Seize the Highest Hill

A Call to Action for Space-Based Air Surveillance

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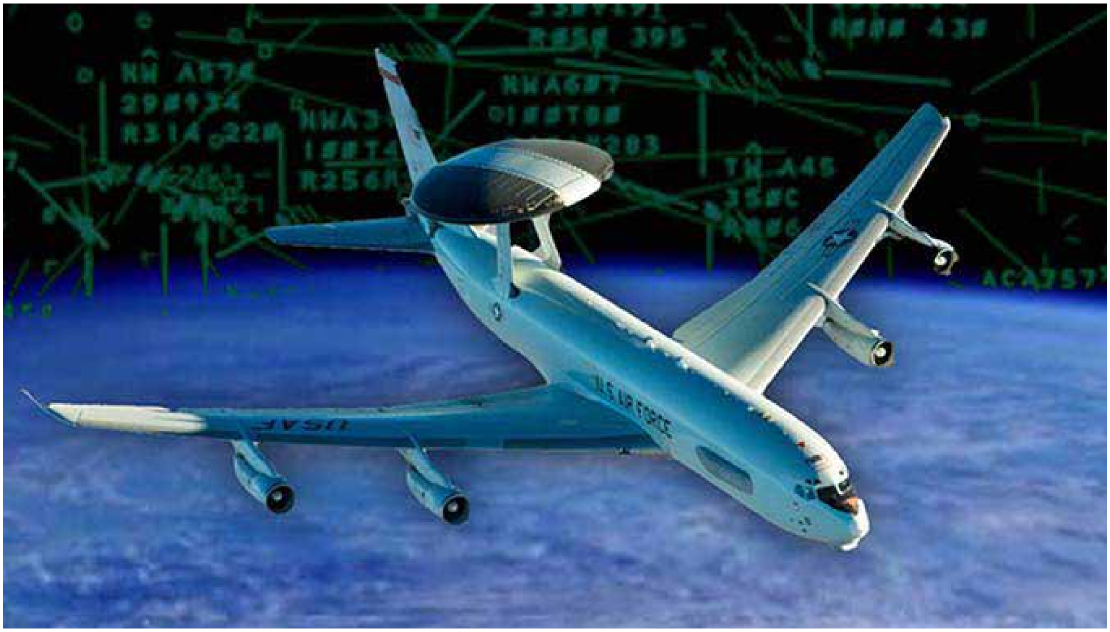
> *All armies prefer high ground to low.*
> –Sun Tzu, *The Art of War*



The Air Force must overcome area denial strategies not by engaging competitors in a technological tug-of-war in the air domain but by leaping over them to exploit the decisive high ground of the space domain. The fusion of airborne and spaceborne sensors will provide the decisive and enduring advantage in air domain awareness necessary to deliver air superiority in 2030 and beyond.

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Joint operations rely heavily on the air component to provide the security of air dominance over friendly forces and air superiority over objectives. The resulting freedom to maneuver is essential to how our land and maritime forces conduct operations. A comprehensive, theater-wide, real-time surveillance picture is a vital prerequisite to control of the air in modern warfare. The success of US-led air campaigns of the 1990s and 2000s has made the rapid establishment and enduring sustainment of that picture so ubiquitous that it is now generally taken for granted. The joint force can no longer accept such a tacit assumption.

The joint force can no longer assume unimpeded access to the airspace or spectrum necessary to conduct air surveillance by current means alone. The air domain awareness advantage of previous generations was built on a technical edge that has eroded. Widely proliferated advanced air defense systems now enable many adversaries to effectively deny air surveillance systems their "god's-eye" view, undermining the air component's situational awareness (SA), complicating air superiority, and putting the joint force at risk. As part of a new disaggregated and distributed approach to command and control, the US Air Force must expand its means of air surveillance to include spaceborne sensors.

Eyes in the Sky

Surveillance as a military activity, and air surveillance, in particular, is often misunderstood. The DOD definition of surveillance— "systematic observation"—is broad.[1] In contemporary use, surveillance is most often crammed between intelligence and reconnaissance in the acronym ISR (intelligence, surveillance, and reconnaissance)—belying the value of systematic observation beyond the intelligence enterprise. For this article, *air surveillance* specifically refers to persistent wide-area surveillance (WAS) of the air domain of the kind currently delivered directly to the theater air control system (TACS) for airborne early warning and battle management, command, and control (BMC2).

Persistence is essential to providing the joint force with continuous coverage, leaving no gaps in observation over time.[2] Wide area means simultaneous coverage of a complete mission operating area, leaving no gaps in three-dimensional space. In major combat operations, the joint force has become accustomed to the TACS providing air domain awareness, measuring coverage in tens of thousands of square miles and persistence in days without interruption.

Radar remains the best tool for rapidly building a picture over such surveillance volumes large enough to cover modern operating areas. Using the Doppler effect, radars can pick out moving objects against background returns at hundreds of miles. When processed, location and vector data presented in this way are called moving target indicator (MTI) data. Surveillance teams use air MTI to detect and track air vehicles. They then layer cooperative identification systems and conduct sensor and intelligence fusion to create the authoritative air picture for all entities requiring SA of friendly air missions, air domain awareness, or "prediction of an adversary's behavior."[3]

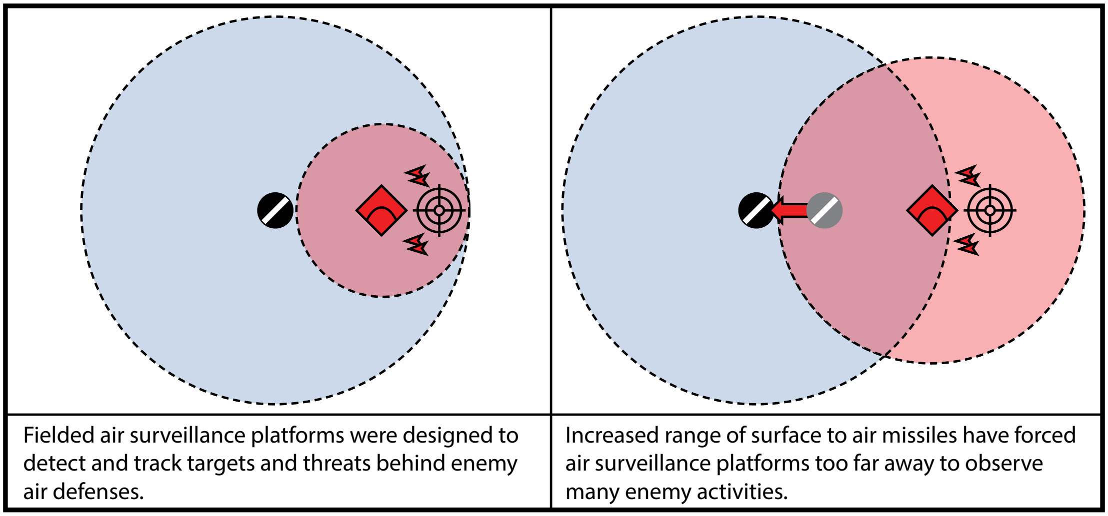
For decades, the Air Force has generated that picture through a combination of ground-based and airborne radars. Ground-based radars provide several advantages, including persistence, flexibility, and a low operating cost. Despite these advantages, ground-based fixed and movable systems are not as rapidly deployable or tactically flexible as aircraft. Airborne systems are more expensive to operate but provide greater tactical flexibility and all the classical benefits of high ground. They can look down valleys to negate terrain masking and move in response to the current situation to optimize sensor coverage as the mission changes. These challenges have made expeditionary airborne surveillance platforms indispensable in the air surveillance role. Unfortunately, this dependence is rapidly becoming a vulnerability.

Losing Our Perch

> *The increasing lethality and reach of adversary weapons will significantly increase the risk to large BMC2 platforms like AWACS in 2030. This will limit their ability to see and manage activities in the contested and highly contested environments.*
>
> —Enterprise Capability Collaboration Team
> Air Superiority 2030 Flight Plan, May 2016

State-of-the-art air and spectrum threats pose grave risks to today's surveillance platforms. Spurred into action by the decisive air-land campaign of Operation Desert Storm, competitors worldwide have invested heavily and effectively in capabilities to contest the West's asymmetric air and spectrum advantages. Air defenses have advanced in lethality, forcing surveillance aircraft to operate ever farther from their areas of interest to survive (fig. 1). Meanwhile, air surveillance has remained fundamentally unchanged over the same interval. Even from the air, radars of sufficient fidelity are generally still constrained by the horizon. The lethality and proliferation of air defenses have tilted both the advantage and cost-benefit substantially in favor of the defender.

Highly accurate long-range surface-to-air missiles (SAMs) are especially lethal to surveillance platforms. Air surveillance radars continue to be flown primarily on modified airliners with no substantial improvements in altitude, speed, stealth, countermeasures, or any other method of self-defense. SAMs, however, have increased in range, accuracy, and affordability, driving lethality and proliferation. The introduction of very long-range air-to-air missiles (VLRAAM) and increased combat radii of leading interceptor aircraft make matters even worse.[4] The differential has grown so great that, in many cases, the air surveillance look into contested airspace has been reduced by more than half.[5]



Fielded air surveillance platforms were designed to detect and track targets and threats behind enemy air defenses.

Increased range of surface to air missiles have forced air surveillance platforms too far away to observe many enemy activities.

Figure 1. Impact of increased air defense ranges on air surveillance

Technology has also driven down the cost of air defenses, putting offensive capabilities on the losing side of the cost equation. Fielding incremental upgrades to air defenses is far cheaper than upgrading aircraft fleets, putting the offense on the losing side of the cost equation.[6] These systems, when integrated into a larger air defense system, can be an effective antiaccess strategy against surveillance platforms that cannot survive inside of missile engagement zones. This vulnerability is not confined to just one geographic combatant command. Many nations, including all four nation-states from the secretary of defense's "4 + 1" baseline threats, have fielded such advanced integrated air defenses.

The advantage air defenses have over airborne surveillance is an unacceptable threat to the US strategy of expeditionary engagement, which relies heavily on the agility and "inherently offensive" nature of airpower. The backbone of the air component's situational awareness has been pushed far enough back that they can no longer be effective where such threats are present. The resulting gap in air surveillance reduces early warning, limits support to the interdiction and deep-strike targets that are the Air Force's unique addition to the kinetic arsenal, and puts other joint missions at risk as well. This gap is a global and enduring risk for which a solution is overdue.

In Pursuit of Access, Coverage, and Persistence

The current platform-centric approach to the TACS relies on sensors that are too few, too vulnerable, and too far from the fight to be effective. The right solution is that there is no single solution. None of the headline-grabbing visions for solving this problem are sufficient on their own. A radical change in the means of air surveillance is needed to regain assured information advantage in contested airspace.

Incomplete Solutions

The simplest solution is to recapitalize legacy systems. Doing so would address platform longevity, availability, and cost concerns and may provide incremental upgrades to sensor range or platform survivability but would only be a continuation of business as usual. An evolutionary approach means engaging adversaries in a losing game of cat and mouse. The Air Force record in the air surveillance and command, control, and communication domain is full of failures, delays, half-measures, and wavering commitment to air surveillance and C2 platforms (e.g. E-10, the Three-Dimensional Expeditionary Long-Range Radar, E-3 Block 45, and Joint Surveillance Target Attack Radar System (JSTARS) recapitalization). In a global arms market defined by rapid evolution and proliferation, DOD acquisition is unlikely to outpace adversaries who can direct acquisition faster, accept more risk, and lean on cheaper defensive options. Sticking to familiar concepts would generate only fleeting advantages. Legacy models are insufficient to produce dominant capabilities or secure a lasting lead over adversaries.

Some concepts advocate saturating areas of interest with autonomous swarms to build situational awareness. Swarming unmanned aerial systems, with the potential to generate enormous amounts of data about the environment around them, are worthy of active investment for application to a variety of mission sets, including surveillance. By their nature, however, they are ill-suited for theater surveillance. There is an enduring need to detect and track the activity of interest anywhere and anytime in the area of responsibility, which requires wide-area coverage and persistence beyond the capability of today's swarm state-of-the-art. The limited size, weight, and power of current drone demonstrations and concepts constrain their altitude, range, speed, and endurance, as well as their sensor field of view and communications. Larger air vehicles are in development as well, but their expendable nature makes them poor platforms to carry expensive long-range sensors. Although they may be able to gain access to contested areas and provide high-fidelity local surveillance, the limited coverage and persistence of swarms will not scale effectively or affordably to theater-wide surveillance.

Knitting numerous sensors may be more effective with larger platforms such as fifth-generation (5G) fighters. They can achieve the needed access and carry larger sensor payloads higher and at sufficient speeds to provide some of the tactical flexibility that swarms lack. Despite advances in their multisensor suites, however, their air pictures continue to be local by design. Their bubbles of awareness are short-range relative to dedicated air surveillance solutions (e.g., SPY-1, APY-2, and TPS-75 radar systems). Even if shared, those rich islands of 5G situational awareness will only exist when and where those fighters are operating. Limited range and presence together mean that a 5G surveillance picture is too limited in both space and time. These gaps must be understood to avoid dependence on the dangerously oversold mantra that 5G fighters can be the lone "quarterbacks" of future air missions. Networked 5G surveillance solves the access problem, but can't provide a comprehensive, persistent picture.

It is increasingly accepted that air superiority will be ephemeral—only assured in localized time and space where and when needed. The tacit assumption seems to be that, because air superiority will be fleeting, the information superiority it relies on can be limited in time and space as well. That is a blatant false-cause fallacy.

Intermittent surveillance cannot be accepted as good enough. The freedom to maneuver and act may be taken and yielded as required by mission objectives, but accepting anything less than constant and pervasive situational awareness is tantamount to ceding the initiative to the enemy. The limitations of these concepts are not unknown but are often glossed over. Leaders must be aware of the limitations of these solutions and how they might be mitigated by combining with each other and with even more radical options. In this way, they can have at least a vision of a complete solution and, if necessary, assume risk consciously and at the appropriate level.

The Necessity of Netting Sensors

The air surveillance system of the future must constitute a system of systems that accepts disaggregated capabilities and distributed platforms. Disaggregated means embracing the flexibility to solve for surveillance, communications, and battle management capability categories independently or in various combinations on separate but networked platforms. Distributed means that those capabilities can be resident in platforms operating in more locations and from more domains, causing a transition from the current platform-centric mindset to a capabilities-centric approach. The surveillance capability of such a new system should include modernized "all-in-one" BMC2 platforms, dedicated surveillance platforms, and opportunistic sensor data from nonsurveillance platforms.

A disaggregated air surveillance system must have three defining traits to be successful. First and foremost, it must include dedicated, long-range, high endurance, look-down sensors as a "backstop" to ensure a minimum amount of continuous coverage over friendly and contested territory even if it cannot assure access to enemy territory. Second, it must be inclusive of all sensors regardless of platform so that no relevant enemy maneuver covered by a sensor goes unreported. Third, it must ensure interoperability between those diverse contributors to realize a cohesive surveillance network able to fuse disparate data into an air picture.

An air surveillance system that combines these traits will be more resilient, scalable, and flexible than the Cold War legacy construct, but will still fall short when engaged against determined adversaries with advanced air defenses. None of these solutions, even operating in concert, will provide sufficiently persistent surveillance in depth.

Space is the Ultimate High Ground

The final ingredient for a game-changing surveillance picture is space. The Air Force Future Operating Concept (AFFOC) urges the force to seek "increased contributions from space-based assets" and specifically acknowledges that "the joint force will increasingly rely on advantages provided by on-orbit assets for air superiority."[7] The AFFOC also warns against concentrating critical capabilities into any single platform or any single domain, lending support to both the distributed surveillance model and an objective consideration of surveillance from space.[8] Extending air surveillance to the space domain is the only mature concept that will grant persistent look-down coverage while bypassing advanced air defenses.

There has been interest in using space for air and ground surveillance since digital communications made real-time sensor feeds from satellites possible, but recent advances in space lift, miniaturization, and computing technologies demand a new look. Previous efforts encountered many roadblocks, but, fundamentally, each failed because the cost and risk of implementation outweighed the cost and risk of continuing the "business as usual" approach. Advances in technology and the increased need to bypass the evolving air threats dramatically change both sides of that equation. The balance has shifted and the time to field a space-based air surveillance system has finally arrived.

Getting to the Launch Pad

The US has been pursuing the use of radar in space since at least the 1960s (fig. 2). Many program details remain classified, but enough information is available to surmise why we do not already have operational space-based radar (SBR) constellations. A quick look at some past programs of record reveals a pattern of cancellations due to unanticipated costs and technical challenges, both stemming from complicated designs or immature technology, often coupled with a lack of political and military leadership commitment.

The US focused early radar satellite programs on synthetic aperture radar (SAR) to provide all-weather alternatives to imagery intelligence. [9]Some of these programs, such as the National Reconnaissance Office's (NRO) 1964 Quill program or the Navy's 1979 Clipper Bow, were limited for utility reasons. Quill's SAR imagery had to be processed on the ground similar to the early Corona photo reconnaissance satellites.[10] This lack of real-time information limited Quill's mission to a one-time test of SAR resolution from orbit. Clipper Bow, meant to provide radar imagery of Soviet ships to complement the electronic intelligence provided by the Navy's White Cloud satellites, was canceled before it flew. When new Soviet bombers became the primary threat to US naval vessels, the need for over-the-horizon detection of ships diminished and the Navy was no longer willing to fund Clipper Bow.[11]

While Quill and Clipper Bow provided little return on investment, the Onyx (also known as Indigo or Lacrosse) SAR satellites enjoyed some success. With five launches between 1988—2005, operational Onyx satellites gained publicity during the 2003 Iraq War when they were able to detect Baathist Army targets through sandstorms.[12] But the Onyx satellites highlighted a problem that continues to plague any large satellite architecture—large satellites are easy to detect and track, so that an adversary can counter them through simple evasion or deception tactics. Small constellations of large satellites are also extremely vulnerable to antisatellite (ASAT) weapons, which peer adversaries, such as Russia and China, have demonstrated and continue to develop.[13]

The first real attempt to use space for an MTI capability came in the form of the 1980s SBR program. The relatively new Air Force Space Command (AFSPC) championed what it envisioned as a supplement to the airborne warning and control system (AWACS) for even earlier warning of Soviet aircraft movements. The end of the Cold War, however, reduced the urgency for supplementing existing airborne air surveillance capabilities.[14] Despite rhetoric about the high priority that SBR held for Air Force acquisition, the secretary of defense and top USAF leadership never accepted it for development. Much like Clipper Bow, leaders could not justify its cost when developing circumstances diminished its primary mission. It is also worth noting that AFSPC was not the Air Force element of the NRO, and a lack of NRO support would significantly hamper the Air Force's next attempt at space-based MTI.

The next incarnation of space-based radar, also called SBR, began as a 1998 Defense Advanced Research Projects Agency (DARPA) proposal. The NRO, however, was tacitly in charge of all satellite intelligence programs and joined with the Air Force to lead the program. This SBR was re-envisioned to provide ground MTI (GMTI) as a space alternative to the JSTARS. The logic behind providing this capability remains sound today: JSTARS is a high-value airborne asset that is not survivable against modern air and missile threats.[15]

The initial phase of this SBR became the Discoverer II program. Again, cost became a factor, especially as the program showed slow progress due to lack of interest. The interagency NRO/USAF/DARPA program died in 2001 when the NRO withdrew its support. Large costs can also be linked to the efforts that developers had to undergo while trying to design a single, large satellite to perform GMTI. Small constellations require lightweight materials, large apertures, and a large field of view, resulting in huge satellite designs that require expensive, heavy-lift rockets to launch. Monostatic radars, with a co-located transmitter and receiver, also have formidable challenges when trying to reject clutter for a clean radar picture.[16] These same technical challenges would lead to exorbitant costs during the next iteration of space-based radar.

In 2006, another space-based GMTI radar was proposed under the name Space Radar (SR). This time, the Congressional Budget Office (CBO) produced a report analyzing the cost and effectiveness of several satellite constellation architectures. While larger, and therefore more expensive, constellations obviously led to better coverage and tracking capabilities, the report noted that "time gaps in covering a given area would probably occur for all of the constellations that CBO considered [and] those systems would be impractical for tracking," so that "constellations larger than the ones that CBO examined would be necessary to track individual ground targets."[17] The satellites also included a SAR capability "among other missions."[18] These were monostatic designs, requiring large apertures to optimize signal processing and improve clutter rejection. The CBO said their 40-square-meter radar arrays, which could not even reliably track targets unless larger constellations were considered, would likely be incapable of detecting any ground targets moving slower than 20 miles per hour.[19] Additionally, the CBO envisioned each satellite operating for 10 years, at which point each satellite would be replaced, resulting in a 20-year anticipated life cycle for the program. The requirements that a 10-year, multirole, large-aperture, SBR satellite demands resulted in an expected cost range of $35–$52 billion for the preferred alternative, and $66–$94 billion for the largest constellation.[20] The defense and intelligence community understandably deemed that cost, driven by architectures based on numerous, complicated, short service life satellites, was "not affordable."[21] While the official cancellation statement included hints that the program would be restructured and continue, no replacement for SR has been announced.

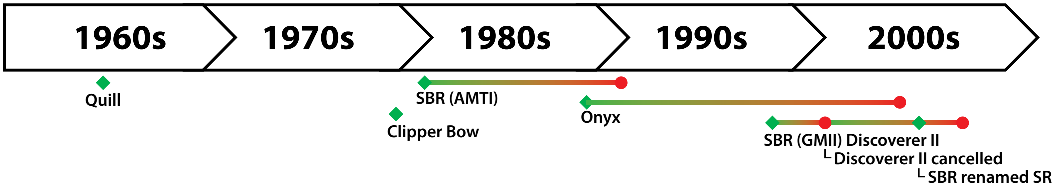


Figure 2. Chronology of US space-based radar programs

Despite previous failures to develop an affordable and capable space-based MTI capability, the idea continued to hold Air Force interest from the original 1980s SBR until the cancellation of SR in 2008. In 1999, Maj Kimberly Corcoran, then an experienced AWACS aircraft commander and student at the USAF School of Advanced Airpower Studies, reflected the optimism of space-based MTI development during the time of Discoverer II. Citing reports from the Air Force chief scientist, Dr. Daniel Hastings, in 1997 and the US Space Command space-based MTI concept of operations with Air Combat Command and Space-Based MTI Roadmap with the USAF Space and Missile Center, Corcoran and the Air Force space community believed that we would already have a GMTI capability in space now, with AMTI becoming operational by 2020.[22] While the 2008 cancellation of the SR has created a vacuum of formal SBR acquisition programs, the intent was not to cease pursuit of the capability. Rather, the NRO said it needed time to restructure the program to reduce the ever-increasing costs the program was generating.[23] Almost 10 years later, the program sits on the shelf as both the satellites and the enabling technologies that can make space-based MTI a reality have continued to mature.

The overall reason for the cancellation of past SBR programs has been unacceptably high cost compared to air domain alternatives for the anticipated gains. The costs have come from large bus satellites that require heavy launch vehicles. These busses are made even larger by requirements creep that adds search and rescue and additional seemingly-related missions, as well as the design requirements to ensure these satellites can operate for a decade or longer. The price per satellite has led to smaller constellation designs to reduce overall program costs. Smaller constellations reduce persistence, complicate tracking of slower targets, and generate a more cluttered picture. The resulting high costs for MTI satellites that can't reliably maintain the targets they were designed to track, and could potentially not even survive against an ASAT-equipped adversary, eliminated organizational will to back up claims of these programs' high priority. Researching and developing technologies that involve smaller busses, larger constellations, multistatic antennas, and virtual apertures has the potential to overcome the problems of the past.

Go for Launch at Last

> *If we don't invest in new ways of doing business now, we will not be competitors in the future.*
>
> Lt Gen VeraLinn "Dash" Jamieson
> ISR deputy chief of staff

Technologies for large constellations of smaller satellites have matured significantly in capability and feasibility in the past decade and offer increased resilience and reduced cost. Even before Discoverer II and SR fell victim to prohibitive cost, Corcoran proposed the use of large constellations of single-purpose small satellites (smallsats) as an alternative. The advantages of large constellations of smallsats over small constellations of large, multipurpose satellites are easy to see. Their great number complicates adversary targeting, their small size makes them more difficult to engage, and since capability is spread across the constellation, the system can degrade more gracefully when individual elements are attacked. A standardized design of numerous satellites could also be mass produced more cheaply, allowing quicker replenishment of damaged units.

In addition to increasing survivability and reducing cost, smallsats could mitigate technical challenges that crippled previous concepts. While previous MTI proposals required apertures so large they could not fit on a launch vehicle, advances in networking and processing could enable smallsats to create effective virtual arrays using existing spacelift options without on-orbit construction. Formation flying of smallsats to create a large virtual aperture for potential use in space MTI is not a new concept, but one that has only recently been tested. The Air Force's first major attempt at testing smallsat formation flying was through the Air Force Research Laboratory (AFRL) TechSat-21 program. The three-satellite system, intended for launch in 2006, was to be a proof of concept for a virtual aperture to perform GMTI. Technological advancements in sensors, antennas, satellites, electronics, and computing had finally enabled such a system to be created, and a lead researcher for the program stated, "we can implement advanced algorithms and dream up new approaches that weren't even possible five or 10 years ago."[24] Unfortunately, the program was canceled by 2003 for unspecified "technical challenges."[25] Still, TechSat-21 is worth mentioning for a few reasons. First, its 100 kg mass can give a general idea of the nominal size that AFRL believed could accomplish an MTI mission. Second, the fact that GMTI—and not the numerous other imaging, sensing, and communication missions that a formation of smallsats could perform – was chosen as the TechSat-21 primary mission shows the high level of interest involved in attaining that capability. Finally, TechSat-21 was seen as possible only through technological advancements that had occurred within the last five years. Since its cancellation, more than a decade of technological advancement has occurred with the potential to overcome the technical challenges of the past.

Improvements in timing, wireless linking, and signal processing are beginning to show success in other programs. In November 2014, the Canadian Advanced Nanospace eXperiment 4 (CanX-4) and CanX-5 satellites completed a very successful formation flying demonstration. The 6 kg satellites verified advanced drift recovery and station-keeping algorithms, "with relative position knowledge of better than 10 cm and control accuracy of less than one metre at ranges of 1000–50 metres."[26] More recently, the National Aeronautics and Space Administration was able to fly a quartet of magnetospheric multiscale mission satellites in a formation 4.5 miles apart, improving the scale at which it can take measurements of Earth's magnetic field.[27] These examples demonstrate both that the technology required for formation flying of smallsats is within our reach, and that this technique can allow several smaller satellites to accomplish the work of one large satellite and, further, the potential to achieve performance greater than any single satellite.

Technology has also delivered significant operational improvements and cost reductions in space lift. The potential for cheaper and more routine access to space has never been better and is consistently improving. The Air Force budget for fiscal year 2018 shows that the United Launch Alliance (ULA) launches range from $100 million for an Atlas V to $350 million for a Delta IV Heavy, and ULA costs are projected to rise to $422 million by 2020.[28] New competitors, however, are beginning to reverse the trend of rising costs. Elon Musk, the chief executive officer of SpaceX, responded to the high launch costs by noting that SpaceX has launched, on average, $300 million cheaper with its Falcon 9 than the ULA rockets, a difference which he boasts makes launching with SpaceX "basically free."[29] Then-Secretary of the Air Force Deborah Lee James recently testified to Congress that companies like SpaceX are significantly expanding Air Force capacity and reducing cost.[30]

Reusable space planes could drive even cheaper and more routine launches, especially for low-Earth orbit (LEO) smallsats. A mix between airplane and space launch vehicles, space planes could be launched into low orbit, deposit their payload, and then recover for a quick turnaround to be launched again as soon as the next day. Most clearly on the horizon is DARPA's XS-1 Experimental Spaceplane. The XS-1 is being designed to carry up to 1,360 kg per launch with the ability to launch 10 times in 10 days.[31] It is also being built with much higher technological readiness than previous ambitious space launch programs, including better airframes, propulsion, and commercial involvement.[32] In March 2017, DARPA announced it had selected Boeing to advance the design of the XS-1, and that launches could cost as little as $5 million. Using TechSat-21 as a guide, this means that the XS-1 could potentially orbit 130 MTI satellites in 10 days at the cost of just $50 million. A single Falcon 9 launch has the potential to carry a payload of 22,800 kg, or 228 TechSat-21 comparable satellites.[33] Combined, the Falcon 9 and XS-1 could initially launch a large constellation of MTI smallsats, then provide routine reconstitution to maintain those satellites at a fraction of the cost of the launch vehicles that were available only a decade ago.

Resilient by Design

Clearly, advancements in technology can be applied to mitigate fiscal concerns and enable new operational concepts, but they will also mitigate the ever-increasing threats to space segments of the system. High-altitude nuclear attacks and their resulting electromagnetic pulses can knock out whole constellations.[34] Conventional threats to current space-based systems are on the rise. Several adversary nations have demonstrated effective kinetic ASAT weapons to attack satellites and electronic attack capabilities to deny their sensors or disrupt communications. Even more sophisticated attacks could include adversary spacecraft designed to approach close enough to directly destroy, disrupt, degrade, or deny friendly satellites.[35] The use of any of these capabilities have legal and debris consequences that have been addressed by other authors, but the threats they pose are credible and must be considered regarding any new constellation, especially in LEO, where an air surveillance augmentation would be ideally located.

Many of the risks that have emerged can be mitigated by the same technologies that make the concept fundamentally more feasible, especially improvements in smallsats and space lift. Smallsats have the potential to overcome many of the current threats to today's space assets. Their size makes them more difficult to target, and the loss of one or even several satellites out of a larger constellation may only degrade rather than deny its capability. With cheaper and more responsive space launch systems deploying multiple satellites per launch, such constellations could also be reinforced, replenished, or repositioned more quickly than the large satellites conceived in previous concepts. The pairing of reusable launch and orbital vehicles with larger constellations of smaller satellites complicates adversary targeting, increases resilience through volume, which reduces the impact of attrition and enables more rapid reconstitution.

Ultimately, conducting surveillance from multiple domains is the best way to mitigate current and future threats. No technical solution is sufficient if it relies on a single domain vulnerable to denial. It is essential that space-based capabilities be combined with, not replace, air-, land-, and sea-based surveillance so that an attack in any one domain is both disincentivized and less effective.

Achieving Escape Velocity

The US cannot afford to take a back seat in the development of this technology. While not overtly pursuing a space-based MTI program, Russia and China are immediately behind the US in their development of the enabling technologies of smallsats and reusable space lift.[36] More efficient Chinese launch vehicles, such as the Long March 11, are not only enabling the launch of their own military smallsats but are also cutting into the domestic commercial launch market.[37] It is possible an adversary will seize on this opportunity for asymmetric advantage and erode US industrial capability in the process. Therefore, the Air Force must finish the countdown and immediately:

3. . . Commission a study on space radar. The time is right to deliver on the 2008 promise to revisit the feasibility of SR, including new alternatives and an assessment of the impact of technical advancements on cost and feasibility. Consideration should be given to space-lift cost, sustainment, single-mission smallsats, and hosted payloads on multirole missions platforms including the use of secondary payloads on planned programs. A comparison of a wider range of potential architectures should be included to provide the Air Force with a wide range of cost and capability alternatives. Opportunities for synergy and cooperation should be sought with other programs pursuing similar concepts for other missions across the intelligence and defense enterprises. MTI surveillance could be combined with other payloads on the same bus, in the same constellation, or in system-of-systems approaches.

2. . . Demonstrate new capabilities. A transition from theoretical to practical capability will do more than any previous effort to evaluate the validity of this long-debated capability. Objectives should include the demonstration of high-risk technologies and new concepts, including cooperative smallsat architectures, virtual apertures, and real-time delivery and fusion of spaceborne AMTI to TACS programs of record through standard existing fusion engines and using existing data standards. These objectives could be accomplished rapidly and at low cost through a partnership with an academic institution already pursuing smallsat research.

1. . . Prototype space sensors for programs of record. These efforts should be independent of, but informed by and supportive of, the Advanced Battle Management System or Advanced Battle Management and Surveillance (ABMS). ABMS is the Air Force's program of record for a modern TACS, including the replacement of AWACS air surveillance capabilities. The recently validated ABMS requirements could be used to update the SR parameters and the lessons learned from new space-based studies, and demonstrations could directly inform the ABMS analysis of alternatives. Demonstration hardware could even serve as the rapid prototypes or initial operational components of ABMS.

King of the Hill

The need for persistent, wide-area surveillance of theater operating areas will continue. As air defenses become more lethal, they push traditional airborne surveillance platforms beyond their effective range. The Air Force cannot allow competitors the ability to deny the joint force of persistent awareness of adversary air activity.

Radar remains a superior tool to overcome the tyranny of distance, but air surveillance must be disaggregated across more platforms in more domains. No combination of legacy surveillance platforms, drone swarms, and 5G aircraft will provide sufficient access, coverage, and persistence, nor will they satisfy strategic guidance to improve capability and present adversaries with all-domain challenges. Space must be a part of the plan.

By its very nature, space lends the best vantage to fill this capability gap and maintain critical situational awareness for theater commanders, especially in future highly-contested fights. Space MTI was unsuccessful in the past, but the technical challenges of yesterday have solutions today.

The solution cannot be intermittent in time or space, should guarantee access, and be derived from sensors in all physical domains. A disaggregated netted sensor grid augmenting air, land, and sea from space will enable the TACS to achieve the long-lasting and decisive edge in air domain awareness that is vital to deliver air superiority in 2030.

The Air Force must act now to overcome area denial strategies— not by engaging competitors in a technological tug-of-war in the air domain but by leaping over them to exploit the decisive high ground of the space domain. It should study new options for space radar, cooperate with academic and industry partners to demonstrate advanced capabilities, and leverage these practical lessons to improve existing systems and prototype surveillance components of ABMS.

The threat is present. The solution is available. The time is now. ✪

Notes

1. Joint Publication (JP) 1-02, *DOD Dictionary of Military and Associated Terms* (2018), s.v. "surveillance," http://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/dictionary.pdf.

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