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CubeSat on an Earth-Mars Free-Return Trajectory to study radiation hazards in the future manned mission

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Abstract

In order to prepare the Human Mission to Mars, few aspects of the mission still have to be known. During a transit to the Red Planet, future crews will be exposed to potentially hazardous radiations [1].

By using a CubeSat, we can then have a relatively cheap and easy way to improve the radiations environment knowledge for a Mars manned mission.

A 1 Unit CubeSat is a type of miniaturized satellite for space research that usually has a volume of exactly one litre (10 cm cube), has a mass of no more than 1.33 kilograms and typically uses commercial off-the-shelf components for its electronics [2]. In this project, it is planned to use a 3 Unit CubeSat having the following dimensions: 10 cm x 10 cm x 30 cm and a maximum mass of 4kg.

1. Mission Objectives

1.1 Primary Mission Objective

Radiations may cause death by cancer, fertility, cataracts and have effects on the central nervous system [3]. Only one instrument (Radiations Assessment Detector on Curiosity) took successfully radiations measurements between Earth and Mars but only on the way to go [4].

Because of the lack of radiations measurements during the Earth-Mars-Earth journey, radiation models which take into account large margins are used. Thus, leading to the (maybe wrong) conclusion that the radiation hazards for a Mars manned mission is too high [5].

We propose then to use a CubeSat to scout the manned mission by catching observational data of radiation hazards during the Earth-Mars-Earth journey.

1.2 Secondary Mission Objectives

In order to realize such a mission, the CubeSat will need to realize some very small correction of trajectories, it will then be mandatory to have a very precise attitude determination and control system with propulsion system onboard.

Having such a system would then allow us to add another scientific payload on the satellite, such as a camera to watch for potential Near Earth Objects. The CubeSat could then contribute to the global hunt for asteroids and other hazardous natural objects that may strike the Earth.

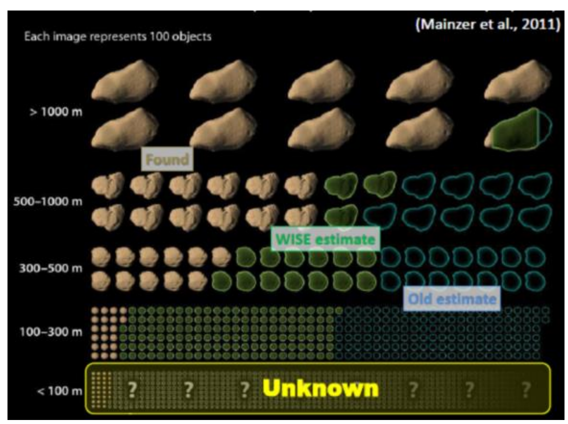

Figure 1 - Near Earth Asteroids observed by WISE (NASA mission) © PERC/Chitec

If the CubeSat is launched and jettisoned as a piggyback of another satellite going to Mars, another mission objective could then be added to this CubeSat. Indeed, after launch, the CubeSat would be separated from its "host". It could then become a travel companion of the "host" mission, separated by few kilometers (no impact on "host" safety). The CubeSat could then, if requested by the mission “host” take pictures of the “host”. Selected pictures of the “host” and/or scientific data could be sent to the “host” which could relay the data back to Earth. By doing so, the CubeSat could then improve the situational awareness of its “host” mission.

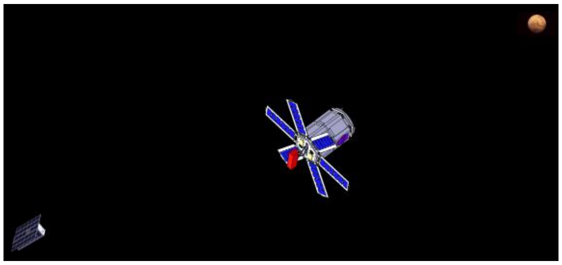

Figure 2 - Artist view of the Martian CubeSat taking pictures of its “host” © NCKU

2. Earth-Mars Free-Return Trajectory

The CubeSat would use an Earth-Mars free-return trajectory that leaves Earth, fly by Mars and return to Earth without any deterministic manoeuvre after Trans-Mars injection. This trajectory will be most likely the one used for human mission to Mars and would allow a CubeSat mission to Mars to be feasible. The duration of the mission would be of approximately 500 days [6].

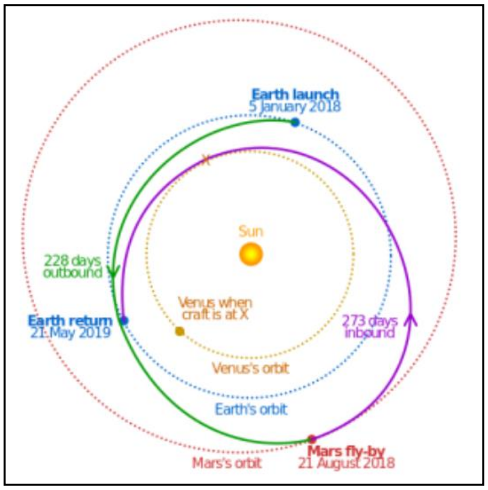

Figure 3 - Earth-Mars Free-Return Trajectory © Inspiration Mars Foundation

3. Main challenges

The major challenges which usually appear when designing a CubeSat mission for the Solar System exploration, like the propulsion and the communications, could be overcome in this particular mission.

3.1 Trajectory Corrections

After Trans-Mars injection, only small corrections of trajectory are needed, making the mission possible by using an electrical micropropulsion system onboard the CubeSat.

Many electrical micropropulsion systems suitable for CubeSats are currently being developed by several private companies and national space agencies.

Such an electrical propulsion system would fit in 0.5U of the CubeSat and has typically a TRL 5.

System Volume	< 0.5 U
System Mass	< 0.55 kg
System Power	2 W (at 2 Hz firing rate)
Thrust	0.5 mN, primary 0.13 mN, ACS
ISP	700 s
Delta V (for 4kg spacecraft)	63 m/s, primary 65 m/s, ACS
TRL	5

Table 1 - e.g. Key performance characteristics of the Busek Micro-Pulsed Plasma Thruster © BUSEK

3.2 Communications

Even if the CubeSat is launched and jettisoned as a piggyback of another satellite going to Mars, we do not plan to rely on the “host” mission to relay the data back to the Earth.

In order to avoid any dependence of the Martian CubeSat to its potential “host”, or in the case that the CubeSat would be launched to Mars alone, it is plan to have only few communication opportunities with the spacecraft.

The CubeSat would acquire data during its way to Mars and on its way back to Earth and would then transmit them to a Martian orbiter while approaching

Mars and to the Ground Station(s) when back nearby the Earth.

The Martian CubeSat would then have three communication opportunities: one soon after launch while still nearby the Earth, one around Mars and a last one on its way back nearby the Earth.

3.3 Onboard Storage and Data Processing

Due to the lack of communication opportunities, the CubeSat will have to be very autonomous.

Strong efforts must be done regarding the onboard data processing.

The COVE (CubeSat Onboard processing Validation Experiment) is a good example of a successful mission dedicated to the improvement of data processing onboard a CubeSat [7].

4. CubeSat Design

At the current stage, the design has not been very precisely established. The Table 1 and Figure 4 show a very preliminary design of this CubeSat.

Size	3U: 10cmx10cmx30cm
Mass	4 kg
Attitude Control	0.5U: Electrical Prop.
OBDH+EPS+COMMS	1U
Scientific Instruments	1.5U: Radiations Payload + Asteroids/NEO Optical Detector
Life time	~ 500 days

Table 2 - Martian CubeSat overview table

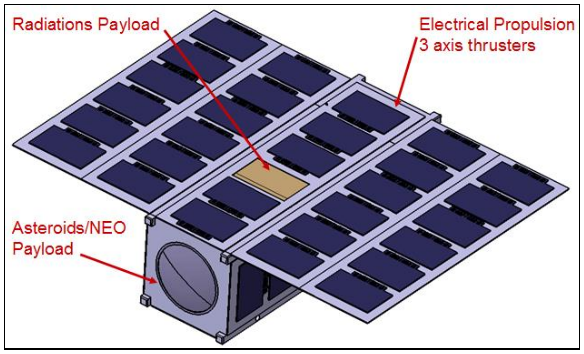

Figure 4 - View of the Martian CubeSat

5. Summary and Conclusions

The Martian CubeSat could then satisfy several mission objectives as:

- Scout the manned mission to Mars by measuring radiations in situ over the full Earth-Mars-Earth journey.

- Improving the Space Situational Awareness for the Earth by contributing to the global hunt for asteroids and other hazardous natural objects that may strike Earth.

- And in the case of a CubeSat launched and jettisoned as a piggyback of another satellite going to Mars, improving the Situational Awareness of the "host" mission.

At the current stage of the project, the Phase 0 is being finalized and the Phase A will start by September 2013.

Such a free-return trajectory opportunity will occur for the next times in 2015 and 2018.

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