ASEN 4018 Senior Projects Fall 2018
Critical Design Review

BEACAN

Buoy-Enabled Analysis of Currents via Aerial Navigation

TEAM: Omar Alshamsi, Meer Baker, Eric Bergman, Jack Lambert, Eli Landers, Quentin Moore, Alex Mulvaney, Donald Palomino, Wyatt Raich, Brody Rosipajla, Aytac Teker, Eric Zhao

Customer: Robert Leben

Advisor: John Mah

Project Objectives

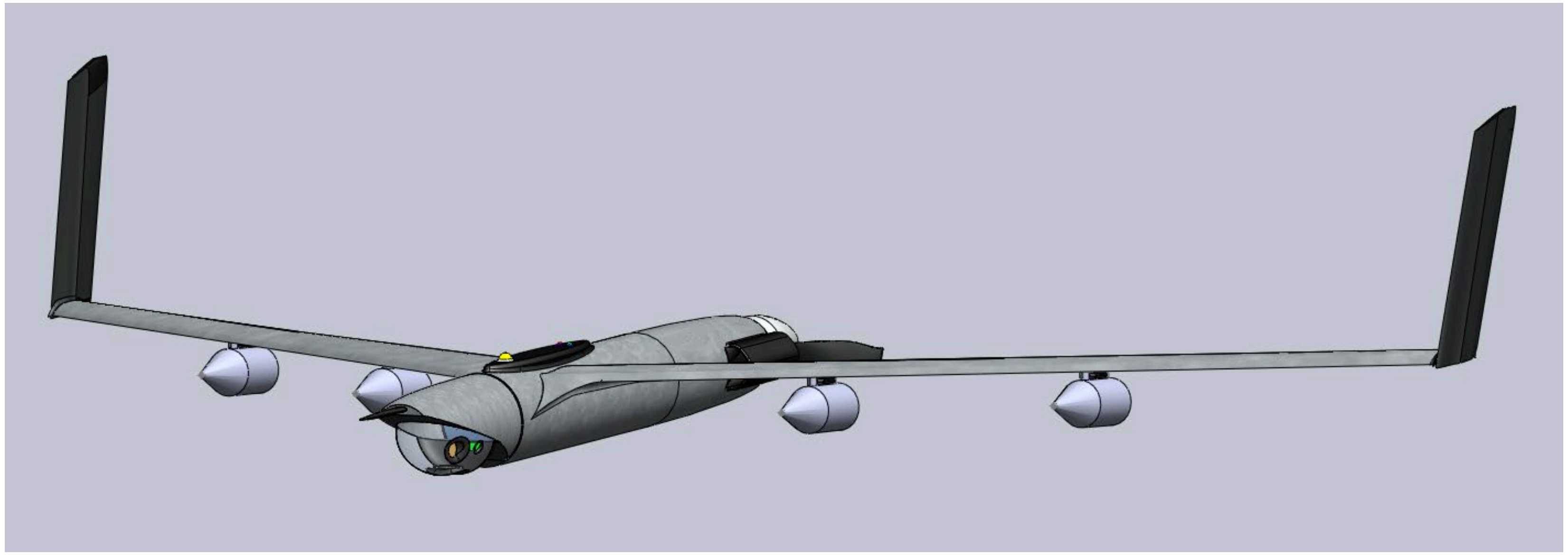
Mission Statement: BEACAN will design, build, and test a miniaturized ocean drifter. The drifter shall be capable of collecting positional coordinates and transmitting coordinates to a communications satellite. Secondary, the team will develop a drifter deployment mechanism.

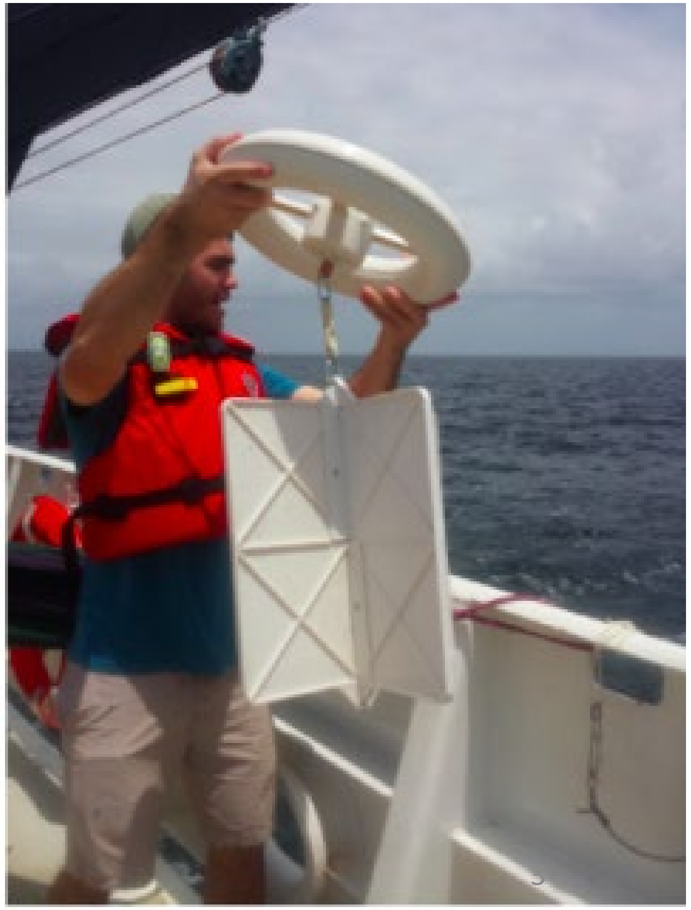
Final Customer Deliverables:

- 1 deployment mechanism, 2 drifters (1 for testing)
- Method for comparing performance metrics of BEACAN drifter to drifters currently on the market

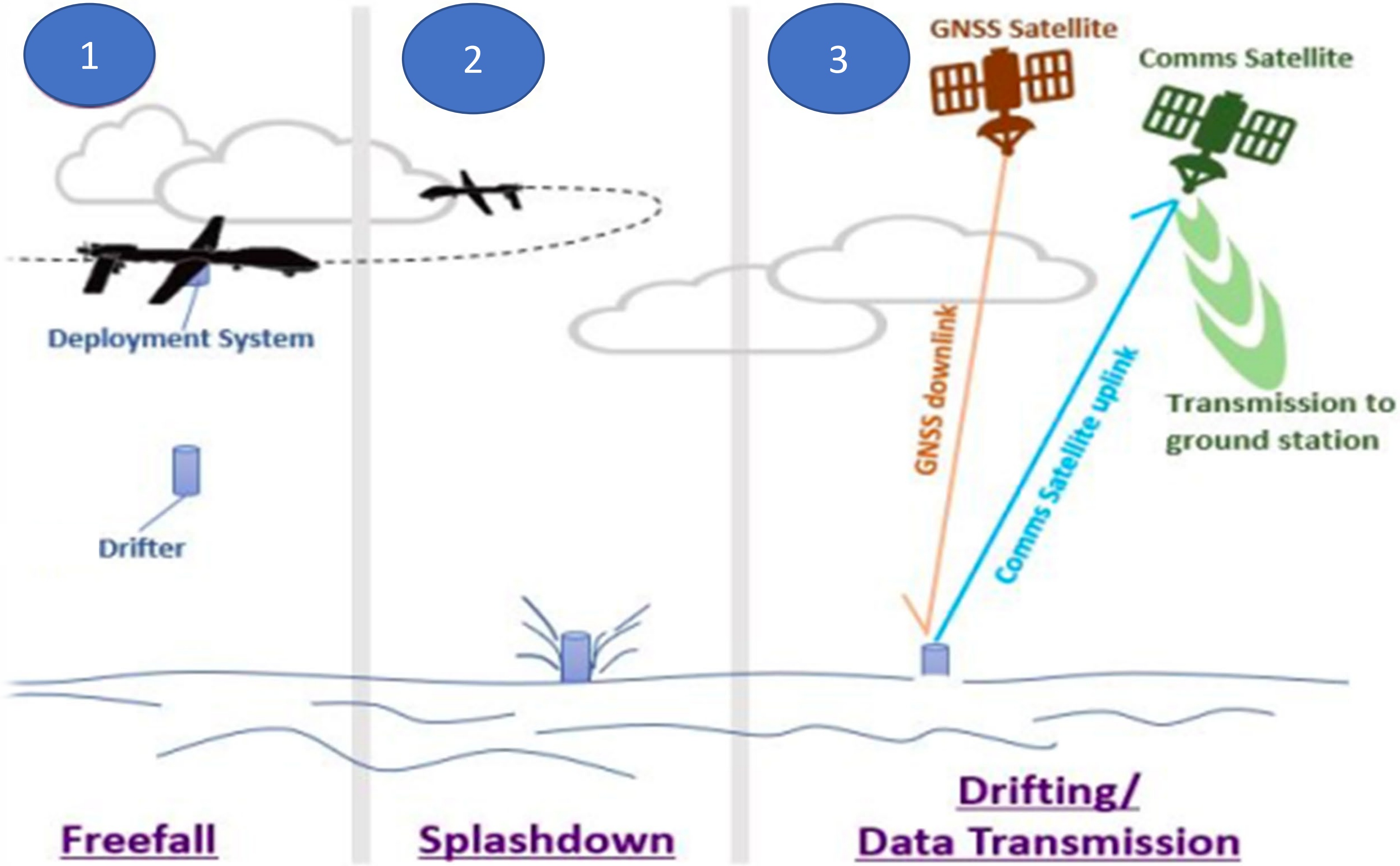
Why Miniaturize the Drifter?

- Current Drifters are bulky which limits deployment methods to large vessels
- Ship time is COSTLY ~ $10,000 /day
- Save costs by deploying via UAV
- Further study currents in the Gulf of Mexico





Customer CONOPS



Freefall

Deployment initiated by onboard autopilot. Drifter falls into Gulf of Mexico

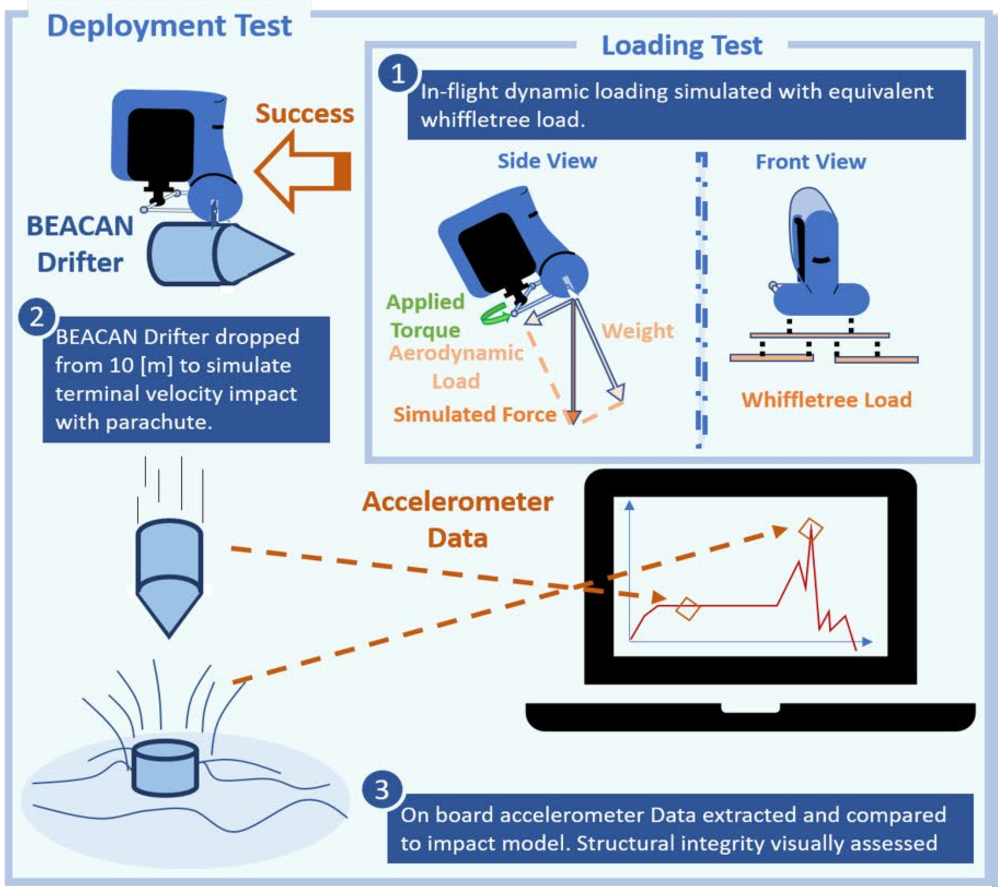
Splashdown

Drifter splashes down. UAV returns to ground station.

Drifting/ Data Transmission

Drifter follows surface currents until end of life. GNSS lock is established, and periodic transmission to comms satellite begins.

Testing CONOPS



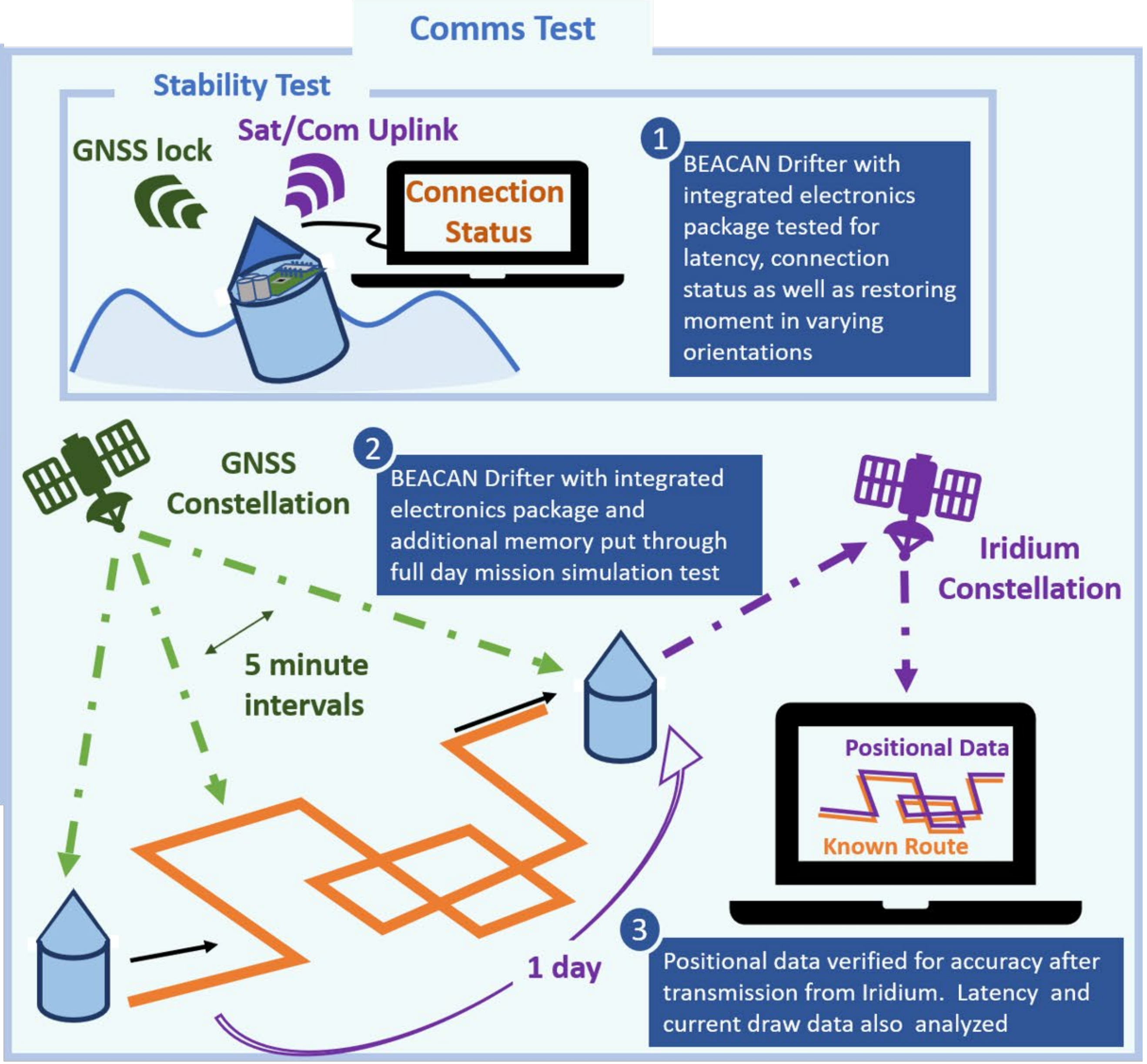
Deployment Test

Loading Test

① In-flight dynamic loading simulated with equivalent whiffletree load.

② BEACAN Drifter dropped from 10 [m] to simulate terminal velocity impact with parachute.

③ On board accelerometer Data extracted and compared to impact model. Structural integrity visually assessed



Comms Test

Stability Test

① BEACAN Drifter with integrated electronics package tested for latency, connection status as well as restoring moment in varying orientations

② BEACAN Drifter with integrated electronics package and additional memory put through full day mission simulation test

③ Positional data verified for accuracy after transmission from Iridium. Latency and current draw data also analyzed

PROJECT CONCEPT OF OPERATIONS

BEACAN

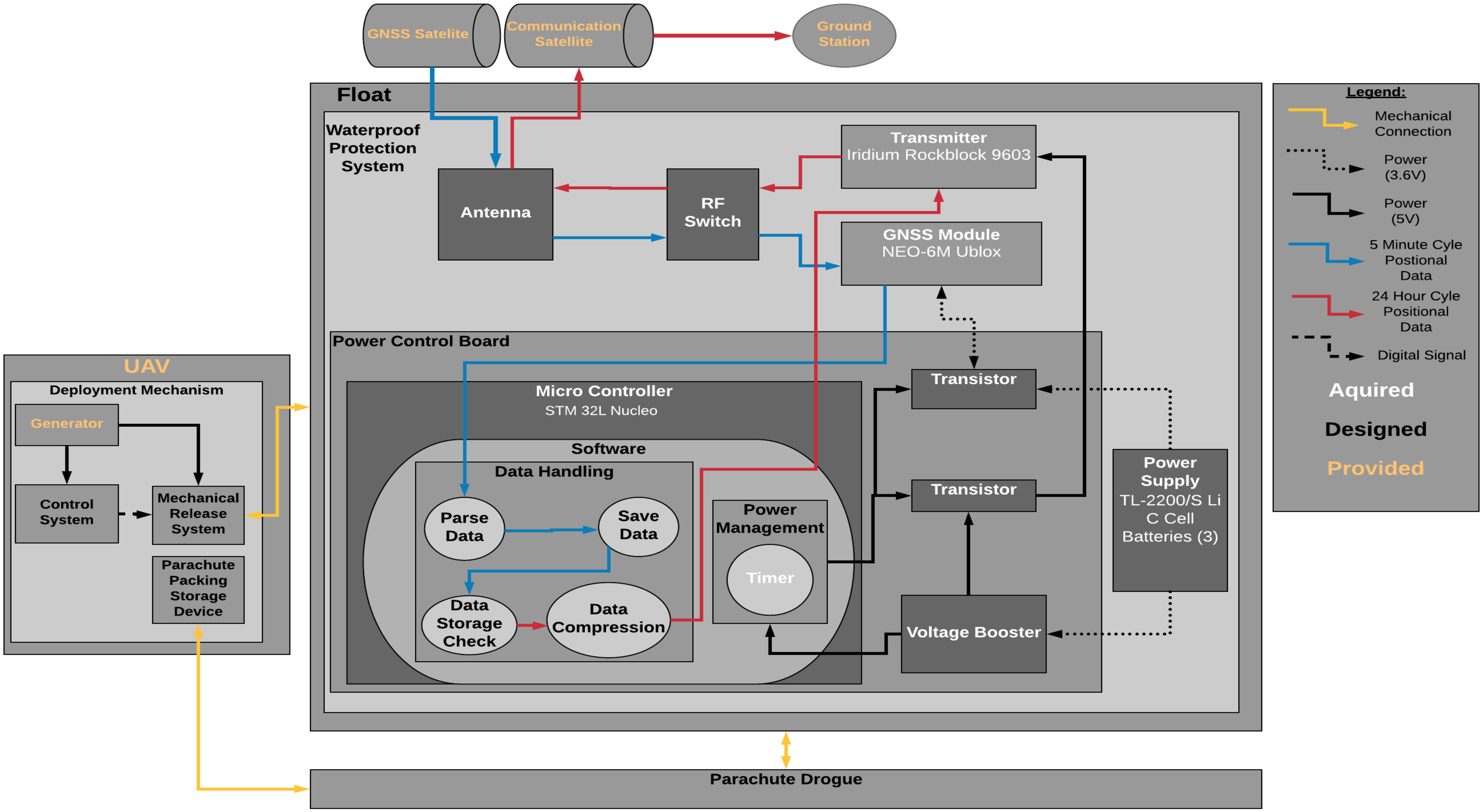
Buoy-Enabled Analysis of Currents via Aerial Navigation

Functional Requirements

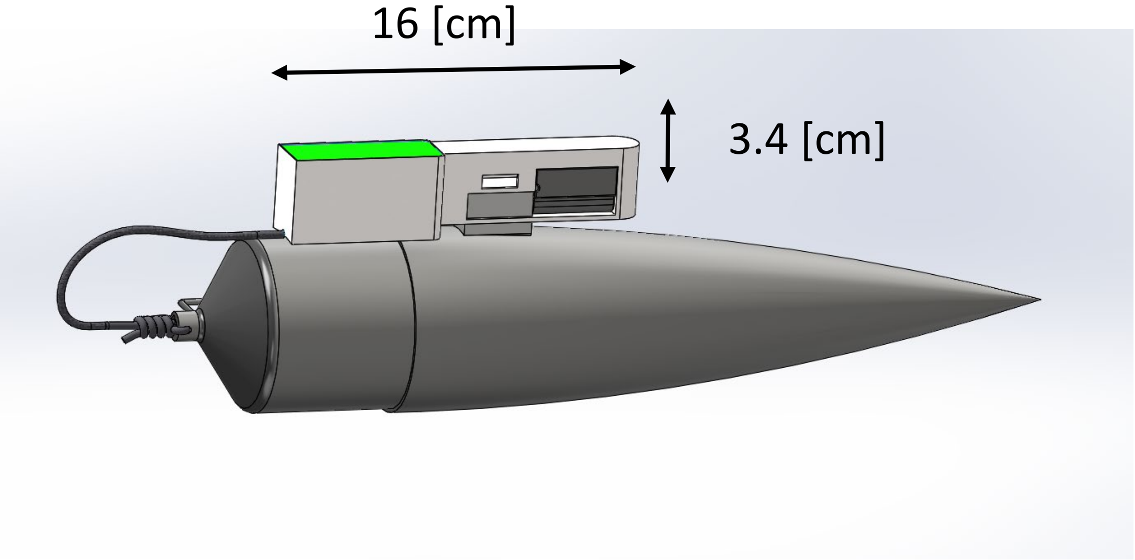
Functional Requirement	Description
FR 1.0	Drifter shall be capable of following ocean currents in the Gulf of Mexico
FR 2.0	Drifter shall maintain a 3-month lifespan
FR 3.0	Drifter shall be deployed from an altitude of 300 [m]
FR 4.0	The drifter shall measure and store position coordinates
FR 5.0	Drifter shall transmit stored position coordinates to a ground station up to 800 [km]
FR 6.0	Mass of 4 drifters and deployment mechanisms shall not exceed 2.7 [kg]
FR 7.0	Cost of manufacturing 1 drifter and required communications package shall not exceed $1000
FR 8.0	The deployment mechanism system shall deploy each drifter individually

Design Solutions

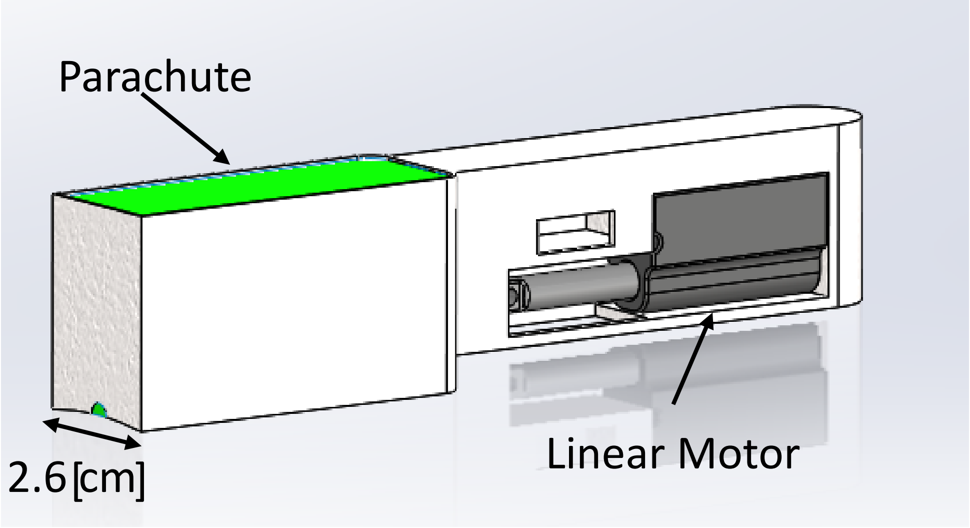
Design Solution: Functional Block Diagram



Design Solution: Deployment Mechanism



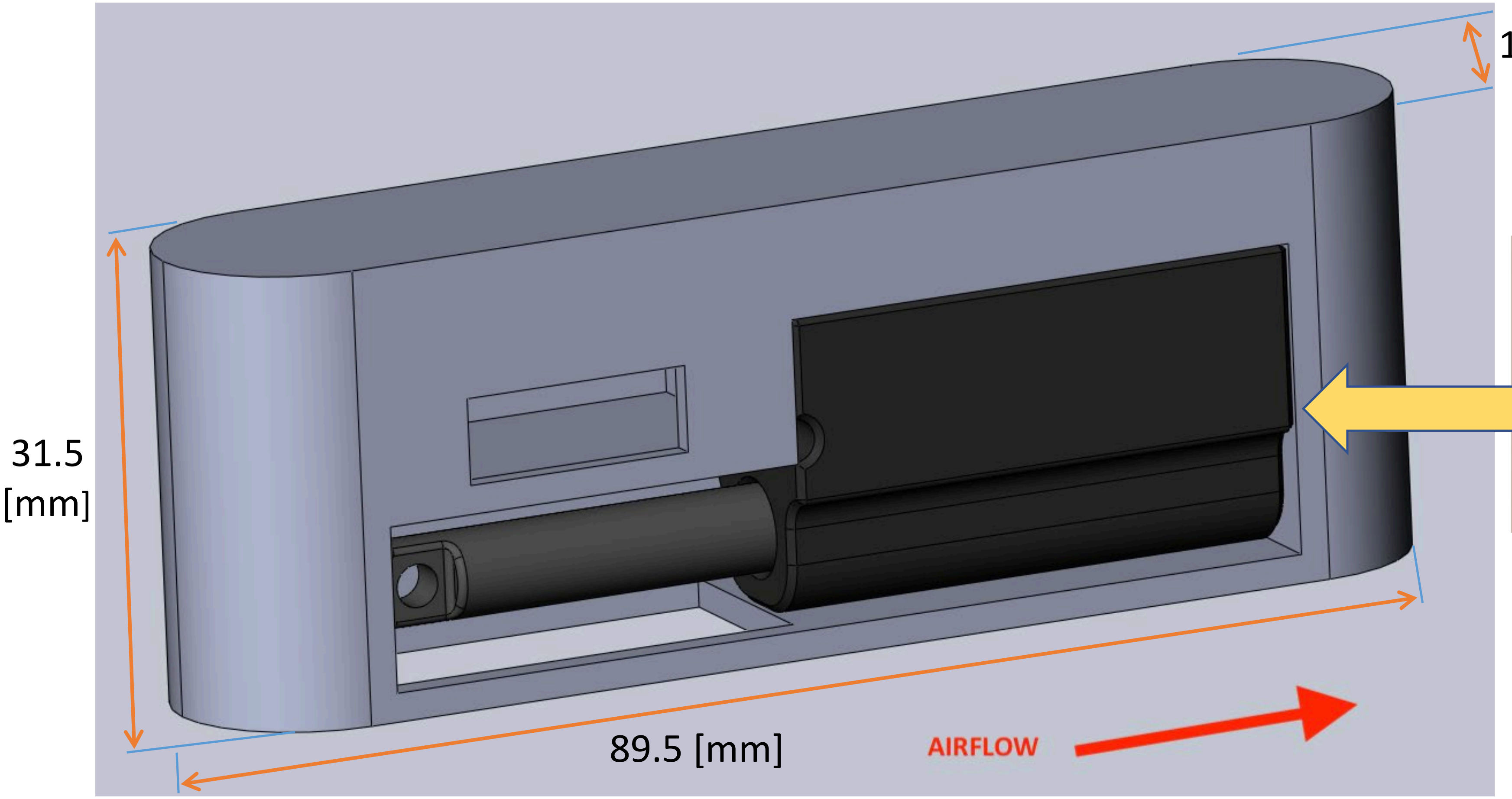
- Mass of Mechanism : 35 [g]



- Deploys drifter upon received signal

- Linear motor pulls pin for deployment
- Rear assembly stores and properly deploys parachute

Design Solution: Deployment Mechanism

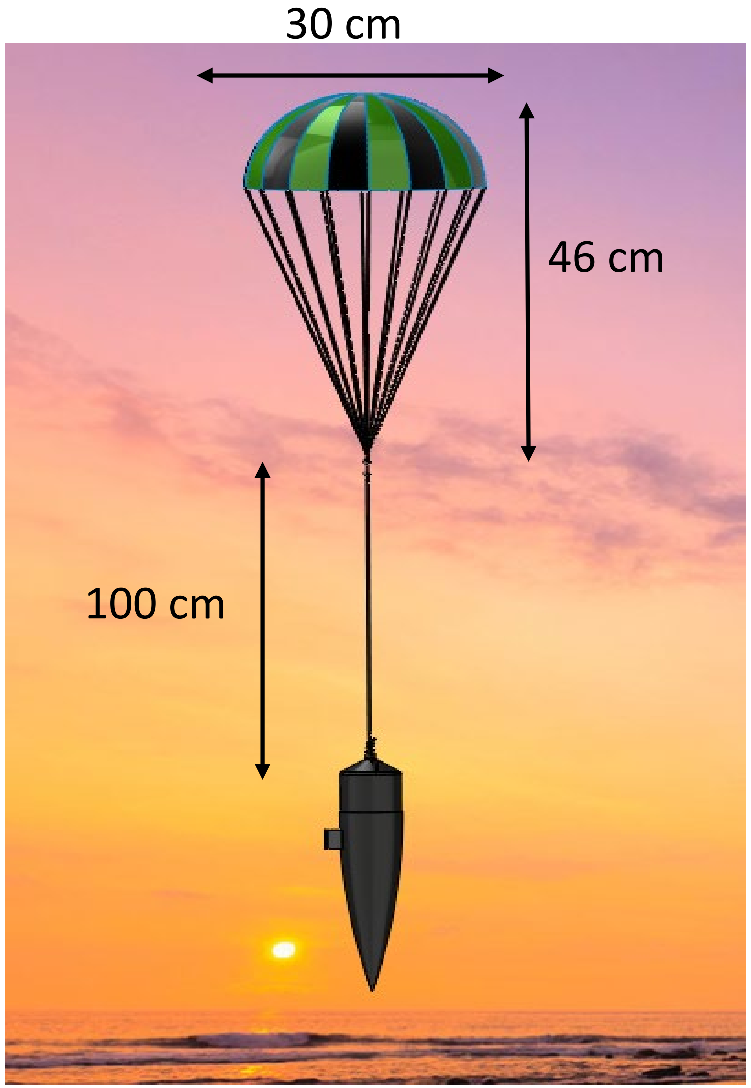


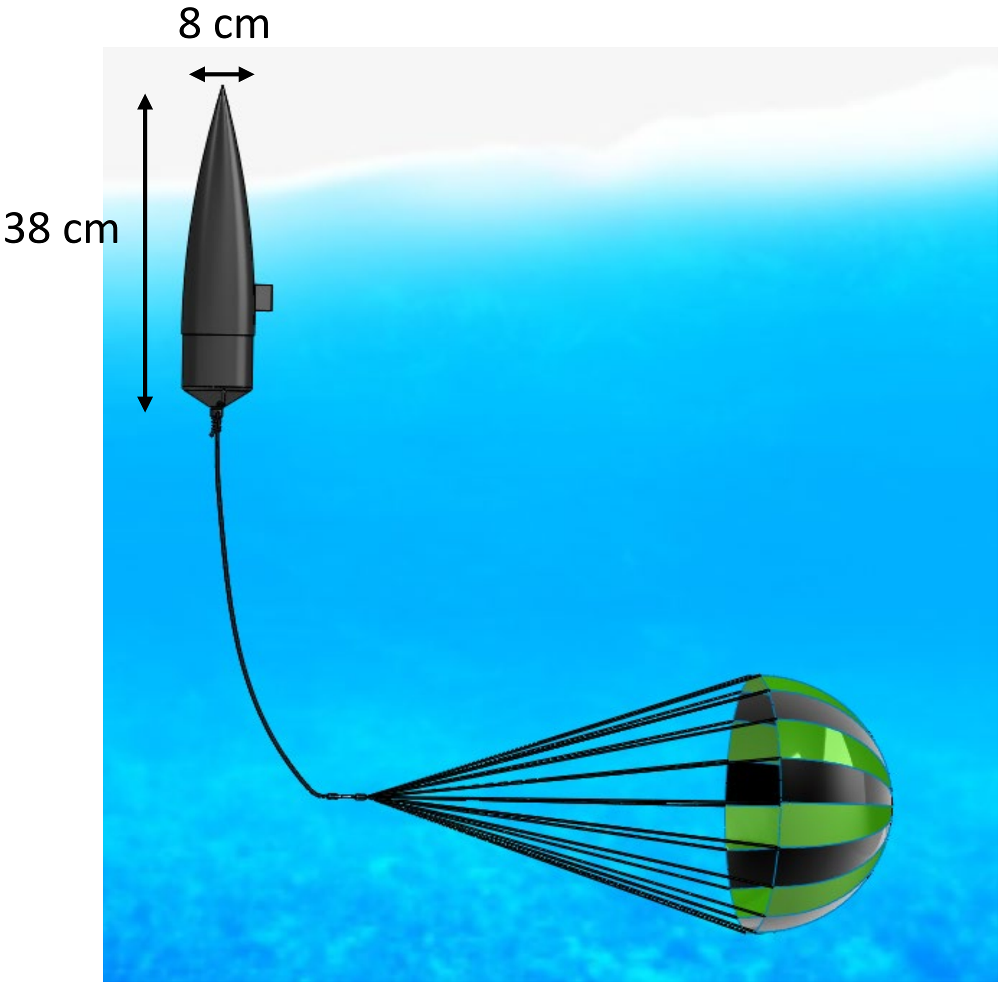
Actuonix Linear Actuator

Design Solution: Deployment Mechanism

- Before deployment, float holds parachute in place
- Linear motor pulls pin
- Float is released from mechanism
- Parachute housing opens
- Falling float pulls parachute from housing
- Deployment not time critical
    - Deployed from 300 [m]

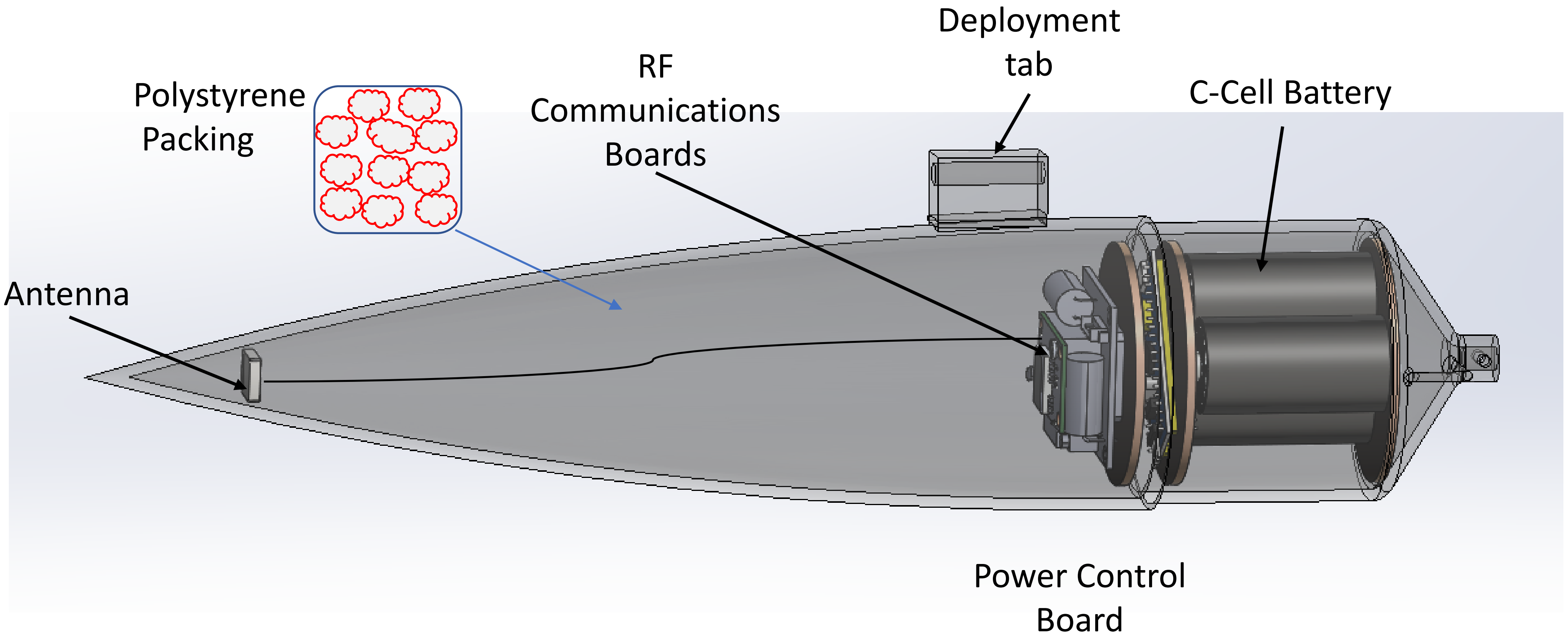
Design Solution: Integrated System





- Drifter in freefall and float stages of mission
- Drifter total mass:
  - 560 [g]

Design Solution: Float



- Mass

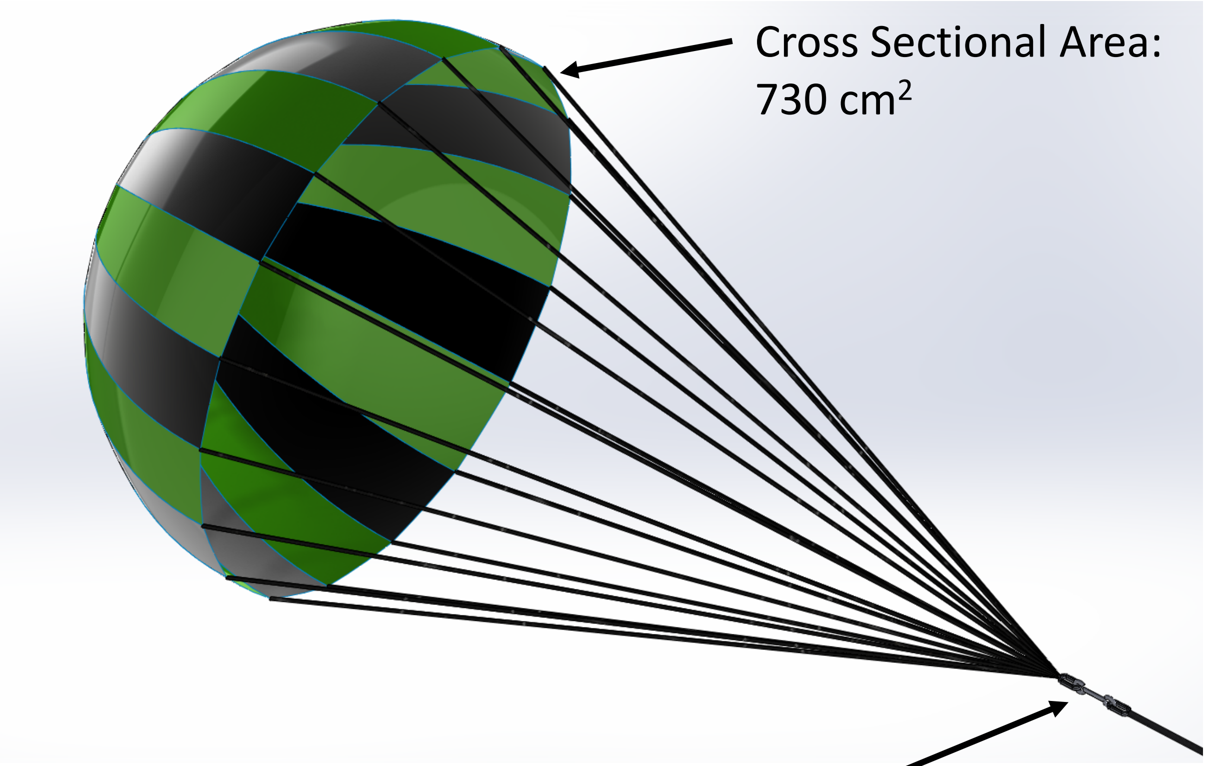
  493 [g]

- Keeps drifter afloat
- Protects electronics

- Components glued together and to float in shown configuration

- Remaining Volume filled with packing peanuts for extra protection

Design Solution: Drogue

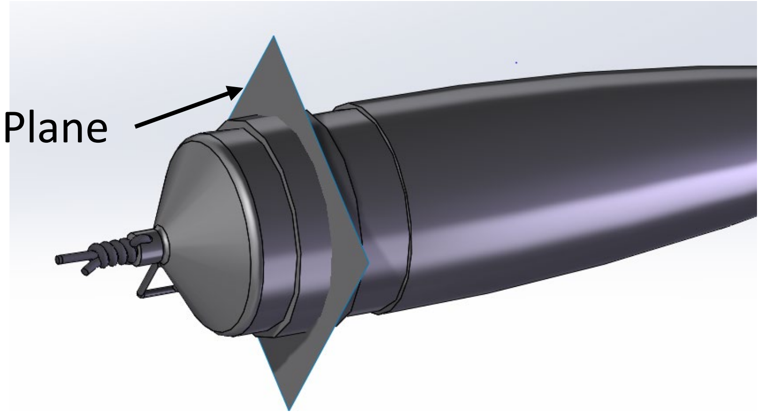


Cross Sectional Area: 730 cm^2

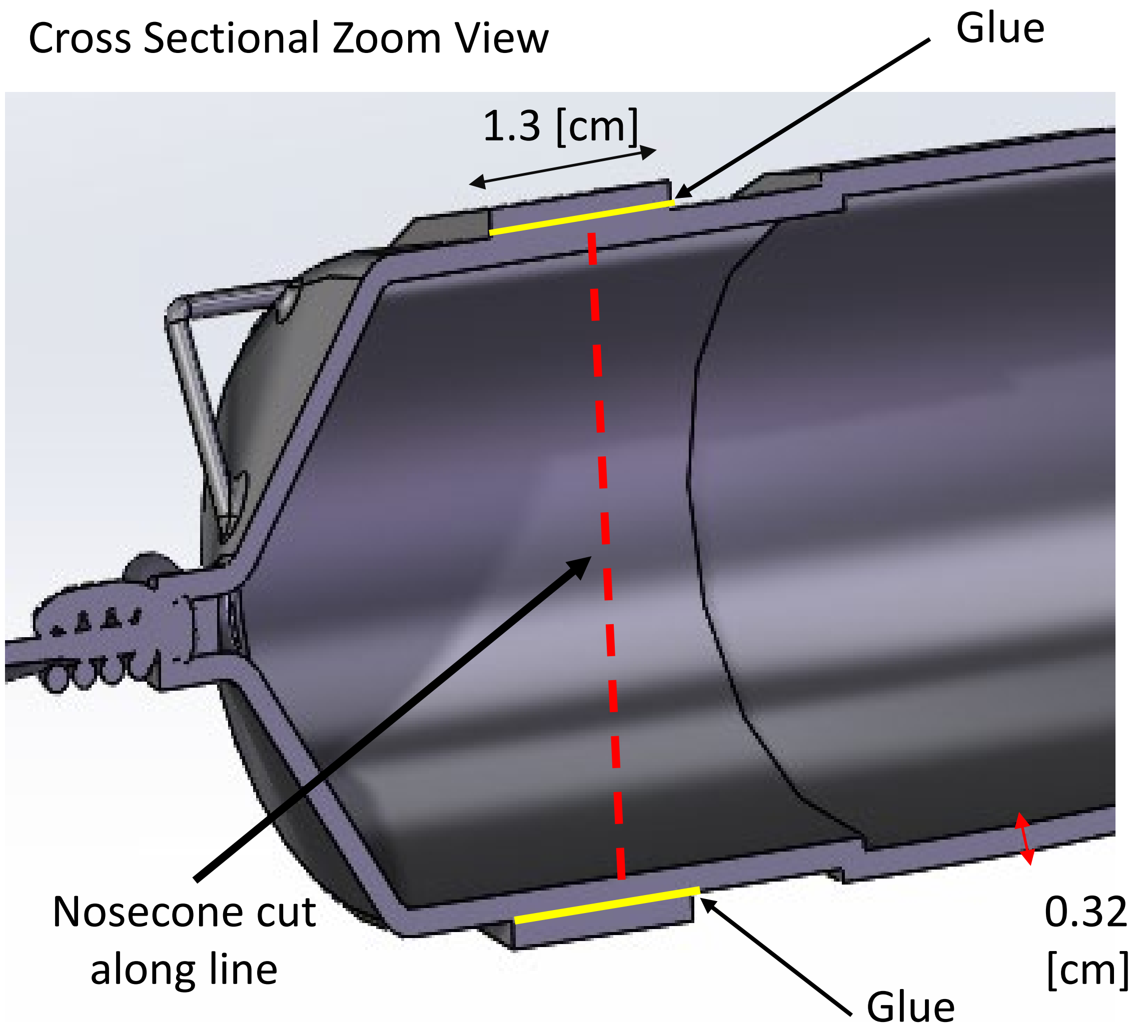
Gimbal joint to weigh down and allow free motion of parachute

- Fruity Chutes: 12 [in] Compact Elliptical Parachute
- Reinforced nylon
- Slows drifter upon impact
- Follows measured currents
- Cd = 1.5
- Mass
    - 24.2 [g]

Design Solution: Float



- Pre-built rocket nose cone by LOC Precisions
- Cut along plane to install electronics
- Loctite Polypropylene glue



Electronics

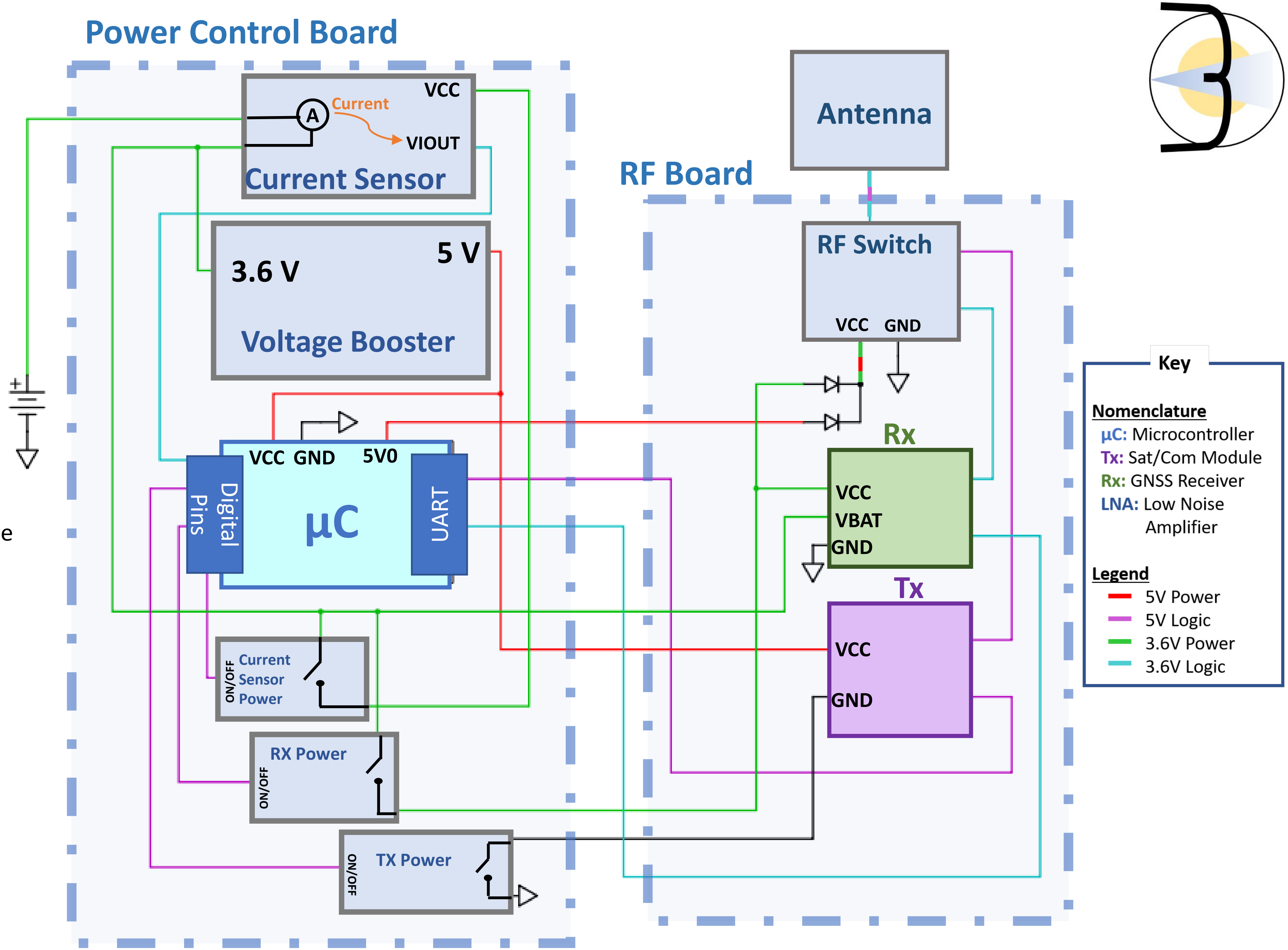
Microcontroller: STM 32L Nucleo
- Low power options
- Industry standard
- Internal low power timer
-

Receiver: NEO-6MUblox
- Industry Standard
- Lightweight
- Low power consumption

Transmitter: Iridium RockBlock 9603
- All-in-one, industry standard package

Battery: TL-2200/S Li C Cell (x3)
- 3.6 V
- 7.2 Ah
- 230 mA max continuous current
- 450 mA max pulse current

Antenna: Taoglas CGIP
- Shared antenna between Rx and Tx
- Hemispherical antenna



Key

Nomenclature

μC: Microcontroller
Tx: Sat/Com Module
Rx: GNSS Receiver
LNA: Low Noise Amplifier

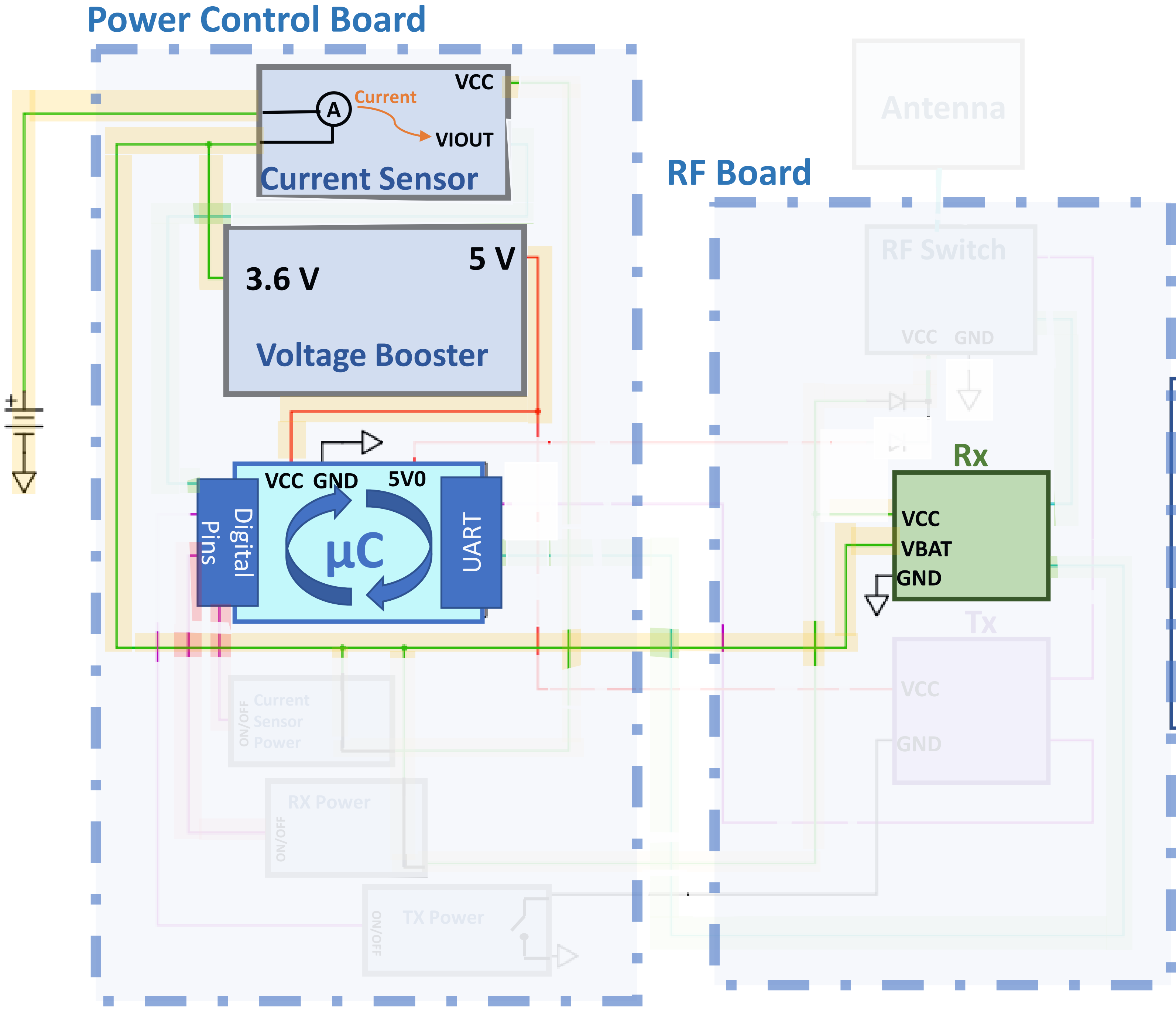
Legend

🟥 5V Power
🟪 5V Logic
🟩 3.6V Power
🟦 3.6V Logic

Electronics

Idle Mode

Only powering internal low power timer on µC, and real time clock on Rx through VBAT pin.



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- 🟦 3.6V Logic

🟨 **Current Flow**

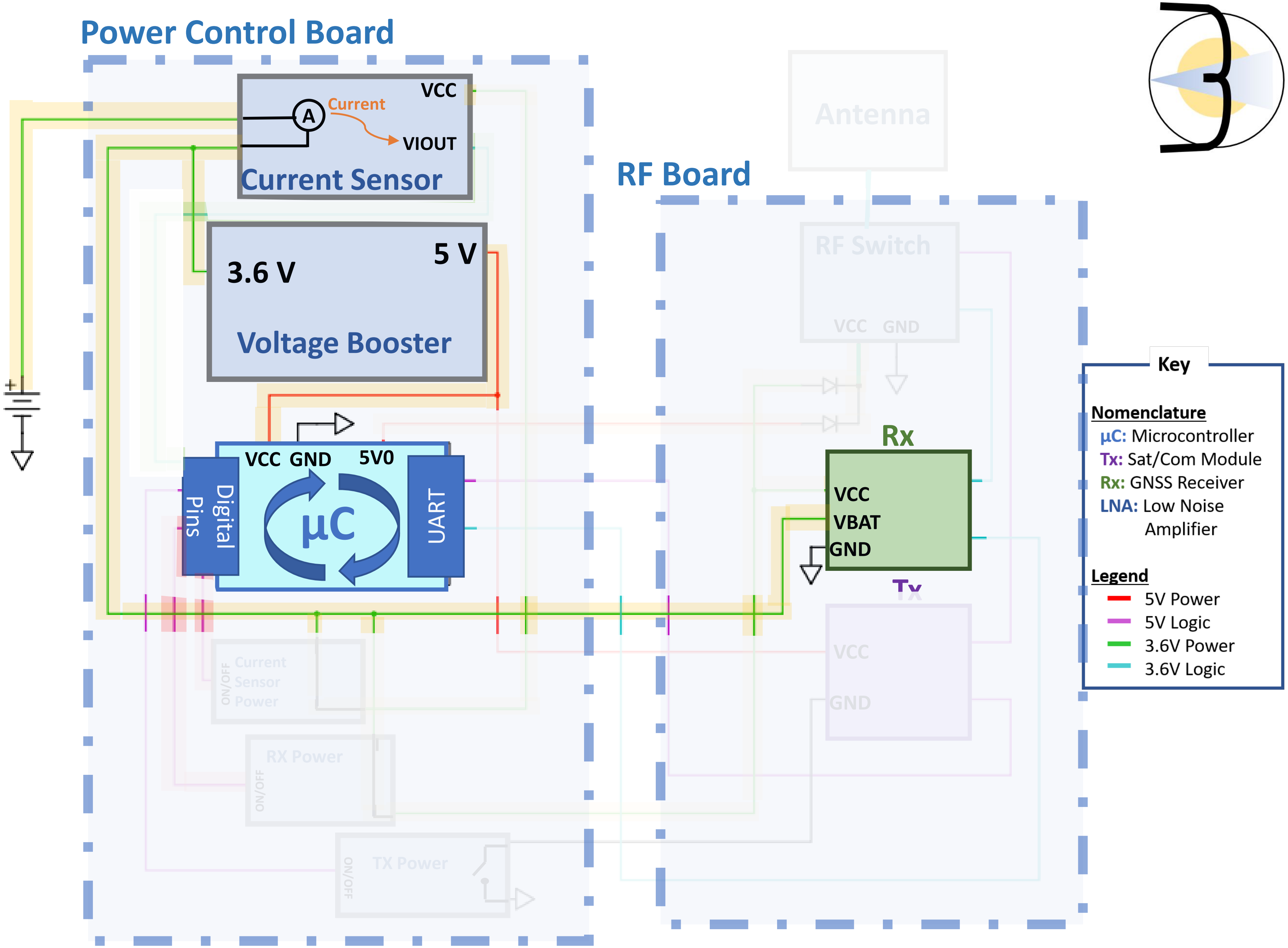
🟥 **HIGH Voltage**

🟩 **Digital Signal**

Electronics

5 minute cycle

1. Microcontroller wakes up, powers on Rx and Current Sensor
2. Rx gets positional data sends it to microcontroller
3. Microcontroller parses data and verifies accuracy
4. Rx and Current Sensor Power off



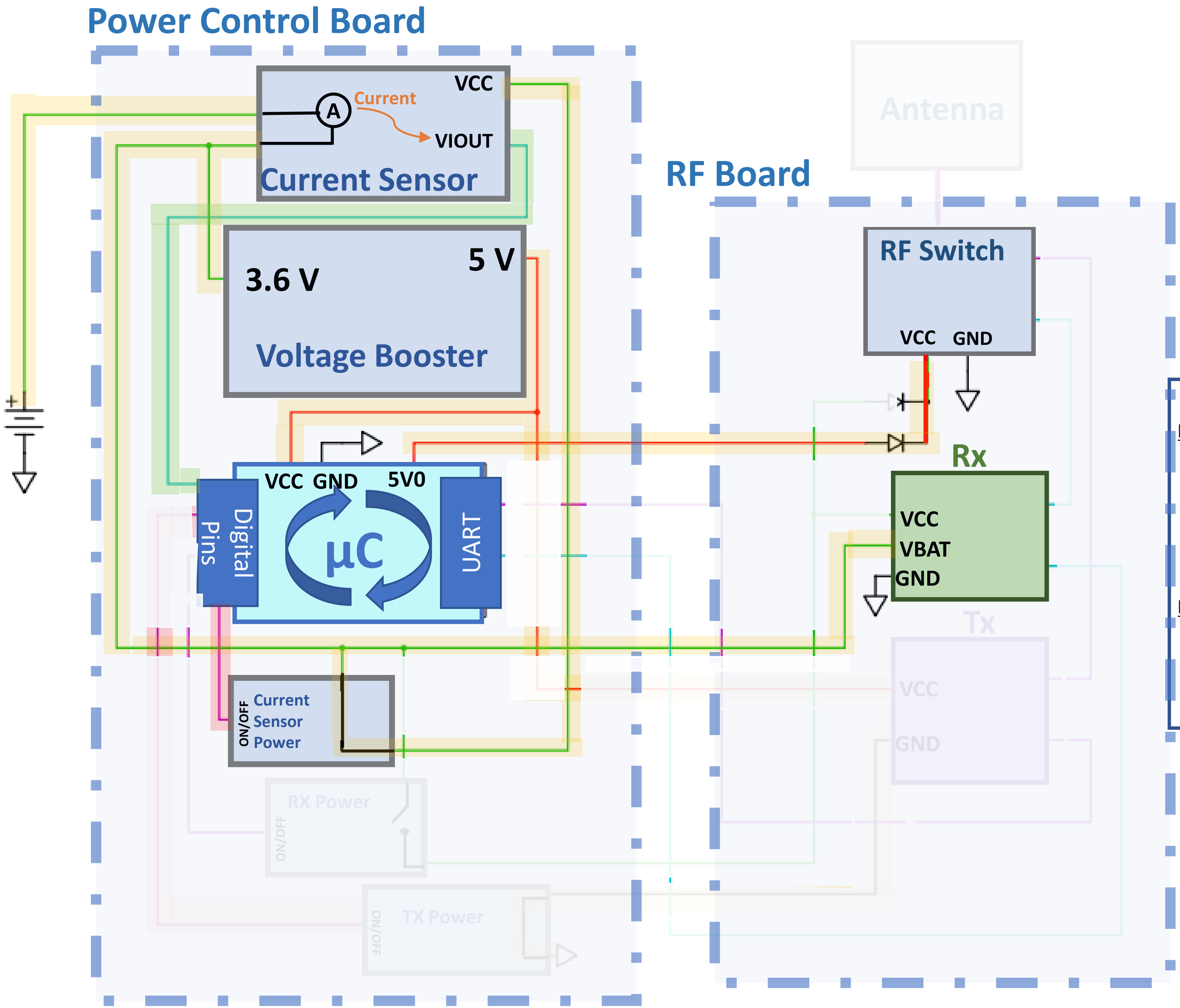
🟨 **Current Flow**

🟥 **HIGH Voltage**

🟩 **Digital Signal**

Electronics

Transmit cycle



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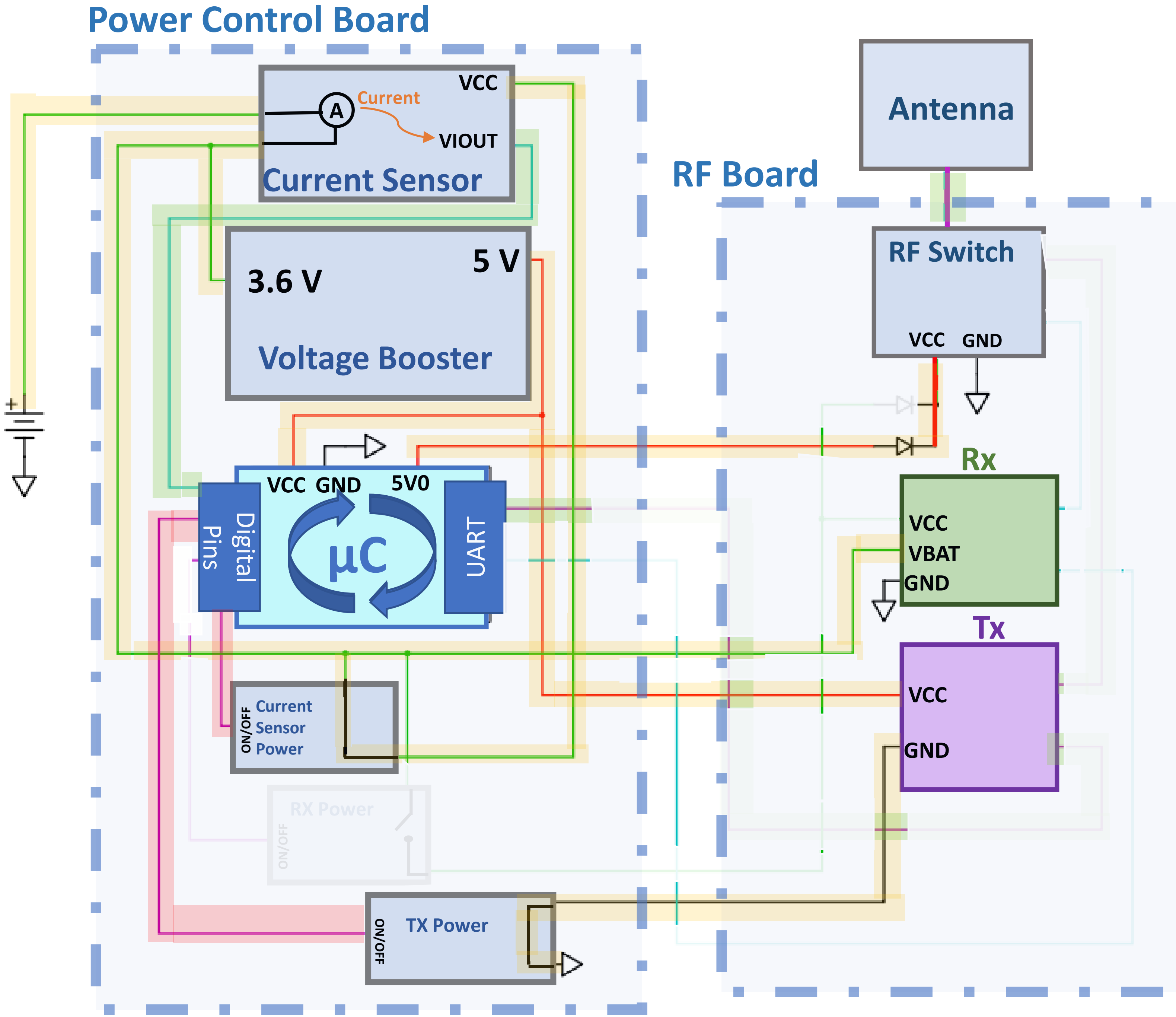
🟥 **HIGH Voltage**

🟩 **Digital Signal**

Electronics

Transmit cycle

1. Microcontroller powers on Tx. Tx begins searching for a fix.
2. Microcontroller compresses saved data



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Nomenclature

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Tx: Sat/Com Module
Rx: GNSS Receiver
LNA: Low Noise Amplifier

Legend

🟥 5V Power
🟪 5V Logic
🟩 3.6V Power
🟦 3.6V Logic

🟨 **Current Flow**

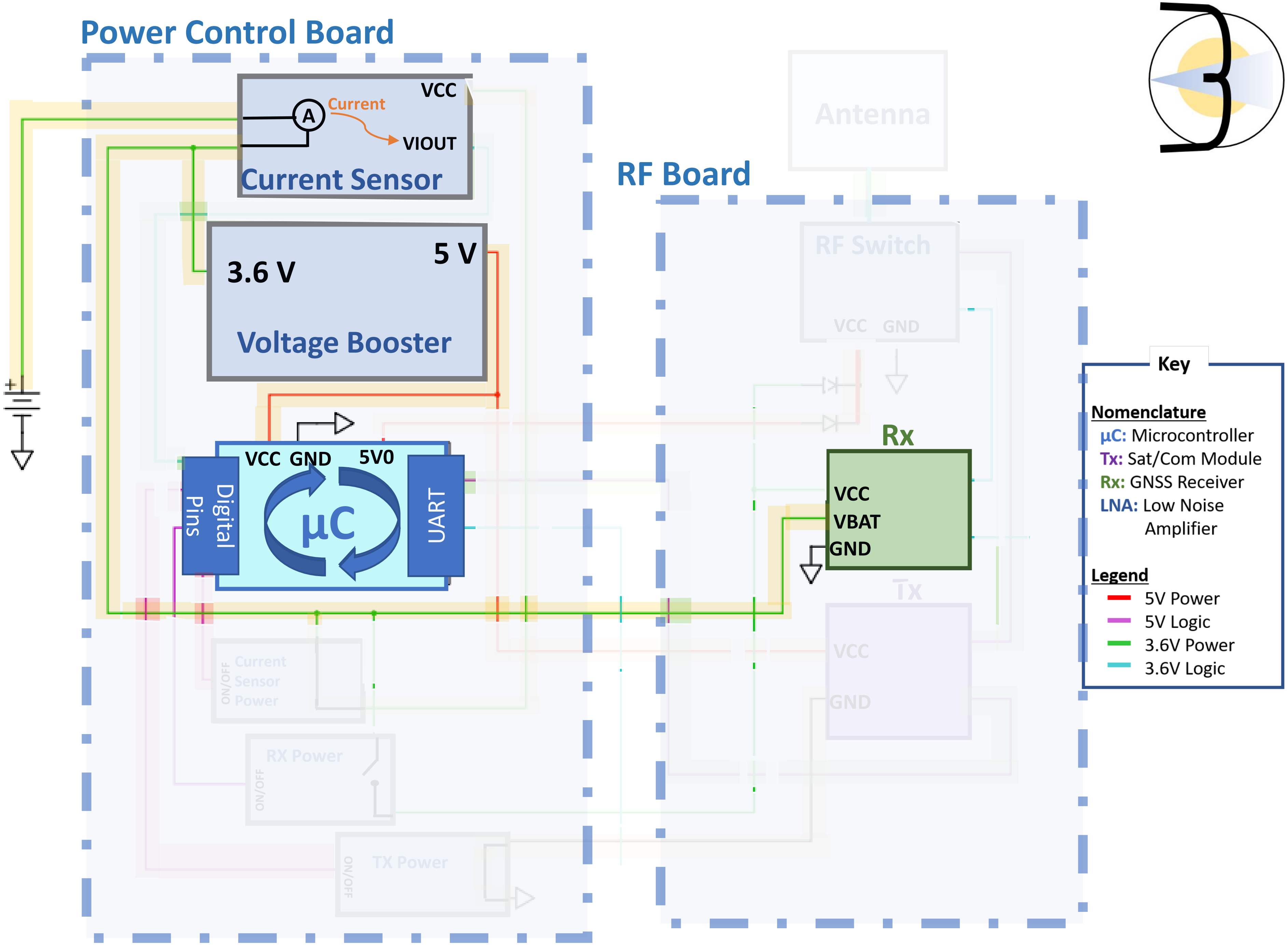
🟥 **HIGH Voltage**

🟩 **Digital Signal**

Electronics

Transmit cycle

1. Microcontroller powers on Tx. Tx begins searching for a fix.
2. Microcontroller compresses saved data
3. Microcontroller sends data to Tx and Tx sends data to Iridium satellite
4. Tx verifies successful transmission and Microcontroller clears saved data

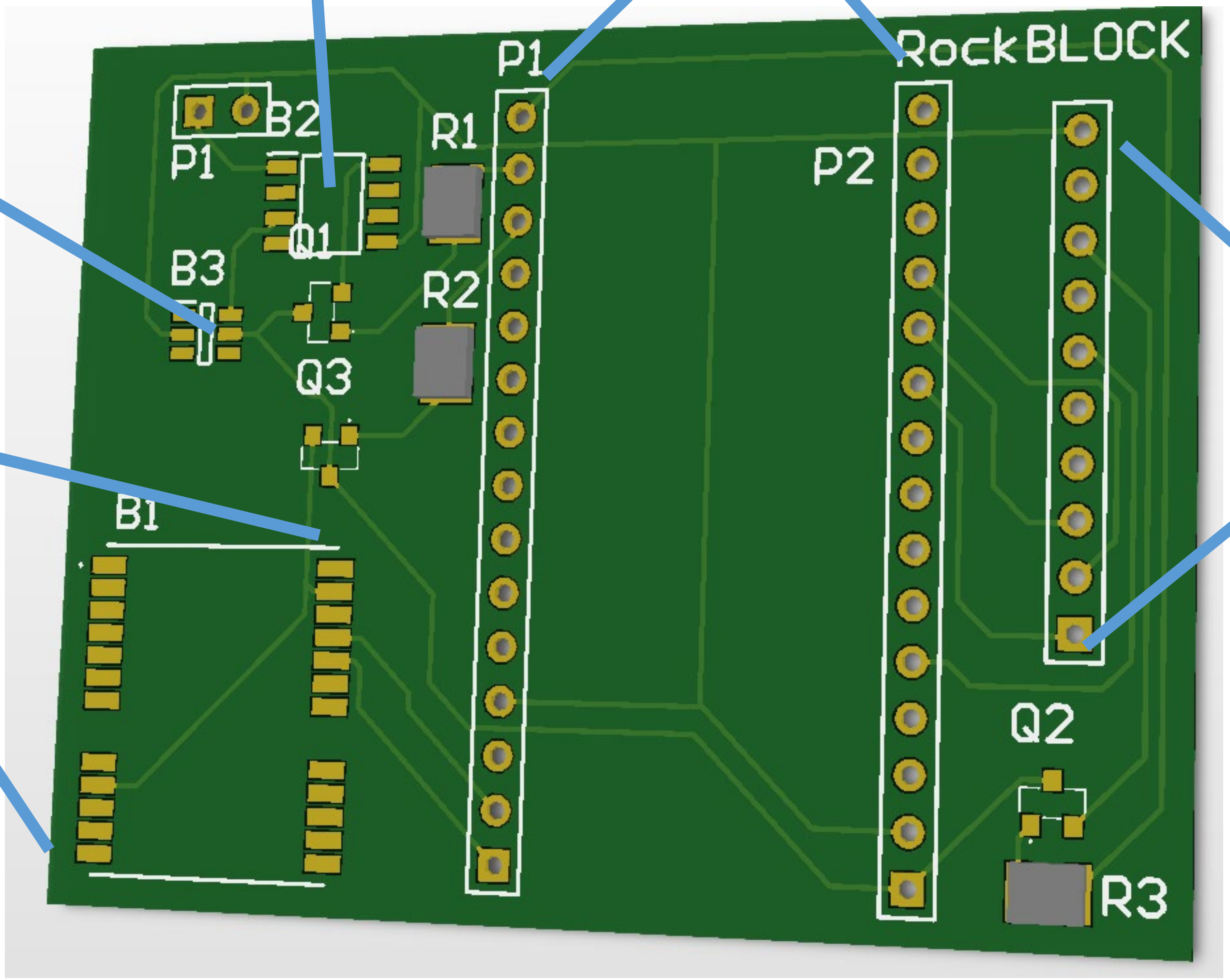


🟨 Current Flow

🟥 HIGH Voltage

🟩 Digital Signal

Power Control Board



Microcontroller

Current Monitor

Voltage Regulator

GNSS Receiver

Sat/Com Module

Serial Interface Connections

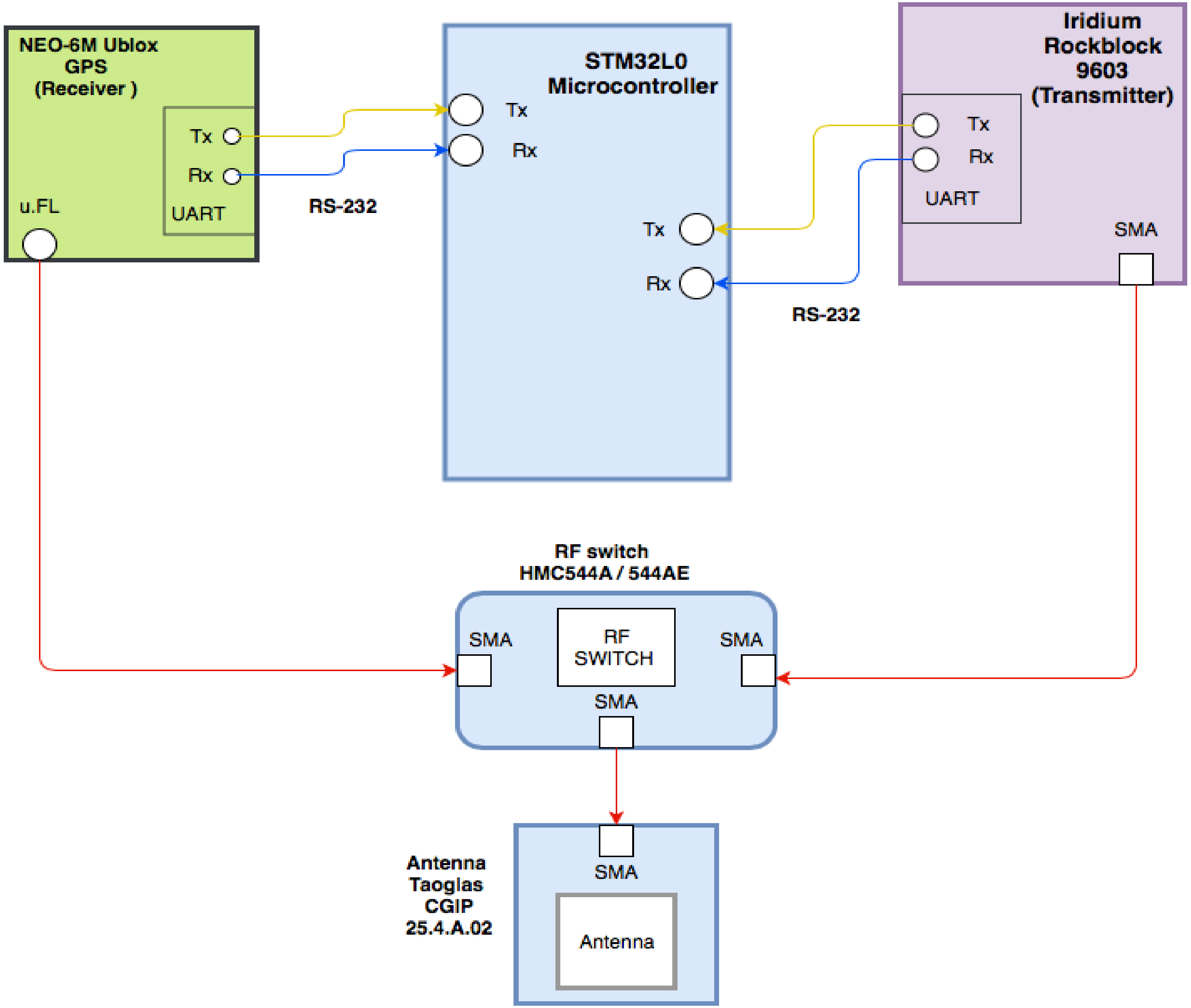
1. NEO-6M Ublox uses UART for serial communication and Asynchronous RS232 protocol.

2. Iridium Rockblock 9603 also uses UART for serial Interface and RS232 protocol.

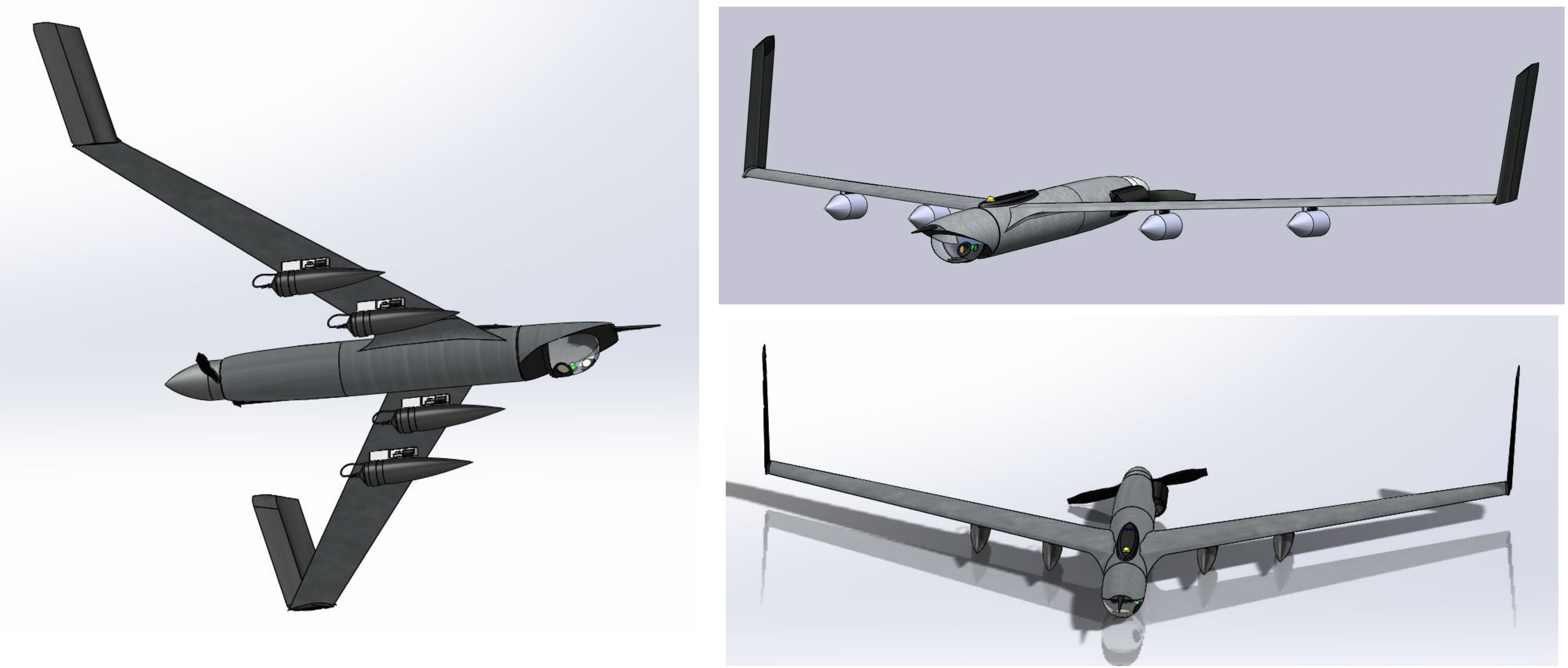
3. RF switch is used to route signal through transmission or receiving path.

4. RF switch insertion loss is 0.9 dB

5. Active 5 dBi Antenna @ 1575 [MHz] to 1621 [MHz]



Design Solution: Mock UAV Integration



Critical Project Elements

Critical Project Elements

COST: manufacturing 1 drifter shall not exceed $1000

MASS: 4 drifters and deployment mechanism shall not exceed 2.7 kg

System	Driving Requirements
Communication Systems	• Shall take position data every 5 minutes to an accuracy of 60 [m] • Shall transmit position data every 24 hours
Electronics/Power Systems	• Shall survive impact at terminal velocity • 3-month power
Structures	• Structural integrity post impact • Flotation Stability

Design Requirements and Satisfaction

Design Requirements: Structures

Structure Functional Requirements

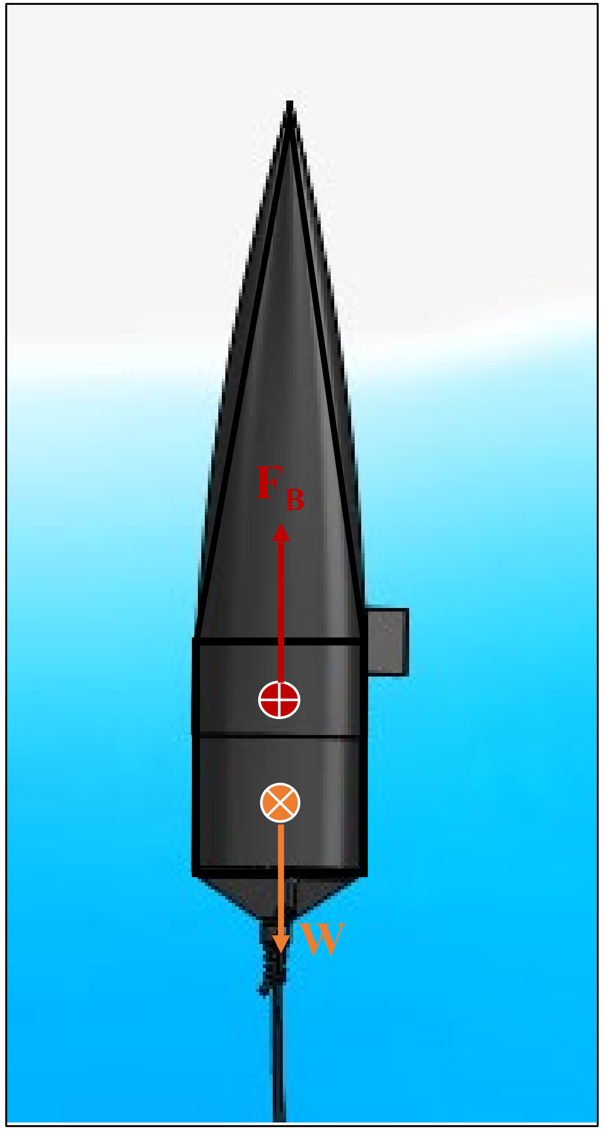
FR 1.0	Drifter shall be capable of following water current flow
DR 1.1	The drifter shall float to keep antenna above water
DR 1.2	The drifter shall maintain stable orientation in the water

FR 3.0	Drifter shall be deployed from an altitude of 300 [m]
DR 3.1	The drifter shall maintain full structural integrity after impact with water
DR 3.2	The drifter shall maintain full component functionality after impact with water

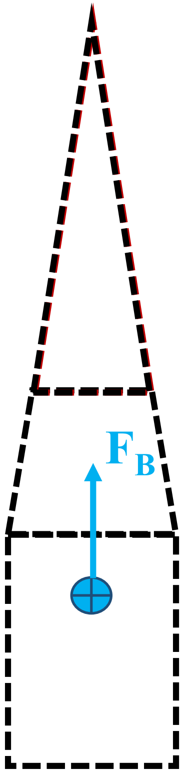
FR 6.0	Mass of 4 drifters and deployment mechanisms shall not exceed 2.7 [kg]

FR 7.0	Cost of manufacturing 1 drifter and required communications package shall not exceed $1000

Design Solution: Antenna Above Waterline



Displaced Water



DR 1.1 The drifter shall float to keep antenna above water

$$\boldsymbol{W_d = F_B}$$
$$\boldsymbol{m_T g = \rho_w g \forall_S}$$

- $\forall_{unsubmerged\ cone} = \frac{1}{3}\pi\, r_{unsubmerged}^2\, h_{unsubmerged}$
- *Using 'similar triangles':*
  - $\forall_{unsubmerged\ cone} = \frac{1}{3}\pi\, r_{cone}^2\, \frac{1}{h_{cone}^2}\, h_{unsubmerged}^3$
- Rearranging and solving for unsubmerged height:

$$h_{unsubmerged} = \sqrt[3]{\frac{3h_{cone}^2}{\pi r_{cone}^2}\left(V_T - \frac{m_T}{\rho_w}\right)} = \sim 24\ [cm]$$

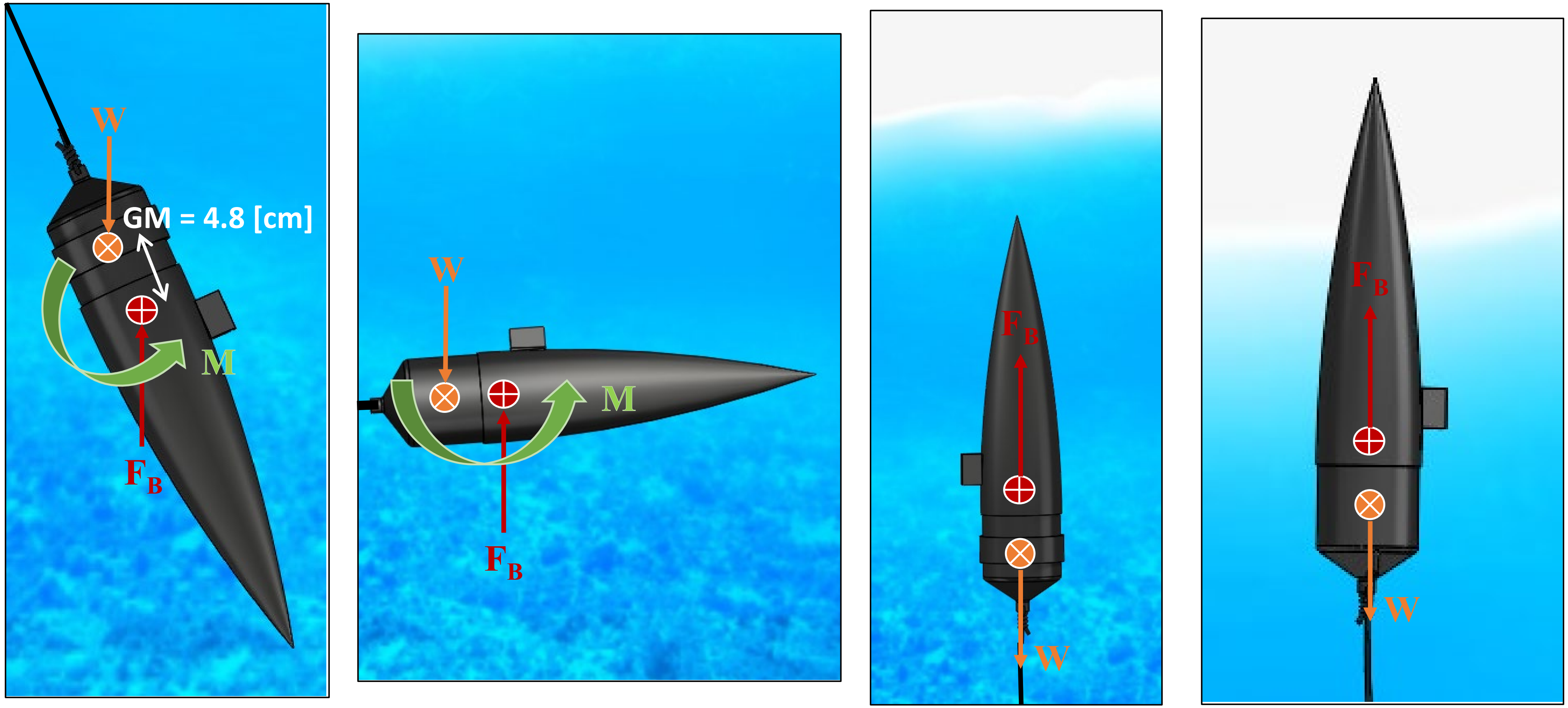
- Knowing the total volume of the submerged buoy, the center of buoyancy (KB) can be calculated using Center of Mass (COM) calculations
  - $KB = \frac{m_{cylinder}COM_{cylinder} + m_{partial\ cone}COM_{partial\ cone}}{m_{cylinder} + m_{partial\ cone}} = 6 \sim [cm]$

Design Solution: Instability

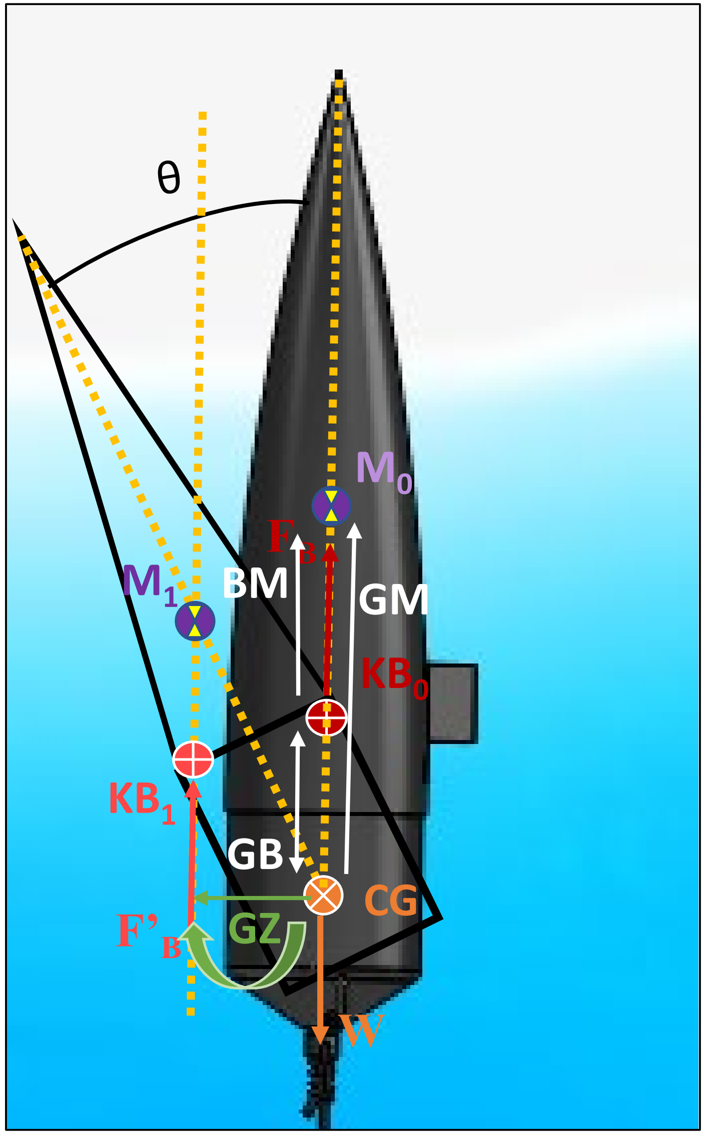
DR 1.1 The drifter shall float to keep antenna above water

- Achieved when the center of gravity (CG) is lower than the center of buoyancy (KB)
- A restoring moment is produced when subjected to disturbances

- From SolidWorks: $CG = \sim 1.6\ [cm]$
- From calculations: $KB = \sim 6\ [cm]$



Design Solution: Stability When Afloat



- Disturbances must not cause drifter to overturn.
- Three criterion must be met:
  1. The metacentre (M) of the buoy must be above the CG
     - The point at which a vertical line passes through KB and intersects the CG vertical
  2. The metacentric height (GM) above the CG must be positive
     - $GM = BM - GB$
       - BM is the metacentric radius: $BM = \frac{I_z}{V_d}$
       - GB is the distance between CG and KB
  3. The righting arm (GZ) must be positive
     - $GZ = GMsin(\theta)$
- Using SolidWorks and previous calculations:
  1. GM = 4.8 [cm]
  2. $\mathrm{GZ} = |4.8|\,\sin(\theta)\ \ [cm]$

DR 1.2 The drifter shall maintain stable orientation in the water

Impact Pressure Load

Equations

$$P_{max} = 0.072\rho V^2$$

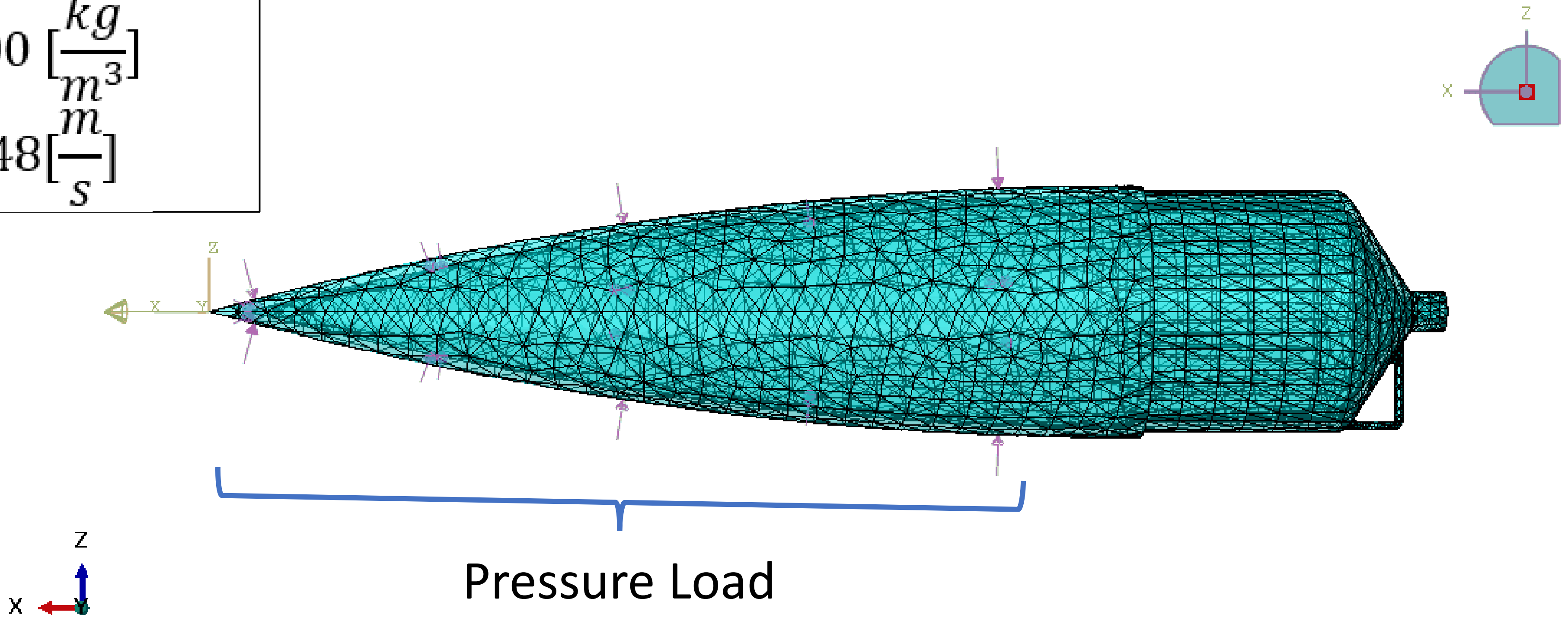
Max Pressure

$$P_{max} = 6522\ [Pa]$$

Known

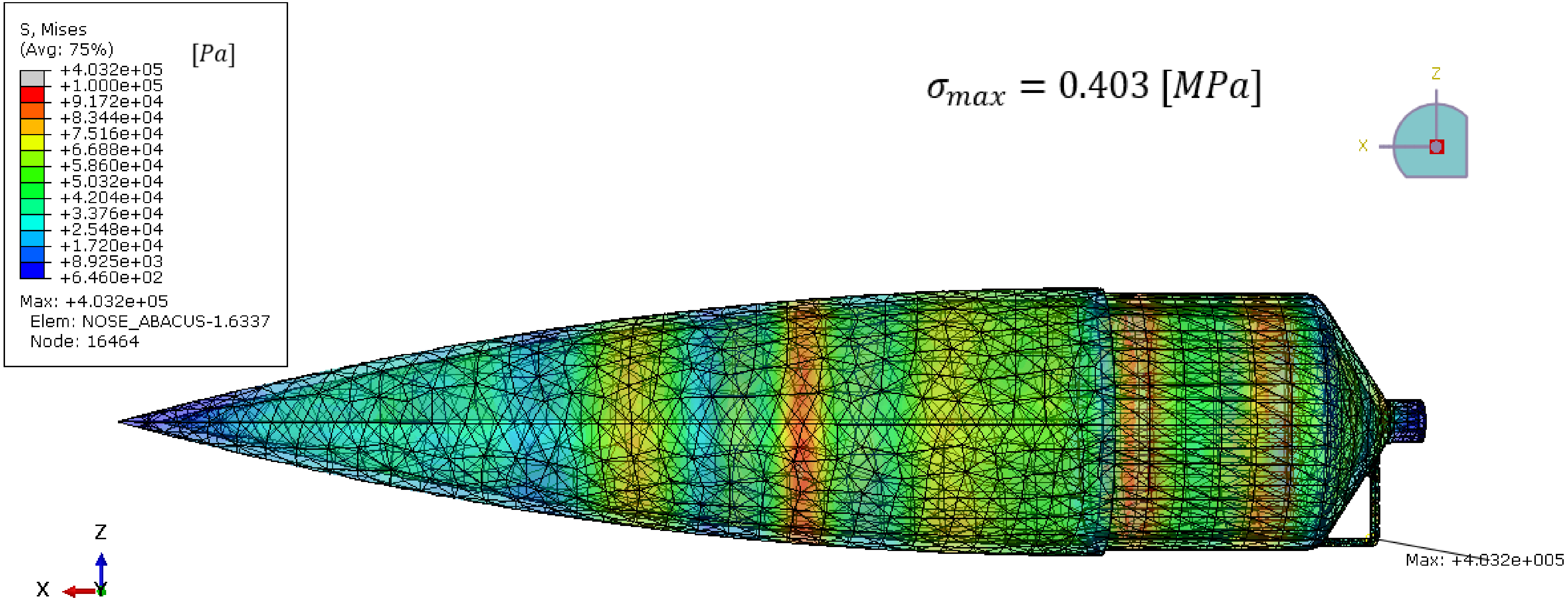
$$\rho = 1000\ [\frac{kg}{m^3}]$$

$$V = 9.48[\frac{m}{s}]$$



Pressure Load

Impact Stress Analysis



$$\sigma_{max} = 0.403\ [MPa]$$

Tensile yield strength of Polypropylene is 40 [MPa]

$$40\ [MPa] \gg 0.403\ [MPa] \Rightarrow \sigma_{yield} \gg \sigma_{max}$$

$$FOS \approx 100$$

DR 3.1 The drifter shall maintain full structural integrity after impact with water

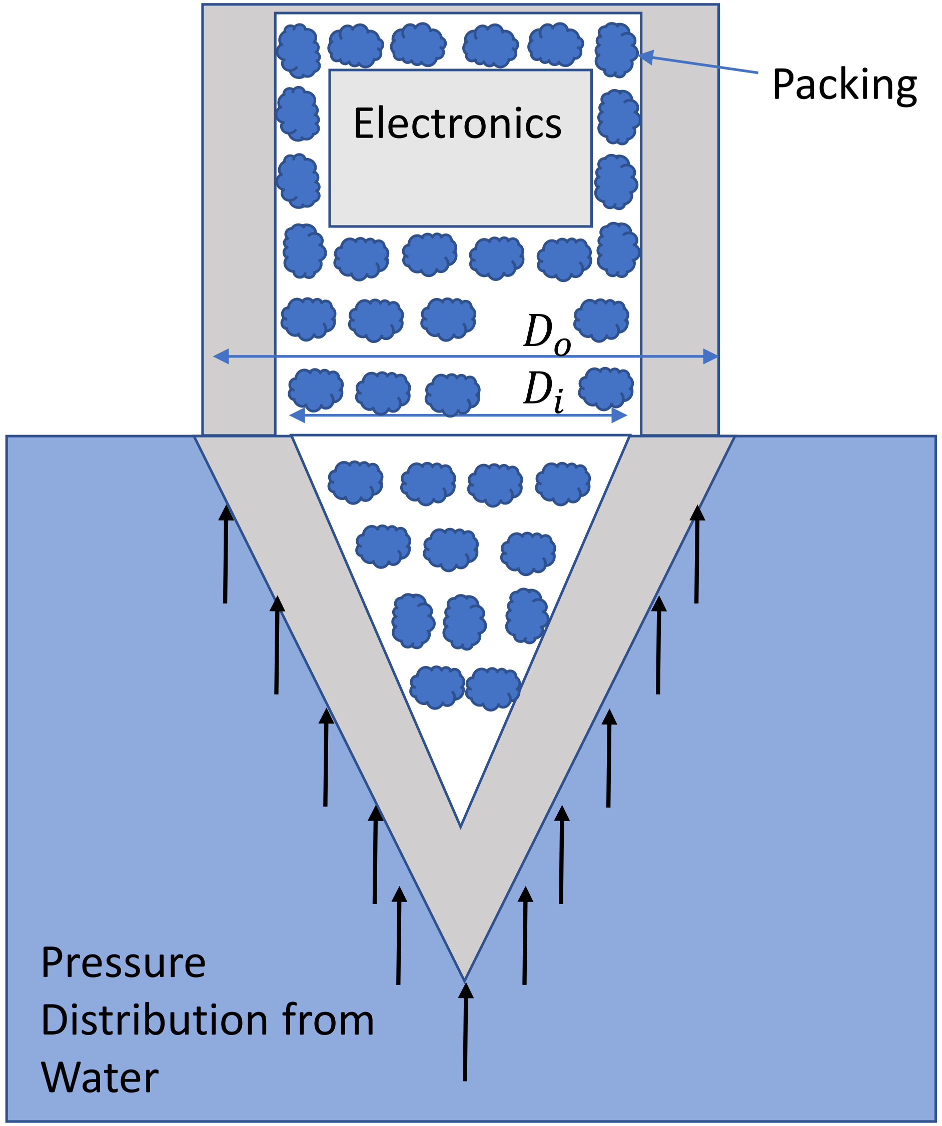
Design Solution: Electronics Survivability

$$F = \sigma A_{cross} = 326.5\ (N)$$

$$a = \frac{F}{m} = 522.4\ \left(\frac{m}{s}\right) = \boxed{53.3\ (G)}$$

53.3 << 1000 [G] Rating

DR 3.2 The drifter shall maintain full component functionality after impact with water



Design Requirements: Electronics

Electronics Functional Requirement

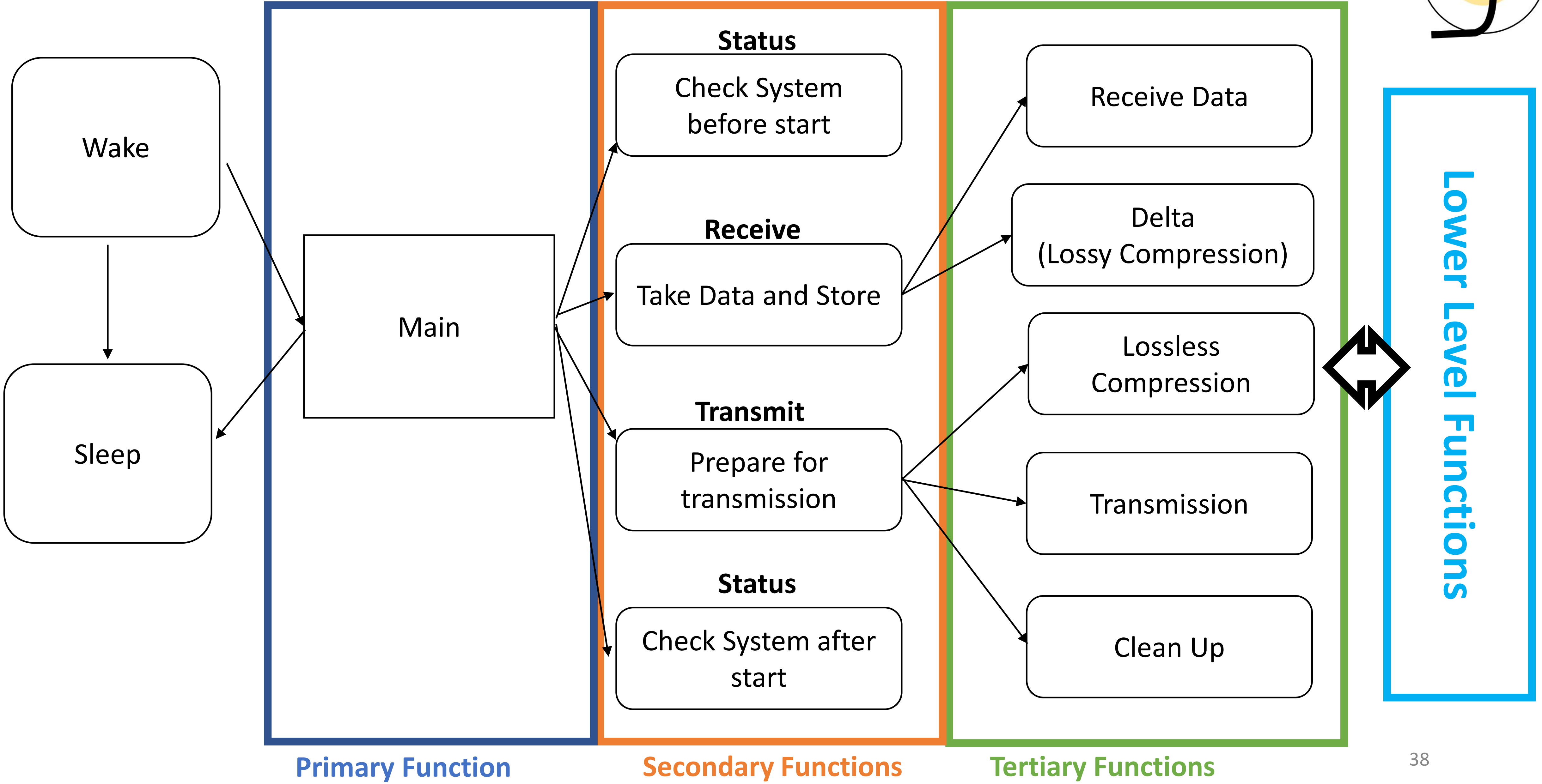
FR 2.0	**The drifter shall maintain a 3-month lifespan**
DR 2.1	The drifter shall contain power to supply all electronic components for 3 months

FR 4.0	**The drifter shall measure and store position coordinates**
DR 4.1	The drifter shall measure position coordinates with an accuracy of 60 [m]
DR 4.2	The drifter shall measure positions coordinates on average every 5 [min]

FR 5.0	Drifter shall transmit stored position coordinates to a communications satellite up to 800 [km] away
DR 5.1	Transmit latency shall be less than 24 hours

FR 6.0	Mass of 4 drifters and deployment mechanisms shall not exceed 2.7 [kg]
FR 7.0	Cost of manufacturing 1 drifter and required communications package shall not exceed $1000

Software Tree



Wake

Sleep

Main

Status

Check System before start

Receive

Take Data and Store

Transmit

Prepare for transmission

Status

Check System after start

Receive Data

Delta (Lossy Compression)

Lossless Compression

Transmission

Clean Up

Lower Level Functions

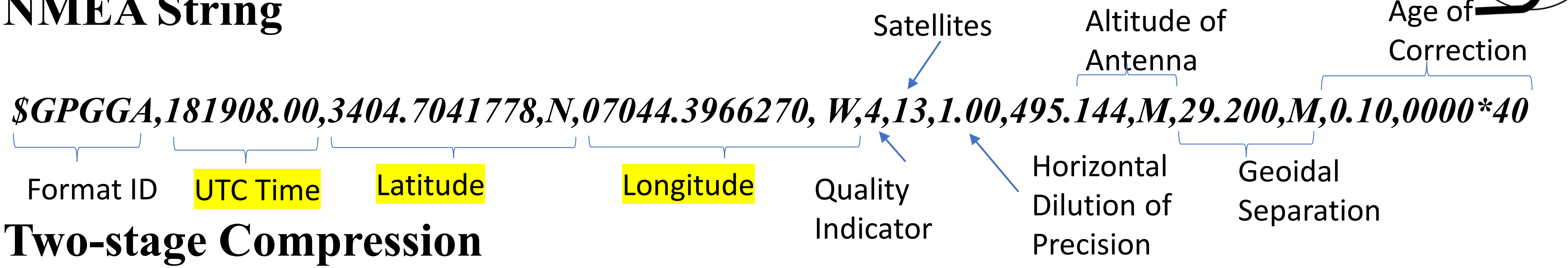
Primary Function

Secondary Functions

Tertiary Functions

Data Compression: Overview

NMEA String



*$GPGGA,181908.00,3404.7041778,N,07044.3966270, W,4,13,1.00,495.144,M,29.200,M,0.10,0000*40*

Satellites

Altitude of Antenna

Age of Correction

Format ID

UTC Time

Latitude

Longitude

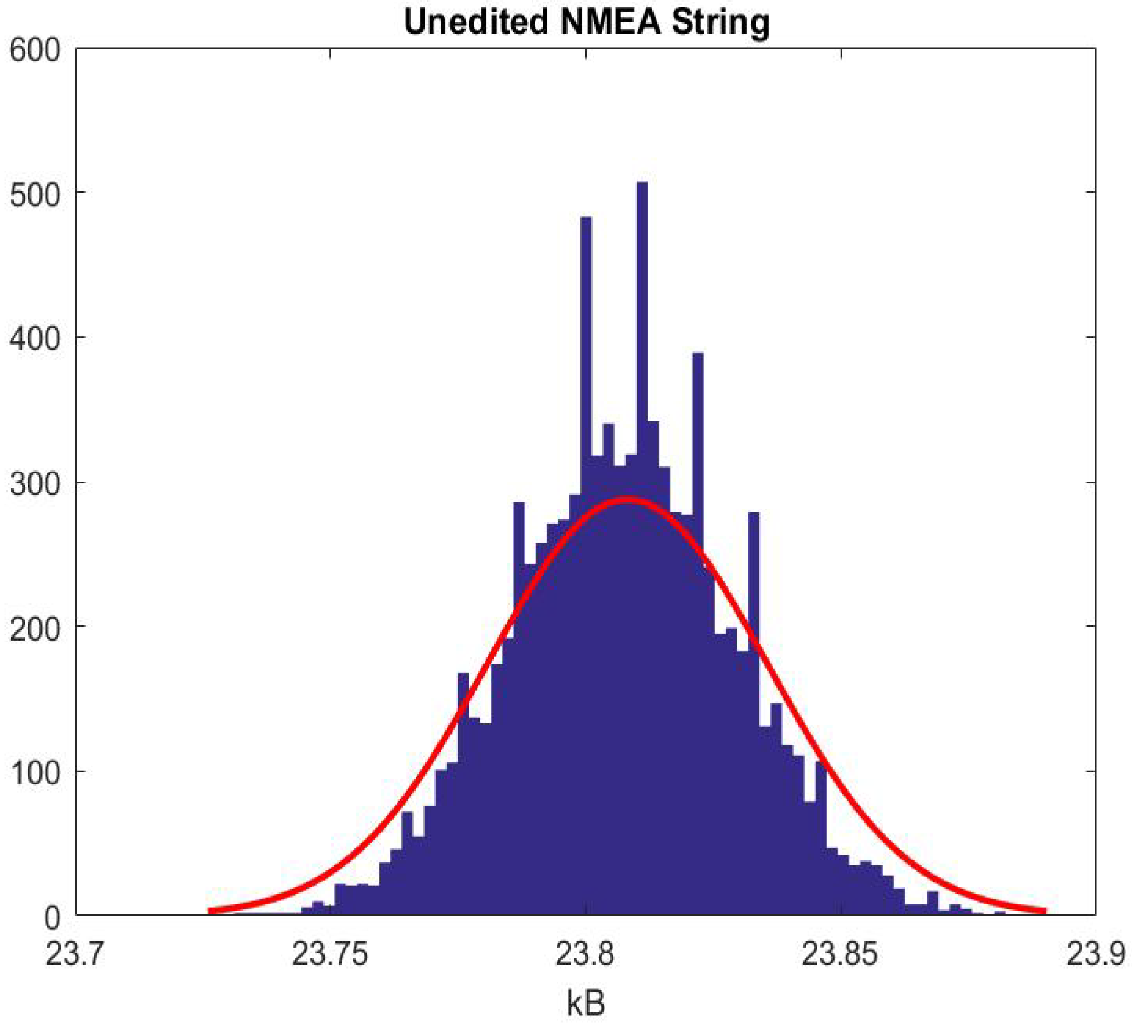
Quality Indicator

Horizontal Dilution of Precision

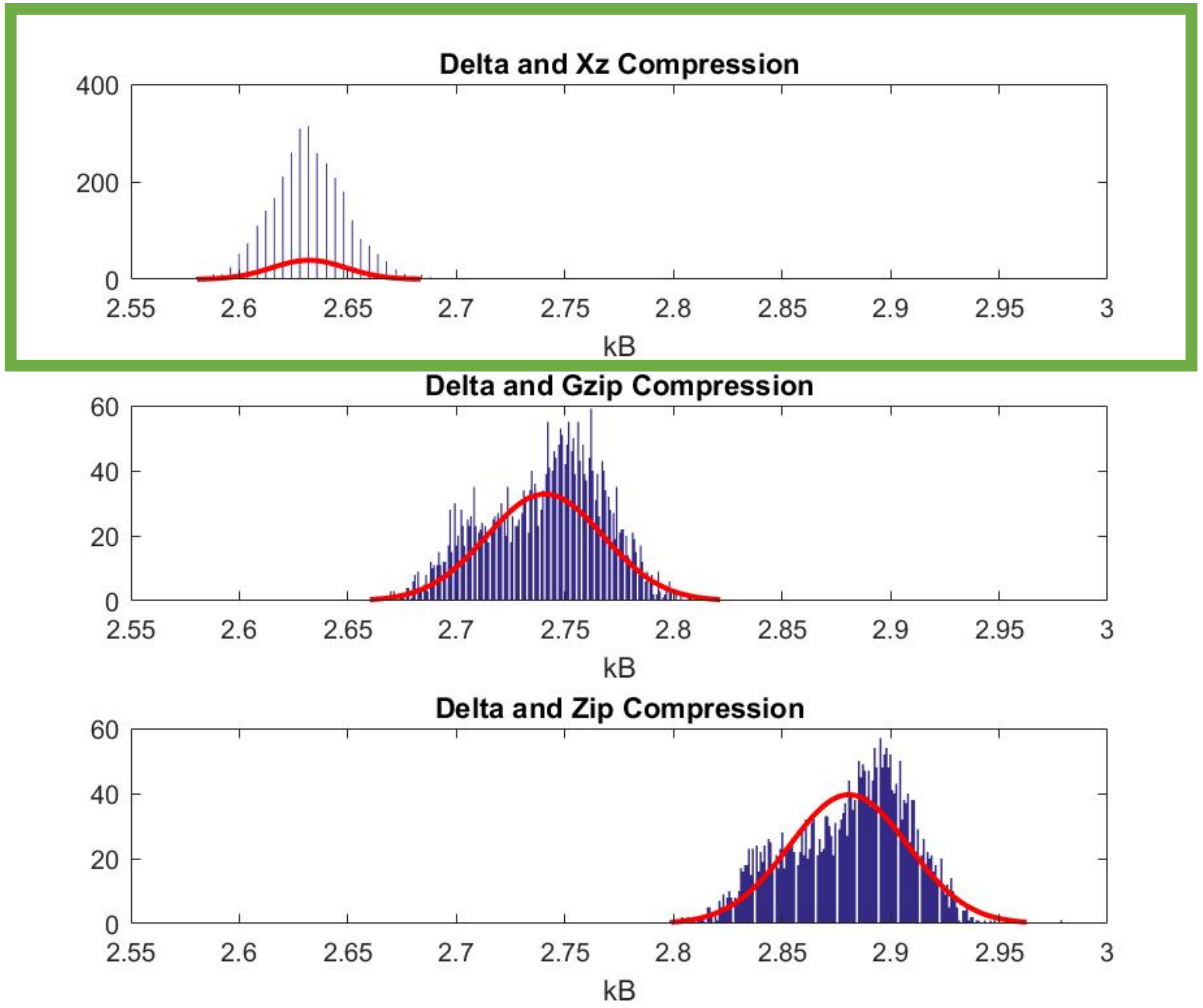
Geoidal Separation

Two-stage Compression

Data Compression



Best Performance



Data Compression: Summary

- 340 Bytes per message
- $0.35 per message

Compression	File size for one day	Messages per day	Transmission time per day	Messages per 90 days	Cost per 90 days
None	23.81 ± 0.027 [kB]	71	730 [s]	6390	$2236.50
Delta + xz	2.632 ± 0.017 [kB]	8	100 [s]	720	$252.00
Delta + gzip	2.74 ± 0.027 [kB]	9	110 [s]	810	$283.50
Delta + zip	2.88 ± 0.027 [kB]	9	110 [s]	810	$283.50

Power Budget: Assumptions

1. Battery self-discharge is negligible (~0.3%/month)
2. Internal battery impedance is negligible
3. Batteries will provide suitable voltage until their capacity drops below 10%
4. Transistors act as ideal electronic switches
5. All current loads are constant
6. Voltage booster efficiency is 92% for currents greater than 1 [mA]
7. All other component inefficiencies are negligible

Power Budget: Model

Q : Charge on battery
I : Current draw
λ_s: Self Discharge rate
t : time

Governing Equation:

$$\dot{Q} = -I(t) - \lambda_s Q$$

$$\longrightarrow Q(t) = e^{-\lambda_s t}\left(Q_0 - \int_{t_0}^{t} I(\tau) e^{\lambda_s \tau} d\tau\right)$$

Assume: $\lambda_s \sim 0 \rightarrow e^{\pm\lambda_s t} \sim 1$

$$\longrightarrow Q(t) = Q_0 - \int_{t_0}^{t} I(\tau) d\tau$$

Assume: $\frac{\partial \mathrm{I}}{\partial \mathrm{t}} = 0$

$$\boxed{Q(t) = Q_0 - I_{Av} t}$$

DR 2.1 The drifter shall contain power to supply all electronic components for 3 months

Constraints

1. $Q(90\ days) = Q(T) \geq \eta_B Q_0$
   - where η_B is the proportion of the batter capacity at which it can no longer draw a suitable voltage
   - $\eta_B \sim 10\%$
2. $Q_0 \left(\frac{mass}{capcity}\right)_{battery} \leq 675\ [g] - m_{buffer}$

FR 6.0 Mass of 4 drifters and deployment mechanisms shall not exceed 2.7 [kg]

Power Budget

Component	Current Draw [mA]	Time per Day (s)	Uncertainty [s]
Microcontroller	15	1042	1042
GNSS Receiver	50	684	684
Sat/Com Module	680	300	300
Current Sensor	10	1042	1042
RF Switch	0.12	1042	1042

Total:

7.36 [Ah] with an uncertainty of **5.76** [Ah] or **13.13** [Ah] total

Power Budget: Current Draw

- Lithium batteries have maximum continuous current draw of 230 [mA]
- Maximum expected current is during transmission

Voltage Booster Conversion

Microcontroller

Iridium transmitter

$$I_{max} = I_{\mu C} + I_{IS} + \left(\frac{5V}{3.6V \cdot 92\%}\right) I_{Tx} = 700\ mA$$

Current Sensor

- Need at least 3 batteries (21.6 Ah total)

Mass Budget: Electronics

Component	Mass [g]
Toaglass CGIP	5
Iridum RockBlock 9603	26
NEO-6M Ublox	4.5
PCB	5
RF Switch	2.5
SMA Cord	13.6 (x4)
SMA Adapter	2.1
Diode	~0.1(x2)

Component	Mass [g]
TL-2200/S Battery	50.5 (x3)
Current Sensor	1.3
Capacitor	~0.1(x4)
Micro-Controller	36
BJT Transistor	~0.1 (x3)
Resistor	~0.1 (x5)
Bipolar Transistor	~0.1 (x2)
Inductor	~0.1
Total	**290 [g]**

Mass Budget: Structures

Component	Mass [g]
Molded Ogive Float	130
12" CFC-12 Parachute	24
Nylon Shroud Lines & Swivel	31.2
Adhesive	16.7
Band-Connection	9.6
Gimbal Joint	30

Component	Mass [g]
Gasket	~10
Packing Peanuts (Full Vol.)	3
(1/16”) Steel Cable (100 cm in length)	15
Crimp	2 (x2)
Total	**273.5 [g]**

Mass Budget: Total

Sub-System	Mass [g]
Electronics	290 (x4)
Structures	273.5 (x4)
Deployment Mechanism	139
Total	**2393 [g]**

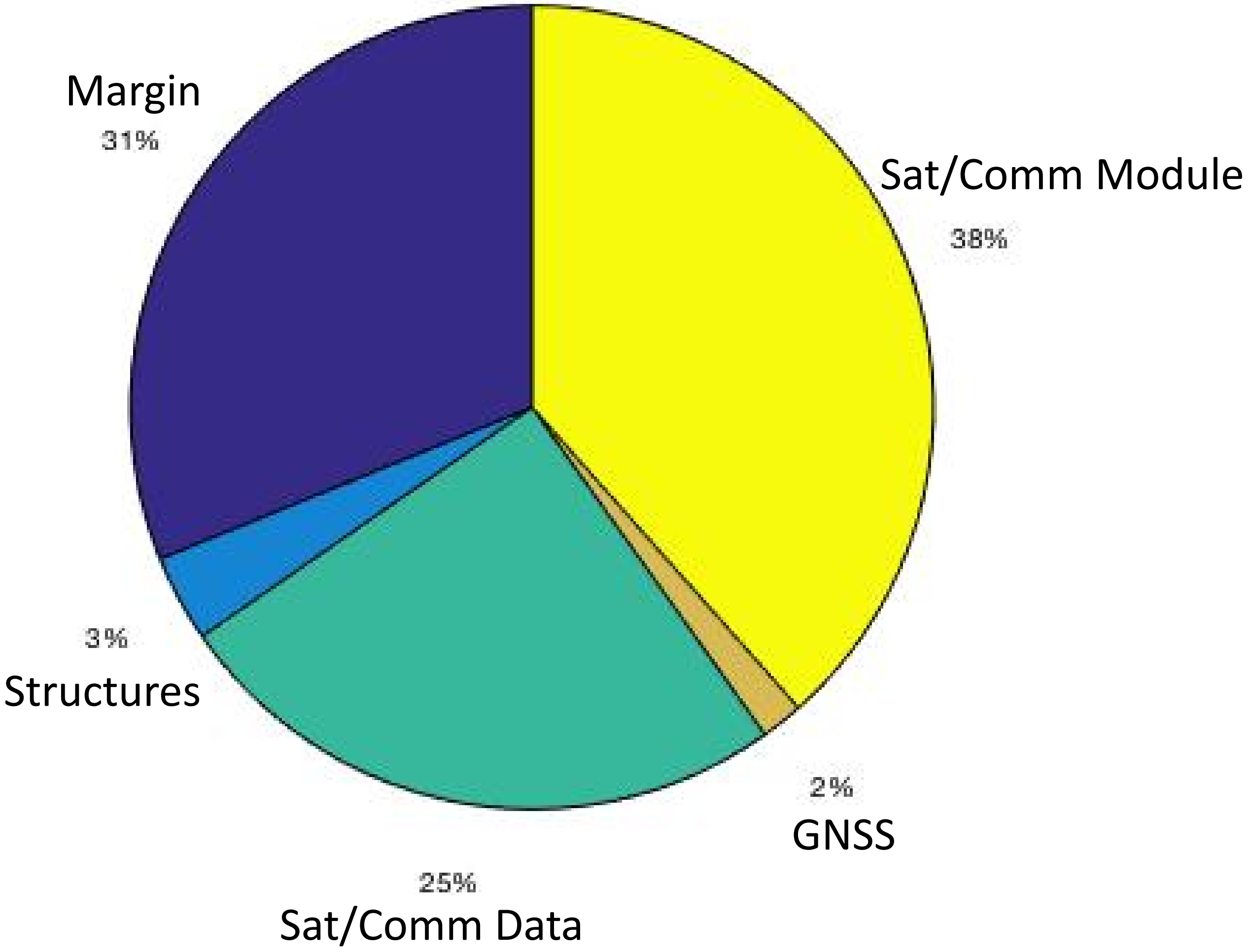
FR 6.0 Mass of 4 drifters and deployment mechanisms shall not exceed 2.7 [kg]

Allotted Mass: 2700 [g]
Margin: 307 [g]

Fiscal Budget

FISCAL SUMMARY	
SUBSYSTEM	TOTAL COST
Electronics	$653.49
Structure	$34.99
Total	$688.48
Margin	$311.52

FR 7.0
Cost of manufacturing 1 drifter and required communications package shall not exceed $1000



Project Risks

Electrical Risks

5 = Highest
1= Lowest

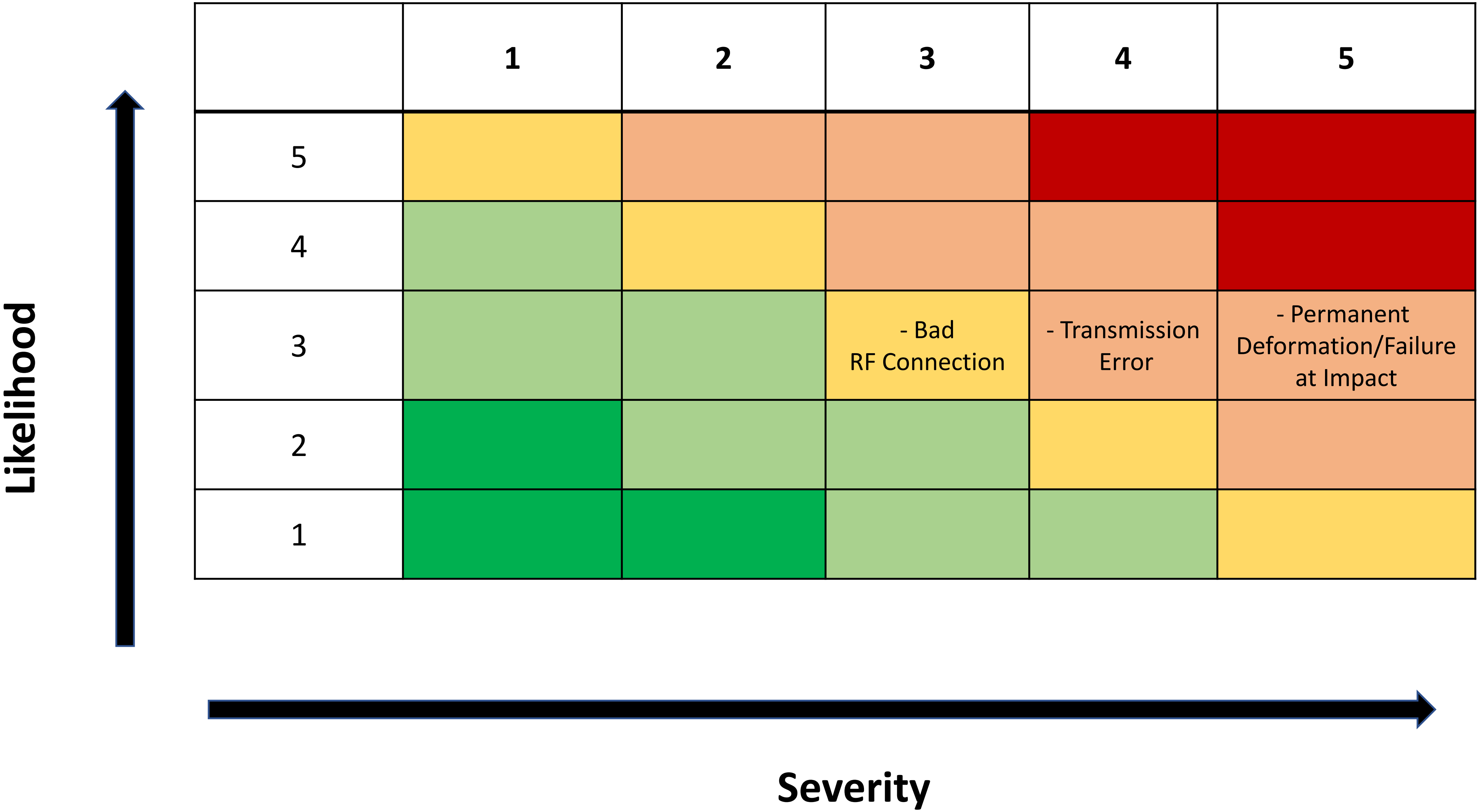
Risks	Pre-Mitigation Likeliness/Severity	Mitigation	Post-Mitigation Likeliness/Severity
Component Failure on Impact	2/5	Increase internal damping/ packing ~ increase mass	1/5
GNSS Connection Loss	3/3	Alternate pre-made nose cone with larger volume or larger gimbal joint	2/3
Transmission Error	3/4	Alternate pre-made nose cone with larger volume or larger gimbal joint	2/4
Internal Overheating	1/5	Add heat transfer system	1/5
Water Leak	2/5	Increase sealing surface height	2/5

Structural Risks

5 = Highest
1= Lowest

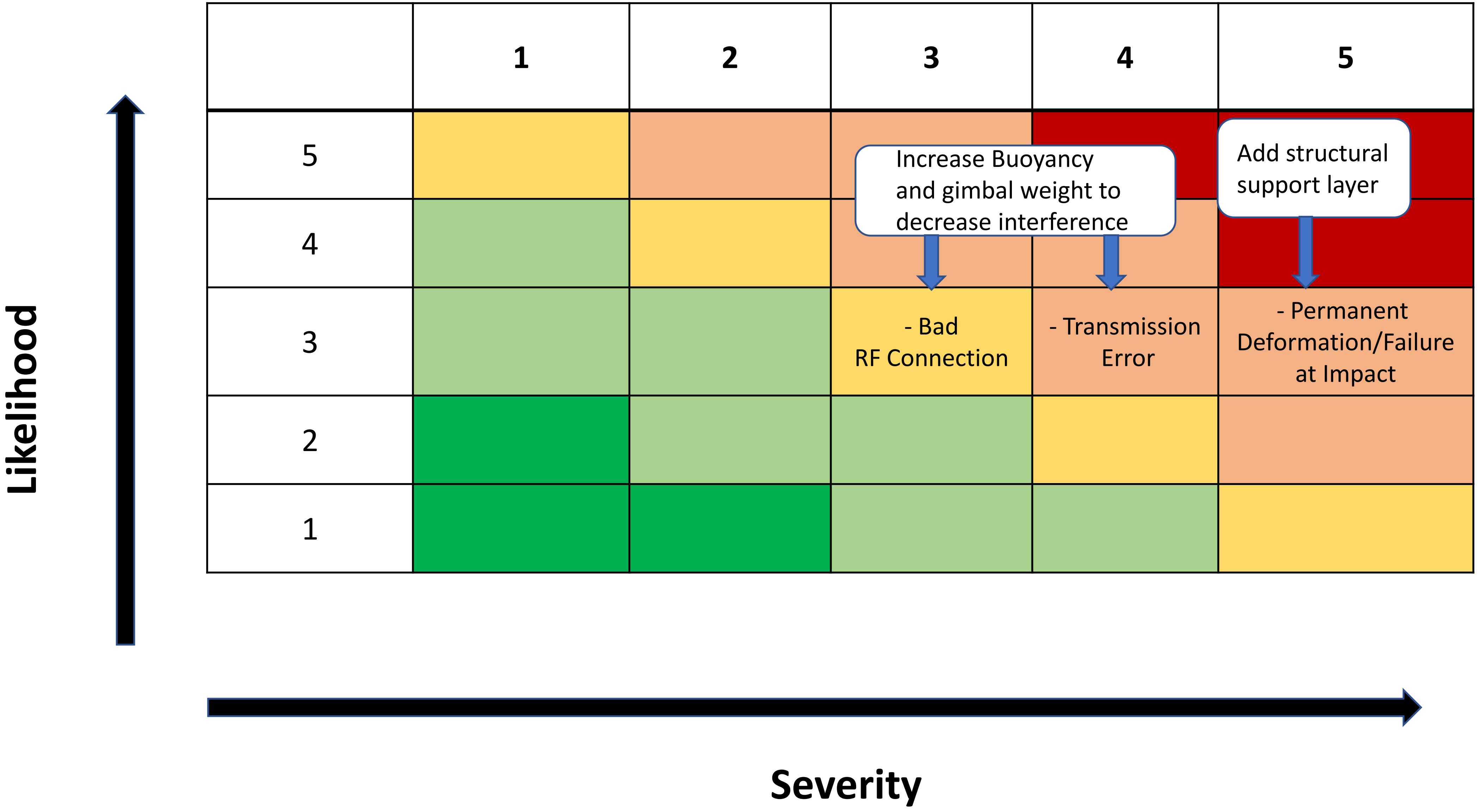
Risks	Pre-Mitigation Likeliness/Severity	Mitigation	Post-Mitigation Likeliness/Severity
Permanent Deformation/Failure at Impact	3/5	Change cone shape or add layer of thickness/ Testing	2/5
Fracture of Connection to Parachute	2/3	Custom	1/3
Material Degradation in Water	1/5	Alternate nose cone material	1/5
Flotation Instability from Drogue	2/4	Gimbel at chute connection to negate chute effects	1/4

Pre-Mitigation Risk Matrix for High Risks



	1	**2**	**3**	**4**	**5**
5					
4					
3			- Bad RF Connection	- Transmission Error	- Permanent Deformation/Failure at Impact
2					
1					

Mitigation Risk Matrix for High Risks

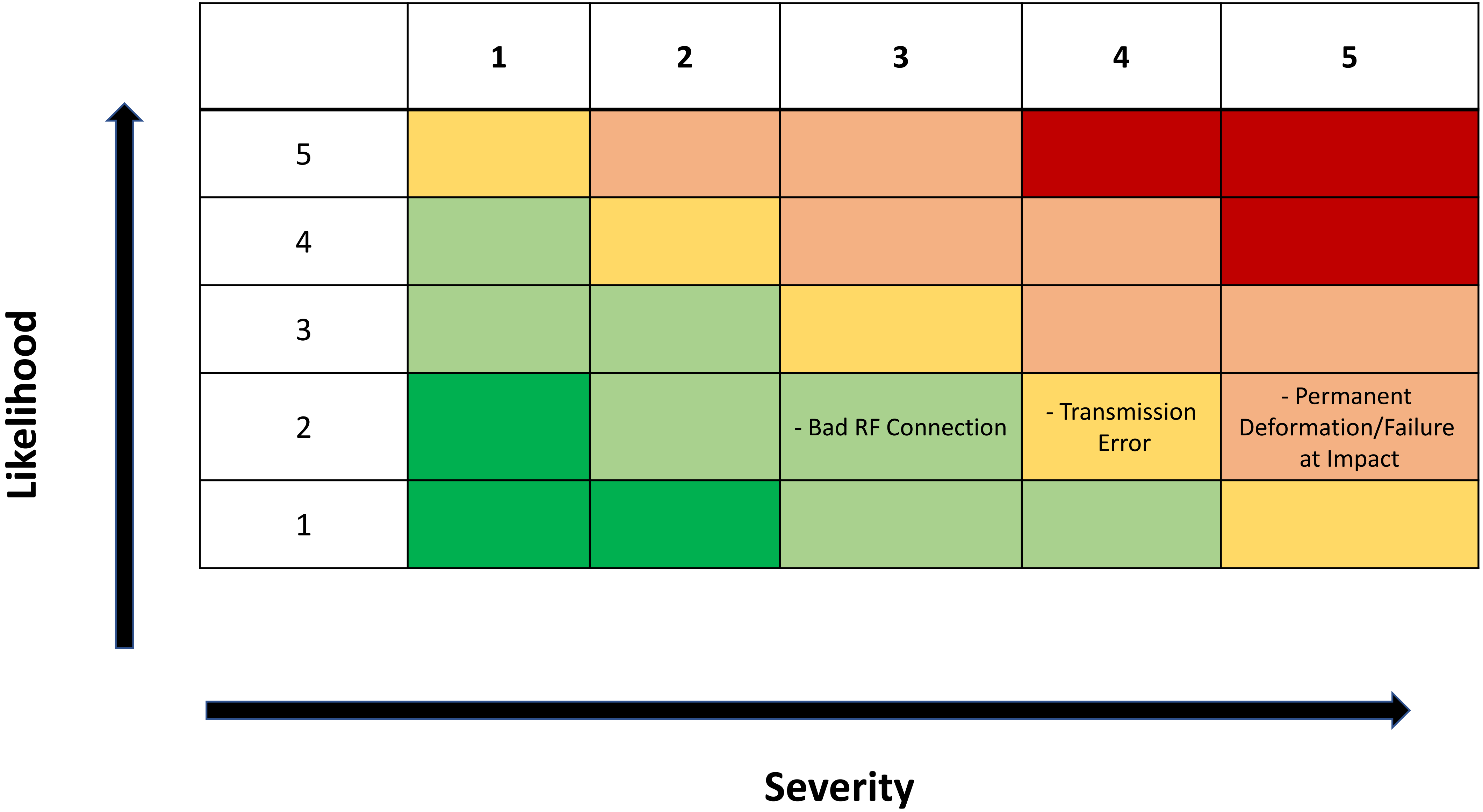


	1	**2**	**3**	**4**	**5**
5	🟨	🟧	🟧	🟥	🟥
4	🟩	🟨	🟧	🟧	🟥
3	🟩	🟩	🟨 - Bad RF Connection	🟧 - Transmission Error	🟧 - Permanent Deformation/Failure at Impact
2	🟩	🟩	🟩	🟨	🟧
1	🟩	🟩	🟩	🟩	🟨

Increase Buoyancy and gimbal weight to decrease interference

Add structural support layer

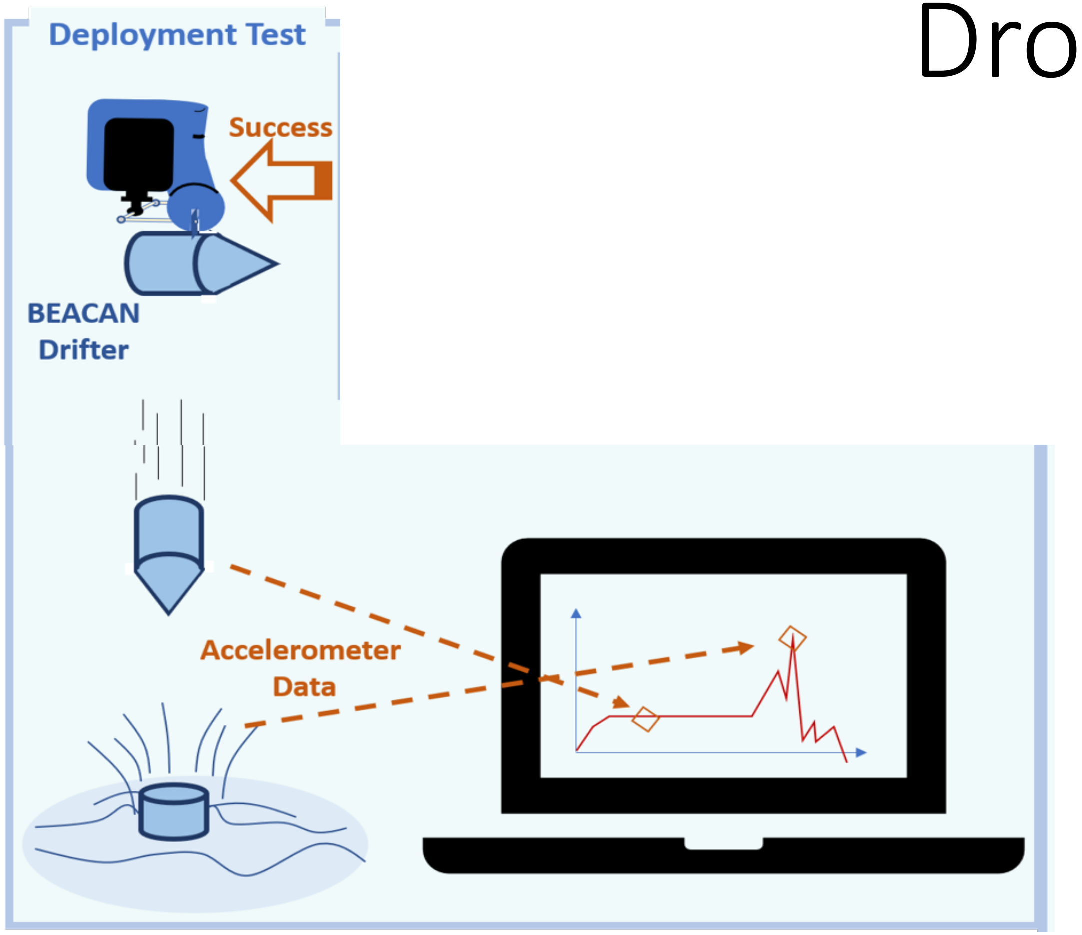
Post-Mitigation Risk Matrix for High Risks



	1	2	3	4	5
5	🟨	🟧	🟧	🟥	🟥
4	🟩	🟨	🟧	🟧	🟥
3	🟩	🟩	🟨	🟧	🟧
2	🟩	🟩	- Bad RF Connection	- Transmission Error	- Permanent Deformation/Failure at Impact
1	🟩	🟩	🟩	🟩	🟨

Verification and Validation

Drop Test



Anticipated Date: January 28th

Motivation	Expected Results According to Models	Actions for Test Failure
Difficult to accurately model water impact	53.3 [G] and roughly 6.5 [kPa] of pressure, but these are over-estimations from model	Use different pre-made nose cone. Have others that are slightly larger than current model.

Set Up:
An accelerometer will be glued to the inside tip of the nose cone. The drifter will then be dropped at 0.5 [m] interval from heights of 0.5 [m] up to 6 [m]. 5 tests will be conducted at each height to obtain peak acceleration, sampling rate 100 [bits/sec] Acceleration data will be gathered to back out impact force.

Verification: Drop Test

Expected Location: East Boulder Community Center

Equipment	Availability	Capability	Requirements	Satisfied
Accelerometer	Already Obtained	Range: -19-19[G]	N/A	Available
Arduino	ITLL	Sampling rate ~ 100 [bits/sec]	Communicate sensor to memory	Available
Data Logging Shield/SD Card	Already Obtained	8GB Memory	Store Acceleration Data	Available

Key Measurement Issues: Impact will cause a spike in acceleration. The data logging process needs to be efficient enough to get an appreciable number of points

DR 3.1	The drifter shall maintain full structural integrity after impact with water
DR 3.2	The drifter shall maintain full component functionality after impact with water

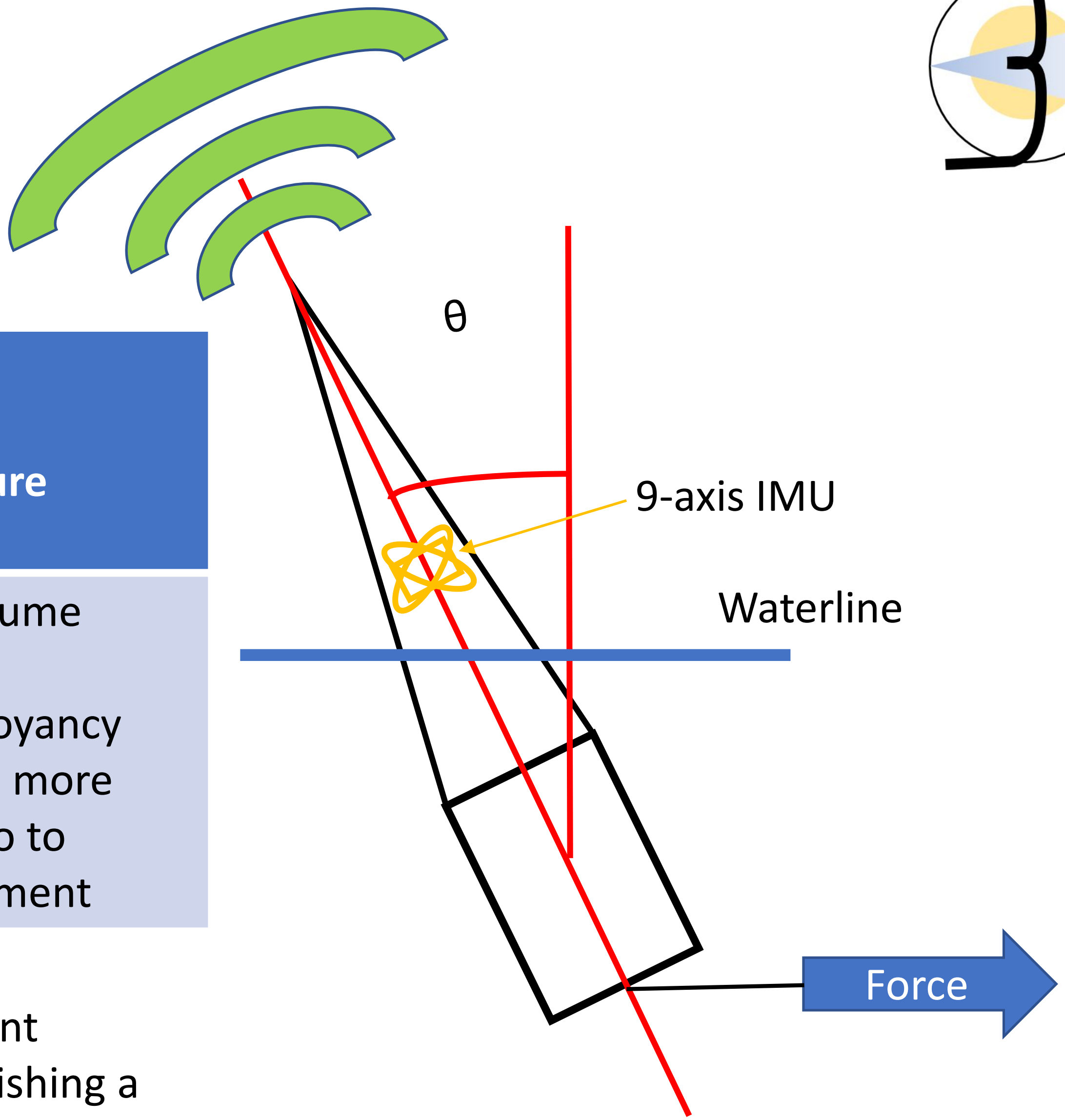
Stability Test

Anticipated Date: February 4th

Motivation	Expected Results	Action for Testing Failure
Verify stability of drifter and determine the critical pointing angle for functioning transmission	A considerable amount of the buoy should remain above water. We expect minimal interference	Increase volume of drifter to increase buoyancy force or add more massive gyro to counter moment

Set Up:

Place drifter with electronics set-up and move drifter increment angles and verify GNSS and Iridium connection. As well establishing a connection we want to verify does the drifter tend toward stability at this angle as predicted.



Stability Test

Expected Location: East Boulder Community Center

Equipment	Availability	Capability	Requirements	Satisfied
Iridium Rockblock, Drifter	Project Funds	Be able to transmit data consistently	Send data once per hour for a 24-hour period	Verify transmission Connection
Pull Reel	Project Funds	13 - 27 [N]	Constant Force	Available
Gyro Sensor	Project Funds	250 [°/s]	N/A	Available

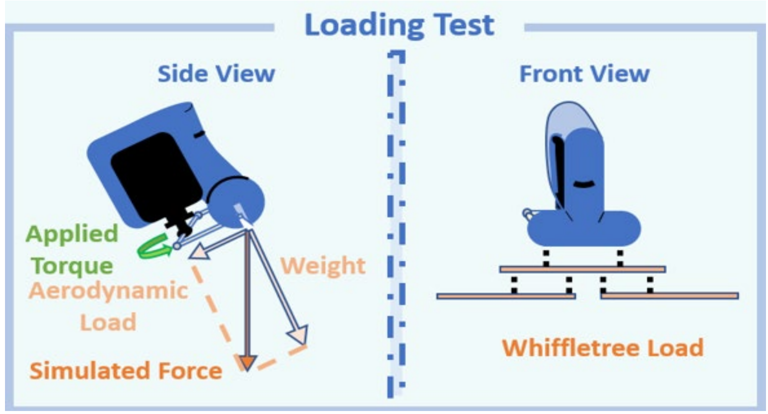
Key Measurement Issues: Obtaining non-accelerating angular measurements

FR 5.0	Drifter shall transmit stored position coordinates to a communications satellite up to 800 [km] away
DR 5.1	Transmit latency shall be less than 24 hours

Validation: Deployment Loading

Anticipated Date: February 4th

Motivation	Expected Results	Action for Test Failure
Validate SolidWorks structural analysis. Validate frictional force analysis.	Pin and structure will not fail under drifter weight. Linear actuator will overcome frictional force.	Increase pin diameter. Increase wall thickness of deployment housing. Implement stronger linear actuator or apply lubrication.



Test set-up: Clamp deployment mechanism to table and load it with a dummy weight. Ensure structure does not fail and load is deployed.

DM: Linear Actuator Force Test

Expected Location: ITLL

Equipment	Availability	Capability	Requirements	Satisfied
Dummy Mass And Table Clamp	ITLL	N/A	Drifter Weight & Aerodynamic Load	Available

Key Measurement Issues: N/A

Verification and Validation Summary

Models Validated	Requirements Satisfied	
Acceleration Model	Drifter maintains full component functionality after impact with water	✓
Communication Model	Drifter shall send location data by means of communications satellite	✓
Link Budget	Electronics maintain positive link budget and strong signal	✓
SolidWorks Structural Analysis	Deployment mechanism will not fail under drifter weight	✓
Frictional Analysis	Linear actuator can overcome forces present during flight	✓
Stability Model	Antenna will be above water line for transmission	✓

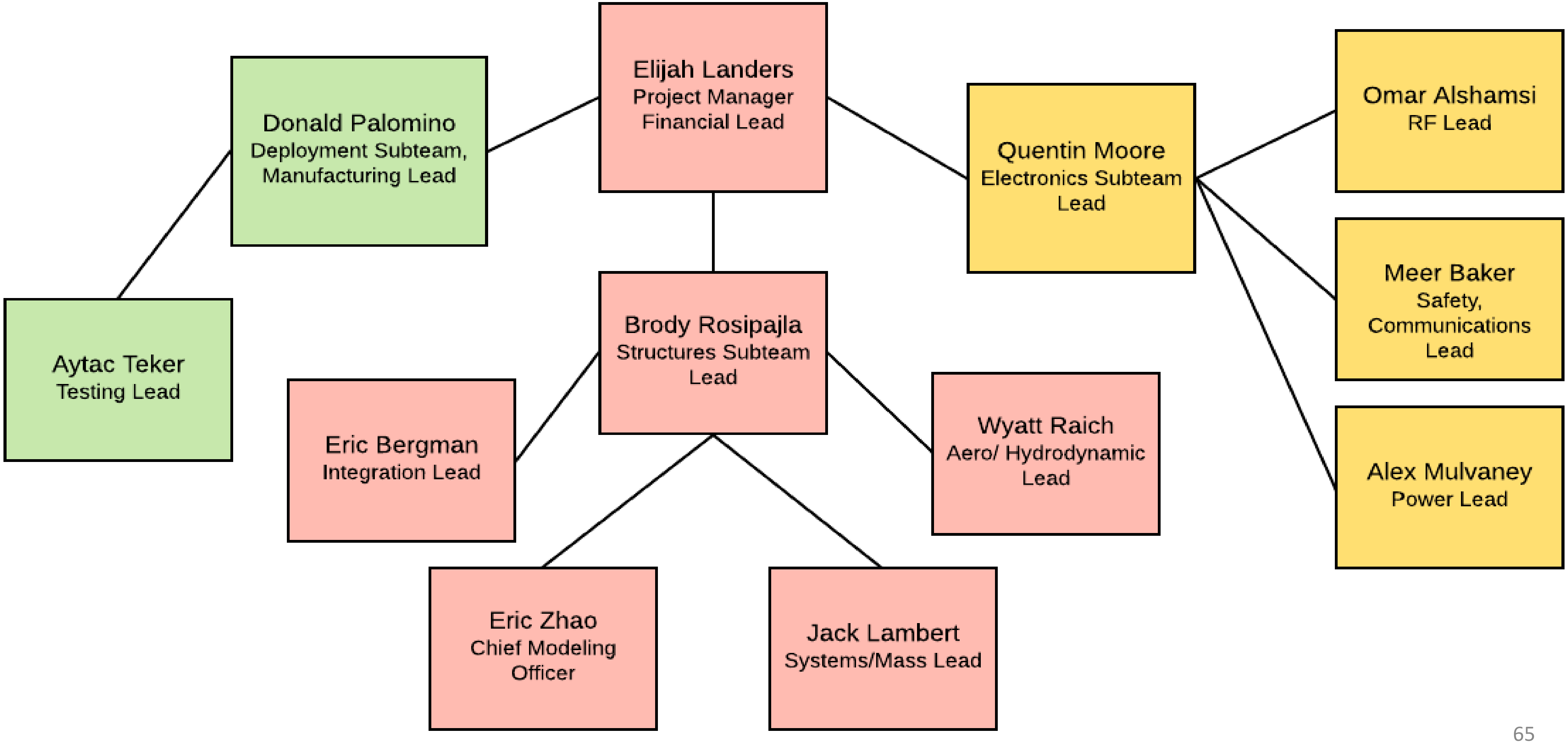
Project Planning

Organizational Chart

Deployment Mechanism Sub-Team

Structures Sub-Team

Electronics Sub-Team



Elijah Landers
Project Manager
Financial Lead

Donald Palomino
Deployment Subteam,
Manufacturing Lead

Aytac Teker
Testing Lead

Brody Rosipajla
Structures Subteam
Lead

Eric Bergman
Integration Lead

Eric Zhao
Chief Modeling
Officer

Jack Lambert
Systems/Mass Lead

Wyatt Raich
Aero/ Hydrodynamic
Lead

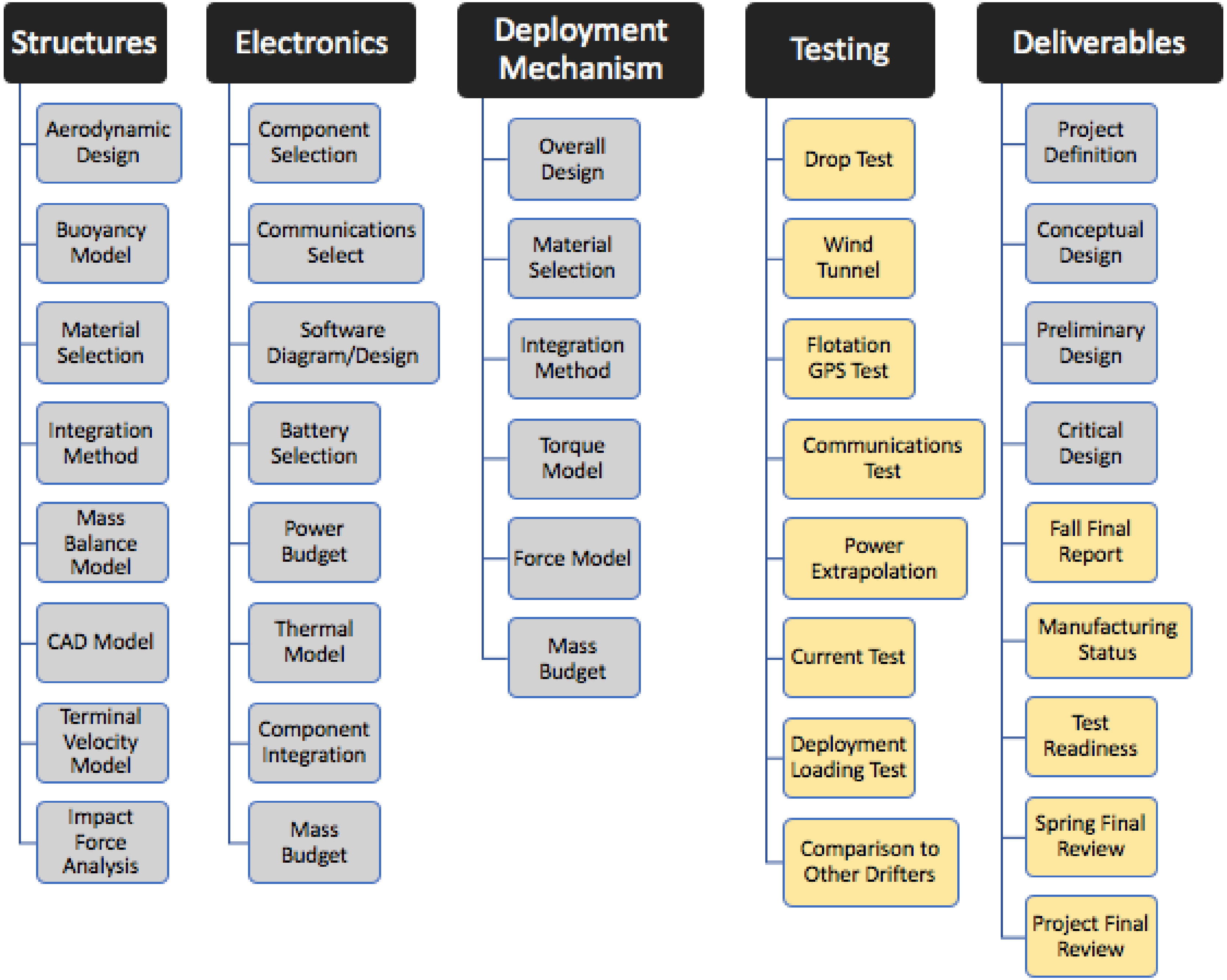
Quentin Moore
Electronics Subteam
Lead

Omar Alshamsi
RF Lead

Meer Baker
Safety,
Communications
Lead

Alex Mulvaney
Power Lead

Work Breakdown Structure

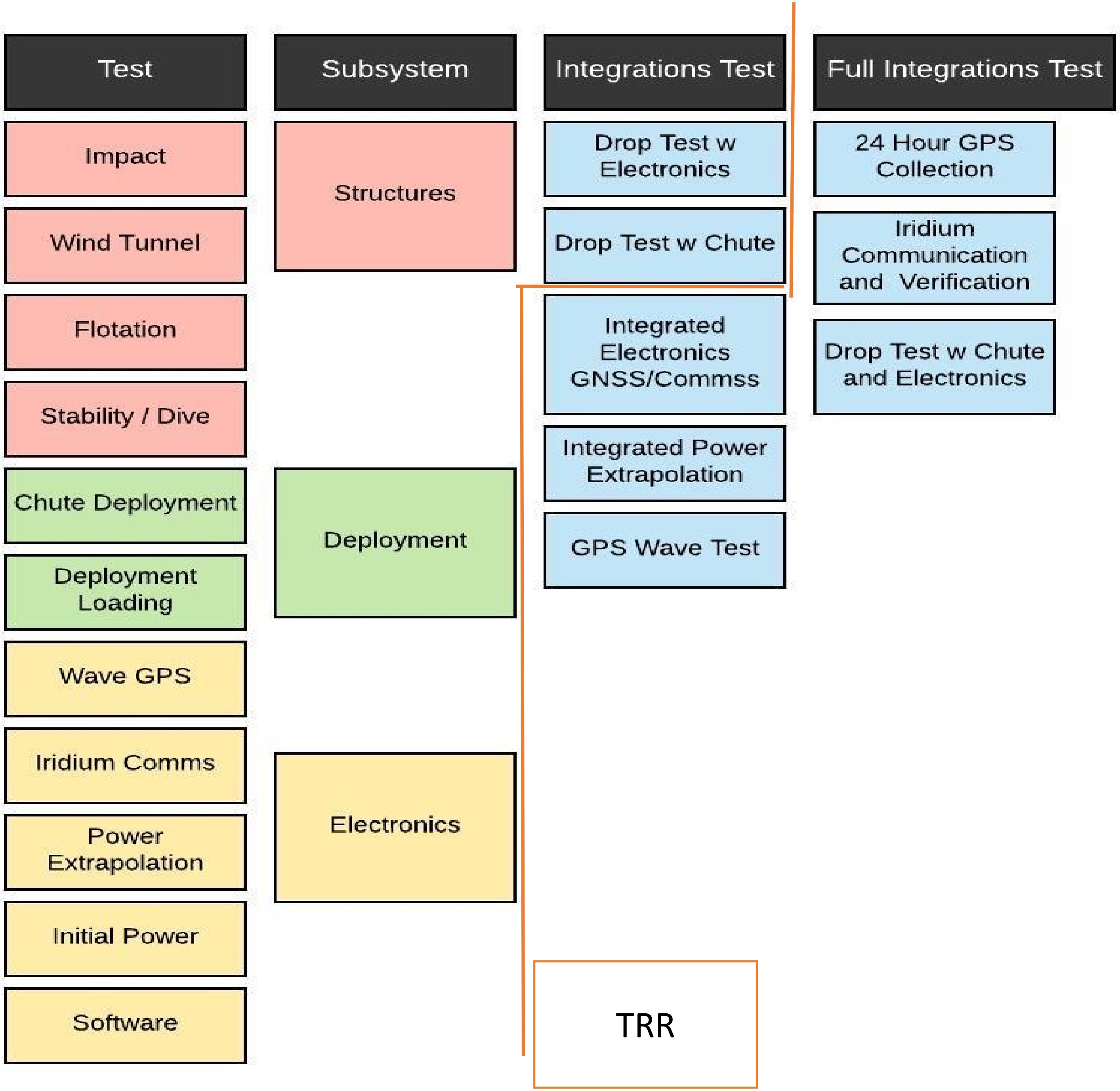


- **Structures**
  - Aerodynamic Design
  - Buoyancy Model
  - Material Selection
  - Integration Method
  - Mass Balance Model
  - CAD Model
  - Terminal Velocity Model
  - Impact Force Analysis
- **Electronics**
  - Component Selection
  - Communications Select
  - Software Diagram/Design
  - Battery Selection
  - Power Budget
  - Thermal Model
  - Component Integration
  - Mass Budget
- **Deployment Mechanism**
  - Overall Design
  - Material Selection
  - Integration Method
  - Torque Model
  - Force Model
  - Mass Budget
- **Testing**
  - Drop Test
  - Wind Tunnel
  - Flotation GPS Test
  - Communications Test
  - Power Extrapolation
  - Current Test
  - Deployment Loading Test
  - Comparison to Other Drifters
- **Deliverables**
  - Project Definition
  - Conceptual Design
  - Preliminary Design
  - Critical Design
  - Fall Final Report
  - Manufacturing Status
  - Test Readiness
  - Spring Final Review
  - Project Final Review

⬜ Complete

🟨 Yet to Complete

Test Plan



Test
- Impact
- Wind Tunnel
- Flotation
- Stability / Dive
- Chute Deployment
- Deployment Loading
- Wave GPS
- Iridium Comms
- Power Extrapolation
- Initial Power
- Software

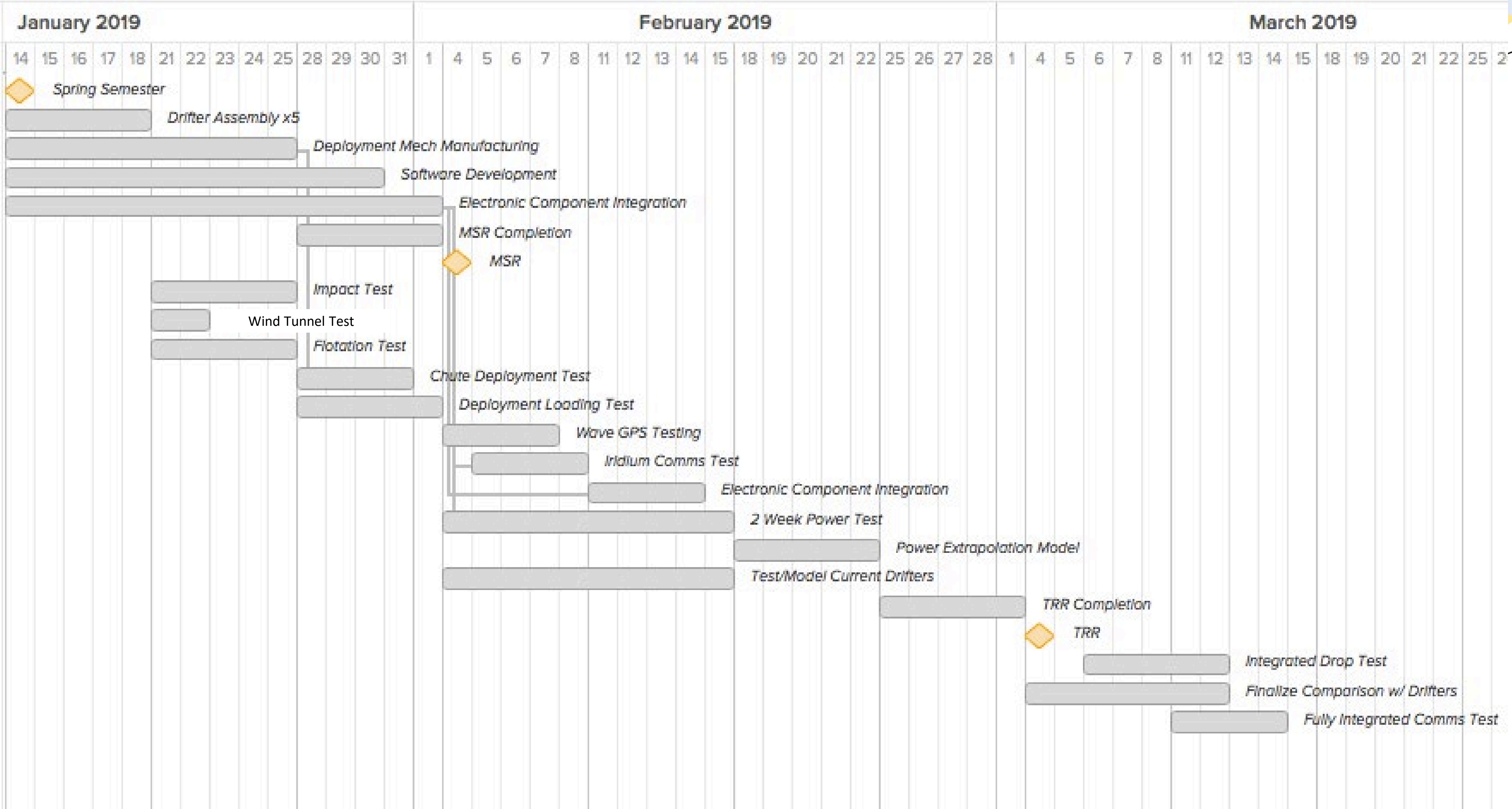
Subsystem
- Structures
- Deployment
- Electronics

Integrations Test
- Drop Test w Electronics
- Drop Test w Chute
- Integrated Electronics GNSS/Commss
- Integrated Power Extrapolation
- GPS Wave Test

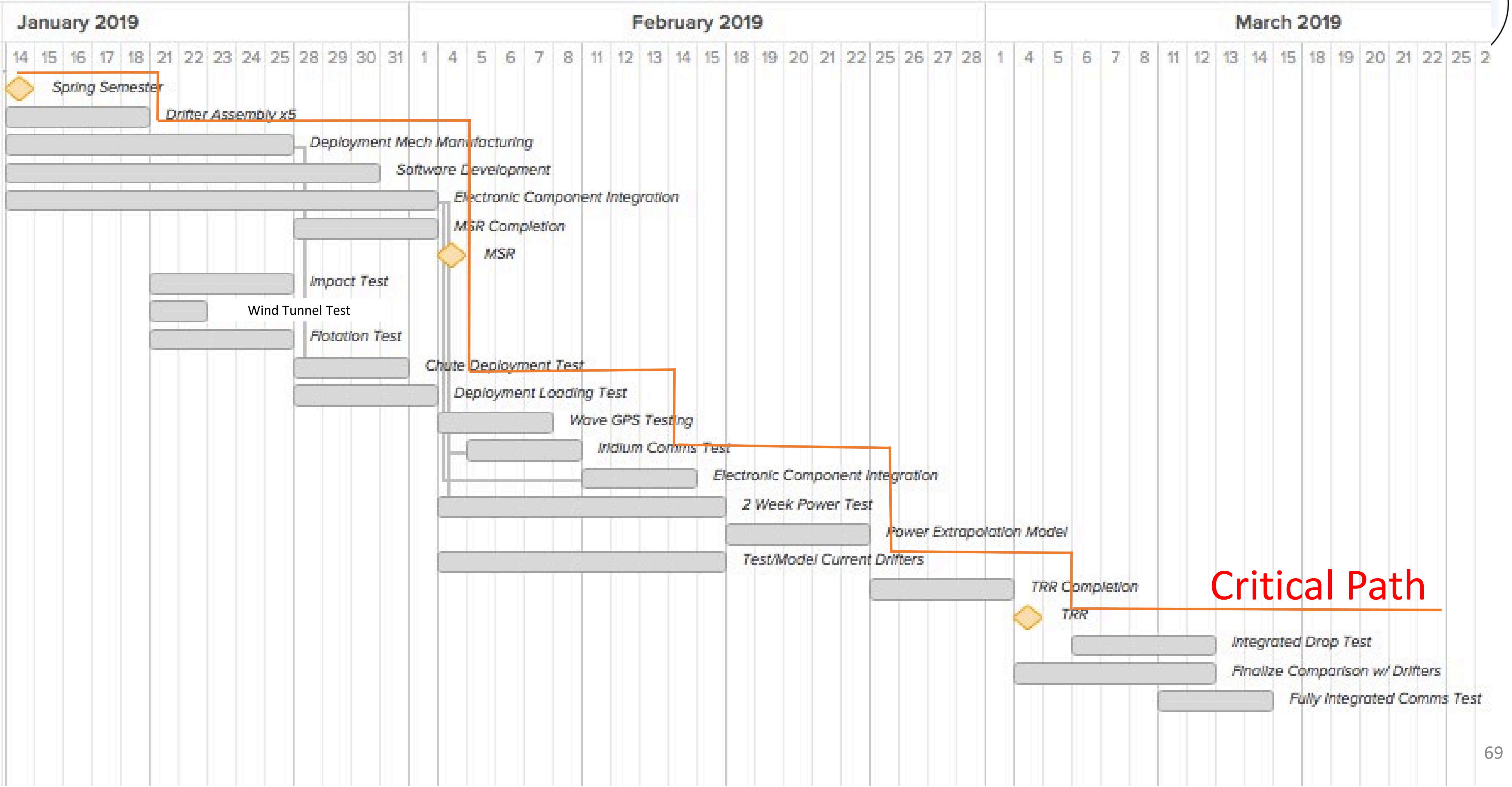
Full Integrations Test
- 24 Hour GPS Collection
- Iridium Communication and Verification
- Drop Test w Chute and Electronics

TRR

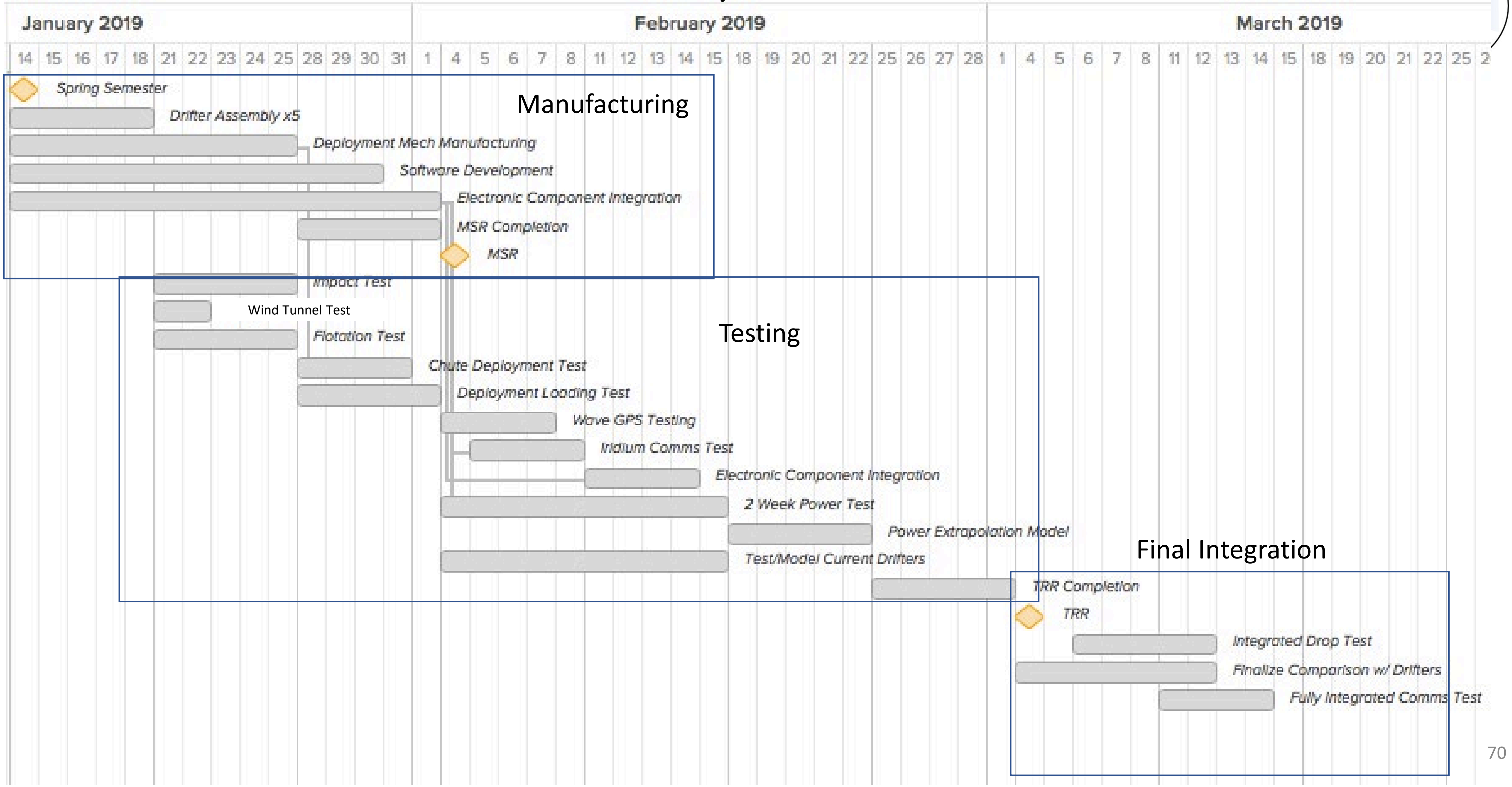
Work Plan/ Gantt



Work Plan/ Gantt



Work Plan/ Gantt



Fiscal Summary

Subsystem	Total Unit Cost	Anticipated Need for Testing	Total Cost
GNSS	$16.99	5	$84.95
Sat/Comm Module	$384.50	2	$769.00
Sat/Comm Data	$252.50	1	$252.50
Structures	$34.98	6	$209.88
Deployment	$115.00	3	$345.00
Total	$798.97		$1661.33

Margin of $3338.67

Questions?

Sources

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- “TLV61220 Low-Input Voltage Step-Up Converter in Thin SOT-23 Package.” *Ti.com*, Texas Instruments, Dec. 2014, www.ti.com/lit/ds/symlink/tlv61220.pdf.
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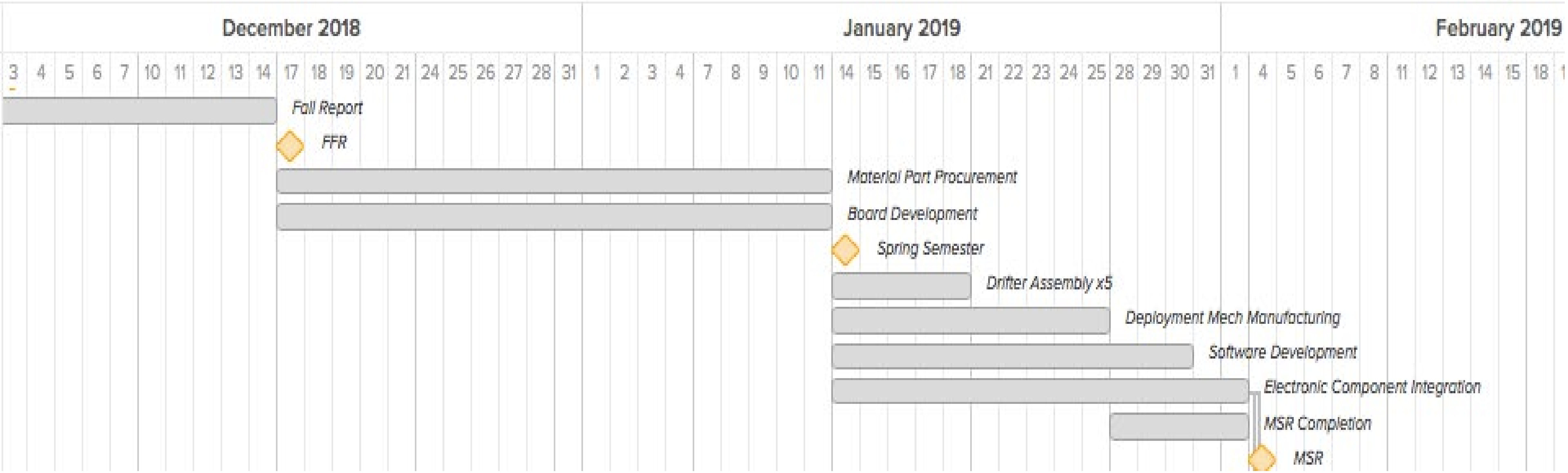
- Abraham, T. S. J., “Velocity and Density Effect on Impact Force during Water Entry of Sphere,” *Journal of Geophysics & Remote Sensing*, vol. 03, 2014.
- Lall, P., Dornala, K., Lowe, R., and Foley, J., “Survivability assessment of electronics subjected to mechanical shocks up to 25,000g,” *2016 15th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm)*, 2016.
- Applied Mathematics Group, New York University, “The Force of Impact on a Sphere Striking a Water Surface,” *The Force of Impact on a Sphere Striking a Water Surface*, Jul. 1945.
- *Overview of materials for High Density Polyethylene (HDPE), Injection Molded* Available: http://www.matweb.com/search/datasheet.aspx?matguid=fce23f90005d4fbe8e12a1bce53ebdc8.

Backup Slides

Work Plan/ Gantt : Fall ~ Winter Break



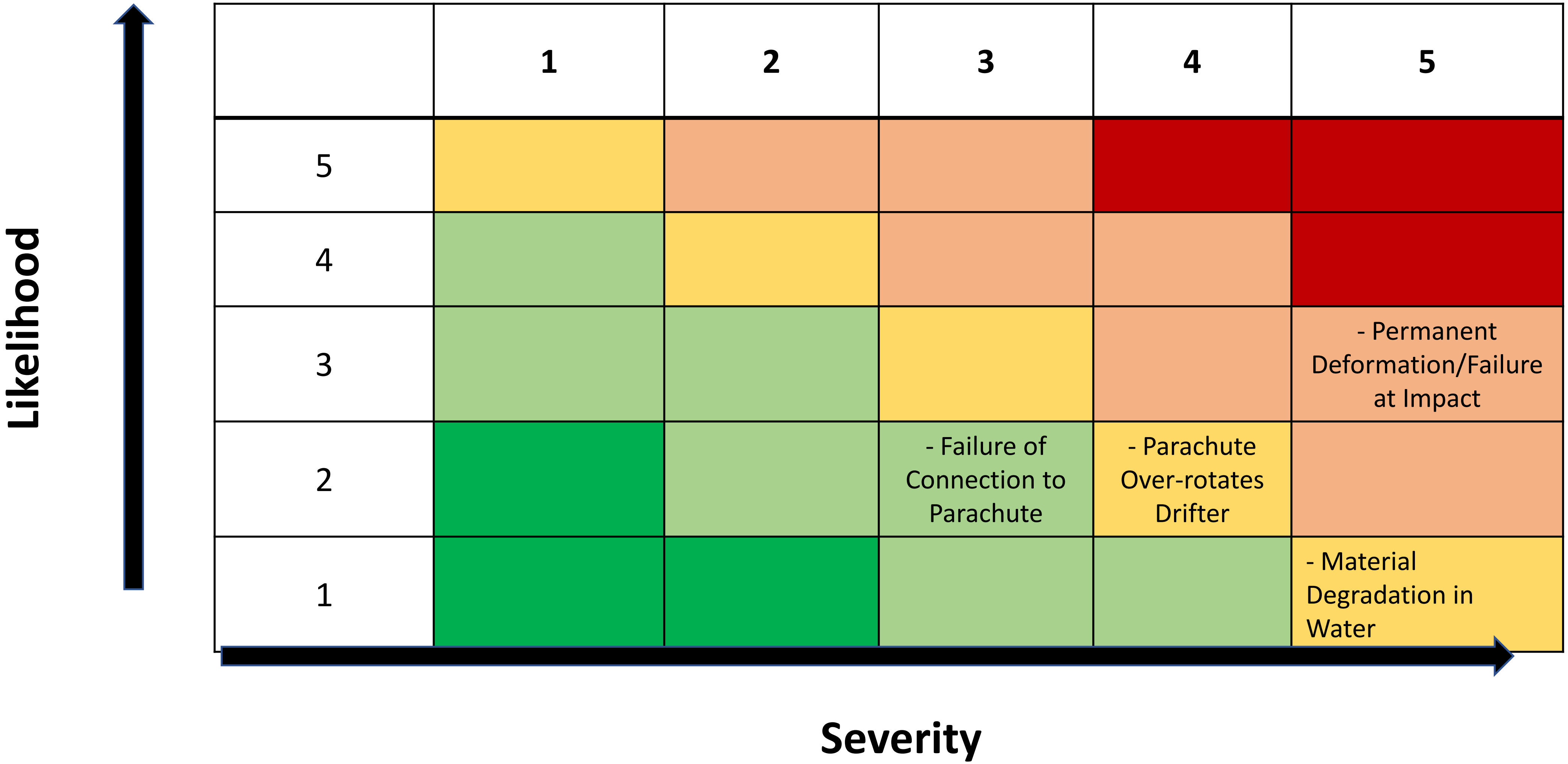
Backup: Risk

Deployment Risks

5 = Highest
1= Lowest

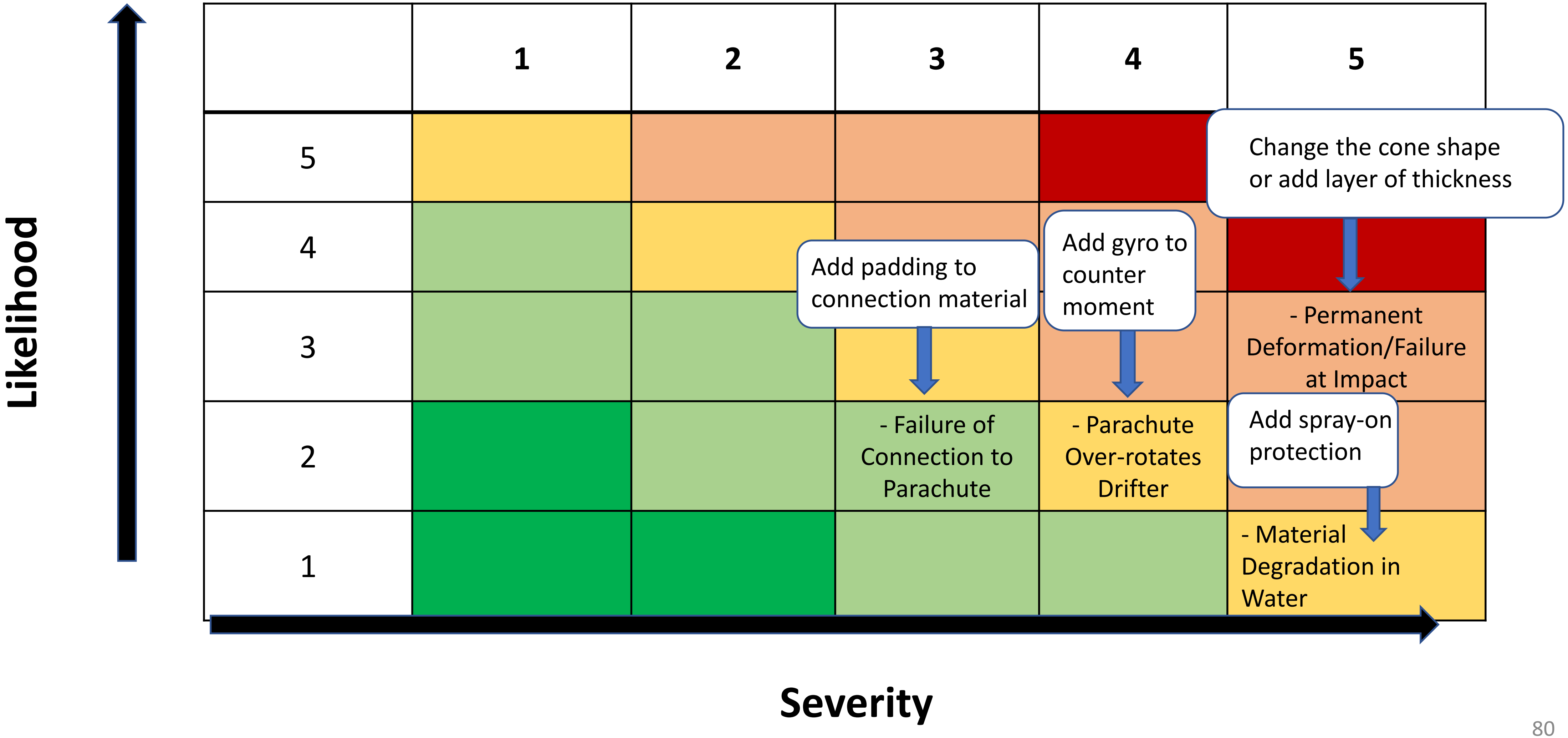
Risks	Pre-Mitigation Likeliness/Severity	Mitigation	Post-Mitigation Likeliness/Severity
Shearing of release pin	2/5	Increase diameter	1/5
Shearing of adhesive on deployment	2/5	Increase length of tab for increased adhesive surface area	1/5
Aileron and deployment mechanism contact	2/4	Lengthen pylon	1/4
Linear actuator not able to pull release pin	3/5	Add lubrication	2/5

Pre-Mitigation Risk Matrix for Structures



	1	**2**	**3**	**4**	**5**
5					
4					
3					- Permanent Deformation/Failure at Impact
2			- Failure of Connection to Parachute	- Parachute Over-rotates Drifter	
1					- Material Degradation in Water

Mitigation Risk Matrix for Structures



	1	2	3	4	5
5					
4					
3					- Permanent Deformation/Failure at Impact
2			- Failure of Connection to Parachute	- Parachute Over-rotates Drifter	
1					- Material Degradation in Water

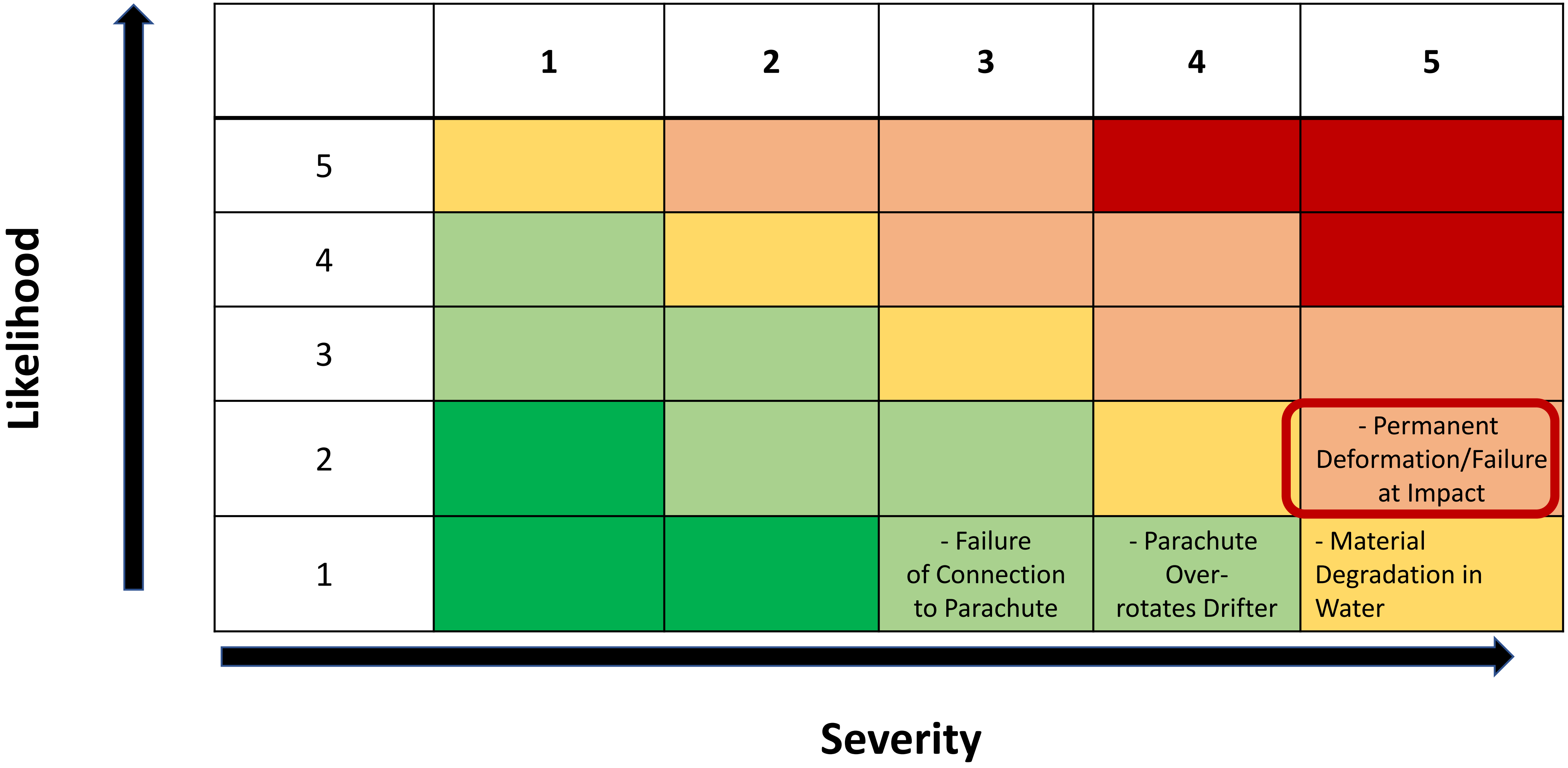
Change the cone shape or add layer of thickness

Add padding to connection material

Add gyro to counter moment

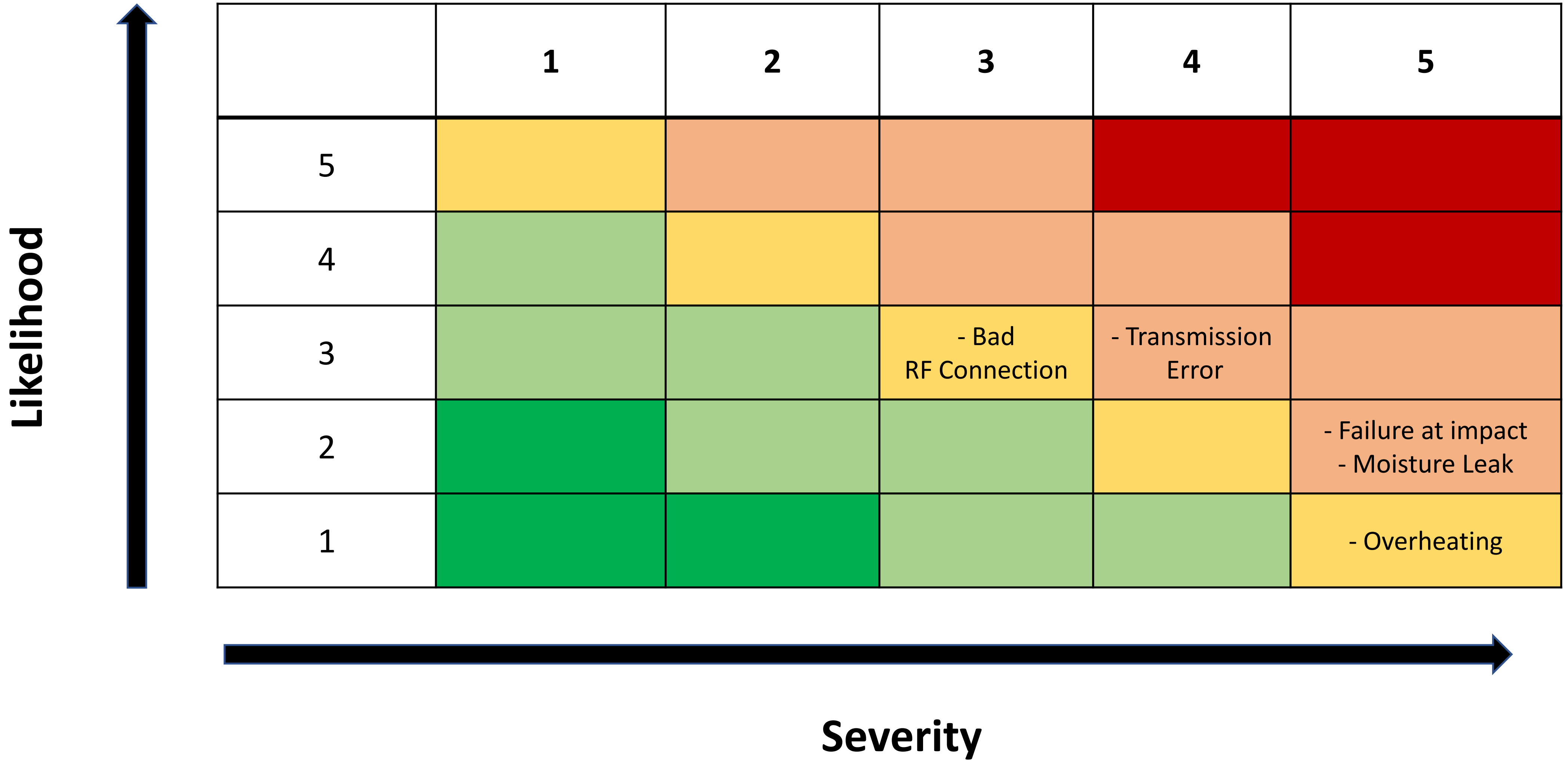
Add spray-on protection

Post-Mitigation Risk Matrix for Structures



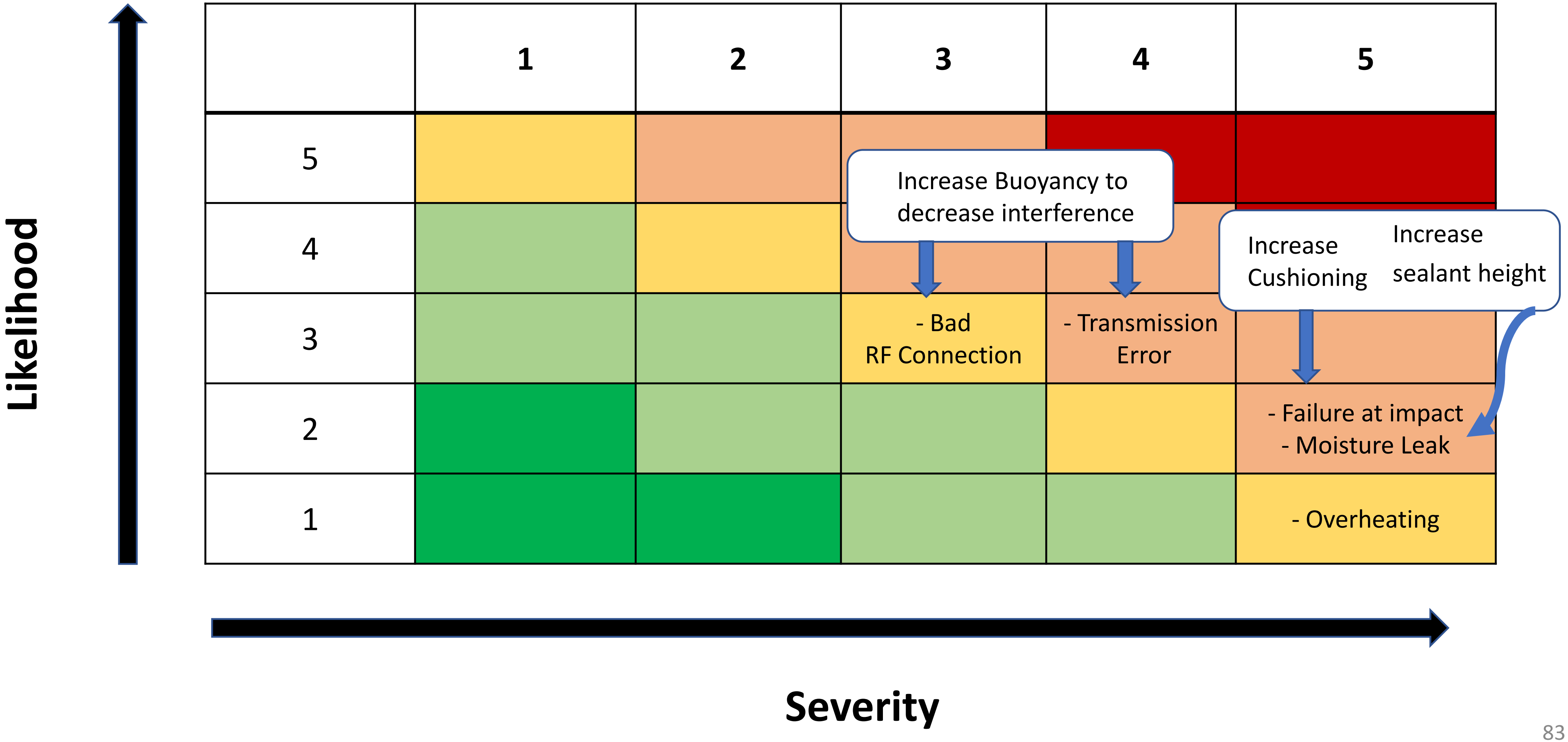
	1	2	3	4	5
5					
4					
3					
2					- Permanent Deformation/Failure at Impact
1			- Failure of Connection to Parachute	- Parachute Over-rotates Drifter	- Material Degradation in Water

Pre-Mitigation Risk Matrix for Electronics



	1	2	3	4	5
5					
4					
3			- Bad RF Connection	- Transmission Error	
2					- Failure at impact - Moisture Leak
1					- Overheating

Mitigation Risk Matrix for Electronics



	1	2	3	4	5
5					
4					
3			- Bad RF Connection	- Transmission Error	
2					- Failure at impact - Moisture Leak
1					- Overheating

Increase Buoyancy to decrease interference

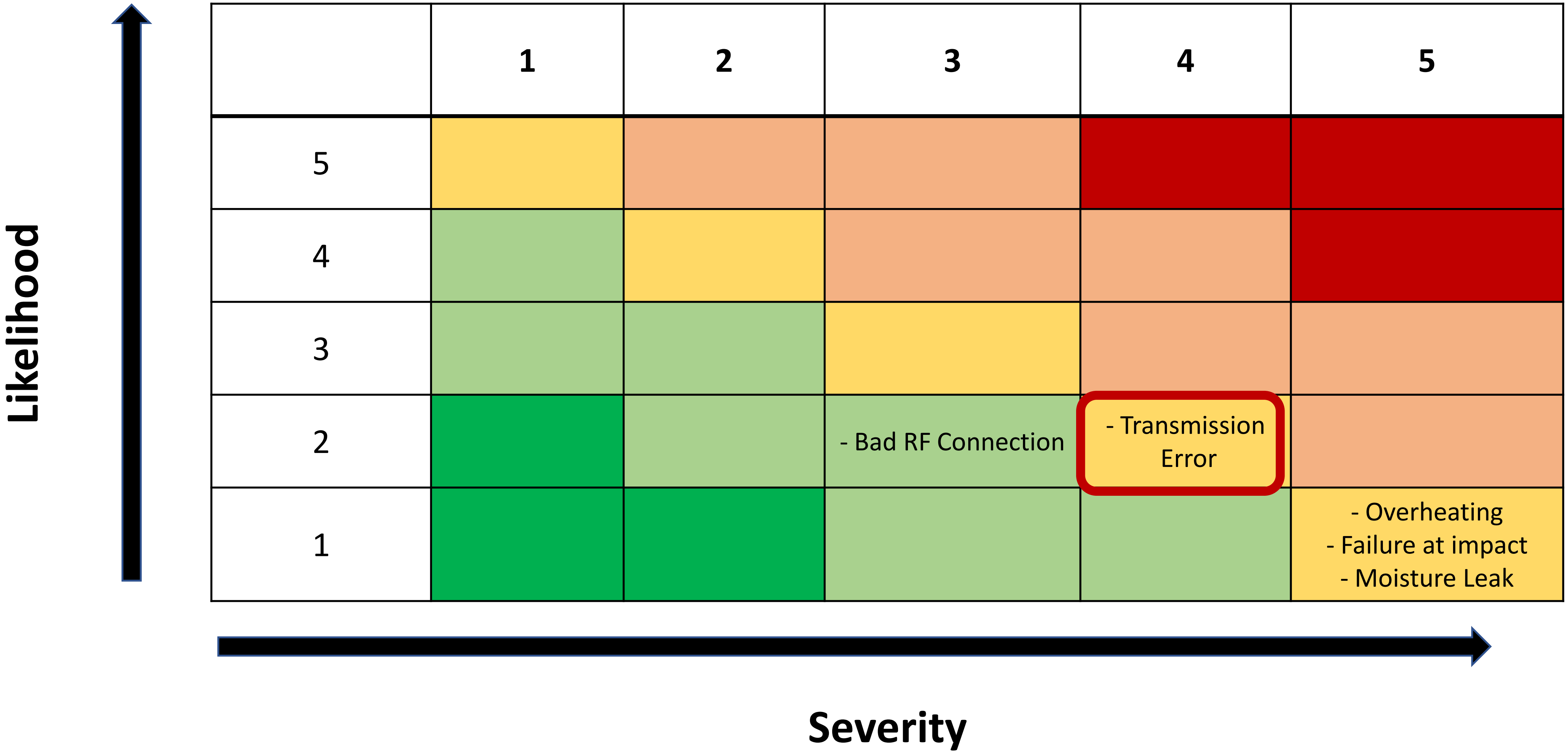
Increase Cushioning

Increase sealant height

Likelihood

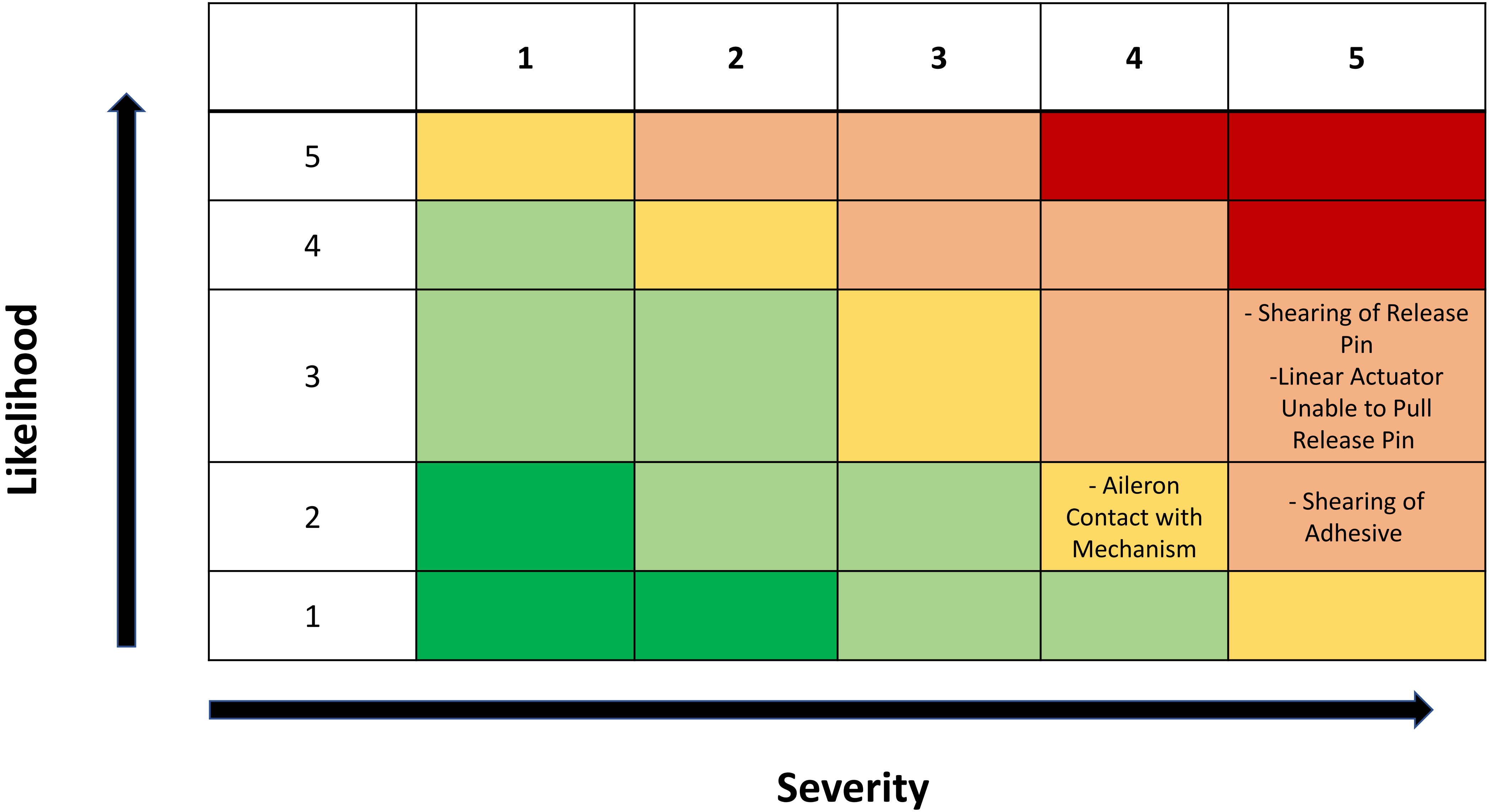
Severity

Post-Mitigation Risk Matrix for Electronics



	1	2	3	4	5
5	🟨	🟧	🟧	🟥	🟥
4	🟩	🟨	🟧	🟧	🟥
3	🟩	🟩	🟨	🟧	🟧
2	🟩	🟩	- Bad RF Connection	- Transmission Error	🟧
1	🟩	🟩	🟩	🟩	- Overheating - Failure at impact - Moisture Leak

Pre-Mitigation Risk Matrix for Deployment

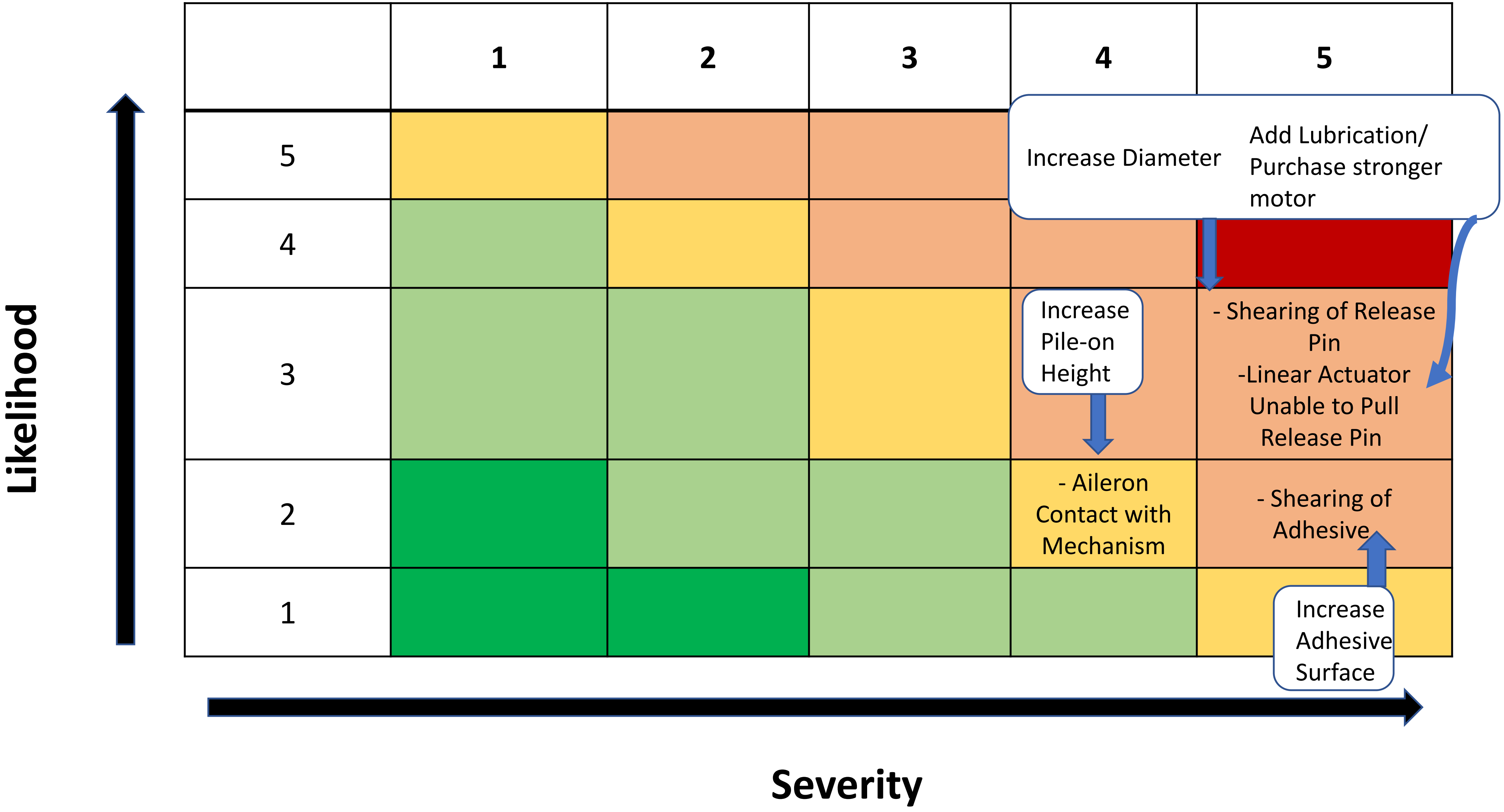


Likelihood

	1	**2**	**3**	**4**	**5**
5	🟨	🟧	🟧	🟥	🟥
4	🟩	🟨	🟧	🟧	🟥
3	🟩	🟩	🟨	🟧	🟧 - Shearing of Release Pin -Linear Actuator Unable to Pull Release Pin
2	🟩	🟩	🟩	🟨 - Aileron Contact with Mechanism	🟧 - Shearing of Adhesive
1	🟩	🟩	🟩	🟩	🟨

Severity

Mitigation Risk Matrix for Deployment



	1	2	3	4	5
5	🟨	🟧	🟧		
4	🟩	🟨	🟧	🟧	🟥
3	🟩	🟩	🟨	🟧	🟧 - Shearing of Release Pin -Linear Actuator Unable to Pull Release Pin
2	🟩	🟩	🟩	🟨 - Aileron Contact with Mechanism	🟧 - Shearing of Adhesive
1	🟩	🟩	🟩	🟩	🟨

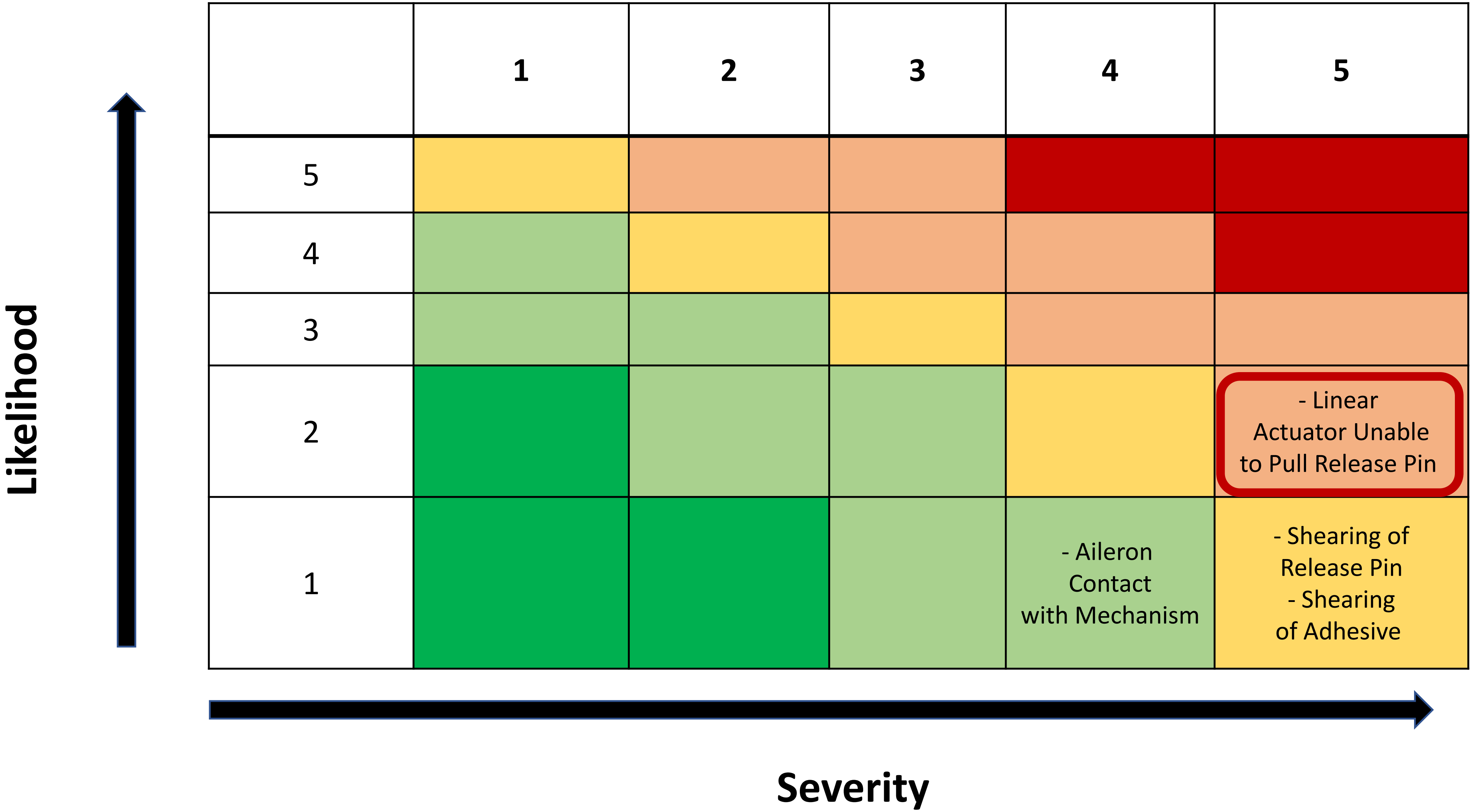
Increase Diameter

Add Lubrication/ Purchase stronger motor

Increase Pile-on Height

Increase Adhesive Surface

Post-Mitigation Risk Matrix for Deployment



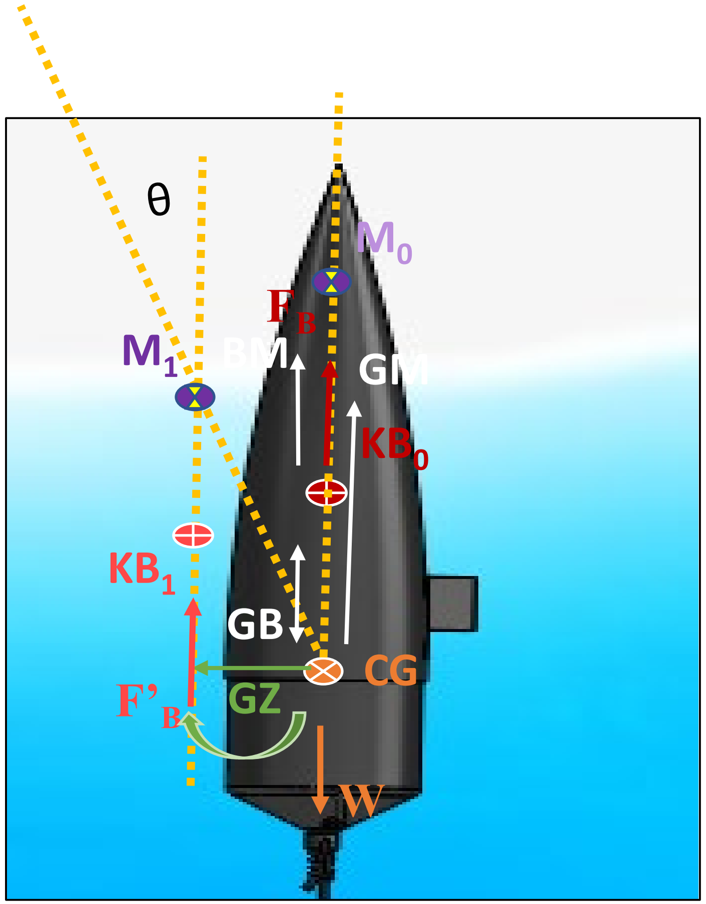
	1	2	3	4	5
5					
4					
3					
2					- Linear Actuator Unable to Pull Release Pin
1				- Aileron Contact with Mechanism	- Shearing of Release Pin - Shearing of Adhesive

Likelihood

Severity

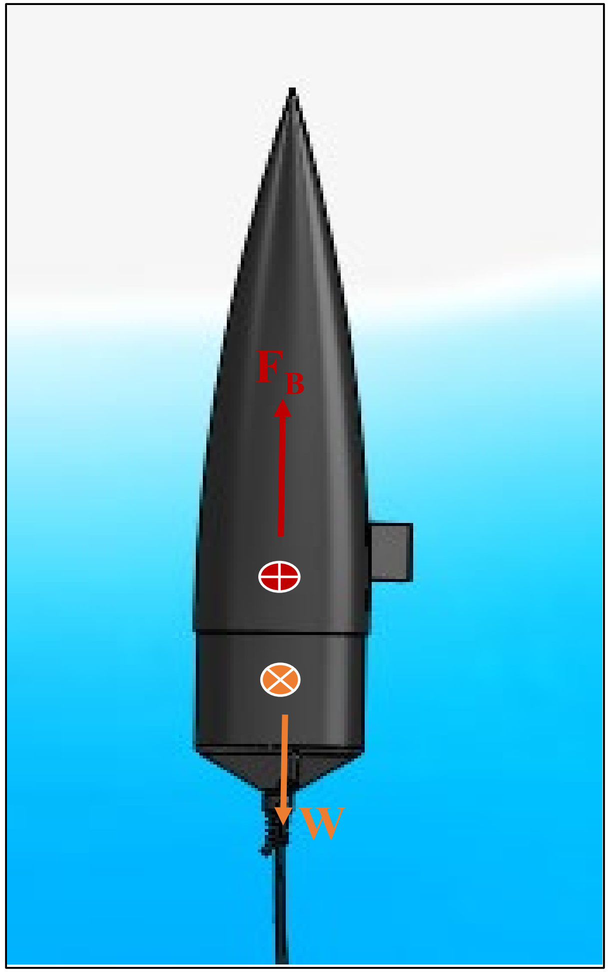
Floatation Experiment

DR 1.1	The drifter shall float
DR 1.2	The drifter shall maintain stable orientation in the water



Current Models:

- Model of stability
- Model of buoyancy and prediction of how much of the body is submerged



Backup: Structures

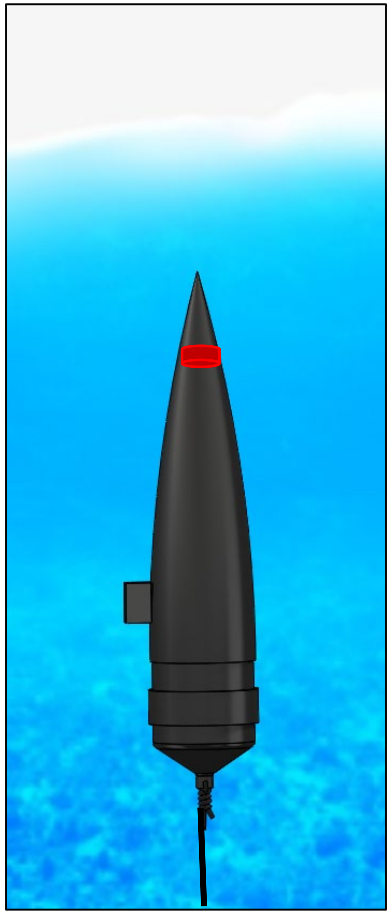
Buoyancy CONOPS

DR 1.1 The drifter shall float to keep antenna above water

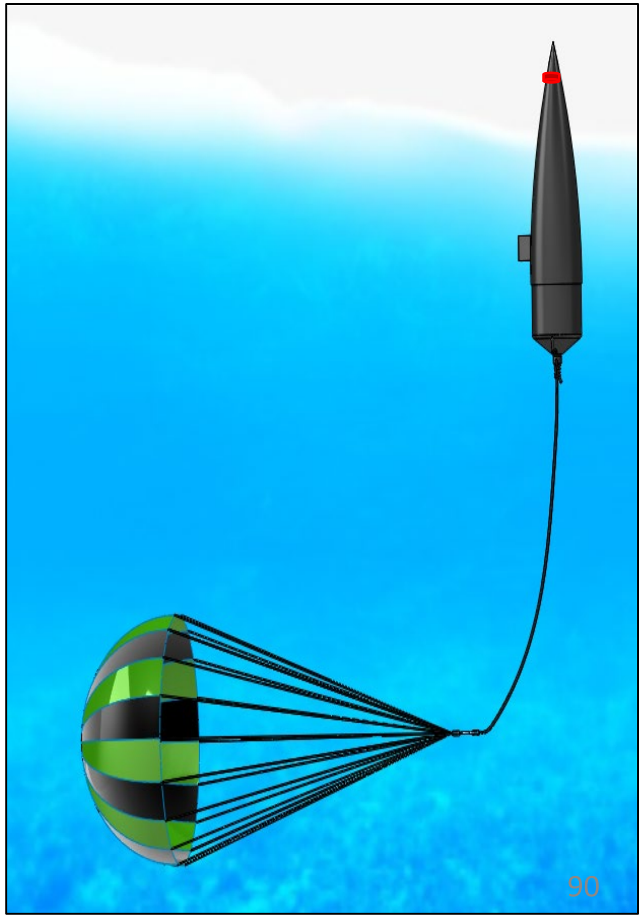
Drifter is expected to impact water nosecone down

Drifter will need to turn upwards to ensure antenna is upright

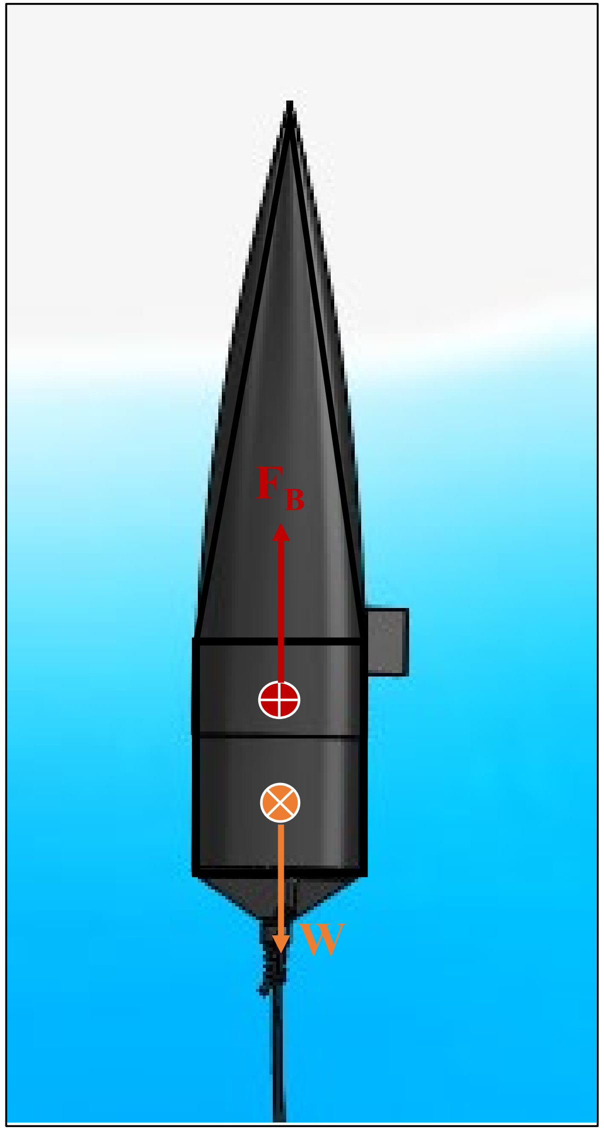
Drifter must float to surface



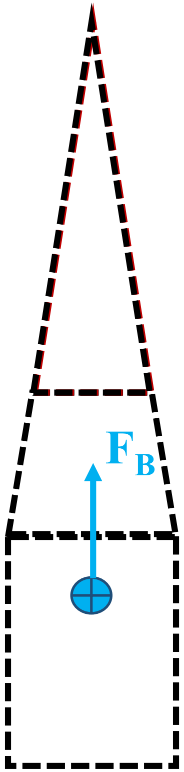
Drifter must be in stable buoyant equilibrium with antenna above the waterline



Design Solution: GPS Above Waterline



Displaced Water



$$\boldsymbol{W_d = F_B}$$

$$\boldsymbol{m_T g = \rho_w g \forall_S}$$

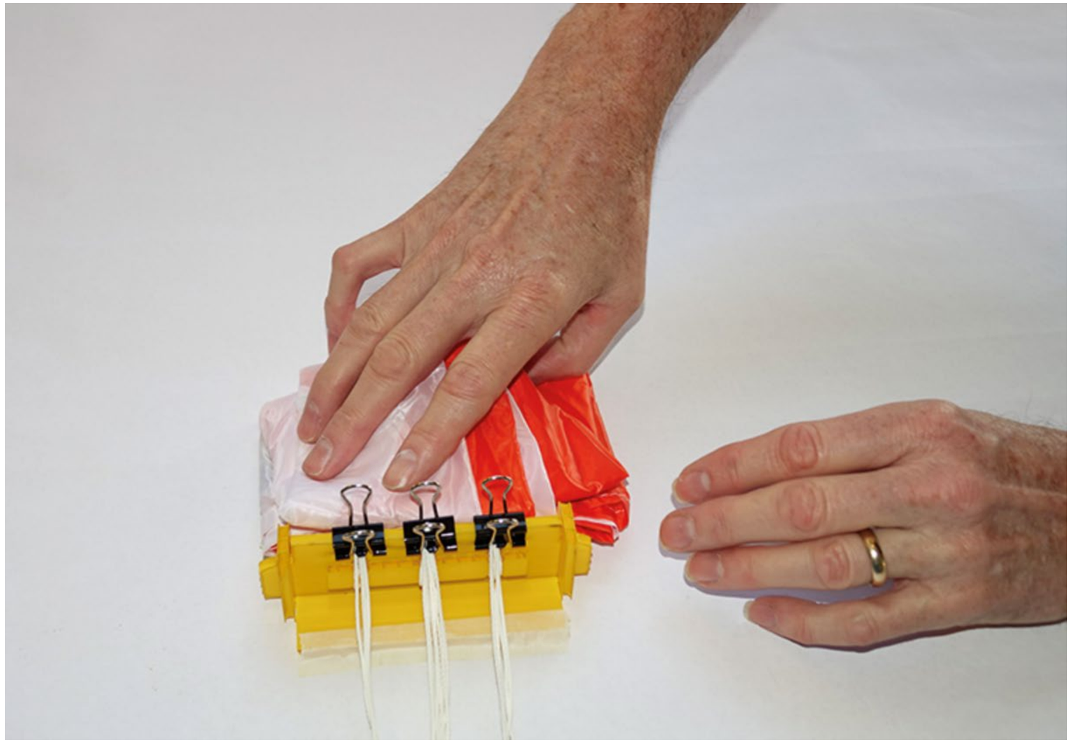
- $\forall_S = \forall_{cylinder} + \forall_{partial\ cone}$
- $\forall_{partial\ cone} = \forall_{total\ cone} - \forall_{unsubmerged\ cone}$
- $\forall_{unsubmerged\ cone} = \frac{1}{3}\pi\, r_{unsubmerged}^2\, h_{unsubmerged}$
- *Using 'similar triangles':*
  - $r_{unsubmerged} = r_{cone} \frac{h_{unsubmerged}}{h_{cone}}$
  - $\forall_{unsubmerged\ cone} = \frac{1}{3}\pi\, r_{cone}^2\, \frac{1}{h_{cone}^2}\, h_{unsubmerged}^3$
- Rearranging and solving for unsubmerged height:

$$h_{unsubmerged} = \sqrt[3]{\frac{3h_{cone}^2}{\pi r_{cone}^2}\left(V_T - \frac{m_T}{\rho_w}\right)} = \sim 24\ [cm]$$

- Knowing the total volume of the submerged buoy, the center of buoyancy (KB) can be calculated using Center of Mass (COM) calculations
  - $KB = \frac{m_{cylinder} COM_{cylinder} + m_{partial\ cone} COM_{partial\ cone}}{m_{cylinder} + m_{partial\ cone}} = \sim 6\ [cm]$

Parachute Packing

- Parachute packed using Fruity Chutes packing jig
- Designed specifically for micro parachutes
- Extremely detailed step by step procedures for optimal packing for fast deployment
- Practice and test parachute packing



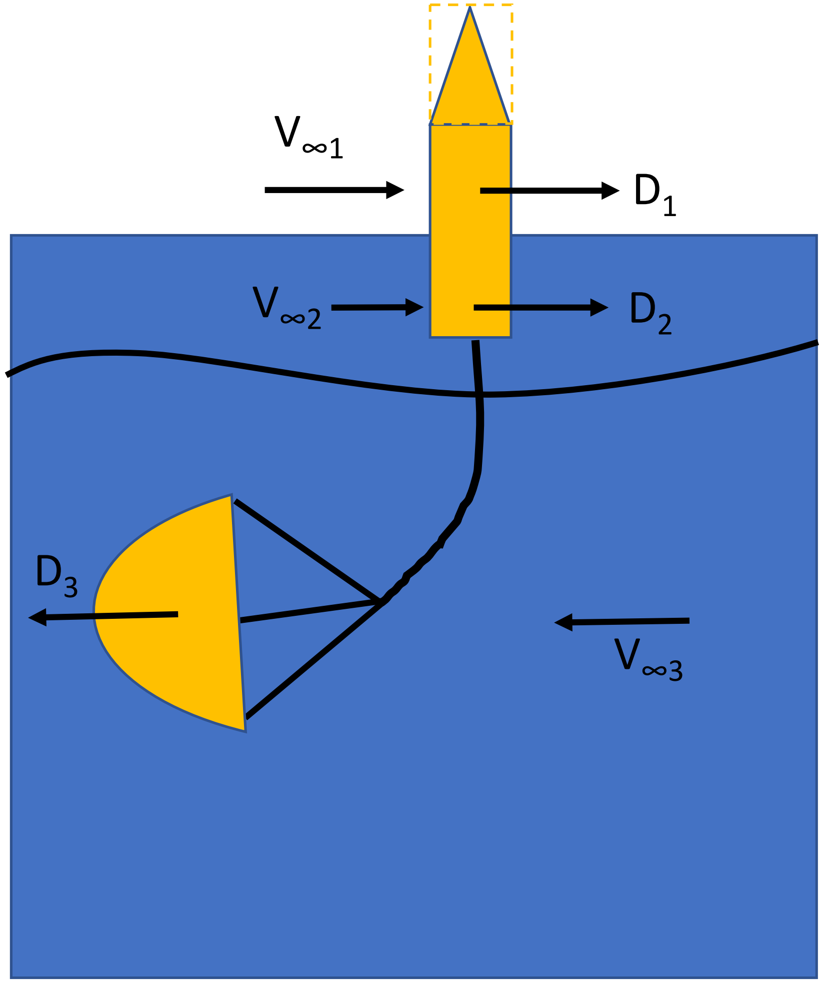
Drogue Design: Drag Model

Drag Analysis:

- Section 1: Drag surface wind
- Section 2: Wind induced current
- Section 3: Tracked current

Assumptions:

- Cylindrical float
  - Cylinder exposed to wind
  - Cylinder exposed to measured current
- Parachute drogue perpendicular to flow
- Density Air = 1.225 $[\frac{kg}{m^3}]$
- Density Water = 1027 $[\frac{kg}{m^3}]$
- Reynolds Number 1,2 = $2.1\text{x}10^4$, $2.4\text{x}10^4$
- Reynolds Number 3 = $7.7\text{x}10^4$
- C_d from experimental data
- 24 cm cylinder above water
- 12 cm cylinder below water



Drogue Design: Drag Model

Givens:

- $V_{\infty 1} = 3\ [\frac{m}{s}]$
- $V_{\infty 2} = 0.3\ [\frac{m}{s}]$
- $V_{\infty 3} = 0.7\ [\frac{m}{s}]$
- $C_{d1} = 0.74$
  - *(assumed cylindrical for worst case)*
- $C_{d2} = 0.68$
- $C_{d3} \sim 1.5$
- $A_1 = 0.006\ m^2$
- $A_2 = 0.023\ m^2$
- $A_3 = 0.073\ m^2$

Solution:

- $D = \frac{1}{2}\rho V^2 C_d A$
- Drag Ratio = $\frac{D_3}{D_1 + D_2}$

Results:

- $D_1 = 0.04$ N
- $D_2 = 0.60$ N
- $D_3 = 27.5$ N

- $\frac{D_3}{D_1 + D_2} = 43.2 \gg 40$

- Exceeds Design Requirement

Impact Velocity Model

Governing Equations:

$$F_{drag} = \frac{1}{2}\rho|V_{rel}|^2 * (C_{d_{drifter}} * A_{drifter} + C_{d_{parachute}} * A_{parachute})\breve{v}$$

$$V_{rel} = [\, V_x - W_x, V_y - W_y, V_z - W_z]$$

$$\breve{v} = \frac{V_{rel}}{|V_{rel}|}$$

$$\frac{\delta \dot{x}}{\delta t} = -F_{drag,x}$$

$$\frac{\delta \dot{z}}{\delta t} = -F_{drag,z} - (m_{drifter} + m_{parachute}) * g$$

$$\frac{\delta \dot{y}}{\delta t} = -F_{drag,y}$$

Initial Conditions:

$$x_0 = 0\ (m/s)$$

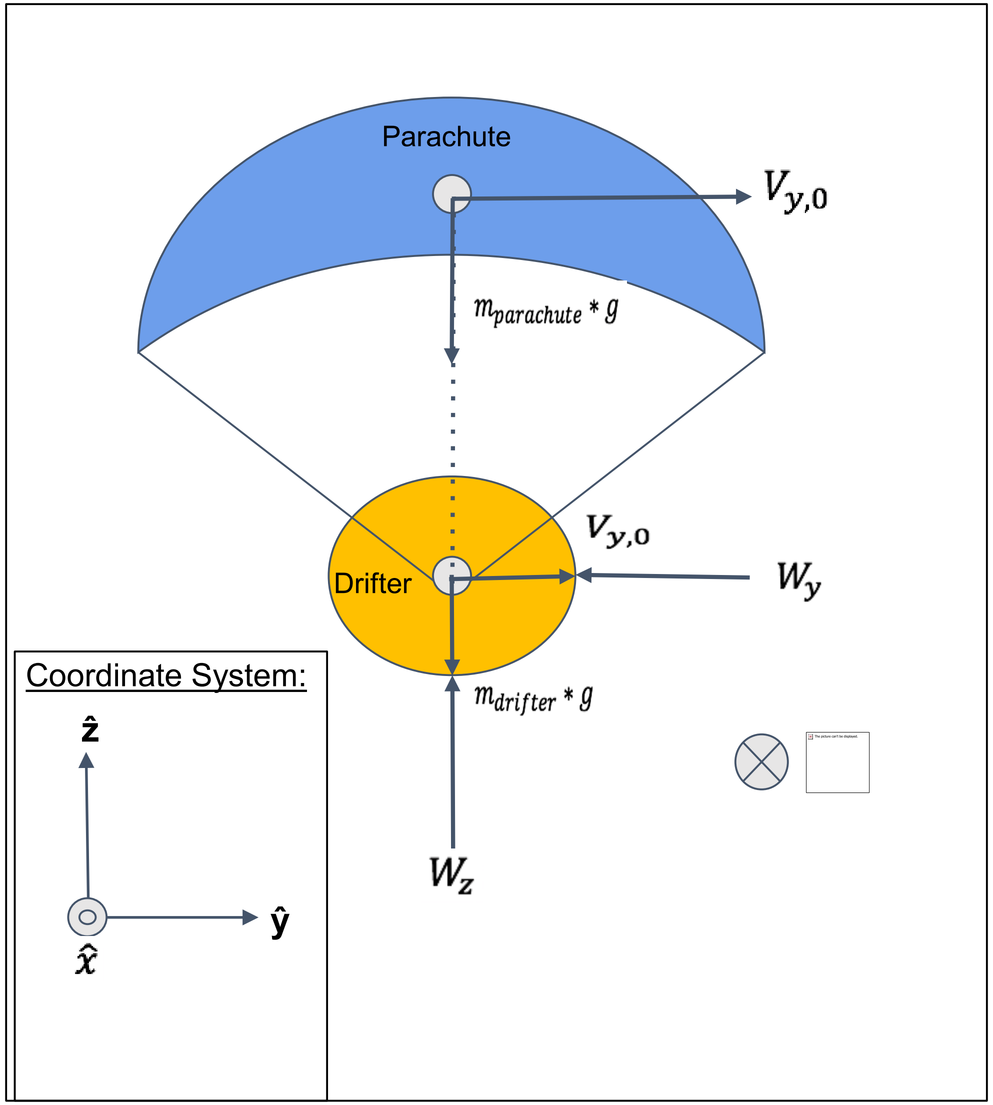
$$y_0 = 0\ (m/s)$$

$$z_0 = 0\ (m/s)$$

$$V_{x,0} = 0\ (m/s)$$

$$V_{x,0} = 20\ (m/s)$$

$$V_{z,0} = 0\ (m/s)$$

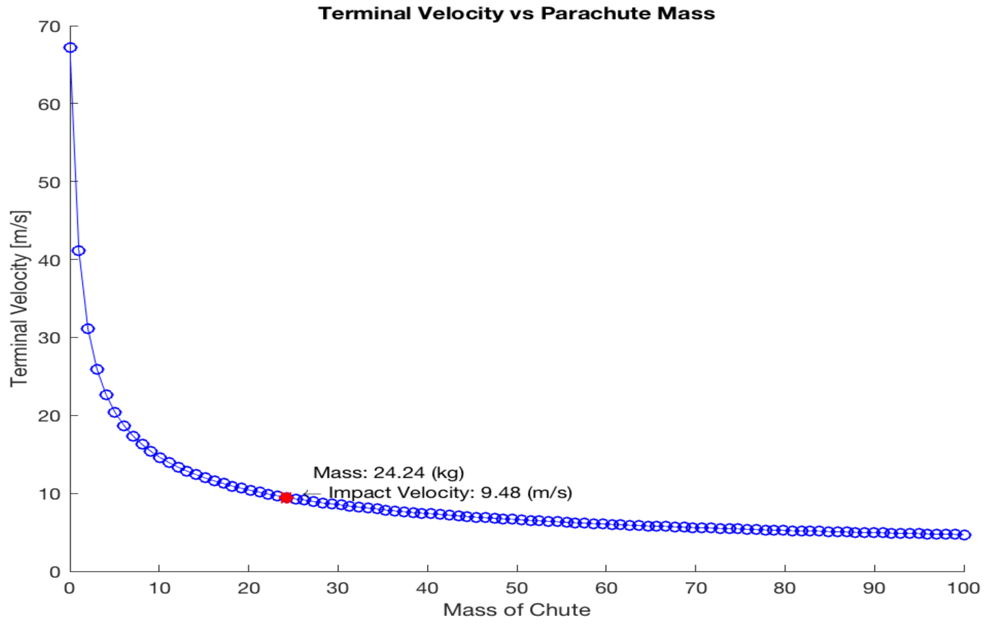


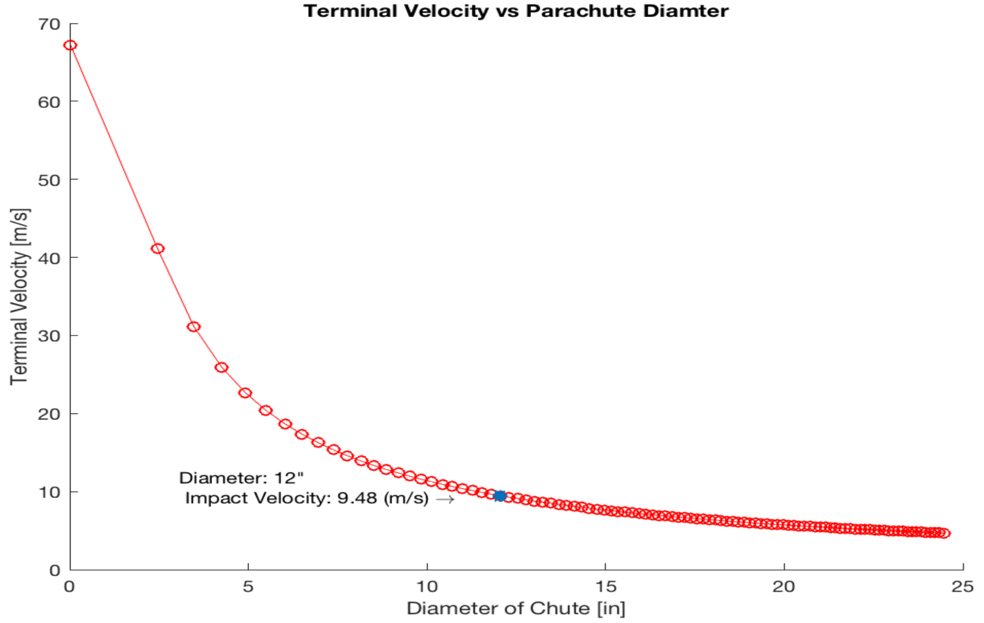
Assumptions:

$\Delta\rho = \sim 4\% \approx 0$ $\quad \frac{dW_x}{dz} = 0 \quad \frac{dW_y}{dz} = 0 \quad \frac{dW_z}{dz} = 0$

Impact Velocity

- Compromise between Impact velocity and additional mass of parachute
- Plots show that velocity drops quickly and levels, but mass continues to increase
- Had to consider sizes that parachutes are manufactured
- <u>Results:</u>
  - Impact Velocity: 9.48 (m/s)
  - Mass of Parachute: ~24 (kg)



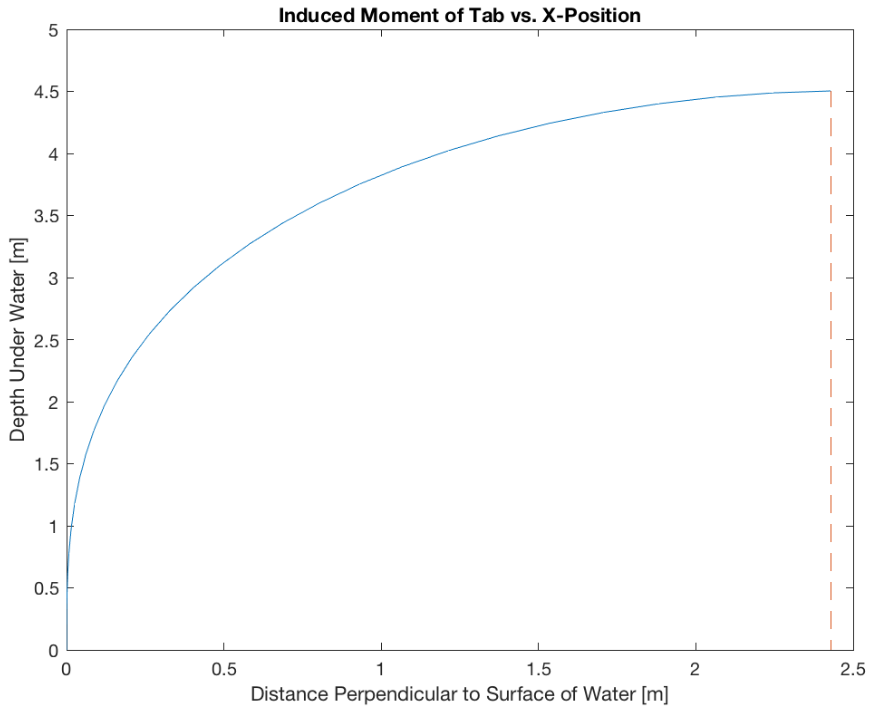


No Parachute on Top:

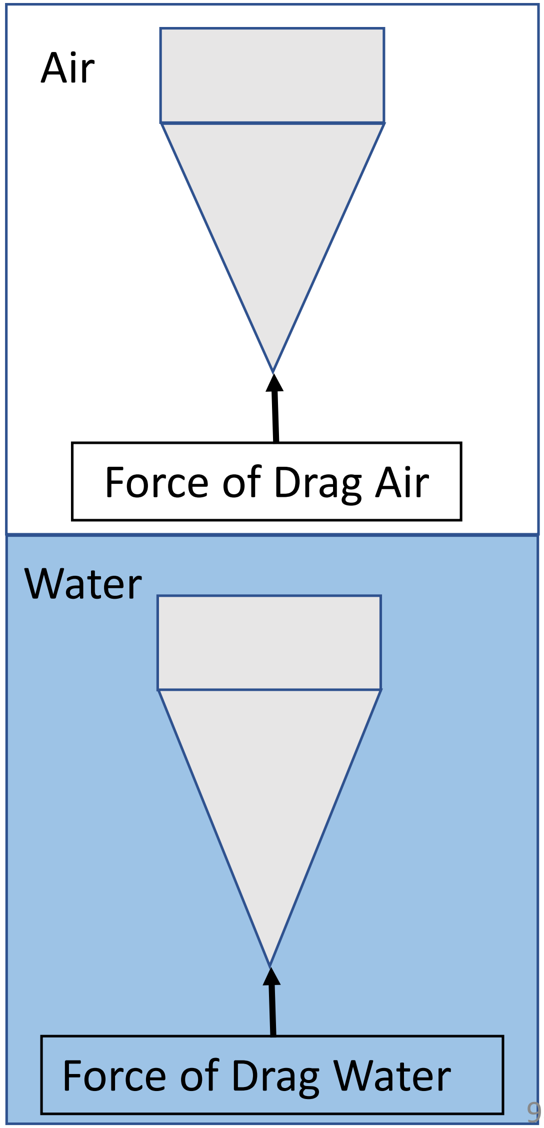
<u>Radius of Parachute:</u>

- 0.152

Distance Tr



Electronics Survival (Back of Envelope)



To give a rough estimate we can approximate the force as the change in drag from air to water:

$$\Delta D = D_w - D_A$$
$$D = \frac{1}{2}\rho V^2 C_d A$$
$$\Delta D = \frac{1}{2} V^2 C_d A(\rho_w - \rho_A)$$
$$A = \frac{\pi}{4} D^2$$
$$\Delta D = 48.4\ [N]$$
$$a = \frac{F}{m}$$
$$a = 77.4 \left(\frac{m}{s}\right) = \mathbf{7.9(G)}$$

<u>Constants:</u>

$$\rho_w = 1024\ (kg/m^3)$$
$$\rho_A = 1.225\ (kg/m^3)$$
$$D = 0.072\ (m)$$
$$C_d = 0.18\ (m)$$
$$V = 9.48\ (m/s)$$

Adhesive Shear Stress Analysis

Finding the minimum height needed for Loctite 496 Adhesive:

$$\sigma = \frac{F}{A_{cross}} = 65\ (psi)$$

$$A_{cross} = \frac{\pi}{4}(D_o^2 - D_i^2)$$

$$F = \sigma A_{cross} = 326.5\ (N)$$

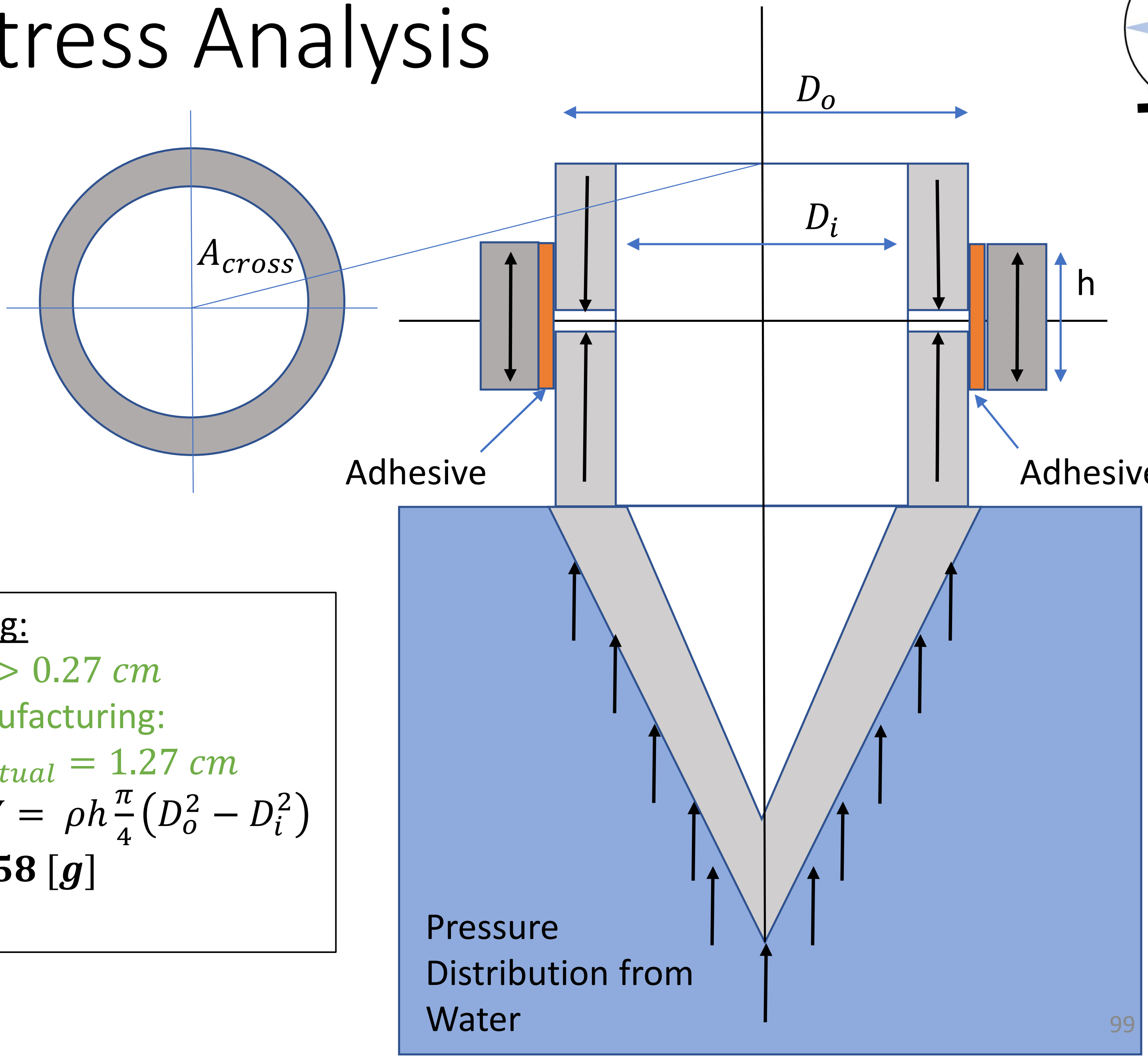
$$\tau = \frac{F}{A_{surface}}$$

$$A_{surface} = \pi D h$$

$$h = \frac{F}{\tau \pi D}$$

$$\tau_{glue} = 5\ MPa$$

$$h = 0.27\ cm$$

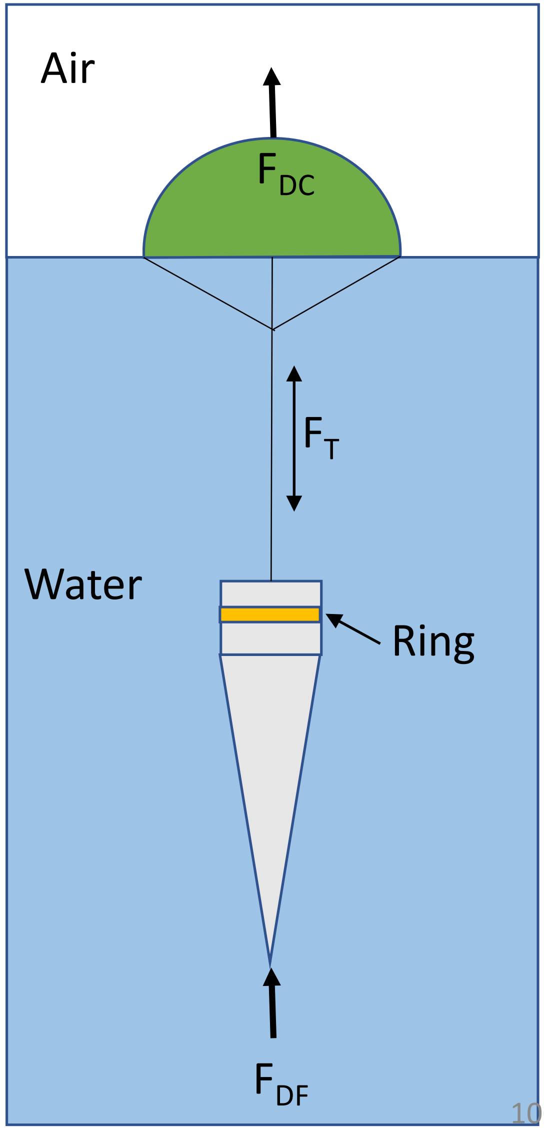


<ins>Mass of Ring:</ins>

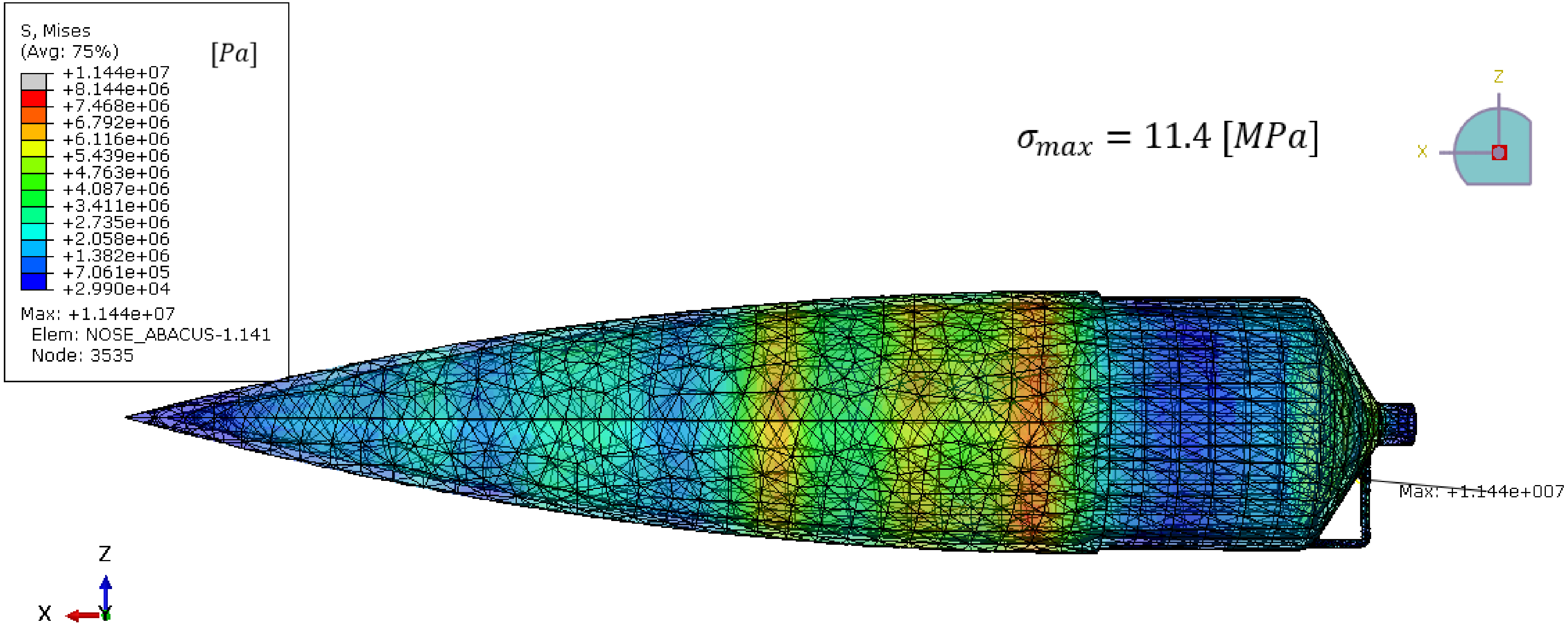
- $h_{actual} > 0.27\ cm$
- For manufacturing:
  - $h_{actual} = 1.27\ cm$
- $m = \rho V = \rho h \frac{\pi}{4}\left(D_o^2 - D_i^2\right)$
- $\boldsymbol{m = 9.58\ [g]}$

Cable Tension/Glue Force

- Assume:
  - Drag forces are from body entering higher density fluid
  - V = 4 m/s
- $F_T = F_{DC} - F_{DF}$
- $F_T = \frac{1}{2}V^2 C_{dC} A_C \rho_w - \frac{1}{2}V^2 C_{dF} A_F \rho_w$
- $F_T =$ 897 N
- $\tau_{glue} = 5\ MPa$
- D = 0.0762 m
- $h_{ring} = \frac{F}{\tau_{glue}\pi D}$
- $h_{ring} =$ 0.075 cm
- $h_{ring} < h_{actual} =$ 0.075 cm < 1.276 cm
- 1/16” cable rated to 2300 N in tension



Impact – No Parachute



$$\sigma_{max} = 11.4\ [MPa]$$

$$40\ [MPa] > 11.4\ [MPa] \Rightarrow \sigma_{yield} > \sigma_{max}$$

Induced Moment on Tab and Trajectory

- Moment will cause a change in path angle

$$\alpha = \frac{M}{I} \rightarrow M = R\ D_{tab} \rightarrow \alpha = \frac{R\ D_{tab}}{I}$$

$$\frac{d^2\theta}{dt^2} = \frac{R\ D_{tab}}{I}$$

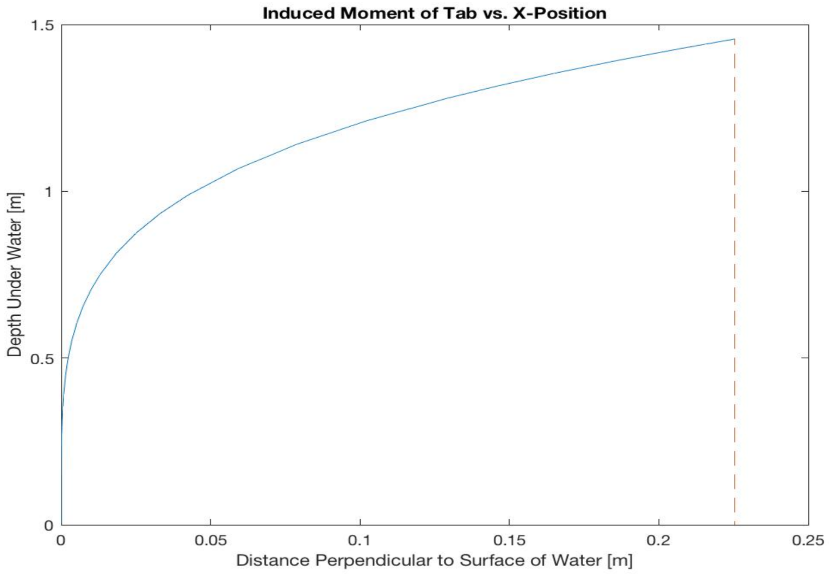
- We can now solve for θ and relate that to the velocity:

$$\vec{v} = |v|\langle \sin\theta \mid \cos\theta \rangle$$

- Velocity will change due to force of drag, gravity, and buoyant force

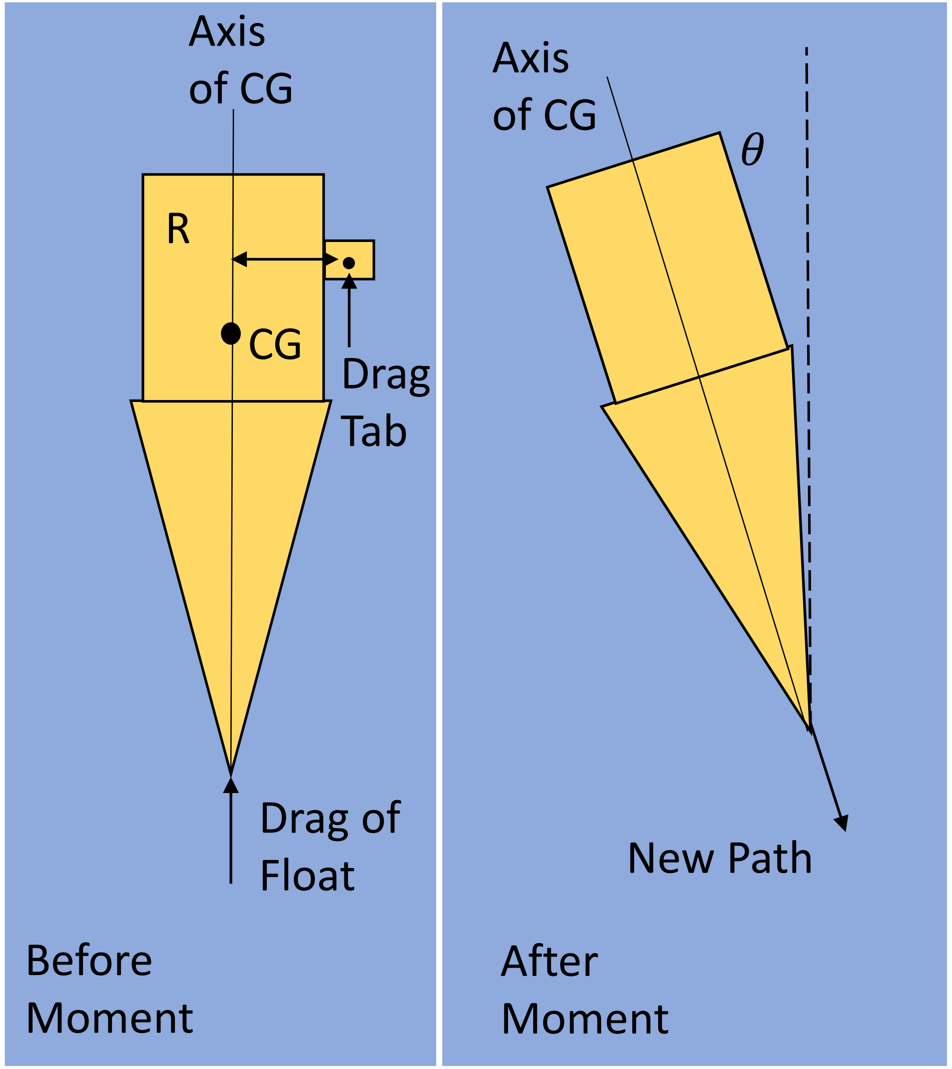
$$\mathrm{m}\frac{d^2v}{dt^2} = -D_{tab} - D_{float} - \ \rho_w V_{disp} cos\theta + mgcos\theta$$

- Parachute trails by 1.45 meters, so we need to find the horizontal distance traveled before parachute impact



<u>Radius of Parachute</u>: 0.15 [m]
<u>Horizontal Distance Traveled:</u> 0.225 [m]

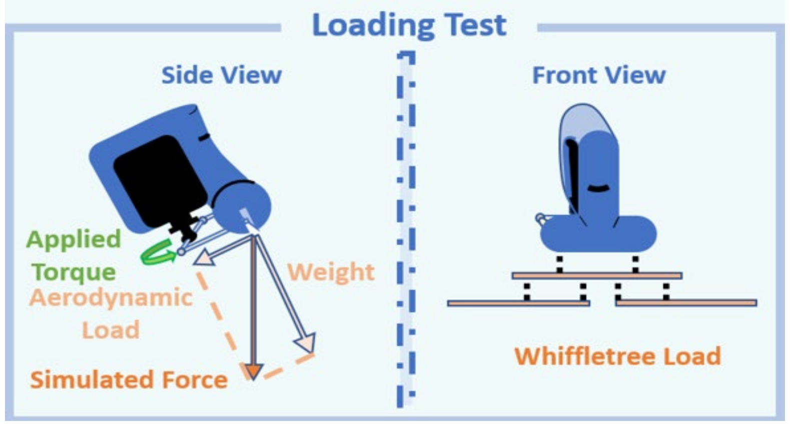
0.225 [m] > 0.15 [m] Parachute will not land on float



DM: Linear Actuator Force Test

Anticipated Date: February 4th

Motivation	Expected Results	Action for Test Failure
Validate frictional force analysis	LA can overcome the frictional force due to the drifter weight and aerodynamic loads	Use a LA that can produce more force. Add lubrication to the pin.



Test set-up: Clamp DM to table and load it with a dummy weight. Then activate the linear actuator to release the dummy weight

Backup: Electronics

Component Overview

Features	Description
Power	3V – 5V @ 10 mA
Serial Interface	5x USART 2x SPI 2x I2C
Internal Timers	21x Timers
Non-volatile Memory	64 Kbytes of flash program 6 Kbytes EEPROM 20 Kbytes of RAM
Cost	$46.5

STM32L0

Features	Description
Power	5V@ 450 mA
Serial Interface	1x UART
Serial Interface	RS-232
Baud Rate	9600 bps
Cost	$200
Weight	26 g

Component Overview

Features	Description
Power	3V – 5V @ 1 uA
Frequency	DC to 4 GHz
Insertion loss	0.7 dB
Type	Switch ,SPDT
Cost	$107
Weight	2.5 g

HMC544A / 544AE
RF Switch

Features	Description
Power	3.6 V@ 100 mA
Serial Interface	1x UART
Serial Interface	RS-232
Baud Rate	9600 bps
Cost	$16.99
Weight	4.5 g

NEO-6M Ublox
GPS Module

Component Overview

Features	Description
Frequency	1575 MHz to 1621 MHz
Gain	5 dBi
Type	Active
Polarization	RHCP
Cost	$6.88
Weight	5 g

CGIP 25.4.A.02

Features	Description
Power	3V @ 20 mA
Gain	16.5 dB
Type	LNA with Pre-filter
Cost	$ ~ 10
Weight	23 g

Low Noise Amplifier
SKY65715-81

Stm32L0

- Ultra low-timer clock
- Dynamic Voltage Scaling
- Power efficient best for batteries and energy harvesting

- Cost: $46.50
- Weight: 4.1 g
- Volume: 235.2 mm³

Iridium 9603

- Smallest form factor of any commercial satellite transceiver today
- Single Board transceiver with Global Coverage
- No sim card required

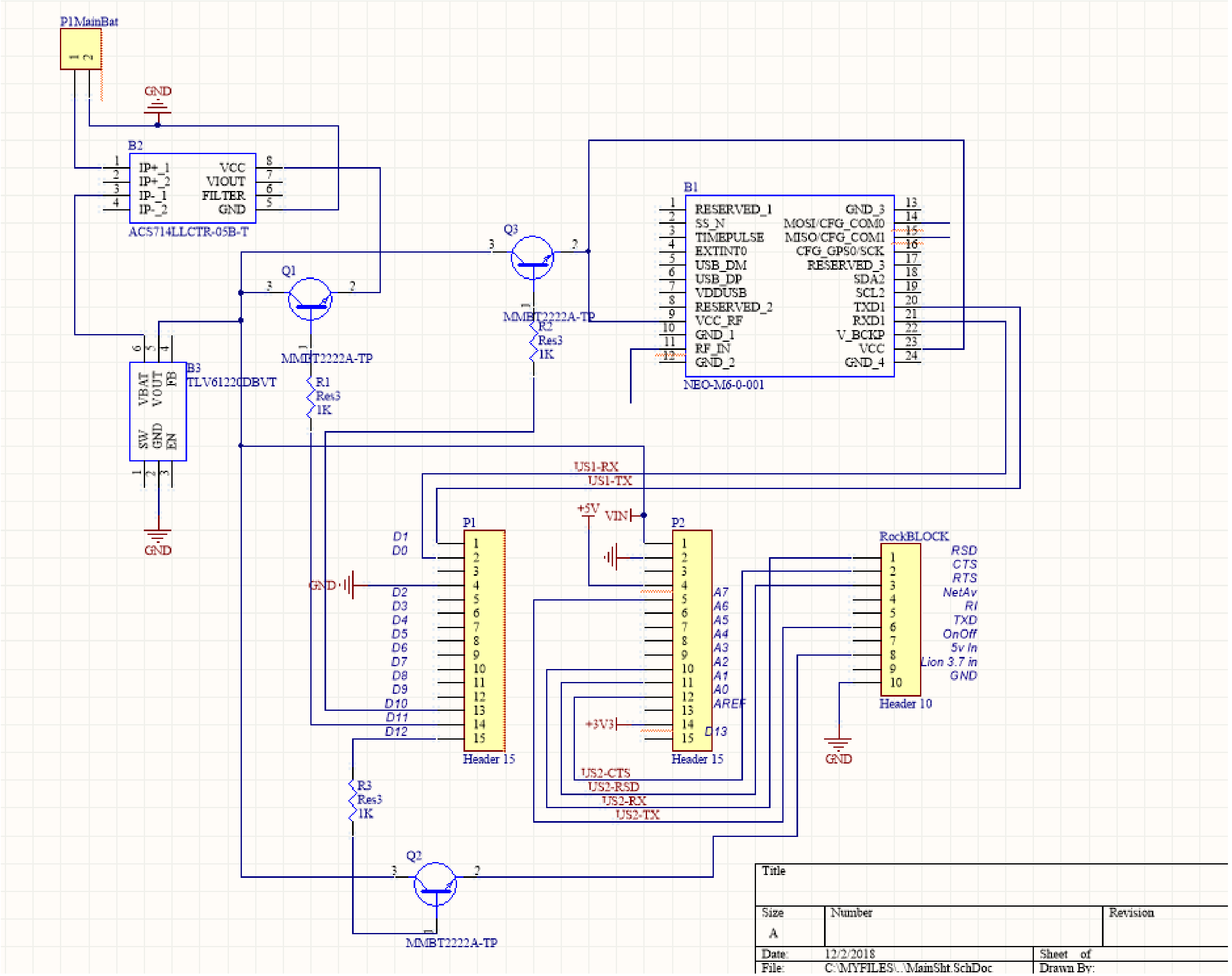
- Cost: $200.00
- Weight: 11.4 g
- Volume: 7552.4 mm^3

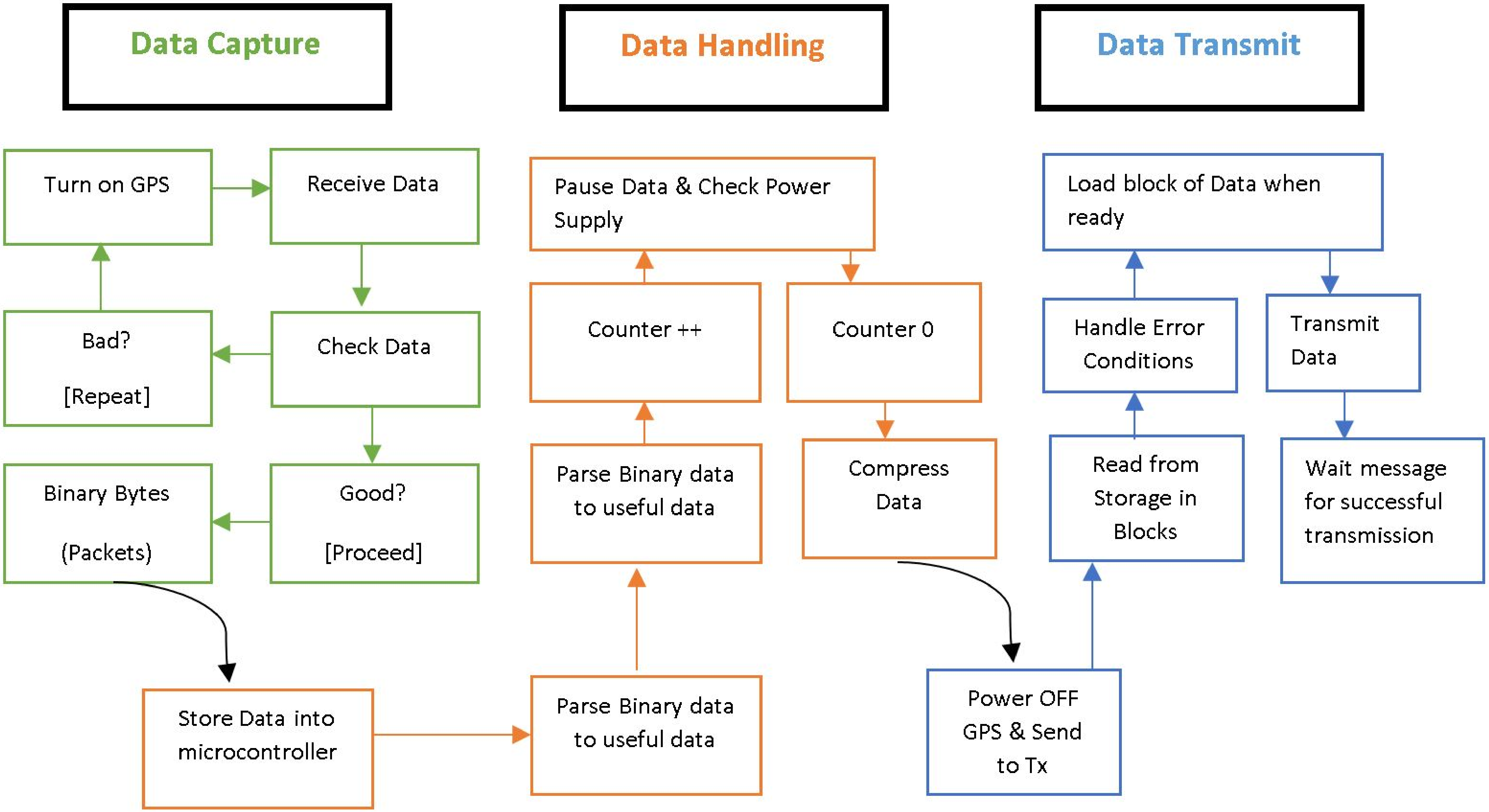
Ublox Neo-6m

- Position Engine fitted into miniature form NEO (strict size)
- Low cost for it’s size and peak performance
- Inspection and testing is conducted for reliability/endurance
- Industry standard worldwide

- Cost: $11.37
- Weight: 16 g
- Volume: 508.8 mm³

Detailed Pin Configuration





Data Capture

Data Handling

Data Transmit

Turn on GPS

Receive Data

Check Data

Bad?

[Repeat]

Good?

[Proceed]

Binary Bytes

(Packets)

Store Data into microcontroller

Parse Binary data to useful data

Parse Binary data to useful data

Counter ++

Pause Data & Check Power Supply

Counter 0

Compress Data

Power OFF GPS & Send to Tx

Read from Storage in Blocks

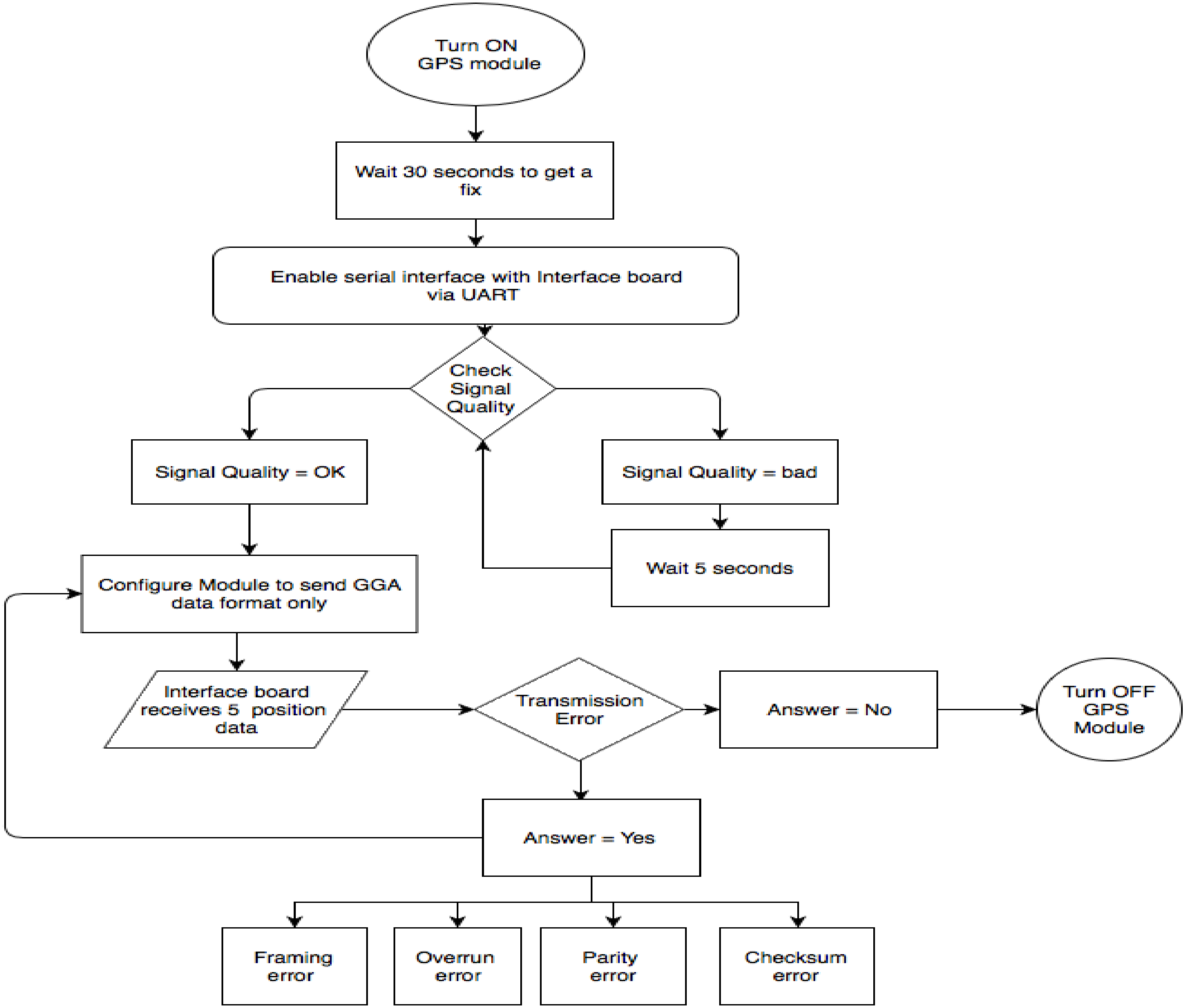
Handle Error Conditions

Load block of Data when ready

Transmit Data

Wait message for successful transmission

GPS Software Interface Plan



Turn ON GPS module

Wait 30 seconds to get a fix

Enable serial interface with Interface board via UART

Check Signal Quality

Signal Quality = OK

Signal Quality = bad

Wait 5 seconds

Configure Module to send GGA data format only

Interface board receives 5 position data

Transmission Error

Answer = No

Turn OFF GPS Module

Answer = Yes

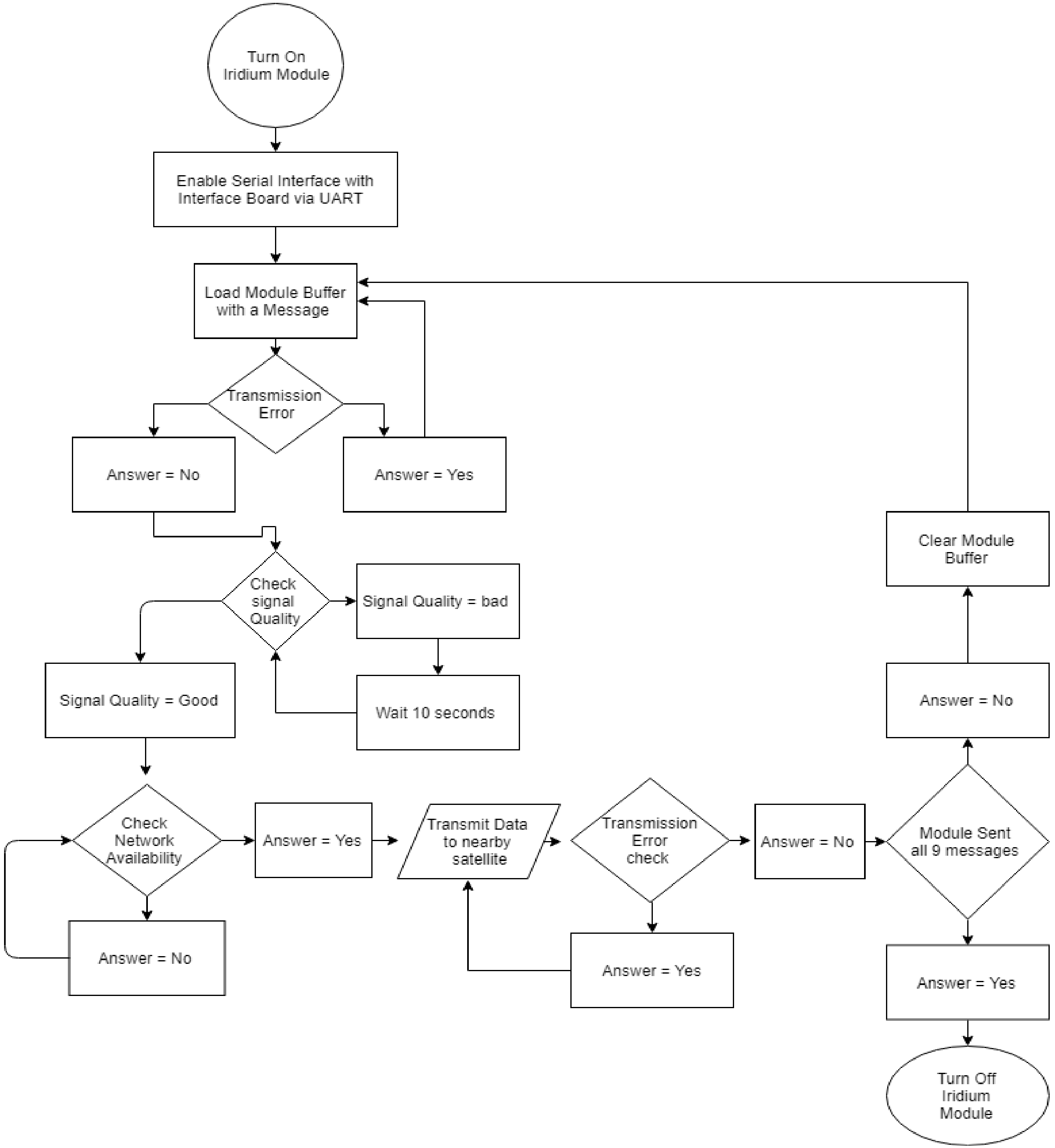
Framing error

Overrun error

Parity error

Checksum error

Iridium Rockblock software Interface Plan



Turn On Iridium Module

Enable Serial Interface with Interface Board via UART

Load Module Buffer with a Message

Transmission Error

Answer = No

Answer = Yes

Check signal Quality

Signal Quality = bad

Wait 10 seconds

Signal Quality = Good

Check Network Availability

Answer = No

Answer = Yes

Transmit Data to nearby satellite

Transmission Error check

Answer = Yes

Answer = No

Module Sent all 9 messages

Answer = No

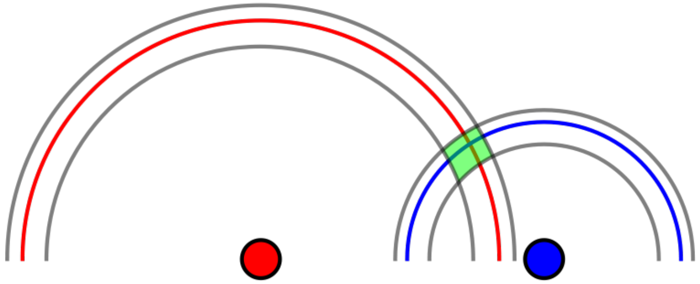
Clear Module Buffer

Answer = Yes

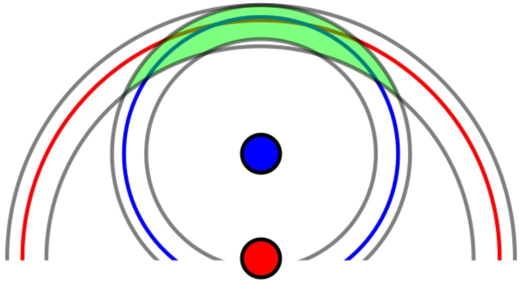
Turn Off Iridium Module

Data Compression: Error Estimate

Horizontal Dilution of Precision (HDOP)



Low HDOP



High HDOP

- Empirical Formula relating root mean squared error in meters to HDOP

$$\boldsymbol{Error_{RMS}} = \sqrt{(\boldsymbol{A} \cdot \boldsymbol{HDOP})^2 + \boldsymbol{B}^2}$$

  - where: A = 3.04 [m], B = 3.57 [m]

Data Compression: Flags

Character	Significance	Binary
V	Questionable vertical accuracy	0001
Q	Low positional quality	0010
N	Insufficient number of satellites (< 4)	0100
P	Low Power	1000

- Total Flag is sum of individual flags, reported as hexadecimal

Hex	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
V	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Q	0	0	1	1	0	0	1	1	0	0	1	`	```	0	1	1
N	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
P	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Data Compression: Flags

- Quality Indicator

Value	Significance	Q
1	Uncorrected coordinate	1
2	Differentially correct coordinate	0
4	Centimeter Precision	0
5	Decimeter Precision	0

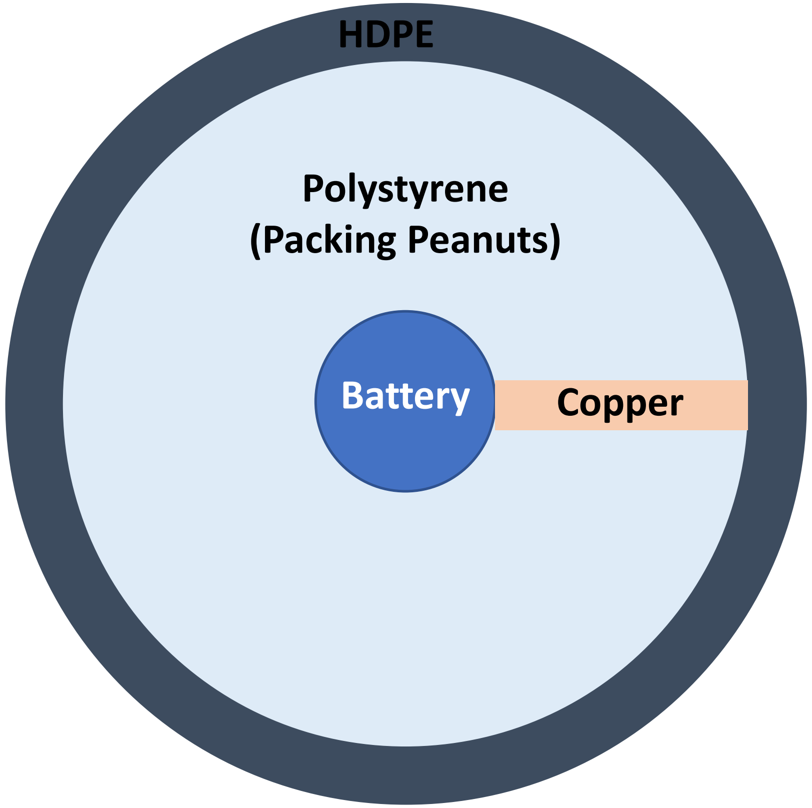
- Vertical Flag
  - Compares E_{RMS} to deviation in altitude from sea level
  - Assumes dilution of precision is similar in all directions

Thermal Model

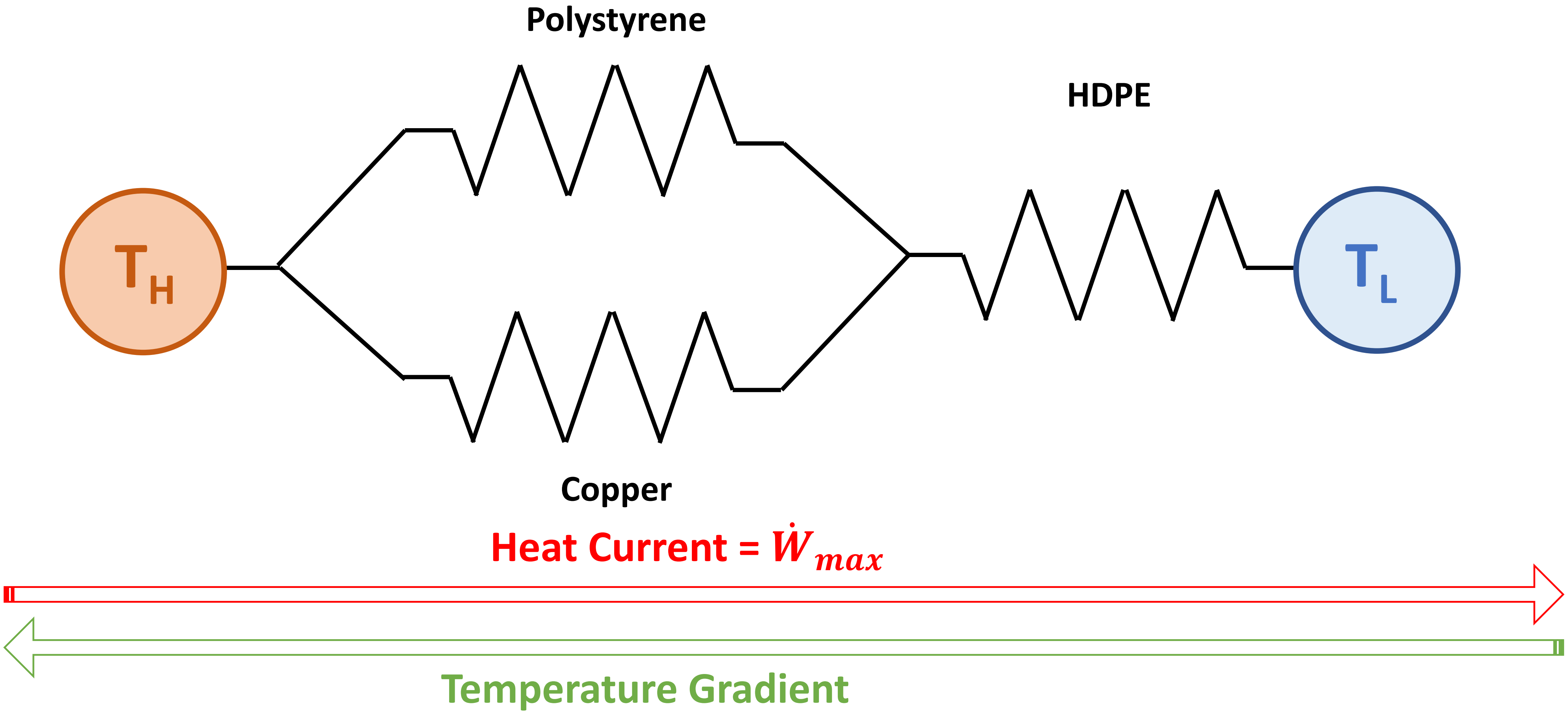
Electronics typically rated up to 85 [°C]

A detail thermal model of our electrical systems would be complex

- **Upper bound:** steady state heat current at maximum power dissipation out of centrally located battery



Thermal Model



Polystyrene

HDPE

T_H

T_L

Copper

Heat Current = $\dot{W}_{max}$

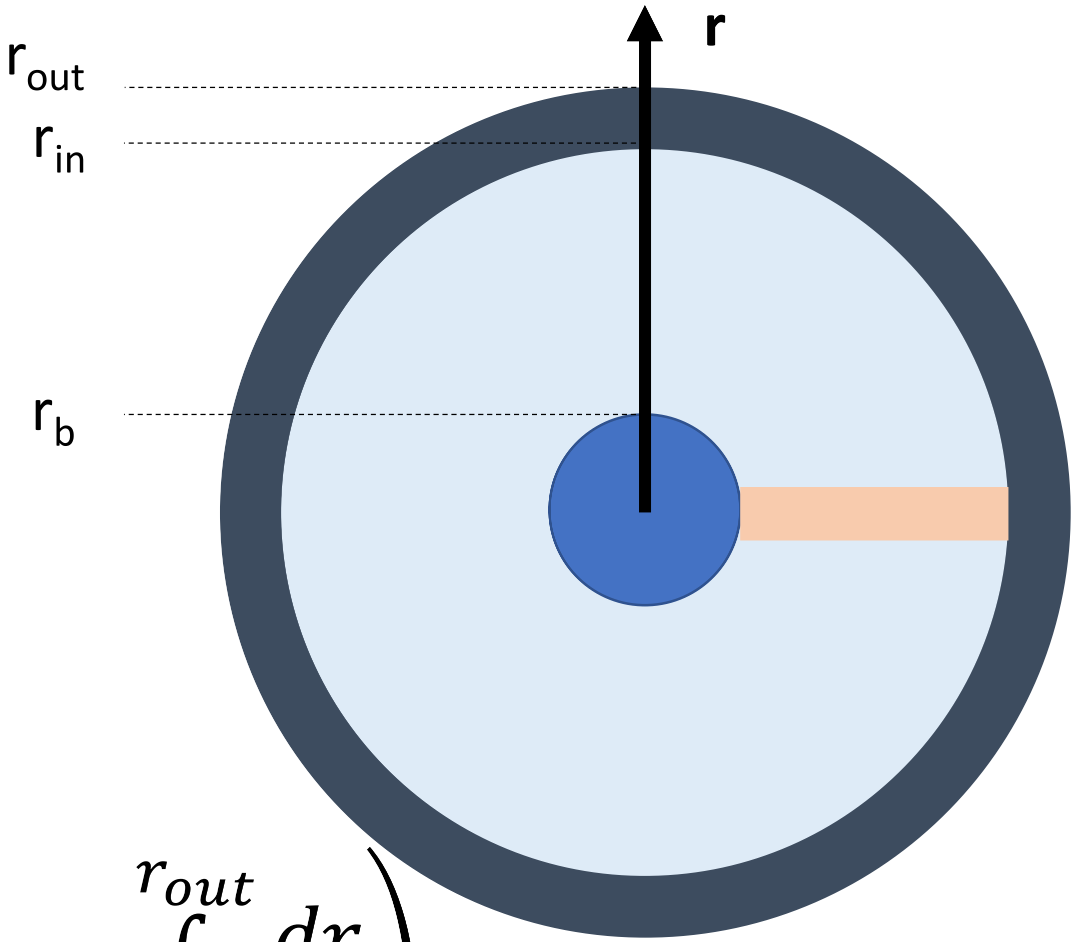
Temperature Gradient

Thermal Model

Effective Thermal Conductivity of Copper and Polystrene

$$\begin{cases} \dfrac{\dot{W}_{Cu} + \dot{W}_{Polystyrene}}{A_{Cu} + A_{Polystyrene}} = -\kappa_{eff}\dfrac{\partial T}{\partial x} \\ \dfrac{\dot{W}_{Cu}}{A_{Cu}} = -\kappa_{Cu}\dfrac{\partial T}{\partial x} \\ \dfrac{\dot{W}_{Polystyrene}}{A_{Polystyrene}} = -\kappa_{Polystyrene}\dfrac{\partial T}{\partial x} \end{cases} \Rightarrow \kappa_{eff} = \frac{(A\kappa)_{Cu+}(A\kappa)_{Polystyrene}}{A_{Cu} + A_{Polystyrene}}$$

Thermal Model



Fourier's Law

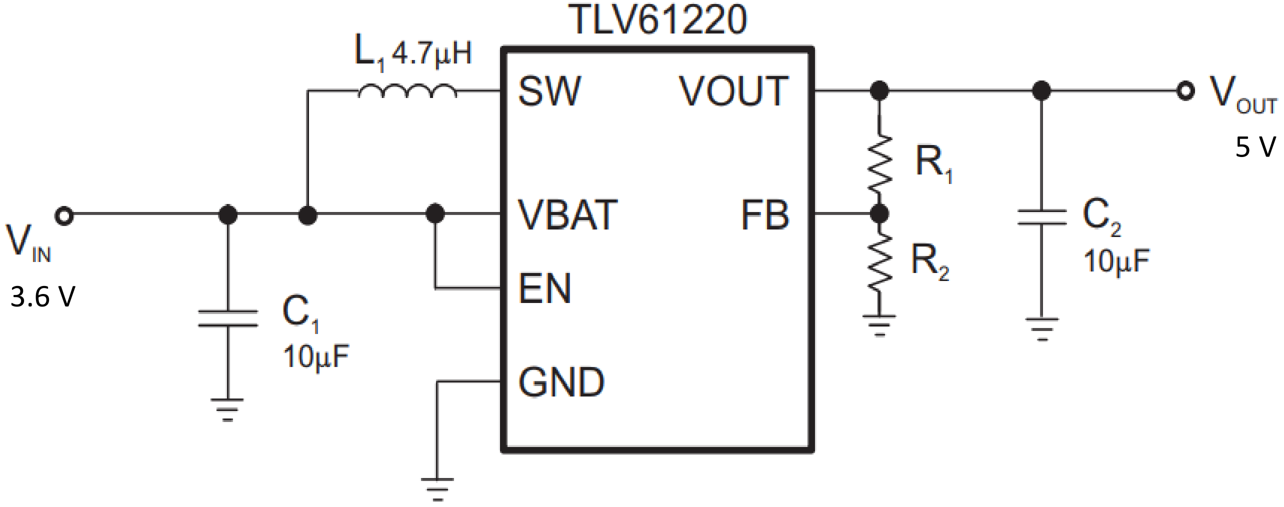
$$\longrightarrow \frac{\dot{W}_{max}}{4\pi r^2} = -\kappa \frac{dT}{dr}$$

$$\longrightarrow dT = -\frac{\dot{W}_{max}}{4\pi r^2 \kappa} dr$$

$$\longrightarrow \Delta T = -\frac{\dot{W}_{max}}{4\pi}\left(\frac{1}{\kappa_{eff}}\int_{r_b}^{r_{in}} \frac{dr}{r^2} + \frac{1}{\kappa_{HDPE}}\int_{r_{in}}^{r_{out}} \frac{dr}{r^2}\right)$$

$$\sim 4°\mathrm{C}$$

Voltage Booster



V_{R1} = 4500 mV

V_{R2} = 500 mV

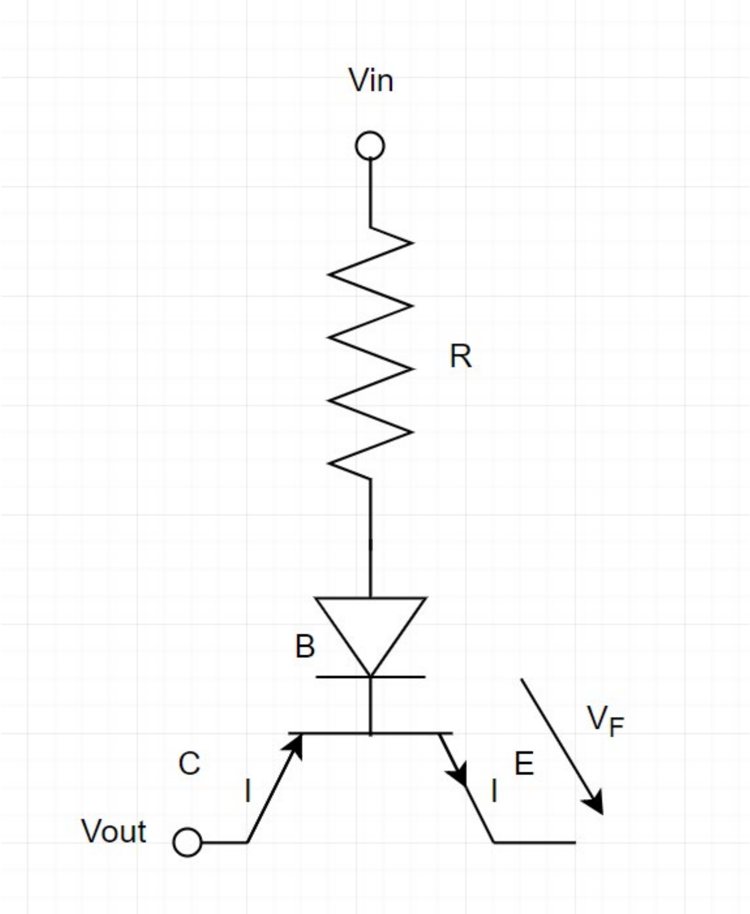
$$L = \frac{1}{f \times 200\text{ mA}} \times \frac{V_{IN} \times (V_{OUT} - V_{IN})}{V_{OUT}}$$

$$R_2 = \frac{V_1}{I_1}\left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

$$R_1 = R_2 \text{ x } \left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

$$R_1 = \frac{V_2}{I_2}\left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

Transistor



$$R_2 = \beta(\frac{V_H - V_F}{I_{Rx}})$$

$I_C = I_B * HFE$

$V_R = V_{in} - V_F$

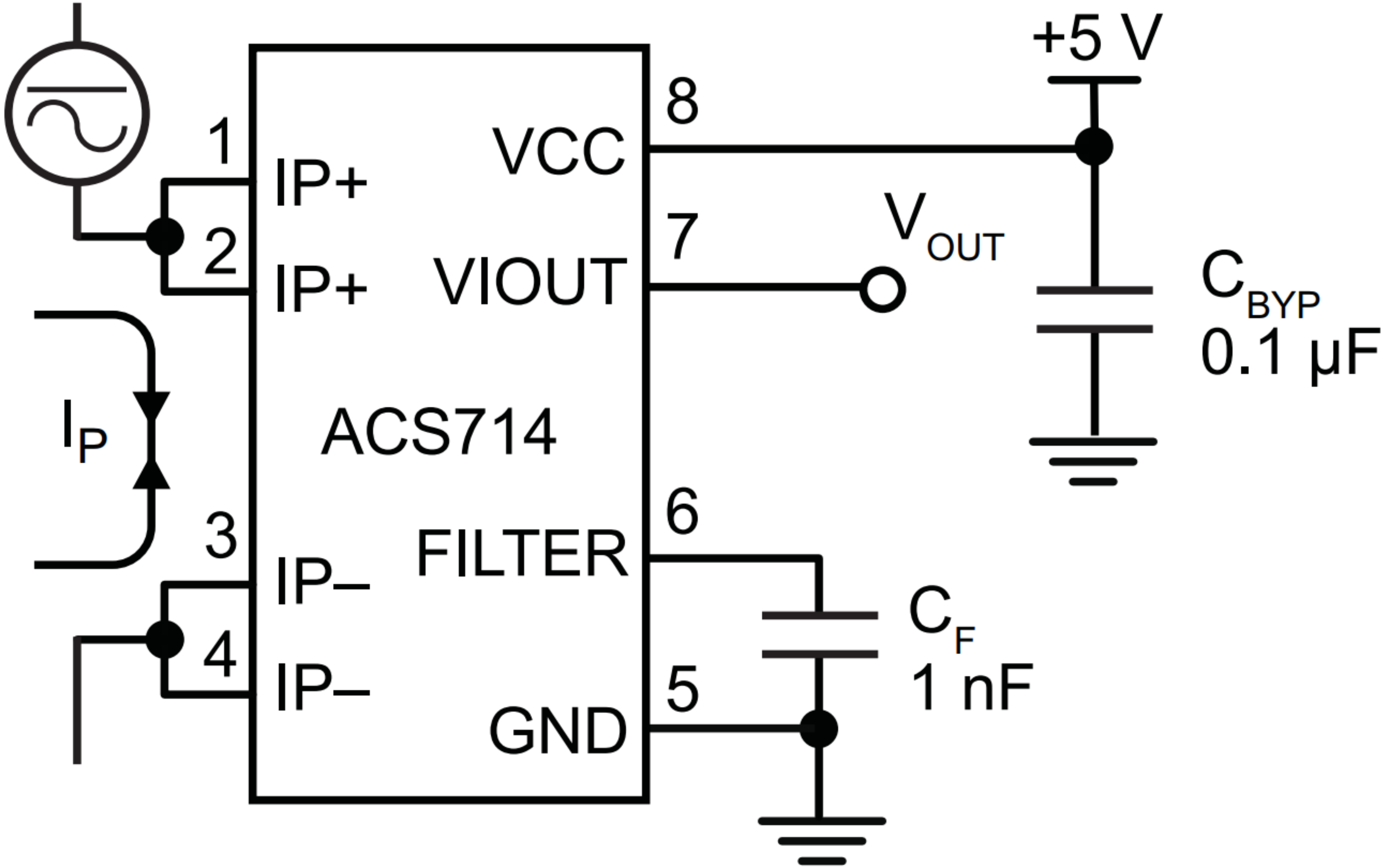
HFE： β Beta of Transistor

C： Connector

E：Emitter

B：Base

Current Sensor



1. Short circuit protection
2. Battery Drain monitoring

Deployment Mechanism

DM: Electronics

- Electronics package will consist of a microcontroller programmed to release 4 drifters individually at specified locations
- Will be located in the payload bay of the UAV
- Wires will extend from the electronics package to the DMs
- Linear actuators will be powered from the power supply provided by the UAV

FR 8.0	**The deployment mechanism system shall deploy each drifter individually**

DM: Shear Stress Analysis

KNOWNS:

- Shear Stress of Loctite 496: 5 [MPa]
- Drifter Surface Area: 0.0761 [m²]
- Density of Air: 1.1901 [kg/m³]
- Tab Surface Area: 0.00045 [m²]

ASSUMPTIONS:

- In worst case scenario, the coefficient of drag is 0.82.
- In worst case scenario, the airspeed is 32.7 [m/s].

EQUATIONS:

$$\tau = \frac{F}{A_{surface}}$$

$$F_D = \frac{1}{2} \cdot C_D \cdot \rho \cdot A \cdot V^2$$

RESULTS:

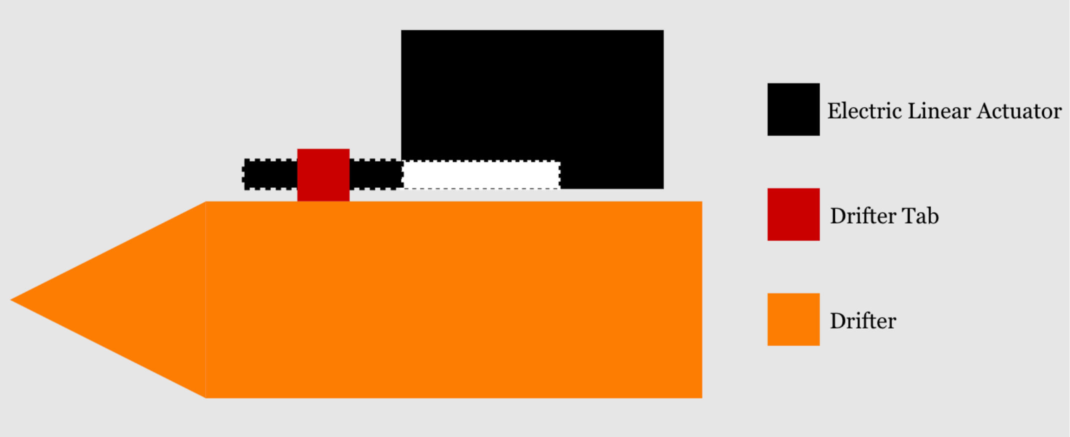
- F = 2250 [N]
- F_D= 39.72 [N]

$$F_D < F$$

DM: Electric Linear Actuator Friction

KNOWNS:

- Applied Force: 15 [N]
- Mass of the drifter: 0.62 [kg]
- Coefficient of Friction of Nylon: 0.25



ASSUMPTION:

- Rod is massless.

EQUATIONS:

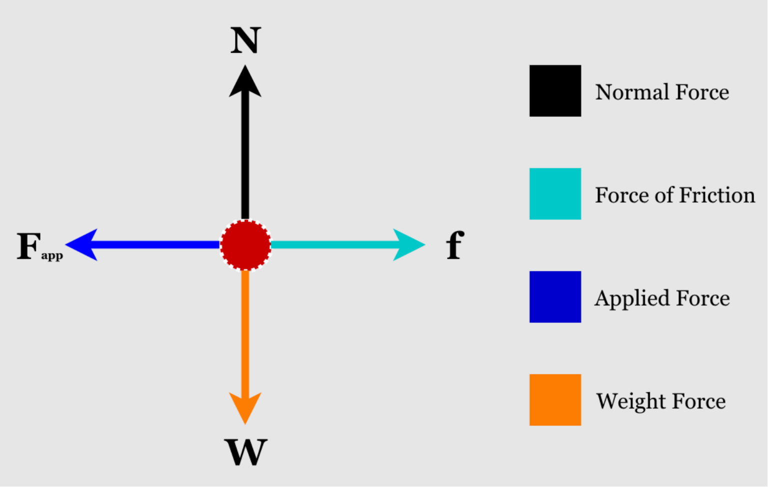
$$f = \mu \cdot N \qquad N = W = m \cdot g$$

RESULT:

- Force of friction is 1.521 [N].

$$f < F_{app}$$

FR 8.0 The deployment mechanism system shall deploy each drifter individually



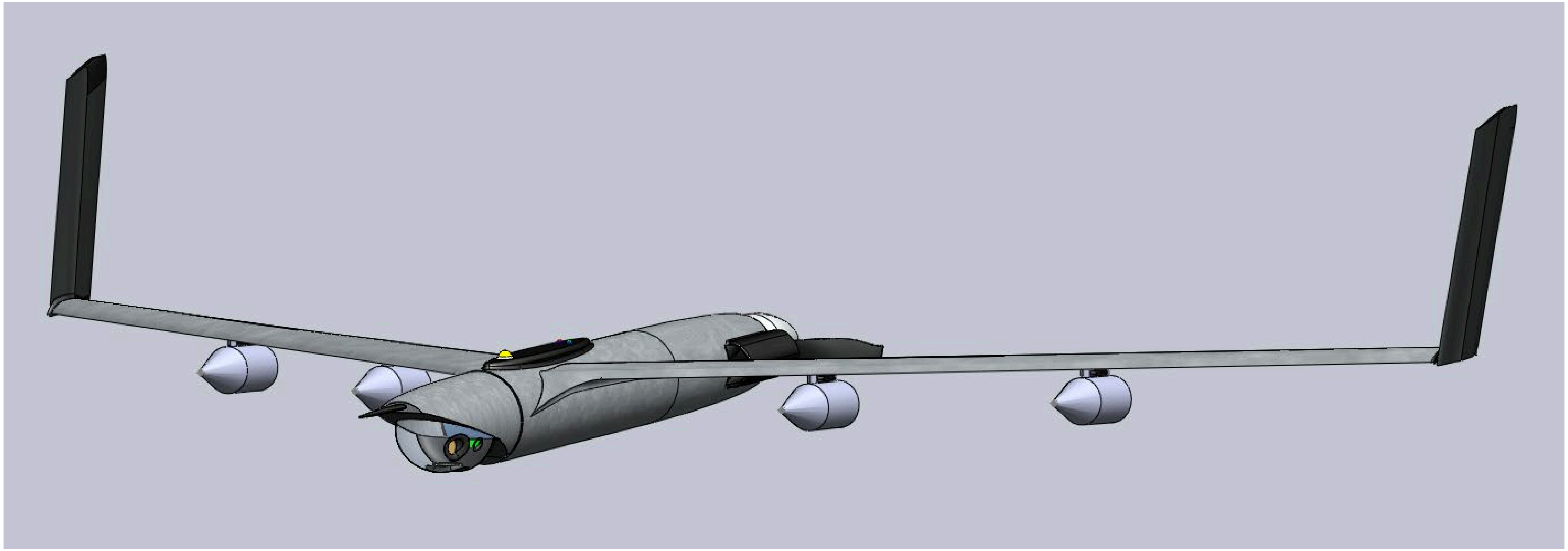
DM: Aerodynamic Analysis

KNOWNS:

- Wetted Area of the Loaded Configuration, S_{wet}: 29.82 [ft^2]
- Wetted Area of the Clean Configuration, S_{wet}: 26.28 [ft^2]
- Planform Area, S: 20.53 [ft^2]
- Correlation Coefficient a: -2.2614
- Correlation Coefficient b: 1

ASSUMPTIONS:

- ScanEagle UAV is applicable for aerodynamic analysis of the project.
- Zero-lift drag coefficient, C_{Do}, can be expressed in terms of parasite area, f, and planform area, S.

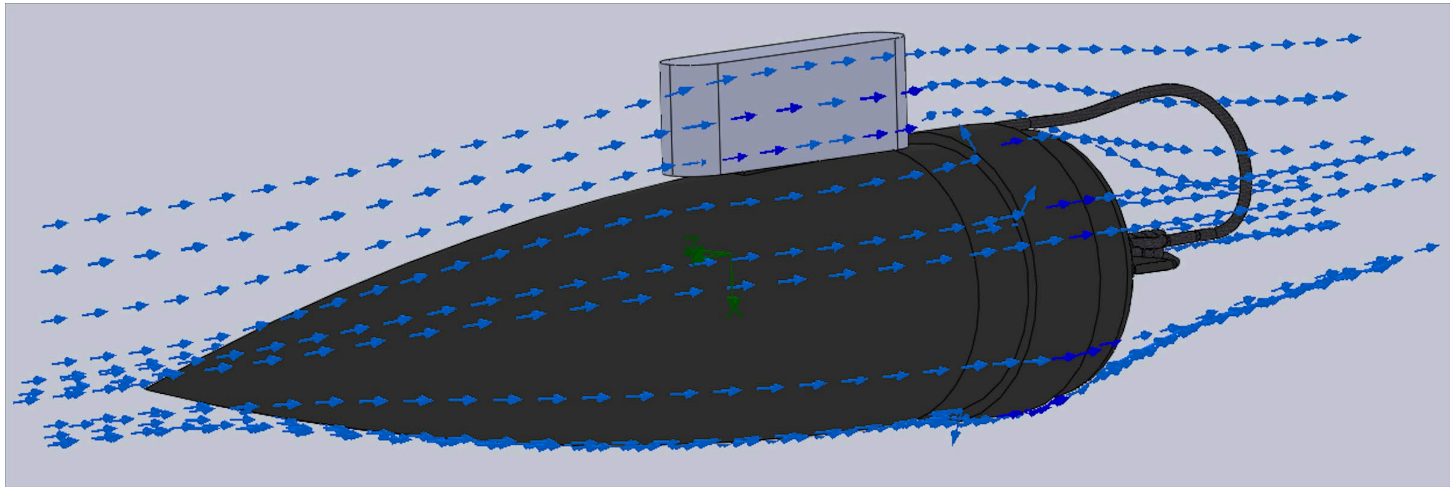


DM: Aerodynamic Analysis

EQUATIONS:

$$C_{D_0} = \frac{f}{S}$$

$$log(f) = a + b \cdot log(S_{wet})$$



RESULTS:

- Loaded Zero-Lift Drag Coefficient = 0.007959
- Clean Zero-Lift Drag Coefficient = 0.007011
- <u>13.5% increase in zero-lift drag coefficient.</u>

DM: Aerodynamic Analysis

KNOWNS:

- Velocity, V: 22 [m/s]
- Density, ρ: 1.1901 [kg/m^3]
- Planform Area: 1.90695 [m^2]
- Oswald's Efficiency Factor, e: 0.85
- Aspect Ratio, AR: 0.85
- Range of ScanEagle, R: 1300 [miles]

EQUATIONS:

$$C_L = \frac{L}{q \cdot S}$$

$$q = \frac{1}{2} \cdot \rho \cdot V^2$$

$$C_D = C_{D_0} + \frac{C_L^2}{\pi \cdot AR \cdot e}$$

$$R = \frac{1}{c_t} \cdot \sqrt{\frac{8}{\rho \cdot S}} \cdot \left(\frac{\sqrt{C_L}}{C_D}\right) \cdot \left(\sqrt{W_1} - \sqrt{W_2}\right)$$

ASSUMPTIONS:

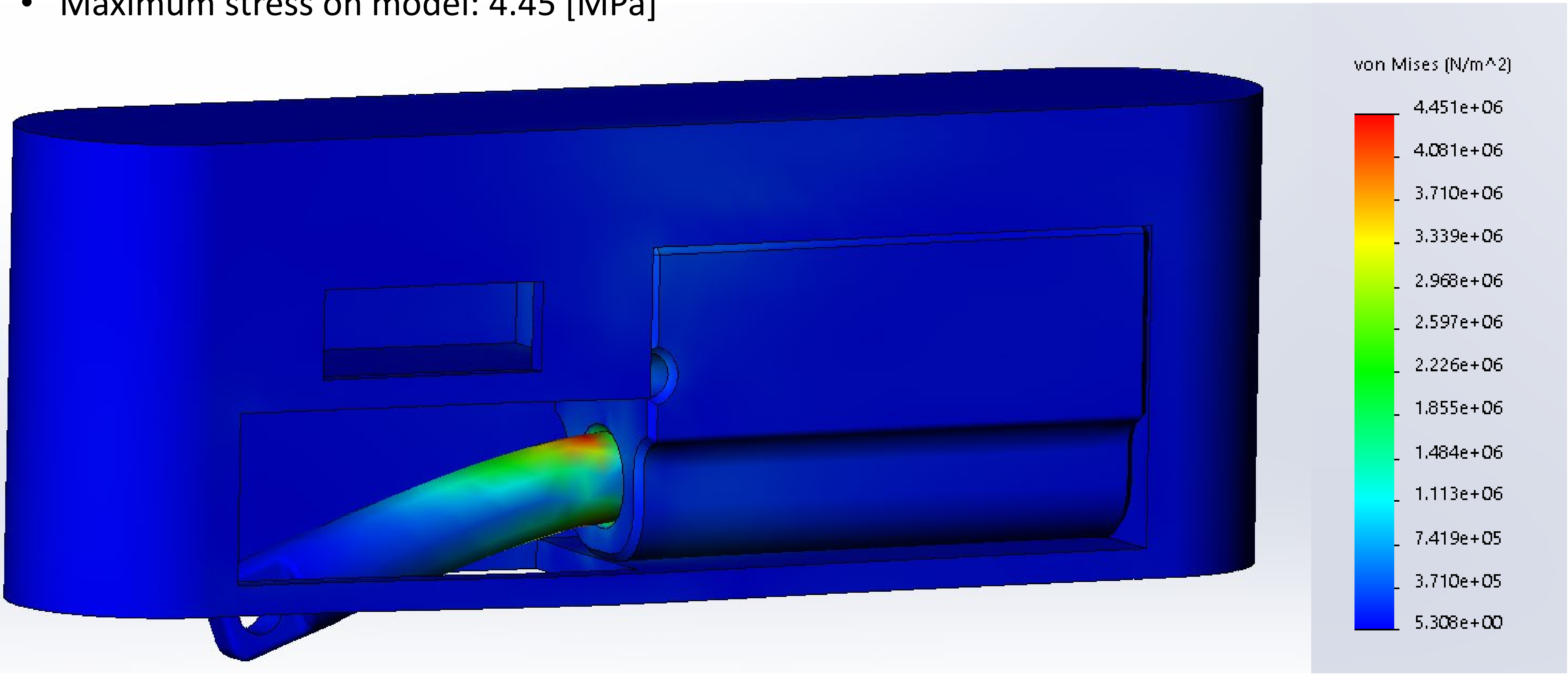
- Steady level flight
- Range is inversely proportional to the coefficient of drag.

RESULTS:

- Loaded Coefficient of Drag = 0.01564
- Clean Coefficient of Drag = 0.01469
- 6.47% increase in coefficient of drag.
- 6.47% decrease for the range of UAV.
- There will be about 84 miles decrease in the range.

DM: Stress Analysis

- Maximum yield strength of Nylon: 50 [MPa]
- Maximum stress on model: 4.45 [MPa]



DR 3.1	The drifter shall maintain full structural integrity after impact with water
DR 3.2	The drifter shall maintain full component functionality after impact with water

Current Predictive Models: What Are We Looking For? What Models Do We Have?

Velocity before Impact → Velocity ODE Goes Here

Force at Impact → Force Equation Goes Here

Acceleration at Impact

Abaqus