

Creating Large Space Platforms From Small Satellites

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Abstract. With the advent of micro-satellites and nano-satellites, many have begun to study the unique attributes of dozens or hundreds of such satellites operating in constellations. But, do these small satellites necessarily need to function separately on orbit? Orbital's unique MicroStar platform offers the possibility of creating a large, rigid space structure with impressive capabilities from a Pegasus-class mission. In its single-ring configuration, up to eight MicroStar spacecraft can be launched on a single Pegasus® rocket. Rather than separating each of the eight spacecraft, the stack of eight (or two stacks of four) could be unfurled to create a single space structure more than 8 meters in length. Since each individual component is itself a spacecraft, the net capability is impressive. The total spacecraft—called a supersat—is capable of generating up to 2.5kW of power, more than half of which may be devoted to the payload. The supersat also boasts very high reliability, since the multiple spacecraft offer inherent redundancy. Using this technique, large apertures could be constructed for certain missions offering advantages that in the past have only been obtainable in much larger systems. Based upon the geometry used, multi-aperture systems might also be possible. This paper provides several examples of how this spacecraft concept may be applied to missions previously reserved for much larger—and more expensive—systems.

Introduction

The use of deployable elements on spacecraft has been around almost as long as satellites themselves. This paper examines the possibility of taking this concept one step further. The development of satellite constellations such as ORBCOMM, Iridium, and GlobalStar has forced companies to develop techniques for flying multiple satellites on a single launch vehicle. This paper examines what might be achieved if the satellites separate from the launch vehicle but remain attached to one another. In particular, the paper outlines some options available with micro-satellites like the ORBCOMM design.

Satellite Design Options

Figure 2 shows an ORBCOMM constellation spacecraft in its deployed configuration. The physical configuration of the spacecraft is designed to allow eight spacecraft to be launched on a Pegasus launch vehicle, as shown in Figure 1. Each spacecraft is about 41 inches in diameter and just 6.5 inches high. Each ORBCOMM spacecraft weighs about 42kg.

A “supersat” is created by deploying the eight spacecraft into a single structure. Different mechanical configurations enable a virtually limitless array of possibilities. For simplicity, the initial example considers a supersat where the eight spacecraft are deployed into

a straight line with each ring locked into place with the adjacent rings as shown in Figure 3. The resulting supersat is more than 8m long.

A supersat is the ultimate distributed system. Each individual satellite is self-reliant, but they communicate with one another to coordinate activities such as attitude determination and control and provision of payload services such as power and data interfaces. Since it is comprised of eight individual satellites, the supersat is extremely reliable. By designing sufficient margin into the individual subsystems, the supersat can withstand the failure of one or more subsystems or even entire spacecraft without affecting system performance. In addition, the supersat naturally provides



Figure 1: Eight ORBCOMM Spacecraft on the Pegasus Launch Vehicle

**ORBCOMM SPACECRAFT
CONSTELLATION CONFIGURATION**

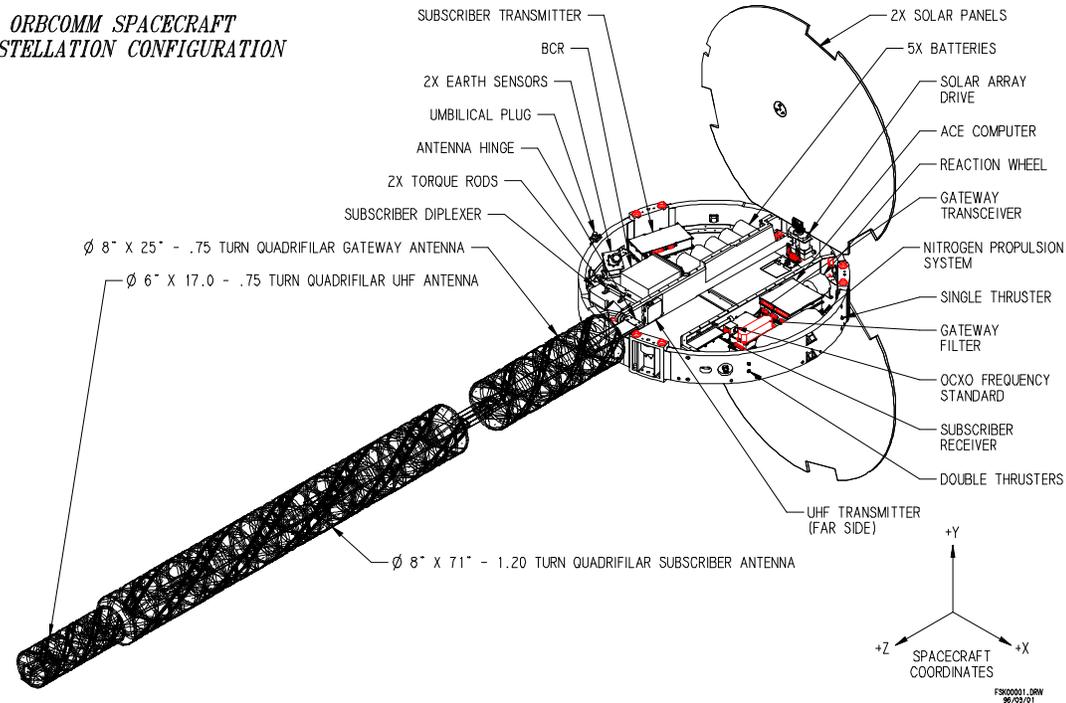


Figure 2: ORBCOMM Constellation Spacecraft

graceful degradation.

By joining the forces of eight individual spacecraft, the supersat performance can be quite impressive. For example, if the solar panels were fully populated with the best available cells, each pair of arrays could produce at least 350W at the beginning of life. Hence, a Pegasus launch with eight spacecraft could generate 2.8kW of array power. Depending upon the mission profile, redundancy approach, and attitude control system requirements, the supersat could provide between 1.0kW and 1.5kW of orbit-average power to the payload.

The payload mass is more constrained. If the supersat consists of eight identical spacecraft, the mass available to the payload is relatively limited. Of course, the payload mass is strongly dependent upon the selected launch vehicle and other spacecraft requirements. For

a Pegasus launch, the payload mass is as little as 50kg. However, this mass could be increased by eliminating some of the duplication of functions inherent in the supersat design approach. For example, two or three spacecraft could be dedicated to attitude control or communication for the entire supersat.

The payload volume is similarly constrained. Each ring has a useable height of just over four inches. Although each of the eight spacecraft has space available, it is more difficult to distribute many payloads across this space. The next section describes some approaches that overcome the payload volume restrictions.

Attitude control system (ACS) performance is tailored to payload requirements. The ACS configuration would also depend upon these requirements. For coarse pointing requirements such as ORBCOMM, all

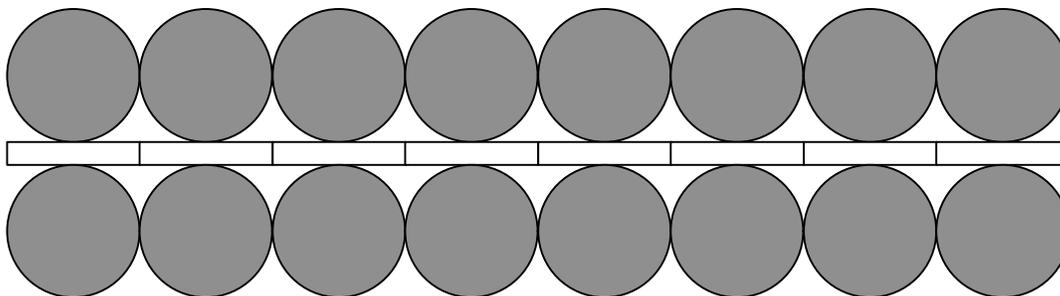


Figure 3: Eight-Satellite Supersat As Viewed from the Sun

eight ACS systems can be identical. More accurate attitude control systems require expensive sensors and actuators. It is probably not cost-effective to purchase eight sets of these sensors, so the supersat would include fewer complete ACS systems. In this case, the attitude control function could be divided among several spacecraft. For example, one satellite might be devoted to attitude determination while the other performs attitude control.

Although it is technically feasible, it is unlikely that each satellite would carry its own communication system. This is true for two reasons: first, communications hardware is very expensive; second, maintaining eight separate ground communications links is unnecessarily complex. Therefore, one or more of the spacecraft serve as the communications hub for the entire supersat.

Supersat Configurations

The basic supersat configuration proposed in the previous section has some limitations, particularly in terms of payload mass and volume. However, the supersat concept has limitless possibilities. The primary trade options are launch vehicle, stacking approach, and deployment configuration.

Launch Vehicle

The MicroStar satellite design was optimized for Pegasus applications; however, the spacecraft is compatible with the Taurus launch vehicle as well. Using the 1.6m (63 inch) diameter fairing, up to 16 single-ring MicroStars can be fit in the available height. If deployed into a straight line as in the previous example, the supersat will be approximately 17m wide. Furthermore, by developing a new, wider ring structure optimized to the Taurus launch vehicle, longer supersats with more payload volume are possible.

Stacking Approach

The stackable MicroStar ring structure provides significant flexibility. Individual rings can be put together to produce larger spacecraft. The BATSAT



Figure 4: BATSAT Deployment Testing

spacecraft shown in Figure 4 consists of three standard rings. Each satellite in the supersat can consist of any number of rings. Increasing the number of rings decreases the available power and the number of separate spacecraft in the supersat. However, it enables much larger payload mass and volume. Figure 5 shows just two of the configuration options available using eight rings. In each case, the eight satellites have been reduced to four, and the available solar array power has been cut in half. However, the option on the left provides two large volumes for the payload. These areas are still separated by about 3m. In addition, the reduction in bus hardware makes more mass available to the payload. The option on the right provides four moderate-size volumes available for the payload. This structure is also features greater stiffness.

In either scenario, additional payload volume can be made available with some creative packaging of the spacecraft stacked upon one another. Using the configuration on the right in Figure 5, the payloads on the outside two spacecraft may protrude into the two center spacecraft as long as adequate clearance is available during deployment as shown in Figure 6. However, this further reduces the available power since an array must be removed from each spacecraft to allow the payload to extend beyond its spacecraft enclosure.

For nadir-pointing instruments, this problem can be overcome by changing the array deployment approach. For most MicroStar spacecraft, one array is stowed against the top and bottom of the spacecraft ring and

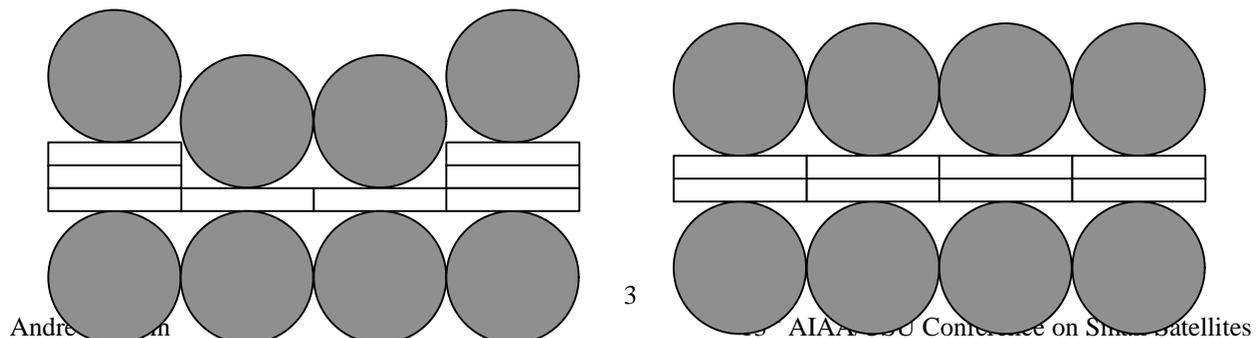


Figure 5: Two Stacking Options Using Eight Rings

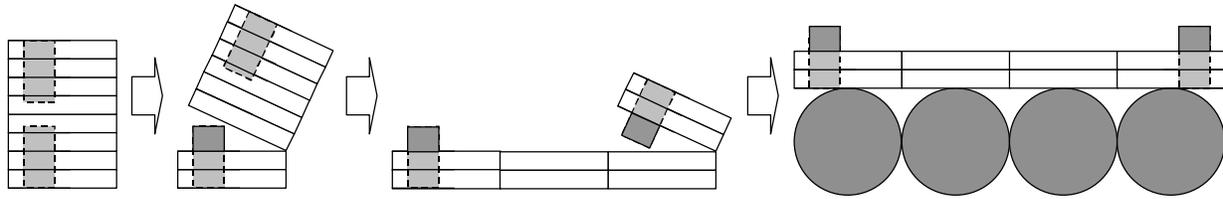


Figure 6: Deployment Scenario for Supersat with Two Payloads Protruding Into Adjacent Spacecraft

deployed to 90° as shown in Figure 2. However, the arrays can be stowed on the same side of the ring and deployed 180° as shown in Figure 7.

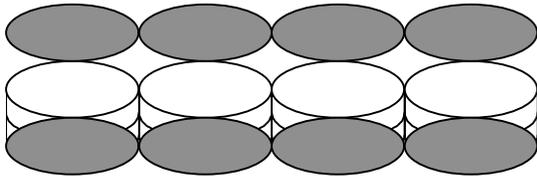


Figure 7: Both Arrays Deployed from Same End of Ring

Deployment Configuration

Although the designs presented thus far have shown the bus structures in a straight line, two- and three-dimensional configurations are equally possible. For example, some missions benefit from a V-shaped orientation as shown in Figure 8. Of course, the number of rings on each side can be varied as can the central angle of the V. The design shown in the figure uses seven rings, but the number of rings and the stacking approach can be tailored to the mission's needs.

The array locations can be changed to accommodate alternate attitude control approaches. The locations shown on the figure are ideal for inertially-pointed missions. Solar instruments would peer through the ring of the spacecraft, while stellar-pointed instruments would look up from the spacecraft disk. This orientation could be used for nadir-pointed instruments if they look at the Earth through the bus ring. However, it is more likely that a panel configuration similar to the one in Figure 7 would be more applicable.

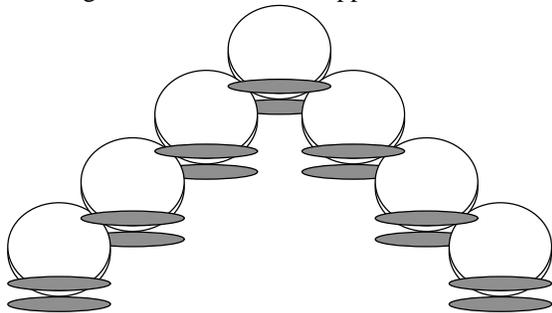


Figure 8: Two-dimensional supersat

The spacecraft can also be configured to deploy into three-dimensional supersats. Figure 9 shows an example with orthogonally pointed satellite rings.

Finally, all of the configurations presented to this point assume that the spacecraft deploy using a hinge mechanism that keeps the satellites immediately next to one on another to maximize structural stiffness. However, it is possible to design more complex deployment systems that separate the spacecraft from one another. This enables much larger baselines. For example, by separating each satellite by the diameter of one ring, an eight satellite supersat can be about 16m long, and a Taurus-launched 16 satellite stack would be approximately 32m long.

Supersat Applications

The supersat is well-suited to a variety of space missions. By its nature, it is ideal for missions consisting of arrays of small sensors. The supersat supports a virtually limitless range of sensor placement and viewing angles. The supersat can also support multiple independent instruments. In this mode, the supersat can be thought of as a supplier of experiment lockers. This mode of operation is perfect for instruments with

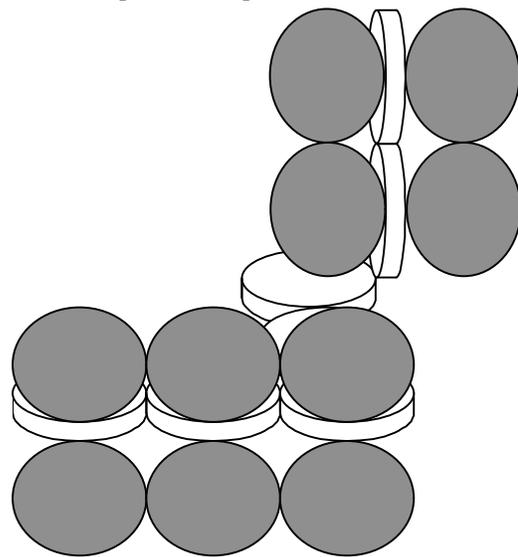


Figure 9: Three-dimensional supersat

high resource demands but low duty cycles. Often, these instruments are carried on free-flying satellites that spend only a small percentage of their time performing the intended mission. With the supersat, this down time can be devoted to other science missions. In addition, by sharing a single bus, the instruments share the launch vehicle costs, greatly reducing the total mission cost.

The two- and three-dimensional supersats can be used to study small-scale phenomena in the Earth's magnetosphere. These applications would probably use larger-baseline structures since structural rigidity is less important than separation of the sensors.

The supersat also provides an excellent platform for interferometric measurements. This can be applied to both Earth and space science missions.

Finally, the high payload power available from a supersat could support missions requiring powerful transmitters such as communications or active remote sensing.

Conclusion

Supersats offer a promising opportunity for conducting a variety of space missions at lower cost. They provide a novel method for translating the benefits of microsatellites into larger scale missions. The modular components can be configured to produce an enormous variety of one-, two-, and three-dimensional configurations with baselines varying from a few meters to several tens of meters or more. By using multiple identical components, supersats have high reliability and very graceful degradation of performance in the event of a failure. Overall, the cost and technical advantages of supersats may be a key enabling technology for a number of exciting new space missions.