

# Changing the Paradigm of Space Testing: the FAST Program\*

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## Abstract

The high cost of access to space is driven in part by a cost spiral -- higher costs lead to fewer missions which leads to a demand for higher reliability which leads to higher costs. One way to potentially break this cycle is to introduce the opportunity for rapid, low-cost experiments leading to a larger number of near term experiments which, in turn, should result in higher performance, greater reliability, and lower cost systems which will spur the demand for additional rapid, low-cost experiments. A program has been initiated to help bring this about, initially with suborbital flights and subsequently with orbital flights of small experiments and instruments. The first FAST experiment was flown on board a Scorpius SR-XM suborbital vehicle launched from White Sands Missile Range on March 9, 2001.

## Background

Why does space cost so much? There is no single, simple answer, of course. As shown in Fig. 1, Sellers and Milton [1996], among others, have suggested that much of the problem is due to a cycle of higher costs leading to fewer missions leading to demands for higher reliability leading to longer schedules and higher costs. Because space is remarkably expensive, everything must work the first time. The mantra of "faster, better, cheaper" has led to significant progress, but has not yet created the major breakthroughs that are needed. If space is to be accessible, then dramatic reduction in cost and schedule are required. One element of this that

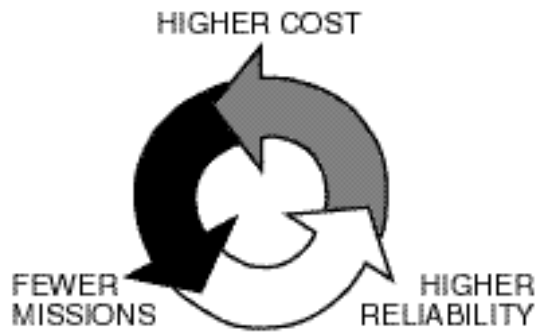
we would like to address is the issue of space testing. One way to start the process of breaking the cycle is shown in Fig. 2. If we can begin to create an environment of rapid, low-cost experiments, there will be more space experiments and shorter schedules. This, in turn leads to higher performance, higher reliability, lower cost systems and additional rapid, low-cost testing. If experiments at the component, box, or assembly level can be done cheaply and quickly, then it is reasonable to accept some level of failure. Experiments can be just that -- experiments. A failure can lead to improved understanding and a subsequent success in the near future

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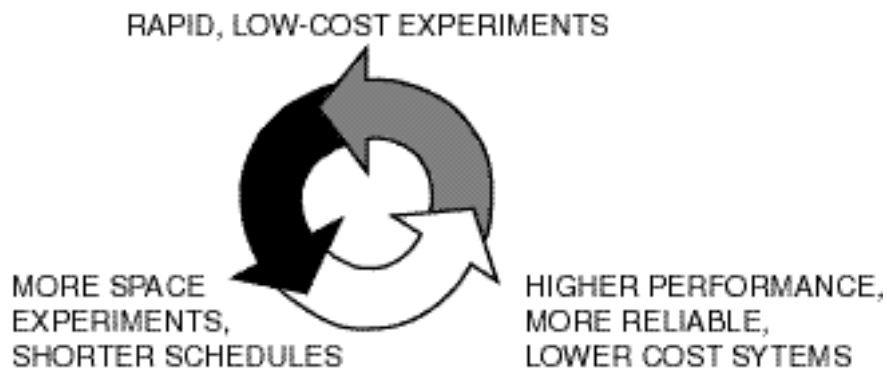
**Fig. 1. The Fundamental Problem of Space Mission Development.**  
(from Sellers and Milton [1996])

Envision a world where space testing is so accessible that no one even thinks about it. Equipment and small experiments are built and flown within a few weeks or months of the time they are completed. Data from the experiment is immediately available. You can re-fly your experiment within a few weeks or months if it doesn't work, or, alternatively, if it works but the results show you a way to make it work better. Of course, the flight and reflight must be available on reasonably short notice and at low cost.

This process is effectively impossible within the current space development and testing environment. Even simple tests take several years to develop and fly. However, we believe that with relatively small steps we can make the above possible and, in the process, significantly change the way we do business in space.

**The Advantages of Fast, Low-Cost Space Testing**

What are the advantages of rapid-access, low-cost space testing? An important issue is that it allows development testing in space, not just a final proof-of-concept. This can be critical for risk reduction and for developing break-through technologies. The best way to reduce risk during development is via extensive testing, but many products -- such as heat pipes, deployment mechanisms, 0-g equipment, and nearly all types of sensors and actuators -- need at least some testing in the space environment. If this testing occurs early in the development cycle, we will quickly learn what works and what doesn't and find ways to minimize both cost and risk. Similarly, it's difficult to justify spending years and large amounts of money on a potential break-through technology that might not work as intended. Demonstrating quickly and at low



**Fig. 2. What Can Be Done to Break the Cost Growth Spiral.**

cost that the basic idea works or doesn't work can give impetus to the development or change the direction of the work.

Continuously availability means that experiments can fly when they're ready. The experimenter can choose between a quick flight on a non-ideal orbit or trajectory or take a later flight to a more appropriate orbit, or do both. Experiment development can move faster, and, therefore, cost less.

A fast, low-cost, space test program will save dollar amounts that are individually small relative to space programs costing \$100's of millions or billions. Nonetheless, a new way of doing business could represent dramatic, long-term cost savings over more traditional approaches. The principal reasons for this are:

- Rapid turn-around testing allows space hardware development on a much shorter time scale
- Shorter schedules save money
- Allows us to truly experiment and try new, innovative ideas
- Can break (or at least severely dent) the "not allowed to fail" syndrome

#### **The Lack of Demand for Low-Cost Launch**

Many of us in the smallsat community believe that a key to making space affordable is accessible, flexible, low-cost launch. At the present time, small low-cost launcher development is largely stalled for lack of funding. This comes about for several reasons. First, there is insufficient identified commercial demand to justify development using commercial funding. Beal Aerospace, a fully commercial venture, focused exclusively on developing a medium-lift GTO launcher. Most business projections show that is where most of the identifiable business base is. In spite of a strong desire to do so, Microcosm has been unable to identify sufficient firm market potential to justify commercial funding for the low-cost launch segment. Many of the start-up launch vehicle businesses from recent years no longer exist. In addition, secondary rides on EELV or other new vehicles will have substantial constraints, will be limited in number, and may not occur at all.

At this time, both DoD and NASA believe that there is insufficient demand to justify a

government-sponsored small launcher development program. The Bantam program has gone away and has not been replaced. There is insufficient pressure, in terms of identified need, to warrant a government low-cost small launcher program.

Nonetheless, the need for small, low-cost launch is real. Payload instruments are continually shrinking in size. Many advanced mission concepts revolve around constellations or formations of small satellites. Even though a formation or cluster of satellites could be orbited by using one or two large launch vehicles, replacement launches are required to create an operationally viable system. Using launches at \$15 million to \$25 million for smallsat replacement is unacceptably expensive. A large number of experimental and university satellites need rides.

We believe that this is a classic "chicken-and-egg" problem. No program can be formally initiated that requires a low-cost small launch vehicle, because none exists. It is an exercise in futility to begin a program based on a technology that doesn't exist and that isn't in the realm of expertise of the experimenters. But because there are no programs that will say they can not survive without a small, low-cost launcher, the government will conclude that there is no demand. This lack of demand will keep the government from perceiving that a need genuinely exists and, therefore, will keep a development program from occurring.

While substantial progress has been made, the cost of launch has not changed dramatically in 30 years. (See, for example, Koelle, 1999[.]) This has been identified by many authors and committees as the fundamental problem for space system growth. However, the government believes this only in the sense of an abstract future need, not a real and present need, because of the lack of identified demand.

We as a community can accept the inevitability of high launch costs for small payloads or try to find ways within our capacity to address the issue. Microcosm would like to take a proactive position by offering both suborbital, and eventually orbital, rides to as many small instruments as possible. We have several specific objectives for doing so:

- Make use of space and mass margin available on virtually all flights to satisfy what we believe, but can not prove, is a potentially large demand.
- Establish that a demand exists, or prove that it does not exist, and obtain quantifiable data on the need for low-cost launch.
- Begin changing the process of how space hardware gets developed and tested by tilting that process toward more low-cost, rapid-turn-around testing.
- Begin the process of changing the paradigm by which business is done in space in favor of more small payloads and small satellites.

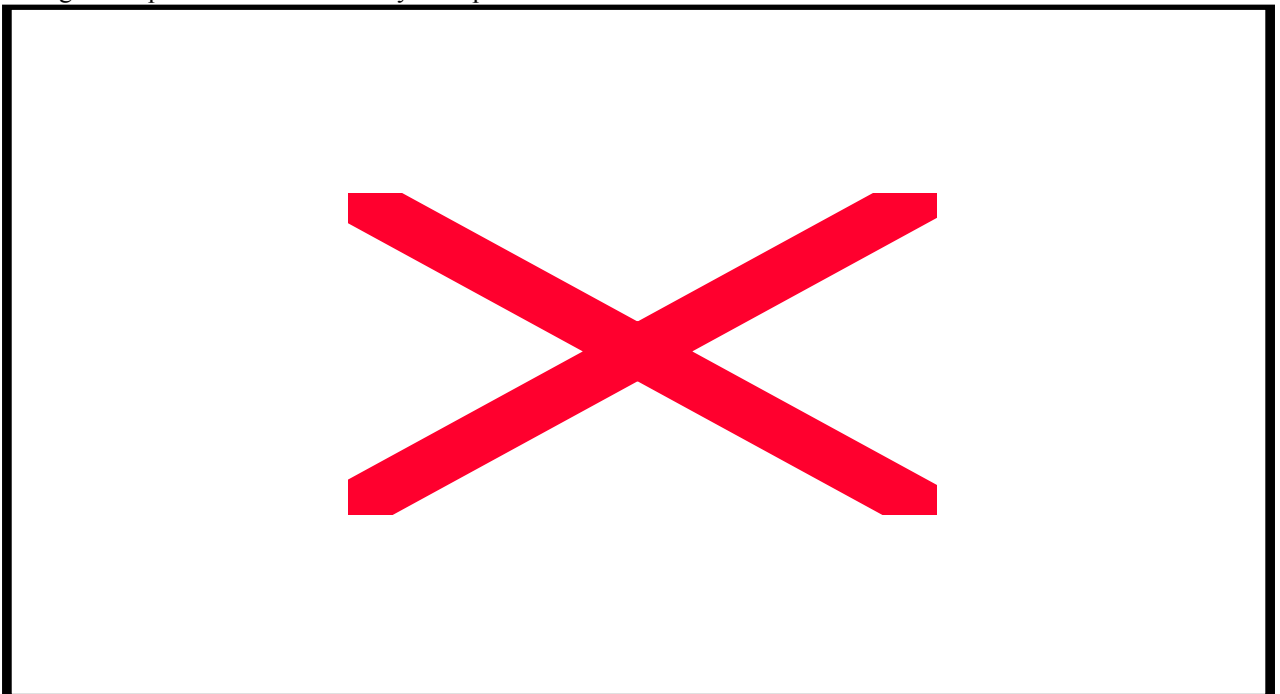
**The FAST Small Experiment Program**

Microcosm and its commercial partner, the Scorpius Space Launch Company, will provide flight opportunities for small equipment for testing or experimentation on every Scorpius®

orbital or suborbital launch over the next several years. [Wertz, et al., 1995, 1996; Berry, et al.,

1999a, 1999b] At present, flights are suborbital and spaced more than a year apart. However, we hope to be launching orbital flights and much more frequent suborbitals within a few years. As the program matures we would like to be able to launch small equipment within weeks after it's ready to go. A nominal flight schedule for the next several years is shown in Fig. 3. Of course, this schedule is dependent on funding, which is by no means assured.

The FAST small experiment program was initiated on the first flight of the SR-XM, which occurred on March 9, 2001, at the White Sands Missile Range, NM. This flight flew a self-contained TRW/DARPA nanotruster experiment. The TRW experiment is shown in Fig. 4 and the SR-XM launch in Fig. 5.



**Fig. 3. Tentative Near-Schedule of Scorpius Flights**

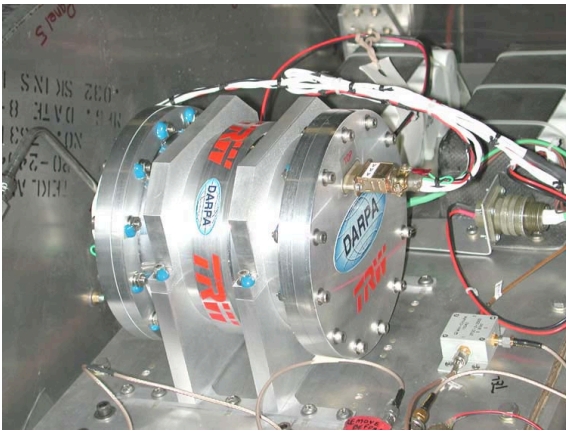


Fig. 4. The TRW Nanotruster Experiment flown on the SR-XM.



Fig. 5. Launch of the Scopus® XR-XM from

## White Sands Missile Range on March 9, 2001.

The details of the basic suborbital and orbital service are still in the process of being defined. A preliminary definition of the basic suborbital package is as follows:

- Up to 8 experiments per flight
- Up to 15 kg per experiment
- Up to 1 amp @ 28 V = 28 W for the entire flight (all experiments)
- Up to 60 kilobits downlink (all experiments)

All experiments will fly on a space available basis. We will try to define a standard "block" of services that will maximize utility and minimize cost. Additional services over and above the standard service will be available at a nominal cost. This would include, for example, additional power, or a CCD color camera and independent video transmitter. Orbital flight accommodations are expected to be similar, but may be more limited in terms of weight and power.

The types of flights available, in order of increasing cost and longer schedule, are:

- Low suborbital
- High suborbital
- Low Earth orbit
- Radiation belt or higher Earth orbit

Initially, FAST experiments are based on captive instruments. Free-flier payloads may be considered at a later date. Our fundamental objective is to fly every small experiment in space (suborbital or orbital) that wants to fly. We would encourage potential experimenters to consider the benefit of near-term suborbital flights. Although initial flights will be further apart, creating a testing environment with flights on a monthly basis is potentially realizable in the future. Some of the substantial advantages of suborbital testing are:

- Flights much more frequent than orbital
- Integration can be much less arduous
- Data recovery is immediate
- Physical recovery is possible at far less cost than orbital flight
- Rapid reflight is possible
- Can provide many of the fundamental characteristics of orbital flight

- Can test all of the processes, data flow, and environmental conditions at very low cost

We recommend using suborbital flights to find problems, look for solutions, and experiment with new approaches. Suborbital flights should be regarded as a low-cost pathfinder for later orbital flights. They should be used for true experimentation and engineering development.

### The Cost of FAST

The basic services package will be provided to the experimenter at no cost, i.e., free. (The FAST acronym stands for Free Access to Space Testing.) Additional services will be made as low cost as possible. While we can not fully determine what that will be, we anticipate, for example, that an additional 200 W for the suborbital flights will cost approximately \$2000.

Of course, we all understand that there is no free launch. What we need in exchange for the "free" ride is the following:

- Formal acknowledgement of Microcosm and Scorpius Space Launch Company in all final reports, press releases, professional papers, and similar public statements
- Support (letters, discussions, meetings, or whatever) on the need for low-cost access to space for small payloads and experiments
- Quantitative estimate of the number and types of payloads that your organization would attempt to fly if low cost orbital launch was available for small payloads
- Quantitative details on your equipment or experiment
  - Mechanical and electrical details appropriate to integration and flight
  - Objectives and performance information appropriate to establishing the utility of your experiment
- Your organizational agreement that we can use this summary data in discussions of space testing applications

Fundamentally, what we want in exchange for a "free ride" is your active cooperation in defining the need for low-cost launch and helping us create genuine low-cost access to space and, hopefully, interest in procuring one of our vehicles in the future.

### **Conclusion -- Why FAST**

Our marketing group believes that we are fundamentally crazy -- "You get what you pay for; if you give it away, we get no revenue and people will perceive it as having no value." Why would we choose to give away that which we could potentially sell? There are a number of reasons:

- It dramatically reduces the actual cost of the ride:
  - Marketing, negotiating, and contracting costs are basically eliminated. These are major cost drivers for a paying "small experiments" program.
  - The interface is whatever we can do economically and we remain in control of that interface.
- What we are giving away is the excess capacity on each flight -- it's not free, but it also doesn't cost a great deal.
- We want to change the basic paradigm of how the space business, and space testing in particular, works.
- We may be able to get the government to cover some of the administrative costs or to fund secondary, related activities.
- Our return on investment is high -- it is worth a great deal to get active and positive cooperation and interaction from throughout the SmallSat community. The only way to do this is to offer you something of value in return for that help.

For those of you that are still uncomfortable with free, we're accepting donations of \$50,000 per flight for our Cheap Access to Space (CAST) program. Our marketing team will like this much better.

The FAST program is already in place. The first FAST payload flew at no cost to the experimenter (TRW and DARPA) on an SR-XM suborbital flight on March 9, 2001. The next suborbital flight is currently scheduled for late 2002. The first orbital flight is scheduled for

2003 or 2004. This date is, of course, strongly funding dependent.

We expect to fly small instruments for free on all, or nearly all, Scorpius<sup>®</sup> suborbital and orbital launches. We can do this for hundreds of small instruments. We would like to work with programs and organizations that have a strong interest in helping to change the way space business gets done to the benefit of both industry and the government.

### **We are Very Interested in Hearing Your Opinion, Flying Your Equipment, and Getting Your Help**

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