Preliminary Design Concept Review

FaLling Aerogel Re-entry Experiment (FLARE)

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December 8th, 2022

FLARE Mission Statement

To develop a Low-Cost Access to Space (LCAS) mission concept that demonstrates the successful deployment and retrieval of low-density ‘space dropsondes’ from a commercial reusable launch vehicle.

Presentation Outline

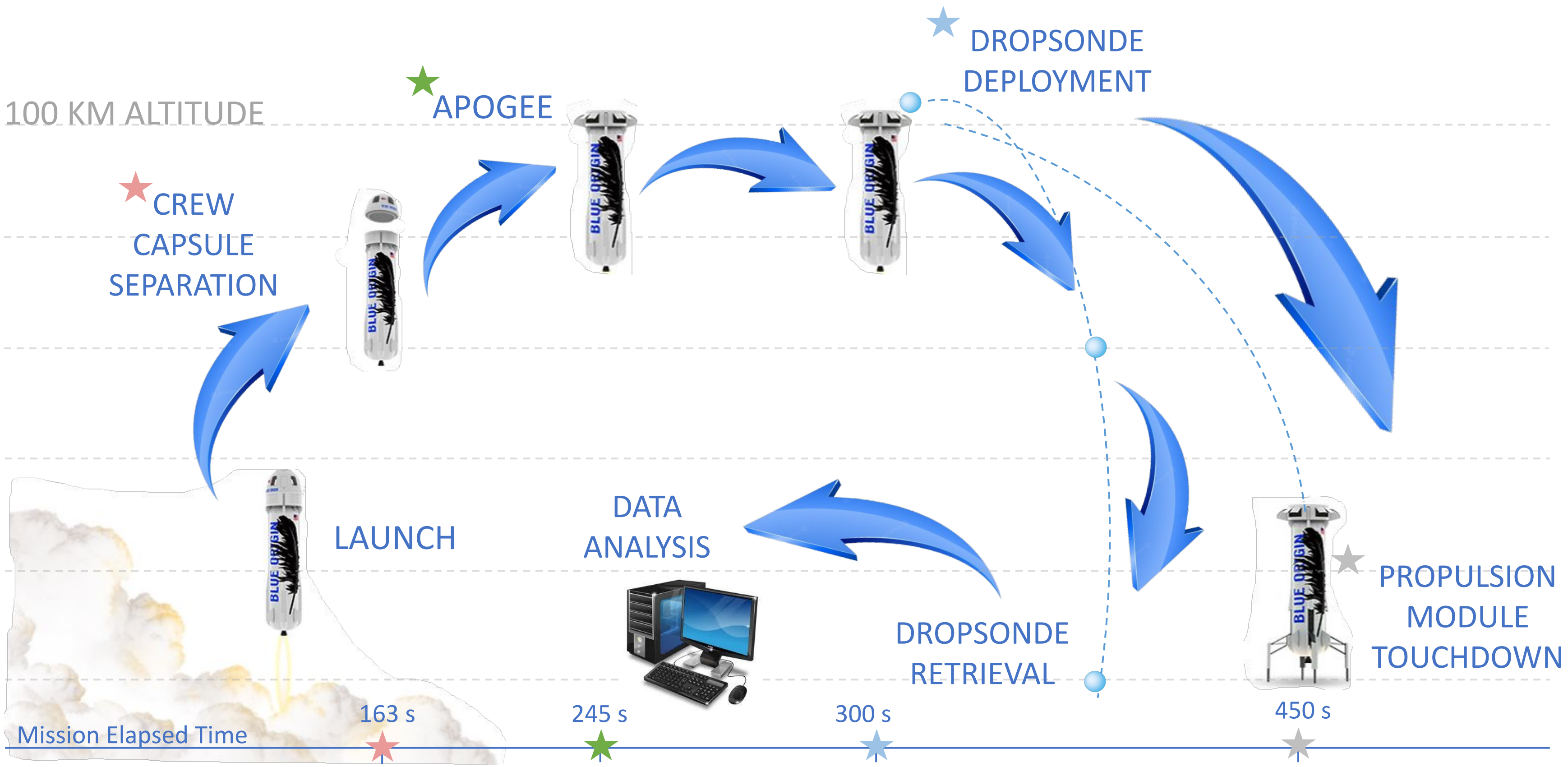
Introduction

Motivation:

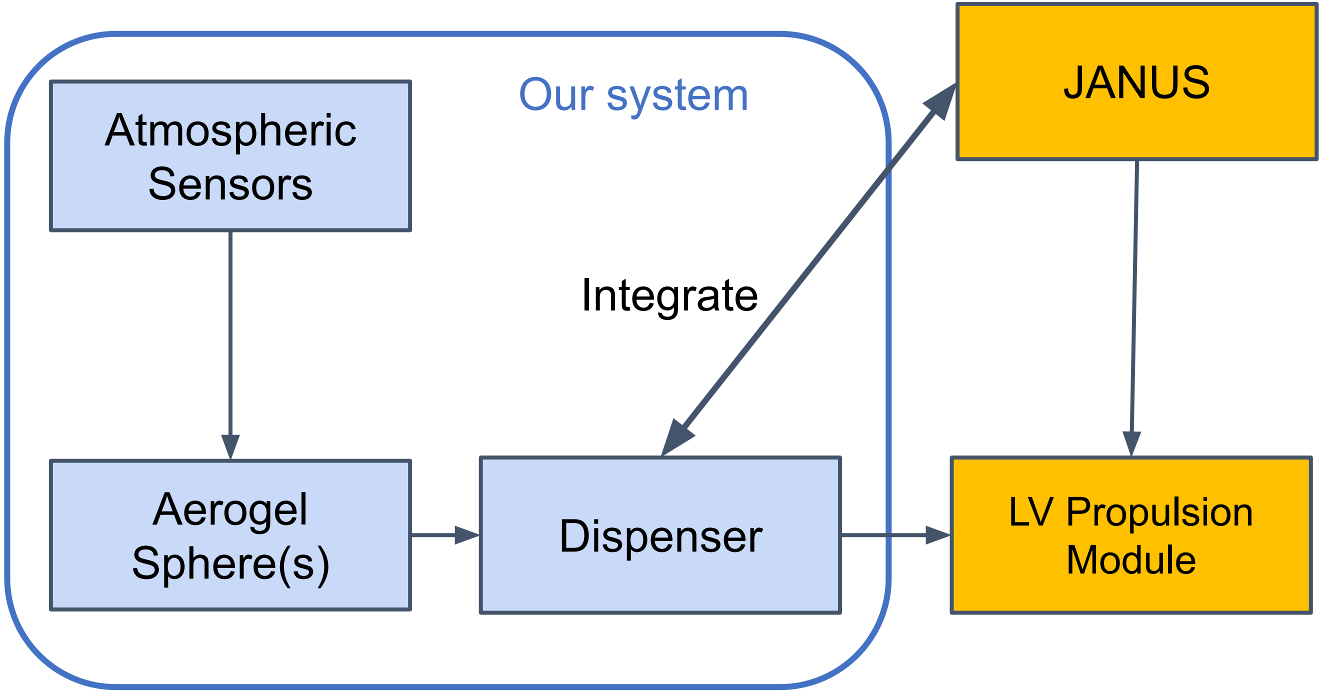
- Current best method to perform sub-orbital high-altitude research is to use sounding rockets ($$$)
- Using private sector short duration space flights (Blue Origin, Virgin Galactic) for collecting science data in addition to primary tourism mission is an appealing option

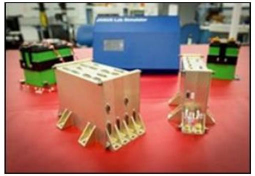
Project Concept:

- Aerogels (NASA, other sources) are low-density solid polymer foams that exhibit strong relative mechanical and thermal properties
- Electronics encapsulated within aerogel (‘dropsondes’) could survive the forces of launch/re-entry, and be used for upper atmospheric measurements

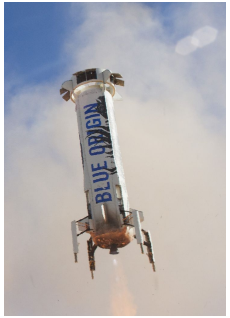

100 KM ALTITUDE
CREW CAPSULE SEPARATION
APOGEE
DROPSONDE DEPLOYMENT
LAUNCH
DATA ANALYSIS
DROPSONDE RETRIEVAL
PROPULSION MODULE TOUCHDOWN
163 s
245 s
300 s
450 s
Mission Elapsed Time

System Concept Diagram





- Power & Data storage
- Instrument control
- Ambient environment characterization
- Standard physical integration to spacecraft

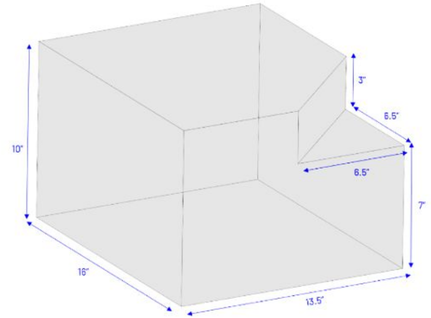


System Constraints/Expected Data

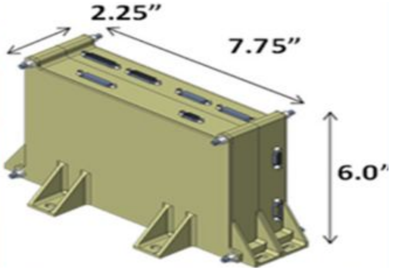
Exterior Constraints

Propulsion Module Payload must fit JANUS and Dispenser

- Propulsion Module Payload Accommodation
  - Length: 40.69 cm (16 in)
  - Width : 33.02 cm (13 in)
  - Height : 25.40 cm (10 in)



- JANUS (JHU APL Integrated Universal Suborbital Integration Platform)
  - Length: 19.685 cm (7.75 in)
  - Width: 5.715 cm (2.25 in)
  - Height: 15.24cm (6 in)



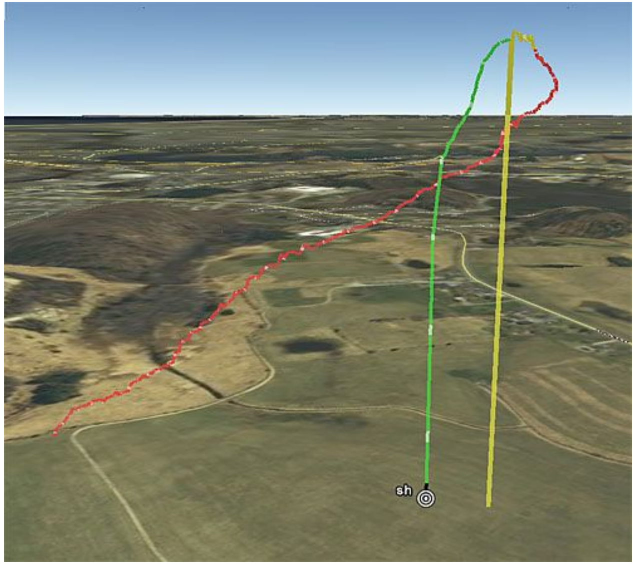
Preliminary System Requirements/MOP's

System Requirement	Measure of Performance (MOP)
Survive Suborbital Flight and Landing - Dispenser	Dropsonde deployer shall survive anticipated launch environments while protecting aerogel dropsondes until deployment
Survive Suborbital Flight and Landing - Dropsonde	Aerogel dropsondes shall protect all internal electronics from the forces of launch, reentry and landing
Successfully Integrate with PM/APL Units	All mission components including the dropsondes and deployer shall successfully integrate with the PM and JANUS unit
GPS Location Data	Dropsonde spheres shall take and transmit location data in the altitude range of 50-100 km
Achieve Total Prototype Development Cost <$5,000	The total prototype system cost (dropsondes, deployer, testing, etc.) shall be <$5,000

Background Science/Expected Data

- GPS measurements taken at predetermined time intervals and stored onboard the probe
- Dropsonde GPS receiver/transmitter system will relay probe location to a ground station for guided locating
- Information such as wind velocity and atmospheric density based on dropsonde acceleration can be backed out of location info

$$F_D = ma_D = \frac{1}{2}\rho_a v^2 C_D A$$



Deployer Concept Designs

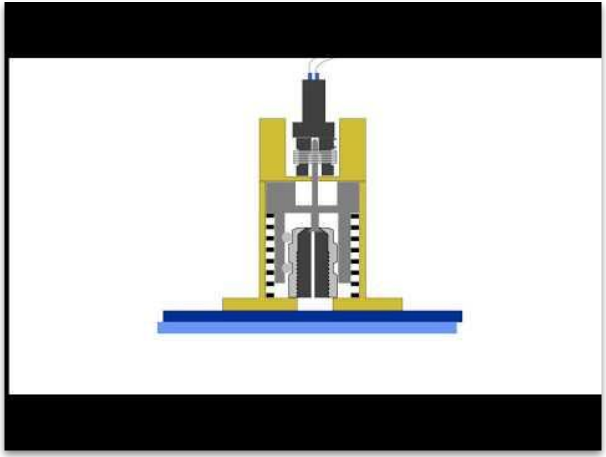
Deployer Concept Mechanical Design

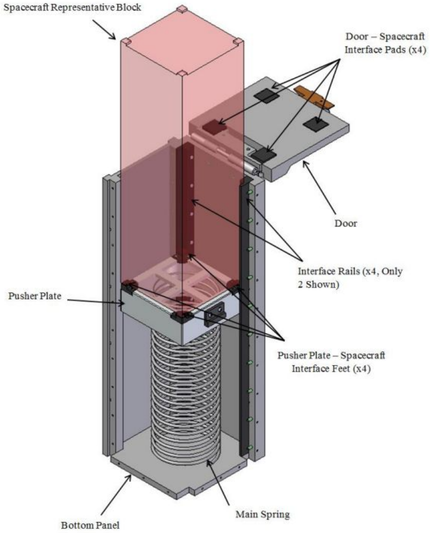
- To make the system easily manufacturable and flexible for different launch platforms, each dropsonde will be stored in it's own 'container'
- Each container includes a linear actuator or spring system for probe deployment, internal systems for keeping the probe in place during launch, and an electromechanically actuated lid
- Prototypes will be 3D printed, and a final revision would be machined (likely out of Aluminum)

1U Cubesat deployer with open lid, similar design to proposed dropsonde deployer concept

Heritage Release Mechanisms

- Frangibolt, TiNi, other market non-explosive actuator (NEA) devices exist, commonly used in CubeSat deployment
- Preloaded spring attached to pusher plate would accelerate dropsonde/container away from the launch vehicle
- Dropsonde container guided with internal deployer rails





Deployer Concept Mechanical Design

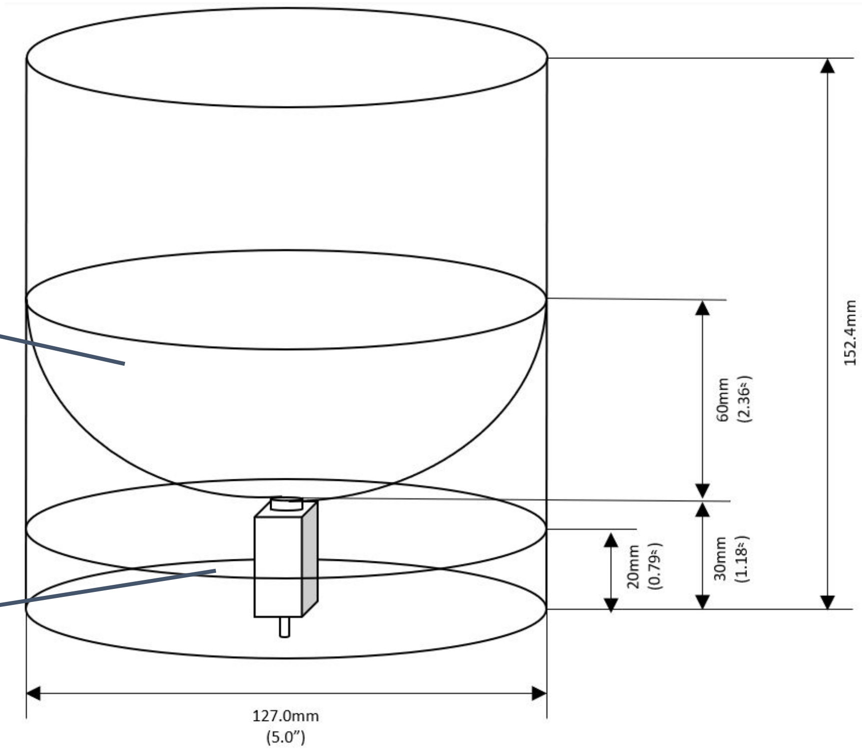
- 5” diameter × 6” height
- 1 deployer for 1 dropsonde

Cup

- Contains the dropsonde
- Protects the dropsonde from the pushing force when deploying

Linear actuator & its holder

- Pushes out the dropsonde on predefined timing



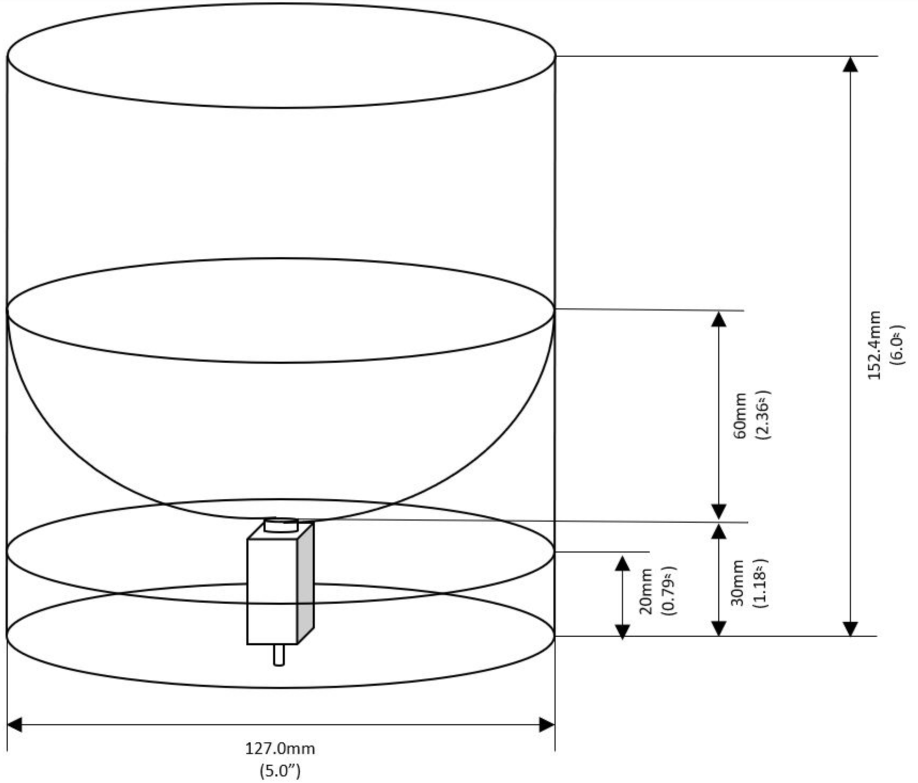
Deployer Concept Mechanical Design

Test on ground to see

- How far it pushes out the dropsonde
- Best angle to deploy

→ Decide on

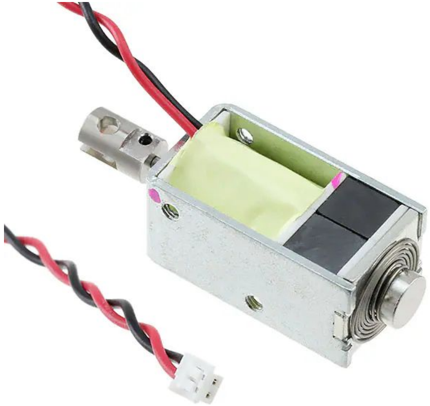
- How many linear actuators to use
- Use of spring system / other mechanisms
- The angle of the deployer / holder

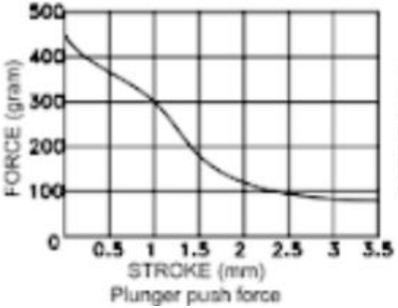


Deployer Concept Mechanical Design

Linear actuator (Latching solenoid)

- Open Frame Latching (Push)
- 1.181" L x 0.630" W x 0.551" H
- Stroke Length: 0.138" (3.50mm)
- Duty Cycle: Pulse
- Voltage: 12VDC
- Power (Watts): 32 W
- DC Resistance (DCR): 4.5Ohm
- Weight: 0.084 lb (38.1 g)





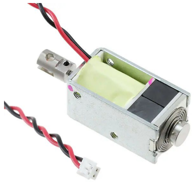
Deployer Mechanical System Diagram

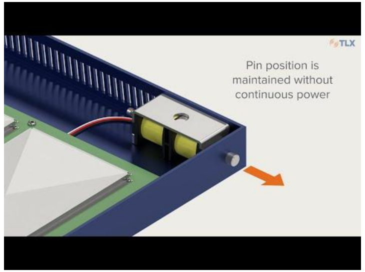
JANUS System

Arduino/RPi

Deployer Lid Latch/Spring System

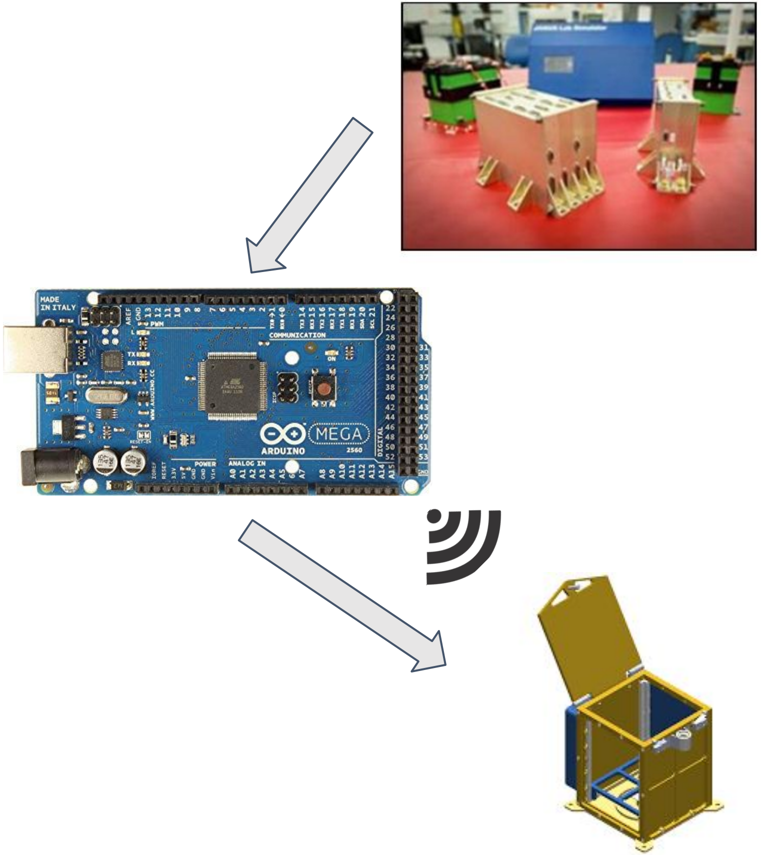
Dropsonde Launch Mechanism



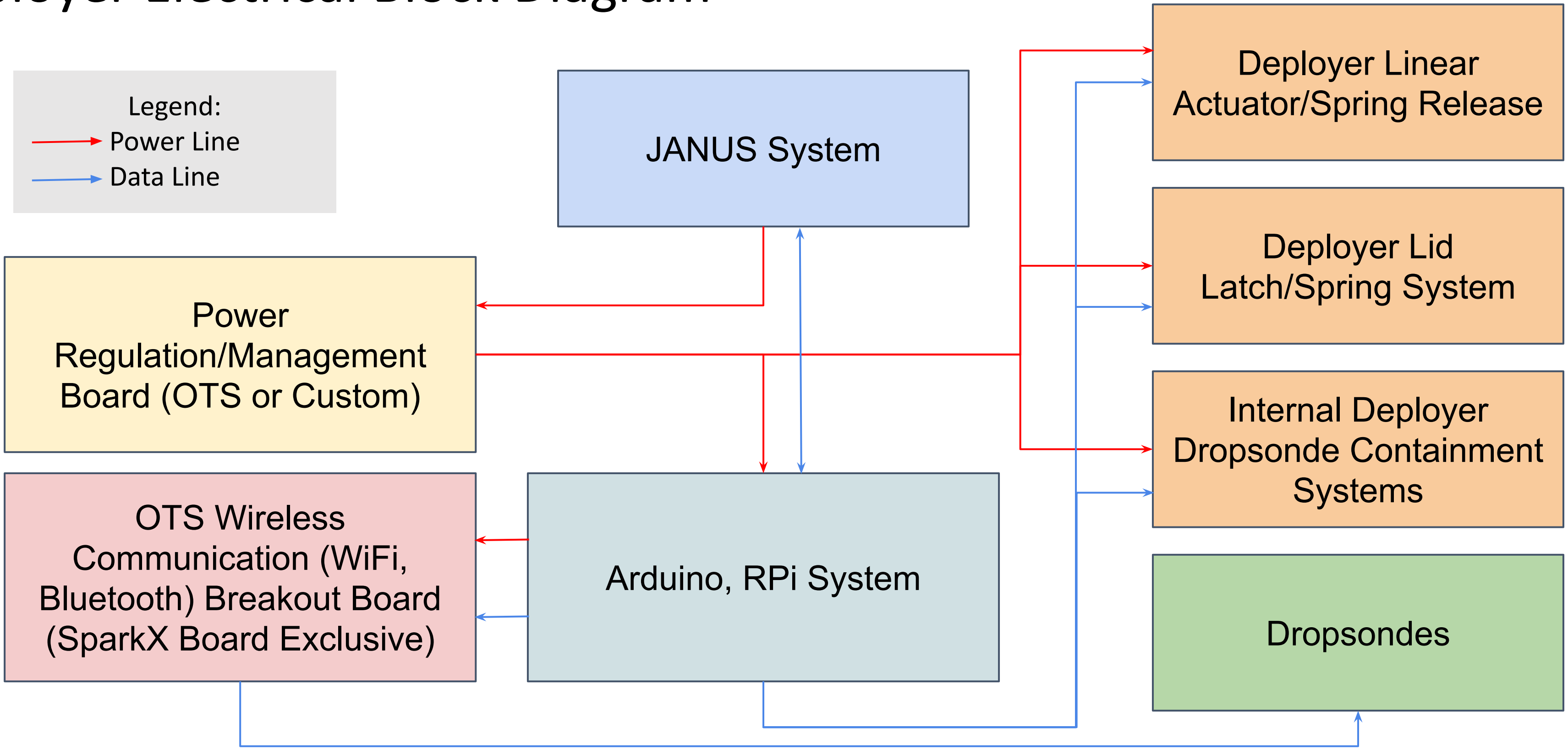


Deployer Concept Electrical Design

- Power and Flight data for the system is provided by the JANUS unit
- Deployment system timing and wireless communications handled by a computer/microcontroller (Arduino, RPi)
- Wireless startup commands sent to individual dropsondes via OTS WiFi/Bluetooth breakout board (or SparkX integrated system)



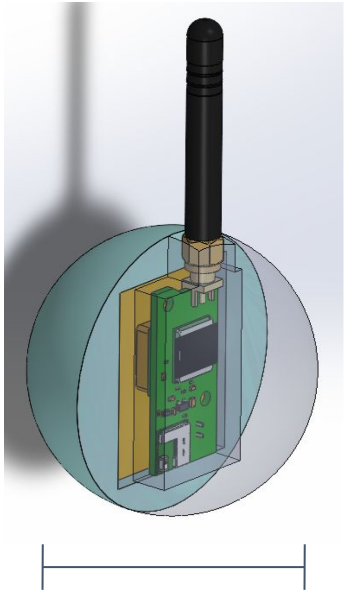
Deployer Electrical Block Diagram



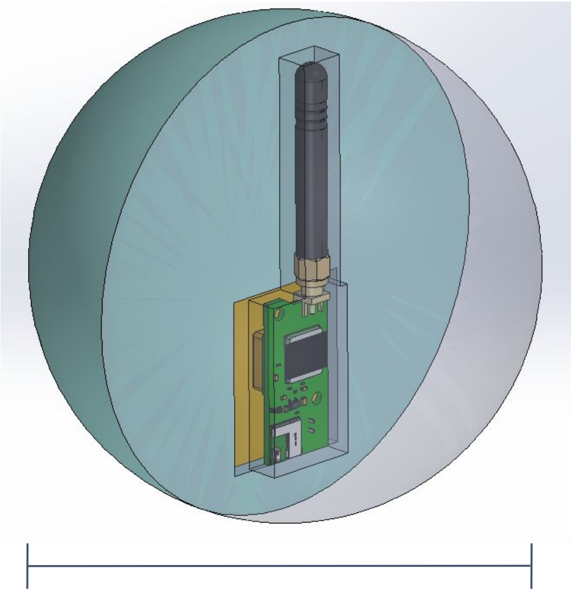
Dropsonde Concept Designs

Dropsonde Mechanical Concept Designs

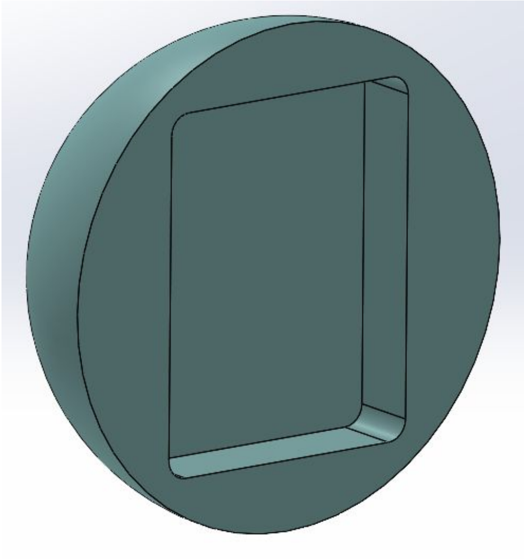
*Images show CAD for featherweight OTS GPS system, small changes would be made if SparkX system is chosen instead



2.5 in. Sphere Diameter,
Partially Encapsulated*



5 in. Sphere Diameter,
Fully Encapsulated*

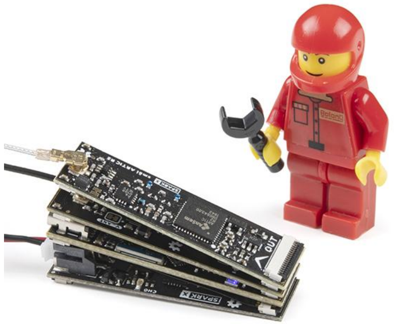


Dual-Hemisphere Aerogel Structure,
Easily Moldable/Manufacturable

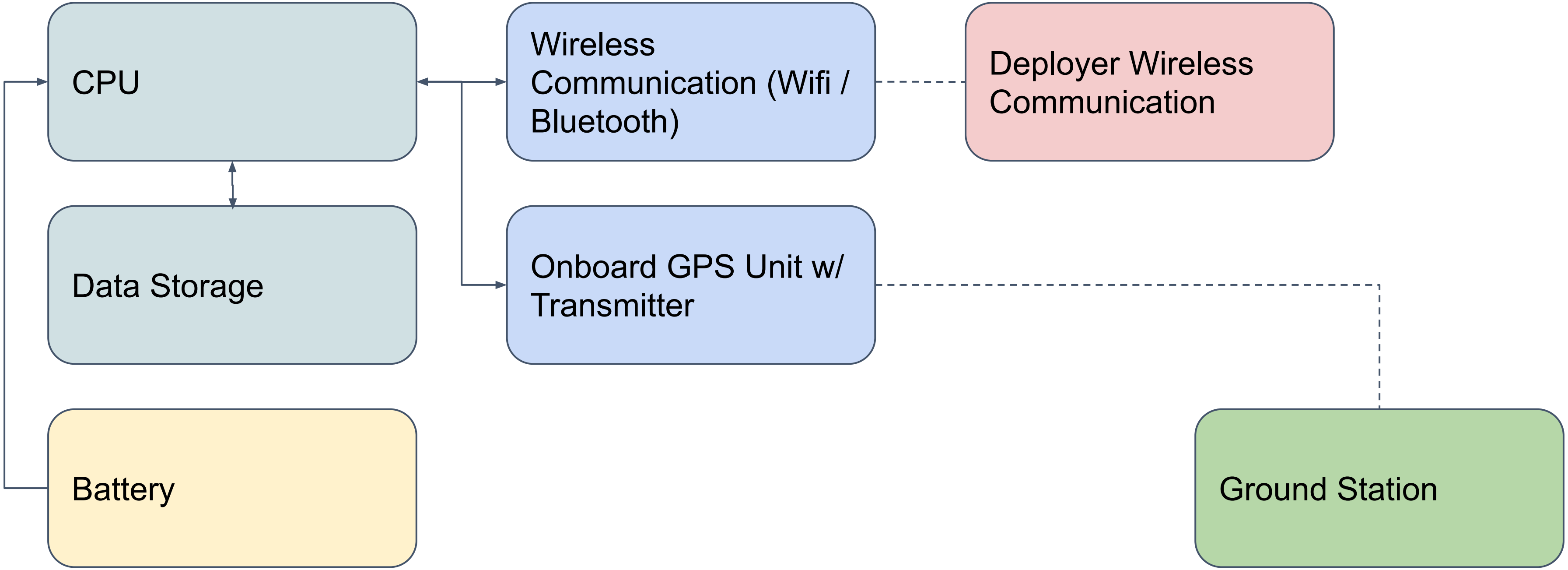
Dropsonde Concept Electrical Design

- Featherweight GPS system
  - COTS all-in-one product which contains a GPS receiver, data storage, and transmitter to communicate with a handheld ground station unit.
  - Small form factor.

- SparkX PCB stack GPS system
  - COTS system with modular components which easily integrate with one another.
  - Very small form factor.
  - GPS unit, wireless transmitter, satellite receiver and other components.
  - Very low power consumption, sleep modes



Dropsonde Electrical Block Diagram

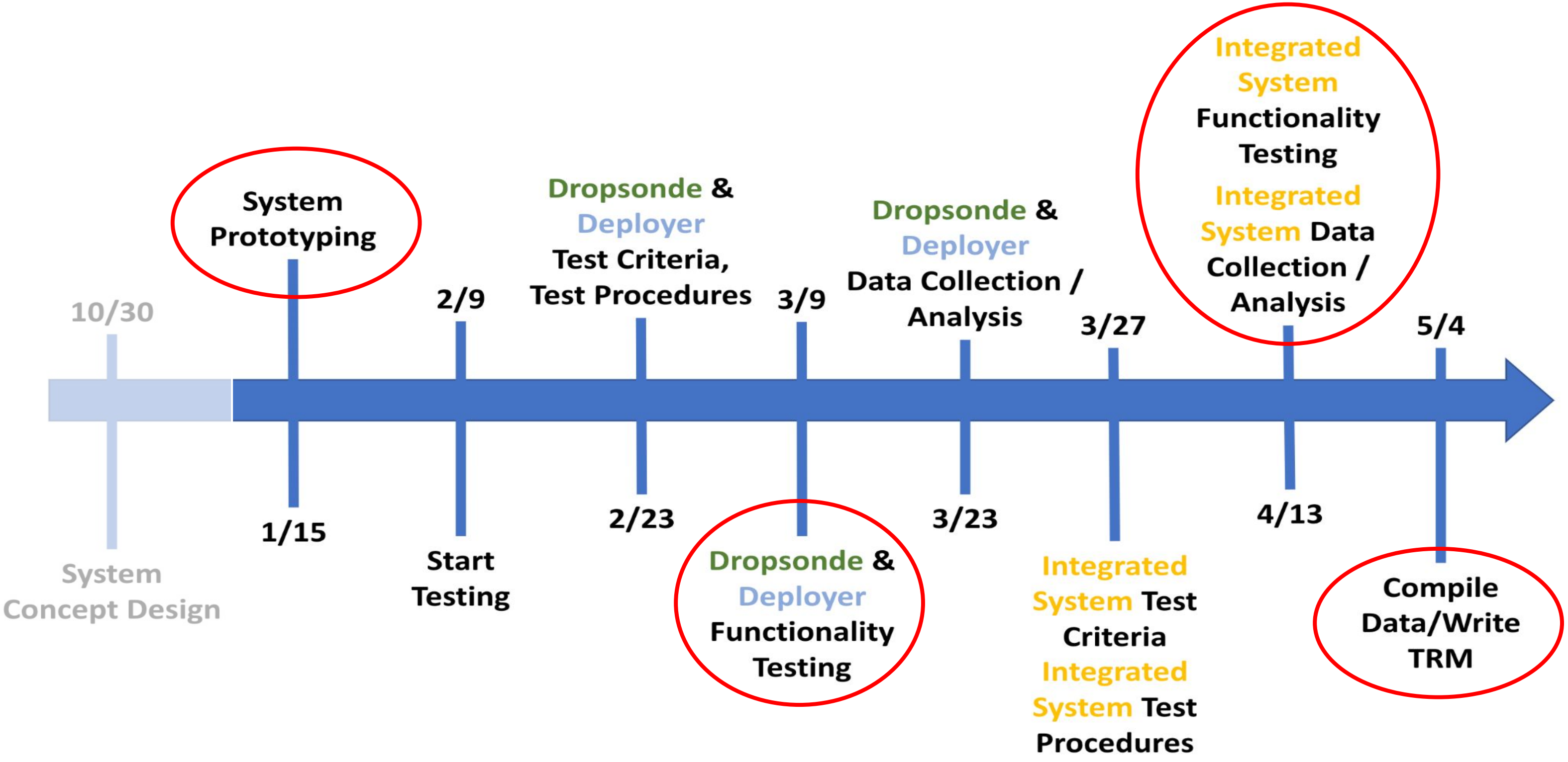


Project Management Updates

Fall Deliverables/Milestones

Deliverable:	Completion Date:
✅Overall Project Schedule/Goals Planning	September 13th
✅Top Level Requirements/AOA	September 20th
✅Preliminary Risk Analysis and CONOPS	September 27th
✅System Concept Review (SCR) Presentation	October 20th
✅Manufacturing, Testing Plan and Technology Roadmap	November 15th
☐ Preliminary Concept Design Review	December 8th (Today)

Spring 2023 Schedule Overview

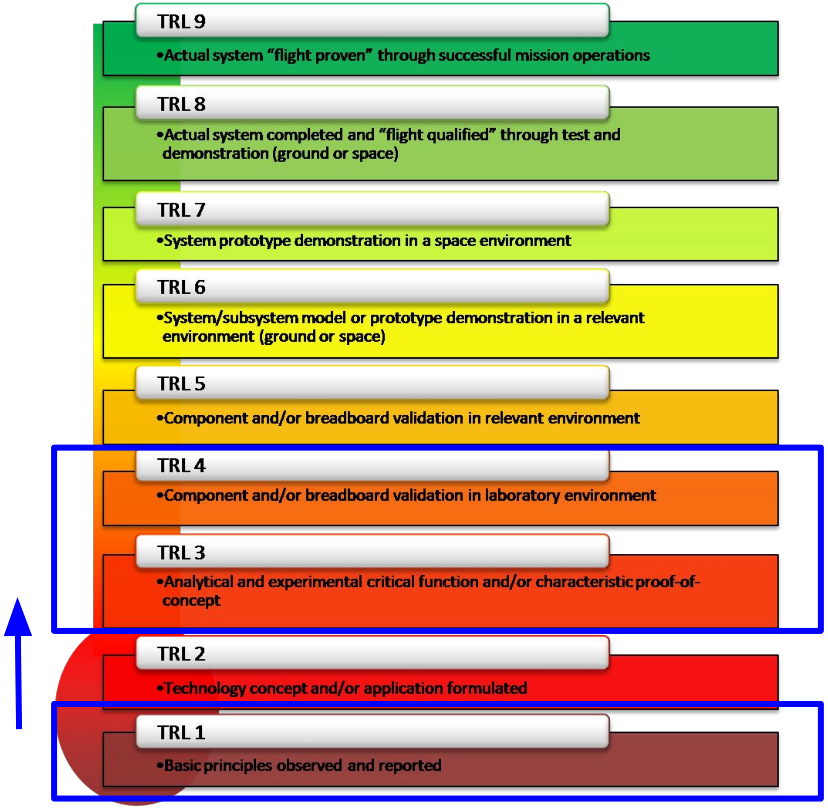


Technology Readiness Developments

So far…

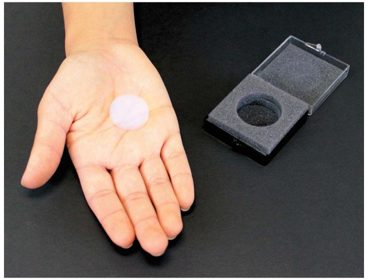
- Completed reports outlining <u>requirements and plans</u> for the complete manufacturing and testing of all FLARE prototype components (TRL Level 1)

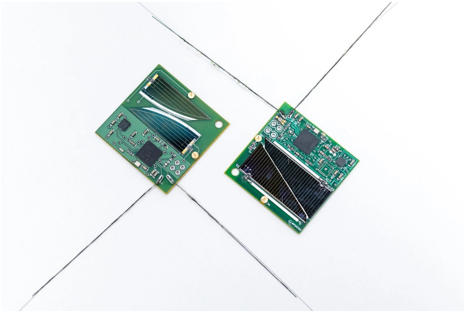
- Next semester, we will be starting individual and integrated system tests, maturing the concept up to TRL Level 3/4 by system delivery



Manufacturing Plans

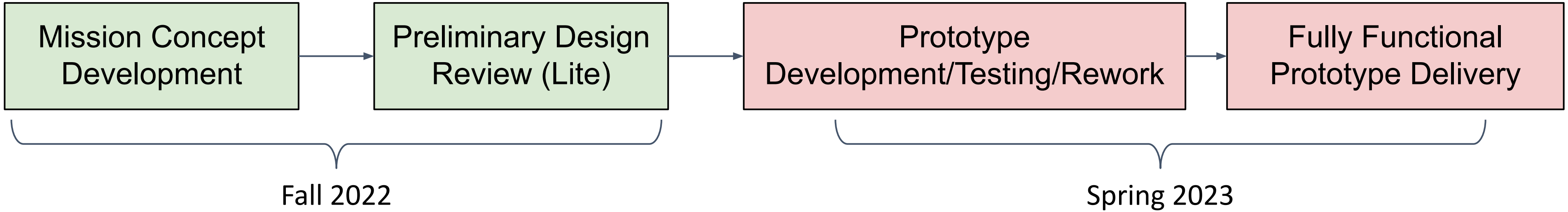
- Deployer prototyping to be completed using 3D printers, shops on campus
- Different options for procuring Aerogel material have been explored, currently planning on purchasing custom molded aerogel hemispheres from a stock supplier, or creating a prototype aerogel for testing at Colorado School of Mines (Valerie contact)
- System concept electronics to be purchased fully off the shelf to test compatibility and functionality, custom PCB could be a future iteration if needed





Next Steps

- Preliminary Design Concept Review (PDR Lite) today
- Baseline designs to be matured based on feedback, completed and ready for prototyping in first weeks of Spring 2023
- Still waiting on Pcard to begin ordering prototyping components
- Spring semester will also involve all concept system testing, successive TRL demonstrations and a delivery of a fully functional prototype to APL in May



Questions?

Appendix

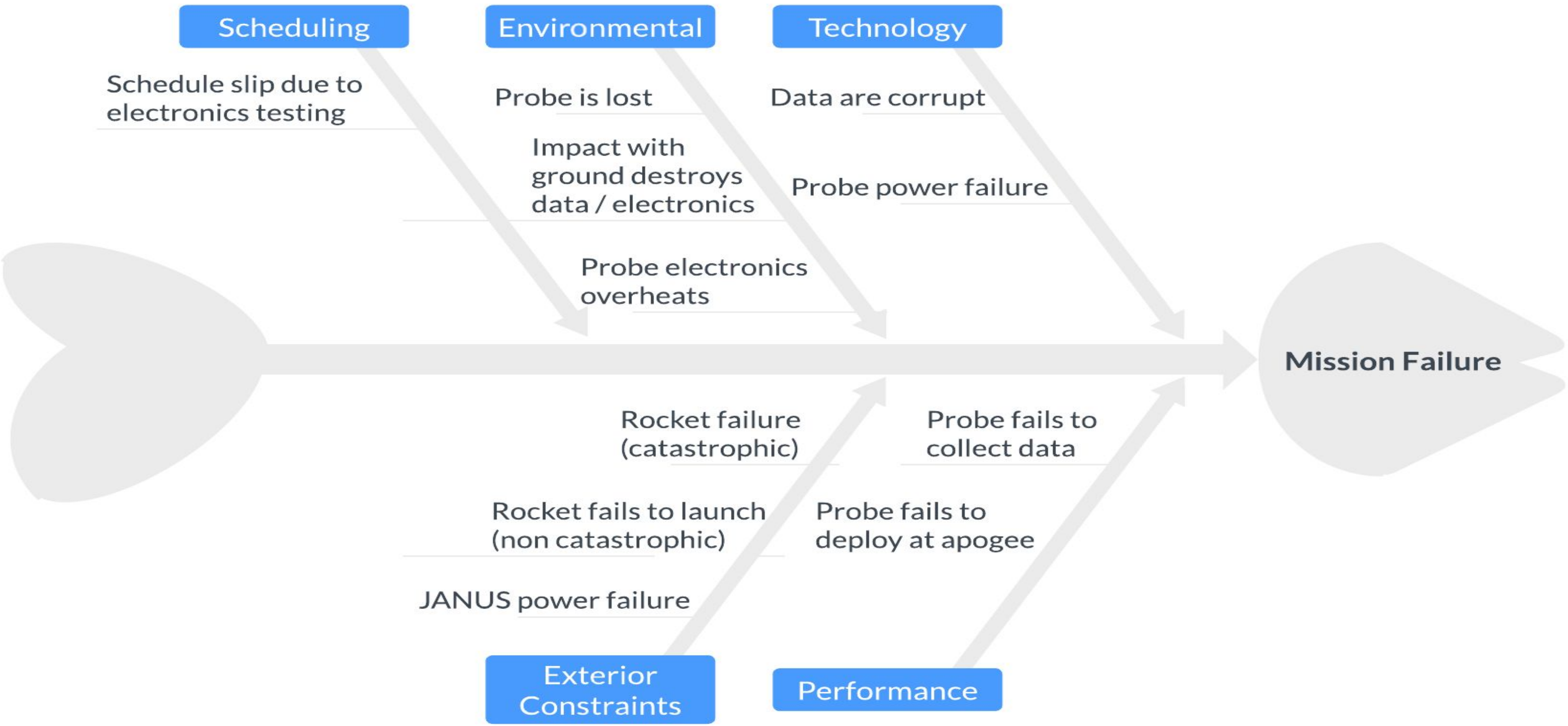
Prototyping Hardware Budget

Prototyping Hardware											
Material	**Type**	**Details**	**Individual Cost**	**Quanity**	**Total Cost**	**Link (Prov.)**	**ID**	**Lead Times**	**Notes**	**Ordered (Y/N)?**	**Received**
Deployer Structure	1 kg PLA Filament	Used with Lulzbot, other low fidelity printers	$25.00	1	$25.00	https://itll.colorado.edu/equipment/				no	no
Deployer Electronics	Breadboard		$10.95	2	$21.90	https://www.sparkfun.com/products/112				no	no
	Arduino Mega		$48.95	1	$48.95	https://www.sparkfun.com/products/11061				no	no
	M/M Jumper Cables (10 pack)		$1.00	3	$3.00	https://www.sparkfun.com/products/19370				no	no
	M/F Jumper Cables (20 pack)		$2.10	2	$4.20	https://www.sparkfun.com/products/12796				no	no
	F/F Jumper Cables (20 pack)		$2.10	2	$4.20	https://www.sparkfun.com/products/12796				no	no
	Resistor Pack		$8.95	1	$8.95	https://www.sparkfun.com/products/10969				no	no
	Latching Solenoid		$28.08	1	$28.08	https://www.digikey.com/en/products/detail/delta-electronics/DSMS-0730-12/5214008				no	no
Dropsonde Structure	Aerogel Material				$0.00					no	no
	Large Styrofoam Balls (Pack of 4)		$15.69	1	$15.69	https://www.amazon.com/Craft-Foam-Ball-Styrofoam-Polystyrene/dp/B07P97L8GL/ref=sr_1_16?crid=40I4KB22FRCA&keywords=styrofoam%2Bballs&qid=1668453673&sprefix=styrofoam%2Bbal%2Caps%2C285&sr=8-16&th=1				no	no

Prototyping Hardware Budget (Continued)

Dropsonde Electronics	Featherweight GPS/Ground Station	Tracker + GS + 400 mAh Tracker Battery	$365.00	1	$365.00	https://www.featherweighthaltimeters.com/store/p22/Featherweight_GPS_Tracker_%28upd%29.html	N/A			no	no
	LiPo Battery Charger	Adaptable so it's good for GPS unit and ground station batteries	$13.50	2	$27.00	https://www.sparkfun.com/products/14380				no	no
	SparkX Smol ZOE-M8Q	GNSS Transmitter/Recever w/o antenna	$39.95	1	$39.95	https://www.sparkfun.com/products/18623				no	no
	SparkX Smol ESP32	Processor Board w/ Wifi chip	$17.95	1	$17.95	https://www.sparkfun.com/products/18619?_ga=2.66393004.345667845.1668067037-562343046.1660079584&_gac=1.56400601.1668067037.CjwKCAiAvK2bBhB8EiwAZUbP1HFIWdVxB5p-IeNIN5HTZawI9R2H				no	no
	SparkX Smol Power Board LiPo	Intelligent power distribution board (+charger?)	$17.95	1	$17.95	https://www.sparkfun.com/products/18622?_ga=2.94721182.345667845.1668067037-562343046.1660079584&_gac=1.183143892.16680670				no	no
	SparkX Smol Header Breakout	Breakout board to work with components on a breadboard	$2.95	1	$2.95	https://www.sparkfun.com/products/18620				no	no
	400 mAh LiPo Battery	Small power source	$5.50	3	$16.50	https://www.sparkfun.com/products/13851				no	no
				Sum Total:	$647.27						

Mission Risk Determination Milestone



Risk summary

1 Probe is lost (final position not known)
2 Probe fails to deploy at apogee
3 Probe power failure
4 Probe fails to collect data
5 Data are unrecoverable (corrupt)
6 Rocket failure (catastrophic)
7 Janus power failure
8 Schedule slip due to electronics testing
9 Probe electronics overheats
10 Rocket fails to launch (non catastrophic)
11 Impact with ground destroys electronics
12 Impact with ground destroys data

Option A

- Limited scientific return.
- Greater risk of losing probe.
- Less risk of electronics failures.
- Less risk of schedule slip.

Likelihood	5					
	4					**1**
	3					**2**
	2					**3**
	1	**4, 5**				
		1	2	3	4	5
		Consequence				

Risk summary

1 Probe is lost (final position not known)
2 Probe fails to deploy at apogee
3 Probe power failure
4 Probe fails to collect data
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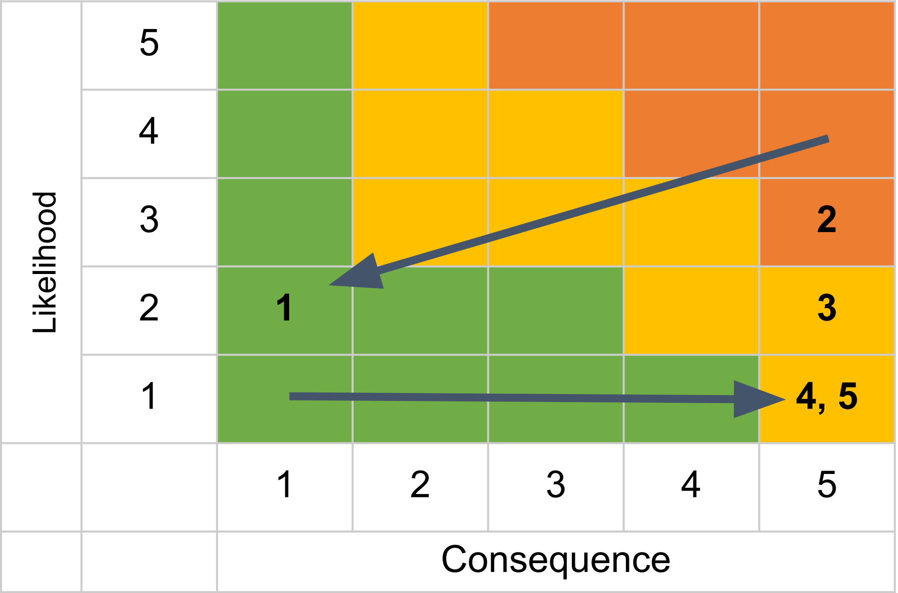
6 Rocket failure (catastrophic)
7 Janus power failure
8 Schedule slip due to electronics testing
9 Probe electronics overheats
10 Rocket fails to launch (non catastrophic)
11 Impact with ground destroys electronics
12 Impact with ground destroys data

Option B
- More significant scientific return.
- Less risk of losing probe.
- Greater risk of electronics failures.
- Greater risk of schedule slip.



FLARE Fall 2022 Introduction Video

https://drive.google.com/drive/folders/17Jm195q_mu_l5kSg1jWRxThq-gm_1_ha