

The NASA ARC Small Spacecraft Division

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As the utility and usefulness of small spacecraft are being demonstrated in orbit by NASA and other organizations and academia, it is becoming clear that small spacecraft can and should have a large roll in the exploration of the solar system. The various benefits associated with small platforms include low cost, frequent missions, and by virtue of those features, repeatable and evolutionary missions. This paper describes the motivation for establishing a dedicated function within the NASA Ames Research Center to pursue and implement multiple missions with small, inexpensive spacecraft, and outlines some future trends and directions of the Small Spacecraft Division within the context of science and exploration.

Introduction

Since the establishment of the Vision for Space Exploration (VSE) by President Bush over 3 years ago, a number of structural transformations have been initiated or are well underway within NASA. One of the most visible examples is the planned shift away from the Space Shuttle as a primary means to launch cargo, instruments and people towards a larger space architecture. Intended to replace the Shuttle and increase our ability to place assets into space, the more capable launch systems of the Constellation Program are expected to begin flying crewed missions by 2014 (see Figure 1). However, development of such a capability will require significant resources, thereby placing pressure on the overall NASA budget. This budgetary pressure will require NASA to find more efficient ways to continue to achieve it's varied mission goals in support of scientific investigation, and

exploration of our local space environments.



Figure 1 Ares I Crew Launch Vehicle (NASA)

Small satellites can become a key component to addressing these challenges that the science and exploration communities are facing. We believe that small spacecraft – of various classes and mission types – can make significant contributions to a number of key NASA goals.

NASA's Missions

Of NASA's many missions, Science and Exploration are the best suited for the application of smallsats and related robotic technologies.

The Science Mission Directorate (SMD) is concerned with understanding fundamental questions about the universe and our home planet. Scientific goals encompass understanding the origin and evolution of the universe, and the forces that shape these processes. SMD is also chartered with investigating the origin of life, and seeking its presence elsewhere in the universe. Finally, the Directorate also sponsors research on how the Earth and Sun interact, and what these interactions and other processes mean for life on Earth.

To achieve these goals, SMD sponsors research and missions using space as a vantage point, and other robotic missions, which place probes directly onto or in the vicinity of the object of interest. This includes robotic space imagers, such as the Hubble telescope for optical wavelengths, and Spitzer Observatory, which measures x-rays from stellar sources (see Figure 2). Another type of SMD missions are in the Earth observation category. These platforms monitor the Earth's air, land, and water from a global perspective. Robotic missions to planets, including

orbiters, and surface landers and rovers have generated a large amount of data and interest in our local neighbors.



Figure 2 NGC 300 (NASA/Spitzer Telescope)

The Exploration Mission Directorate's (ESMD) strategy is primarily targeted at extending man's presence into the solar system. At the foundation of this strategy is to return and sustain men on the moon in preparation for future manned and unmanned missions to Mars (see Figure 3). In addition, ESMD sponsors and pursues applied scientific and technical activities in order to understand fundamental questions about the solar system and our place in the universe. Both SMD and ESMD also engage, inspire and educate the public on NASA's activities and missions.

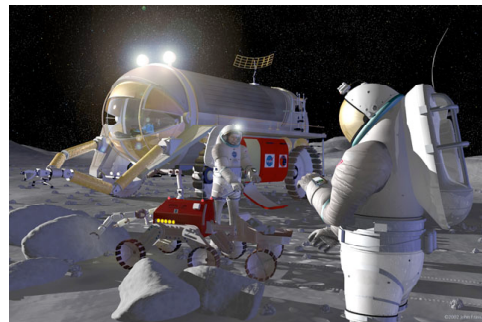


Figure 3 – Artist's Concept of a manned Moon mission (NASA)

The Role of Small Spacecraft

For the purposes of this discussion, smallsats are generally less than 100kg in mass, and may or may not be launched as primary spacecraft. Small spacecraft have a number of advantages, including relatively lower life cycle costs, and increased access to space as compared to larger spacecraft.

As of 2007, a significant number of satellites in the Micro-, Nano-, and to a lesser extent, Pico- range have been successfully demonstrated by a number of countries, space agencies, and companies. The smaller of these satellites generate interest due to their flexible nature and the associated ability to be able to respond to new scientific opportunities. Development cycles have been shown to be less than one year, with significant science return. The shortened development time also translates into reduced budgets required to field and operate these spacecraft. Additionally, short life cycles allow researchers to pose questions and answer those questions in reasonable periods of time, and then repeat the process with the next set of questions. Finally, since smallsat projects are compatible with typical educational timeframes, they provide students at many levels with unique opportunities to train in science and engineering disciplines.

Therefore, the underlying philosophy behind the use of smallsats lies within the associated cost-benefit analysis. Small spacecraft are inherently lower in cost due to their size, which is manifested by their lower complexity. Smallsats must therefore, be narrowly focused and targeted on a limited number of technical performance

metrics. While a smallsat may not be able to return the same amount of absolute science that a larger spacecraft system would, the dramatic reduction in cost easily overtakes this limitation. Lower life cycle costs per mission/spacecraft can be translated into more missions, or recurring or follow-on missions, which in the long run reduce programmatic risk, and if architected correctly, an equivalent science return.

Examples of some unique scientific roles for small spacecraft include small aperture optical imagers or spectrometers for remote sensing applications, both looking away to the universe and viewing the Earth as it passes below. While some investigations are dictated by the size of the aperture, many others can use advanced sensor and computing technologies to achieve resolutions and sensitivities required for specific measurements.

Another application of smallsats resides in the realm of biological systems and their interaction with the space environment. This area is of interest for both human health reasons during extended spaceflight missions, as well as the field of Astrobiology, which is concerned with the origin and existence of life elsewhere in the universe.

Another feature that small spacecraft add to the discussion is their ability to act as risk reducers and technology demonstrators for follow-on missions or larger applications. These spacecraft can be easily used to test and validate subsystems and novel technologies in the space environment while segregating risk from the parent program or primary mission.

Finally, small spacecraft provide an excellent venue for training and workforce development opportunities. These opportunities can be in the form of small spacecraft designed, constructed, and launched entirely by a team of students, to students participating on small spacecraft projects as mission team members.

The ARC Small Spacecraft Division

The Small Spacecraft Division was established in early 2007 at Ames Research Center to exploit the benefits of small spacecraft in support of NASA's missions. The Division's charter is to:

- Develop spacecraft, processes and related systems to make access to space routine.
- Secure and provide methods to access space reliably and frequently, and
- Reduce overall mission costs to increase value added to investigators and customers

The Small Spacecraft Division incorporates a Multi-Mission Operations Center (MMOC), which is being developed to manage several small spacecraft missions simultaneously from a single location at ARC. In addition, the Center for Engineering Innovation (CEI) provides and/or coordinates certain infrastructure elements for spacecraft integration and test. Finally, the Division has established a Mission Design Center (MDC), which facilitates concurrent design projects and studies. The various flight projects include the Pharmsat nanosatellite mission, which launches in early 2008, a study to

demonstrate a low-cost imaging platform, and other concepts

Approach

Smallsats actively contributing to NASA's objectives is the cornerstone of the operational philosophy of the Small Spacecraft Division. A number of approaches are involved in this process.

1. Exploit secondary payload opportunities.

By designing missions and spacecraft to take advantage of excess margin on planned launches, the overall program costs can be reduced significantly, and opportunities would actually increase for small spacecraft missions.

2. Define and accept a tolerable level of risk.

Small spacecraft do not always have the ability to fly redundant systems or other similar features available to large spacecraft. However, this does not make smallsat missions unfeasible. Other methods can be implemented to offset technical risk, without the associated high costs of eliminating the last 2-3% of technical risk.

3. Design spacecraft from subsystems.

Instead of procuring components, and then integrating them into systems via an independent custom process, the availability of mature, proven subsystems in

the aerospace industry now make it possible to construct a spacecraft from a “kit”. Performance and reliability of these subsystems are known well enough to design workable solutions. Since smallsats do not typically create large resource issues with launch providers, such as mass limitations, system optimization is not required, nor desired. This represents another area of cost savings compared to larger, highly integrated spacecraft.

An example of this type of thinking is the Common Spacecraft Bus modular design activity currently underway within the Division. The design incorporates a number of subsystems from existing

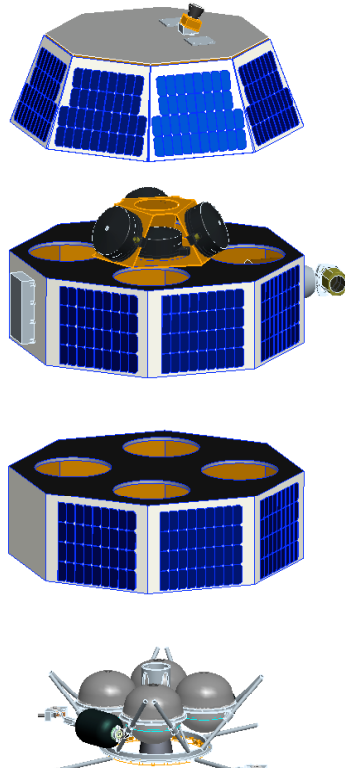


Figure 4 Common Spacecraft Bus

flight hardware designs.

Figure 4 shows how such a spacecraft could be constructed from a suite of modular elements.

The top module is the bus module, and contains the spacecraft avionics, guidance, and power distribution subsystems. Below that module is the payload module. Depending upon mission needs, an extension module could be fitted to carry more propellant or other resources. At the bottom of the stack is the propulsion module, which is based on an existing system used for defense applications. Finally, if the mission is a landed vehicle, legs can be attached.

Other configurations are also possible, from the same building block, such as the orbiting version shown in Figure 5.

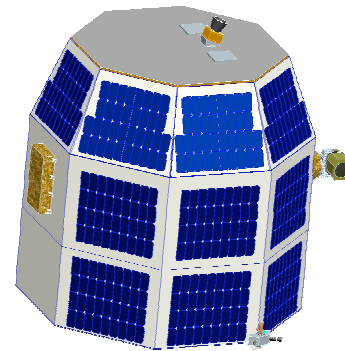


Figure 5 Common Bus Orbiter

4. Utilize rapid integration processes and interface standards

The use of interface standards, proven processes, combined with the elements described in item 3

above, can result in shorter spacecraft development cycles, thus further reducing cost and programmatic risk.

No single approach will create the desired results, but married with a small, flexible organizational structure, we feel the value of small spacecraft as significant contributors to the most important of NASA missions will steadily increase as these missions are executed.