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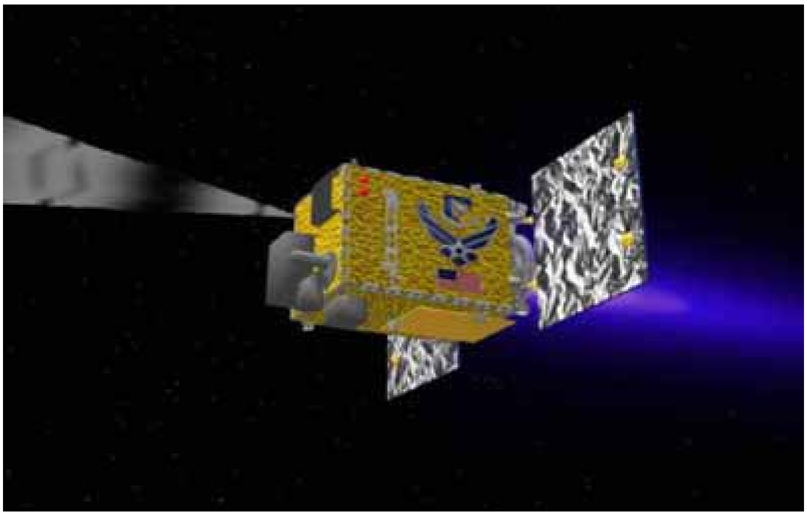

XSS-11 is an experimental satellite testing autonomous rendezvous technologies that have both civilian and military applications. (credit: USAF)

Military space systems: the road ahead

by Matthew Hoey
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In recent years military space contracts have been an "oligopoly" of the "Big 6" in the US defense industry: Boeing, Lockheed Martin, Northrop Grumman, Raytheon, General Dynamics (Spectrum Astro), and Orbital Sciences, which is slowly becoming a leading provider of space systems alongside the other five. These companies are listed by economic dominance over the past 12 months. Satellites developed by these companies typically range in size from 500 to 10,000 kilograms and in price from $25 million to $1 billion. Big companies, big satellites, and big price tags.

This industry norm is now being challenged, however, and challenged effectively. The catalyst for change is affordability, which is leading to a realignment of the space systems industry. This affordability has not yet been realized in a profoundly beneficial sense, but dramatic advances towards affordability are coming.

The space systems oligopoly of the present is slipping into the past and new players are appearing on the scene. Small space systems companies like Space Development Corporation (SpaceDev), Surrey Satellite Technology Limited (SSTL), Microcosm, Space Exploration Corp (SpaceX), AeroAstro, and MicroSat Systems are getting recognized and, in turn, are receiving space systems contracts and attention by the military and researchers alike.

These companies are working in two main areas. The first is affordable launch services. Increased competition in the launch service industry was a driving factor behind the decision by Lockheed and Boeing to form a joint venture, United Launch Alliance, to reduce the cost of their launch services. Additional technologies are space asset protection systems, asset maintenance systems, and anti-satellite (ASAT) systems using small satellites. I will highlight the relationships among those applications.

The space systems oligopoly of the present is slipping into the past and new players are appearing on the scene.

Government development of military space systems is being accelerated specifically regarding programs in the early stages of development, thanks in part to partnerships that blur the line between military research and commercial applications. This blurring is a result of dual-use systems—many military space systems have legitimate commercial applications. As various government agencies become more reliant on space, they are increasingly collaborating on space systems with each other, with support from industry- and university-based research teams. Collaborators on a single project might include military research laboratories, NASA, defense contractors, and university researchers.

ORS: moving toward space weapons and ASAT capabilities

Increases in funding for military space systems and the overall growth of the industry are being partially fueled by a military strategy called Operationally Responsive Space (ORS), directed by the Office for Force Transformation. ORS objectives are: for development, reduce the timeline from years to months; for deployment, reduce the timeline from months to hours;

and for operations, reduce the timeline to continually or seconds. New systems will help make ORS a reality and revolutionize the space industry in two ways: by reducing the cost of space access and by streamlining the time and effort required to place assets in space. The first technology tier involves increasingly affordable launch vehicles and next-generation expendable launch vehicles. Companies such as Lockheed, Boeing, and SpaceX are making great strides in this arena, particularly SpaceX with the Falcon launch vehicle. Microcosm's Sprite Mini-Lift vehicle, in development, is designed to be launched on eight hours' notice and by the 10th launch will be able to place over 300 kilograms into LEO for $1.8 million—a dramatic reduction in launch time and cost. Although this system has not been tested one must ask that, if this technology is developed, what are the implications of such technological leaps?

The combination of affordable, short-notice launch capability with small satellite technology has the potential to revolutionize the space industry, especially military space systems. For example, ESPA is a structure developed by the Air Force Research Labs (AFRL) and the Space Test Program (STP) as a means to deploy small satellites. The ESPA stage is currently available only with the Atlas 5 or Delta 4 EELV, but similar deployment platforms could, in time, be developed and adapted to use with more affordable next-generation vehicles like Space X's Falcon and the Microcosm's Sprite. This would further reduce the cost of military space programs and commercial space launches.

As examples of how fast the small satellite industry is moving, consider SSTL, SpaceDev, and AeroAstro. Each of these small satellite developers uses different terminology to describe its satellite classes and has different weight standards. For example, the largest smallsat offered is called a mini-, micro- or small satellite, and the minimum weights for these range from 40 kg to 150 kg. As weights decline, the different companies use the terms micro- and nano- to refer to different weight ranges. Such variations are likely to continue for some time, and then gradually become more uniform across the space systems industry as this field continues to evolve.

AeroAstro, a space systems company based in Ashburn, Virginia, was founded in 1988. With just 50–60 employees, AeroAstro is conducting research and development for various government agencies including the intelligence community and the military. One AeroAstro project is the Escort program, about which the company boasts that direct engagement and ASAT capabilities are system objectives. The eventual applications are as follows:

- Monitor space around a large satellite to detect attacks;
- Stealthily inspect and monitor a large satellite;
- Stealthily attack to permanently or temporarily disable a large satellite; and
- Actively defend a large satellite against attacks by microsatellites.

The Air Force is a major funder of this program. Applications such as monitoring the international space station and the space shuttle are also foreseen, underscoring the dual-use potential of such systems.

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SpaceDev is developing a technology called MoTV, maneuverable orbital transfer vehicle. A SpaceDev MoTV can be used as a standard propulsion module to transport a customer's payload in orbit. The MoTV provides the change in velocity (delta-V) and maneuvering capabilities to support a wide variety of applications for on-orbit maneuvering, proximity operations, rendezvous, inspection, docking, surveillance, protection, inclination changes, and transfer. SpaceDev and other companies are utilizing TCP/IP-based command and control technology. SpaceDev demonstrated this technology with a satellite named Cosmic Hot Interstellar Plasma Spectrometer Satellite (CHIPSat). CHIPSat was the first US mission to use end-to-end satellite operations with TCP/IP and FTP utilizing SpaceDev-developed Windows NT-based mission control software—all running across a secure Internet link. This means that command and control can be achieved via an Internet connection and a desktop computer. We can expect that advances in computer and information systems over the next few years—undertaken independently of space-related programs—will significantly advance the technological foundation for military space applications. The steady increase is speed will lead to several obvious benefits: a reduction in footprint, a significant reduction in operation-and-maintenance costs, and the ability to directly view, process, exploit, and disseminate information throughout a theater of operations without reaching back to a fixed mission ground station. As faster systems are deployed and military benefits are reaped, there will be a further increase in the need to protect military space assets from a threat that is currently undefined.

Another recent advance involves what are called "re-docking cubesatellites." Imagine a mother satellite with multiple "cubesats" loaded on board. Each would be no larger than 25 centimeters per side. These satellites could fly in formation, dock with other space assets, provide imaging, and, most importantly, perform inspections of other satellites. In theory, a cubesat might, for example, place a black swath of adhesive material over a satellite lens or solar array, and then remove it once the objective (concealment of some activity) has been met. This is referred to as a "stealth" satellite attack, an attack that duplicates natural phenomenon or is reversible. Once this act was executed the cubesat would return to the host satellite and re-dock via various means, such as electromagnetism. Once the cubesat returns to the host it would recharge its batteries and transfer images or data collected. With such systems the cubesat could return to the target satellite and reverse the attack once a conflict had passed or an objective had been achieved. This is a technology currently in the research stage, though universities—which make up for a large portion of the experiments in this arena—have been very active with re-docking cube satellites, with some projects being supported by the Air Force. Internet research and conversations with program personnel make clear that such systems are being pursued and are in various stages of research and development.

XSS, the Experimental Satellite Series, is one of the better-known rendezvous-capable satellite programs. It was developed by the Air Force Research Laboratory in concert with the Air Force Space Command, Air Force

Space and Missiles Systems Center, NASA, the Naval Research Laboratory, and the defense contractors Boeing and Lockheed Martin—again offering an example of NASA's close relationship with the military on rendezvous-capable satellites, which in time could have direct military applications.

The objective of the XSS is to perform on-orbit experiments to develop "a satellite-oriented space logistics and servicing capability." In 1999 the US Air Force conducted a Microsatellite Technology and Requirements Study, which called for "the deployment, as rapidly as possible, of XSS-10-based satellites to intercept, image and, if needed, take action against a target satellite," according to an unclassified summary published in 2000. Such tasks are achieved by the deployment of a microsatellite or satellites from a carrier vehicle to perform precision maneuvering to and around orbital assets. The XSS-10 was the first microsatellite in the series and was launched in 2003, performing experiments lasting 24 hours. The total project cost was approximately $100 million. The second generation is the 100-kilogram satellite XSS-11. Originally scheduled for launch in 2004, was launched on April 11, 2005 from Vandenberg Air Force Base aboard a Minotaur rocket. XSS-11 is expected to rendezvous with up to eight objects and perform proximity operations that will add to the US military's space toolkit.

While the Air Force Research Laboratory (AFRL) argues that the XSS-11 could be used ultimately to provide the capability for proximity operations, observers worry that it could be tweaked into an anti-satellite weapon. Program manager Harold "Vern" Baker says, "We are staying a good ways away from it [its upper stage]." But AFRL is cutting it close: XSS-11 is supposed to get within two kilometers of the rocket. Such a capability to engage either with a rocket, enemy space asset, friendly space asset, or object in theory could be a precursor to an active defense capability or ASAT system. XSS-11 is another example of a rendezvous-capable satellite that blurs the line between commercial, civil, and military space applications while bringing industry, NASA, and the Department of Defense together on a project with potential uses that range from asset maintenance to peaceful inspection service to military interdiction capabilities. As of December 2005 the XSS-11 had completed more than 75 natural motion circumnavigations of the upper stage of the Minotaur 1 launch vehicle and performed proximity operations five to six times with the expended rocket body at distances between 1.5 kilometers and 325 meters.

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The DART (Demonstration of Autonomous Rendezvous Technology) spacecraft was successfully launched on April 15, 2005 from Vandenberg Air Force Base, California. During its time in space it successfully demonstrated a rendezvous capability, acquisition of the target spacecraft, and approach to within approximately 90 meters, according to the initial report on the mission. On April 22, NASA spokeswoman Kim Newton reported, "The DART spacecraft did make contact with the target satellite during the rendezvous phase of the mission and boosted it into a slightly higher orbit." Newton added that neither DART nor its target satellite (a retired US military spacecraft called Multiple Path Beyond Line-of-Site Communication satellite or Mublcom) appeared to have been damaged in the incident. The computer-guided DART spacecraft was equipped with an advanced video guidance sensor and a Global Positioning System (GPS) receiver to allow DART to approach its target. Program leaders include NASA's Marshall Space Flight Center and Orbital Sciences Corporation. DART was designed to approach within five meters of Mublcom without any guidance from spacecraft operators on the ground and to perform a series of maneuvers. The entire mission was expected to last less than 24 hours and cost an estimated $110 million. It ended when the system ran out of fuel.

Like the XSS, this program brings together technologies similar to those needed for a direct-engagement ASAT system and has performed operations nearly identical to those required to attack an enemy space asset. Both systems bring together NASA, the military, defense contractors and commercial space entities. In addition, like the XSS the DART system has legitimate peaceful applications—though these applications are in fact precursors to an operable ASAT system and the research sponsored in part by NASA in time may be used in a military ASAT system.

The Orbital Express Space Operations Architecture program seeks to validate the technical feasibility of robotic, autonomous in-orbit refueling and reconfiguration of satellites in support of a broad range of future US national security and commercial space programs. Refueling satellites will enable frequent maneuvers to improve coverage, change arrival times to counter denial and deception and improve survivability, as well as extend satellite lifetime. These abilities are revolutionary and will provide extensive benefits to the military and commercial space systems, reducing costs and thus passing value to customers using various services. According to the Defense Advanced Research Projects Agency (DARPA), Orbital Express can support deployment and operations of microsatellites for missions such as space asset protection and sparse aperture formation flying, or deploy nanosatellites for inspection to provide data to support satellite repair. Like other systems mentioned in this presentation, this one is being developed jointly by the military, a defense contractor (Boeing) , and NASA. It is a dual-use system with clear commercial and military applications. Orbital Express is scheduled for launch in 2006.

What are the implications of development and deployment of an ASAT system?

For hundreds of years countries used shipping blockades and trade embargos to cripple opponents' economies and compromise the rival nations' military efforts and movement. As military technology evolved during World War 2, nations began to explore technological means of electronic communications and the means to defeat those systems. During the armed conflicts and diplomatic confrontations of recent decades, economic

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sanctions have been used to cripple a nation's economy, as was the case in Iraq in the 1990s. Today and even more in the future, as we rely increasingly on space systems for trade, communications, imaging, intelligence gathering, military targeting and navigation, and other functions, the objectives of war planners can and will be achieved by attacking, compromising, or temporarily rendering inoperable a nation's space assets. Whether or not these objectives are beneficial to the war planner and our national security is another question. This will occur without the need for UN approval, without the need for overflight permission, and on short demand (if the objectives of operationally responsive space become a reality)—if the international community fails to set the "rules of the road" for space.

In sum, we have three rapidly evolving technologies that will accelerate military space projects and make them more affordable. These are: short-notice launch capabilities; next generation small satellites that significantly reduce launch costs and are capable of direct engagement; and ESPA-ring technologies and similar deployment stages for launch vehicles. Technology forecasting suggests that once fully integrated, these technologies will significantly reduce the cost of the militarization of space process and its transition to weaponization. Programs are in development, the defense and research communities are hard at work, and there is no adequate international legal framework in place to ensure that ASAT systems and weapons will not be placed in space. Weaponization will first be initiated in space asset protection systems, built on small satellite platforms, under the guise of asset protect systems with active defense capabilities. Once such systems are in place, the act of attacking or compromising an enemy space system will be limited only the intention of the user. The road to space being weaponized may also be shortened thanks in part to a space-based missile defense system—should it be developed.

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