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November 2011

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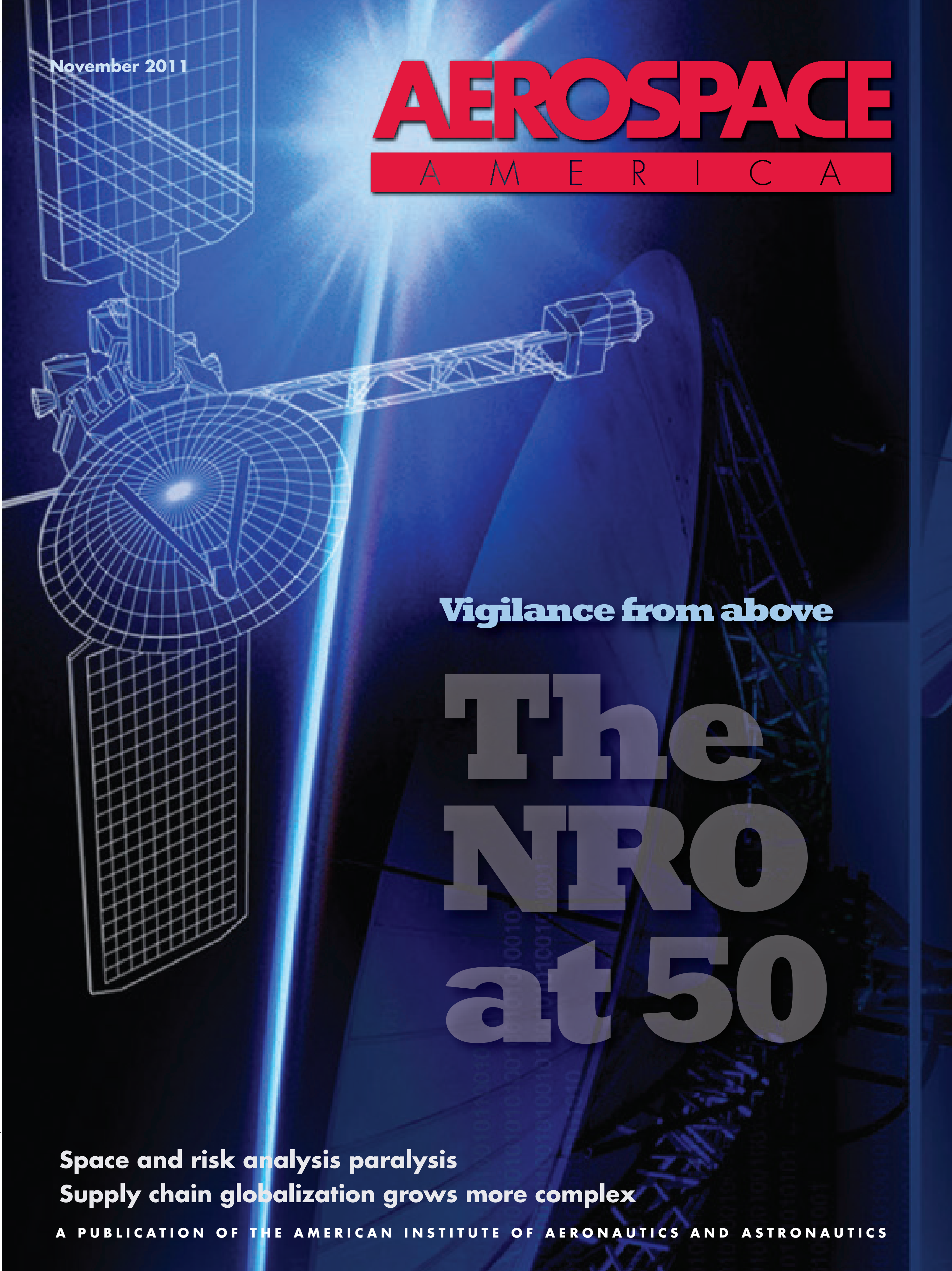

Vigilance from above

The NRO at 50

Space and risk analysis paralysis

Supply chain globalization grows more complex

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Viewpoint

Space AND risk analysis paralysis

Aversion to failure or loss has become so endemic to our space enterprise that programs are often very late, deeply over budget, or canceled. Acknowledging that the possibility of loss or failure is part of the space equation is the only way to break this cycle.

by Col. Fred G. Kennedy

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In November 2010, the deputy secretary of defense approved the establishment of a Defense Space Council, a high-level forum chaired by the executive agent for space (the Air Force) and chartered to provide a central coordinating mechanism for the numerous space activities the DOD oversees.

Why was this necessary? From our senior leadership's perspective, the national security space community is suffering from a profound diffusion of authority, an inability to collectively plan for the long term or set priorities, and the lack of any effective enforcement mechanism for its architectural choices. No one appears to be in charge.

For its part, the Air Force agrees: After undertaking a review of its headquarters functions, the service concluded that space responsibilities "are fragmented…[with] five separate offices…reporting directly to the Undersecretary." Some of the individuals the Air Force chose to interview called the current structure 'confusing.'

To address this fragmentation, the service responded with a reorganization. Among an array of similar measures, space acquisition was realigned under SAF/AQ (assistant secretary of the Air Force-acquisition). This sounds logical, unless you recall that space acquisition resided in SAF/AQ all through the 1990s. It was stripped out of AQ and placed in the undersecretary's office precisely because of the 'fragmented' nature of our space efforts circa 2001. Whatever it is that ails our space enterprise compels us to strive for unity of effort, but try as we might, we cannot seem to achieve it.

So are we barking up the wrong tree? Fragmentation of space, or a diffusion of responsibility among multiple offices and agencies, may be a fact of life, but it is not necessarily a problem in and of itself. Each of the services manages to procure, operate, and maintain air platforms without the intercession of an 'executive agent for air.'

Yet space is somehow different. Without ever quite saying what is wrong with space, senior leaders inside DOD have concluded—repeatedly—that if only we achieved unity of effort (across DOD, or between DOD and the intelligence community, or perhaps among all interested parties within the U.S. government), that 'problem' would dry up and blow away.

This may in fact be true, but isn't it worth a bit more analysis than simply saying, "We have a problem?" Taking steps to ensure that one has "the right structure and relationships in place for space management" implies that one has an inkling that the current structure is not 'right.' What led us to believe that? What, exactly, is the problem we are attempting to solve? And why are we so afraid to write it down?

THE PROBLEM

Let's look at the two most blatant symptoms, and see if we can discover an answer.

Building spacecraft takes too long (a lot longer than we thought it would).

Examples are legion. As of this writing, the Space Based Infrared System (SBIRS) program is in its 15th year and has only recently managed to place its first satellite in geosynchronous orbit. SBIRS was originally planned to field its satellites between 1999 and 2004. The nearly decade-long delay we have experienced is beginning to cause significant concern within the missile warning community, as it watches the remaining suite of legacy Defense Support Program satellites degrade while successor satellites drift ever further to the right.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) program, managed by DOD, NOAA, and NASA, awarded a contract to Northrop Grumman in 2002, with a risk reduction demonstrator satellite launch expected in 2006, to be followed by launch of the first NPOESS satellite in 2009. By the time the White House effected the NPOESS 'divorce' (a program restructuring that leaves NOAA/NASA at the helm of one program and DOD running another) last year, the demonstrator had slipped five years, to 2011, while the first spacecraft would not have been available until 2014. We have been told, unofficially, that were we to stop the program entirely and restart it at a later date, it would take 11 years to build and launch. That's longer than Apollo, yet we are only going as far as LEO and not sending a single human being.

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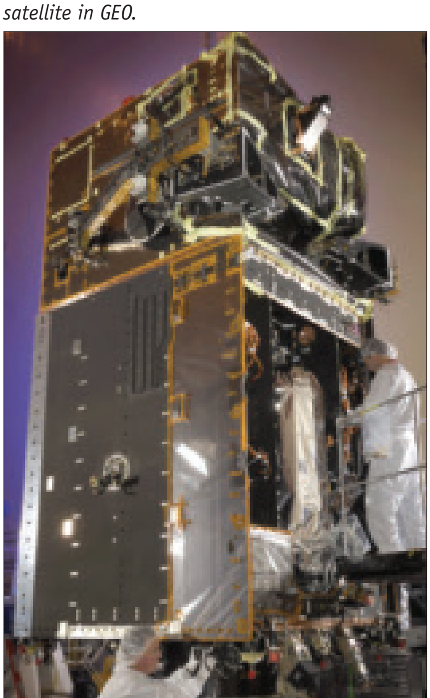


The Navy's Mobile User Objective System, the Air Force's Advanced EHF (and its predecessor, Milstar), and the NRO's Future Imagery Architecture have similar stories and serve only to demonstrate that delays are an equal opportunity affliction. If anyone retains the 'recipe' for putting capability on orbit in a timely fashion, they are keeping it to themselves.

Space is too expensive (even more expensive than we could have imagined).

Clearly, programs forecast to take five years to complete that end up requiring 10 are unlikely to cost less. But I submit that there is a common factor driving both cost and schedule, and that it is not just simple delays that drive cost, but something more insidious.

Turn again to SBIRS, since it so clearly demonstrates the point. SBIRS began life in 1996 at an estimated cost of $4.1 billion (then-year) for five satellites. The Air Force recently notified Congress that its estimate has been revised upward to $15.1 billion. In its defense, the Air Force has added a satellite, so they are now buying six. Yet a straightforward calculation of unit cost shows an increase from an already expensive $820 million to an unbelievable $2.5 billion per copy over the course of a decade and a half.

And NPOESS? In 2002, $6.1 billion was supposed to buy DOD, NASA, and NOAA six satellites. That figure had risen to $11 billion by the end of 2009—while the number of satellites was cut to four.

No sector or organization is immune. Despite its eventual on-orbit success, my own space program at DARPA experienced significant cost growth over the nearly seven years of its existence. How much? Well, I now 'multiply by pi' to predict a program's final cost based on an initial contractor estimate.

Sure, you say, but space is different. It is inherently a complex undertaking. Our systems have to operate in an incredibly hostile and unforgiving environment for long periods of time without benefit of repair or upgrade. We no longer properly sustain our space-savvy 'industrial base,' that cadre of engineers and facilities we could not do without. And worse, our requirements (or acquisition, or operations) discipline is absolutely shot.

And yet, who said space has to be complex? Most of what goes onboard a typical satellite—with the exception of propulsion and attitude control effectors (control moment gyros, momentum wheels, magnetic torquers) are sensors and electronics. We have been lapping and polishing (and lightweighting) big pieces of glass for a very long time, and every digital camera on the planet contains the technology that allows you to collect, digitize, store, and transfer sensor data.

We have any number of electrical engineers who can design and implement any circuit you'd care to name, and there is certainly no shortage of software engineers in the U.S., or around the world. How about the space environment? To be honest, it is actually quite benign, even if you have to cope with the Sun's exhalations and unusual thermal effects you rarely encounter on Earth outside a bell jar.

So why the outrageous expense? Why the interminable and apparently unavoidable delays?

In just three words: Rampant risk aversion. More precisely, an endemic, deep-seated inability to accept even the most unlikely of risks, a condition that affects every aspect of the space enterprise, driving cost and schedule beyond all of our most conservative predictions. And it feeds on itself.

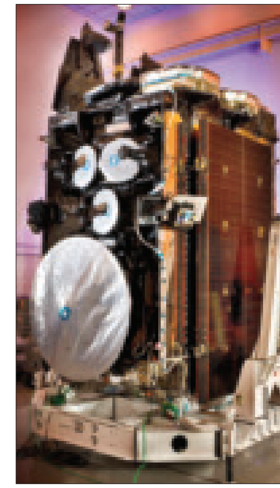
This is the real problem underlying the tripling in cost of SBIRS, the doubling in cost of NPOESS, the tripling in unit cost of Advanced EHF, and build schedules that now occupy the better part of a decade. Pathological risk aversion—the belief that the system must work, at any cost—drives us to perform an exacting sequence of component, subsystem, and system tests, ad nauseam, before we ever attempt to launch a satellite. Acoustical testing (to simulate conditions present immediately following launch), mass properties testing (to precisely determine moments of inertia and allow us to finely tune the pointing of the satellite), modal surveys, vibration testing, thermal balance and thermal vacuum testing, flight software dry runs, clean runs, qualification and acceptance tests, and integrated ground segment—launch—spacecraft tests, are run again and again and again to ensure that our billion-dollar investments do not end up as orbital debris.

A large satellite such as AEHF or SBIRS may spend 18 months or more in its final system-level test campaign. And these programs often carry 1,000 to 1,500 contractor personnel once they begin assembling the satellite and preparing for system test. At a conservative $250,000/contractor/year, a 1,500-person program spends more than half a billion dollars to test just one satellite.

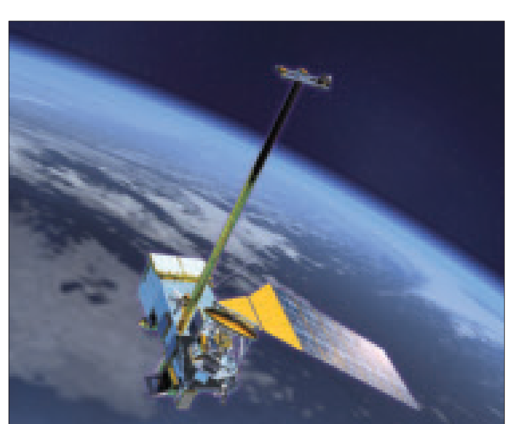
The sequence of events that has led us to this obsessive-compulsive procurement model is well known. It applies to every sector of the enterprise, but is most pronounced in mission areas that have settled on a small number of large platforms, often in expensive-to-achieve orbits.

A requirement—say, for space-based missile warning—is often developed in tandem with the realization that a capability is within (or nearly within) our technological grasp. In this case, the capability was infrared detection of missile plumes, and the emerging requirement was the Air Force's 1955 decision to extend our warning time for Soviet missile launches by complementing the ballistic missile early warning system with a space-based counterpart. The result was MiDAS (missile defense alarm system), a polar-orbiting constellation of 8-12 satellites.

Twelve launches (and three failures) later, the Air Force determined that on-orbit detection of missiles was both feasible and useful. Note that the first nine MiDAS spacecraft were launched in a 3.5-year period between February 1960 and July 1963. The initial program plan was submitted by the Advanced Research Projects Agency (ARPA, the progenitor of today's DARPA) in February 1959. Four years, nine satellites. And one year from program initiation to first launch.



The AEHF satellite system was no stranger to the stretch-out encountered by development of programs. Photo by Jim Dowdall.



As the price tag on the NPOESS satellites continued to rise, the number of spacecraft dropped.

MiDAS led directly to the Defense Support Program (DSP). The Air Force delivered its first DSP satellite to geosynchronous orbit in 1970, the first of an envisioned three-satellite constellation. The last, DSP 23, flew in November 2007. During that time, DSP doubled in weight and nearly tripled in power consumption. An occasional launch vehicle would fail, so we adopted increasingly stringent range safety requirements, culminating in the publication of EWR 127-1, a document that has invigorated an 'industrial base' of bureaucrats on both coasts, dedicated to ensuring that every launcher must work, at any cost.

We adopted cryptological requirements on our radios to ensure that no one but the rightful owner can talk to our satellites, spawning another industrial base at Ft. Meade. We founded the Aerospace Corporation, now 3,700 strong, to augment the not-so-small armies of mission assurance personnel that every contractor now maintains, and to provide "independent verification and validation," in effect overseeing the overseers of the engineers and technicians who build our satellites. We adopted rigid standards for tracking program cost and schedule, and demanded that our contractors use these (validated, approved) tracking systems when they build our spacecraft. Even if individual program managers decide they add little value.

This sensor infrared alarm system was part of the 1950s MiDAS program.

The ninth DSP satellite flew 11 years after program initiation.

The ninth SBIRS satellite is not forecast to fly, assuming we could find the money to build it, before at least the mid-2020s. That's 30 years after program start. This is literally time enough for a generation to grow up, educate itself, and decide that space is too frustrating a career choice to even consider.

Some might argue that it is not (simply) our fear of failure but our insatiable appetite for more capability that drives us over the cost and schedule cliff. Yet in the vast majority of instances, the hardware that we attach to our honeycomb face sheets is several generations behind the times. We use gate arrays and memory and processors that are years old, ostensibly to ensure that we overtest them and generate sufficient statistics to 'space-qualify' them. Rocket engines? The technology is 60 years old, and the fundamentals have scarcely changed. It is difficult to draw a line from increased capability to increased cost and schedule, since in many cases we are not even keeping up with state of the art!

Were we, today, to resurrect the requirements documentation for MiDAS and attempt to design, build, and launch a spacecraft based on it, would anyone in the community dare to present a plan that reaches orbit in 12 months? Of course not. We would recognize that it would take at least 12 months just to get through a proper system test, with another 90-120 days tacked on for launch processing and checkout. And this is with an array of advanced sensors, bus components, analytical and design tools, many off the shelf—a far cry from the situation our predecessors faced back in February 1959.

Risk aversion is a creeping process. It starts with indisputable logic in the wake of a failure—more testing, more checks, more documentation, more oversight might have prevented said failure. So additional personnel are hired, standards and directives are issued, augmented test strategies are implemented—and everyone breathes a sigh of relief when it appears to work. That is, until the next failure, and the cycle begins anew.

This vicious cycle spawns other, pathological, strategies: Since any single launch is now expensive, and there are few opportunities, programs will be banded together on a single spacecraft in the hope of harmonizing the requirements of multiple payloads and their parent organizations in the name of efficiency and cost containment. Yet the eggs-in-one-basket approach only strengthens calls for increased oversight, testing, and proper documentation, as the organizations quickly realize that everything is riding on that single launch. Moreover, those multiple payloads are likely to have competing (and in some cases, mutually exclusive) requirements, forcing design compromises and—as we have seen in cases such as NPOESS—program termination and restructure, but only after the expenditure of billions of dollars.

We are over a half-century removed from the trial-and-error, try-again-if-it-fails mentality of our forebears. Risk aversion is firmly in control of our culture. In multiple mission areas (communications, missile warning, environmental monitoring), the 'community' has decided that a capability—in many cases, a single asset—is irreplaceable or indispensable, and will take any action, expend any amount of manpower, time, and money that can be made available, to ensure mission success. Is it too much to point out that this is an absurdity?

The ninth DSP satellite flew just 11 years after program initiation.

THE FIX

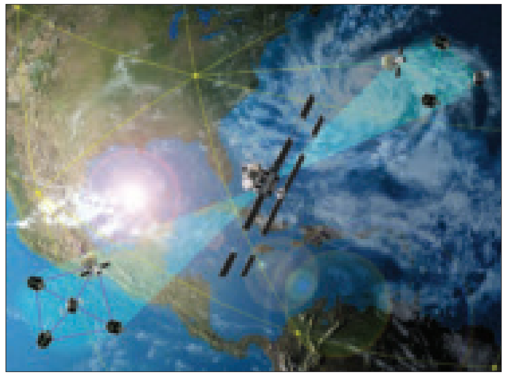
The solution (like the problem), is cultural. Within the DOD's space portfolio, we need to find approaches that allow us to embrace risk, and not simply avoid it or beat it down through repetitive test loops. That requires top-down direction and a firm hand on the wheel. We have come full circle to the question of appropriate space governance, unity of effort, and the problem we wish to solve. That problem is risk aversion, and the solution is aggressively pursuing solutions that will not feed the beast.

What does it mean to allow ourselves to accept risk? First, we must do away with classical "Battlestar Galactica" strategies in key mission areas, where we assign a handful of satellites to perform critical missions. This is consistent with the president's national space policy, and speaks to a stated need for 'resiliency.' We need to approve only those concepts of operations and acquisition strategies that eschew the 'indispensable node' in favor of dispersed or disaggregated capabilities. We should strive for a scenario in which a launch failure evokes no soul-searching, backbiting, or blue-ribbon panels bent on assigning blame.

Failure should not simply be tolerated, it should be accepted as part and parcel of the space business. But that cannot happen in an environment and architecture where a single launch or on-orbit failure compromises national security.

So should we replace SBIRS with 12 'MiDAS-like' satellites in LEO? Or 50? Does it imply that we ought to dispense with wideband global SATCOM in favor of Teledesic (the 800+ constellation conceived of in the 1990s to provide worldwide broadband Internet services)?

Not necessarily. It might take the form of DARPA's F6—a concept that 'fractionates' a satellite into individual subsatellites, each launched separately, with an eye to spreading risk among the various launches. Or it might take the form of on-orbit refueling, repair, and upgrading, another DARPA concept tested on orbit in 2007 and perhaps soon to be adopted by commercial industry. The impossibility of repair is one driving force behind our risk-averse mentality: A spacecraft, and all of its critical subsystems, has to last for its planned mission life. An on-demand repair service would blunt



DARPA's F6 concept 'fractionates' a satellite into individual subsatellites, each launched separately.

that risk aversion, allowing a satellite operator to accept levels of failure that would today be labeled 'catastrophic.'

A strong, centralized space governance construct—with a charter to specifically fight risk aversion and its stranglehold on the culture of space—could halt our downward spiral and encourage the community to refocus its efforts on resilient constellations of satellites providing many of the same capabilities we have today.

Architectures—or analyses of alternatives—that propose 'indispensable nodes' must be forcefully rejected. Requirements that drive such architectures need to be questioned, and acquisitions that rely on 'all-eggs-in-one-basket' approaches must be returned to the lead agency for rework.

Program managers and their staffs will (slowly) come to realize that exquisite testing regimes will not be worth the added reliability or performance they provide. Bureaucracies that subsist on mission assurance will, over time and as their utility noticeably subsides, fade (although they will likely require a little prodding).

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On the heels of a new national space policy, and in an era of increasing fiscal austerity, we have a unique opportunity to reconfigure the culture of the space enterprise, and for the better. If the DOD can, at a high level, insist on resilient, 'no indispensable node' architectures for these and other areas, we may be able to beat back the forces of risk aversion and finally recapture the innovation and agility that were the hallmark of our earliest years in space.

This will be the task of a generation. It will not be easy.