Maximizing Science Return of SmallSats with Programmatic Support

Thematic Area: Electromagnetic Observations from Space

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Key Issue

An entirely new opportunity is opening up to the astrophysics community with the advent of SmallSats to do innovative astrophysics from space (e.g. Shkolnik 2018). But the infrastructure support for them right now is basically limited to a free or reduced-cost launch. We propose that NASA set up a support infrastructure for SmallSats by paying for common services separate from the SmallSat budget. This is already being put in place for mission operations, but is absent for ground system support like data reduction, archiving, and potentially, a guest observer program. A dedicated support system for SmallSats would allow limited team resources to be spent on improving capabilities, while also greatly expanding the science return of each mission.

What is a Small Satellite?

We provide a brief summary here of what we define as a SmallSat. For more details please see the companion white paper by D. Ardila et al. on SmallSat Astrophysics.

In the recent Explorer call a SmallSat was defined as having mass ≤180 kg, small enough to be launched as a secondary payload.* At the upper end, a SmallSat would have dimensions 61 cm x 71 cm x 97 cm limited by the current secondary payload capacity. At the lower end, the Starshot Initiative recently launched six 4 grams satellites (Crane 2017). The most common SmallSats are CubeSats, sized in standardized units of 10 cm x 10 cm x 10 cm which defines 1U. Each 1U has a mass of ~1.3 kg.

Introduction

A very successful initiative at NASA has been the suborbital rocket and balloon program, funded through the Astrophysics Research and Analysis (APRA) program. They have served as platforms for technology development for new space missions like the High Energy Focusing Telescope (HEFT) which became the Nuclear Spectroscopic Telescope Array (NuSTAR; Harrison et al. 2005), and as missions capable of making scientific breakthroughs on their own with the rocket-borne telescope discovery of the first x-rays from a black hole: Cygnus X-1 (Giacconi et al. 1967).

These advances were made possible by NASA infrastructure for supporting and launching these missions. The Wallops Island Facility of the Goddard Space Flight Center provides support for pre-launch, launch, tracking, and recovery of scientific payloads for both balloons and rockets. By providing a standardized infrastructure, NASA has freed up the science PIs to be concerned primarily with the payload and its science goals.

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* The limit comes from the capabilities of the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA). The secondary payloads attach to this adapter and are released after the primary is deployed. A variety of larger ESPA rings that can host larger masses are also available.

In the case of CubeSats NASA is providing a similar service for the selected team in the form of free (for CubeSats sizes of 3U or less) or subsidized launches through the CubeSat launch initiative (CSLI). For SmallSats there is no charge under the current Explorer Mission of Opportunity call. But in practice, SmallSat missions have additional infrastructure requirements beyond launch that are not shared by rockets and balloons. By addressing those needs in a systematic way NASA can free up the full potential for SmallSat science.

Difficulties Facing SmallSats

Although the size of SmallSat instrumentation and the focused mission goals are very similar to rocket based and balloon based missions, the durations of SmallSat missions fundamentally places them in a very different category resulting in the following common requirements:

1. Mission Operations: Since SmallSat missions can last from months to years, there is a need to regularly communicate with them to downlink data, uplink new targets, and monitor operations.

2. Data Reduction Pipelines and Archives: Longer missions lead to larger datasets. Also, due to current regulatory restrictions on bandwidth, not all of the data can be downlinked. But in the near future both of these issues will be solved by laser communications that will allow very large data returns from SmallSats (Carrasco-Casado et al. 2017). So larger data returns will require a much greater effort in pipelining and archiving than is possible under current SmallSat funding.

3. Guest Observers: SmallSats have very well defined missions and science teams, they also have the potential for becoming more general observatories once their primary mission is over. Guest Observer (GO) programs are opportunities for scientists outside of the mission team to propose novel observations and/or new target objects. SmallSat missions do not have the personnel to administer a community GO program.

A Solution in Progress for Mission Operations and a Model to Expand

Standardization can be a great source for cost saving. NASA has started a process of standardizing the mission operations side for SmallSats. How best to achieve this is being considered by the NASA HQ SmallSat Coordination Group (SSCG), under the focus area for “services and infrastructure.” The results will be part of the NASA SmallSat Strategic Plan.

As the details of this approach are figured out, it is vital that NASA take this approach of providing cost saving infrastructure for mission operations and apply them to both the data reduction and archival challenges noted above, as well as to the GO challenges.

A Solution for Data Reduction and Archives: A Unified Science Operations Center

Science centers for larger NASA space missions have been established for decades, and a very pared down version is being implemented for the individually funded CubeSats. But because of limited funds these centers are designed to do a very narrowly focused job and so have little additional funds for anything beyond tailoring their efforts to the specific science question for each mission. For example, a mission to study exoplanet transits would not spend a great deal of effort on photometry or light curves of other sources in their field of view. But the data gathered by these missions can have a much broader impact to astronomy with a more general purpose reduction and archive allowing for future uses.

Thus the decadal survey should consider recommending that NASA fund an integrated astrophysics SmallSat science center funded separately from individual SmallSats. This approach will minimize or entirely avoid the difficulties mentioned above by providing the following:

1. Efficiency: Instead of funding multiple SmallSat science centers that duplicate each other's efforts (i.e. two separate UV imaging missions should not need to come up with two completely new UV data reduction pipelines). A single center will provide a much more efficient use of money for pipeline processing of data by leveraging components from previous missions.

2. Data Archive: A proper archive requires documentation of the reduction methods and contains all the calibration reference files used in the reduction. To maximize usability the archive will need modern tools for searching, cross-matching, and visualizing the data and catalogs resulting from the mission. Such tools can be leveraged from existing NASA archives. This will provide future astronomers not only easy access to the dataset for science beyond what was originally intended, but also allow for better future reductions of the data with the advent of new techniques.

3. Maximizing Future Returns: As the number of SmallSats grows, there will be a build-up of best practices for these highly cost constrained missions within the science center allowing for much greater returns per mission.

With a unified center the science teams from each new approved SmallSat will interact with the experienced team at the center to help establish the best possible data reduction and archiving procedures for their mission without having to generate the new software to implement those procedures with their limited funds. The center can also take the longer view of the data reduction and archiving and implement procedures which would be beneficial for the community but not necessary to the mission at hand.

A Solution for General Observer (GO) Programs: A NASA Administered SmallSat GO program

NASA could foster broader community participation in SmallSat astrophysics missions by taking on the administration of GO programs either during the prime mission or extended mission(s). NASA's Science Mission Directorate (SMD) can serve as an objective evaluator of proposals using peer review infrastructure already in place at the various larger mission science centers. GO programs for SmallSats would promote diversity and inclusion by providing an opportunity for more scientists to participate in space-based observation planning and data collection and also provide a training ground for future participation in mission proposals. Students, early career scientists, and researchers from institutions without a strong tradition in space missions would benefit from a NASA-administered SmallSat GO programs.

Summary

We have seen infrastructure support result in great science from very cost constrained missions on rockets and balloons and so an appropriately tailored infrastructure support for SmallSats should also be implemented.

As NASA establishes infrastructure support for the mission operations side of SmallSats, it should look ahead and do the same for data pipelines and archives for all upcoming SmallSat missions and consider using its already established GO infrastructure to provide greater access for the astronomical community to these new space based opportunities.

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