

**Mars-BARS (Balloon for Aerial Regional-Scale Science): a Proposed Martian Aerial Platform Mission.** C. Todd<sup>1</sup>, J. Espley<sup>2</sup>, R. Bowens<sup>1</sup>, L. Cacciottolo<sup>1</sup>, M. Chattrabuti<sup>1</sup>, S. Cruz<sup>1</sup>, A. Festa<sup>1</sup>, R. Glait<sup>1</sup>, R. May<sup>1</sup>, J. McDougall<sup>1</sup>, E. Prober<sup>1</sup>, J. Schachter<sup>1</sup>, J. Wich<sup>1</sup>, J. Gruesbeck<sup>2</sup>, and S. Guzewich<sup>2</sup>, <sup>1</sup>University of Michigan (cwtodd@umich.edu, rpbowens@umich.edu, lucaccio@umich.edu, mchattra@umich.edu, juanse@umich.edu, afesta@umich.edu, glait@umich.edu, remay@umich.edu, jackmcd@umich.edu, etprober@umich.edu, jschach@umich.edu, jameswic@umich.edu), <sup>2</sup>Goddard Space Flight Center (jared.r.espley@nasa.gov, jacob.r.gruesbeck@nasa.gov, scott.d.guzewich@nasa.gov).

**Introduction:** Mars-BARS is a proposed regional-scale environmental study of Mars that leverages an aerial platform capable of covering hundreds of kilometers (500+ km) at low-altitude (1-8 km) while carrying a suite of scientific instruments that collect data to address several fundamental questions regarding the Martian environment. A mission of this type and scale fills a gap between the local- and planetary-scale whereby certain regional phenomena could not be adequately measured.

Through a rigorous down-select process, the aerial platform for this mission has been selected to be a balloon, which was preferred to both fixed-wing and rotary-craft options. The proposed design consists of a balloon capable of lifting a 100 kg strawman payload with an average power consumption of 140 W. The balloon does not carry an onboard propulsion but features an altitude control system and it can determine its location with an accuracy better than 100m.

**Top-Level Science Objectives:** The strawman science payload for the evaluated mission concept was derived from the regional-scale science proposal produced by the science team at Goddard Spaceflight Center (GSFC) and supplied to the student engineering team at the University of Michigan's Department of Climate and Space Sciences and Engineering (UM CLaSP). The mission design was conducted as part of a graduate-level course on spacecraft design.



The four primary science objectives of this mission are as follows: 1) to show how regional crustal magnetic fields demonstrate the history of Martian tectonics, volcanism, and cratering; 2) to determine the astrobiological significance of regional surface radiation; 3) to resolve contradictory understandings of methane distribution around sources and sinks at a regional and planetary scale; 4) to identify landscape

geomorphology as well as capture video for mineralogy analysis.

**Top-Level Mission Requirements:** The mission requirements for the platform were either directly dictated by the science team at GSFC or derived from the needs of the science objectives, and are as follows: 1) the mission shall conduct science observations for 500 km in linear distance traveled. The mission shall cover at least three approx. linear segments each at least 30 km long and separated by a mean distance of at least 10 km; 2) the mission shall sample the Martian atmosphere to a spatial resolution of better than 1 km; 3) the mission shall report its location at all times to better than 1 km accuracy in all three dimensions; 4) the platform shall have a mean altitude during observations of between 1 and 8 km; 5) the mission shall be conducted in the region 30 to 60 S, 150 to 210 E at Mars; 6) the mission shall return at least 1.5 Gbits of data to Earth using the DSN via orbiting relay to downlink science and housekeeping data per Martian sol; 7) during science observations, all instruments shall be collecting data; 8) the mission shall conduct observations for at least two Martian sols.

**Platform Trade Study:** Several vehicle platforms were evaluated to satisfy the top-level mission requirements. A trade study was performed to analyze which platform could best meet these requirements.

**Fixed-Wing Platform.** The first platform considered was a fixed wing vehicle. Fixed wings are capable of performing forward motion with respect to a moving medium to generate lift. The scientific payload is kept inside the body of the aircraft. Three different fixed wing technologies were considered to determine the most appropriate application to Mars-BARS. The glider concept would be released upon entry into the Martian atmosphere and would collect data while gliding to the ground. The propeller-driven fixed-wing craft would generate lift through a rotary propeller mechanism. The rocket-propelled glider would use chemical rockets to increase its velocity (and therefore altitude) by generating thrust in bursts and then gliding back down following a thrusting maneuver.

**Rotorcraft Platform.** The next platform considered was a rotorcraft. Rotorcraft generate lift through rotary propellers mounted at the top of the platform, which

rotate parallel to the ground and are controlled via remote input. The rotorcraft stands out from other platforms by having the capability of making precise directional changes even on Martian atmospheric flight, where the flow easily separates from a wing surface, allowing for precise acquisition of image data in various places on the Martian surface. Control is attainable without increasing flight speed, as flight speed directly affects measurement resolution. These requirements were mission-essential restrictions through which prospective aircraft were evaluated.

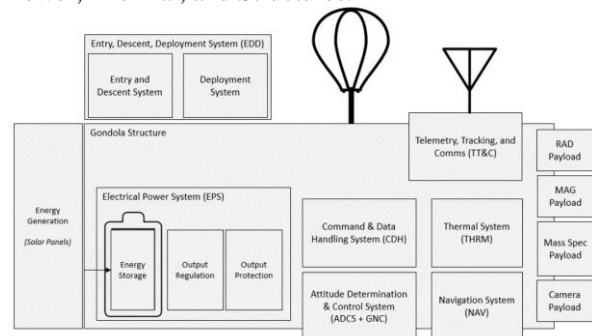
**Balloon Platform.** The final platform considered in this trade study was the balloon, defined to be any platform that achieved altitude through the passive containment of a lifting gas in an envelope. This method operates at a lower power cost to the fixed-wing and rotorcraft platforms, though it lacks control over the direction of the platform, which would drift passively in accordance with the wind at a given altitude of operation. For this trade study, three platform types were considered: a Montgolfiere-style balloon with an open-to-atmosphere envelope that uses heated gas for lift, a high-altitude-balloon (HAB)-style balloon such as those used for weather monitoring in the upper Earth atmosphere, and a zeppelin-style airship with rudder control and an elongated envelope.

**Platform Selection.** The criteria for platform selection were defined as all aspects of the vehicle essential to carrying out the top-level requirements. Criteria were further subdivided into high weight (valued at 3) and low weight (valued at 1) scores based on the impact of the criteria on the overall mission. A Pugh chart was used to categorically rate each platform in each of the criteria. The balloon craft was used as a baseline for comparison, meaning it received a score of zero for each. For the other two platforms, a positive rating indicates that the craft will accomplish the criteria in a simpler or more robust manner than the balloon, and a negative rating indicates that the craft will have more difficulty accomplishing the criteria.

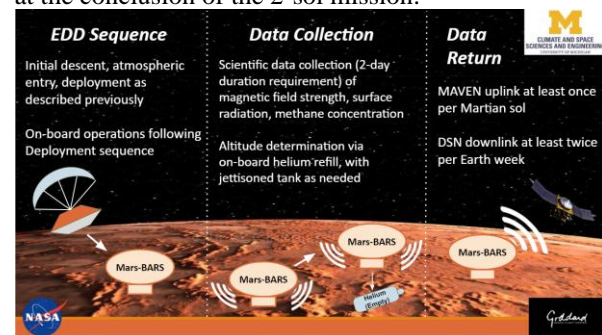
Criteria	Weight	Balloon	Fixed-Wing	Rotorcraft
Mass	3	0	0	0
Ease of Deployment	3	0	0	-1
Flight Distance	3	0	0	-1
Power Requirements	3	0	0	-1
Spatial Awareness	3	0	0	0
Packing	3	0	0	1
Max. Altitude	3	0	0	-1
Ease of take off	1	0	0	-1
Lifetime	1	0	-1	-1
Flight Time	1	0	-1	-1
Speed	1	0	1	0
Robustness	1	0	0	0
Level of Autonomy	1	0	-1	-1
Controllability	1	0	1	0
+1		--	2	3
0		28	23	9
-1		--	3	16
<b>TOTAL</b>		<b>0</b>	<b>-1</b>	<b>-13</b>

As neither the fixed-wing nor the rotorcraft platform succeeded in outperforming the balloon platform, the latter was selected as the platform for the mission to be carried out on.

**Subsystems:** After selecting the balloon platform, the next step was to consider all relevant subsystems. The eight subsystems needed are as follows: Entry, Descent, and Deployment (EDD), Attitude Determination and Control (ADCS), Guidance and Navigation (GNC), Command and Data Handling (CDH), Telemetry, Tracking, and Command (TTC), Power, Thermal, and Structures.



**Concept of Operations:** The full operation of the platform over the 2-day mission duration is broadly divided into three modes of operation – EDD Sequence, Data Collection, and Data Return – with provisions to continue operation between the Data Collection and Data Return modes indefinitely should the mission duration be extended beyond this. There is opportunity for multiple passes over the course of the 2-sol mission duration, meaning that the current operational mode of the balloon will vary between Data Collection and Data Return multiple times before the data is finally transmitted across the DSN to Earth at the conclusion of the 2-sol mission.



**Conclusion:** The Mars-BARS regional-scale aerial platform will address fundamental questions about the Martian environment with low-cost methodology. A balloon platform was chosen to accomplish this task, with detailed subsystem analysis performed to ensure the proper function and fulfillment of critical mission requirements while operating in the Martian environment.