System Concept Review

FaLling Aerogel Re-entry Experiment (FLARE)

Aaron Pickens, Moe Suemura, Josh Elliott

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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.

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Introduction

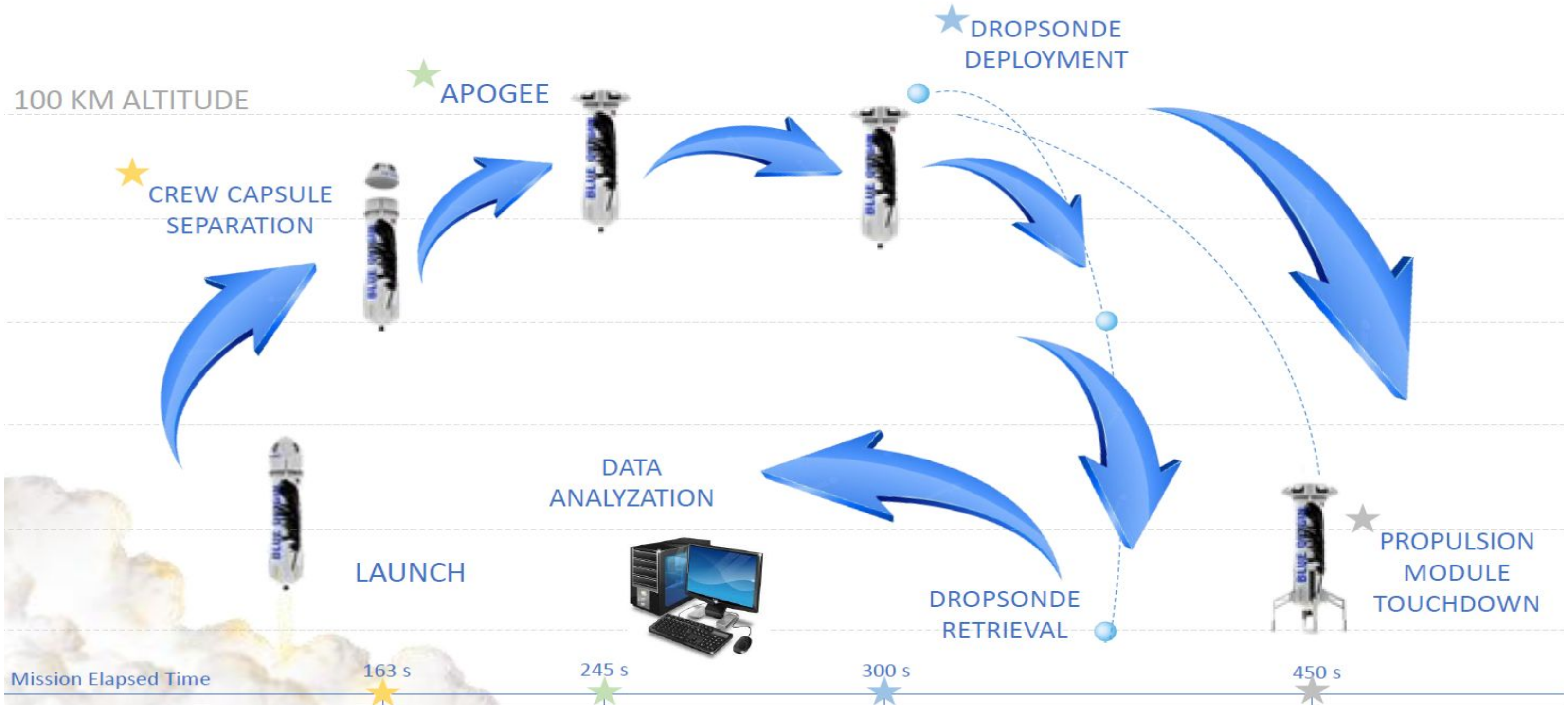
Motivation:

- 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

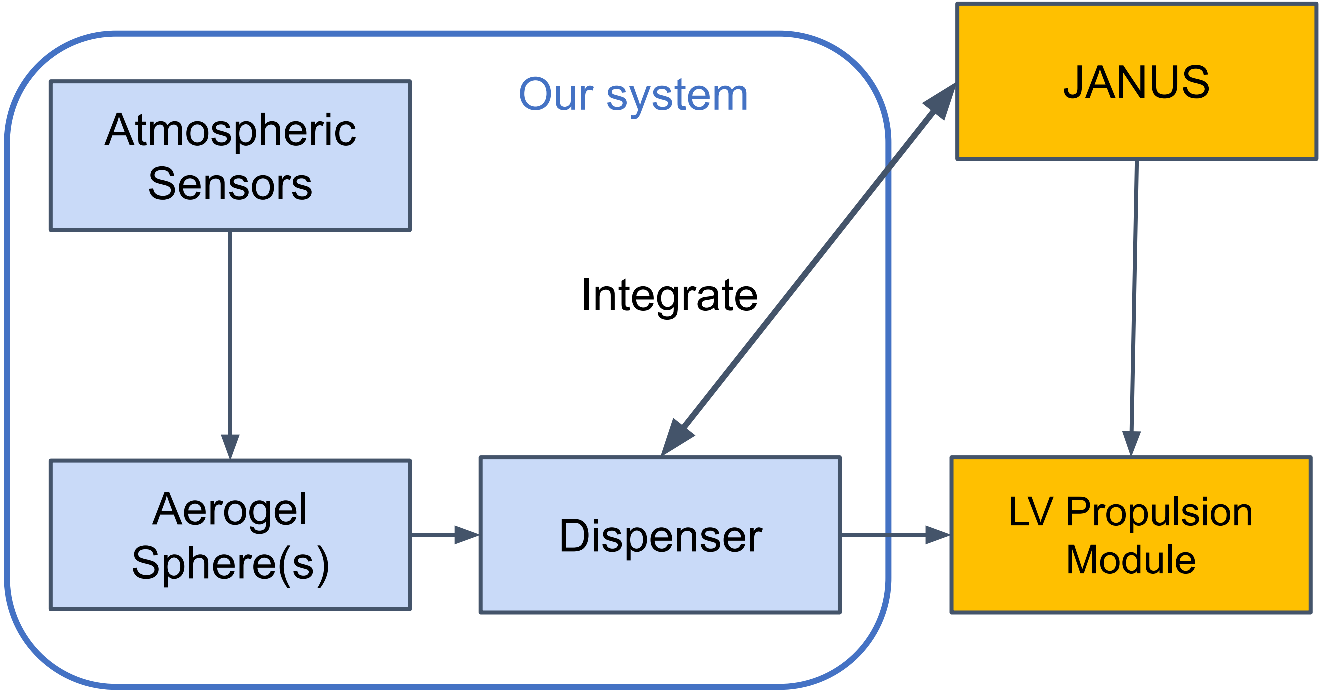
Project Concept:

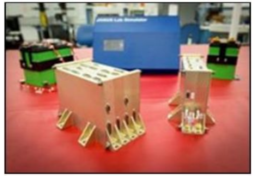
- Aerogels (NASA, other sources) are low-density solid polymer foams that exhibit strong relative mechanical and thermal properties
- Electronics encapsulated within aerogel ('dropsondes') could survive the forces of launch/re-entry, and be used for upper atmospheric measurements

System Concept (Mission CONOPS)

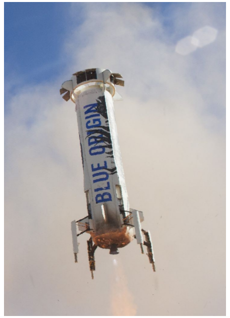


System Concept Diagram





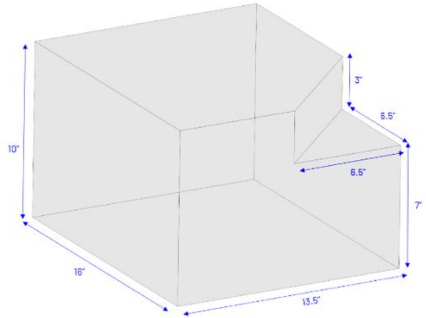
- Power & Data storage
- Instrument control
- Ambient environment characterization
- Standard physical integration to spacecraft



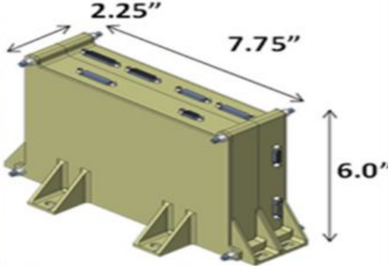
Exterior Constraints

Propulsion Module Payload must fit JANUS and Dispenser

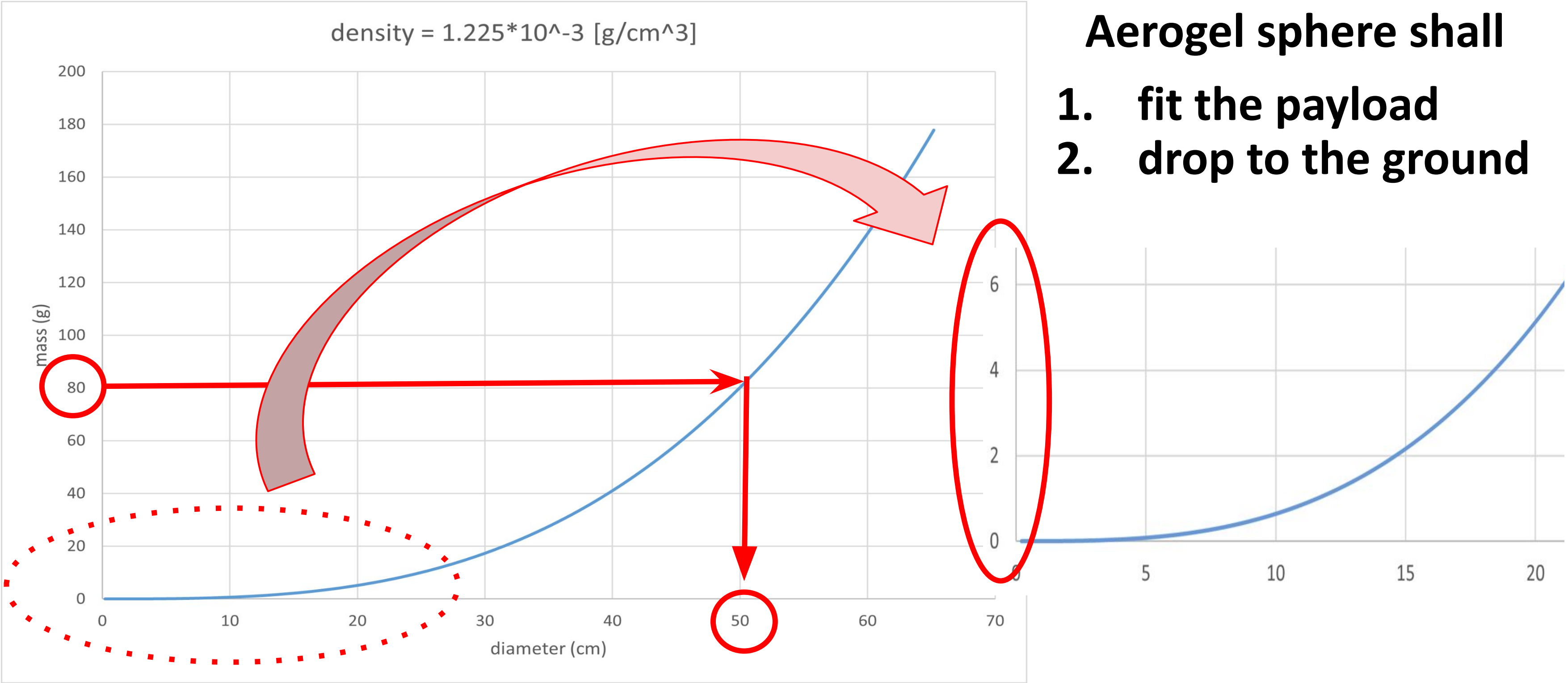
- Propulsion Module Payload Accommodation
  - Length: 40.69 cm
  - Width : 33.02 cm
  - Height : 25.40 cm



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



Environmental Constraints (Sphere Density)



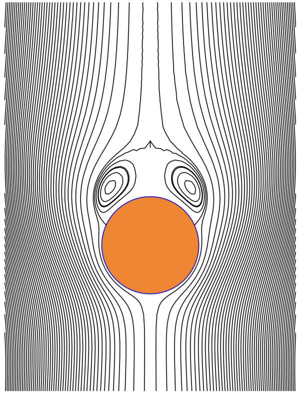
Aerogel sphere shall

1. **fit the payload**
2. **drop to the ground**

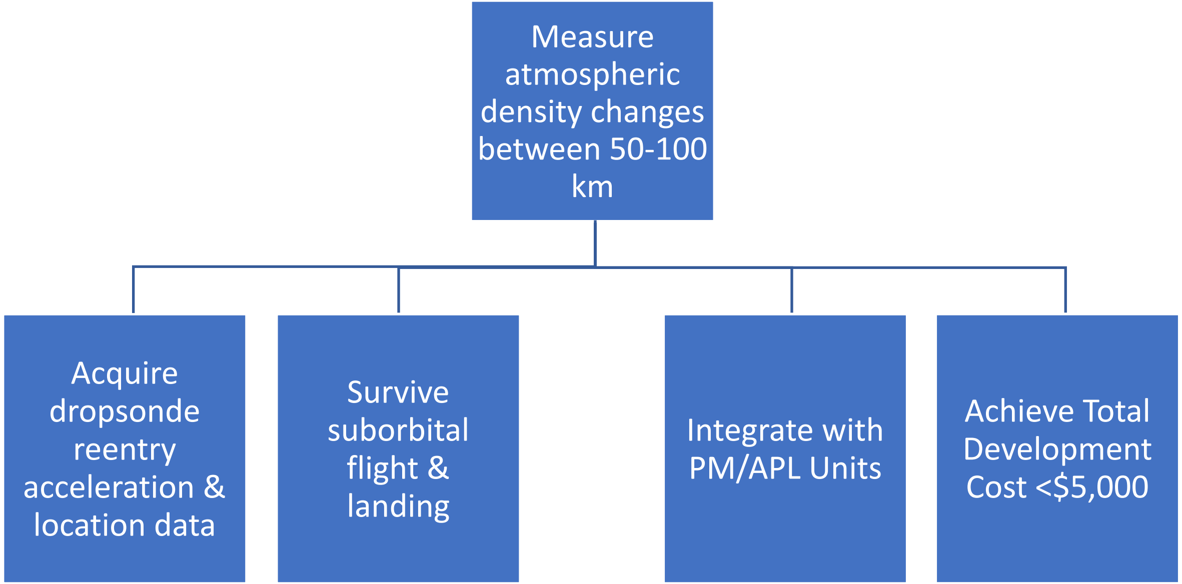
Atmospheric Measurements

- Estimate drag coefficient C_D via wind tunnel.
- Measure Acceleration due to atmospheric drag as well as probe velocity during descent.
- Calculate atmospheric density profile as a function of altitude.

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



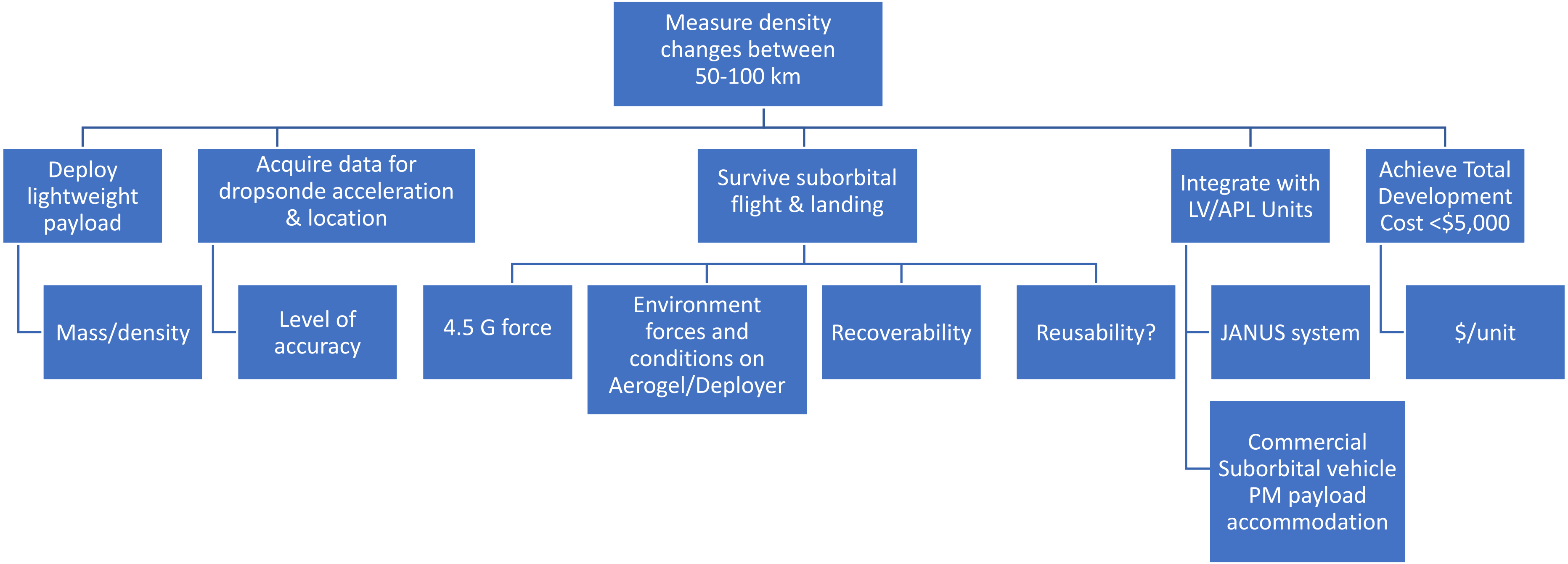
Systems Objectives Tree



System Objectives (Measures of Effectiveness)

System Objective	Measure of Effectiveness (MOE)
Acquire Data for Dropsonde Acceleration and Location	Successful retrieval of data from dropsondes
Survive Suborbital Flight and Landing	Dropsondes survive drop tests (e.g. buildings) to qualify reentry, while deployer with dropsondes should survive imposed random vibe/shock/thermal environments given in PM ERD
Successfully integrate with LV/APL Units	Deployer fits the volume constraints given by the PM, while also successfully interfacing electrically and mechanically with the APL JANUS system
Achieve Total Development Cost <$5,000	Total system cost (dropsondes, deployer, testing, etc.) <$5,000

Systems Description (Top-Level Function Tree)

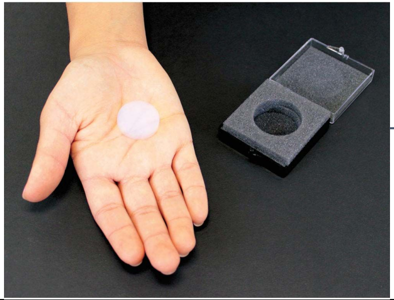


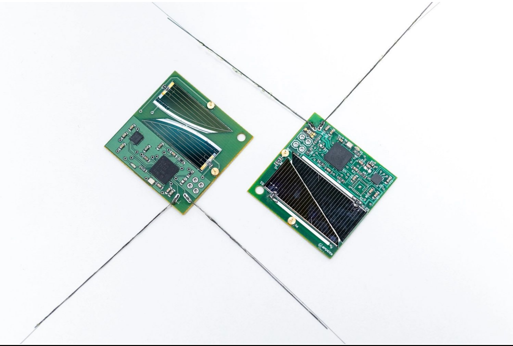
Preliminary System Requirements and MOP's

System Requirement	Measure of Performance (MOP)
Dropsonde Relative Density	Dropsonde spheres shall be composed of aerogel, and shall not exceed an overall density of 1.225E-3 g/cm^3
Dropsonde Relative Density	Dropsonde spheres shall not exceed an exterior diameter of 20 cm
Survive Suborbital Flight and Landing	Dropsonde deployer shall survive anticipated launch environments while protecting aerogel dropsondes until deployment
Survive Suborbital Flight and Landing	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
Measure Atmospheric Density Between 50-100 km Altitude	Dropsonde spheres shall measure atmospheric conditions with acceleration/location sensors during descent
Achieve Total Development Cost <$5,000	The total system cost (dropsondes, deployer, testing, etc.) shall be <$5,000

Analysis of Alternatives (AOA)

- After discussion with mentors, dropsondes need to be kept as light as possible
- A design requirement to meet is trying to match the density of air at sea level (1.225E-3 g/cm^3)
- Option A is a material proof of concept, while option B uses a lightweight ‘chipsat’ design





AOA Design Options

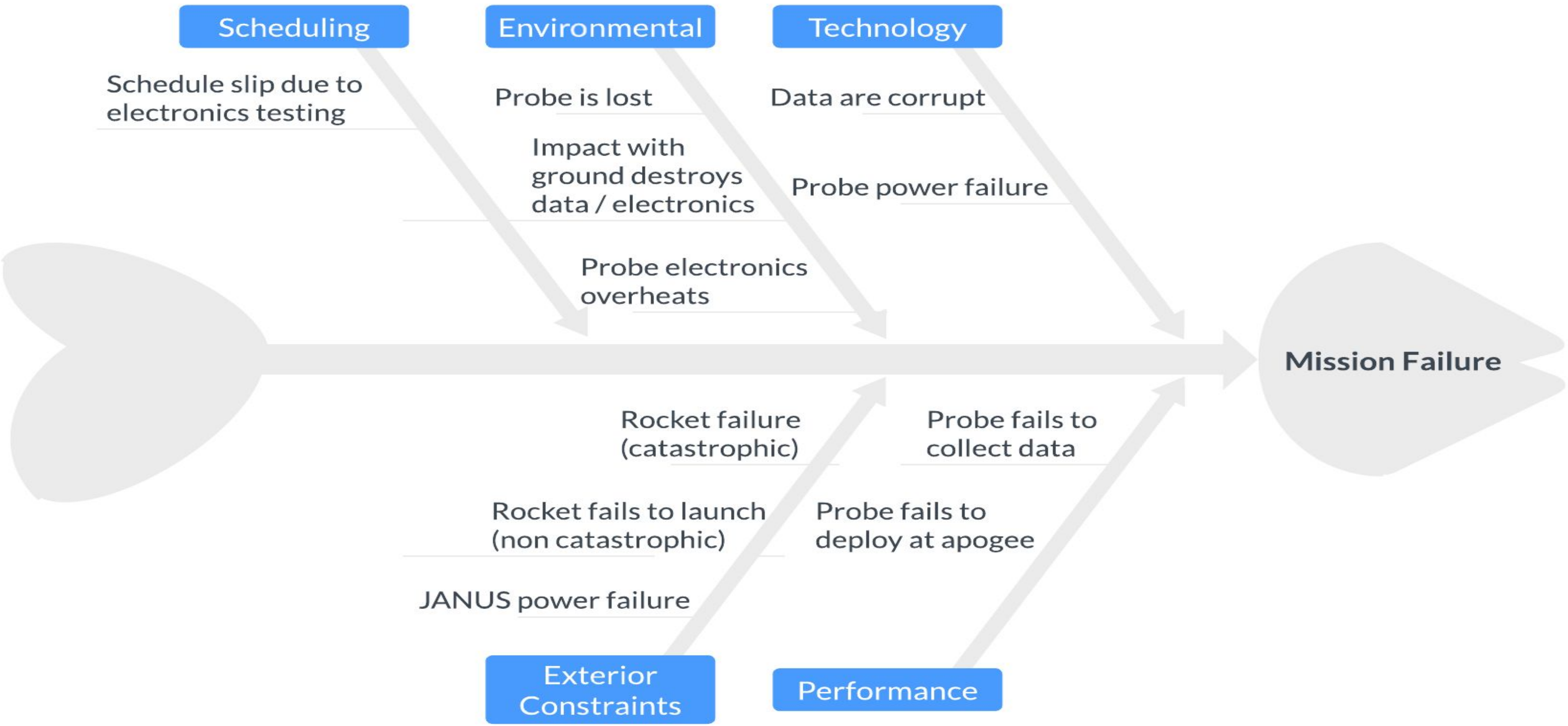
Parameters	Option A: Aerogel capsule reentry technology demonstration	Option B: Custom Built Transmitter Chipsat/Sensor Array System
Temperature Requirements	High Range (Based on Aerogel)	Medium Range (Based on Electronics)
Manufacturability	Easily manufacturable	Moderate difficulty in manufacturing
Cost (Money)	Lowest cost	Highest Cost
Cost (Time)	Lowest time needed	Most time needed
Data Validity	Materials technology info only	Most valid data expected
Recoverability	More difficult to recover	Easier to recover, transmitter on board
Mass/Weight/Density	Lowest expected payload mass	Moderate expected payload mass
TRL	6-7	4-5
Risk (To Mission Objectives)	Moderate	Moderate-Low

Lower Risk

Moderate Risk

Higher Risk

Mission Risk Determination



Risk Level (Highest to Lowest Mission Impact)	Risk	Risk Type
1	Probe is lost (final position not known)	Environmental
2	Probe fails to deploy at apogee	Performance
3	Probe power failure	Technology
4	Probe fails to collect data	Performance
5	Data is unrecoverable (corrupt)	Technology
6	Rocket failure (catastrophic)	Exterior Constraints
7	JANUS power failure	Exterior Constraints
8	Schedule slip due to electronics testing	Scheduling
9	Probe electronics overheats	Environmental
10	Rocket fails to launch	Exterior Constraints
11	Impact with ground destroys electronics	Environmental
12	Impact with ground destroys data	Environmental

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
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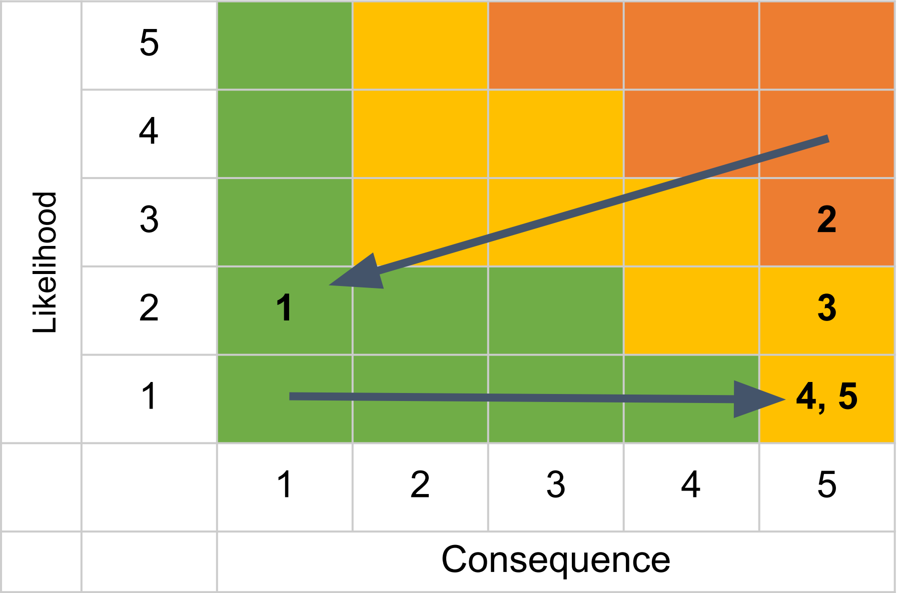
Option B

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



Top-Down Cost Analysis

- Top-down and bottom-up cost analyses ran for comparison of AOA design options A and B
- Top-down estimate looked at criteria such as prototyping costs, overall material needs, testing costs, and flight hardware to provide a preliminary value

Level 1 AOA Top-Down Cost Estimate (Revised AOA Options)			
AOA Option	Estimated Cost	Estimate Uncertainty	Overall Project Estimate
Option A: Aerogel capsule re-entry technology demonstration	$3,850.00	0.1	$4,235.00
Option B: Custom Built Transmitter Chipsat/Sensor Array System	$4,100.00	0.1	$4,510.00

Bottom-Up Cost Analysis

- Total project costs based on calculated individual dropsondes/deployer requirements also completed
- Bottom-up estimate for option A showed significantly lower cost than top-down, so actual value may be somewhere between
- Top-down and bottom-up estimates nearly matched for AOA option B

Level 1 AOA Bottom-Up Cost Estimate					
AOA Option	Estimate Individual Dropsonde Cost	Estimate Individual Deployer Cost	Max # of Dropsondes	Estimate Uncertainty	Overall Mission Estimate
Option A: Aerogel capsule reentry technology demonstration	$150.00	$1,050.00	10	0.1	$2,805.00
Option B: Custom Built Transmitter Chipsat/Sensor Array System	$300.00	$1,050.00	10	0.1	$4,455.00

Conclusions

Project Feasibility

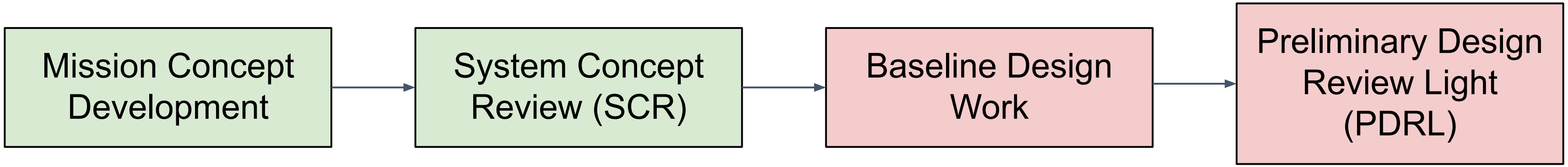
- Early analysis has demonstrated that mission objectives seem possible given the exterior engineering and environmental constraints
- The recent inclusion of lightweight fully integrated PCB units (chipsats) into our design concepts allows for full system feasibility while meeting baseline density and volume envelope requirements

AOA Option Selection:

- In order to meet all science objectives <u>including</u> measurement of atmospheric conditions, design option B seems the most promising candidate to move into preliminary design
- Since design option A is a subsidiary of option B, if issues are encountered either with engineering or management constraints this could be a fallback to still maintain successful project delivery

Next Steps

- System Concept Review (SCR) today
- Baseline designs AOA options to be refined over the coming weeks
- Project concept Preliminary Design Review (PDR) scheduled down the road on November 29th



Questions?

Appendix

Preliminary Analysis of Alternatives (AOA)

- Initially four options proposed that could meet our engineering/science objectives
- Mass recognized as an important factor in mission possibility, since spheres need to travel with the wind

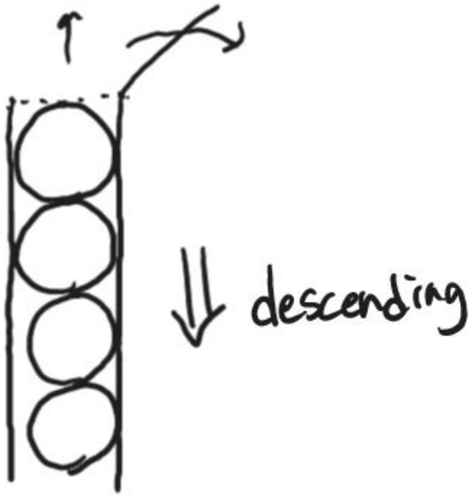
	Option 1: Aerogel capsule reentry technology demonstration	Option 2: OTS Accelerometer/Sensor Combination	Option 3: OTS GPS Unit w/ Iridium Transmitter	Option 4: Custom Built GPS PCB Unit w/ Iridium Transmitter
Estimate Dropsonde Mass:	>5 grams	5-20 grams	100-200 grams	100-200 grams

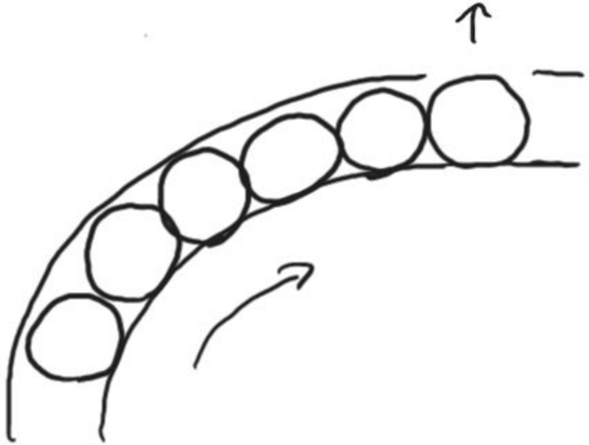
Deployer Design Brainstorming

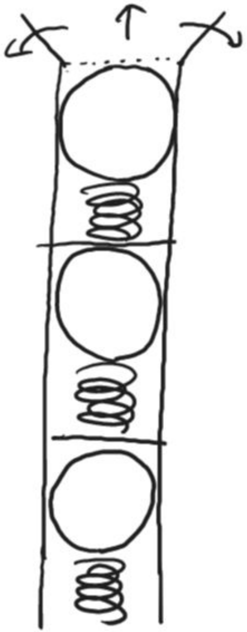
- How many aerogel spheres in a deployer
  - Have multiple deployers, 1 aerogel sphere each
  - OR 1 deployer with multiple spheres inside
- How to deploy
  - Just release when PM is descending ⟶ Drag force?
  - Push out by using springs
- If multiple spheres in 1 deployer, how to load the spheres
  - Rails
  - Springs

Deployer Design Brainstorming

Sketches:

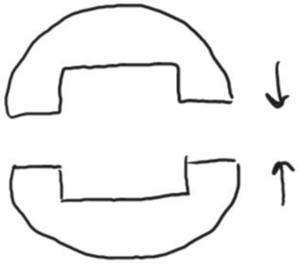


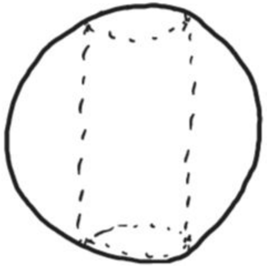




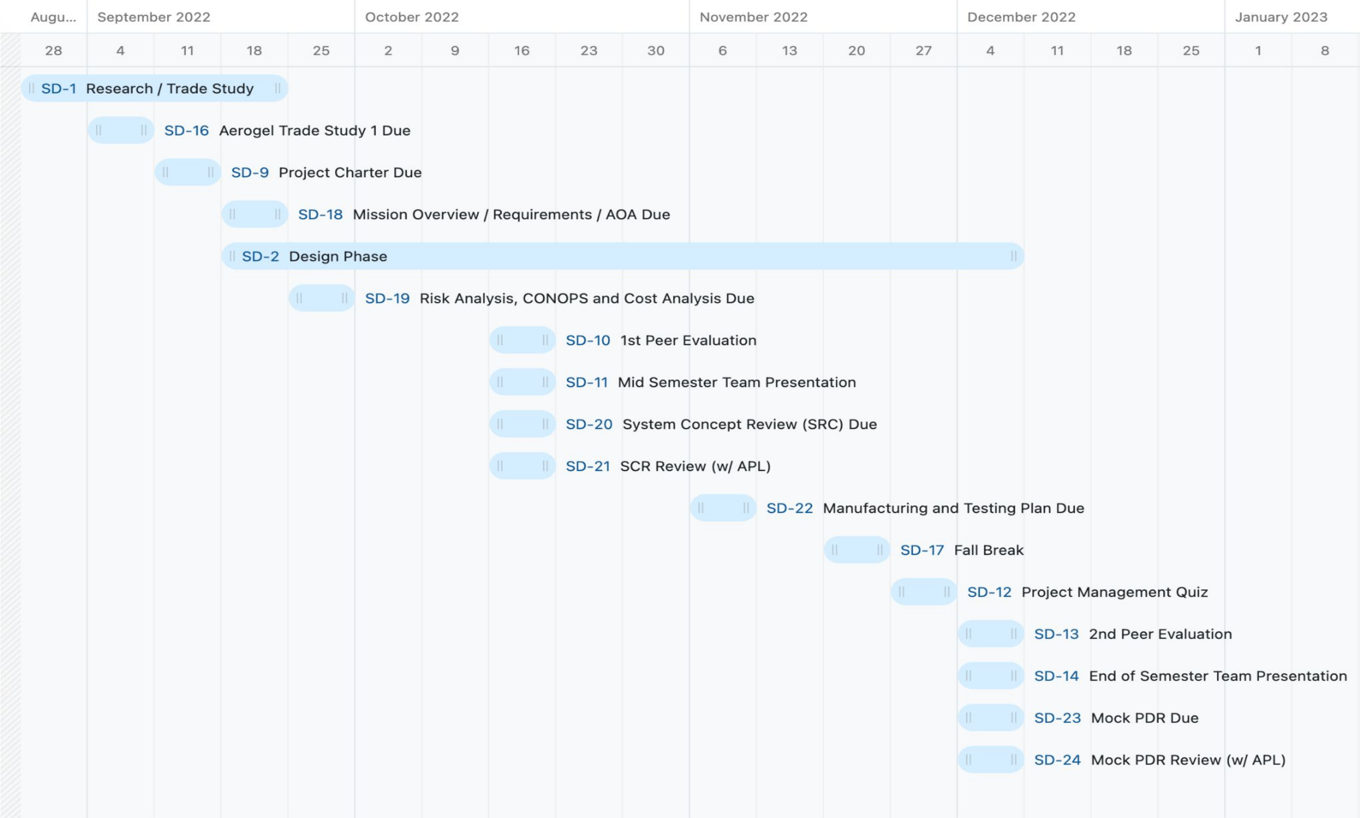
Dropsonde Design Brainstorming

- Size
  - Maximum of 20 cm diameter
- How many
  - Maximum of 10
- How to integrate electronic systems
  - Layers
  - Cylinder space
- Coating
  - Needed to protect from the landing impact?





Project Schedule



Electronics Design Brainstorming

- GPS vs Iridium+GPS?
  - GPS only: Data are not transmitted, and therefore must be retrieved on the ground.
  - Iridium + GPS: Location data transmitted during flight.
    - Bonus: even if we can't locate the probe, or if it is destroyed, we have the data.
- How to recover/locate?
  - LED lights
  - RADAR pulses
  - Aircraft / ATV / Other mode of transportation?
  - If we use Iridium, we will have it's exact location.
- Alternative sensors?
  - Perhaps just an accelerometer + gyro? i.e. an IMU?
    - This would allow us to derive drag force, etc.
- Minimum electronics dimensions:
  - ~ 80mm x 60mm x 50mm
- Decided on chip-sat design which is much smaller, both in mass and volume.

AOA Option 1 Risk Analysis

Risk #	Risk Element and Description	Mitigation Strategy
1	Probe fails to deploy at apogee	Rigorous testing of the deployment mechanism early and throughout the design phase will help to ensure this doesn't happen. Thermovac testing of the constructed unit will give us confidence that it can operate in the intended environment.
2	Probe power failure	Rigorous testing prior to flight. Charge battery via our interface with JANUS up to the moment of launch.
3	Rocket failure (catastrophic)	Not much to be done here.
4	Probe fails to collect data	Software and hardware testing throughout the development cycle should help.
5	Janus power failure	Unknown mitigation strategy.
6	Data are unrecoverable (corrupt)	Store data uncompressed. Perhaps write to two SD cards
7	Schedule slip due to electronics testing	Short continuous integration cycles, design-build-verify. Often referred to as "Agile" development.
8	Probe electronics overheats	Rigorous testing on the ground, including TVAC testing. Implement intelligent power cycling.
9	Rocket fails to launch (non catastrophic)	Wait, relaunch again.
10	Impact with ground destroys electronics	
11	Probe is lost (final position not known)	Locator beacon of some kind. Perhaps a flashing LED and/or a Radar pulse signal that we can detect from a distance.
12	Impact with ground destroys data	Perform impact testing prior to launch. Perhaps write to two SD cards simultaneously for backup.

Likelihood						
	5					
	4					**11**
	3	**9**				**1**
	2					**2**
	1	**4,6, 7,8, 10,1 2**				**5,3**
		1	2	3	4	5

AOA Option 5 Risk Analysis

Risk #	Risk Element and Description	Mitigation Strategy
1	Probe fails to deploy at apogee	Rigorous testing of the deployment mechanism early and throughout the design phase will help to ensure this doesn't happen. Thermovac testing of the constructed unit will give us confidence that it can operate in the intended environment.
2	Probe power failure	Rigorous testing prior to flight. Charge battery via our interface with JANUS up to the moment of launch.
3	Rocket failure (catastrophic)	Not much to be done here.
4	Probe fails to collect data	Software and hardware testing throughout the development cycle should help.
5	Janus power failure	Unknown mitigation strategy.
6	Data are unrecoverable (corrupt)	Store data uncompressed. Perhaps write to two SD cards
7	Schedule slip due to electronics testing	Short continuous integration cycles, design-build-verify. Often referred to as "Agile" development.
8	Probe electronics overheats	Rigorous testing on the ground, including TVAC testing. Implement intelligent power cycling.
9	Rocket fails to launch (non catastrophic)	Wait, relaunch again.
10	Impact with ground destroys electronics	Test system early and often to ensure electronics survivability
11	Probe is lost (final position not known)	Locator beacon of some kind. Perhaps a flashing LED and/or a Radar pulse signal that we can detect from a distance.
12	Impact with ground destroys data	Perform impact testing prior to launch. Perhaps write to two SD cards simultaneously for backup.

Likelihood						
	5					
	4					
	3	**9, 10**				**1**
	2	**11**		**7**		**2**
	1	**12**		**8**		**3-6**
		1	2	3	4	5
		Consequence				