# Interplanetary (IP) CubeSats for Mars Missions

July 2014

Jacob Teepen

*Mars Initiative, 5521 Greenville Ave.*
*Suite #104-238 Dallas, TX 75206*
*562-536-1982, jacobteepen@yahoo.com*

**Abstract.**

A human mission to Mars will be a complex undertaking that will require extensive supporting infrastructure. Many measurements must be taken and the deployment of supporting infrastructure must first be achieved. For instance, the planet must have a GPS system, atmospheric data must be constantly measured, etc. For large satellites to go out and do these specific missions is extremely expensive and inefficient. But the solution is already here – Interplanetary CubeSats. Interplanetary CubeSats are much smaller and lighter, but can accomplish specific infrastructure missions as well as prove to be extremely useful to science and exploration in other ways. Thanks to the small size and mass of CubeSats, many missions can be achieved and combined in a single launch.

**Keywords:** CubeSat, Mars, Mission to Mars.

## 1. INTRODUCTION

A CubeSat is a type of nano-satellite, or miniaturized satellite, which is exactly 1 liter (10x10x10cm) [5]. Originating in 1999 at the California Polytechnic State University and Stanford University, the CubeSat was first designed for graduate students to receive hands-on experience with creating a spacecraft [5]. Although the CubeSat is defined as one size, additions may be added to proportionally lengthen the spacecraft in increments of unit volumes or U's. CubeSat sizes may range anywhere from 1U (10x10x10cm) to a more typical size of 3U (10x10x30cm), or even that of a 12U (30x10x40cm) [2]. This paper will address several concepts and missions that the CubeSat is capable of, but go into detail of the 3U CubeSat, as far as specifications and budgets, as well.

## 2. CUBESAT ADVANTAGES

Having been created for educational purposes, the CubeSat is not only good for education, but for scientific research as well. It's relatively low cost makes kits affordable for students to build and gain hands-on experience in spacecraft development. In addition, its simplicity allows the younger population to understand it and creates a possible tool for outreach to gain support in the space industry. The fact that it is a simple satellite with a payload sector makes it easy to specify to complete certain tasks. The CubeSat is small, lightweight, and can easily fit into tight payload spaces. Another unintentional advantage is, due to the size, it has a lower probability of a collision with other satellites and therefore has lower risk in the field of "space junk."

## 3. 27 CUBESATS TO MARS CONCEPT

The main idea of this mission is to send 27 CubeSats to mars to do various tasks. As mentioned throughout the paper, each CubeSat can be easily modified to do a specific task. With 27 CubeSats, each specified to their own mission, a lot of important information can be gathered and important services, such as navigation, delivered.

One concept for getting CubeSats to Mars is to use a secondary payload adapter ring. This ring will adapt to nearly any EELV-class rocket and fits between the primary payload and the payload mounting ring above the final stage. See figure 1 for the mission concept.

Once the rocket has reached low earth orbit, or enough altitude for the primary payload to separate, the adapter ring will come off as well. From the ring, solar panels will extend and provide power to the spacecraft. Using an ion drive propulsion system, the ring will use the energy from the sun and its electric propulsion as a way of transportation. From there, it will begin the journey to Mars using orbit and propulsion. Once it has reached the Martian orbit, the ring will deploy all 27 CubeSats to their various operational Martian missions and orbits.

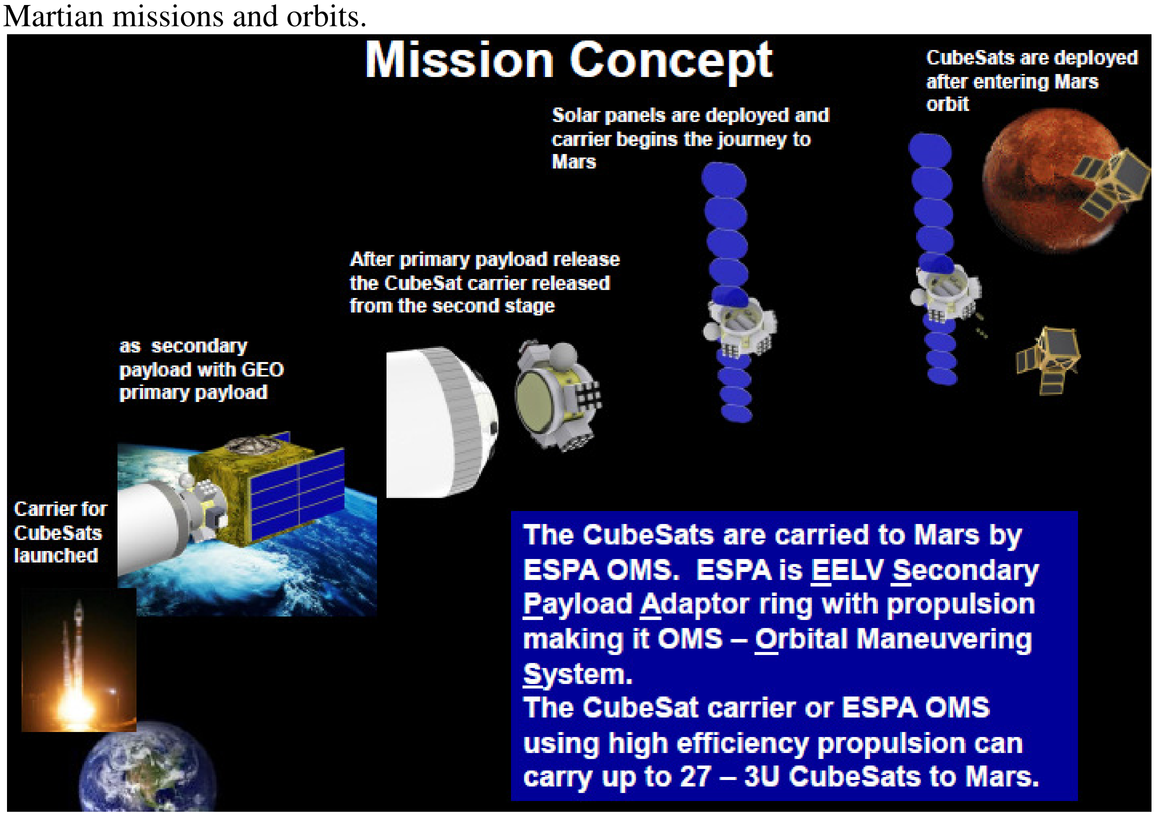


*Figure 1, A mission concept to send 27 CubeSats to Mars, [6]* Once the CubeSats have been deployed, the ring will then continue to be of use by orbiting Mars and continuing operation as a communication relay back to Earth. Due to the small size of the CubeSat, their radio transmitters are not strong enough to reach Earth. However, the adapter ring will act as a middle-man, making communicating with the CubeSats much easier. The ring is an amazingly versatile thing; it works well for the rocket, can deliver many CubeSats, can act as a satellite on arrival to Mars, and can act as a radio relay on its own.

## 4. STANDARD 3U CUBESAT BUDGETS

### 4.1 Volume Budgets

As noted in the introduction, a 3U CubeSat typically measures 10x10x30cm. However, with only 30cm of length to work with, this makes fitting the satellite essentials a challenge. Fortunately, the solar panels do not contribute to the space occupied by the spacecraft, allowing many solar panels, deployable and non-deployable, to be added. However, the 3U CubeSat is generally occupied 50% by the satellite essentials and 50% by the payload sector. See table 1a for a volume budget.

Of the satellite essentials, the propulsion unit takes the most space with 0.5U. Following the thruster are the battery and reaction wheel assembly at 0.25U each. The last 0.5U are occupied by components such as the radio transmitter, Power Management Board [PMB], Command and Data Handling board [CDH], and the Inertial Reference Board [IRB]. The other 1.5U is used for the payload sector or non-essential, but highly useful, satellite components.

### 4.2 Mass Budget

Nearly all CubeSats have a general rule of thumb concerning the weight of the spacecraft – 4/3, or 1.334, kilograms per U more or less. By this definition, the 3U CubeSat should not weigh more than 4 kg. However, as with all CubeSats, weight variance is allowed, but for the 3U, no more than 5kg. The reasoning behind this is because CubeSats must remain lightweight and virtually unnoticeable to ensure it does not have a toll on the rocket. In addition, the light weight helps keep the CubeSat intact during the vibrations of travel, as well as ensure maximum efficiency once underway. See table 1b for a mass budget.

Because of the light weight of the entire spacecraft, each component of all CubeSats must be compact and lightweight as well. Unlike the volume occupation, solar panels and the skeleton do contribute to the weight. These outer components together take up approximately 1.2kg. The satellite essentials go as follows: propulsion unit at 1kg, battery at 0.8kg, CDH and IRB both at 0.35kg, and the radio transmitter and PMB both at 0.1. This entire subsystem comes to a total of 2.8kg. This leaves exactly 1kg for the payload sector or any other components.

### 4.3 Power Budget

All manmade systems in space require power, usually generated by solar energy. This is no different for interplanetary CubeSats. Nearly all CubeSats are equipped with 5-watt solar panels. The number of solar panels depends on the size of the CubeSat and the number of U's it possesses. However 5 watts is not nearly enough to run a spacecraft. Fortunately, because the spacecraft is in the sunlight for a great deal of time during an orbit, one solar panel could provide up to 25 watts of energy in one orbit. Additional solar panels could contribute more energy up to 40 watts total. Deployable solar panels can nearly double the surface area and possibly provide even more power. Even with all this solar energy, power storage as well must be taken into consideration for operation during orbital eclipses. CubeSat batteries can store anywhere between 10-30Whr. Note that multiple batteries can be placed in parallel to achieve higher capacities. See table 1c for a power budget.

Though the statements above may appear to provide a great deal of energy, power budgeting is extremely important as the subsystems consume a great deal as well. Some propulsion units can take anywhere from 10-20 watts to run, depending on the type. The onboard computers, or CDH, can easily consume another 0.3 watts as well. Following the CDH are the radio transmitter and reaction wheel assembly at 0.2 watts each. Finally, the microchip boards, or the PMB and IRB, consume very little at 0.1 watts each. The remaining power supply can be contributed to the payload sector and other components or subsystems to carry out a mission.

*Tables 1a, 1b, and 1c: Typical Volume, Mass, and Power Budgets for 3U CubeSats*

| Tables 1a, 1b, 1c | Volume, Mass, Power Users | No. of "U's" | mass, Kg | power, W |
|---|---|---|---|---|
| Outer Components | Solar Panels | 0 | 0.2 | 25 |
| | Skeleton | 0 | 1 | 0 |
| | | | | |
| Required Components | Radio | 0.1 | 0.1 | -0.2 |
| | Battery | 0.25 | 0.8 | 0 |
| | Power Management | 0.1 | 0.1 | -0.1 |
| | Command & Data Handling | 0.1 | 0.35 | -0.3 |
| | Inertial Reference Board | 0.2 | 0.35 | -0.1 |
| | Reaction Wheel/Thruster Asbly | 0.25 | 0.1 | -0.2 |
| | Propulsion | 0.5 | 1 | -10 |
| | | | | |
| Payloads | Payload Sector | 1.5 | 1 | -12 |
| | | | | |
| | Totals (margin for power) | 3 | 5 | 2.1 |

# 5. SELECTED CUBESAT MISSIONS FOR MARS

## 5.1 Mars GPS Mission

As mentioned in the 27 CubeSats to Mars Concept, 27 CubeSats are assigned and deployed to specific missions on Mars. One highly important mission is the configuration of a GPS system of the planet. 18 of the 27 CubeSats will be assigned to this mission in a pattern of three orbits, with six CubeSats per orbit. The idea behind this system is to replicate that of Earth's GPS system as closely as possible, minimizing software impacts to the GPS receivers (originally designed for Earth).

The GPS payloads are standard L1 and L2 transmitters, using about 10 watts of power (replacing power budget of propulsion unit once in orbit). As the Mars expedition grows, the GPS system will be of dire need as locating supplies and equipment will be life critical.

## 5.2 Mars Atmospheric Imagers & Sounders

The main goal of this mission is to track weather patterns on the surface and in the atmosphere of Mars. Of the 27 CubeSats, four will be dedicated to these two missions: two CubeSats for atmospheric imaging, and two CubeSats for atmospheric sounding. Atmospheric imaging uses a payload with live video camera that allows us to visually see and track weather patterns throughout the planet. Due to lack of liquid water, the atmospheric imager would have a main concern of dust storms.

Atmospheric sounding works much like SONAR in the sense that the payload will release a sound and measure the density and/or particles of each element in the atmosphere based on the sound that is returned. Doing so allows scientist to determine more closely what particles are in the atmosphere in addition to how dense it is. This also allows a good mapping process to take place for entry and re-entry of the Martian surface.

## 5.3 Mars CubeSat sized Exolance Reentry Vehicles

As a payload-delivering satellite, the five remaining CubeSats would deliver Exolance Reentry Vehicles [ERV] to the surface of mars. The ERV are a type of payload designed to search for life on Mars. The idea behind the ERV is rather than sending a complicated lander down to carefully deliver a device to the surface, the ERV, like a missile, will enter at hypersonic speed, and, without a parachute, will project itself into the surface of Mars. In the tip of the ERV will be a bio-sensor to detect for any forms of life, or what could potentially be life, beneath the surface of Mars. The end of the ERV will contain an antenna with radio transmitter to relay information to an orbiter, possibly the adapter ring, which will boost the data to Earth. To save on power, the transmitter will collect the information in bulk, and only send bursts as the orbiter is within view.

## 6. CONCLUSIONS

The small size of the Interplanetary CubeSat allows multiple missions to be supported by one launch. In addition, thanks to its weight and low cost, CubeSats can be variously personalized not only for infrastructure or research, but as a possible academic teaching tool as well.


## 7. ACKNOWLEDGEMENTS AND DISCLAIMERS

I would like to acknowledge Gary V. Stephenson for mentoring me throughout this process and to the Mars Initiative for making this possible. Disclaimer: Each CubeSat mentioned throughout the paper is referencing a 3U CubeSat unless otherwise stated. This paper represents one approach to a mission design and should not be construed as design guidance for other missions. The views expressed in this paper are solely the author's and do not represent the position or views of Mars Initiative, or any other organization.


## 8. REFERENCES


[1] Clark, Craig, and Ritchie Logan. "Power Budgets for Mission Success." *Clyde Space*. Clyde Space Ltd, 28 Apr. 2011. Web. 15 June 2014.

[2] Crook, Matthew R. *NPS CubeSat Launcher Design And Model*. Rep. no. 0704-0188. Monterey: Naval Postgraduate School, 2009. Print.

[3] "CubeSat Launch Initiative." *Human Exploration and Operations*. Ed. Erin Mahoney. NASA, 28 June 2014. Web. 30 June 2014.

[4] "NASA Announces Fifth Round of CubeSat Space Mission Candidates." *PR Newswire*6 Feb. 2014. *Student Resources in Context*. Web. 7 July 2014.

[5] Paluszek, Michael, Eloisa DeCastro, and Derrek Hyland. *The CubeSat Book*. 1st ed. Vol. 1. Plainsboro: Princeton Satellite Systems, 2010. Print.

[6] Carberry, Chris, et al., "CubeSats-to-Mars Program, A private, not-for-profit Mars Mission Concept developed by Explore Mars Inc., Busek, Tyvak, and Cal Poly. Presentation. 7 July 2014

[7] "Exolance Reentry Vehicle." *The Mission*. Exolance, 12 July 2014. Web. 17 July 2014. <http://exploremars.org/exolance/the-mission/>.