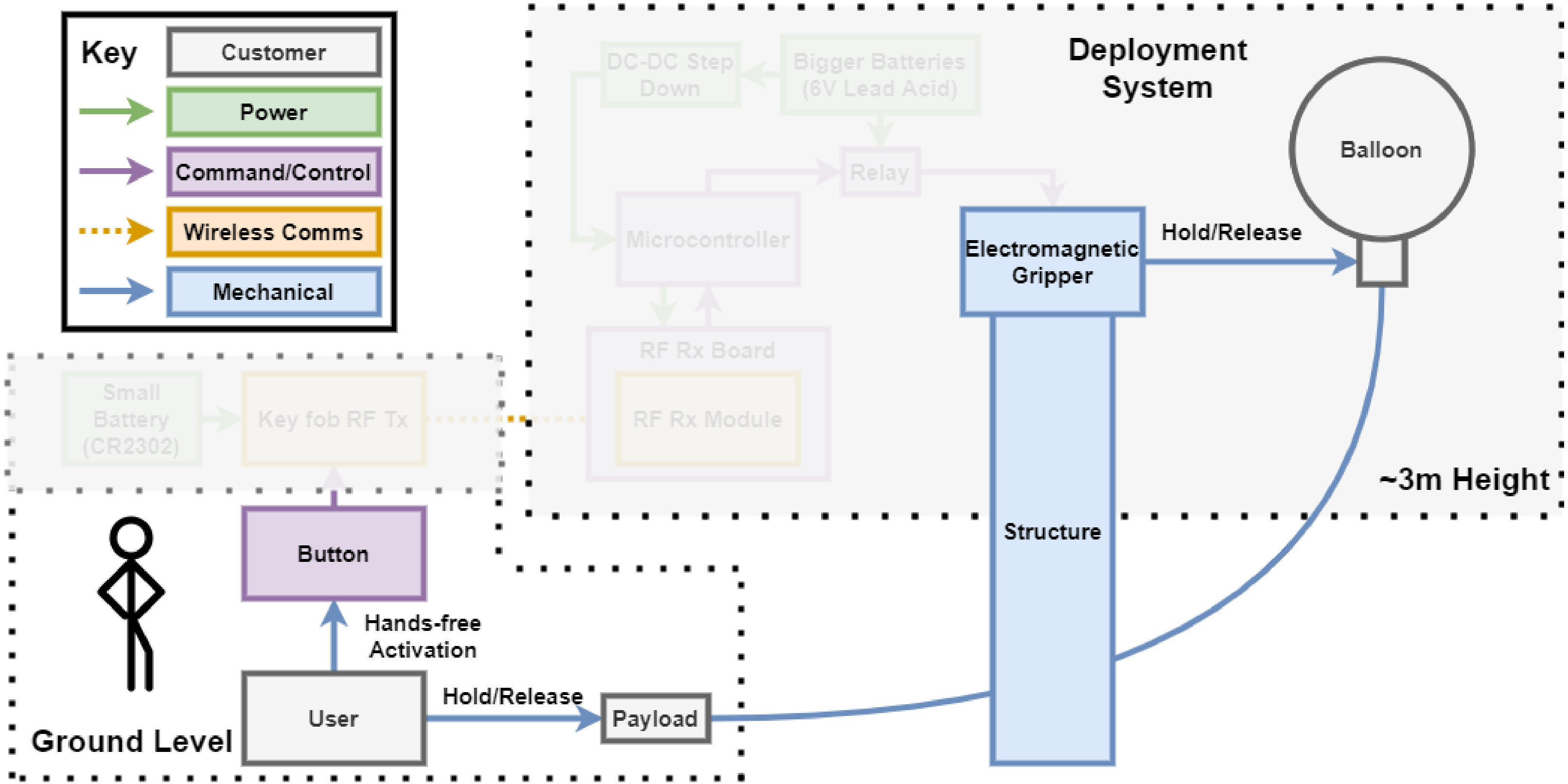

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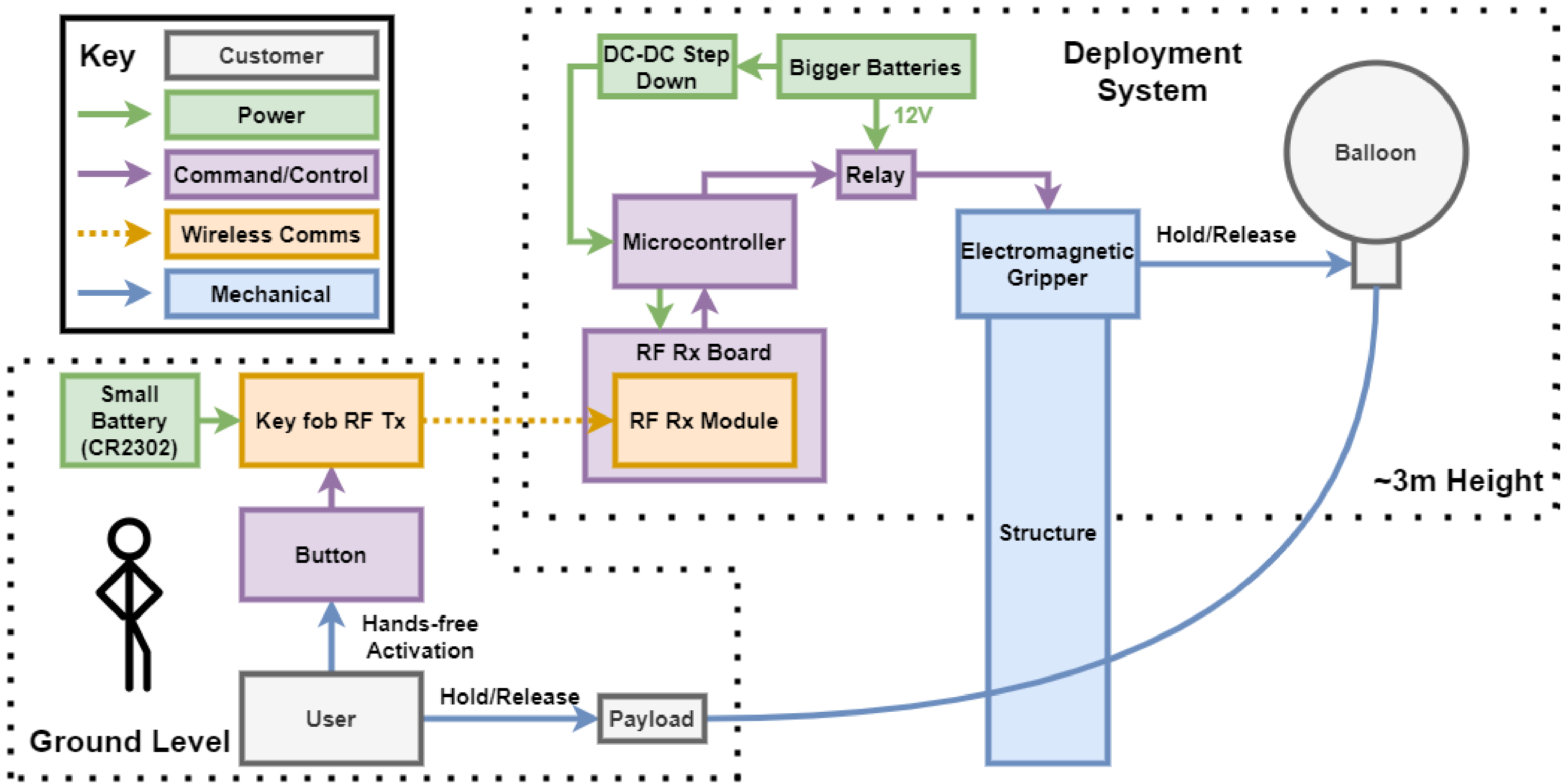
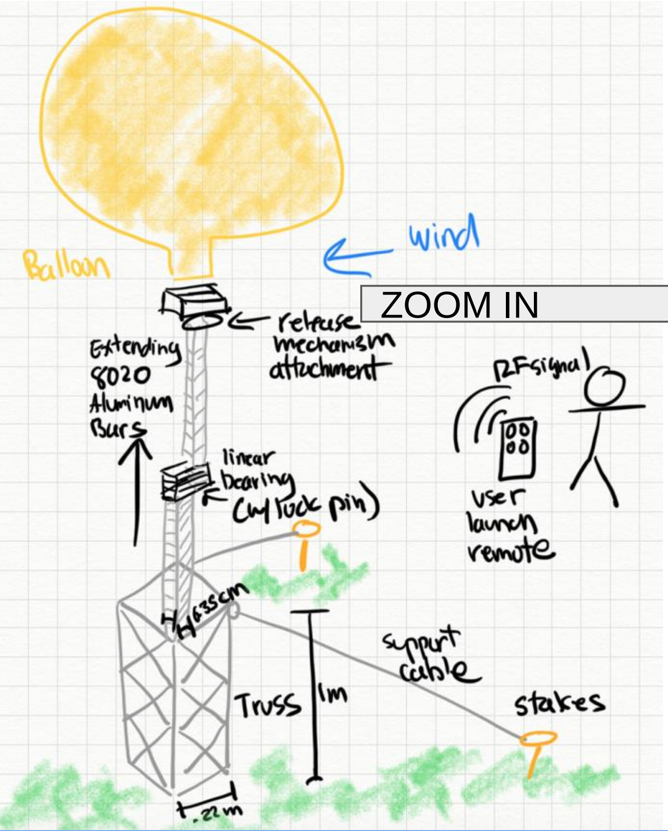
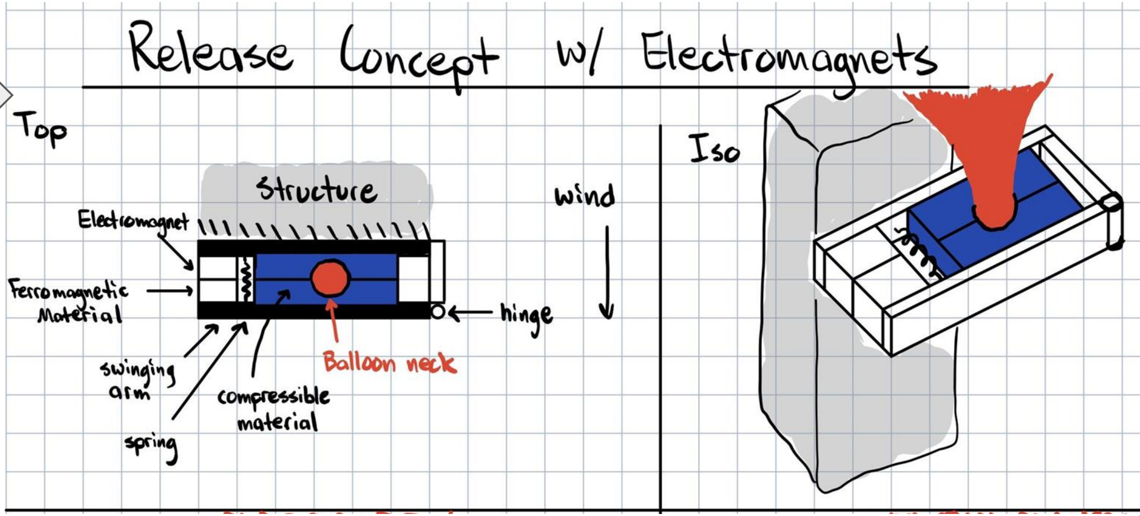


Project Description: Baseline Design



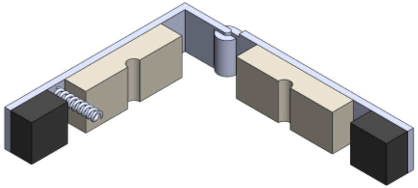
ZOOM IN



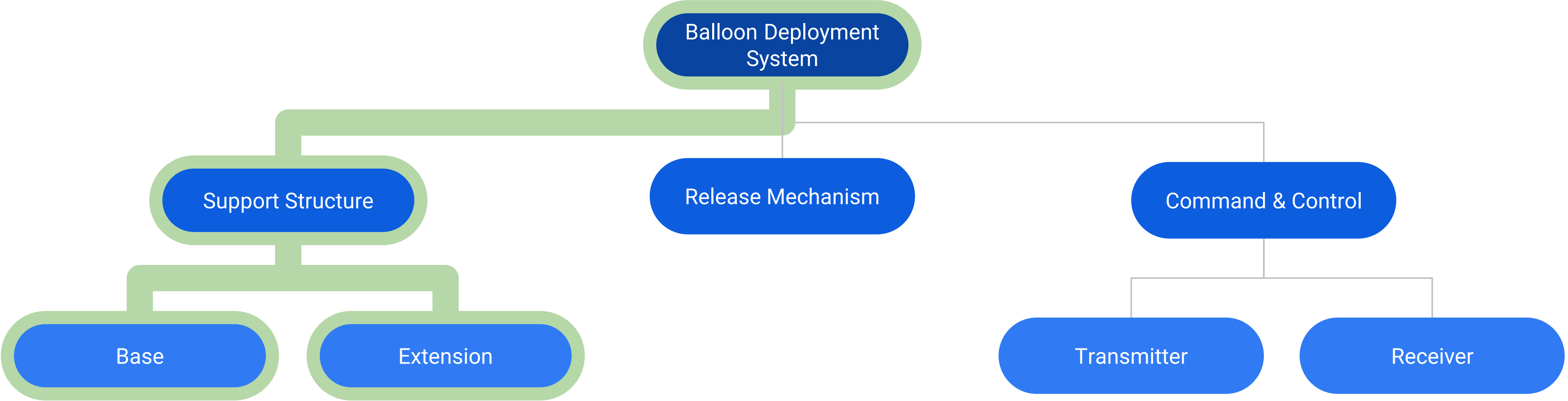
Project Description: Baseline Design

BDS Subsystems

- Balloon Deployment System
  - Support Structure
    - Base
    - Extension
  - Release Mechanism
  - Command & Control
    - Transmitter
    - Receiver



BDS Subsystems

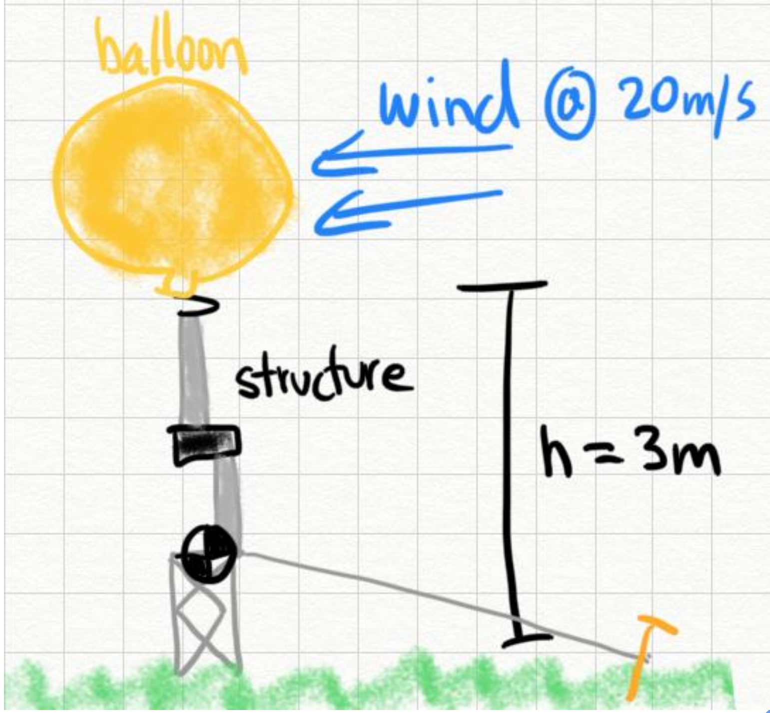


Critical Project Elements

Critical Project Elements	Requirements	Feasible
Structure	• Stable in 20 m/s winds @ 3m high • Withstand forces/moments • Balloon loaded by an avg. height user • User safety	
Release Mechanism	• Thick rubber neck with a grasp that will not damage the neck • Secure Grip of balloon in 20 m/s wind	
Command and Control System	• Hands-free operation • Wireless link and battery powered release mechanism	

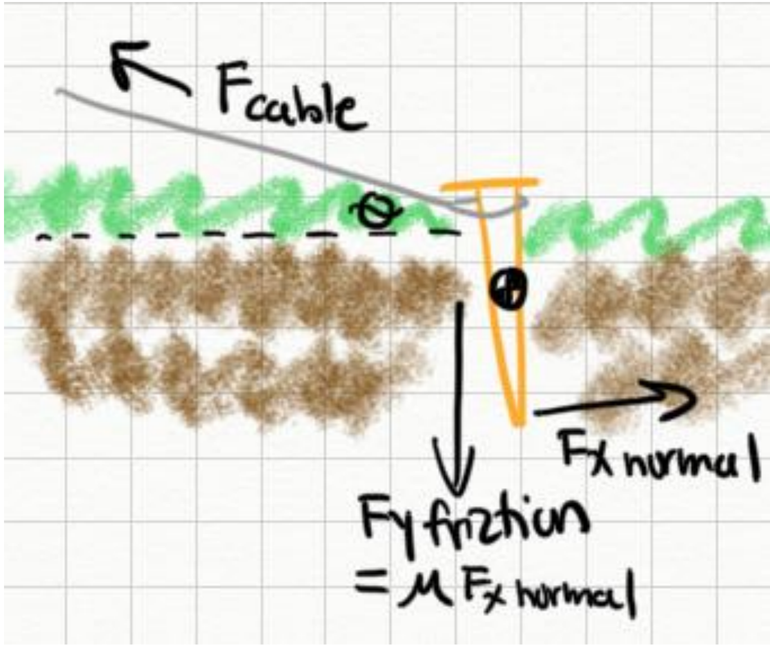
Evidence of Baseline Feasibility: Structure

- Problem: Stability in 20 m/s winds
  - Large moment to resist
    - Drag of a sphere: 308N (upper bound)
    - Force acting at 3m high
    - Moment=924 [N*m]
  - Solutions:
    - Freestanding (unfeasible due to size)
    - Anchored via staked cables



Evidence of Baseline Feasibility: Structure

- Problem: Stability in 20 m/s winds
  - Anchoring as part of set up:
    - Most launches occur on dirt or grass
    - Anchored cables on truss to resist moment
    - Max pull in x direction and min pull in y direction keeping stake in ground
      - Longer cable reduces angle of pull on stake wrt ground
        - F*cos(θ)=Fx
      - Increases x normal force and friction of stake



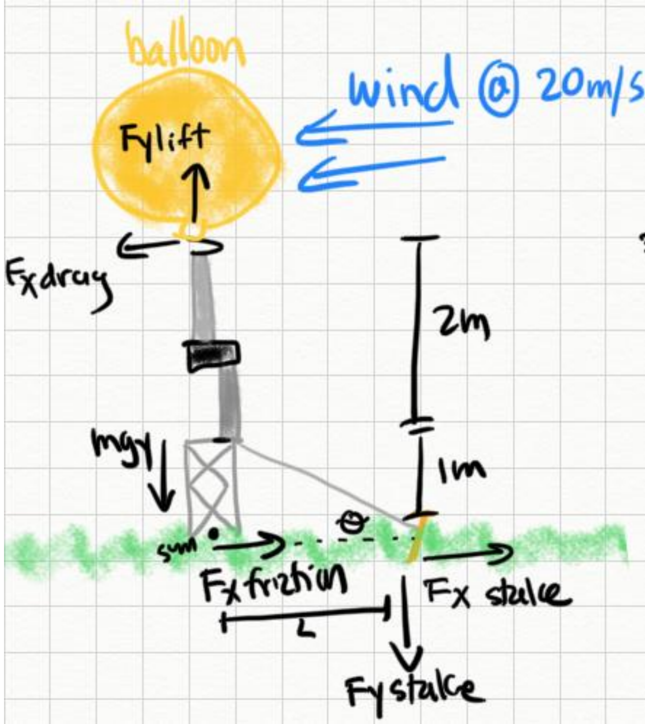
Evidence of Baseline Feasibility: Structure

- Problem: Stability in 20 m/s winds
  - Anchor hold strength
    - 6.5 [in] aluminum tent stake
    - Spring scale
    - Hammered into ground
    - Pulled at ~45 deg (structure angle ~15 deg)
      - Expect higher hold force at lower pull angle by maximizing Fx of stake

Tent Stake	Pull Force	Pull Force
Sand	67 [N]	15 [lbf]
Top Soil	267 [N]	60 [lbf]
Clay	330 [N]	74 [lbf]

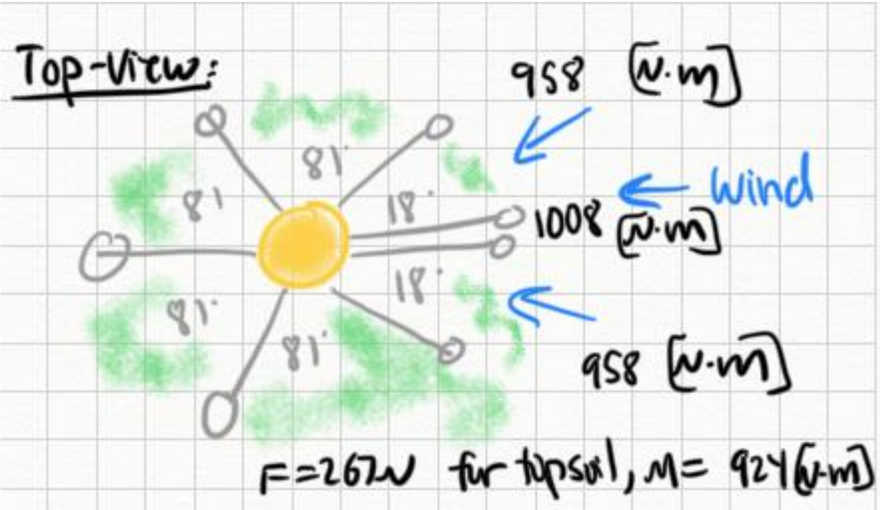
Evidence of Baseline Feasibility: Structure

- Problem: Stability in 20 m/s winds
  - Anchored solution to resist balloon moment:
    - Cable length: 4 m
    - X component of stake pull F*cos(θ):
      - Sand: 65 [N] need 14 stakes (unfeasible)
      - Topsoil: 258 [N] need 4 stakes
      - Clay: 319 [N] need 3 stakes



Evidence of Baseline Feasibility: Structure

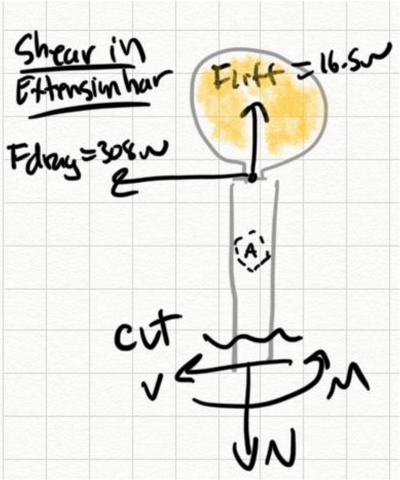
- Problem: Stability in 20 m/s winds
  - Maintain stability in changing wind direction:
    - Most wind direction change sub 17 deg
    - Most anchors placed on upwind side
      - 2 anchors into wind
      - 2 anchors at 18 degrees off predominant wind (designed to resist max moment at 18 deg wind change)
      - 3 remaining anchors in case of wind change (user safety)



Evidence of Baseline Feasibility: Structure

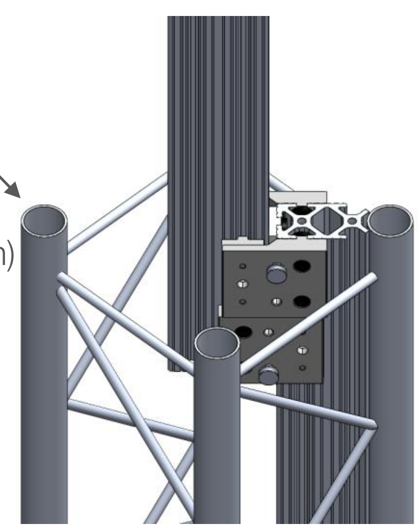
- Structure strength:
    - Shear (V) in extending bar (8020 Aluminum):
        - τ=.4 MPa < τ_{max}=170 MPa

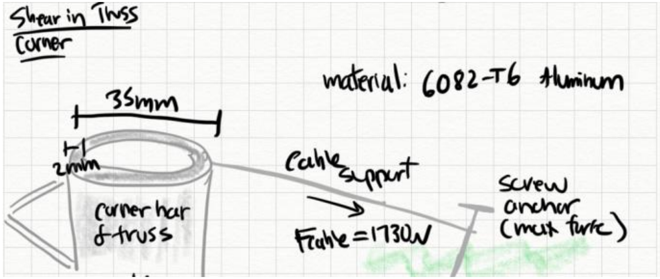
Zoom View:



Evidence of Baseline Feasibility: Structure

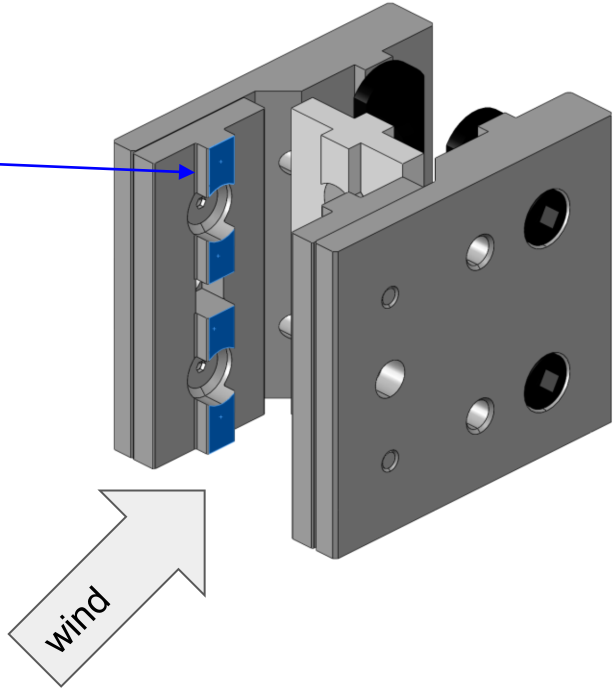
- Shear (V) in truss corner bar (6082-T6 Aluminum):
  - τ=16.2 MPa < τ_{max}=210 MPa
- Truss overall loading
  - Load/ft: 604 N load/foot
  - Max center load: 3962 N
  - 1/4 in. Steel Wire Rope: 6227.5 N (tension)





Evidence of Baseline Feasibility: Structure

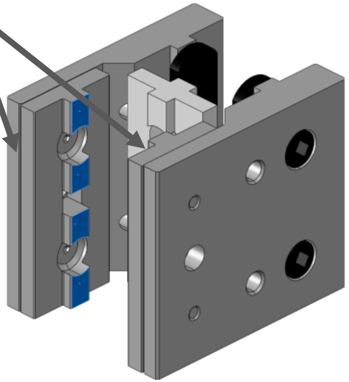
- Shear (V) in linear bearing:
  - UHMW material
  - Weakest configuration w/ wind as indicated
  - Area subject to shear (blue)
  - τ=.55 MPa < τ_{max}=20 MPa

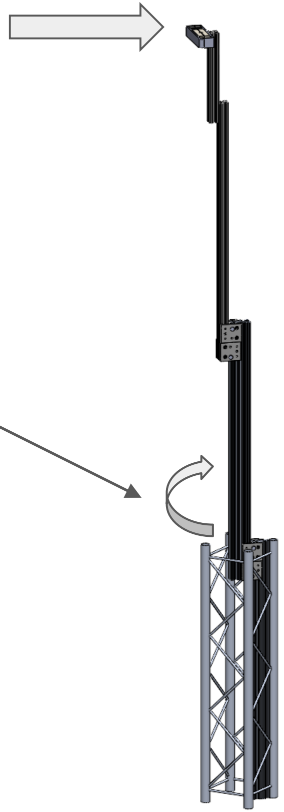


Evidence of Baseline Feasibility: Structure

- Structure Strength:
  - Bending Stress: 61.5 kPa ~ 8.91 Psi
  - Bending Moment: ~ 620 Nm

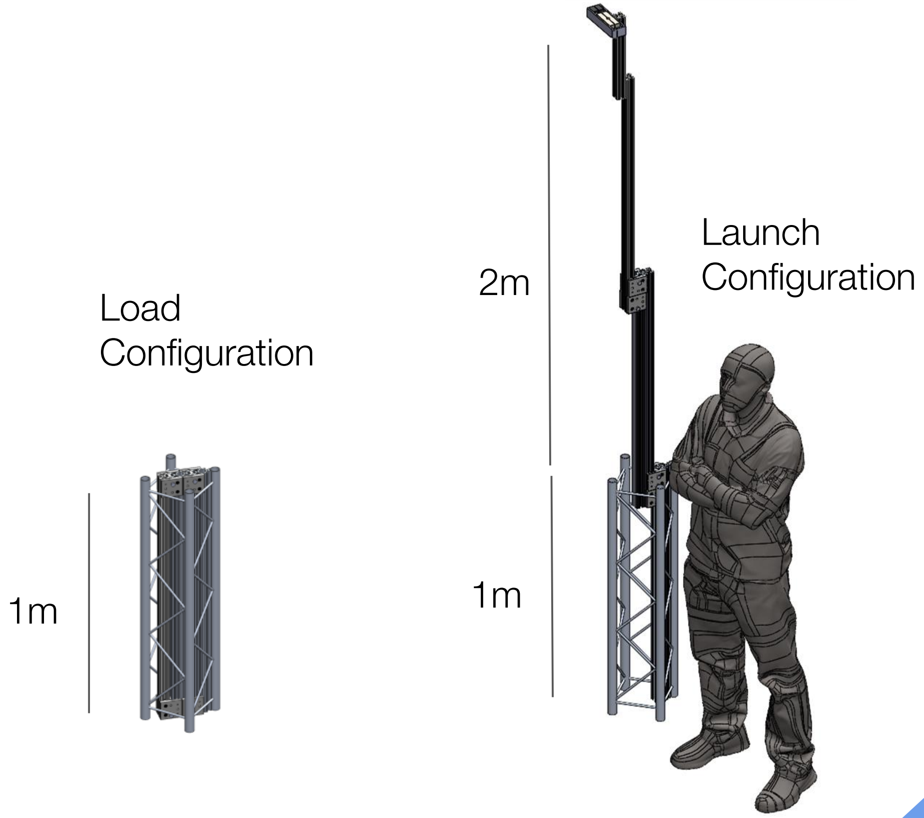
- Structure Strength:
  - Bending Stress: 190 kPa ~27.6psi
  - Bending Moment: ~620 Nm





Evidence of Baseline Feasibility: Structure

- Launch height from 3m
  - Average user height: 1.6 m (~62 in)



Critical Project Elements

Critical Project Elements	Requirements	Feasible
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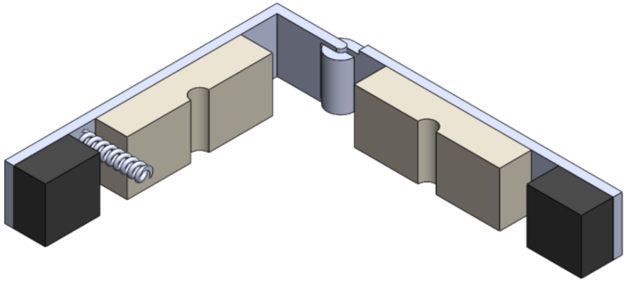
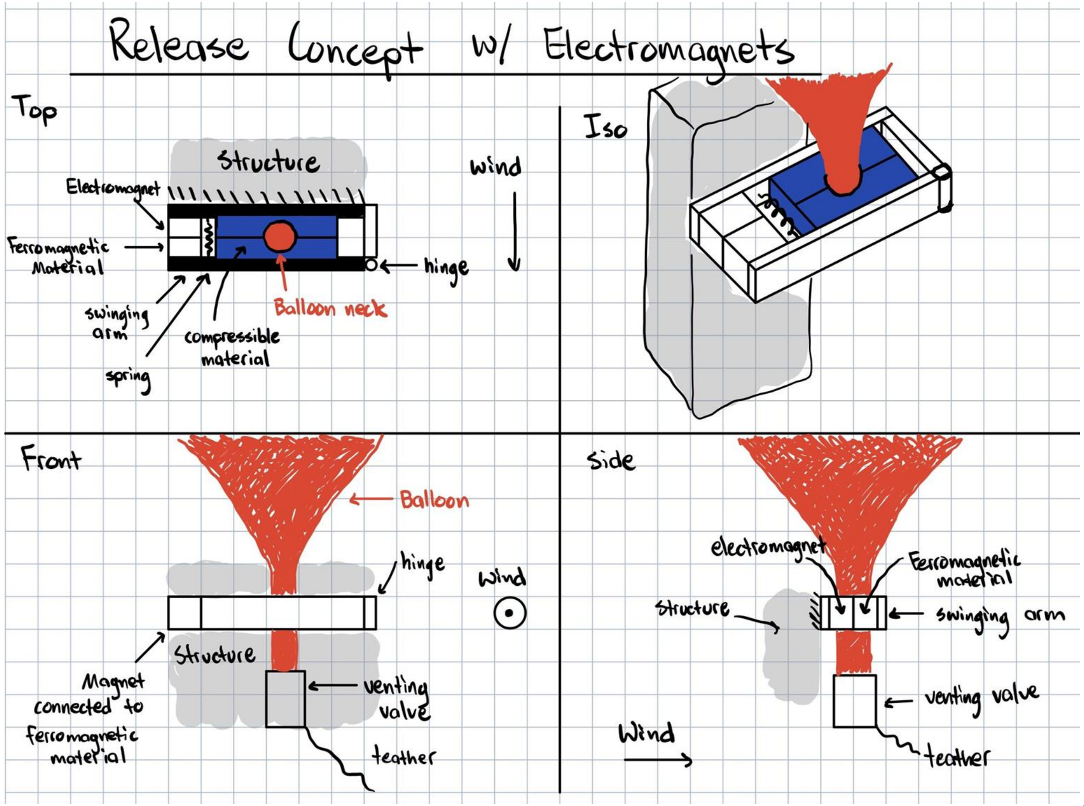
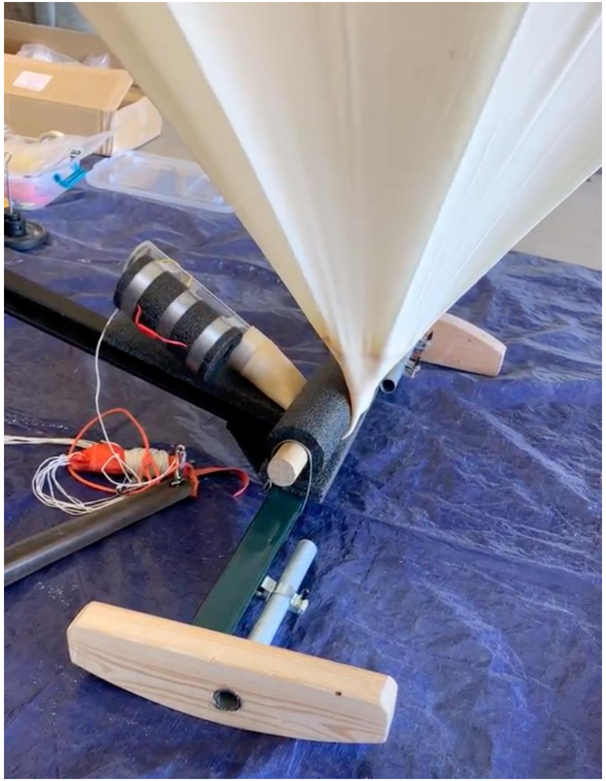
Evidence of Baseline Feasibility: Release





Evidence of Baseline Feasibility: Release

- Current method for transport
- Similar to BDS method
- Will not damage balloon



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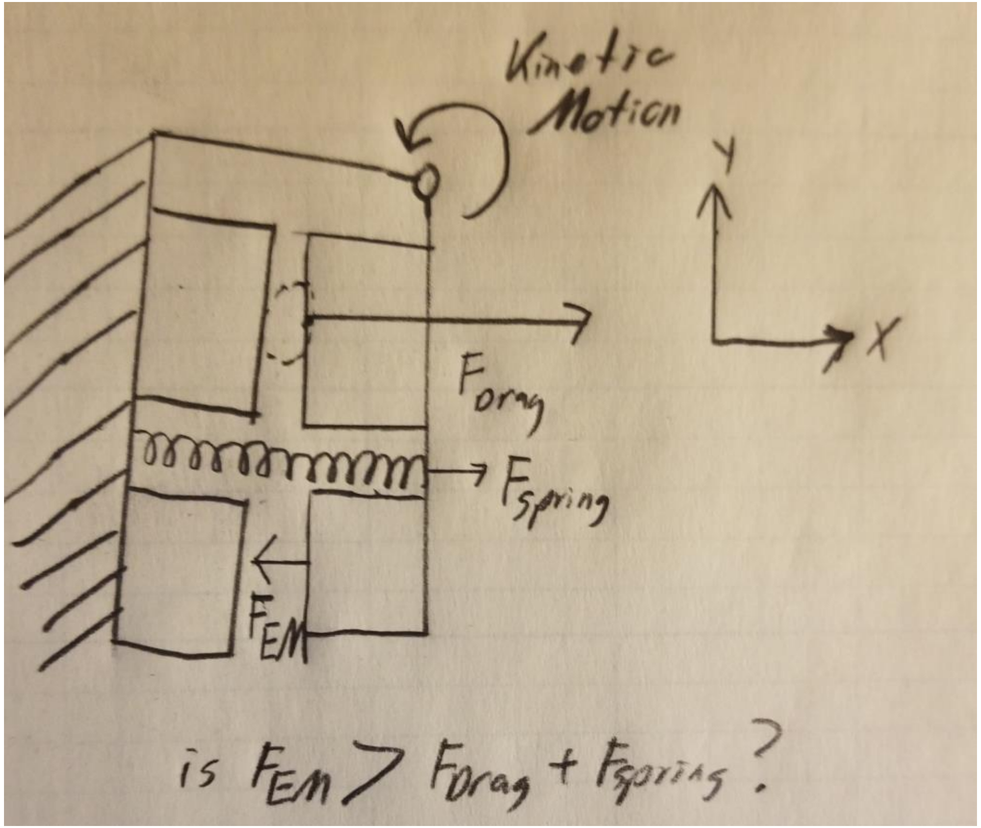

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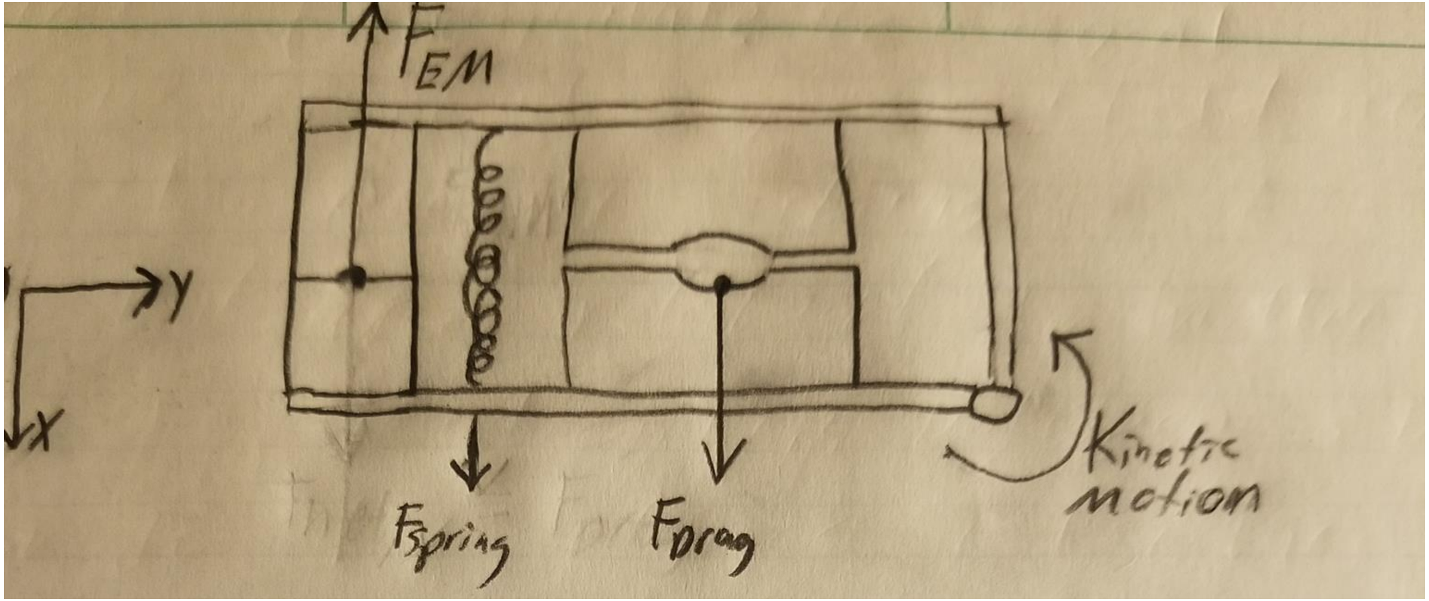


$$F_{Drag} \approx 30lbf$$
$$F_{Drag} \approx 70lbf$$

$$F_{Spring} \approx 10lbf \longrightarrow 40 \leq \sum F_{net_x} \leq 80lbf$$

Evidence of Baseline Feasibility: Release

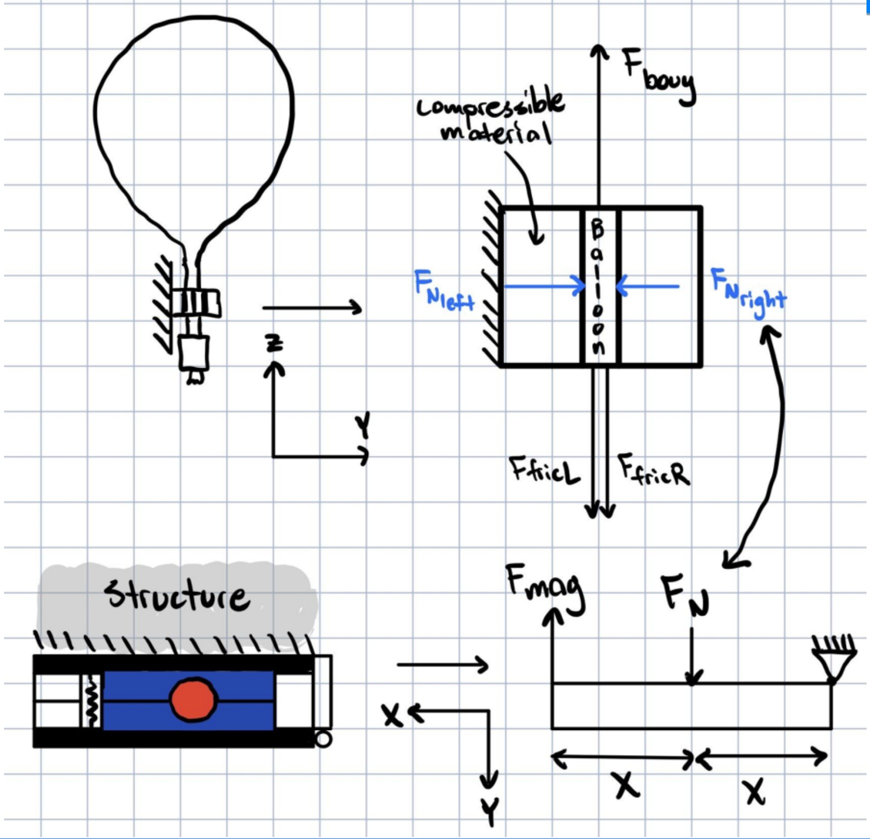
- Rectangular electromagnet that produces 200 lb pull force
  - Thinner but pricier than circular magnet
  - Easier interfacing for systems engineering
  - Lightweight (~1 lb)

$$40 \leq \sum F_{net_x} \leq 80lbf$$

Part #	Width (A)	Length (B)	Height (C)	Mount (D)	Thread & Depth (E x F)	Location of Leads (G - H)	DC Volts	Watts	Pull Force (lbs)	Specs	Price	Quantity	
BRE-1515-1	1.50	1.50	1.25	center hole	10-32 x .375	.500 - .062	12	8	100	Download	$75.00	1	ADD
BRE-1525-1	1.50	2.50	1.25	1.00	10-32 x .375	.750 - .500	12	5	200	Download	$95.00	1	ADD

Evidence of Baseline Feasibility: Release

- Will the mechanism keep the balloon from floating straight up?
- Assume μ_s between dry urethane and rubber
- Total friction force = 268 lbf
- Balloon upward Force = ~5 lbf



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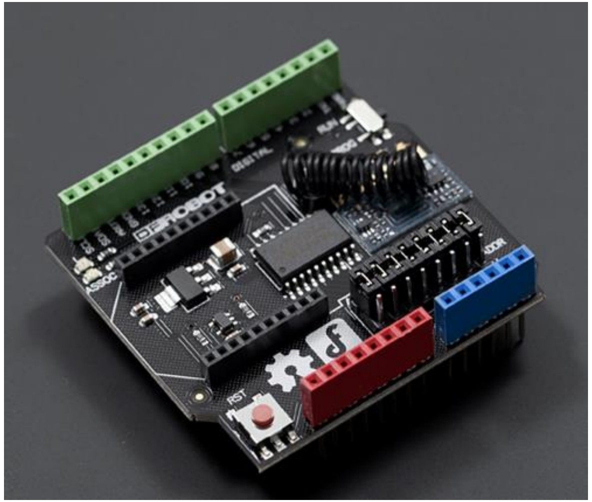
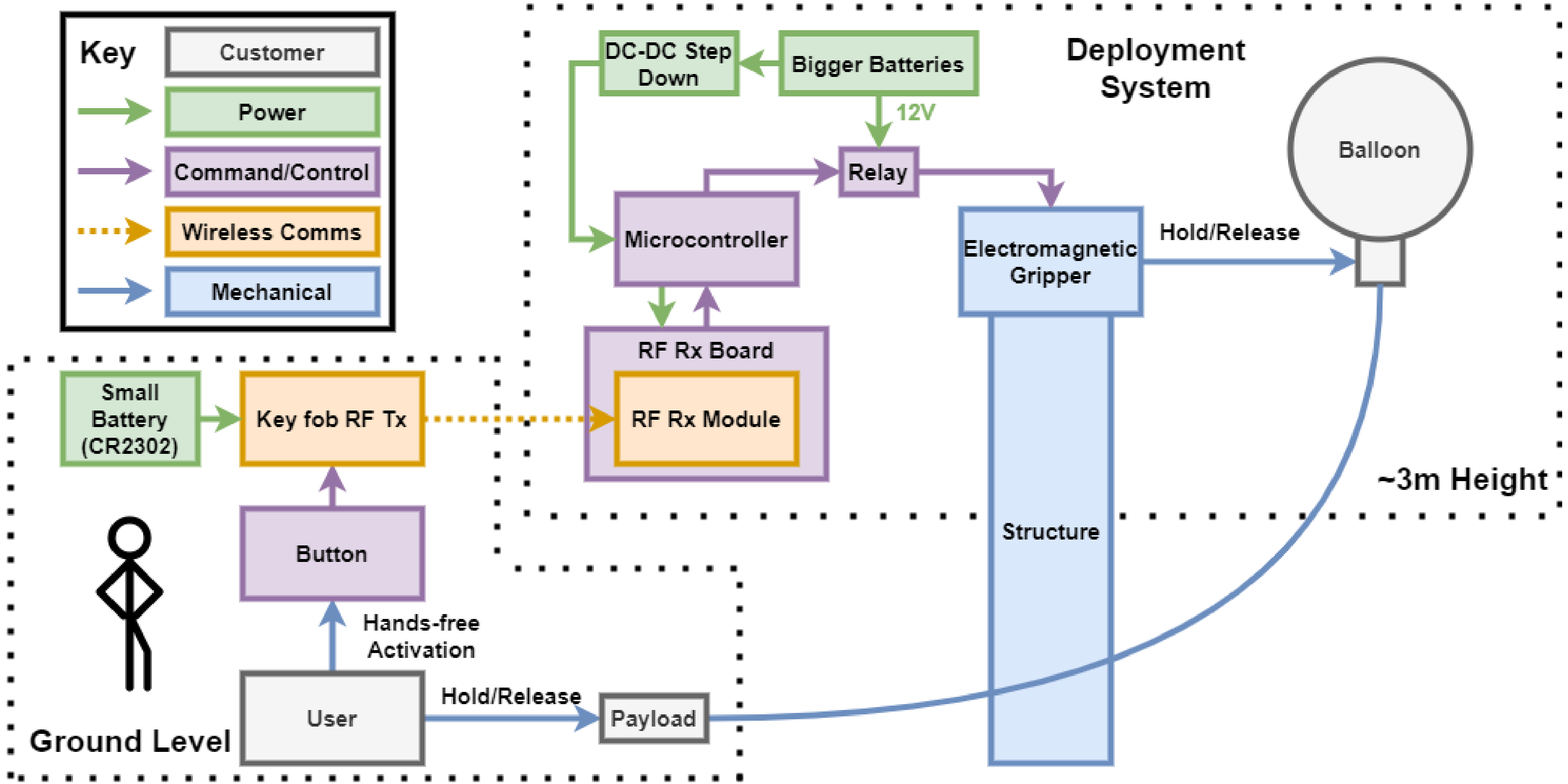
Evidence of Baseline Feasibility: Command/Control



Evidence of Baseline Feasibility: User Control

- User holds payload with both hands
- Button attached at waist
- Pressed with elbow to send signal when ready

Evidence of Baseline Feasibility: Command/Control



Evidence of Baseline Feasibility: Command/Control

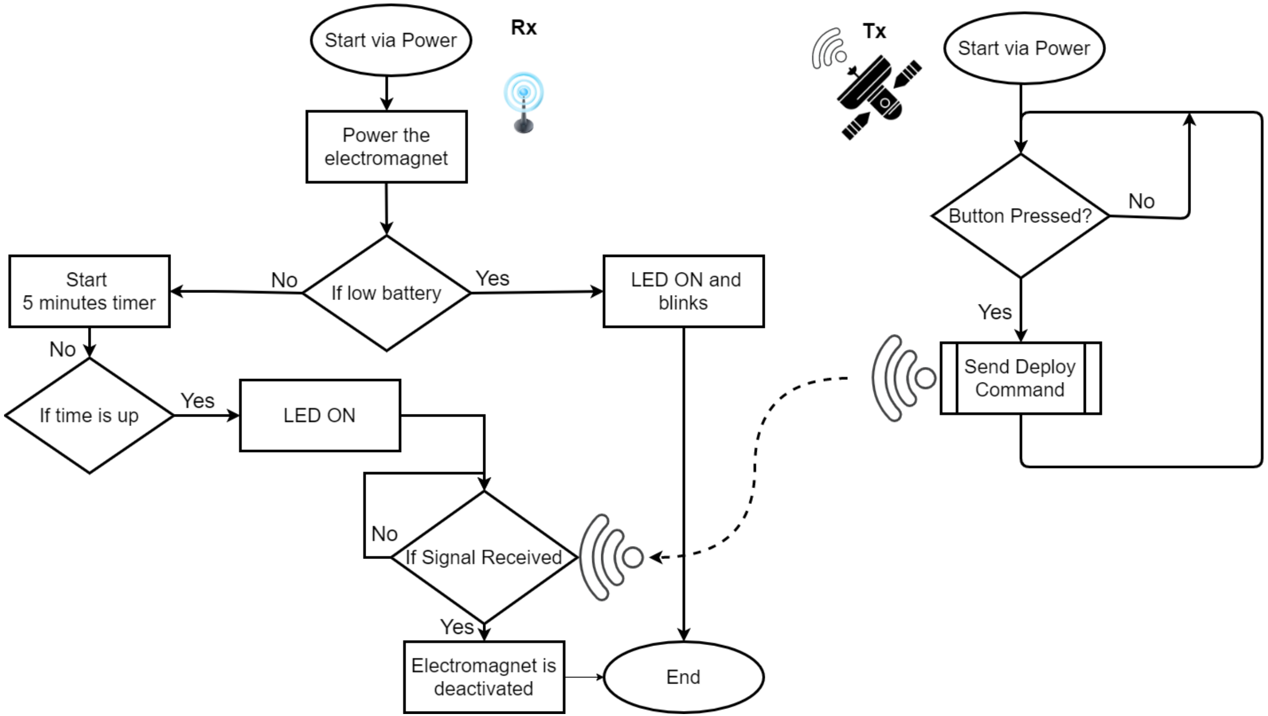
- 2.6 lb for 12V
- 13 Ah

Evidence of Baseline Feasibility: Command/Control

Component	Voltage (V)	Current (A)	Power (Watts)	Time On (Minutes)	Charge (A-Hr)	Number of Launches
Receiver:						
Arduino Uno	12	0.2	2.4	5	0.01666666667	
Electromagnet Gripper	12	0.416	4.992	5	0.03466666667	
RF Board	5	0.01	0.05	5	0.0008333333333	
RF Rx	5	0.01	0.05	5	0.0008333333333	
Rx Total					0.053	245.2830189
User:						
Remote Wireless Key Fob	3	0.04	0.12	0.5	0.0003333333333	630
Power:						
2 In-Series 6V Batteries (Rx)	12	4			13	245.2830189
CR2302 (Tx)	3	0.2			0.21	630

Evidence of Baseline Feasibility: Command/Control

1. Power the electromagnet
2. Start the timer to prevent accidental launch during set-up
3. Send Deploy Command
4. When signal is received (and the time is up), electromagnet is deactivated
5. Balloon is launched



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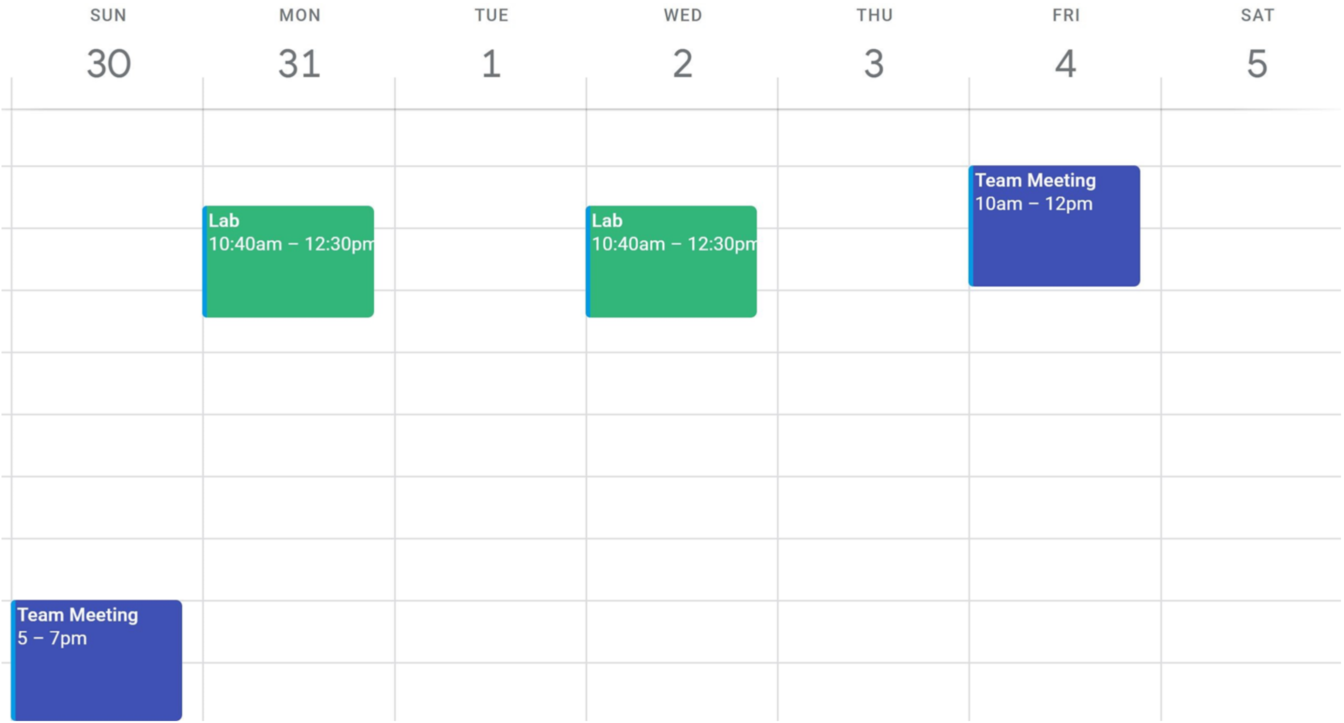
Prices

Item	Quantity	Price per Unit (USD)	Shipping Cost (USD)	Total Cost
Arduino Uno	1	$23.00	$1.63	$24.63
RF Board	2	$23.00	$0.00	$46.00
RF Rx	2	$6.80	$0.00	$13.60
Remote Wireless Key Fob	1	$5.20	$0.00	$5.20
6V (lead acid) Battery (Rx)	4	$14.99	$0.00	$59.96
CR2302 (Tx)	1	$2.85	$0.00	$2.85
Electromagnet	1	$95.00	$0.00	$95.00
F24 Truss	1	$231.00	$0.00	$231.00
1515 8020	1	$154.00	$0.00	$154.00
80/20 Linear Bearings	4	$48.50	$0.00	$194.00
			Total Cost	$826.24

Current Status and Remaining Studies



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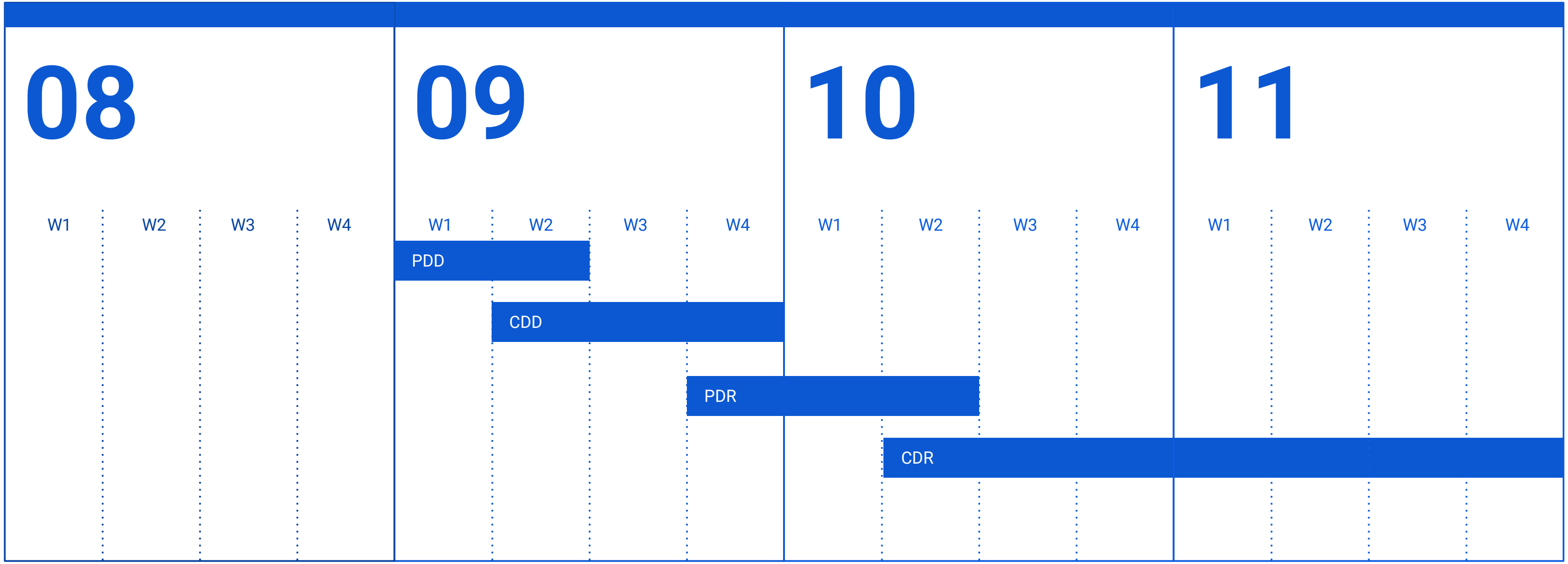


Approximate Build & Test Schedule

December

Complete CDR & Order Materials

Order materials shortly after CDR so we can use winter break as shipping time.

January

Collecting Materials & Dry Assembly

Checking on remaining orders and organizing what we have into our assembly. No machining or custom parts are required.

February

Assembly & Preliminary Tests

Testing for our requirements will begin and simulated launches will be conducted.

March

Design Revisions & Final Tests

BDS will be tested against adverse effects to see the operating range of our device.

April

Final Deliverable & Demonstration

Delivering final product to Dr. Lawrence and demonstration levels of success by end of semester.

Current Status and Remaining Studies

- In depth analysis on wind/drag modeling on the balloon
  - Lower project cost
  - More portable
  - Higher factor of safety

Acknowledgements

Dr. Dale Lawrence
Customer

Matt Rhode
Advisor

Dr. Jelliffe Jackson
Instructor

References

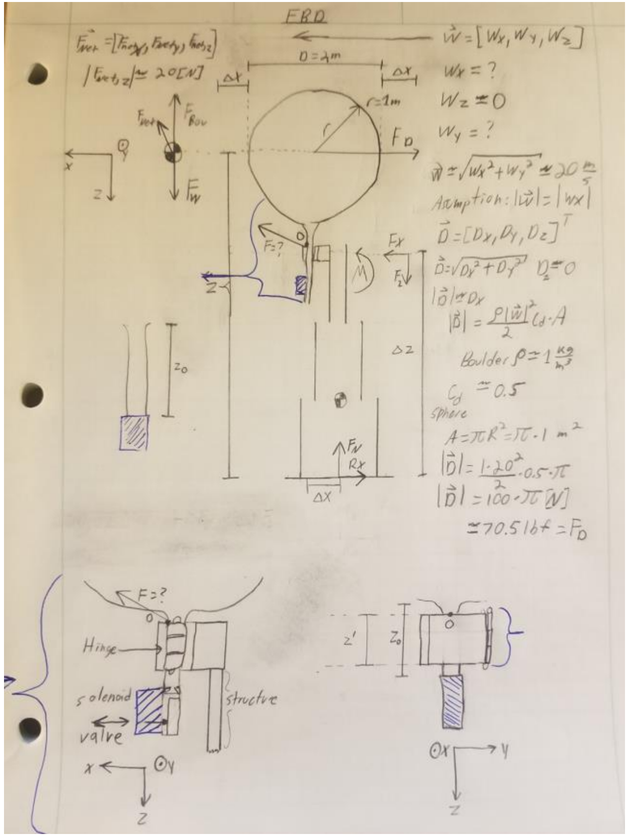
Modulus of Elasticity: https://www.azom.com/properties.aspx?ArticleID=920

Wind direction change: https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1256/wea.176.04

Coefficient of Drag:
https://www.arc.id.au/CannonballDrag.html#:~:text=Newton%20experiments%20yielded%20the%20first%20accurate%20measurements%20of,for%20low%20speed%20drag%20on%20a%20smooth%20sphere.

Electronics:
https://store.arduino.cc/usa/arduino-uno-rev3
https://buymagnets.com/product-pdfs/BRE-1525-12.pdf
https://www.dfrobot.com/product-1089.html
https://www.dfrobot.com/product-1607.html
https://www.dfrobot.com/product-1090.html
https://www.grainger.com/product/45EK05?gclid=CjwKCAjwzvX7BRAeEiwAsXExo6VwS4nzvN8WSBvfhlht9TifD0_Tg1Hkt1imEHrhyUy84__Bfgz7GBoCJEUQAvD_BwE&cm_mmc=PPC:+Google+PLA&ef_id=CjwKCAjwzvX7BRAeEiwAsXExo6VwS4nzvN8WSBvfhlht9TifD0_Tg1Hkt1imEHrhyUy84__Bfgz7GBoCJEUQAvD_BwE:G:s&s_kwcid=AL!2966!3!281698275282!!!g!470981977891!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231
https://www.uline.com/Product/Detail/S-17590/Batteries/Duracell-6V-Lantern-Alkaline-Battery?pricode=WB0943&gadtype=pla&id=S-17590&gclid=Cj0KCQjw2or8BRCNARIsAC_ppyZeiSM-_7YcD-PU2886X0NzdmHSN3YnyFqzdSNg8qxcJ6U0IQ7NSjkaAmJ3EALw_wcB&gclsrc=aw.ds
https://cdn-shop.adafruit.com/datasheets/maxell_cr2032_datasheet.pdf

Appendix - Pat Drag Work



Changing the assumption $\Delta t = 0.2$ for linear impulse

$$\sum F_{avg} = m\frac{\Delta v}{\Delta t} = \frac{3(20)}{0.2} = 300 N \simeq 68 [lbf]$$

$$D = qC_dA = \frac{1(20)^2}{2}(0.5)\pi = 314 N = 71 [lbf]$$

Cd huh $\quad Re = \frac{\rho V L^*}{\mu} \quad 17.64(10)^{-6} < \mu_{air} < 18.71(10)^{-6} \frac{Ns}{m^2}$

$\rho \simeq 1 \frac{kg}{m^3} \quad T = 50°F \quad T = 90°F$

$V = 20 \frac{m}{s}$

$L^* = r = 1m \quad Re = 1 \cdot 20 \cdot 1/(18.4(10)^{-6}) \simeq 1(10)^6$

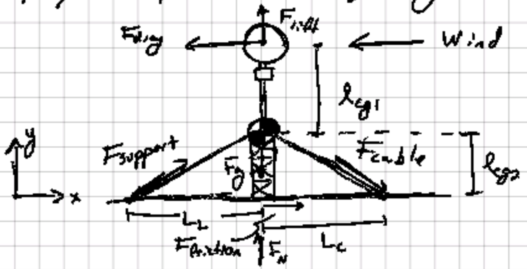
$C_D \simeq 0.2$ for smooth spheres experiencing 10^6 Re

$$D = \frac{20^2}{2}(0.2)\pi = 125.66 [N] \simeq 30 lbf$$

Appendix - Grant Moment Work

10/5/2020

Purpose: Review Full Stability FBD



$$\Sigma F_x = \underbrace{F_{cable,x} + F_{support,x} + F_{friction}}_{\text{Call this all "}F_{resistance}\text{" which acts parallel to the ground, antiparallel to drag.}} - F_{drag} = 0$$

$\overset{+}{\rightarrow} \Sigma F_x = F_{resistance} - F_{drag} = 0, \longrightarrow F_{resistance} = F_{drag}$

$+\uparrow \Sigma F_y = F_N + F_{lift} - F_g = 0, \quad F_N = F_g - F_{lift}$

$$\oplus\circlearrowleft \Sigma M_{Ground} = (F_{drag}) \cdot (l_{cg1} + l_{cg2}) + (F_{resistance})(0) - (F_{support,y}) \cdot (L_L) - (F_{cable,y}) \cdot (L_c) = 0$$

$$\boxed{(F_{drag}) \cdot (l_{cg1} + l_{cg2}) - (F_{support,y})(L_L) - (F_{cable,y})(L_c) = 0}$$

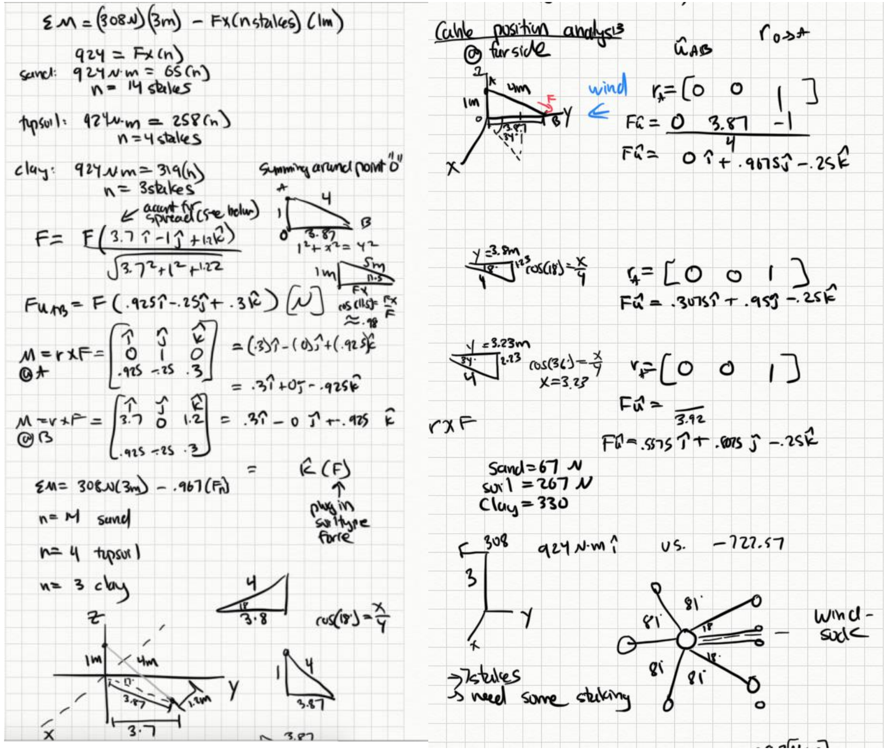
$$\oplus\circlearrowleft \Sigma M_{CG} = (F_{drag}) \cdot (l_{cg1}) + (F_{resistance}) \cdot (l_{cg2}) - (F_{support,y}) \cdot (L_L) - (F_{cable,y}) \cdot (L_c) = 0$$

B/c $F_{resistance} = F_{drag}$:

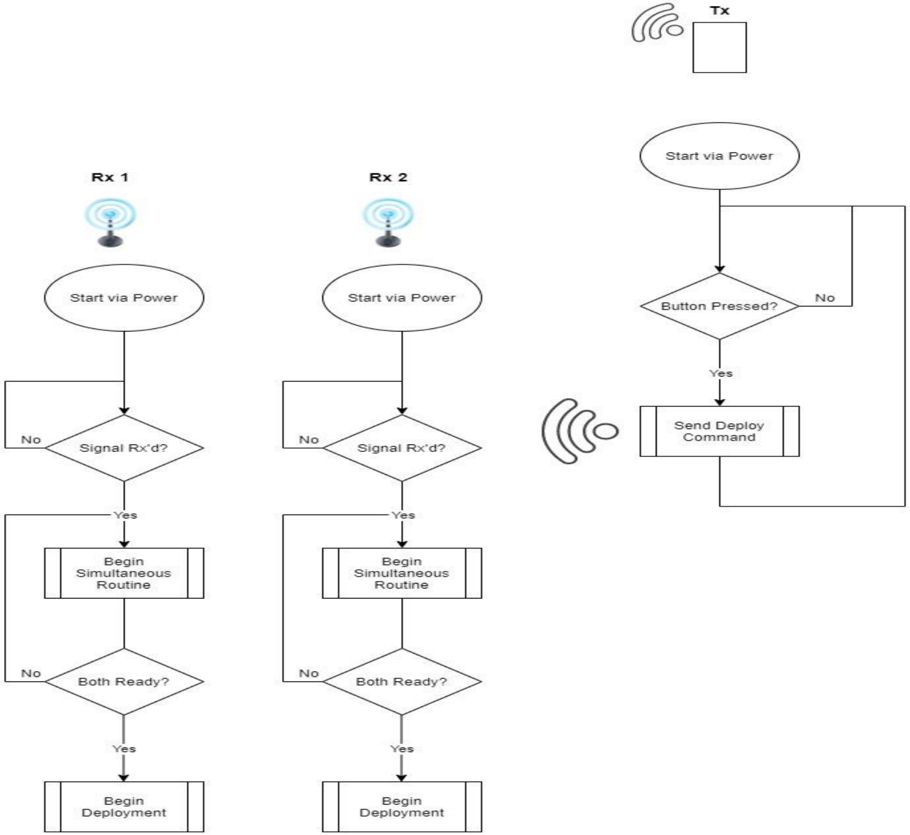
$$(F_{drag}) \cdot (l_{cg1}) + (F_{resistance}) \cdot (l_{cg2}) = (F_{drag}) \cdot (l_{cg1} + l_{cg2}) + (F_{resistance})(0)$$

And we arrive at the same expression.

Appendix - Pete Moment Work



Appendix- Secure two system deployment



Appendix: Evidence of Baseline Feasibility - Structure

- Material properties:

	Description	Material	Area	Tensile Strength	Shear Strength	
Extending Bar	8020 bar 1.5 in x1.5 in	6105-T5 Aluminum	744.16 m^2	280 MPa	170 MPa	
Base Truss	Global Square Truss F24	6082-T6 Aluminum	1.068e-4 m^2	250 MPa	210 MPa	
Support Cables	Steel wire rope ¼ inch	Steel	3.166e-5 m^2	200 MPa	NA	
Support Legs						

Appendix:Evidence of Baseline Feasibility - Structure

Fasteners/Junctions stress

The bolt will be used for connecting rail and the top bar. Two bolts stabilize the connection point.

- Assumption:

  - Wind force is acting on the connection part in the y direction.

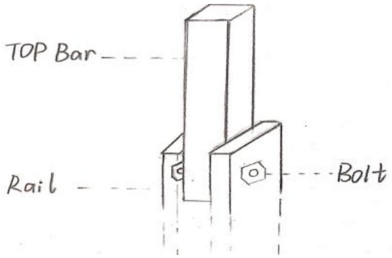
  - Two bolts are identical, the reaction force from each bolt is the same.

- Purpose:

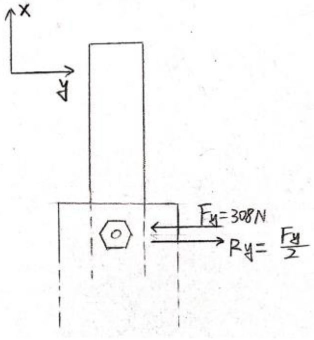
  - Determine the maximum shear stress on each bolt.

  - Minimum diameter of the bolt.

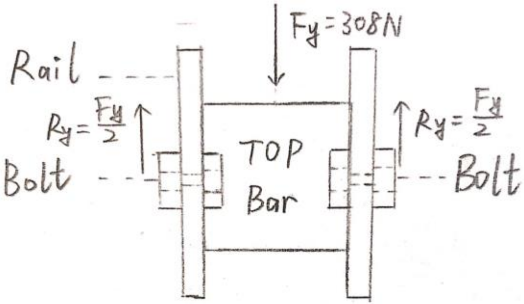
Connection between rail and top bar :



Front view :



Top view :



Appendix:Evidence of Baseline Feasibility - Structur

- Fasteners/Junction Stress:
  - Minimum diameter required for Grade 5 anchor bolts is 1/2 inch (12.7 mm)
  - Minimum required area for the bolt:

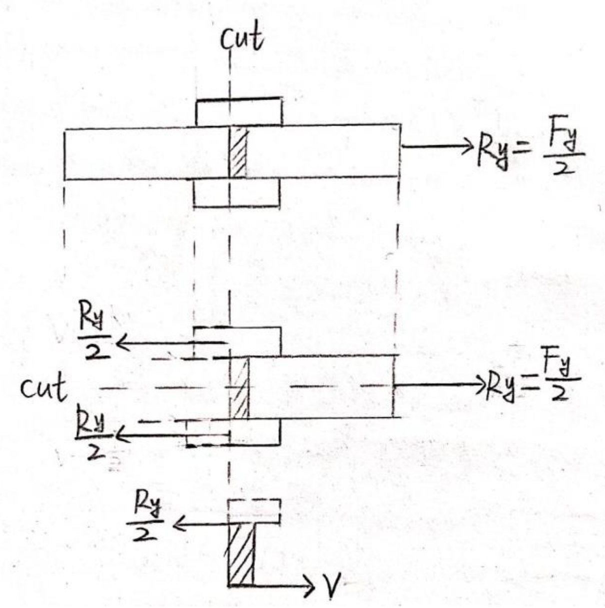
$$A_{min} = \frac{\pi \cdot d_{min}^2}{4} = \frac{\pi \cdot 0.0127^2}{4} \qquad \therefore A_{min} = 1.2668 \cdot 10^{-4} (m^2)$$

  - Shear stress of the bolt:

$$V = \frac{R_y}{2} = \frac{154N}{2} = 77N$$

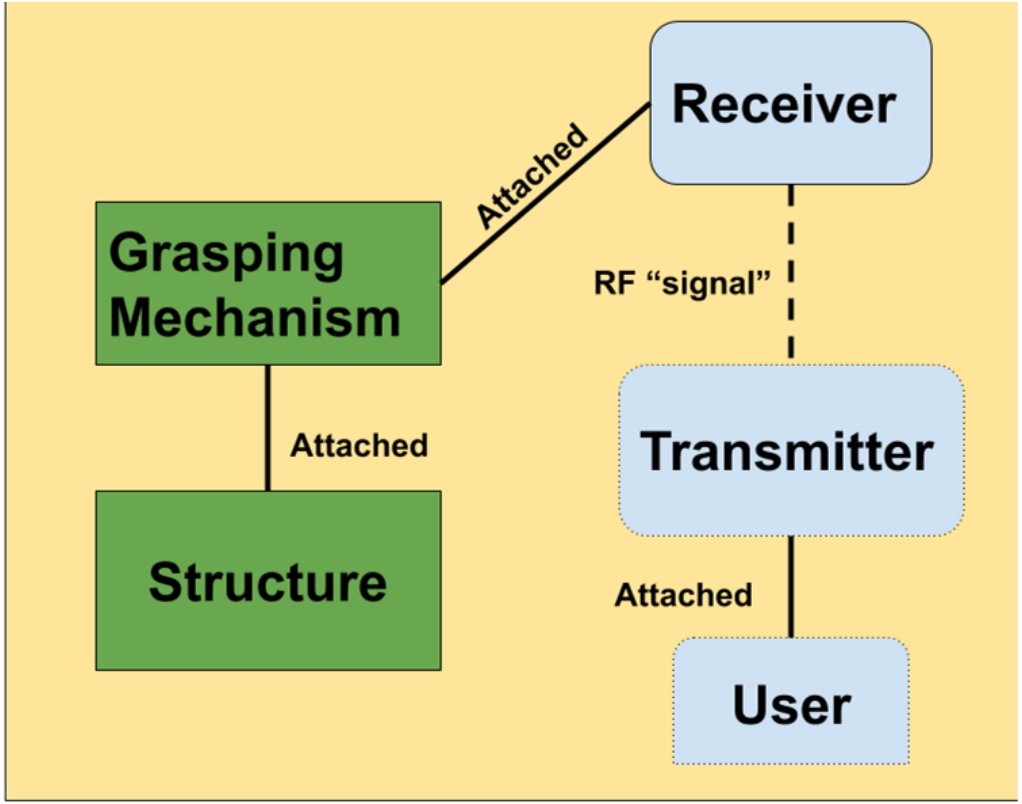
$$\tau = \frac{V}{A} \qquad \tau_{max} = \frac{V}{A_{min}} = \frac{77N}{1.2668 \cdot 10^{-4} m^2}$$

$$\therefore \tau_{max} = 607.830kPa \approx 88.158psi$$



Tip:For a commonly used Grade 5 hex cap anchor bolt,its tensile strength of **120,000 psi,** and the shear strength is nearly **70000 psi**.

Appendix - Project Description - Functional Block Diagram



Appendix:Evidence of Baseline Feasibility - Structure

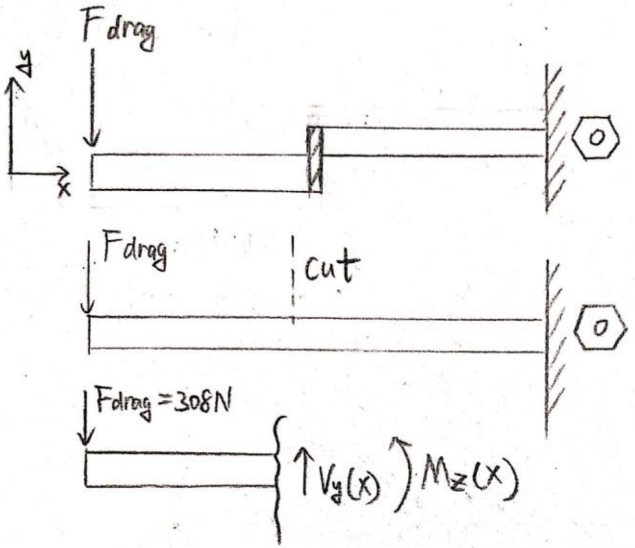
- Structure strength:
  - Moment and deflection of the bolt section:

$$M_z(x) = -311.376x$$

$$EI_{zz}v''(x) = \frac{-311.38}{2}x^2 + C_1$$

$$EI_{zz}v'(x) = \frac{-311.38}{6}x^3 + C_1x + C_2$$

$$v(x) = \frac{-51.896}{EI_{zz}}(L-x)^2(2L+x)$$

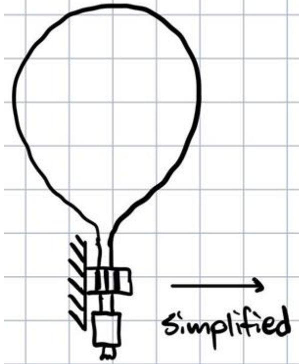


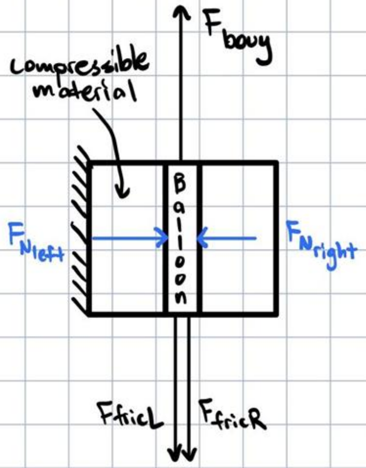
Appendix: Evidence of Baseline Feasibility - Release Mechanism

Governing equation: $F_{fric} = F_N \mu$

Governing principle: Friction independent of surface area

assume: thickness of balloon neck negligible, no wind condition



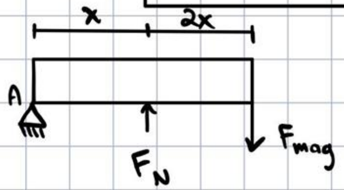


Solution: Force on each side of neck $= F_N \cdot \mu_s$

$\therefore$ $\boxed{\text{Total Force Friction} = 2F_N \cdot \mu_s \quad \text{where } F_N = \text{magnet weight rating}}$

* Balloon will stay in place as long as:

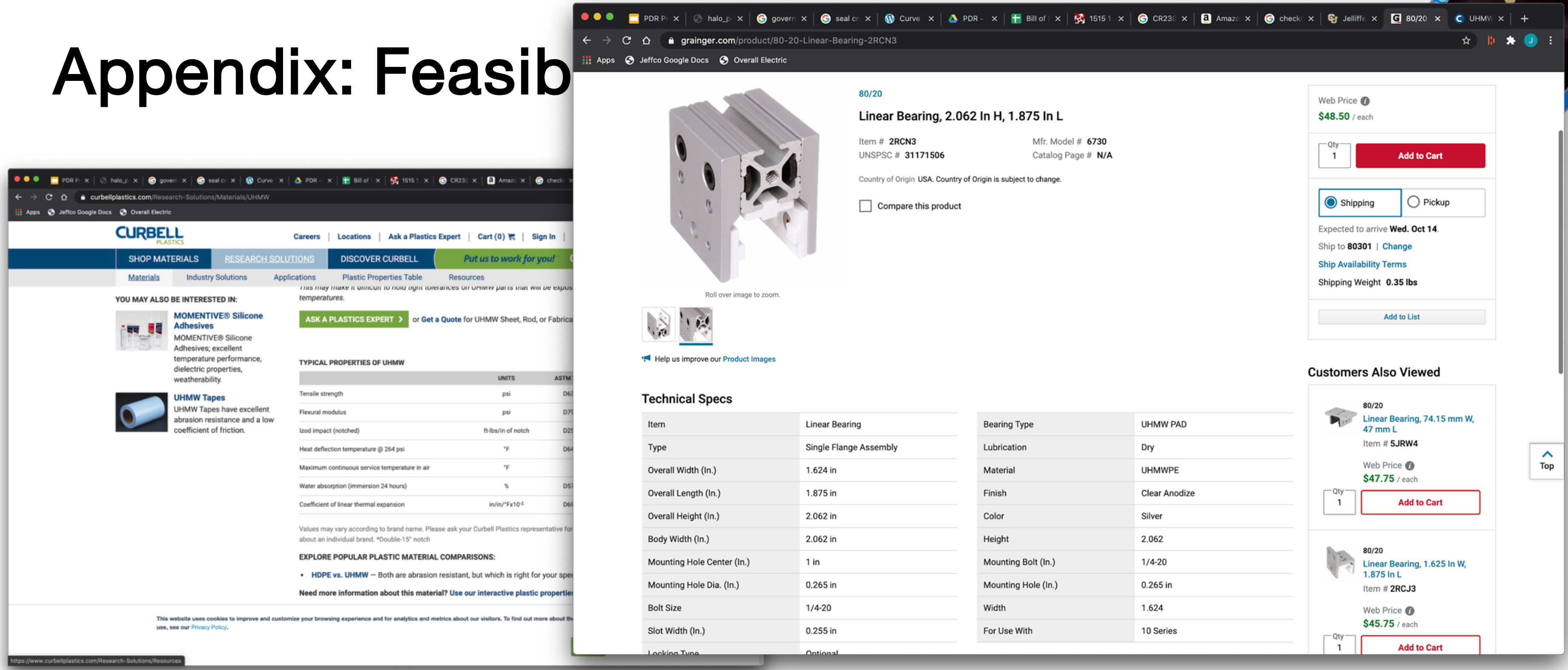
$$\boxed{2F_N \cdot \mu_s > F_{bouy}}$$



$$\Sigma M_A = 0 = x F_N - 2x F_{mag}$$

$$\boxed{F_N = 2F_{mag}}$$

Appendix: Feasib

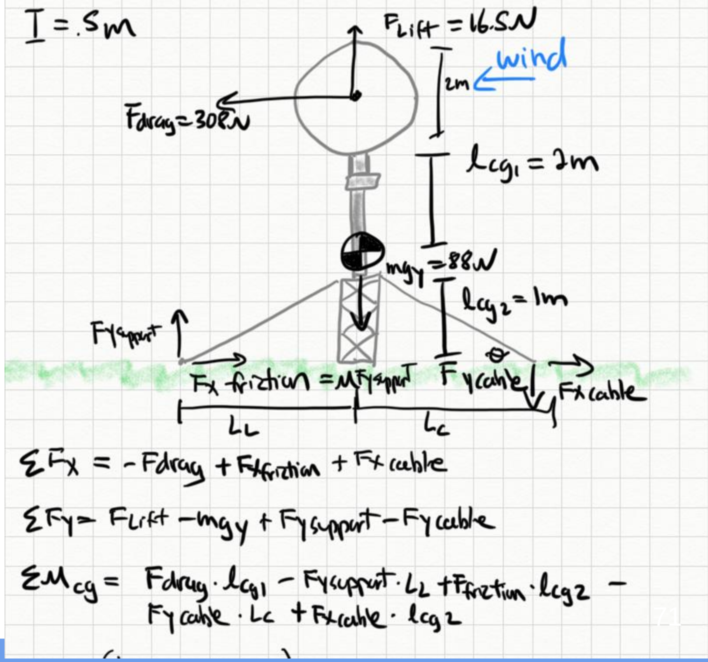


Previous slide shows max shear stress of ~88 PSI; UHMW has a tensile strength of 3100 PSI; FOS ~35

Appendix - Evidence of Baseline Feasibility - Structure

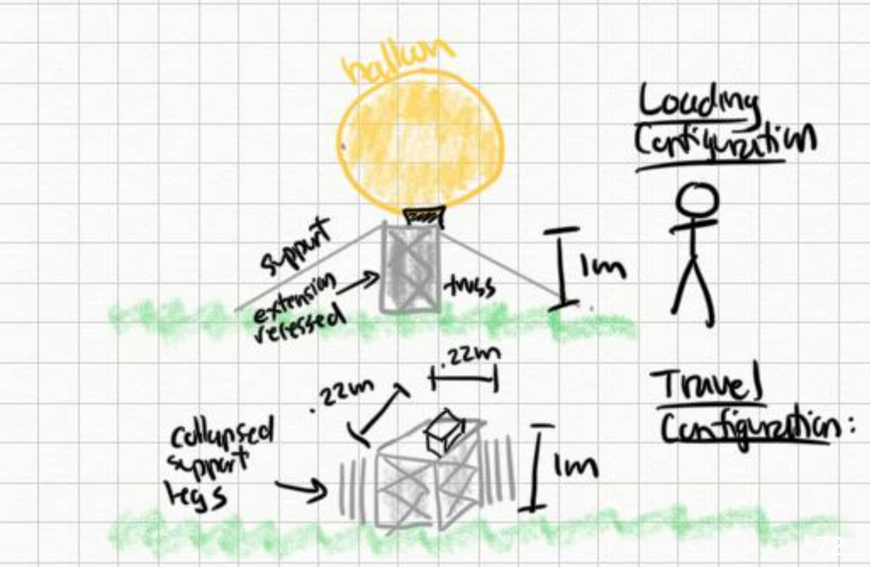
- Stability in 20 m/s winds
  - Max x-dir force on balloon: 308 N or 70lbs @ 3m high
    - Drag of a sphere:
      - $D_{sphere}=q_\infty * S * C_d$
      - $q_\infty=(½)\rho_\infty V_\infty^2$
      - $S=(\pi/4)d^2$
  - Anchor pull out force/Support line tension:
    - Tent Stakes: 66N vert pull, 133 N angle pull
    - Screw Style: 1165 N vert pull, 1730 N angle pull
    - 1/4 in. Upwind Steel Wire Rope: 6227.5 N in tension
  - X-dir length of upwind cables/downwind support legs:
    - No anchoring: 9.5 m (unfeasible)
    - Tent stake anchoring: 5.7 m
    - Screw anchors: 1.55 m

$$D = q_\infty S C_d \qquad q_\infty = \frac{1}{2}\rho_\infty V_\infty^2 \qquad S = \frac{\pi}{4}d^2$$



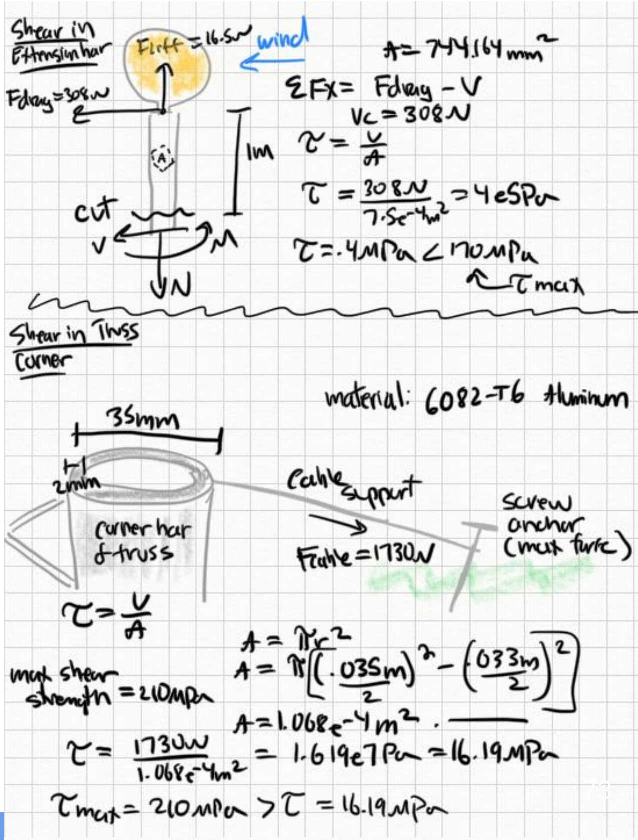
Appendix - Evidence of Baseline Feasibility - Structure

- Loaded by Single User
  - Truss section staked to ground
  - Balloon loaded at 1 m (3.3 ft)
    - Within reach of user
  - Extension bar raised/locked for launch at 3m height
- Collapsible
  - 1 m truss section, 2x 1 m bar extension
  - Support legs assembled in 1 m max length sections
  - Cross section of truss: .22m x.22m
  - Wing nut/bolt on support legs
  - Carabiner clip on upwind cable anchors
  - No tools required besides hammer for staking



Appendix - Evidence of Baseline Feasibility - Structure

- Structure strength:
  - Shear (V) in extending bar:
    - 8020 Aluminum
    - τ_{max}=170 MPa
    - A=744 mm^2
    - τ=V/A=.4 MPa < τ_{max}
  - Shear in extension bearing:
  - Shear (V) in truss corner bar:
    - 6082-T6 Aluminum
    - τ_{max}=210 MPa
    - A=106.8 mm^2
    - τ=V/A=16.2 MPa < τ_{max}
  - Truss support leg/cable junction
    - Load/ft: 604 N load/foot
    - Max center load: 3962 N



Appendix - Evidence of Baseline Feasibility - Structure

- Structure Strength:
  - Shear Stress = 0.4 MPa
  - Axial Stress = 2.79 KPa
  - Bending Stress = 102 MPa
  - Maximum bending moment= 616N·m
  - Maximum moment acting on linear bearing: 308N·m
  - Maximum deflection= 2.369e-9 m(~0m)

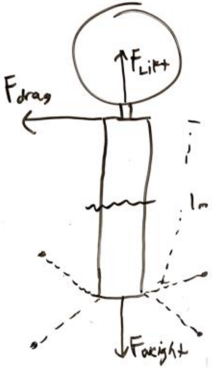
$$\sigma_b = \frac{My}{I}$$

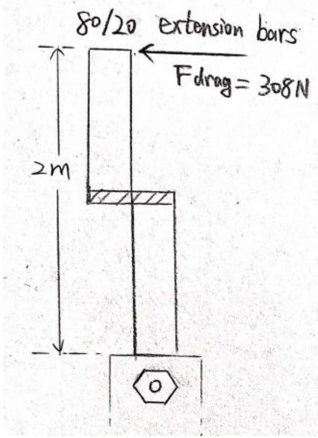
σ_b – Bending stress

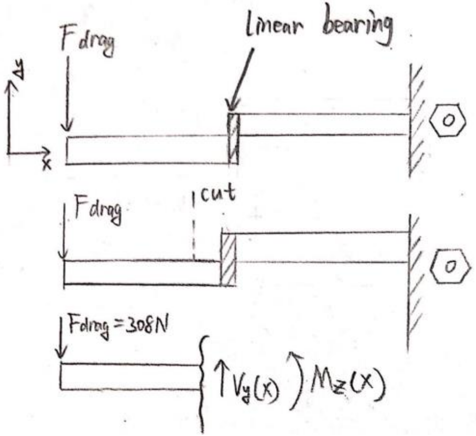
M – Calculated bending moment

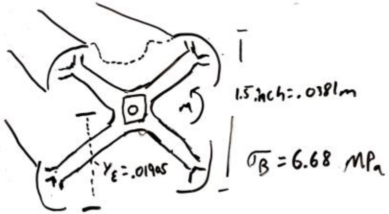
y – Vertical distance away from the neutral axis

I – Moment of inertia around the neutral axis





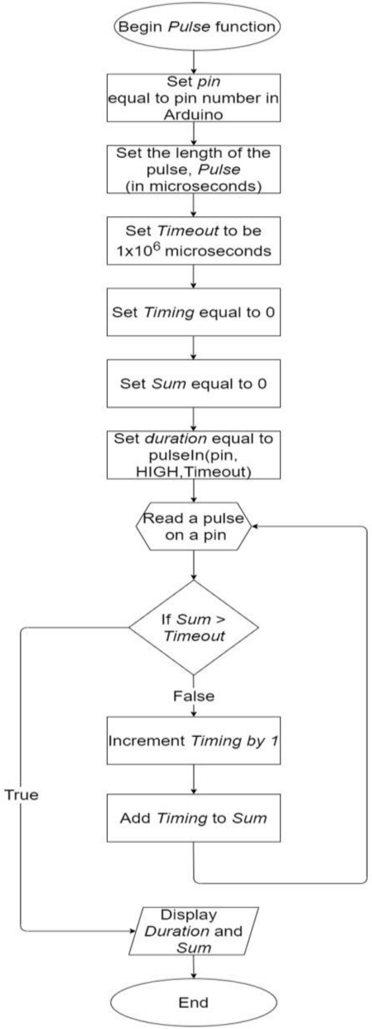




Appendix - Evidence of Baseline Feasibility: Command/Control

sketch_oct08a §

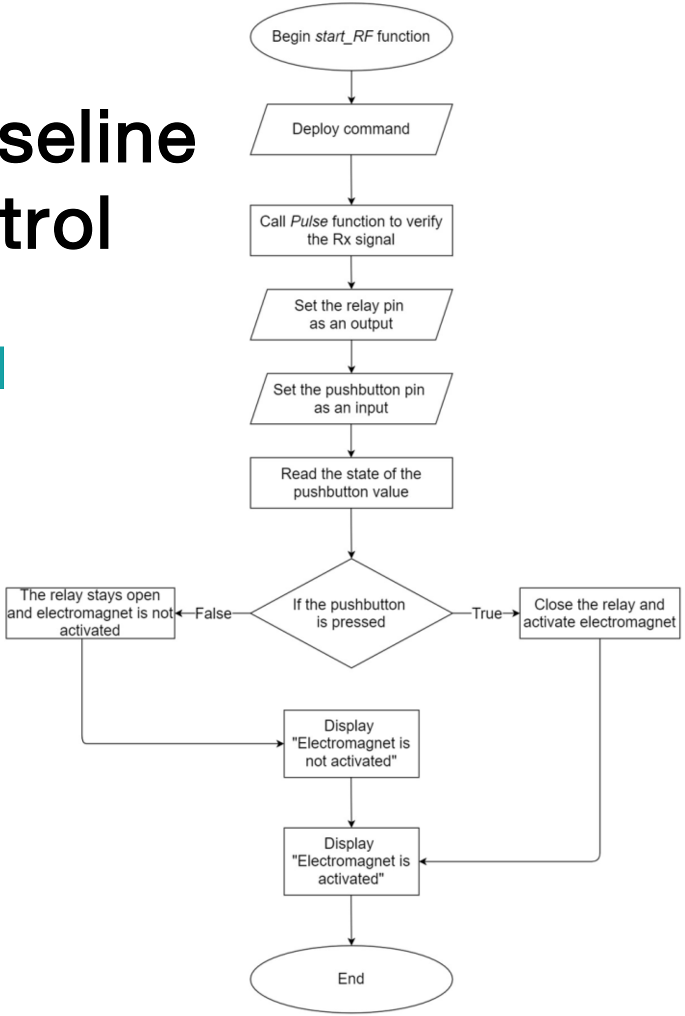
```
int pin = 7;
unsigned long duration;

void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pinMode(pin,INPUT);
}

void loop() {
  // put your main code here, to run repeatedly:
  time = pulseIn(pin,HIGH);
  Serial.println(time);
}
```



Appendix - Evidence of Baseline Feasibility: Command/Control

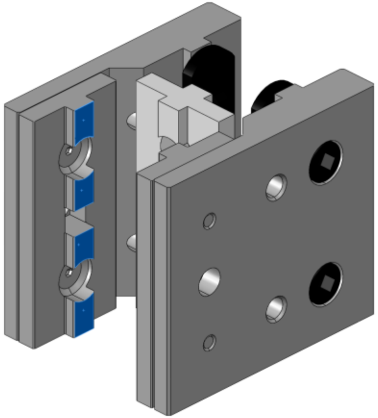
start_RF

```
// constants won't change. They're used here to set pin numbers:
const int pushbuttonPin = 2;      // the number of the pushbutton pin
const int relayPin =  13;       // the number of the LED pin

// variables will change:
int buttonState = 0;           // variable for reading the pushbutton status

void setup() {
  // initialize the relay pin as an output:
  pinMode(relayPin, OUTPUT);
  // initialize the pushbutton pin as an input:
  pinMode(pushbuttonPin, INPUT);
}

void loop() {
  // read the state of the pushbutton value:
  buttonState = digitalRead(pushbuttonPin);

  // check if the pushbutton is pressed. If it is, the buttonState is HIGH:
  if (buttonState == HIGH) {
    // relay close:
    digitalWrite(relayPin, HIGH);
  } else {
    // relay open:
    digitalWrite(relayPin, LOW);
  }
}
```



Appendix - Evidence of Baseline Feasibility: Structure

- Shear (V) in linear bearing:
  - UHMW material
  - Area subject to shear
  - τ=.55 MPa <τ_{max}=20 MPa



80/20

Linear Bearing, 2.062 In H, 1.875 In L

Item # 2RCN3 Mfr. Model # 6730
UNSPSC # 31171506 Catalog Page # N/A

Country of Origin USA. Country of Origin is subject to change.

Compare this product

Roll over image to zoom.

Help us improve our Product Images

Technical Specs

Item	Linear Bearing	Bearing Type	UHMW PAD
Type	Single Flange Assembly	Lubrication	Dry
Overall Width (In.)	1.624 in	Material	UHMWPE
Overall Length (In.)	1.875 in	Finish	Clear Anodize
Overall Height (In.)	2.062 in	Color	Silver
Body Width (In.)	2.062 in	Height	2.062
Mounting Hole Center (In.)	1 in	Mounting Bolt (In.)	1/4-20
Mounting Hole Dia. (In.)	0.265 in	Mounting Hole (In.)	0.265 in
Bolt Size	1/4-20	Width	1.624
Slot Width (In.)	0.255 in	For Use With	10 Series

Max shear stress of ~80 PSI; UHMW has a tensile strength of 3000 PSI; FOS ~37.5