

Space once was ours. Then came the space junk, collisions, and dangerous interlopers.

Illustration by Erik Simonsen



Insecurity in Space

By Rebecca Grant

In the 1991 Gulf War, American airmen benefited from uncontested control of space. They came to view this vast region as airpower's ultimate high ground. Back then, it was a domain filled with war-winning advantages and all but devoid of adversaries.

Today, crowded orbits and the conflicting aims of multiple nations have changed the game.

The Obama Administration is finishing up a number of key space policy reviews. As they do, US officials and military leaders have come to face ques-

tions about how the nation will keep its edge in military space operations. Air Force Space Command, in particular, has taken a lead role in the effort to determine just what it will take to protect US access to the advantages of space.

The head of Space Command, Gen. C. Robert Kehler, is now only too aware of the developing threats. He noted, "We certainly have seen the Chinese demonstrate a kinetic kill anti-satellite weapon," referring to Beijing's early 2007 use of a direct-ascent weapon to kill a target satellite in space.

Yet, attack from a direct-ascent satellite-killer is not the only danger out there. Threats range from proliferating space junk and orbital vehicle collisions to ground-based jamming, which now can be used to neutralize or disrupt spacecraft in medium Earth orbits.

One way or another, the job of securing military space is about to change, and a top mission for Air Force Space Command is to preserve and expand the ability to deliver space effects to joint forces in combat.

A fresh technical review of space protection options began in the spring of 2008. Andrew W. Palowitch, a former Navy submariner with extensive CIA experience, took the helm of the new office of space protection policy. Air Force Space Command and the National Reconnaissance Office together created the office to assess the natural and man-made hazards to space systems. Its main job is to report on technical risks and deliver recommendations that flow into the Air Force and NRO acquisition systems.

The fact that a formal space protection office was deemed to be necessary underscores how risks in space have increased.

Space efforts, which began in the mid-20th century, grew tremendously through the 1960s and 1970s. By the 1980s, matters had reached a point where "the Soviet Union had adversarial capabilities and demonstrated a viable threat" to US and other space systems on orbit, said Palowitch.

However, everything seemed to change with the fall of the Berlin Wall in 1989 and subsequent collapse of the Soviet Union. After those events, said Palowitch, the perceived threat in space was "almost negligible."

From 1989 to 2007, the operational capabilities of space systems—and dependence on them—grew massively. The US invested with great results in capabilities such as communications, positioning, navigation, timing, and sensing without investing a lot in the defense of those assets, Palowitch added.

Meanwhile, the number of nations using space grew, as did their own capabilities.

According to Palowitch, several rogue states possess at least some ability to interfere with US space systems or their effects. North Korea's Taepo Dong II long-range ballistic missile, if armed with a nuclear warhead, could pose a potential threat to satellites in orbit. Iran's Safir missile could wreak



Left, space debris hits a solar panel on a satellite in an artist's conception. Above, Gen. C. Robert Kehler, head of Air Force Space Command, speaks at the 2009 Air Force Information Technology Conference.

the same type of damage, should the Islamic Republic finally succeed in going nuclear.

Much further up the scale of threat is China. Palowitch categorized China's 2007 destruction of its own defunct weather satellite as "the first-ever demonstration of direct-ascent launch" of a kill vehicle against a space target. (The US showed that it, too, has the capability with the February 2008 intercept of an inoperable NRO satellite.)

Beyond the danger of overt attack, on-orbit perils are increasing. Active satellites can collide with debris or even with each other.

Currently the most dangerous place is low Earth orbit—out to 300 miles—and just beyond. Imagery satellites dominate in this region. Satellites operating from about 300 to 700 miles above the planet's surface can be targeted by direct-ascent attack. As long as the geometry is correct, any nation with space launch and tracking capability could in theory take out a LEO satellite.

Space debris in the low Earth orbit bands also poses a significant hazard. Space Command leads an effort to track and deconflict objects in space. The Joint Space Operations Center (JSpOC) at Vandenberg AFB, Calif., regularly and continuously tracks 19,000 major items. However, NASA officials believe space may be littered with at least 10 times as many objects.

Of the objects tracked, as many as 700 per day approach "conjunction"—defined by Palowitch as "close proximity between two space objects." Crews at Vandenberg use software to anticipate conjunctions and make recommendations for emergency course corrections.

Worries about a collision are intensifying. On Feb. 10, a defunct Russian military communications satellite collided with an operational Iridium commercial satellite 480 miles above Siberia, destroying both spacecraft and creating a wide debris field orbiting in space.

A Pummeling

On May 12, French and US officials convened a conference to discuss what to do about a French SPOT Image satellite nearing a dangerous conjunction.

Space Command officials have shown reluctance to discuss methods for deconfliction or to speculate on increasing risks of collisions. Still, there's no question that the risk of debris or other spacecraft knocking out a satellite is a real hazard for those depending on the space-based effects.

It's not only satellites that are at risk. Manned spacecraft are in danger, too. The International Space Station keeps an eye out for debris in its low Earth orbit band.

The recent expedition of space shuttle *Atlantis* on a major Hubble repair mission illustrated the dangers also.

Traveling up to the Hubble telescope's altitude required transit through a major debris field. As Palowitch described it, the worst debris in LEO is right in the Hubble's band. The known debris put *Atlantis* "at a one-in-200 chance of being

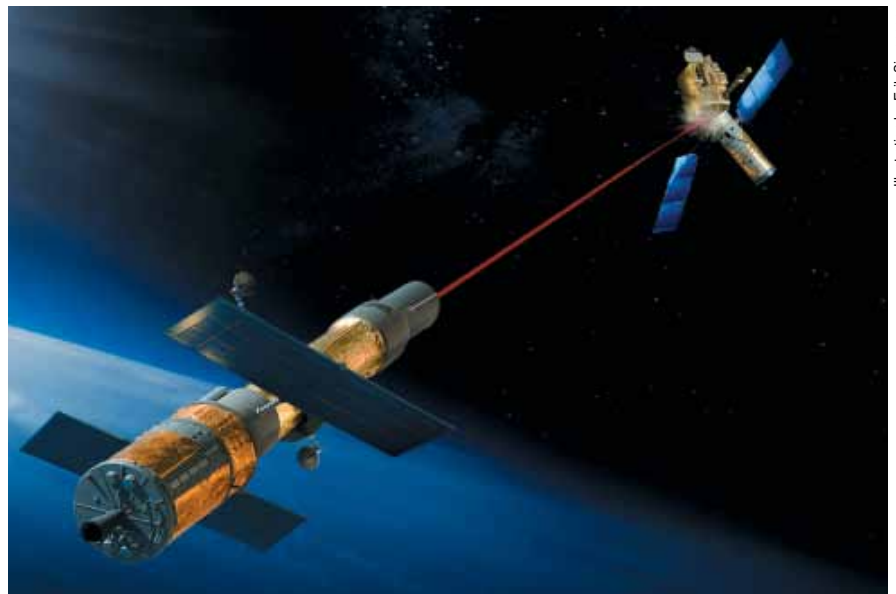
totally destroyed by impact in flight," he said. When it landed, *Atlantis* was pockmarked with more debris hits than any other shuttle in history.

Several factors contributed to the pummeling. First was the transit through debris fields. Then, once in position, the complex repairs required *Atlantis* to spend more time in the junk-strewn orbit.

As is obvious, growing debris fields pose a problem for critical space operations. The Air Force in June awarded development contracts to three industry teams for the Space Fence, a next generation space tracking system with planned initial capability in 2015. The Space Fence should track both low and medium Earth orbit objects ranging from space junk to operating satellites and other spacecraft. Space Fence will allow tracking of up to about 100,000 objects. The new system should also reliably track objects as small as two inches in diameter.

The US isn't alone. China, with its own manned space program, soon will have to deal with the space junk it has done so much to spread.

Far above the debris fields of LEO wait other hazards. Many communications satellites operate in geosynchronous Earth orbit more than 22,000 miles above the equator. Interdicting satellites in GEO is a whole different proposition—at least for now. Many experts maintain that direct-ascent attack currently can't pose a threat to satellites in medium Earth orbit (MEO), highly elliptical orbit (HEO), or the far-distant geostationary or geosynchronous Earth orbit (GEO).



An artist's conception of a spacecraft taking down an enemy satellite.



A satellite photo taken by DigitalGlobe shows what is believed to be the exhaust trail and vehicle launched from Musudan-ri, North Korea, in April.

Collisions aren't necessarily head-on crashes—satellites extend long arrays for positioning. Often, these tentacles crash into each other. Still, even glancing blows can obliterate satellites closing on each other at thousands of miles per hour. In theory, any object on orbit is a potential satellite-killer, by accident or on purpose.

Why do satellites collide? Avoiding accidental collision is a matter of better tracking data. When Iridium and the Russian satellite hit each other, "we weren't looking at them," Gen. Kevin P. Chilton, head of US Strategic Command, explained.

About 1,300 satellites orbit above the Earth. Of those, approximately 800 can be maneuvered with short fuel burns. The JSpOC now performs conjunction analyses on all of them. Priorities begin with manned space vehicles, such as the space station and shuttle, and the vital national security satellites, and on down. Last February, before JSpOC increased its analyses from 140 to all 800 maneuverable satellites, Iridium wasn't on the list. Nor were Iridium's minders regularly feeding data on its position.

Currently, sensors may check the position of a satellite irregularly and

extrapolate its position according to Kepler's laws. Over time, the position data changes from an exact location to an ellipse containing the probable location. When two ellipses overlap, a conjunction is possible. The problem is that error margins grow as the ellipses grow. Officials would like to know whether a predicted conjunction will scrape solar arms or miss by miles.

Taking Stock of Threats

More and better sensors on orbit are part of the answer. "You want the ellipses to be as small as possible," Chilton said, and that takes more frequent position updates.

STRATCOM would like to upgrade sensors and software to track 300 satellites or more, with a precision measured in feet, not kilometers. Maneuvers cost fuel, so operators want a good reason to move. In the future, officials would "like to give them the opportunity to get out of the way. If you run into something, it hurts everyone," Chilton said.

When it comes to active, deliberate military action, adversaries are much more likely to try to disrupt the signals or the ground stations from the surface of the Earth. "We have seen evidence

from a number of places around the world that our potential adversaries or others are developing capabilities here that can challenge us in all three of those pieces of our space capability: the space segment, the link segment, and the ground segment," said Kehler.

High-flying communications satellites are susceptible to ground-based jamming. Palowitch estimated there are "multiple hundreds" of jammers, which are "a lot cheaper than any other means for localized effects" to disrupt communications.

Ground-based jamming is creeping upward to higher altitudes. DOD's official report this year on Chinese military capabilities noted the purchase of jammers from Ukraine several years ago, and the probability of Chinese-made jammers, as well.

"We've seen GPS jamming, and GPS is in MEO," noted Palowitch. Opinions vary on whether commercial communications capability leased by the US military is truly safe or not.

Laser dazzling is another form of ground-based disruption. "It's not hard to go buy sufficient laser capability—at the low end—that would allow you to potentially dazzle sensors that would either be in the air or in space or wherever," said Kehler.

Space Command has concluded that heavier defenses for space assets can help. For example, GPS is a low-power system, which is easier to jam. Kehler said Space Command is working on "increasing the power of the systems, and we're headed towards GPS III, which will give us a platform to be able to deal with this more robustly in the future."

Space Command is taking stock of threats and vulnerabilities. "We are looking ... across the board at how we protect these high-value assets. In some cases, these assets are very well-protected," explained Kehler, because they were "designed to operate through a nuclear exchange. Some of our communications at the high end are still intended to operate through nuclear activities, and, of course, our early warning satellites are designed at some length with some amount of inherent survivability."

Hardening satellites is part of the package. Kehler described on-orbit protection as primarily an engineering issue. Satellites have to be built tougher, with threats in mind. "This is not an overnight solution [where] we can engineer protection solutions in,

Is Heavy Lift the Chinese Game-Changer?

During America's reach for space in the 1960s, the hallmark of success was the heavy lift of the massive Saturn rocket. Saturn Vs like the one that boosted Apollo 11 generated 7.5 million pounds of thrust from its mix of kerosene and liquid oxygen fuel. Remarkably, all 32 of the Saturn rockets launched without a single failure.

This is the capability that space up-and-comers such as China lack today, but are trying to acquire.

China is taking steps toward putting rovers on the moon and, eventually, to landing a human astronaut there. China flew its first manned spaceflight in 2003, and plans the moon landing for 2024.

Getting the boost power needed to lift heavier vehicles toward the moon will also give China the technology to put heavy spacecraft in orbit.

China is nowhere near the Saturn V capability yet, but 50 years of steady progress has left the Chinese space program well-positioned to achieve its goals in another decade. In that time, China will pursue advanced reconnaissance and communications satellites and make a big decision about whether to create its own precision timing and navigation constellation to compete with the Global Positioning System.

Mastering heavy lift will create ancillary options for the Chinese military use of space. "Many of China's space programs, including the manned program and the planned space station, are run by the [People's Liberation Army]," confirmed this year's DOD annual report on Chinese military power.

and have them up there tomorrow," he cautioned. "It's going to take us some amount of time, here."

One example of a well-defended system is Milstar. Its original name of Military Strategic and Tactical Relay summed up its mission well. Five Milstar satellites in geosynchronous orbit provide jam-resistant communications for forces around the world. Milstar satellites process signals on-board and can talk to other Milstar satellites as well as to ground terminals. The three newest Milstar satellites have greatly improved data flow rates. The ability of Milstar to form a signals relay in space significantly improves the security of the information it handles because operators can choose to bypass ground links, in some cases.

Scheduled to replace Milstar is the Advanced Extremely High Frequency Satellite Communications System. With AEHF, defensive protection has been an engineering requirement from the start. AEHF is designed with extremely high frequency uplinks and superhigh frequency downlinks to potentially thousands of joint user terminals. Kehler said Advanced EHF includes "improved protection on it because of its jam resistance." Its bandwidth rate of eight million bits of data per second is a leap ahead of Milstar.

Bandwidth alone is not the measure of secure, space-based communications. Cross-links among the AEHF satellites remain critical, as do mobile ground links. Of course, all depends on injecting

enough cyber security into the system to ward off attack from that domain.

Protecting satellites is both a design issue and "a maneuver issue," to use Kehler's terminology. "Protection isn't just about the satellites. It's a balanced activity that we're going to be careful that we maintain," he said.

Part of the smart and balanced solution may lie with the international community. As with the law of the sea or nuclear arms treaties, agreements take time and political will, but hold the potential to reduce danger and reshape behavior. International initiatives could help ensure that US military forces can rely safely on space effects.

Looking at Alternatives, Backup

Many nations are heavily invested in capabilities such as the Air Force's Global Positioning System. China, for one, depends on GPS for precision navigation and targeting.

For now, sticking with an international community approach is preferred. "We decided that we wouldn't move into a NATO-ish system of alliance," Palowitch told *CAISR Journal* last year. "You actually increase the perception of conflict by excluding people and driving them to the other side."

Not surprisingly, minimizing debris is of major international interest.

Palowitch likened it to the experience of protecting more of the oceans from pollution. For centuries, no one gave ocean dumping a second thought. Then, as more nations became aware of the effects of pollution, political momentum grew for keeping the oceans clean.

"We're at the exact same stage in space today," said Palowitch. In his view, there is a "huge international cooperation effort to ensure space-debris mitigation."

Remedies may include laser ablation of debris or nudging objects to a lower orbit so they can burn up in the atmosphere. So far, major cleanup operations are only in the conceptual stages.

With all the concern about debris, direct attack, and interference, airmen have also begun serious exploration of tactical and strategic alternatives to space systems. The idea is to create a backup plan. "We're not trying to save satellites," Palowitch told *CAISR Journal*. "We're trying to preserve our national space effects."

Creating the ability to augment constellations on demand is one option. Space Command is "looking at operationally responsive space as a national strategic capability to give ourselves the ability on a relatively short time frame to either augment a constellation or replenish it if we have issues either from technical reasons or from some kind of attack," said Kehler.

Another alternative actively being explored is to create backup communications links via manned aircraft, unmanned systems, and high-altitude airships. Tactical, theater-specific communications relays could flow through airborne platforms.

Space Command experts see the approach not as a threat but as a way of delivering effects under emergency conditions. The Air Force's newly released unmanned air systems flight plan includes explicit reference to backup communications links.

There are many ways to preserve space effects.

"In some cases, the most effective way to counter a loss of a space capability may be with a nonspace [capability]," Kehler said. "It might be an aircraft, it might be a ground system of some kind, it might be a UAV." ■

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