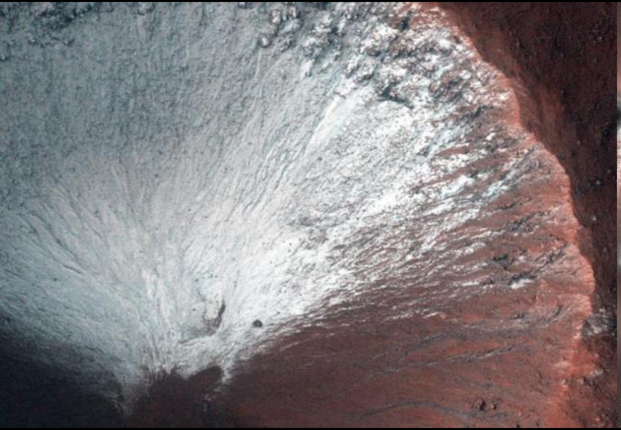

Mars Exploratory Balloon (MEB) CubeSats

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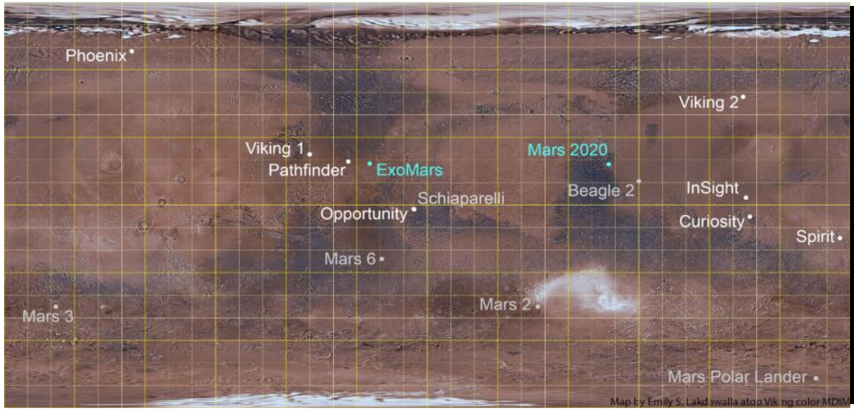
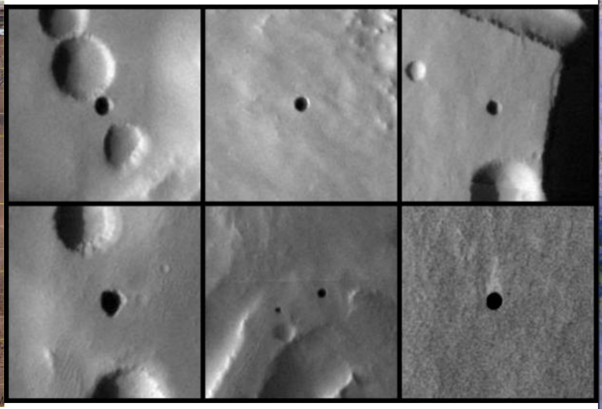
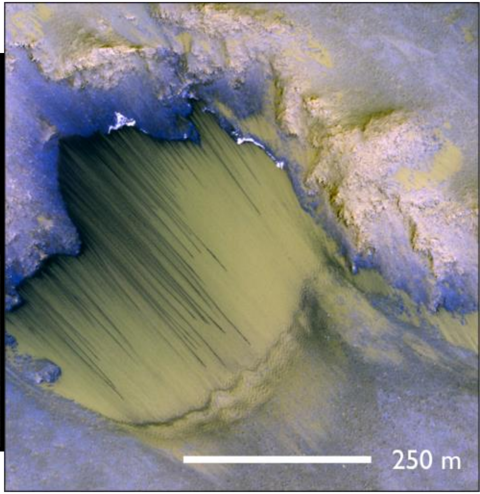
University of Arizona

ISSC - May 12, 2020

Mission Objective



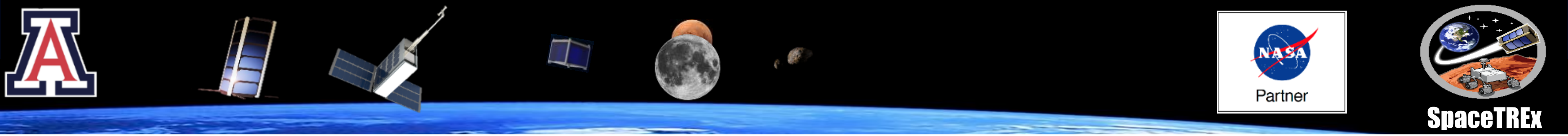




Less than 1% of Mars has been explored. Aerial vehicles provide a method to explore rugged terrain, cliff/canyon walls, RSL, and skylights

Outline

- Overview
- Concept of Operations
- CubeSat System Design
- Altitude Control Model
- Discussion
- Future Goals
- Conclusion



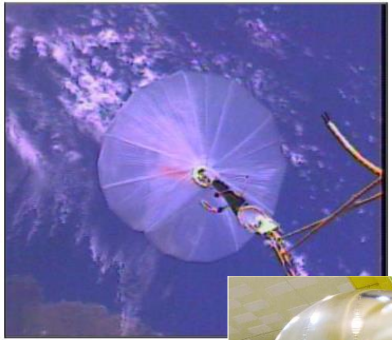
Related Research

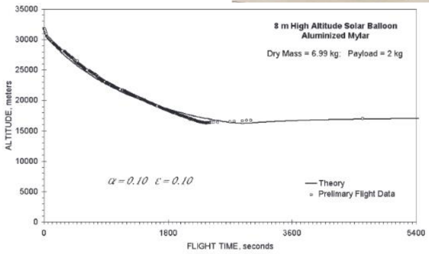
Hall, Jeffery, et al. "Flight test results for aerially deployed Mars balloons." *AIAA Balloon Systems Conference*. 2007.

Jones, Jack A. "Inflatable robotics for planetary applications." (2001).

Jones, Jack, and Jiunn Wu. "Solar montgolfiere balloons for Mars." *International Balloon Technology Conference*. 1999.

Farley, Rodger. "Balloon Ascent: 3-D simulation tool for the ascent and float of high-altitude balloons." *AIAA 5th ATIO and16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences*. 2005.

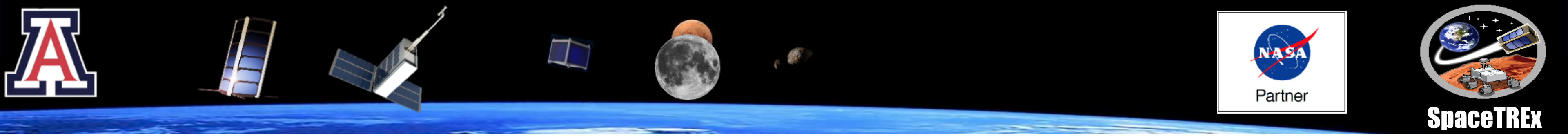




Atmospheric Comparison

	MARS	EARTH
Atmospheric Pressure	636 Pa	101325 Pa
Surface Level Temperature	210 K	288.15 K
Air Composition	95% CO_2	78% Nitrogen
Distance from Sun	1.524	1 AU
Gravity	3.711 m/s^2	9.81 m/s^2

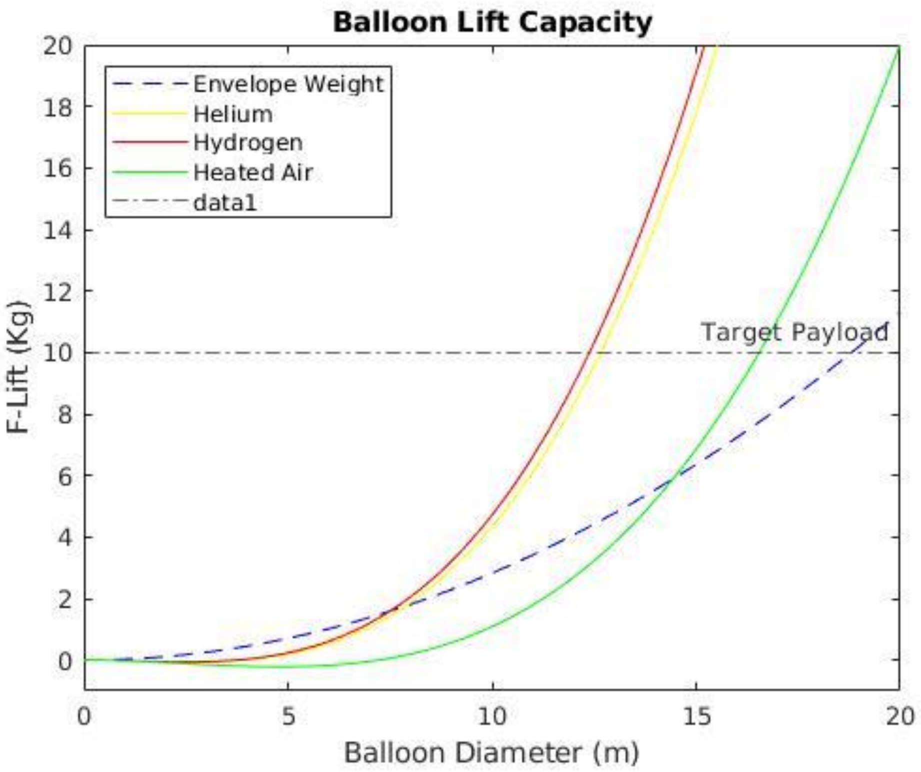
The atmospheric pressure on Mars is less than 1% of Earth's, resulting in difficult flying conditions for LTA vehicles. However, flight is feasible.



Types of Balloons

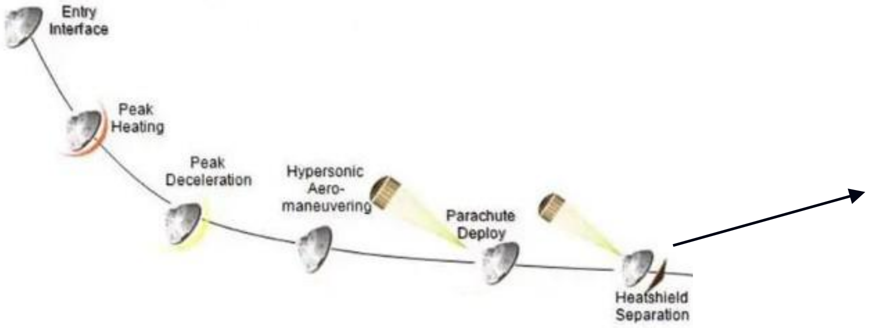
- Super Pressure Balloon
- Zero Pressure Balloon
- Vacuum Airship
- **Solar Montgolfiere**

Lift Capacity - Various Gasses

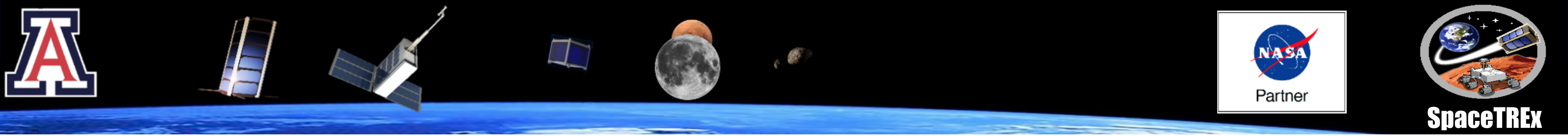


Helium and Hydrogen balloons can lift a 10kg payload at approximately 12m diameter. Solar balloons can lift the same payload at ~17m diameter

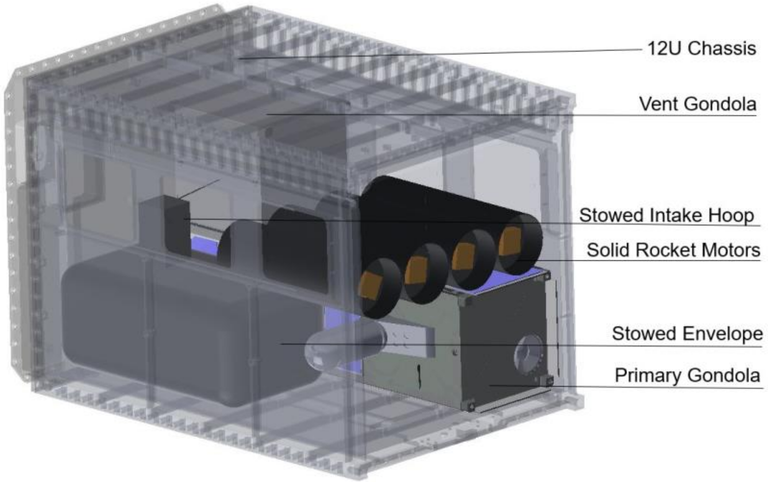
Concept of Operations



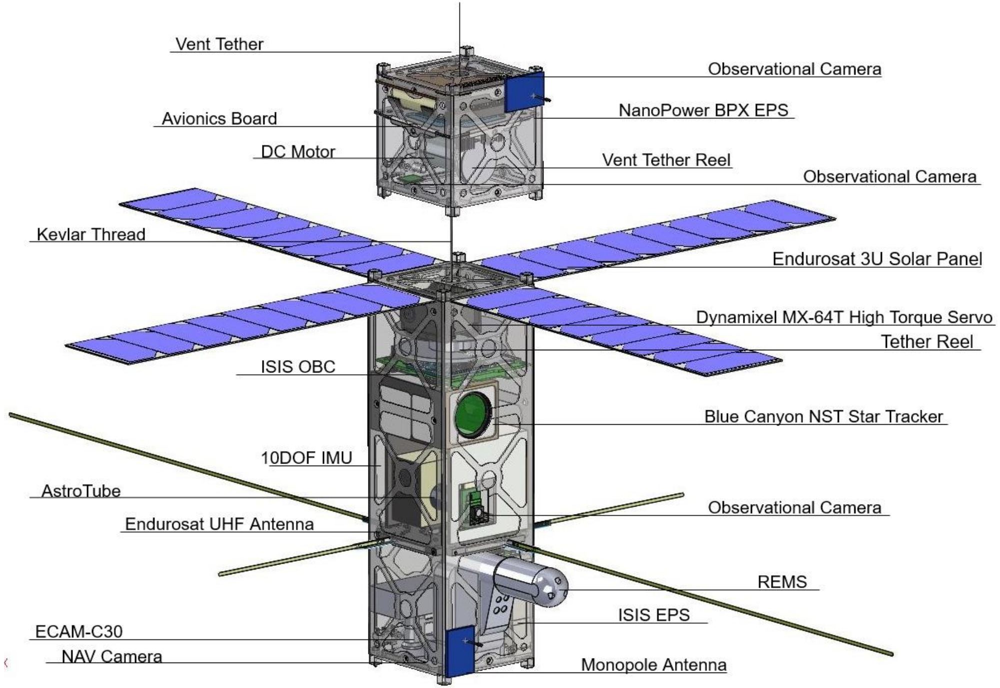
With a light enough payload, and pre-heating of the envelope, the MEB can achieve buoyancy during EDL.



MEB CubeSat System Design

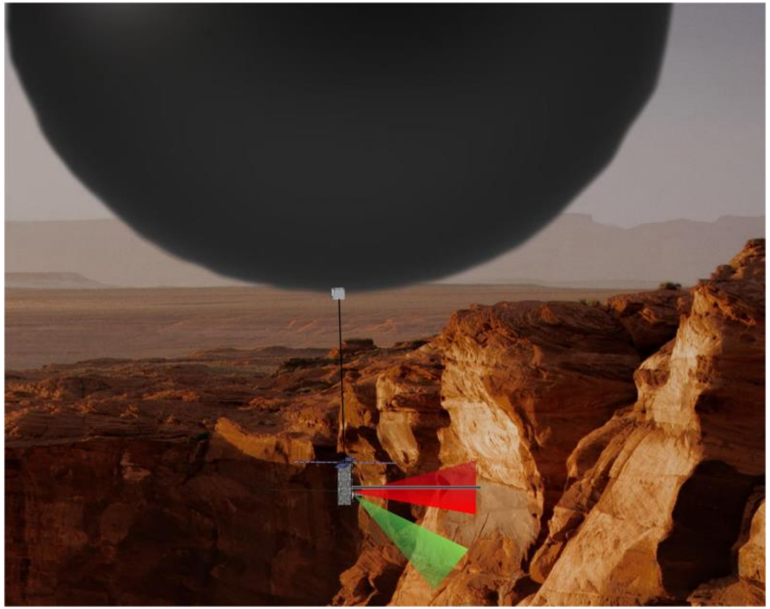


MEB Stowed 12U Configuration

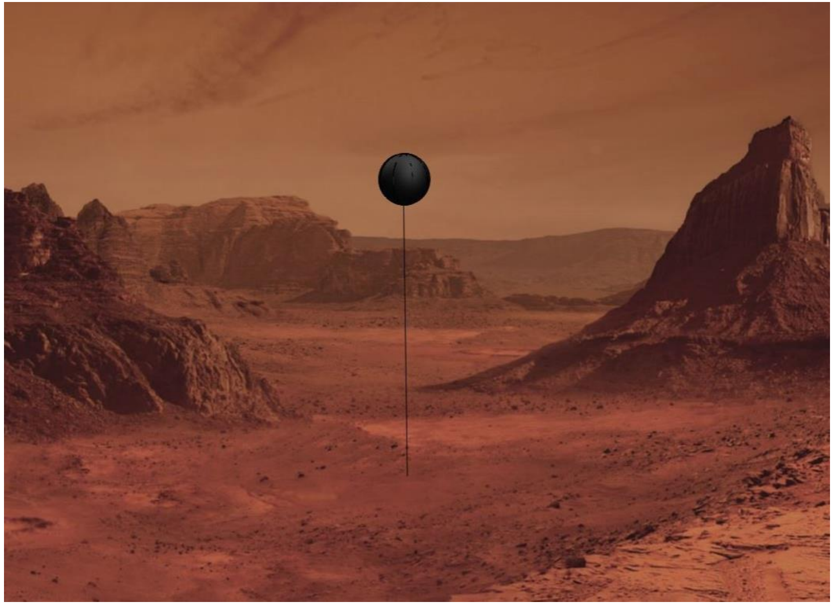


MEB Deployed Primary & Vent Gondolas

Exploring Mars



MEB collecting science data on an exposed Martian cliff wall: high res-imagery, stratigraphy, core sampling, LIDAR



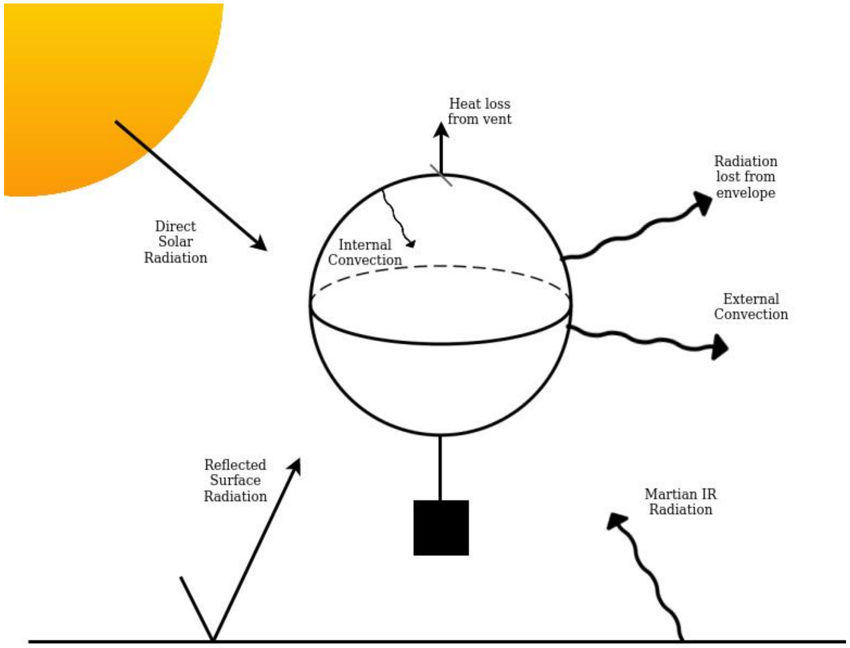
Anchored MEB, collecting extended atmospheric data and imagery, 1 km above the surface

Envelope Radiation Model

$$A_{proj} = 0.25 * \pi * d^2$$

$$ViewFactor = \frac{1 - \cos(HalfCone_{angle})}{2}$$

$$HalfCone_{angle} = \arcsin\left(\frac{R_{Mars}}{R_{Mars} + z}\right)$$



Absorbed direct sunlight is denot

$$Q_{sun} = \alpha * A_{proj} * q_{Sun}$$

Absorbed Albedo Heat is denoted by:

$$Q_{Albedo} = \alpha * A_{surf} * q_{Albedo} * ViewFactor$$

Absorbed Martian Surface IR Heat is denoted by:

$$Q_{IR,Surface} = \alpha_{IR} * A_{surf} * q_{IR,Surface} * ViewFactor$$

Emitted IR Energy from the Envelope is denoted by:

$$Q_{IR,emit} = \sigma * \epsilon * A_{surf} * T_{envelope}^4$$

The overall heat radiation on the balloon is then denoted by:

$$Q_{rad} = Q_{sun} + Q_{Albedo} + Q_{IR,Surface} - Q_{IR,emit}$$

Energy Balance Equations

Venting for Altitude Control

$$Q_{vent} = \dot{m} * c_v * (T_i - T_{atm})$$

Envelope Temperature

$$\frac{dT_s}{dt} = \frac{\dot{Q}_{rad} + \dot{Q}_{conv,ext} - \dot{Q}_{conv,int}}{c_{v,env} * m_{envelope}}$$

Internal Temperature

$$\frac{dT_i}{dt} = \frac{\dot{Q}_{conv,int} - \dot{Q}_{vent}}{c_{v,CO^2} * m_{CO^2}}$$

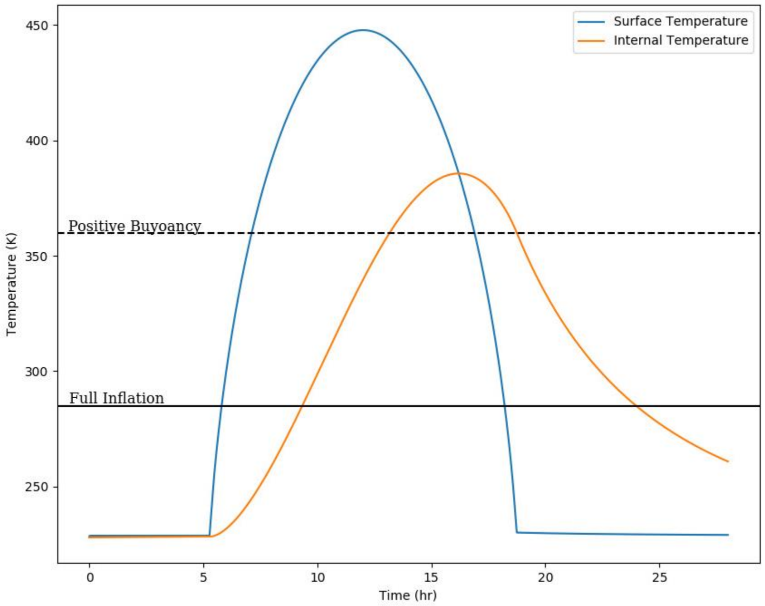
These equations provide the dynamic temperature response as a function of time.

Partner

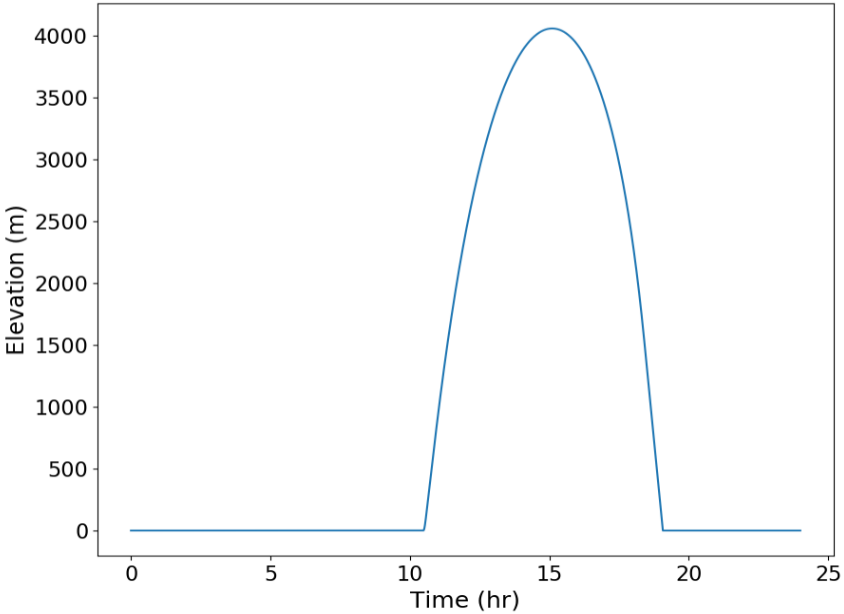
SpaceTREx

Trajectory for Baseline Balloon Model

Temperature

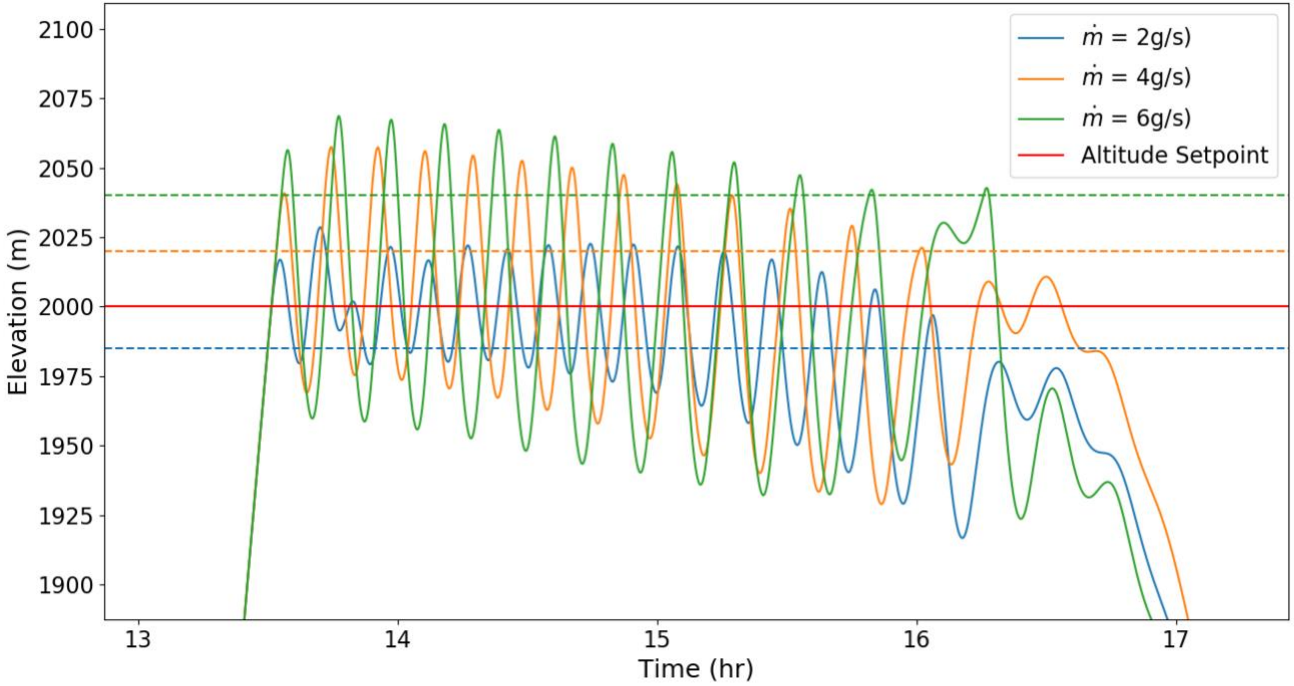


Elevation



A smaller envelope-to-payload ratio results in longer flight times as well as higher maximum achievable altitude.

Altitude Position Control for Baseline Model - With Venting

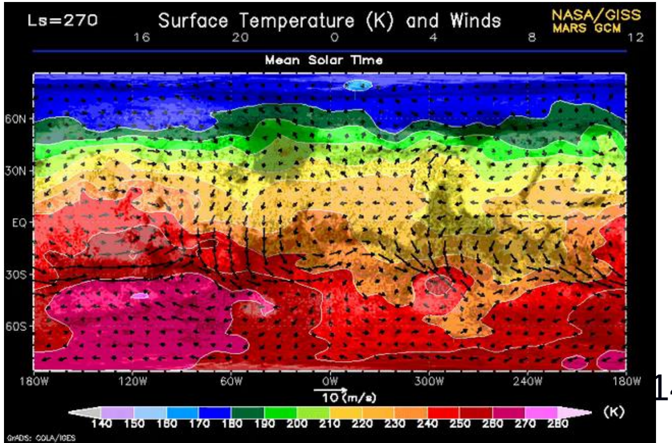


A smaller vent results in smaller limit cycle, but more vent openings.

As vent size increases, “deadzone” for altitude control increases as well.

Discussion

- Extended sunlight from exploring poles in summer/winter results in longer flights without anchoring
- Mars is a breathing planet, seasonal climate change and winds
- Can compliment other surface vehicles
- **Biggest Challenge**: Multi-day flights



Conclusions

- Flying solar balloons on Mars is challenging but this model shows feasibility of the platform.
- Highly customizable and can be designed for specific missions.
- Future work:
  - 3D control model
  - Terrestrial experiments
  - Swarm and Multi-Agent Systems


SpaceTREx
Adventure Awaits