OPEN Beyond Orbit: Using the Designs from the Open Prototype for Educational NanoSats Outside of Earth Orbit

Jeremy Straub

Available at: https://works.bepress.com/jeremy_straub/125/
Overview

This paper presents an overview of the Open Prototype for Educational NanoSats (OPEN) and its prospective use in interplanetary missions. OPEN is framework to facilitate the low-cost creation of CubeSat-class spacecraft via using publically available (provided by the OPEN project) designs, software, fabrication instructions and test plans. The base open configuration is designed to be able to be produced with a parts budget of under $5,000. Despite this low cost, it is a very robust spacecraft (with capabilities meeting or exceeding many of the vendor-kit solutions which cost eight-or-more times this amount).

Two approaches for using the OPEN designs in the context of an interplanetary mission are presented. Under the first, a 6-U variant of the OPEN design is considered. This approach utilizes the OPEN subsystems and structural configuration in a conjoined configuration. The second considers the use of 1-U and 2-U and 3-U OPEN-derived CubeSats as part of a ‘hitchhiker’ style mission. Overviews of both these approaches for planetary science missions are analyzed with consideration given to the value produced as a function of mass and volume (which correlate with launch costs). This paper concludes with a discussion of the logistical impediments to using low-cost hardware, such as that incorporated in OPEN in an interplanetary mission. Considerations discussed include the radiation environment and the perception of risk that may preclude the spacecraft’s incorporation in a ‘hitchhiker’ mission environment with an expensive interplanetary spacecraft. A prospective pathway to possible acceptance is presented.

Logistical Impediments

Several logistical impediments exist to the use of CubeSats for planetary science and the ‘hitchhiker’ mission concept. These include:

1. Long-duration in space testing has not been performed.
2. Limited shielding may make operations outside of Earth’s magnetic shield (or a similar one) problematic.
3. Limited volume constrains onboard capabilities: communications, power generation, etc.
4. Craft containing pressure vessels may be seen as a risk to the primary (deploying) spacecraft.
5. Deployment of small craft (particularly for a non-related mission) may be seen as a waste of time and waste of primary mission resources.
6. The concept has not been demonstrated previously.

Radiation and Other Risks

Two key areas of risk exist: radiation damage to the spacecraft and risk to the primary spacecraft. While some level of radiation protection can be incorporated into the small spacecraft, the limited mass and volume constrains the level of radiation protection that can be incorporated. Given this, the risk can be mitigated through having a large number of craft, incorporating regular reset cycles (to clear the effects of single event upsets) and using RAD-resistant/hardened components. Risk to the primary craft can be mitigated through careful sub-satellite deployment procedures and limiting the maximum pressure that can be contained in a sub-satellite pressure vessel.

Value as a Function of Mass and Volume

Because of their limited mass and volume (and, arguably), dependence on a primary spacecraft for deployment and other capabilities, the value that can be produced as a function of the mass and volume of the spacecraft is quite high. While characterizing scientific value is problematic, several surrogate measures can be considered. For example, the number of images that the spacecraft can collect and return to controllers or the completion of a gravitational map (and the associated resolution levels of both of the aforementioned) can be used to compare different approaches to data collection about a target. The aforementioned is problematic, however, with a secondary ‘hitchhiker’-style mission as, while the collection capabilities of the spacecraft can be projected, the dependence on the primary spacecraft for data transmission creates a significant unknown. Specifically, the transmission needs of the primary mission (or agreement for usage between primary and secondary mission controllers) may constrain the amount of data that can be sent back to Earth to significantly below collection capabilities. As a result, onboard analysis is highly desirable to increase the value-per-byte of data transmitted.

Pathway to Implementation

The pathway to implementation begins with the completion of the 1-U OPEN design and its in-space validation. From this, 2-, 3- and 6-U chassis can be created which can reuse (perhaps with modifications to make them more radiation resistant) OPEN-style Boards. Radiation environment testing must be conducted and the ADCS needs of the larger system assessed and responded to.

References