Dramatically Reducing Space Mission Cost

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Summary.

The current financial crisis is likely to severely restrict the American space program that is already suffering from cost and schedule overruns and dramatically expensive missions. However, it is at least possible that some good for the space program may result from these financial problems. We will have no choice but to undergo the painful process of reducing space mission costs. If we choose to spend wisely, it is possible that, being forced to change how we do business in space, we may, in the end, have a better, more robust, more responsive, and lower cost space program with a larger, more diverse, more cost-conscious industrial base that can compete successfully on the world market and achieve our military, scientific, and exploration goals at much lower cost. Or, of course, we may continue with business as usual with an ever-smaller number of both large companies and large programs that we cannot afford, students with no real opportunity to learn what space is about, and individuals and small businesses increasingly less able to take part in the Great American Dream of space exploration and exploitation.

The Problem.

The American space program is remarkably expensive. In the last 5 years, we have launched 95 space missions (i.e., less than 20/year). The total American space budget (NASA, DoD, the intelligence community, and a small amount for other agencies) is a bit more than $50 billion/year, or somewhat over $2.5 billion/mission. Of course, this covers a great many things beside space missions, but the net result is that the whole process costs too much for what we are able to achieve. In contrast, the first photos from space of the aftermath of hurricane Katrina that were published in *Aviation Week* were taken by NigeriaSat, a smallsat built by Surrey Satellite Technology Limited for on the order of $10 million.

Although expensive, space has become critical to our national security and is important to science, education, commerce, and our standing in the world. We must maintain our space infrastructure. But, we also must find a way to reverse the space spiral of ever increasing costs, ever longer mission timelines, schedule delays, and huge cost overruns. We have no choice but to finds ways to do a better job, more responsively, and, most important, for less money. It certainly will not be easy, but it is possible.

The Traditional Response to Reduced Budgets.

Many organizations respond to reduced budgets by protecting their big, remarkably expensive programs at all cost, and, to do that, will eliminate virtually all of the small, low-cost programs and "different" approaches to solving the problem. This makes sense because it took a long time and a great deal of effort to get these programs underway. Nonetheless, it is the wrong answer -- the technological equivalent of eating our own

seed corn and hoping that next year will be better. At the state level, this would be the same as closing all of the schools in order to fund prison overcrowding.

Potential Solutions.

Reducing mission cost, while still achieving the broad mission objectives, is unquestionably hard and there are no simple solutions. Nonetheless, it is clear from prior programs both in the United States and worldwide, that space program costs can be greatly reduced (i.e., by a factor of 2 to 5) without sacrificing reliability.[*] Of course, the same spacecraft built the same way we built it last time, will cost about the same or, in the ever-increasing space spiral, potentially quite a bit more. "Reducing space mission cost" does not mean buying the same spacecraft for less, but rather achieving the broad mission objectives, or the most critical ones, for far less money.

Specific solutions will depend on the circumstances and the program, but will likely include the following:

- **Make Near-Term Cost Reduction a Priority.** Traditionally, reducing cost has been a priority only after all other needs were fully satisfied. The two top priorities should be meeting mission objectives (not system objectives) at low cost.
- **Create a Proactive Program to Reduce Cost.** Reducing cost requires changing the way we business in space, but culture and inertia are two of the hardest things to change in any organization. To create real change and generate lasting benefits, a proactive program is needed to focus attention on the problem, develop and evaluate solutions, and respond to those who will think of thousands of reasons to continue business as usual.
- **More Emphasis on Mission Engineering.** Most mission cost reduction doesn't come from buying cheaper solar arrays or driving down a supplier's profit, but from the up-front mission engineering—that fuzzy process by which the mission is defined and the requirements determined. Looking broadly at new approaches to meeting mission objectives and learning from the experience of others can pay great dividends.
- **Trade System Reliability for Mission Reliability.** Launch systems and on-orbit systems fail from time to time. (Historically, launch vehicles are about 90% reliable.) Rather than spend huge sums to try to drive the failure probability to zero, find ways to ensure that mission objectives can still be met when occasional system failures occur. In the SmallSat community this is often called Reducing the Cost of Failure and is the space equivalent of sending multiple airplanes or cruise missiles to ensure that a mission is achieved.

[*] For specific examples with extensive cost data, see J. Wertz, *Reducing Space Mission Cost*, Kluwer Academic and Microcosm, 1996. For a bibliography of literature and information sources on reducing mission cost, send an E-mail to jwertz@smad.com.

- **Use a Constellation of SmallSats.** Replace a large, multi-sensor, vulnerable single satellite in a Sun synchronous orbit with one or a small constellation of much lower cost, small satellites in prograde Responsive Orbits. Spacecraft agility and the ability to fly low are potentially key characteristics.
- **Develop Lower-Cost, More Frequent Access to Space.** Launch is not the largest cost element of a mission, but drives the mission cost. Frequent, low-cost opportunities are key to innovation, education, low-cost testing, and gaining experience and confidence in new, low-cost solutions.
- **Trade on Requirements.** Rather than having a car built to our specifications, we should first look at the available budget and then find a car that meets as many of our needs as possible within that budget.
- **Use a Greater Amount and More Current On-Board Processing.** Many SmallSats fly with computer technology that is 6 to 12 months old, rather than requiring flight heritage, which implies 6 to 10 year old technology (or older). Even with physically smaller and less sophisticated systems, they are often able to achieve good results. In addition, the on-board software can be repaired and replaced on orbit.
- **Use Low-Cost Satellites and Replace Them as Needed**. This reduces the system cost, allows more rapid introduction of new technology, maintains a stronger industrial base, and is less vulnerable to either natural failures or attack.
- **Use CubeSats for Development, Testing, and Some Operations**. Very low-cost CubeSat technology (and entire CubeSats) are well developed and available off-the-shelf. These can be used for rapid development and testing, and also as a means of understanding both the strengths and limitations of very small, low-cost, replaceable systems.
- **Sharing Costs with Other <u>Users</u>.** Sharing costs with the supplier or manufacturer (e.g., having them pay for the up-front development costs) is likely to drive costs up rather than down, but sharing costs with other users can be a productive approach, if done carefully. (This approach can also drive <u>up</u> cost if there are too many conflicting requirements or additional payloads, so it must be done as an integral part of the mission engineering process.)

Many changes that are intended to reduce cost and risk, end up increasing cost, risk, and schedule. There are three ***Litmus Tests*** that can be used to judge whether a particular proposed solution is more likely drive costs up, rather than down:

- **Does it Increase or Decrease the Likelihood of Smaller, Innovative Companies Taking Part?** Innovative cost-reducing approaches are more likely to come from small businesses or individuals, than from large corporations. Anything that makes it harder or impossible for them to take part, such as forcing them to share or entirely cover the up-front costs, is likely to kill off most real cost reduction or innovative solutions. The large corporations will invest initially to obtain contracts and fully recover that cost (and then some) during later phases.

- **Does it Cause a Break in Program Funding?** Discontinuities in program funding dramatically drive up cost, increase risk, and lengthen schedules as key people move on to other projects. This means retraining, re-evaluating, replanning, and potentially redesigning that is both expensive and time consuming. Loss of learning and operational disruption are two highly underestimated cost drivers since they are difficult to quantify. No one wants to take "credit" for these cost and schedule increases, leading to nearly guaranteed cost and schedule overruns.
- **Does it Incentivize the Behavior You Want?** A classic example is the department computer or equipment budget. If you spend less than allocated, the reward is that your budget is reduced for all subsequent years. Therefore, at the end of the fiscal year, the full budget is magically spent. The right answer is to reward people, groups, and organizations that find ways to dramatically reduce cost and schedule.

We need to find solutions to reduce costs now, in the near-term (24-36 months), and in the long-term (2-8 years). Of course, today's space program procurements stretch out over decades, but that is a part of the problem that needs to be fixed.

Reducing cost now typically requires slowing the procurement on major systems. This is likely to drive up long-term costs, but there may be no choice. The key to minimizing impact is to make the changes smoothly and, so far as possible, never stop funding entirely and then pick it up again later.

Near-term cost reduction (24-36 months) can come from any or all of the techniques described above. In particular, small satellites can be designed, built, and launched in 18 to 30 months at very low cost (i.e., for many missions $15 M to $30 M for the spacecraft bus, payload, launch, and first year of operations). A real key here is to not shortchange the up-front mission engineering. Reducing cost and meeting our objectives is hard if we have a well-defined plan, and nearly impossible if we don't.

Reducing cost in the 2-8 year time frame requires several things: Changing how we do business to foster smaller, more diversified solutions; developing key enabling technologies either for reducing cost directly or to allow SmallSats to more effectively and responsively offload the work of our more traditional, larger systems; and to gain the insight and confidence we need to truly reverse the space spiral and return to many of the processes that created major successes in the early space program – but with the added wisdom and technology that has been gained over 40 years.

Microcosm Background.

Microcosm is the leading authority in the US on ways to reduce space mission cost:

- We literally "wrote the book" on how to do it (*Reducing Space Mission Cost*, Kluwer Academic, 1996, 615 pgs) under contract to the AF.

- We created and edited the *Journal of Reducing Space Mission Cost*, now gone due to lack of interest.
- We teach both a 5-day professional course and an academic course (USC, Spring 2009) on "Design of Low-Cost Space Missions," and also one on "Responsive Space Mission Analysis and Design" with an emphasis on rapid, much lower cost missions.
- We helped start much of the current interest in Responsive Space, intended to create much lower cost missions, and run the annual conference on this topic on behalf of the LA and Orange County sections of the AIAA.
- We have developed, and are continuing to develop, much lower cost space systems and space technologies.
- We have proposed specific, very low-cost responsive missions in areas that are the most important to both disaster mitigation and national defense.
- We work closely with virtually every small and low-cost satellite manufacturer in the US and Europe

Unfortunately, efforts toward reducing space mission cost have not been particularly well received in the past. It isn't because the approaches or the technology don't work, since it is evident from worldwide experience that they do. It is because reducing cost is hard work, requires fundamental changes in how we do business in space, and has not been the highest priority in the US space program in the past. That must change, if our space program is to remain healthy and continue to provide the services that we have come to expect and create innovative new solutions to the challenges of the future.