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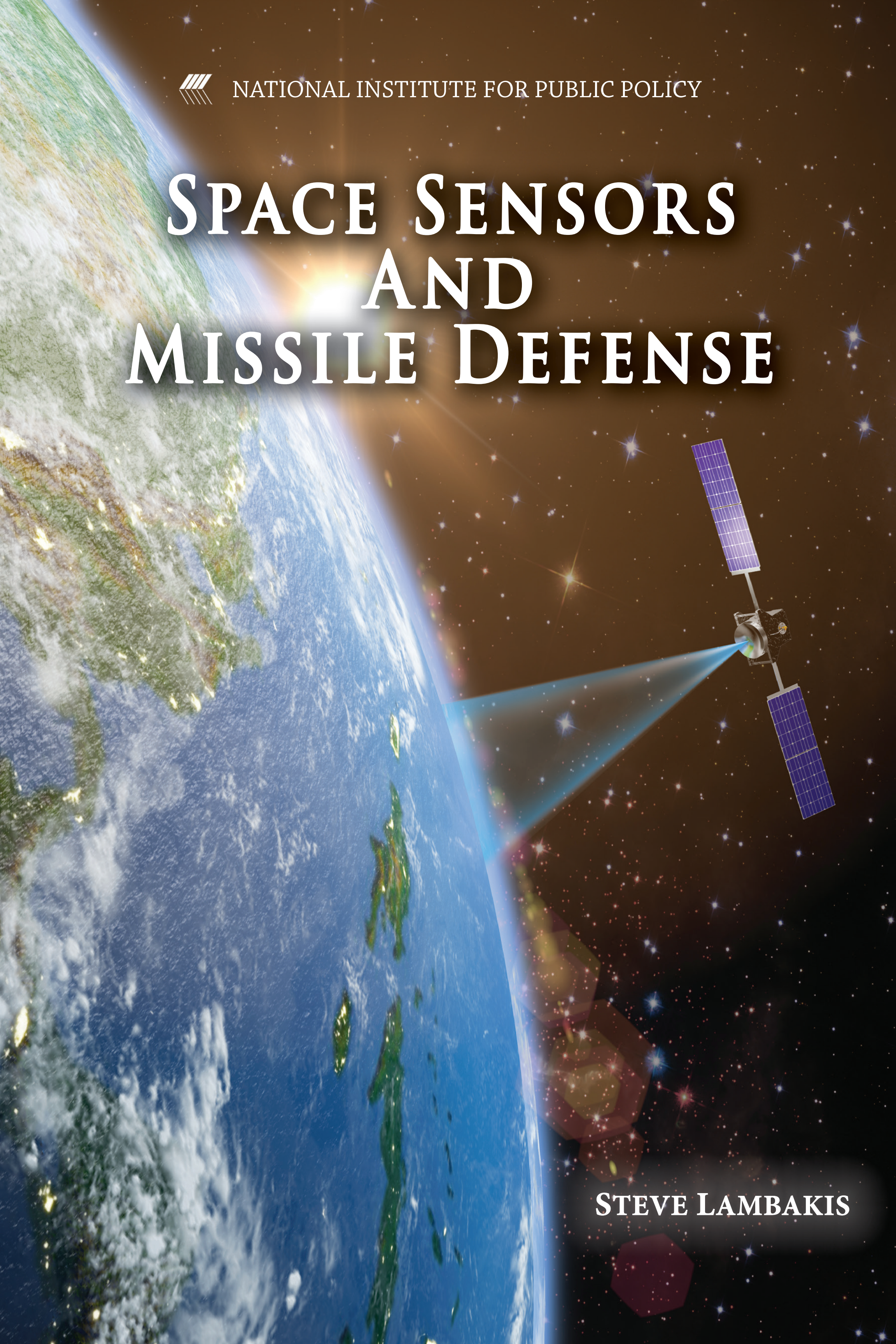
# SPACE SENSORS AND MISSILE DEFENSE



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# Space Sensors and Missile Defense

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# Executive Summary

The Defense Department has long understood the importance of leveraging space to accomplish the ballistic missile defense mission. Now the threats posed by ballistic missiles are evolving to include technically more challenging hypersonic and cruise missiles. The main challenge posed by these high-speed offensive systems is that they can either fly under or maneuver around existing missile defense tracking sensors based on land and at sea, thereby avoiding engagement by missile defense interceptors.

Today, missile defenses offer protection of the U.S. homeland against long-range ballistic missile attack from North Korea, and they provide point and regional defenses for U.S. forces abroad as well as U.S. allies and international partners against ballistic and some hypersonic missile threats. Now the United States must push its missile defense tracking sensor "center of gravity" (that is, the major concentration of the tracking sensor architecture) to space to improve the overall performance of the nation's Missile Defense System against an increasingly diverse missile threat. The country must rely on a layered sensor architecture consisting of terrestrial and space sensors to detect, track, and discriminate threat objects, provide precise targeting data to interceptors, and conduct kill assessments following engagements.

Today the country must worry about more than ballistic missiles, which fly very predictable paths against very predictable targets. More and more, missile systems are being designed to act in less predictable manners. Maneuvering payloads and payloads that change velocity challenge the ability of defenders to use the initial boost phase of flight immediately after launch to project where the payload is heading and the time of impact. Without the ability to track the missile payload throughout the flight, the ability of a missile defense system to intercept the payload diminishes significantly. An inadequate sensor architecture will prevent, in some scenarios, the U.S. armed forces from combating these highly dangerous missile threats with any real consistency.

Today, the United States deploys a mix of terrestrial-based radars and space-based sensors to execute the missile defense mission. It has terrestrial radars (ground- and sea-based) and overhead sensors to alert political and military leaders and warfighters to an unfolding missile attack. In the 1960s and 1970s, the nation's military and civilian leadership saw the wisdom of putting missile warning capabilities in space, where it might then be possible to watch most of the Earth's surface for a missile launch. That system today relies on early warning Defense Support Program and Space-Based Infrared System communications, Global Positioning System satellites, and other space sensor assets.

The nation's current missile tracking and discrimination sensor capabilities, in sharp contrast to the missile warning and detection sensor capabilities, reside almost entirely on Earth, either on the ground or at sea. Given our understanding of why the nation placed the missile warning and detection sensors in space, where there is the advantage of persistent global coverage in closer proximity to the threat missile (which frequently travels through space), it is striking that the United States to this day relies on its Earth-bound sensor network for the missile tracking function. Indeed, the current terrestrial tracking sensor network has significant performance limitations.

The U.S. Missile Defense System depends on continued host-nation approval for the use of its terrestrial missile tracking sensors, which are spread across the northern hemisphere. The arrays on all U.S. terrestrial tracking radars are fixed—they do not rotate and the platforms are not mobile. In other words, they only face one direction, so it would be possible for a maneuvering threat to approach the target from outside the bounds of the existing radar fans. The system tracking sensors set up for defense of the U.S. homeland today are oriented to maximize viewing of missile threats launched from two countries, North Korea and Iran. Change the threat country, or move the missile trajectory outside the corridors that may be covered by the fixed radar (by using a submarine or an air platform to launch the missile, for example), and the missile defense mission becomes more challenging. There is also a basic physics problem associated with terrestrial radars. For many of the more advanced threats, terrestrial radars would not be able to acquire the incoming target at sufficient range because of the curvature of the Earth.

The potential advantages space offers missile defenders can be extraordinary. Since they are able to provide a global presence, constellations of tracking satellites would be able to provide persistent "birth-to-death" (launch to termination of flight) coverage of threats by augmenting ground-based radar coverage and filling coverage gaps. Space provides the best viewpoint for addressing missile threats, including threats posed by hypersonic glide vehicles, which might begin their flight on a ballistic trajectory before moving into glide and maneuvering phases. Such coverage would improve the overall performance and effectiveness of the system, especially if the threat is carrying midcourse countermeasures, which also may be detected and tracked as they travel through space. Another advantage derived from the use of space sensors for missile defense is force protection. The more the sensor "center of gravity" moves to space, the more complicated and challenging it would be for an adversary to attack those assets.

While the country is now making good progress towards the goal of placing more sensors in space, especially for missile defense, the current state of space sensors is inadequate to meet near- and far-term evolving missile threats. Currently, the U.S. Space Force Space Development Agency (SDA) and Space Systems Command, and the Missile Defense Agency (MDA), are developing prototype and operational satellites to improve the country's ability to acquire, track, and disseminate data required to successfully track, target and cue, and then intercept ballistic and hypersonic missiles.

SDA's mission is to develop elements of a new and responsive space architecture through the deployment of many small satellites in Low Earth Orbit (LEO) as a foundation, utilizing commoditized buses for a more resilient and affordable alternative to the very large, expensive satellites traditionally developed by the Department of Defense (DoD). SDA's vision is to field this sensor architecture using two pillars: 1) increasing the number of satellites in the transport (data distributing and processing satellites) and tracking layers, so that the satellite constellation will have resiliency and persistent coverage of the globe, and 2) an acquisition approach that leverages spiral development, which will enable timely deployment of minimum viable product capabilities without having to rely on the standard DoD acquisition system that can slow down or even kill a program by laying on exquisite requirements. Space Force is also developing an independent Medium Earth Orbit constellation of satellites to bolster the architectural resiliency of the LEO tracking layer and provide global access for missile warning, tracking, and defense.

MDA initiated the Hypersonic and Ballistic Tracking Space Sensor (HBTSS) program in 2018 to address the requirement to detect and track hypersonic threats and ballistic missiles. HBTSS will detect hypersonic, ballistic, and other advanced threats much sooner than terrestrial radars, providing hypersonic threat-tracking data for hand-off through linked missile defense weapons. The unique contribution of HBTSS when compared to the SDA-developed missile tracking satellites will be its ability to provide very precise data, or what warfighters call "fire control quality data," which is data needed for targeting the threat missile. The country is moving towards adding HBTSS satellites to its current constellations of dedicated early warning spacecraft in an effort to leverage some of the obvious advantages space offers missile defenders.

There is a growing warfighter requirement for integrated space sensors, not simply to meet the newest missile and space threats, but also to replace increasingly obsolete terrestrial sensors. Indeed, the greatest leap in capability that could be achieved in today's Missile Defense System is the addition of a space tracking layer. Such a change in the sensor architecture would buy valuable mission response time globally. The transformation of the tracking sensor architecture so it can fully leverage the space domain must be the Defense Department's next crucial consideration. What is standing in the way of implementing a vision of a missile defense architecture that puts the sensor center of gravity in space?

Technology has bedeviled implementation in the past, but significant progress has been made over the decades. Significant advances have been made in sensor, spacecraft, and computer processing technologies, in large part because of private sector investments and commercial space ventures. Today, the government must do what it can to capture the remarkable progress made in the private sector. Still, there are significant technical challenges that must be taken on, with some of the more pressing ones stemming from the growing complexity of the modern battlefield and the need to retrieve information, process that information, decide, and act within a tactically meaningful timeframe.

Another challenge is the rapid deployment of advanced space capabilities in order to counter a very dynamic threat. Special acquisition authorities will be critical to the rapid development of advanced satellites to counter the emerging missile threat. Today, the timelines for development in most programs are lamentably slow. The traditional ways of doing space acquisition must be reformed in order to add speed to the nation's acquisitions to meet its priorities. While progress is being made, the troubling bottom line remains that the Pentagon is not yet accustomed to refreshing short-lived spacecraft in LEO system.

The Pentagon is looking into deepening its partnerships with private companies. Capitalizing on the commercial investments that have been made makes sense. The possible use of commercial services will likely remain restricted to the use of satellite communications. And indeed, there are some defense activities that must remain strictly owned and operated by the government. Regarding the missile tracking and missile defense mission, the Government would understandably want to retain control over the tactical data links that are tied into weapon systems.

The development and deployment of space-tracking satellite constellations also are encountering obstacles at the policy level. The United States today recognizes the changed dynamic in the space environment in its security policies and strategies, and its leaders have been promoting greater awareness of the space threat while also reorganizing the Joint Force and command structure to protect U.S. space assets and mature U.S. spacepower. Space-based systems are increasingly seen as vital to the American way of life. Yet this higher-level assessment of the importance of space at the policy level is not well reflected in the nation's vision or budget.

The emergence of the space warfighting environment should be driving U.S. strategies for space technology and system development. The absence of a clear and unified vision aimed at where the nation should be heading in the defense space arena is a stumbling block. The lack of coherent vision impedes development of important military systems that leverage the space environment to maintain the U.S competitive edge. Inconsistent and uncoordinated strategies also negatively affect investments by the government and commercial sector. Absent a clear vision, bureaucratic obstacles hinder the execution of more responsive launch operations, despite the push by senior space officials to be more open about strategies and capabilities. Overclassification problems continue to hinder space program advocacy and important collaboration with allies. If we want deterrence to be effective, the nation's leaders must be able to talk about existing and planned capabilities as well as the threats posed by adversaries.

The deployment of missile defense tracking sensors in space also will benefit three other missions that belong to the Department of the Air Force and the Space Force—Missile Warning, Space Domain Awareness (or what used to be called Space Situational Awareness—that is, an understanding of which spacecraft are orbiting Earth, operated by which country, and what activities they are engaged in), and counterspace operations (or defense of friendly space assets). Policymakers and those responsible for funding the development, deployment, and operation of the missile defense space tracking capabilities should be aware that these investments will have mission-multiplying effects that benefit other mission areas critical to U.S. space superiority and Joint Force operational agility.

America has made great strides in defending against ballistic missile threats posed to the U.S. homeland by lesser powers, such as North Korea, and against theater-range missile threats to U.S. forces deployed abroad and U.S. allies and partners. It is generally recognized that missile defenses can help deter an attack, provide leaders options and additional time to respond to attacks or stabilize a crisis situation, assure U.S. allies and reinforce alliance unity, and provide a measure of protection in the event deterrence fails. Yet, with an increasingly diverse threat set, the effectiveness of the Missile Defense System will hinge on the agility, persistence, and precision of its sensors, particularly those in space.

The country still must move beyond development and initial deployments that will occur over the next few years to fill out the entire architecture that is envisioned. This not only requires continued funding and advocacy for satellite and ground system development but also the development of responsive launch capabilities. If the missile tracking and discrimination capability is to be fully realized, satellites will need to be placed in orbit in sufficient numbers and then incrementally and periodically replaced with follow-on satellites.

The Biden Administration must drive a shift of the missile-tracking center of gravity from Earth to space. A clearly articulated vision will put the nation on the best path to coming up with solutions for protecting its space systems from attack and providing reassurance to the commercial sector. Leaders should use the opportunity of a newly published directive to publicize broadly the U.S. vision for space in forthcoming policy and strategy documents. All federal departments and agencies and the Congress need to be educated and enabled to carry out this policy direction. Whatever approach is taken, the adoption of a vision within national security policy will invariably require a whole-of-government approach.

# Chapter 1
# Introduction

Political and military leaders in the United States increasingly view space, like the land, sea, and air, as a warfighting domain.[1] Over the past decades, satellite functions such as remote sensing, communications, and navigation have become integrated into U.S. national security and economic activities. Satellites are especially important contributors to the defense against advanced threats, especially threats posed by a growing variety of missiles deployed worldwide that can carry nuclear, chemical, biological, and conventional payloads. According to the Deputy Secretary of Defense, Kathleen Hicks, "ongoing efforts to improve national missile defense with a particular focus on improving discrimination capabilities and sensors for detection of both ballistic and hypersonic missiles" is a top national security priority.[2]

The Defense Department organizations responsible for the development of missile defenses since President Ronald Reagan introduced the Strategic Defense Initiative in 1983 have long understood the importance of leveraging space to

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[1] Steve Lambakis, *Space as a Warfighting Domain: Reshaping Policy to Execute 21st Century Spacepower* (Fairfax, VA: National Institute Press, May 2021), available at https://nipp.org/wp-content/uploads/2021/06/Space-as-a-Warfighting-Domain-pub-5.21.pdf.

[2] Cited in Samantha Beu, "Sensor Tech Key to Effective Missile Defense," *National Defense*, April 2, 2021, available at https://www.nationaldefensemagazine.org/articles/2021/4/2/sensor-tech-key-to-effective-missile-defense See also Statement of Dr. John F. Plumb, Assistant Secretary of Defense for Space Policy, *Before the House Armed Services Committee, Strategic Forces Subcommittee on Fiscal Year 24 Strategic Forces Posture*, March 8, 2023, p. 13, available at https://armedservices.house.gov/sites/republicans.armedservices.house.gov/files/ASD%20Plumb%20Written%20Statement%20-%20HASC-SF%20FY24%20Strat%20Forces%20Posture.pdf.

accomplish the ballistic missile defense mission.[3] Now the threats posed by ballistic missiles are evolving to include technically more challenging hypersonic and cruise missiles. The main challenge posed by these high-speed offensive systems is that they can either under-fly or maneuver around existing missile defense tracking sensors based on land and at sea, thereby avoiding engagement by missile defense interceptors.

The purpose of this monograph is to improve understanding among policymakers, defense planners and analysts, and the general public of the urgency of developing and deploying space sensors, particularly for the missile defense mission, which today relies on sensors that are primarily based on Earth. The basic argument is that the United States must push its missile defense sensor "center of gravity" (that is, the major concentration of the sensor architecture) to space to improve the overall performance of the nation's Missile Defense System against an increasingly diverse and dynamic missile threat. It must rely on a layered sensor architecture consisting primarily of space sensors to detect, track, and discriminate threat objects, provide precise "fire control" quality data to interceptors, and conduct kill assessments following engagements. That sensor architecture would also include terrestrial layers, which, because they view the threat from a different angle, would provide different data to the Missile Defense System, allowing it to have a fuller, more complete picture of the threatening missile and its payload.

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[3] Since 1983, the Missile Defense Agency (MDA) and its predecessor organizations, the Strategic Defense Initiative Organization (SDIO) and the Ballistic Missile Defense Organization (BMDO), have been responsible for researching, developing, testing, and fielding missile defenses. Before SDIO, the Army, Navy, and Air Force missile defenders looked to space for a tactical advantage. See Steve Lambakis, *On the Edge of Earth: The Future of American Space Power* (Lexington, KY: The University Press of Kentucky, 2001), pp. 217-235.

## The Missile Threat

Defending against missile attacks requires that we are able to "see" them with sensors. When missile threats change or become more challenging, as they have in recent years, U.S. sensor capabilities need to be upgraded. Thus, it is best to begin with a look at the missile threats defenders are trying to see in order to defeat them and to understand why these threats are so challenging.[4]

World War II saw the first use of ballistic missiles, and missiles have been used with increased intensity in conflicts over the past 30 years, especially in Middle East confrontations. They will continue to be a threat in future conflicts involving U.S. forces. The use of missiles in Russia's war against Ukraine in 2022 and 2023 is only the latest conflict featuring the use of many and different kinds of missiles. Yet this conflict also provides a window into the future we are likely to see.

The capabilities of missiles to evade or confound sensors used in U.S. missile defenses have grown dramatically in the last few years. Missile systems being developed and deployed by potential adversaries of the United States—China, Russia, North Korea, and Iran -- are designed to have global reach, increased velocity and maneuverability, greater accuracy, different basing modes, and improved countermeasures.[5] Today's ballistic missile systems feature maneuverable reentry vehicles (MaRVs), multiple

[4] Missiles have been used in several conflicts for more than 30 years, especially in Middle East confrontations, and they will continue to be a threat in future conflicts involving U.S. forces. The use of missiles in Russia's war against Ukraine in 2022 and 2023 is only the latest conflict featuring the use of many and different kinds of missiles. Yet this conflict also provides a window into the future we are likely to experience.

[5] Defense Intelligence Ballistic Missile Analysis Committee, *2020 Ballistic and Cruise Missile Threat*, available at https://www.mda.mil/global/documents/pdf/DIBMAC%20Slicky%202020.pdf, pp. 2-5.

independently targetable reentry vehicles (MIRVs), along with decoys and jamming devices. They are growing in complexity and proliferating.

China has the most active and diverse ballistic missile development program in the world and deploys a variety of regional missile systems and Intercontinental Ballistic Missiles (ICBMs) capable of reaching the United States and its allies. Beijing is upgrading missile systems and developing methods to counter ballistic missile defenses. Russia has ICBMs and Sea-Launched Ballistic Missiles (SLBMs) capable of reaching the United States and is developing and deploying new ICBM and SLBM systems. Moscow has the largest force of strategic ballistic missiles outside the United States. North Korea has conducted over 60 missile launch events since 2019, the vast majority of which have been short-range launches. In January 2022, North Korea launched an intermediate-range missile, the first launch of that category of missile since 2017.[6] Iran continues to increase the lethality, reliability, survivability, and accuracy of its ballistic missile force, including short-range ballistic missiles with increasing range and antiship capability, underground ballistic missile launchers, and Medium-Range Ballistic Missiles (MRBMs) with accuracy and warhead improvements.[7]

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[6] Admiral John C. Aquilino, Commander, U.S. Indo-Pacific Command, *Statement before the Senate Armed Services Committee*, March 10, 2022.

[7] Defense Intelligence Ballistic Missile Analysis Committee (DIBMAC), *2020 Ballistic and Cruise Missile Threat*, available at https://www.mda.mil/global/documents/pdf/DIBMAC%20Slicky%202020.pdf, pp. 2-5. The report was prepared by the National Air and Space Intelligence Center in collaboration with DIBMAC and published in July 2020. See also Tom Karako and Masao Dahlgren, *Complex Air Defense: Countering the Hypersonic Missile Threat* (New York: Rowman and Littlefield, 2022), p. 4, available at https://www.csis.org/analysis/complex-air-defense-countering-hypersonic-missile-threat.

Today we must worry about more than ballistic missiles, which fly very predictable paths against very predictable targets. The free-falling parabolic flight of a ballistic missile and the fact that it betrays where it is heading presents an advantage to missile defenders. Ballistic missiles fly along predictable trajectories, which means the defensive system can more easily calculate point of intercept. Yet more and more, missile systems are being designed to act in a less predictable manner. Maneuvering payloads and payloads that change velocity challenge the ability of defenders to use the initial boost phase of flight to project where the payload is heading and the time of impact. Once a threat missile maneuvers, the defender may have difficulty picking it up with a sensor and tracking it in order to provide the fire control quality data (sufficiently precise data) needed by the defending weapon system for intercept, which means that the system will be stressed and be denied intercept opportunities. Without the ability to track and retain custody of the missile payload throughout the flight, the missile defense system's chances of intercepting the payload diminishes significantly.

Russia and China are developing advanced cruise missiles that can be launched from aircraft, ground launchers, and ships and submarines, as well as hypersonic missile systems that can travel at great velocities and fly over changeable and even erratic flight paths in ways that pose significant problems to intercept systems.[8] China is pursuing land-attack, supersonic cruise missiles, and other advanced weapons along with a new generation of mobile missiles that use MIRVs and hypersonic glide vehicles (HGVs) designed to evade U.S. missile defenses.[9]

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[8] DIBMAC, *2020 Ballistic and Cruise Missile Threat*, pp. 2-5; Karako and Dahlgren, *Complex Air Defense*, p. 4.

[9] Aquilino, *Statement before the Senate Armed Services Committee*, March 10, 2022.

When compared to more predictable ballistic missiles, hypersonic missiles fly very differently and have a maneuvering trajectory once they reenter the atmosphere—making them a major concern for Defense Department planners and policymakers.[10] The ability of hypersonic missiles to fly at lower altitudes and in the atmosphere, maneuver, and change speeds, makes them a very attractive offensive weapon system. In December 2019, Russia fielded its first nuclear-capable ICBM equipped with a hypersonic glide vehicle payload.[11] Regional hypersonic missiles are capable of causing significant damage to deployed U.S. forces, allies, and international partners, so that HGVs delivered by ballistic missile boosters will pose new challenges to U.S. regional missile defenses.[12] China continues emphasizing HGVs to counter ballistic missile defense systems, carrying out hundreds of hypersonic tests over the last five years, and it began deploying the DF-17 missile system with a conventionally armed HGV in 2020.[13]

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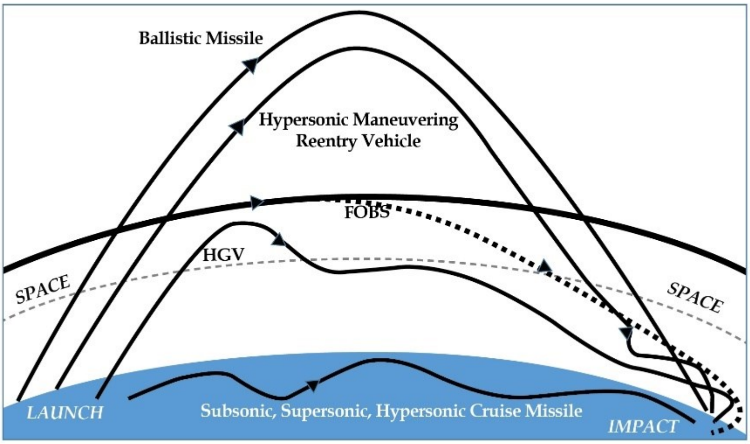
[10] Karako and Dahlgren, *Complex Air Defense*, pp. 1, 2. DIBMAC, *2020 Ballistic and Cruise Missile Threat*, p. 38.

[11] DIBMAC, *2020 Ballistic and Cruise Missile Threat*, p. 26.

[12] Vice Admiral Jon A. Hill, written testimony *Before the House Armed Services Committee, Strategic Forces Subcommittee*, June 15, 2021.

[13] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2021: Annual Report to Congress*, November 2021, pp. 60-63, available at https://media.defense.gov/2021/Nov/03/2002885874/-1/-1/0/2021-CMPR-FINAL.PDF

**Figure 1: Missile Trajectories**




Source: Missile Defense Agency, used here with permission.

Other developments include China's hypersonic Fractional Orbital Bombardment System (FOBS), which was tested in July 2021.[14] The FOBS leverages Earth's orbit to deliver payloads, including hypersonic missiles, on targets using unanticipated trajectories to skirt around missile defense sensors.[15] China's FOBS demonstration delivered a

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[14] China's space-based kinetic weapons research has "included methods of reentry, separation of payload, delivery vehicles, and transfer orbits for targeting purposes." The FOBS "demonstrated the greatest distance flown (~40,000 kilometers) and longest flight time (~100+ minutes) of any PRC land attack weapon system to date." U.S. Department of Defense, *Military and Security Developments Involving The People's Republic of China 2022: Annual Report to Congress*, November 2022, pp. 93, 94, 98, available at file:///C:/Users/Steve/Documents/NIPP/Space%20Sensors%20Project/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF.

[15] Written Statement, General Glen D. Vanherck, Commander United States Northern Command and North American Aerospace Defense Command, *Hearing before the Senate Armed Services Committee*, March 24, 2022; Defense Intelligence Agency, *2022 Challenges to Security in Space*, March 2022, p. 18, available at https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf?emci=d66ab957-

hypersonic glide vehicle that survived reentry into the atmosphere and subsequently performed high-speed gliding maneuvers. When fielded, this weapon, which can fly at a low altitude once it reenters Earth's atmosphere and change its flight path, will be able to evade or confound current ground and space-based detection and early warning capabilities.[16] According to Admiral Charles Richard, then-Commander of the U.S. Strategic Command, the missile "has an unlimited range, can attack from any azimuth, and comes down in a hypersonic glide vehicle with great performance. ... No nation in history has ever demonstrated that capability."[17] Admiral Richard also stated: "I'm not convinced at all we've fully thought through the implications of what that weapon system [FOBS] means."[18] Such weapons, he believes, will decrease warning timelines and make it difficult to determine which nation owns or fired a weapon, impacting deterrence and stability and increasing the threat to traditional space and missile defense forces.

The bottom line is that 21st-Century missile defenders must prepare to engage an increasingly diverse set of threat missiles. The emerging challenge is daunting. Most missile systems under development by Russia, China, Iran, and

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[16] DIA, *2022 Challenges to Security in Space*, March 2022, p. 18.

[17] Bill Gertz, "Pentagon board meets on space-based hypersonic threat," *Washington Times Online*, September 14, 2022.

[18] Jen Judson, "Strategic Command boss reveals No. 1 need for missile defense," *Defense News Online*, August 12, 2022, available at https://www.defensenews.com/digital-show-dailies/smd/2022/08/12/strategic-command-boss-reveals-his-no-1-need-for-missile-defense/. See also Joe Gould and Courtney Albon, "Russia and China's space weapon plans spur high-level Pentagon meeting, *Defense News*, August 30, 2022, available at https://www.defensenews.com/pentagon/2022/08/30/russia-and-chinas-space-weapon-plans-spur-high-level-pentagon-meeting/.

North Korea have maneuvering capabilities. According to the Intelligence Community, "modern ballistic missiles can include maneuvers during boost, midcourse, and/or terminal phases of flight. Some ballistic missiles payloads remain in the atmosphere for large portions of their flight with control provided by aerodynamic surfaces. In-flight maneuvers, combined with guidance updates, can allow ballistic missiles to be precision strike weapons."[19] Systems have the ability to maneuver after the burnout of the first stage, or boost, using aerodynamics or propulsion or maneuver in other phases of flight, midcourse and terminal, to deviate significantly from their ballistic trajectories.[20] Indeed, a study published by the Aerospace Corporation describes a taxonomy of threat missiles currently deployed or under development that places a missile payload in one of five categories, which is presented below.[21] The variety of missile payloads in categories 2 through 5 are capable of some level of maneuvering or change in velocity—that is, they are capable of introducing some level of unpredictability to confound missile defenses:

1. **Ballistic** – the payload travels along a *parabolic flight* path, similar to a cannonball, which permits an accurate estimate of the missile flight path and the target. North Korea continues to introduce new types of ballistic missiles which do not use post-boost maneuvering.

2. **Ballistic and Impulsive Propulsion** – using short propulsion bursts, a payload can *change its velocity*

[19] DIBMAC, *2020 Ballistic and Cruise Missile Threat*, p. 12.

[20] Steven T Dunham and Robert S. Wilson, *The Missile Threat: A Taxonomy for Moving Beyond Ballistic* (Arlington, VA: Aerospace Corporation Center for Space Policy and Strategy, August 2020), pp. 1, 8.

[21] The list uses the taxonomy described in greater technical detail in Dunham and Wilson, *The Missile Threat*, pp. 9-19.

following separation from the booster to aid in the deployment of Multiple Independently Targeted Reentry Vehicles (MIRVs) to targets separated by hundreds or thousands of kilometers.

3. **Aerodynamic** – the unpowered payload *changes its flight path* in the atmosphere, glides using aerodynamic control surfaces for extended periods at hypersonic speeds and maneuvers—examples include MARVs and HGVs.

4. **Aerodynamic and Impulsive Propulsion** – payload can maintain ballistic trajectory or use propulsion bursts to *change trajectory in space* and then descend into the atmosphere where it can *glide at extended ranges or maneuver* in the atmosphere.

5. **Aerodynamic and Sustainer Propulsion** – payload essentially uses powered flight for all or part of its trajectory following boost phase, similar to a cruise missile. The *emphasis on subsonic, supersonic, or hypersonic velocity* limits payload maneuverability, and payload range will depend on fuel capacity.

So where is the missile threat going? Large numbers of ballistic missiles are still being developed and deployed, yet the challenge is that new capabilities are being introduced. Given the trends in missile development in near-peers and rogue states, by mid-century we should expect to see more maneuvering, velocity-changing threats.[22] Even today, threats are becoming less ballistic, which has major implications for the Missile Defense System, which was initially designed and activated in 2004 as the *Ballistic* Missile Defense System to engage ballistic threats to the U.S. homeland. Threat missile developments over the past five

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[22] Author conversations with MDA Director, VADM Jon Hill (July 14, 2022), and MDA Chief Architect, Mr. Stan Stafira (August 2, 2022).

years led to the Missile Defense Agency dropping "Ballistic" from the name of the system it is developing.

China and Russia are already deploying next-generation long-range missiles capable of flying non-ballistic, maneuvering trajectories at hypersonic speeds that cannot be tracked by the U.S. military's current ballistic missile warning architecture. The Space Based Infrared System (SBIRS) deployed in highly elliptical and geosynchronous Earth orbits provides missile warning but lacks the accuracy for persistent tracking and often does not meet the latency requirements.[23]

We also are seeing the continued proliferation of missiles to potential adversaries, including terrorist organizations. Since the start of the ballistic missile age, states or groups that could not afford to build and maintain an Air Force and train pilots have sought missiles to compensate for their inadequate air power. This trend seems to be continuing. For example, the Houthis in Yemen have launched missiles at the United Arab Emirates and Saudi Arabia.[24] Even if the inaccurate missiles do not hit their targets, they can have damaging psychological effects on the targeted populations and leaders. In Ukraine, Russia is launching large numbers of different types of missiles—ballistic, hypersonic, and cruise—without serious regard for

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[23] The distances of satellites from Earth deprive the missile defense system of the ability to use the data received in near-real time. It takes time for data to travel the 22,000 miles to Earth, which means that by the time the interceptor kill vehicle receives the data, the target will likely be in another position in space, making it unlikely that the kill vehicle can acquire it. See the discussion on "latency" in Chapter 4.

[24] Kareem Fahim and Sarah Dadouch, "Yemen's Houthi militants launch new attack on UAE as conflict widens," *Washington Post*, January 24, 2022, available at https://www.washingtonpost.com/world/2022/01/24/yemen-houthis-uae-missiles-coalition/.

where they land.[25] In many ways, the Russian war against Ukraine is a harbinger of what can be expected in the future when we take into account the number of missiles fired by Russia during hostilities and the use of space by both sides to prosecute war aims.

Senior military leaders have recognized the requirement to defeat missile raids involving a variety of missile types when developing integrated air and missile defense capabilities to defend Guam, a vital U.S. territory in the Pacific Ocean. Planners had to design a system that could deal with a combined arms attack, because if defenders do not address all of the types of missiles they might need to counter, one missile may get through and take out a critical asset. Moreover, a hypersonic threat capable of significant maneuvering could come at a target from any direction. Hence, there is a requirement to defend Guam by deploying a "360-degree" sensor capability to track missile threats from all possible directions.[26] While land- and sea-based radars may be deployed to provide this coverage, a space-based tracking capability that could also provide the data needed to guide the weapons to their targets would be monumentally helpful. Let us now look at what steps must be taken to intercept a ballistic missile.

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[25] David Vergun, Defense Official Says Ukrainians Continue Strong Resistance Against Russian Invaders, *DoD News*, March 21, 2022; https://www.defense.gov/News/News-Stories/Article/Article/2973122/defense-official-says-ukrainians-continue-strong-resistance-against-russian-inv/.

[26] Meredith Roaten, "Budget 2023: Pentagon Requests Funds to Finish Guam Missile Defenses," *National Defense*, March 29, 2022, available at https://www.nationaldefensemagazine.org/articles/2022/3/29/mda-story; Jason Sherman, "2026 target for INDOPACOM's No. 1 priority, Guam Defense System, appears to be slipping," *Inside Defense*, December 5, 2021; Brent Sadler, "Guam Needs Effective Missile Defense Now, Not in 2028," *The Heritage Foundation*, July 18, 2022, available at https://www.heritage.org/missile-defense/commentary/guam-needs-effective-missile-defense-now-not-2028.

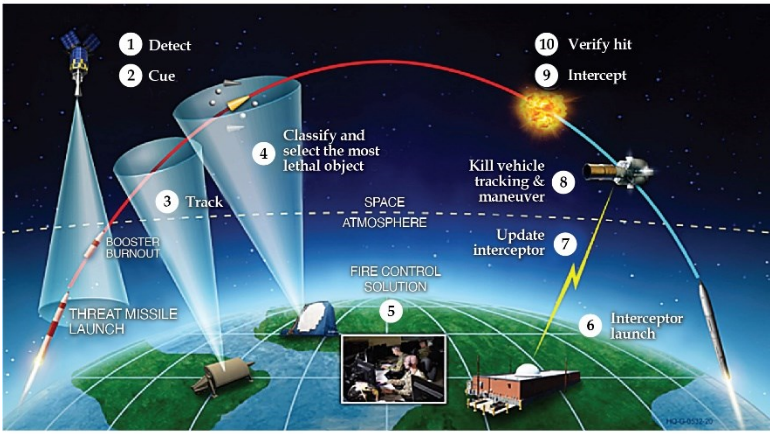
## Missile Flight and Missile Defense Engagement Sequence

The physical world poses many challenges for missile defense. An ICBM can travel at extremely high speeds, at times more than 15,000 mph, or almost 20 times the speed of sound. Kinetic energy interceptors can travel fast enough to create closing speeds exceeding 25,000 mph. Hypersonic missiles change trajectory and speed, and missiles of all kinds can be launched at their targets from multiple directions, from near and very far away, from land or sea, through air and space, and in large raid sizes. Hypersonic weapons are defined as anything traveling beyond Mach 5 (about 3,800 mph), or five times faster than the speed of sound. So, the speeds, trajectories, and points of launch that defenders must take into account always change.

In missile defense, success lies in precision and the ability to act quickly. Defenders must respond in milliseconds while the missiles and warheads they are targeting are bull's-eyes measured in centimeters. All the while we can expect adversaries to utilize countermeasures to fool the defending system and interrupt its operation, and to launch many missiles at once to confuse defenses. Missile defense, in other words, is one of the most technically challenging missions for the Department of Defense.

Once a missile is launched, there are steps that missile defenders follow to intercept the missile or its warhead—an engagement sequence. Sensors, the eyes of the Missile Defense System, play a critical role in this sequence. The description below assumes the launch of a ballistic missile as well as a homeland defense scenario, and it assumes Missile Defense System architecture available in 2023.

**Figure 2: 10 Steps to Ballistic Missile Intercept**




In the current scenario, space-based infrared sensors deployed in geosynchronous orbit or in highly elliptical orbit detect the launch of a missile and can even track it as long as the first stage booster continues to fire and give off an intense heat signature. These SBIRS satellites provide global coverage and, in this sense, are always in "close" proximity to the launch and ascent of a missile. If they are close enough, forward-based terrestrial radars, either on land or at sea, also might detect the launch and track the ascending missile. These sensors are able to cue the system through the Command and Control, Battle Management and Communication (C2BMC) network infrastructure.

The C2BMC system is the "brains" of the Missile Defense System and it integrates all system elements—sensors and interceptors—that are globally deployed. C2BMC passes the targeting information on the ascending missile that it received from the satellites or terrestrial sensors to other terrestrial sensors that may be in a position to pick up the threat track. In a homeland defense scenario, warfighters at consoles and in control of the system also receive this information. These warfighter control stations are called the Ground-based Midcourse Defense fire control nodes and they are situated in Colorado Springs, Colorado, and Fort Greely, Alaska.

As the missile ascends into space, into the midcourse phase of its flight, other terrestrial radars capable of greater precision receive the data needed to pick up the missile traversing space to provide more refined data on the target, which is then passed into the system through C2BMC. The more advanced radars in the system are able to watch the missile as its boosters separate and fall away and as it deploys other objects to confuse the system. Countermeasures deployed in space, for example, are intended to trick the Missile Defense System into going after the wrong object in space. Yet highly precise radars are able to take the measurements necessary to help the system distinguish the lethal object from the non-lethal objects.

As the terrestrial radars watch the missile engines burn out and the warhead separate, they continue to acquire information on the target cluster as it flies along the same ballistic trajectory (there are no sensors in space today that can do this work). That target cluster might have rocket debris (such as batteries and boosters, decoys, and other countermeasures). Warfighters are then able to decide whether to engage the missile and with how many interceptors. Launch commands are then sent to interceptors in the missile fields or on transportable or mobile platforms.

The terrestrial radars will keep custody of the missile warhead as it streaks through midcourse and begins its descent and as the interceptor approaches it. The radar search fans feed data to the interceptor and its Exo-atmospheric Kill Vehicle (EKV), which is essentially the final stage of the interceptor booster stack. Once it is unleashed, the EKV sets out on a course toward the inbound warhead guided by the data it received from the radars. Once it gets closer to the streaking warhead, the shields peel away from advanced sensors on the EKV and the EKV sensors work to pick up the lethal object so that it can home in on it, adjusting its flight path using its small rocket motors. Once the EKV hits the target, it obliterates it using the sheer force generated by the collision.

There are no explosives involved in a hit-to-kill missile defense system. The closing speed of 26,000 miles per hour is capable of destroying the target, leaving behind minimal debris. Hit and kill assessment sensors on advanced ground-based radars and in space provide hit assessment data to the system using C2BMC to confirm the intercepts and ensure that no further threats remain.

## Sensors—the Eyes of the Defense

According to the former vice chairman of the Joint Chiefs of Staff, General John Hyten, "If you can't see it, you can't shoot it. And if you can't see it, you can't deter it either."[27] Seeing is power, and it is a power required to execute basic national defense missions. Seeing is necessary to understand what is happening. Seeing—using "eyes" in space and on Earth—is needed before the nation's leaders can act and respond to threats. In terms of national security, seeing is required for deterrence and defense, to attribute a threat to an adversary and to counter it, especially when it involves defense against very challenging modern threats posed by an increasingly diverse set of missiles.

The U.S. Department of Defense has sought to develop and deploy sensors in the high ground of space for the missile defense, space defense, and space domain awareness missions because seeing the threat, and understanding what is being observed, is the first principle of defense. According to a study completed by the Center for Strategic and International Studies, "the single most

[27] Cited in Beu, "Sensor Tech Key to Effective Missile Defense."

important program element for hypersonic defense is a resilient and persistent space sensor layer capable of observing, classifying, and tracking missile threats of all types, azimuths, and trajectories."[28] Looking primarily at the missile defense mission, it is reasonable to ask, however, whether the projected growth in space capability is happening quickly enough to keep pace with rapidly evolving ballistic, hypersonic, and cruise missile threats.

The problem is that increasingly advanced missiles already fly today, and they will be increasingly available for use over the next several years and decades against a U.S. Missile Defense System that has an inadequate sensor architecture — one that has gaps, or areas that missile defenders will be unable to observe and adversaries will be able to exploit. This inadequate sensor architecture will prevent, in some scenarios, the U.S. armed forces from combating these highly dangerous missile threats with any real consistency or regularity. Moreover, the steady growth in counterspace capabilities, especially those under development by China and Russia, increases the chances that sensors on U.S. satellites and on Earth may be targeted during hostilities, which will be addressed in the Chapter 5.[29]

Sensors for tracking hypersonic missiles in flight are under development today and are scheduled for initial operations in the mid-2020s, assuming their development is not knocked off track. The nation has had many past problems, stretching over decades, fielding space sensors to perform basic missile defense functions, especially tracking and discriminating threat objects that are in flight (or keeping "custody" of the threat payloads) and providing fire-control quality data to the interceptors to improve the

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[28] Karako and Dahlgren, *Complex Air Defense*, p. 3.

[29] DIA, *2022 Challenges to Security in Space*, pp. 4, 17, 18, 28, and 29.

likelihood of intercepting the payload. These problems will be examined in Chapter 3.

The security of the United States depends on the ability of its military forces and leaders to see from space, but the country does not have yet the sensor capabilities it needs. The country is not much beyond where it was—in terms of how it leverages the space domain for the missile defense mission—30 years ago. The reasons for the delays are complex but have mainly to do with an undeveloped private or commercial sector, the exorbitant cost associated with developing exquisitely designed systems, and politics.

# Chapter 2
# Missile Defense Sensors—Terrestrial and Space

Today, the United States deploys a mix of terrestrial-based radars and space-based sensors to execute the missile defense mission. The Missile Defense System has networked sensors for target detection and tracking, sufficient discrimination capability to see the target, and enough precision to intercept it. The system also has a C2BMC system to allow the warfighters to talk to and control the system and an inventory of interceptors to destroy the target. The kill technology in use in the interceptors today is "hit-to-kill," which means that the interceptor uses the sheer force of a direct collision against the target to destroy it.[30]

The United States has terrestrial radars and overhead sensors to alert political and military leaders and warfighters of an unfolding missile attack. The bulk of U.S. early warning and launch detection sensors, such as the SBIRS and Defense Support Program (DSP) satellites, are in space today. These satellites are the backbone of the nation's missile warning sensor capability, though they remain insufficient. According to Admiral Charles A. Richard, retired Commander of U.S. Strategic Command:

> We need new missile defenses starting with missile warning. That's the number one thing I need is missile warning so I know what to do on how to posture and dispose my forces. It's due to

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[30] For a more in-depth description of the Missile Defense System and how it works, see Megan Crouse, "The technological challenges of complex missile defense," *Military & Aerospace Electronics*, August 26, 2022, available at https://www.militaryaerospace.com/sensors/article/14280041/missile-defense-sensors.

> these rapidly expanding and evolving threats: hypersonic weapons, cruise missiles potentially with intercontinental range, unmanned aerial systems, proliferation of shorter-range ballistic missiles, and several novel weapon systems.[31]

## Missile Warning and Detection Assets

One of the reasons this network of satellites is critical to the warning mission is that it provides coverage over all areas of possible U.S. interest in the world. Global coverage is needed to remove the tactic of surprise from an adversary who might choose to threaten the United States, its deployed forces, and its allies with missiles. Since it is not always possible to predict from where on Earth a missile might be launched against the United States, the persistent and worldwide coverage of today's missile warning satellites dramatically improves the nation's ability to respond to a ballistic missile attack.

*Space-based.* The system today relies on early warning DSP and SBIRS satellites, communications and Global Positioning System satellites, and other space sensor assets. The SBIRS satellites are in the process of replacing the orbiting DSP spacecraft, which have been standing guard against missile threats since the early 1970s.[32] Today there are six satellites in geosynchronous Earth orbit (GEO), each of which has a scanning sensor that continuously monitors the Earth and a staring sensor that provides more precise, targeted coverage of specific theater missions. The SBIRS

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[31] Cited by Theresa Hitchens, "The nuclear 3 body problem: STRATCOM 'furiously' rewriting deterrence theory in tri-polar world," *BreakingDefense.com*, August 11, 2022, available at https://breakingdefense.com/2022/08/the-nuclear-3-body-problem-stratcom-furiously-rewriting-deterrence-theory-in-tri-polar-world/.

[32] DSP was bell-ringer only, but SBIRS staring sensors also provide missile tracking to improve defense opportunities.

constellation includes two scanning sensor payloads on satellites located in highly elliptical orbits (HEO) to provide coverage of the polar regions.[33] SBIRS provides data to the SBIRS Mission Control Station at Buckley Space Force Base, in Colorado, which then sends the data out to operators.

***Terrestrial***. Should a missile be launched within their field of view, terrestrial radars would be capable of detecting a launch and providing warning to the system. The Long-Range Discrimination Radar (LRDR) in Alaska, Cobra Dane radar in the Aleutians, Upgraded Early Warning Radars (UEWRs) located at multiple locations in the northern Hemisphere, the forward-based Army Navy/Transportable Radar Surveillance and Control Model 2 (AN/TPY-2) radar positioned near rogue state threat countries in the Pacific and Middle East regions, and sea-based SPY-1 radar (which are part of the global and mobile Aegis BMD fleet of ships) are capable of providing "bell-ringer" notification to the Missile Defense System of an impending missile attack shortly after launch.

## Missile Tracking and Discrimination Assets

The nation's current missile tracking and discrimination sensor capabilities, in contrast to the missile warning and detection sensor capabilities, reside almost entirely on Earth, either on the ground or at sea. Given our understanding of why we placed the missile warning and

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[33] Courtney Albon, "Space-Based Infrared satellite launch to complete missile warning system," *C4ISRnet*, August 3, 2022, available at https://www.c4isrnet.com/battlefield-tech/space/2022/08/03/space-based-infrared-system-satellite-launch-to-complete-missile-warning-system/. See also US Air Force, *Fact Sheet: Space Based InfraRed System*, May 2019, at https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104549/space-based-infrared-system/ and Lockheed Martin promotional site at https://www.lockheedmartin.com/en-us/products/sbirs.html.

detection sensors in space, where there is the advantage of global persistent coverage in closer proximity to the threat missile (which frequently travels through space), it is striking that the United States still relies on its Earth-bound sensor assets for the tracking function. The U.S. has the ability, according to Missile Defense Agency (MDA) Director Vice Admiral Hill, within today's terrestrial sensor architecture to "see and track some of these threats depending on where they are, [but] space makes it better for us."[34] Using C2BMC, the warfighter is able to fuse all existing space-, land- and sea-based sensors, to build tracks and fill in gaps, as will be described below.

***Terrestrial***. The LRDR, located in Alaska, is the most advanced sensor in the U.S. homeland missile defense architecture and can track and discriminate threats to the continental U.S. to make ground-based interceptor engagements more efficient and lethal. Its primary mission is to provide continuous and precise tracking and discrimination of ballistic missile threats to the United States from the Indo-Pacific theater (especially North Korea). The radar's primary purpose is to provide a discrimination capability that delivers data to the system to distinguish lethal objects as they fly through space from debris and decoys around the lethal object.[35] This ability to

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[34] Jen Judson, "Missile Defense Agency priorities include hypersonics, Guam, Hill says," *Defense News Online*, August 12, 2022, available at https://www.defensenews.com/digital-show-dailies/smd/2022/08/12/missile-defense-agency-priorities-include-hypersonics-guam-hill-says/.

[35] LRDR incorporates "S-band" radar. A radar sends out electromagnetic waves that propagate through the atmosphere and space at high speed. Whenever the radar signals hit an object, the wave reflects back to the radar. Rain, fog, snow, ice, and heat can influence atmospheric conditions and affect radar detection. S-band radars can make accurate observations under severe weather conditions. See Cadence System Analysis, *S-Band Radar Advantages and Disadvantages*, blog accessed August 13, 2022, available at https://resources.system-

differentiate between real threats (warheads) and decoys provides critical information to the warfighter to help preserve interceptor supply, since imprecise information on the incoming threat "cluster" of objects flying through space might force the release of more interceptors than are needed just to ensure that the lethal object is destroyed. MDA deployed the LRDR to Clear Space Force Station in Alaska in December 2021, which was handed over to the Space Force in 2023.[36]

The five Space Force UEWRs are located at Beale Air Force Base, California; Royal Air Force Fylingdales, United Kingdom; Thule Air Base, Greenland; Clear Space Force Station, Alaska; and Cape Cod, Massachusetts. These radars are integrated into the system to provide surveillance and tracking information. The homeland defense radars improve sensor coverage in the midcourse of a threat missile flight by providing early warning, tracking, object classification, and cueing data. These radars are able to detect objects up to 3,000 miles away and operate in the Ultra High Frequency Band. Yet these radars cannot provide the precise fire-control quality discrimination data required to distinguish threat objects from non-threat objects.

The Sea-Based X-band (SBX) radar acquires, tracks and discriminates the flight characteristics of ballistic missiles. This very powerful radar, which operates in the Pacific Ocean, is mobile and used to conduct operational and realistic testing of the Missile Defense System and its

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analysis.cadence.com/blog/msa2022-s-band-radar-advantages-and-disadvantages.

[36] Theresa Hitchens, "Long-range missile defense radar ready to 'plug in' at NORTHCOM within 'months,': BreakingDefense.com, August 10, 2022, available at https://breakingdefense.com/2022/08/long-range-missile-defense-radar-ready-to-plug-in-at-northcom-within-months/ See also https://mda.mil/system/sensors.html.

elements and provide an operational capability to U.S Northern Command.

Cobra Dane radar is operated by the Space Force on Shemya, Alaska, in the Aleutians. This radar's primary mission is intelligence gathering and providing tracks for objects in space. It also can view the threat objects in their midcourse phase of flight and provide acquisition, tracking, object classification, and data that can be used to cue the launch of an interceptor and assist with threat engagement.

The AN/TPY-2 is a transportable X-band, high-resolution radar designed for regional missile defense. The AN/TPY-2 is capable of tracking multiple classes of missiles and identifying small objects at long distances. In the "forward-based mode," this radar also plays a vital role by detecting missiles early in flight and providing precise tracking information for use by the system. In the terminal mode, the same radar provides surveillance, track, discrimination, and fire control support for the regional missile defense system, Terminal High Altitude Area Defense (THAAD).[37]

The SPY-1 radar is used aboard Aegis Ballistic Missile Defense cruisers and destroyers primarily for regional and Fleet defense. SPY-1 is an S-band radar and is able to track short-, medium- and long-range interceptors from a mobile platform that can be stationed around the globe. Land and sea-based radars (AN/TPY-2 and SPY-1), which are used to execute regional missile defense operations, may also be deployed near the threat launch site to provide early tracking information to the system for homeland defense.

***Space-based.*** The United States recently deployed a network of Space-based Kill Assessment (SKA) sensors on commercial satellites for the homeland missile defense

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[37] With a change in software, this radar can be forward deployed to get eyes on missiles launched out of threat countries or an organic sensor for the THAAD system. U.S. THAAD systems are currently operationally deployed in South Korea and Guam.

mission to inform the warfighter whether an intercept has eliminated the target or whether the target needs to be re-engaged.[38] The SKA sensors were launched and on-orbit checkout was completed in spring 2019, and they were made operational after a successful Ground-based Midcourse Defense (homeland defense) intercept flight test.[39] While not tracking sensors *per se*, SKA sensors do provide data on the termination of a warhead's flight.

MDA also has made progress in using existing overhead sensors and algorithms to detect and track advanced missile threats.[40] The BMDS Overhead Persistent InfraRed (OPIR) architecture—known by the acronym BOA—uses data from the DSP and SBIRS satellites and other overhead sensors to detect, type, and track advanced missile threats and then forward track reports to C2BMC, which in turn cues other sensors to locate the threat missile or payload.[41] BOA provides a very limited tracking capability from space.

## Limitations of Current Missile Defense Tracking Sensors

The U.S. missile defense tracking sensor architecture is almost entirely based on Earth. The sensors used by DSP

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[38] Hill testimony, June 15, 2021.

[39] Jason Shermon, "Pentagon moving to convert SKA from experiment to operational capability by 2022," *Inside Defense*, March 23, 2020.

[40] Vice Admiral Jon A. Hill, written testimony *Before the Senate Appropriations Committee, Defense Subcommittee*, April 28, 2019, p. 16.

[41] "BOA is a system within the C2BMC enterprise that receives raw infrared sensor information on boosting and midcourse ballistic objects and feeds that track data to C2BMC (S8.2-1 and beyond) for use in cueing BMDS sensors and weapon systems, and for situational awareness." Director for Operational Test and Evaluation, "Sensors," *FY17 Ballistic Missile Defense Systems*, p. 283, available at https://www.dote.osd.mil/Portals/97/pub/reports/FY2017/bmds/2017sensorsC2.pdf?ver=2019-08-19-113818-147. See also Crouse, "The technological challenges of complex missile defense," August 26, 2022.

and SBIRS satellites currently in orbit were designed primarily to provide launch-detection warning and do not have the sensor suites and processing software required to provide continuous track and fire-control information to the defensive systems that engage ballistic or hypersonic missiles. The current terrestrial-tracking sensor network has significant performance limitations.

Since the system must rely on fixed, land-based sensors and mobile sea-based sensors to acquire and track threat missiles as they fly from one region of the globe to another, some of the sensors must be deployed on allied territory. This sensor infrastructure tends to be located closer to the threat launch sites. For example, the United States operates UEWRs in the United Kingdom and Greenland, and forward-based X-band radars in Japan, Turkey, and the Middle East region because these countries or regions are ideally situated to view missiles launched out of the threat countries (e.g., North Korea and Iran) towards countries needing protection (the United States and its international partners). Essentially, given their locations and given intelligence community estimates on how threat missiles are likely to fly toward their targets, the radar fans from the forward-deployed sensors cover specific corridors through which these missiles are expected to travel. The by-product of this system architecture is that the Missile Defense System depends on continued host-nation approval for the use of these critical sensors. Thus, a reassessment by a foreign government of the contribution of the U.S. radar to its national security could mean that any of the U.S. foreign radar sites might be shut down quickly, creating a significant gap in the system's tracking architecture.

The arrays on all U.S. terrestrial tracking radars are fixed—they do not rotate, and the platforms are not mobile. The arrays only face one direction, so it would be possible for a maneuvering threat to approach the target outside the bounds of the existing radar fans. Moving transportable radars (in the case of the forward-based AN/TPY-2 radars) to cover a threat launched from an unexpected region in a timely manner is not practical. A similar challenge exists in tracking the launch of shorter-range ballistic missiles (which might carry weapons of mass destruction) off ships that are close to U.S. shores. There may not be a radar off the coast to pick up the threatening missile.

The unpredictability of war highlights the limitations of fixed and Earth-bound sensors. As stated above, the current system's tracking radars are set up to counter known threats. Yet missiles will continue to proliferate around the world, and we cannot know with certainty from where the next threat will come. For example, Hezbollah and other terrorist groups use missiles and are able to hold targets in partner countries at risk. And wars such the Russian invasion of Ukraine arise with little warning. Even transportable radars, such as the AN/TPY-2 radar, are unable to provide a timely flexible response in a dynamic security environment. It would be difficult to rush a radar into the European battle theater quickly and make it operationally effective. There are only a few such transportable radars available, in any case. Full defensive coverage in a theater might require the deployment of several such radars. When the radars do arrive in-theater, they would have to be set up to provide search fences and send data back to the system, which would take time.

As stated above, the system tracking sensors set up for defense of the U.S. homeland are oriented to maximize viewing of missile threats launched from two countries: North Korea and Iran. In effect, we have set up the means to watch the flight of missiles within very specific corridors from the threat country to target areas in the United States. Change the threat country, or move the missile launches outside the boundaries that may be covered by the fixed radar (by using a submarine or an air platform to launch the missile, for example), and the missile defense mission becomes more challenging.

Populating the Earth with radars is not practical or financially feasible. Constructing and operating a radar is very expensive. Placement of a tracking radar in Hawaii, for example, could cost roughly $2 billion. There are also environmental and cultural concerns that make deployment of large radar facilities highly challenging politically.[42] Moreover, there are places where radars simply cannot be deployed. In most of the Pacific Ocean, for example, artificial "island chains" would need to be created to support the infrastructure—and the resulting missile-defense assets would be vulnerable to attack.

There is also a basic physics problem associated with terrestrial radars. For many of the more advanced threats, terrestrial radars would not be able to acquire the incoming targets at sufficient range because of the curvature of the Earth. Radars essentially look upwards, so that while they can get a look at a ballistic missile 4,000 to 5,000 miles out, which flies through space along a predictable trajectory, when the threat is maneuvering in the atmosphere, or flying on a depressed trajectory, it will not appear within the radar's field of view until it is much closer to the target, depending on the elevation. While the LRDR, for example, can see several thousand miles up and out into space, it cannot see Russia. The horizon breaks off those viewing opportunities.

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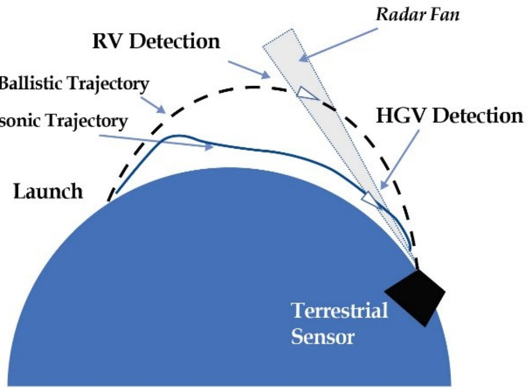
[42] Kevin Knodell, "Kauai residents raise concerns over planned $1.9 billion missile radar," *Star Advertiser*, January 18, 2022, available at https://www.staradvertiser.com/2022/01/18/hawaii-news/kauai-residents-raise-concerns-over-planned-1-9b-missile-radar/.

**Figure 3: Hypersonic Missile Threats Avoid Detection by Terrestrial Radars**




## The Benefits of Space

The potential advantages space offers missile defenders can be extraordinary. Space assets are critical for warfighting because they can perform a number of important functions. As discussed above, for the missile defense mission, they can provide situational awareness and early launch warning. As the bell-ringers for the Missile Defense System, satellites do not require advanced warning of threat launches. Space-based sensors are essential for detecting threat launches in boost phase from within adversary countries.[43]

Space sensors also provide a global presence, allowing constellations of tracking satellites to provide persistent "birth-to-death" (launch to termination of flight) coverage of threats by augmenting ground-based radar coverage and filling coverage gaps. Space provides the best viewpoint for

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[43] "Our missile warning systems have focused on detecting the heat signature generated by the booster (rocket) to determine where an incoming missile attack is headed and when it will impact. But this approach does not account for maneuvering done by the payload rather than the booster. And if we do not know the missile's trajectory or target with confidence, defending against it becomes more complicated." Dunham and Wilson, p. 2.

addressing missile threats, including threats posed by hypersonic glide vehicles, which might begin their flight on a ballistic trajectory before moving into glide and maneuvering phases. Such coverage would improve the overall performance and effectiveness of the system, especially if the threat is carrying midcourse countermeasures, which also may be detected and tracked as they travel through space.

Overhead capabilities give the nation the ability to view missile flight activity all over the world, without having to rely on ground sensors. Sensors in orbit are able to track launches coming from the deep interiors of adversary states that are otherwise inaccessible to terrestrial sensors. They would eliminate both geographic basing constraints such as posed by the oceans and potential overflight issues requiring complex diplomacy. Space systems overcome both host-nation approval and the basing challenges posed by broad oceans areas.

Our current terrestrial sensors are arrayed against a certain threat to the U.S. homeland: North Korea. Yet it may one day be possible for a state such as North Korea to threaten the United States by using an unanticipated trajectory, avoiding the current network of fixed radars. Space sensors would be able to watch threats coming from unexpected areas or flying on unexpected trajectories, and they would add robustness to the terrestrial sensor architecture. Defenders would be less challenged in having to predict where the threat is going to come from.

The United States does not orient its missile defense radars to provide coverage against a missile strike from the south. As a result, should North Korea use a Fractional Orbiting Bombardment System (FOBS), it would be able to take advantage of Earth's orbit to skirt around the missile defense sensors to deliver its payload. FOBS are designed to leverage approaches to the target that ballistic missiles cannot take. The U.S. must have sensors in space to address this type of threat.

As discussed in Chapter 1, while states will still develop and deploy ballistic missiles, the threat missiles of tomorrow will also become more capable of undertaking unexpected maneuvers, which, with the current sensor architecture, would cause the Missile Defense System to lose track of the threat payloads. Hypersonic missiles and FOBS are the logical next development steps for some states. The more advanced threat missiles, in fact, would not have to do major maneuvers to get outside the field of view of current ground-based tracking radars, but their ability to change up their speeds to mess with the defender's fire control system would cause significant problems.[44]

Another advantage derived from the use of space sensors for missile defense is force protection. The more the sensor "center of gravity" moves to space, the more complicated and challenging it would be for an adversary to attack those assets. In other words, a proliferated constellation of satellites encircling the globe offers some built-in protection. Ground-based radars are set up to cover specific threat corridors, so the adversary knows exactly where these immobile targets are. In a shooting war, they would undoubtedly be the main targets in the early stages of the conflict. Absent a high-altitude nuclear explosion, attacking on-orbit space military assets, however, would not be an easy thing to do for most nations, although a nation could also attack the heavily protected ground segment or the communications links of a space system.[45] China and Russia have made strategic choices to develop their space-power capabilities, already conducting live anti-satellite tests in space and building capabilities that can

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[44] Interview with VADM Jon Hill.

[45] A single high altitude nuclear detonation could cause failure of all LEO satellites not specifically hardened against this effect in weeks to months.

damage or destroy U.S. space assets.[46] It is, however, more difficult to attack proliferated space assets. Satellites are also moving, which further complicates the adversary's ability to counter them.

A networked system of terrestrial- and space-based sensors is desirable because the various sensors will provide multiple phenomenology and different data to the system. In the decades ahead, the terrestrial sensors will continue to provide a different look at the target and provide more information to the system about it. Thus, the terrestrial sensors currently contributing to the system will not necessarily go away once additional tracking capability is moved into space.

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[46] Department of Defense, Defense Space Strategy Summary, June 2020, p. 1 available at https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_DEFENSE_SPACE_STRATEGY_SUMMARY.PDF See also Gen. John W. "Jay" Raymond, "Space dominance requires taking technology and policy risks," *Defense News Online*, September 14, 2020; DoD, Defense Space Strategy Summary, p. 3. Defense Intelligence Agency, *Challenges to Security in Space*, 2019, p. 14, available at http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf.

# Chapter 3
# Missile Defense and Space—Current Development Efforts

The primary uses of space for missile defense are to leverage satellites to detect missile launches, facilitate global communications, and provide positioning, navigation, and timing data to missile defense systems. The case can be made that because the U.S. is a global power with global interests—and the country is set up to fight on a global scale across oceans—it also makes sense to push the sensor center of gravity for the entire Joint Force (not just for missile defenders) into space. This chapter will review the state of play with current U.S. missile defense space tracking sensors and development efforts. While the country is now making good progress towards the goal of placing more sensors in space, especially for missile defense, the current state of space sensors is inadequate to meet near- and long-term evolving missile threats.

## A Brief Look at History—Early Warning Systems

The nation's experience with early warning systems for the detection of missile launches offers some important lessons. Ballistic missiles were first introduced in warfare by the Germans in the Second World War, and German long-range rocketry research and the employment of the V-2 rocket against Allied targets inspired the United States and the Soviet Union to ramp up their own research efforts on a new weapons system that could be used to strike targets hundreds and eventually thousands of miles away. U.S. defense planners and the Intelligence Community also began to realize in the 1950s that with the growth of the Soviet long-range bomber force and an intercontinental ballistic missile capability, it would become possible for the

Soviet Union to launch a nuclear attack on the United States without strategic warning.

To fill this gap in indications and warning, the United States Air Force deployed the first missile early warning system in 1959. The ground-based Ballistic Missile Early Warning System (BMEWS) was the first operational missile detection radar capable of providing long-range warning of an unfolding Soviet ballistic missile attack over the northern polar region. It also could provide tracking information on incoming warheads. This vast network of radars could provide 10 to 20 minutes warning and relay its data to warfighters at North American Air Defense Command (NORAD) for analysis and decision making. These radars were deployed at Thule Air Base in Greenland, Royal Air Force Fylingdales in the United Kingdom, and Clear Air Force Station in Alaska, which provided sensor coverage within the corridors analysts determined a Soviet ballistic missile would fly through to reach targets in the United States. The BMEWS stations supplemented coverage provided by other radar systems, such as Pine Tree Line, Canada Line, and Distant Early Warning Line radars, all of which were ground-based.[47] The BMEWS facilities, which were periodically upgraded, were operational until the 2000s. Since the United States did not have an operational missile defense system to provide active defense at the time, these radars supported strategic nuclear deterrence. Warning is essential to the function of deterrence and to convincing an opponent that an aggressive action will be met by force and impose a great cost on the attacker. Without warning of an impending nuclear attack, the would-be aggressor might assume it could get the upper hand in a conflict and eliminate any retaliatory response.

[47] See website "Ballistic Early Warning System," at https://military-history.fandom.com/wiki/Ballistic_Missile_Early_Warning_System, accessed September 2, 2022.

Strategic warning removes the edge the attacking country might think it has.

To counter the BMEWS radars, the Soviets developed a Fractional Orbital Bombardment System (FOBS).[48] Recall from Chapter 1 that a FOBS carries a warhead into low Earth orbit, an action that reduced opportunities for the BMEWS to view the threat when compared to the full ballistic trajectory of an ICBM. The Soviet FOBS was similar to the weapon China demonstrated in 2022, which alarmed leaders in the U.S. defense establishment who understood that it could avoid the current networked system of missile defense tracking radars.

Given the evolving threat posed by ICBMs and novel weapon systems such as FOBS, the desire in the United States to detect missile launches anywhere in the world drove scientists and defense planners to consider pushing the early warning systems into space. While the BMEWS could provide some warning of attack by bombers, it was limited by its technology and the fact that it was ground-based. In 1955, scientists at RAND began exploring the use of sensors to detect the infrared bloom associated with missile launches, including sensors mounted on satellites. They developed ideas that eventually led to the Missile Detection and Alarm System, or MIDAS, which was launched in 1960.[49] MIDAS was intended to be a 12-satellite constellation to provide advanced notice of a Soviet ICBM attack and to direct a U.S. strategic response before its nuclear forces could be destroyed.

Plagued by many failures as the nation struggled to pioneer a new early warning system that orbited Earth, MIDAS had several technical limitations, including an

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[48] See website "Ballistic Early Warning System."

[49] Website article, "Missile Early Warning: Peeking Over the Curtain," Military.com, available at https://www.military.com/history/missile-early-warning-peeking-over-the-curtain.html, accessed September 3, 2022.

operational life of six months to one year and a relatively low Earth orbit, which meant that the system would have required many satellites and a very aggressive satellite replenishment schedule.[50] Despite the difficulties in the MIDAS program, proponents for the system continued to drive home the case for space-based missile warning.[51] The attraction of doing the early warning mission from space remained very strong, and scientists, Defense Department officials, and Members of Congress continued to push for a space-based capability.

The follow-on to MIDAS was the Defense Support Program (DSP) system of satellites, which were designed to use only three or four satellites circling in geosynchronous Earth orbit (GEO) to provide the required surveillance against the Soviet launch of ground- and sea-based strategic ballistic missile systems. DSP satellites were integrated with the existing U.S. ground-based early warning radar systems already reporting to NORAD. DSP data provided significant details on in-flight missiles, including the number of missiles, their azimuth, and projected impact points. Despite being operational and on-watch against strategic missile systems since the early 1970s, the first use of DSP satellites in combat actually involved the detection of an Iraqi Scud missile, a theater-range ballistic missile,

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[50] R. Cargill Hall, *Missile Defense Alarm: The Genesis of Space-Based Infrared Early Warning*, NRO, July 1988, available at https://www.nro.gov/Portals/65/documents/foia/docs/foia-mda.pdf See also Website article, "Missile Early Warning: Peeking Over the Curtain."

[51] Defense Secretary Harold Brown, "Memorandum for the Assistant Secretary of the Air Force (Research and Development), Subject: Midas System," June 25, 1962, available at https://nsarchive2.gwu.edu/NSAEBB/NSAEBB235/05.pdf; see also General B.A. Schriever, Commander of Air Force Systems Command, Subject: DoD Program Change (4.4.040) on MIDAS (239A), August 13, 1962, available at https://nsarchive2.gwu.edu/NSAEBB/NSAEBB235/06.pdf.

during the 1991 Persian Gulf War. Still operational in 2023, the DSP early warning system proved since the early 1970s to be very reliable and effective in offering a greater response time (compared to ground-based systems) to U.S. counter-nuclear forces.[52]

As discussed in Chapter 2, the Defense Department upgraded this missile warning system with the SBIRS network of satellites, which became the follow-on system to DSP. Officials believed SBIRS could get even better performance and more accurate information, especially against the short-range ballistic missile threat. Today, SBIRS satellites fly in GEO (which allows the satellites to dwell over a theater of interest) and HEO using highly advanced sensors to see a wider range of the infrared spectrum.

The increase of warning time from 15 to 30 minutes achieved by placing early warning assets in space was a key driver in the decision to move the U.S. missile early warning system's center of gravity from ground to space. The advantages to strategic defenders grew considerably to include global early warning, launch point detection, detection of launches from surprise countries, collection of intelligence data such as missile staging, missile-strike assessment, attack assessment, and nuclear test ban monitoring.[53] The benefits of space-based early warning are so significant to national security that the Defense Department is already planning for the follow-on to the SBIRS program, called Next Generation Overhead Persistent Infrared, which will fly in both GEO and polar orbits and be part of a multi-orbital, layered architecture.[54]

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[52] DSP also provides dual phenomenology (IR and radar) for greater confidence and less likelihood of some sensor or computer glitch providing false warning of an attack.

[53] R. Cargill Hall, *Missile Defense Alarm,* p. 27.

[54] Interview with Roger Cole, "A resilient, layered space-based architecture is well-suited to missile warning systems," *Breaking Defense*,

There are also plans in place to eventually end procurements of very large GEO infrared satellites and start transitioning to a proliferated architecture of smaller satellites in lower orbits.[55]

The logical next question is, should the nation take advantage of the significant capabilities that space-based sensors provide for missile tracking and discrimination? And what other benefits to national security might be obtained? Chapter 5 addresses some of the possible additional advantages of such a move to missile warning, space defense, and space domain awareness.

## Current Program Activities

We have reasonable indications and warning today and now must look to develop and field a globally persistent, robust, and resilient hypersonic and advanced missile threat warning, tracking, and defense capability. In this section, the study will briefly review current Department of Defense development and acquisition efforts. Currently, the Space Development Agency (SDA), which formerly reported to the Under Secretary of Defense for Research and Engineering (USD(R&E)) but is now part of the U.S. Space Force, the U.S. Space Force's Space Systems Command (SSC), and the Missile Defense Agency (MDA), which reports to USD(R&E), are developing prototype and operational satellites to improve the country's ability to acquire, track, and disseminate data required to successfully track, target and cue, and then intercept

December 20, 2021, available at https://breakingdefense.com/2021/12/a-resilient-layered-space-based-architecture-is-well-suited-to-missile-warning-systems/.

[55] Sandra Erwin, "DoD to end procurements of geosynchronous missile-warning satellites," *Space News*, September 21, 2022, available at https://spacenews.com/dod-to-end-procurements-of-geosynchronous-missile-warning-satellites/.

ballistic and hypersonic missiles. MDA also is in the early phases of integrating a space sensor capability to determine whether engagement attempts are successful.

### *Space Force Programs*

The SDA, established in 2019, is developing the Proliferated Warfighter Space Architecture to unify and lead proliferated LEO space development efforts in the Department of Defense.[56] The DoD established the agency because the existing U.S. national security space systems lacked the persistent, timely, global awareness required to handle emerging threats posed by near-peer competitors and regional actors.[57] Officials observed that the nation requires a resilient, threat-driven space surveillance and communications architecture to deter, preempt, or respond to adversary action, including offensive missile operations. SDA will play a prominent role as part of the U.S. Space Force in future space architecture development, organizing it into seven functional layers, including threat detection, warning, tracking, fire control, and communications capabilities.[58] This space architecture will serve as the

[56] Theresa Hitchens, "Space Development Agency's satellite plan gets new name, but focus on speed stays," *BreakingDefense.com*, January 23, 2023, available at https://breakingdefense.com/2023/01/space-development-agencys-satellite-plan-gets-new-name-but-focus-on-speed-stays/#:~:text=By%20Theresa%20Hitchens%20on%20January%2023%2C%202023%20at,Layer%20communications%20mesh%20network%20in%202024.%20%28Northrop%20Grumman%29.

[57] From the March 12, 2019 Secretary of Defense memo (signed by Acting Secretary of Defense, Patrick M. Shanahan) on the "Establishment of the Space Development Agency."

[58] Amanda Miller, "Emerging Emphasis on Missile Tracking Reflected in Space Force's 2023 Budget Request," *Air Force Magazine Online*, April 26, 2022, available at https://www.airforcemag.com/emerging-emphasis-on-missile-tracking-reflected-in-space-forces-2023-budget-request/. According to the SDA public website, https://www.sda.mil/transport/, "SDA's Transport Layer will provide

backbone of the Joint All Domain Command and Control (JADC2). The SDA Director reports to the Chief of Space Operations and head of the U.S. Space Force directly for all non-acquisition related activities (such as personnel and requirements) and to the Assistant Secretary of the Air Force for Space Acquisition and Integration for all acquisition-related matters. SDA is an independent acquisition organization and direct reporting unit of the U.S. Space Force.

SDA's vision is to field a new and responsive space sensor architecture using two pillars: 1) proliferating the number of satellites in the transport and tracking layers, so that the satellite constellation will have resiliency (meaning that it is more difficult for an adversary to take out a large number of satellites) and persistent coverage of the globe, and 2) an acquisition approach that leverages spiral development, which will enable timely deployment of "minimum viable product" capabilities rather than awaiting the exquisite capabilities that can slow down or even kill a program (discussed in Chapter 4).[59]

The ambitious SDA objective will require a reliable satellite launch capability to place new satellites in orbit every two years. Despite early delays in the launch of the Tranche 0[60] transport and tracking satellites, the SDA

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assured, resilient, low-latency military data and connectivity worldwide to the full range of warfighter platforms. SDA's Transport Layer is envisioned, modeled, and architected as a constellation varying in size from 300 to more than 500 satellites in Low Earth Orbit (LEO) ranging from 750km to 1200km in altitude. With a full constellation, 95% of the locations on the Earth will have at least two satellites in view at any given time while 99% of the locations on the Earth will have at least one satellite in view. This will ensure constant world-wide coverage around the globe."

[59] Author's interview with Dr. Derek Tournear, August 5, 2022.

[60] SDA refers to its capability releases for Low Earth Orbit as "Tranches." Tranche 0 consists of demonstration satellites and Tranche 1 will consist of the first operational constellation.

Director, Dr. Derek Tournear, stated that the launch of the first mission-capable Tranche satellites is still planned for the fall of 2024.[61] Unlike the plans for the Hypersonic and Ballistic Tracking Space Sensor (HBTSS) development and launch by MDA, which develops and delivers an integrated mission capability (sensors, weapons, C2BMC) to the warfighter, SDA will continually provide and replenish a space-based mesh network, ground command stations, and tactical communication data links to the DoD's end users to perform different missions, such as hypersonic missile defense, ballistic missile defense, and offensive operations.

The SDA architecture will have the basic constellation functions, such as a communications data transport layer to handle the movement of data, and it will have "end users," including MDA and the joint and allied operators of missile defense forces. SDA's pLEO constellation will contain tracking satellites for detecting and tracking hypersonic weapons. The transport layer will optically interconnect the tracking layer with other capability layers as they become available. The Space Force Tranche 1 tracking satellites will contain operational Wide Field of View (WFOV) infrared sensors to maximize a satellite's coverage area on the Earth (which will track missiles soon after launch when they are the brightest).

In April 2023, SDA began launching its Tranche 0 ("Tranche" is SDA's term for its LEO development spirals) tracking and transport satellites, which will demonstrate the initial transport and tracking functions.[62] To be

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[61] "There's 10 launches total and the launches are one month apart," Tournear said. "It's basically one-a-month starting in September 2024." Cited in Hitchens, "Space Development Agency's satellite plan gets new name."

[62] Courtney Albon, "SpaceX rocket launches Space Development Agency's first satellites," *Defense News Online*, April 2, 2023, available at https://www.defensenews.com/battlefield-tech/space/2023/04/02/spacex-rocket-launches-space-development-agencys-first-satellites/.

considered successful, these Tranche 0 satellites will have to: (1) show that they can receive data from a targeting cell and send that data down to an existing tactical data link, a soldier in the field, a sailor on a ship, or an airman in the cockpit; and (2) detect and track a missile in flight and send that data down to the current architecture for real-time data transfer.

The plan is to have the first operational pLEO constellation with Tranche 1 two years after the launch of Tranche 0 to support persistent regional access in an adversarial conflict through the fielding of Tranche 1—126 Transport satellites and 35 Tracking satellites.[63] As with Tranche 0, the Tracking satellites will be equipped with WFOV infrared sensors providing missile warning and missile tracking of hypersonic glide vehicles and other advanced beyond-the-horizon threats.

SDA, additionally, will leverage MDA's development of a medium field of view (MFOV) sensor, called HBTSS, and integrate that sensor onto four spacecraft. Thus, SDA will demonstrate cueing of the prototype MFOV satellites from the operational WFOV satellites to provide more specific, fire control quality data as the target grows dimmer in the glide phase of flight to a ground-based interceptor. The vision today is to add other layers, including satellites to facilitate the targeting of hostile mobile assets on Earth and to detect potentially hostile actions in deep space.[64] With

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[63] Greg Hadley, "SDA Taps Raytheon for Seven More Missile-Tracking Satellites," *Air and Space Forces Magazine*, March 6, 2023, available at https://www.airandspaceforces.com/sda-taps-raytheon-for-seven-more-missile-tracking-satellites/.

[64] Kelley M. Sayler, "Hypersonic Missile Defense: Issues for Congress," *Congressional Research Service*, January 24, 2023, pp. 1, 2, available at https://s3.documentcloud.org/documents/23588919/hypersonic-missile-defense-issues-for-congress-jan-24-2023.pdf See also Kelley M. Sayler and Stephen M. McCall, "Hypersonic Missile Defense: Issues for Congress," *Congressional Research Service*, January 26, 2022, pp. 1, 2, available at https://crsreports.congress.gov/product/pdf/IF/IF11623.

the Space Force and SDA plans now in place and being executed, the country has an architectural foundation for a robust, resilient, and persistent space-based tracking capability.

Two years following the launch of Tranche 1, Tranche 2 LEO tracking will be deployed, providing a globally persistent capability able to support two adversarial campaigns. SSC also is collaborating with SDA to develop an independent Medium Earth Orbit (MEO) constellation of satellites to bolster the architectural resiliency of the pLEO tracking layer and provide global access for missile warning, tracking, and defense.[65] The MEO program is also following a spiral development process with spirals called "Epochs." SSC is currently planning to launch MEO Epoch 1 in late 2026, and then will launch follow-on Epochs every two years in order to build upon and refresh the constellation. Plans are to launch Epoch 2 (MEO) in 2028, pending budget approval.[66]

In the future, Space Force is expected to have WFOV missile-tracking sensors deployed in GEO. These satellites underwent initial demonstrations in late 2022. Once

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[65] Sandra Erwin, "Millennium Space's missile-warning satellite clears design review," *SpaceNews Online*, November 27, 2022, available at https://spacenews.com/millennium-spaces-missile-warning-satellite-clears-design-review/.

[66] Tournear interview. See also Theresa Hitchens, "Space Force targets 2027 for resilient on-orbit posture initial capability," *BreakingDefense.com*, May 17, 2022, available at https://breakingdefense.com/2022/05/space-force-targets-2027-for-resilient-on-orbit-posture-initial-capability/. See also Rachael Zisk, "The National Defense Space Architecture: Inside Space Force's splashy new initiative," *Fast Company*, December 9, 2022, available at https://www.fastcompany.com/90821502/the-national-defense-space-architecture-inside-space-forces-splashy-new-initiative; Theresa Hitchens, "Space Force asks industry input for second phase of MEO missile warning/tracking," *BreakingDefense.com*, April 3, 2023, available at https://breakingdefense.com/2023/04/space-force-asks-industry-input-for-second-phase-of-meo-missile-warning-tracking/

operational, they will be able to monitor more than 3,000 kilometers of the Earth's surface at one time, gathering data on missile launches and flight activity, which will then be analyzed and used to cue missile tracking sensors at lower altitudes in MEO and LEO. This data on threat targets will allow the lower altitude satellites to know exactly where to look and take more precise measurements required by the weapon systems.[67]

### *Missile Defense Agency Programs*

MDA's HBTSS and SDA's Tranche (LEO) missile tracking architecture progression seem to be very similar efforts. MDA initiated the HBTSS program in 2018 to address the requirement to detect and track hypersonic threats and ballistic missiles. The HBTSS is unique to the missile defense mission and its place within the broader space architecture is being developed in coordination with the Space Force and SDA. When fully operational, HBTSS will be part of the Unified Overhead Persistent Infrared Enterprise Architecture and will detect hypersonic, ballistic, and other advanced threats much sooner than terrestrial radars, providing hypersonic threat-tracking data for hand-off through linked missile defense weapons.

The country is moving towards adding HBTSS satellites to its current constellations of dedicated early warning spacecraft in an effort to leverage some of the obvious advantages space offers missile defenders. Driven primarily by the emerging hypersonic missile threat, HBTSS is different from the predecessor midcourse ballistic missile tracking space sensors because its sensors will stare downward to pick out and track missile targets against the "cluttered" background caused by the "warm" Earth. The

[67] Sandra Erwin, "Space Force to activate sensor on Wide-Field-of-View missile warning satellite," *SpaceNews Online*, October 24, 2022, available at https://spacenews.com/space-force-to-activate-sensor-on-wide-field-of-view-missile-warning-satellite/

previous midcourse tracking satellites, including the recently retired Space Tracking and Surveillance System demonstration satellites, looked upwards against the "cold" background of space (ideal for viewing ballistic missiles in midcourse flight).

This novel tracking system will contribute to regional missile defense, providing fire-control quality tracking data (which the SDA Tranche tracking satellites are unable to provide) on hypersonic, ballistic, and potentially even cruise missile threats (should they be traveling fast and hot enough for the sensors to pick them up) for hand-over to missile defense sensors for engagement.[68] According to the MDA Director, Vice Admiral Jon Hill:

> That's how we handle the global maneuver problem. If you don't have a sensor, tracking from launch all the way through demise, there's a period of uncertainty in that track. And what we don't want to do is launch a weapon that then opens a seeker and there's nothing there, because the target has maneuvered.[69]

HBTSS will be a critical asset for the mission to destroy hypersonic missile threats in the glide phase of their flight, before they get to the terminal phase where they can begin to undertake maneuvering that will stress missile defenses.

The unique contribution of HBTSS will be the ability to provide very precise data, or what warfighters call "fire control quality data." This high "quality of service" weapons-engagement quality data will determine with accuracy the threat's position, the velocity of the missile warhead or glide vehicle, and the glide vehicle's

[68] Hill testimony, June 15, 2021.

[69] Theresa Hitchens, "MDA Director Sees New Space Investment," *BreakingDefense.com*, June 29, 2021, available at https://breakingdefense.com/2021/06/mda-director-sees-new-space-investment/.

acceleration. The tracking sensor layer provided by SDA satellites will help to acquire and do initial target tracking. While the HBTSS spacecraft will have gimbaled seekers (meaning that the sensors can be pointed toward objects on Earth), the SDA tracking sensors are fixed and cannot change the direction in which they stare, and so the Space Force will be in charge of making sure that these two different systems work together.

This data is handed over to HBTSS through C2BMC, which will do its job of refining the picture of the target. In a layered sensor architecture, when the HBTSS data is combined with other higher-fidelity ground-based X-band and S-band radars, such as the Sea-Based X-band radar and Long-Range Discrimination Radar, the precision in the data would be extraordinary and provide a clear track for engagement by interceptors. When the threat is maneuvering, this precision data will be vital to successful completion of the defense mission. Ideally, the U.S. would want as many sensors on the threat as possible so that missile defenders can know with the greatest precision possible where it is after it takes a big lateral move.

Another consideration is the desire for "dual-phenomenology" in the assessment of attacks on the U.S. homeland, that is, the use of both infrared sensors and radars to collect enough information using different sources in order to increase confidence that a missile is indeed on a trajectory towards the United States. As homeland defense terrestrial radars, such as the LRDR or UEWRs mentioned earlier, are phased out, the availability of radio frequency data to supplement the infrared data delivered by satellite sensors will diminish. In some cases, there may be only infrared sensor data to work with—that is, single phenomenology. During this transition from reliance on terrestrial radars to the proliferation of space sensors to do the missile tracking function, the U.S. military will have to evolve its thinking in response to adversaries' advances in such areas as hypersonic glide vehicles that are designed to evade terrestrial radars. Perhaps the confirming data can be obtained using multiple infrared bands from space or by collecting that same data using different space-based platforms. In any case, as missile tracking satellites proliferate, new opportunities to accomplish the mission more efficiently will present themselves to developers, engineers, and warfighters.

Once operational, HBTSS will have three things that the warfighter needs to defeat hypersonic missile threats: sufficient sensitivity, fire control quality of service, and the ability to meet "latency" requirements: a measure of the time it takes the sensor to deliver information through the system to the in-flight interceptor.[70] The transfer of vital information needs to occur in near real-time. If the transfer of data takes more than seconds, the information provided by the sensor becomes stale. If the information is too old, when the interceptor opens its shroud to expose its own sensors, it will not be able to see the target because it will have moved off the predicted point in space and out of range of the interceptor's eyes. In that situation, the interceptor must be more agile (which is more expensive) if it is going to have a chance at executing big maneuvers to intercept the threat.

The ability to process data in space rather than at ground stations also would improve latency. While this transfer of data to the interceptor will never be real time just because of the physics involved (that is the vast distances between Earth and Earth's orbits), there will be a period of time, a latency requirement, wherein it will be possible to get the target into the interceptor's sensor field of view. The combination of the shortest possible latency and high level

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[70] See also, CSIS Interview Transcript, "Complex Air Defense: Countering the Hypersonic Missile Threat," February 9, 2022, available at https://www.csis.org/analysis/complex-air-defense-countering-hypersonic-missile-threat-0.

of accuracy will deliver a fine track to the system for engagement. To achieve this required latency, MDA is working closely with the developers and operators of C2BMC and the Glide Phase Interceptor (GPI) office in MDA to make sure they can get the hypersonic missile defense interceptor to the right space in time. This reality of needing to work closely with other developers of the integrated Missile Defense System is one of the main reasons that MDA is developing this advanced sensor system, and not SDA or the Space Force.

Latency is also determined by the orbit the satellite sensor flies in. On average, LEO satellites fly at 1,200 miles or less altitude, and can fly as low at 100 miles. Given that LEO satellites can orbit Earth several times a day, a greater number of them are needed to provide sufficient coverage of the Earth. MEO satellites, however, circle the earth at a much higher altitude, from roughly 13,000 to 22,000 miles above the Earth, orbiting the earth at least twice a day.[71] SDA is focused on building out a proliferated LEO, or pLEO, tracking sensor constellation using wide field of view sensors. Proliferated LEO is optimal for missile tracking because of its proximity to Earth. The higher the altitude, the farther away the sensor will be from the threat missile target. While MEO will be useful for the initial tracking and surveillance mission, it will be more difficult to deliver fire control data to interceptors in a timely manner given the greater distances from Earth. Yet if new technologies arrive that permit the delivery of fire control data from higher orbits, the MDA Chief Architect stated that "[a]s long as you can provide me fire control quality data, I don't care what orbit you're in. I need a certain kind of data. You can decide the orbit."[72]

[71] Highly elliptical orbits (HEO) can have apogees of more than 30,000 miles.

[72] Author interview with Mr. Stan Stafira, MDA Chief Architect, August 2, 2022.

While meeting latency requirements is more of a challenge from MEO, the orbital diversity, or layering, in the tracking satellite constellations is an advantage for the missile defense mission. Indeed, Space Based InfraRed satellites can be distributed among different orbits, creating significant advantages for defense. Multiple layers will provide different views of the threat missile and provide fuller coverage.

As a result, the sensor capabilities being developed by SDA complement the satellites under development by MDA.[73] HBTSS's unique mission is to provide fire-control quality data capability for tracking hypersonic threats to the Missile Defense System. MDA plans to launch two prototype demonstration satellites developed by different industry teams in 2023 to demonstrate that they can meet sensitivity, latency, and fire control requirements. Once operationally deployed, probably around the middle part of this decade, HBTSS will provide a persistent, global capability to detect and track boosting ballistic missiles, hypersonic glide vehicles, as well as missile raids.[74]

This is how it all works together. To ensure a unified and seamless operation, the MDA-developed HBTSS will be leveraged on prototype satellites in Tranche 1. The SDA-developed Tranche tracking satellites will contribute sensor data to the MDA C2BMC and be a disseminator of fire

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[73] Samantha Beu, "Space Assets Critical to Defeat Hypersonic Threats," *National Defense Magazine Online*, September 23, 2022, available at https://www.nationaldefensemagazine.org/articles/2022/9/23/space-assets-critical-to-defeat-hypersonic-threats.

[74] Courtney Albon, "New missile warning, tracking force design could accelerate SDA Tranche 1 tracking layer," *InsideDefense.com*, August 26, 2021, available at https://insidedefense.com/daily-news/new-missile-warning-tracking-force-design-could-accelerate-sda-tranche-1-tracking-layer; David Vergun, "Space Development Agency Transitioning to U.S. Space Force," *DOD News*, August 26, 2021, available at https://www.defense.gov/Explore/News/Article/Article/2747675/space-development-agency-transitioning-to-us-space-force/.

control solution from C2BMC. Satellites in LEO will send their data to the transport layer and then down to the ground. The LEO and MEO tracking layers will publish data to the real time transfer service (RTS), which is managed by the Joint OPIR Ground (JOG)—a group led by MDA, Space Force, and the National Geo-Spatial Intelligence Agency. RTS will send data to multiple places, including C2BMC. C2BMC will take all the data off RTS and fuse it together with terrestrial radars and send the data to the C2BMC engine, where it will be turned into fire control quality data, which is the precision data needed by the warfighter to increase confidence that a target can be successfully engaged. It will send that out via the Navy's Mobile User Objective System (MUOS) of satellites and Advanced Extremely High Frequency (AEHF) communications satellites. These are operated by the Space Force and other Link-16 networks connected by fiber. SDA will receive a feed from C2BMC to go to the transport satellites, so that the SDA transport satellites can then send the feed out to tactical data links in the theater.

There is one other promising development effort that contributes to the space-based missile tracking architecture. SKA sensors, which are deployed on commercial satellites, might also be considered part of the space-based tracking system, because they will verify that the flight of a lethal object has been terminated. In 2019, SKA began providing hit assessment situational awareness to US Northern Command to support homeland missile defense, which is the first step towards having a kill assessment capability, which will provide fuller confidence that the lethal object was destroyed. This hit assessment capability was successfully tested in 2019 involving a salvo launch of Ground Based Interceptors against an ICBM target.[75] Today, SKA sensors continue to be used in a variety of flight

[75] Jason Sherman, "Pentagon moving to convert SKA from experiment to operational capability by 2022," *Inside Defense*, March 23, 2020.

tests and engineering activities to characterize the sensors' capabilities and provide valuable data to support future post-intercept assessment capabilities for the Missile Defense System.

## A Long Way to Go

There is a growing requirement for integrated space sensors, not simply to meet the newest missile and space threats but also to replace increasingly obsolete terrestrial sensors.[76] A space-based sensor layer would enable the United States to use its interceptor inventory more efficiently and effectively to counter a broad array of threats.[77] Yet efforts to deploy "eyes" in space to enable global and persistent tracking of the less challenging (when compared to the hypersonic missile threats) in-flight ballistic missile threats have been on-again off-again and, in the end, have not resulted in the deployment of a new operational constellation.

Past efforts to deploy missile tracking capabilities in space have not been fruitful, undermining confidence that the current and future plans to lay in a missile tracking architecture can be successfully completed. The Space Surveillance and Tracking System program and Brilliant Eyes program (part of the Global Protection Against Limited Strikes architecture) were started by the Strategic Defense Initiative Organization to track and discriminate space objects, including ballistic missiles and warheads. Brilliant Eyes was terminated by the Clinton Administration and replaced in 1994 by an Air Force-led effort called Space Based InfraRed System (SBIRS) Low, a

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[76] Lieutenant General John E. Shaw, Deputy Command U.S. Space Command, *Testimony before the House Armed Services Committee, Strategic Force Subcommittee*, May 11, 2022 [draft].

[77] Hill testimony, June 15, 2021.

proposed constellation of Low Earth Orbit satellites to support National Missile Defense.

SBIRS Low was transferred to MDA in 2001, during the George W. Bush Administration, and renamed in 2002 the Space Tracking and Surveillance System (STSS). Two STSS satellites were launched in 2009 to perform sensor technology demonstrations and collect data useful for the development of follow-on systems for tracking objects on a ballistic trajectory in space. After some consideration was given during the Obama Administration to establishing a more robust STSS Follow-On program, plans shifted to the development of a Precision Tracking Space System (PTSS), a constellation focused on the regional ballistic missile threat (i.e., non-Russian, non-Chinese threats). The planned PTSS constellation, which would have covered most of the Earth's landmass along the equatorial belt, was terminated in 2013 for cost and questions about its long-term sustainability.

Following the completed mission of the two STSS demonstrator satellites in 2022, the United States today has no dedicated satellites in orbit to track in-flight ballistic missiles. As noted above, while they are not yet fully integrated into the operational system, the country recently deployed SKA sensors on commercial satellites for the homeland missile defense mission to inform the warfighter whether an intercept had eliminated the target and whether the target needed to be re-engaged. MDA also made progress in using overhead sensors and algorithms to detect and track advanced missile threats. Yet the bottom line remains that there are currently no operational satellites in orbit and integrated into the Missile Defense System.

# Chapter 4
# Taking Missile Defense Seriously—Shifting the Tracking Sensor Network Center of Gravity to Space

The United States does not have today a constellation of tracking and discrimination satellites to provide persistent discrimination and tracking data on a ballistic missile's midcourse flight and countermeasures, or on a hypersonic missile's glide or terminal phases of flight. Instead, missile defenders are largely left to rely on "islands" of ground- and sea-based radars that dot vast tracts of land and ocean to provide critical information to the integrated Missile Defense System. The greatest leap in capability that could be achieved in today's Missile Defense System is the addition of a space tracking layer.

Such a change in the sensor architecture would buy valuable mission response time globally.[78] In the fight against ballistic missiles, a truly layered defense system would create intercept opportunities in the boost or ascent phase, the midcourse phase, and the terminal phase of a ballistic missile's flight—potentially making the overall system much more effective. A space sensor network, composed of satellites that perform the same functions as the recently retired demonstrator Space Tracking and Surveillance System satellites, would fill a critical sensor gap between boost phase and terminal phase, a time during a ballistic missile's flight when an adversary is most likely to deploy countermeasures and decoys to try to confuse the radars.

Layered defenses leveraging different sensors in different environments can provide the Missile Defense

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[78] Raytheon Intelligence & Space, "Why space-based assets are crucial for effective missile defence," *Shephard Media*, June 29, 2021.

System improved "vision" when it comes to maneuvering threats: the ability to see, track, and discriminate. This is especially true in space because of the ability of satellites to be persistent and closer to the threat, and follow the trajectory of a threatening missile. The transformation of the tracking sensor architecture so that it can fully leverage the space domain must be the DoD's next crucial consideration. What is standing in the way of implementing a vision of a missile defense architecture that puts the sensor center of gravity in space?

## Technology Challenges

Dr. Mark Lewis, former director of defense research and engineering and acting deputy undersecretary in charge of technology modernization, stressed that it is not enough to spot the threat. Effective missile defense also requires the system to follow that threat while in flight until it can be intercepted: "[Offensive hypersonic missile systems] can be stopped but doing so will require leveraging state-of-the-art space sensors, rapid processing and decision-making, and an assortment of available intercept techniques."[79]

Technology has been a bedeviling obstacle in the past. During the days of the Strategic Defense Initiative (SDI), in the 1980s and early 1990s, the Department of Defense focused on improving the necessary technology.[80] Now, significant advances have been made in sensor, spacecraft, and computer processing technologies, in large part because of private sector investments and commercial space ventures. Today, the government must do what it can to

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[79] Samantha Beu, "Sensor Tech Key to Effective Missile Defense," *National Defense Magazine*, April 2, 2021, available at https://www.nationaldefensemagazine.org/articles/2021/4/2/sensor-tech-key-to-effective-missile-defense.

[80] Author's interview with Mr. Walt Chai, MDA Director for Space Systems, June 29, 2022.

capture the remarkable progress made in the private sector. The Department of Defense has been able to capitalize on the progress of the industrial pioneers and is, in many ways, following their lead. Industry has been putting up thousands of satellites and the government is now in a position to leverage associated technology and experience. As a result, current development efforts such as the HBTSS can help the nation finally realize the vision of former President Reagan's SDI.

The government also has a better understanding of sensors following decades of building, demonstrating, and operating satellites. Today, satellites can be more readily manufactured than they were during the days of SDI, when each satellite was essentially "handmade." Commercial space entities have been driving down the costs of being in space, in part by adopting more efficient manufacturing processes, which was not possible even ten years ago. The government now has the luxury of being able to focus on the sensor technology and use commercial entities for the commodities, such as the satellite bus, cryo-coolers, solar arrays, and launch services.

Significant technological advances have been made in industry that are being put to use in the development of the SDA Tranche 0 tracking space sensors (wide field of view for initial tracking of hypersonic threats) and in the MDA HBTSS (medium field of view of precision tracking), which have demonstrated already on the ground that they have the sensitivity to detect launches from orbit. Capabilities to track in-flight objects will be further demonstrated in the next few years. The technology exists now to take data from multiple tracking systems, fuse that data for the purposes of calculating a solution for engaging the threat object, and sending that data directly to the weapon system to handle hypersonic glide vehicles and multiple missiles simultaneously. The technology for spacecraft, payloads, ground software, and advanced algorithms is such that these systems are now efficient and affordable, and can be evolved to counter the emerging threat. This includes on-orbit algorithms to support detection and tracking of hypersonic missiles through the multiple stages of flight and atmospheric conditions.[81]

Still, there are significant technical challenges that must be taken on, with some of the more pressing ones stemming from the growing complexity of the modern battlefield and the need to retrieve information, process that information, decide, and act within a tactically meaningful timeframe. The ability to execute more and more of the processing of data in space will enable faster responses that are closer to real-time when compared to what can be achieved today. SDA intends to tackle this challenge through its spiral development process. In Tranche 0, SDA is doing all of the networking in space, yet all of the other processing will be done on the ground. In Tranche 1, only the network routing has to be done autonomously on board, with the goal of getting the data to the ground for processing. According to SDA Director Derek Tournear, the "stretch goal" is to do more and more processing on board the spacecraft as well, including the track formation: "As we spiral, we want to get to where we do all detection, fusion, and dissemination on board [the spacecraft]."[82]

Space developers do not do a great job of developing ground systems. This is not their line of interest and they are generally not trained to do that. Ground systems are always an afterthought. Space is "cool." But the ground segment is not, and as a result it can be mismanaged or at

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[81] Megan Crouse, "The technology challenges of complex missile defense," *Military-Aerospace Electronics*, August 26, 2022, available at https://www.militaryaerospace.com/sensors/article/14280041/missile-defense-sensors.

[82] Author's interview with Dr. Derek Tournear, SDA Director, August 5, 2022.

least not executed in the most effective way possible.[83] MDA has been tackling this challenge of marrying up ground and space systems. The challenge has been that every satellite system, until now, has had different command and control equipment on the ground. Yet what is required to improve the efficiency of the operation is to have every satellite commanded the same way, so that the hardware used in the ground equipment of different systems is similar.

Similarity in ground equipment across different satellite systems would in turn simplify training for console operators, who would be more likely to have familiarity with ground system operation. Following the Space Force lead with the goal of implementing this vision, MDA has been using what is called Enterprise Ground Services. Government developers also should take some lessons learned from private industry, which is becoming increasingly proficient with onboard processing.

There is also a need to improve technology and concepts of operation to better correlate enemy missile tracks using the data provided by different sensors and efficiently exchange that data to ensure it is delivered to the right weapon system. The problem of "track confusion" is very real, and it needs to be solved if the nation is going to get the most out of its space (and other) tracking sensors.[84] There are likely to be multiple military services and combatant commands involved in a regional conflict as well as other U.S. and possibly foreign entities. Who processes the data and how to get that data to the weapons is a control problem that must be solved if the country is to be militarily successful on an increasingly complex battlefield.

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[83] Author's interview with Mr. Walt Chai. Ground user equipment is almost always a separate program element and often controlled by another Service like the Army or Navy.

[84] Author interview with VADM Hill.

## Acquisition Challenges

The DoD acquisition enterprise is designed around the development of long-lifetime products, and it can take many years to develop a very expensive, exquisite, or a one-of-a kind satellite, one that is able to last on orbit for at least ten years. Thus, one of challenges this country faces is achieving the rapid deployment of advanced space capabilities in order to counter a very dynamic threat. Many leaders in the defense space community have trumpeted the disturbing reality that this country is not moving quickly enough to acquire the weapon systems it needs.[85] This is a problem of bureaucracy, which generally means there is a bureaucratic solution. The problem is that understanding and then endorsing the requirements in the conventional acquisition process involve 10- or 20-year studies. In other words, using the standard Defense Department acquisition processes does not allow missile defense developers to get through that process before the system they are developing is overtaken by events.

In 2002, under the Administration of President George W. Bush, DoD created MDA, and it granted the agency special acquisition authorities to accelerate the process of deploying missile defenses.[86] Among the defining characteristics of this new agency was that all of its efforts would be consolidated into a single Major Defense Acquisition Program called the Ballistic Missile Defense System (BMDS). Rather than develop each sensor and interceptor as a separate program, MDA would develop them as elements in an integrated "system of systems" and

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[85] See, for example, Sandra Erwin, "Space Force procurement chief criticizes over-engineered satellite programs," *SpaceNews Online*, September 20, 2022, available at https://spacenews.com/space-force-procurement-chief-criticizes-over-engineered-satellite-programs/.

[86] Donald Rumsfeld, "Missile Defense Program Direction," Office of the Secretary of Defense Memo, January 2, 2002, http://fas.org/ssp/bmd/d20020102mda.pdf.

manage them as a single program. According to the MDA Director at the birth of the agency, Air Force Lieutenant General Ronald Kadish, there were two major reasons for the new acquisition approach:

> The first is to reduce the cycle time for making key decisions. The structure provides more direct, focused, frequent, and comprehensive decision making and is designed to attack head-on the tough problems of complex "system-of-systems" integration that are key to the success of such a complex undertaking as missile defense.[87]

Structuring the program in this way allowed the MDA Director broad authority to set the capabilities required from each element and trade requirements (discussed below) between elements as technology develops. General Kadish pushed the Agency towards a "capabilities-based" acquisition approach, explaining that "[i]nstead of developing a system in response to a clearly defined threat from a known adversary, we are looking at missile capabilities that any adversary could have in a given timeframe. We also continually assess missile defense technology options and availability."[88]

Since its establishment in 2002, MDA has viewed "capabilities-based" acquisition as a critical element in its approach to defeating a very dynamic, ever-changing missile threat. With the wide range of missile threats posed by potential near-peer and rogue adversaries, it was determined in the early days of MDA that the acquisition

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[87] Lt. Gen. Ronald T. Kadish, *On the Missile Defense Program*, Statement before the Subcommittee on National Security, Veteran Affairs, and International Relations, House Committee on Government Report, July 16, 2002.

[88] Lt Gen Ronald T. Kadish, *The Missile Defense Program*, Statement before the Senate Armed Services Committee, Strategic Forces Subcommittee, March 7, 2002, https://www.mda.mil/global/documents/pdf/ps_kadish7mar02.pdf.

process could not be "threat-based" with regard to individual missile threats. Any operational requirements document, which relies on very precise definitions of the threat, would be largely guesswork. Working from an Operational Requirements Document would have made the missile defense development process difficult given the unprecedented engineering work to be conducted. An evolutionary, capabilities-based approach, on the other hand, relies on ongoing comprehensive assessments of the missile threat, available technology, and what can be built to do an acceptable if not perfect job.

The U.S. began using this process by issuing presidential guidance directing the Defense Department to deploy by 2004 an initial homeland defense capability against limited threats from North Korea. The Director's new accountability, granted to him by the special authorities, would help the missile defense program clear bureaucratic hurdles to accomplish the mission. According to Ambassador Robert Joseph, who was a Special Assistant on the National Security Council of President George W. Bush, "antibodies embedded in the department had impeded progress for years and would continue to do so if development were conducted through acquisition authorities designed for a previous era." Joseph also noted that in the following two decades "that same bureaucracy has been steadily seeking to pare back MDA's authorities to build and deploy defenses, despite the reaffirmation in both the 2010 and 2019 missile defense reviews of the need for MDA to possess flexible acquisition authorities."[89]

As the prime acquisition organization for both ballistic and hypersonic missile defenses, today MDA manages a substantial portion of DoD development programs for integrated air and missile defense. MDA believes the

[89] Robert Joseph, "The Missile Defense Agency must be free to move quickly and with limited restrictions," *Defense News Online*, September 15, 2021.

country will need critical tracking and discrimination space sensors by mid-century to defeat the anticipated threats. As discussed earlier, HBTSS will be required to track and intercept offensive hypersonic missiles. Insofar as an advanced cruise missile acts like a hypersonic missile, HBTSS could also tackle that threat because the faster the missile goes, the hotter it will be, and the more readily it can be picked up by HBTSS sensors. The as-yet-unprogrammed Discrimination Space Sensor will be needed to defeat the anticipated advanced ballistic missile threat.[90] If MDA is going to succeed in the timely acquisition of these systems, it cannot follow the conventional DoD acquisition practices.

Similar to MDA, SDA's focus also is on experimenting, prototyping, and accelerated fielding. SDA also has special authorities to procure systems, unbounded by the standard requirements and acquisition systems, which today are the Joint Capabilities Integration and Development System (JCIDS) and the DoD 5000 series.[91] With this approach, both agencies are able to explore, prototype and demonstrate systems and architectures at a rapid pace that allows them to risk, try, fail, learn, and succeed in the development of low-cost systems at an accelerated pace. They both will seek to combine innovation with exquisite capabilities unique to the DoD. These will include sensors that can detect and track hypersonic threats, machine learning to make sense of

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[90] HBTSS will look down from orbit to view objects against the warm Earth background that will be rich with clutter. Once deployed, DSS would view objects in midcourse flight against the cold background of space. Author interviews with Stan Stafira and Walt Chai.

[91] The Joint Capabilities Integration and Development System is the process used by the Joint Requirements Oversight Council (JROC) to fulfill its statutory responsibilities to the Chairman of the Joint Chiefs of Staff (CJCS), including but not limited to identifying, assessing, validating, and prioritizing joint military capability requirements. https://www.dau.edu/acquipedia/pages/ArticleContent.aspx?itemid=643#:~:text=JCIDS%20is%20the%20process%20used,prioritizing%20joint%20military%20capability%20requirements.

the enormous data we will collect, Artificial Intelligence to link sensors and shooters, and cyber-security designed in from the start of system development.

According to SDA Director Tournear, the spiral development model the organization is using may run into some roadblocks because the Department of Defense is wedded to DoD 5000, and so getting DoD leadership to embrace spiral development will be a challenge.[92] Recall the SDA spiral development vision: within seconds, to detect, track, fire control, and send data to a weapons platform to close that portion of the kill chain autonomously and as rapidly as possible. Using a very similar philosophy to MDA's, whose leaders have insisted that the country does not have to deploy a perfect defense in order to have an effective defense, SDA's understanding of spiral development means the developers are not going to get to the end goal on their first deployment. The current approach in SDA is to define a minimum viable product that SDA can provide in two years that pushes the developer towards the ultimate goal. This approach is very similar to the MDA capabilities-based acquisition understanding.

As mentioned above, SDA does not receive endorsement of requirements for its satellites using the JCIDS process, but rather uses a Warfighter Council to establish requirements, which has representatives from the Combatant Commands and Services, and meets twice a year. The council gives its blessing on what is judged to be the minimum viable capability for the next Tranche, which is then what SDA marches towards. The Warfighter Council is similar to the MDA senior leader body in the Pentagon that approves missile defense requirements: the Missile Defense Executive Board.[93]

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[92] Author interview with Derek Tournear.

[93] One of the problems in the past has been one of mission creep, where the developer is told Pentagon stakeholders to keep adding in

SDA's working relationship with MDA, especially in determining the roles each would play, has been marked by friction and confusion until recent years.[94] It is becoming clearer that SDA's role falls squarely on the mission of populating the pLEO constellation of operational tracking sensors, which of course will be managed by the Space Force. Unlike MDA, SDA is not in the technology development business. SDA, rather, relies on MDA for the development of high-precision tracking sensors, such as the medium field of view sensors to be carried onboard HBTSS. This advanced technology is subsequently transitioned to the SDA industry developers to produce the tracking satellites.

Much of the future of missile defense tracking from space will hinge on how the Space Force manages the MDA and SDA spacecraft. With the Space Force undertaking many missions, it is possible that missile defense could get sidelined in priority. In any case, it is important MDA continue to be the keeper of the requirement for HBTSS sensor technology because that role provides the Director room to manage the larger hypersonic missile defense program. Another way to view this is that Space Force has the space enterprise, which includes HBTSS, and MDA has the missile defense enterprise, which also includes HBTSS. If the country is to have a successful hypersonic missile defense capability, both organizations need to work together. To that end, in early 2022, a governance concept

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requirements, which adds not only to the cost of the satellite but also to the length of time it takes to put it on orbit, making the development and procurement of the satellite unaffordable. The lower the satellite cost, the simpler and more stable the requirement, the easier it will be to get through the development cycle and place it on orbit.

[94] Author interviews with Derek Tournear and Walt Chai. See also Kelley M. Saylor, "Hypersonic Missile Defense: Issues for Congress," *Congressional Research Service*, October 3, 2022, available at https://s3.documentcloud.org/documents/23118899/hypersonic-missile-defense-issues-for-congress-oct-3-2022.pdf.

of a Combined Program Office among SSC, SDA, and MDA emerged that will enable coordinated capability development across the mission areas.[95] This office is intended to deliver integrated sensor-to-shooter capabilities that meet requirements in strategic missile warning, missile tracking, and missile defense.

One of the most significant acquisition challenges deals with the subject of trade space. If HBTSS belonged entirely to the Space Force, it would restrict the MDA Director's flexibility to "trade" performance among the systems. One potential trade, for example, might involve the HBTSS sensor and the new Glide Phase Interceptor under development. The more accurate the sensor is, or the better the sensor quality of service, the "dumber" the interceptor can be. Dumb interceptors are preferable because they are expendable and cheaper than a smart interceptor.

Developers also want to do as much as possible of the processing work in space to reduce reaction time. A sensor that can deliver highly accurate data to the interceptor means the interceptor's divert capability would not have to be as great as it would otherwise have to be. This might impact, for example, the interceptor seeker window. The seeker window heats up at hypersonic speeds. Developers are looking for material to withstand that heat in order to shroud the seeker for as long as possible. Yet when the shroud comes off, the seeker has a limited amount of time to search for the target before the seeker window starts to degrade from the heat. If developers could provide better quality of data to send the interceptor to the exact point in space, the system could keep the shroud on longer, so that when the interceptor "opens its eyes," the target would be there.

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[95] Rachael Zisk, "The National Defense Space Architecture: Inside Space Force's splashy new initiative," *Fast Company*, December 9, 2022, available at https://www.fastcompany.com/90821502/the-national-defense-space-architecture-inside-space-forces-splashy-new-initiative.

If the window material problem is not solved, then developers have to make that up with spacecraft sensors, processing, C2BMC, or perhaps the development of a smarter interceptor. These are "trades" the Director must make in light of the progress in technology among different elements of the missile defense system. As an outside organization, Space Force might not understand the nuances and what the trades are. Without that knowledge, Space Force might trade away something that is very important for the interceptor, for example. Therefore, the location of the development requirement is critical to ensuring the success of the missile defense mission. In this case, it is better for MDA to own the requirement for the development of both the high precision sensor technology and the prototype spacecraft.[96]

Another obstacle to putting up a robust space sensor architecture is "the tyranny of the now," under which near-term needs and drivers supplant long-term planning to counter an emerging threat. Among the voices in the debate over new space sensors are those who say that the nation needs a capability "now," and that it will take too much time to deliver a space capability. It is not uncommon for "now" to win. Yet if the nation keeps putting off the

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[96] MDA is building the HBTSS prototype (STSS and Near Field InfraRed Experiment were the prototypes for HBTSS) which will be handed off to someone else for production. MDA paid for new BM signal processor for the ships—from air warfare to ballistic warfare. MDA is used to proceeding this way. THAAD is owned by Army, but MDA produces it. MDA prototyped the multi-mission signal processor and the navy took it over and took it to sea. A good partnership with the Navy. We made it operation and Navy picked it out for construction and MDA is not in the business of building signal processors for ships anymore. SPY-6 radar is BMD capable, but is not based on MDA requirements—so we don't know what we're going to get with that radar. They took a different path. The (Baseline 10 Flt III) ship's capability will take a step backwards when it is installed and their capability will be less than the SPY 1 ships out there, because it's not just about the radar, it's also about the processing of the data and the combat control.

deployment of space capability, it never gets to where it needs to be. That $2 billion spent on the ground radar could have been put towards the long-term payoff resident in the space architecture.[97] Developers, in other words, must continually advocate for the space architecture.

Special acquisition authorities are critical to the development of advanced satellites deployed on a rapid timeline to counter the emerging missile threat. The long timelines for development in most programs today are lamentable, as the DoD is not used to buying systems with five-year lifespans. This obviously impacts launch programs, which today are not used to launching on short timelines. The good news is that the Air Force leadership understands the problem and are pushing within the Pentagon the ideas that the DoD must build smaller satellites and ground systems, use existing technologies and designs when possible, and acquire ground- and software-intensive systems in smaller pieces that can be delivered faster. According to Air Force acquisition chief Frank Calvelli, "the traditional ways of doing space acquisition must be reformed in order to add speed to our acquisitions to meet our priorities."[98] While progress is being made, the troubling bottom line remains that the Pentagon is not yet accustomed to refreshing short-lived spacecraft that are part of a proliferated LEO system.

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[97] The Global Positioning System of satellites was a hard pill to swallow for the nation. Initially it was put up to support nuclear warfighting, but the warfighter and the rest of the country eventually found out how important the precision timing coming off the system was. At first, the cost of the maintaining the constellation looked unreasonable, but eventually the GPS system came to be so important for the United States and the world that paying for it became a no-brainer.

[98] Sandra Erwin, "New guidance from Space Force acquisition boss: 'The traditional ways must be reformed," *SpaceNews Online*, November 1, 2022, available at https://spacenews.com/new-guidance-from-space-force-acquisition-boss-the-traditional-ways-must-be-reformed/.

## Commercial Challenges and Opportunities

It should be too obvious a point to state the importance of private sector contributions, and even leadership, in space programs for national defense. Industry, of course, has always played a critical role in military programs. The government does not build anything, after all. Industry does. This is nothing new. In the defense space world, as has been addressed above, industry is making important technological advances in space that the U.S. government should continue leveraging, if it wants to remain a preeminent space power.[99]

According to the Chief of Space Operations (CSO) for the Space Force, Lieutenant General B. Chance Saltzman, it is "a top priority as CSO to get the most we can from the private sector." Indeed, General Saltzman believes Space Force will need to tap the commercial market for innovative technologies to supplement government systems.[100]

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[99] "With so many new capabilities being provided by industry, commercial services are taking off in ways that we never probably imagined just a few years ago," said Brigadier General Timothy Sejba, program executive officer for space domain awareness and combat power at the USSF Space Systems Command. Sandra Erwin, "New Space Force procurement shop subscribes to the space-as-a-service model," *SpaceNews Online*, November 21, 2022, available at https://spacenews.com/fighting-fomo-with-comso/ See also Jon Harper, "Spacecom leader warns of potential 'failure modes' as DOD pursues commercial space capabilities," *DefenseScoop.com*, January 24, 2023, available at https://defensescoop.com/2023/01/24/spacecom-chief-warns-of-potential-failure-modes-as-dod-pursues-commercial-space-capabilities/ See also Theresa Hitchens, "White House advisory group to explore DoD use of commercial space," *BreakingDefense.com*, February 23, 2023, available at https://breakingdefense.com/2023/02/white-house-advisory-group-to-explore-dod-use-of-commercial-space/.

[100] Sandra Erwin, "Space Force nominee sees growing threats to U.S. satellites from rival powers," *SpaceNews Online*, September 13, 2022, available at https://spacenews.com/space-force-nominee-sees-growing-threats-to-u-s-satellites-from-rival-powers/.

Organizations such as SDA are already leaning forward when it comes to leveraging commercial innovation, investments, and products. It is the vision of the SDA Director to take commercial products and use those for its space system needs wherever this makes sense. Commercial practices and commercial spacecraft (see discussion of Space-based Kill Assessment below) can offer tremendous value to a defense space program. SDA has adopted commercial practices to do quality control and program management and it expects its partners and performers to treat these missions as "commercial class" and not to apply more rigorous military specifications and quality assurance.[101]

The Pentagon is also looking into deepening its partnerships with private companies by establishing a fleet of commercial spacecraft that could be on standby for military use.[102] Capitalizing on the commercial investments that have been made makes sense. The possible use of commercial services will likely remain restricted to satellite communications. And indeed, there are some defense activities that must remain strictly owned and operated by the government. Regarding the missile tracking and missile defense missions, the Government understandably wants to retain control over the tactical data links that are tied into weapon systems.

The private sector is also making giant strides in commercial space launch services and has become a major player in the launching of military satellites. Commercial space launch will play a critical role in the future

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101 Author interview with Derek Tournear.

102 Courtney Albon, "Space Force may seek commercial fleet to augment wartime needs," *Defense News Online*, October 19, 2022, available at https://www.defensenews.com/battlefield-tech/space/2022/10/19/space-force-may-seek-commercial-fleet-to-augment-wartime-needs/. SSC is implementing the Commercial Augmentation Space Reserve (CASR) approach that is somewhat similar to the Civil Reserve Airlift Fleet (CRAF) model.

deployment of missile defense satellite tracking sensors. The Space Force is going to rely on the growing launch industry to place the advanced tracking spacecraft, which will be launched several at a time and grouped into planes, into proper orbits.

The current acquisition system is not set up to be responsive and must be changed if the SDA vision of continual spacecraft replenishment is going to be realized. So, there remains a disconnect in what the government is asking industry to do—to provide rapid and responsive production of spacecraft—and what the government can accomplish to launch those payloads into orbit. There is also a significant challenge in how the DoD acquires its launch services. Under current processes, the Space Force will have to pay for these services two years in advance. This is a system that clearly cannot support a responsive launch strategy.

The challenge of responsive launch to meet wartime timelines for space-based capabilities is clearly on the minds of Space Force leadership.[103] They have begun a Tactically Responsive Space program with the goal of making sure SDA's satellites make it into orbit on schedule. The program involves a demonstration that will attempt to launch a satellite within 24 hours of receiving a "go" order.[104] That goal has not yet been achieved, which allows

[103] See, for example, Sandra Erwin, "Military to tap commercial industry for 'space mobility' services," *SpaceNews Online*, February 21, 2023, available at https://spacenews.com/military-to-tap-commercial-industry-for-space-mobility-services/.

[104] Theresa Hitchens, "24 hours from 'go': Next Space Force 'responsive launch' experiment aims to loft satellite in a hurry," *BreakingDefense.com*, September 28, 2022, available at https://breakingdefense.com/2022/09/24-hours-from-go-next-space-force-responsive-launch-experiment-aims-to-loft-satellite-in-a-hurry/; Sandra Erwin, "Space Force lays out timeline for 2023 rapid-response launch experiment," *SpaceNews Online*, November 6, 2022, available at

some skepticism to creep into our assessments of the ability of SDA and the Space Force to deploy and maintain operational missile tracking sensors in LEO. Nevertheless, commercial launch has reduced launch costs significantly, and technology has progressed to the point where smaller satellites are more operationally relevant. Now is the time to leverage these developments to become more responsive.[105]

As discussed above, the Defense Department has traditionally relied on large satellite programs to undertake critical defense space missions. Commercial space today, however, has transformed how the Department views the space industry and even how it operates. Small, medium, and large satellites can provide many similar capabilities.

There may be other innovative ways to leverage commercial spacecraft for military benefit. MDA's SKA program was designed to deliver data from space on whether a warhead has been hit and destroyed. Again, these SKA sensors may be considered a critical element in the missile defense tracking mission because they enable the warfighter to understand when a missile payload, or the lethal object, has stopped flying and no longer needs to be tracked. SKA is in orbit today because of some innovative thinking in the use of commercial spacecraft and program management. This program was established to leverage the private sector's ability to put capabilities into orbit quickly.

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https://spacenews.com/space-force-lays-out-timeline-for-2023-rapid-response-launch-experiment/.

[105] Courtney Albon, "Next Space Force chief should focus on resiliency, Raymond says," *C4ISRNET.com*, November 3, 2022, available at https://www.c4isrnet.com/battlefield-tech/space/2022/11/03/next-space-force-chief-should-focus-on-resiliency-raymond-says/; Courtney Albon, "U.S. acquisition exec on being faster, stronger and more united in space," *C4ISRNET.com*, December 8, 2022, available at https://www.defensenews.com/outlook/2022/12/05/us-acquisition-exec-on-being-faster-stronger-and-more-united-in-space/.

The unique feature of the kill assessment sensors is that they are hosted on commercial satellites. The developers at MDA did not have to go through the process of building a satellite to house the payload. Developers also had to work on a compressed schedule to meet the commercial launch schedule. This forced the sensor development to be finished in 15 months and required MDA to deliver flight hardware to the satellite integrator four months later.[106] The development and deployment and eventual operation of SKA sensors showed that critical capabilities could be developed on accelerated timelines with proper management and a culture that allows and even encourages innovative acquisition.

## Policy Challenges

The development and deployment of space tracking satellite constellations also are encountering challenges at the policy level. The United States today recognizes the changed dynamic in the space environment in its security policies and strategies, and its leaders have been promoting greater awareness of the space threat while also reorganizing the Joint Force and command structure to protect U.S. space assets and mature U.S. spacepower. Space is increasingly recognized as vital to the American way of life. Yet this higher-level assessment of the importance of space at the policy level is not well reflected in the nation's vision or budget.

Leaders in the Department of Defense have strained to make the point to the Congress and public that losing access to space and loss of space assets would be catastrophic to

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[106] For an excellent discussion of the SKA program and associated management challenges, see Michael Schlacter, "How Commercial Space Spurred DoD Innovation," *Defense AT&L*, March-April 2018, available at https://www.dau.edu/library/defense-atl/DATLFiles/Mar-April_2018/Schlacter.pdf.

U.S. security. Moreover, other nations have deployed space assets and weaponry that may be used to deprive the United States of its freedom to use space for defense or economic purposes, which we will address in Chapter 5. With the growth in transparency in the defense space world since 2013, there has been a greater willingness among political and military leaders to talk about threats to space systems, counterspace systems used in actual demonstrations, and the nations developing them. This recognition of the threat to U.S. space systems drove the United States to consolidate the U.S. military space organization by establishing a U.S. Space Force and U.S. Space Command. Yet there remains a significant gap in public knowledge about U.S. defense space systems and threats to them, which will continue to hinder advocacy for critical military space programs, including missile defense space tracking sensors.

Recognition of space as a warfighting environment should be driving U.S. strategies for space technology and system development. The absence of a clear and unified vision of where the nation should be heading in the defense space arena is a stumbling block. The lack of a coherent vision not only impedes development of important military systems but also limits government and commercial investments. According to the 2022 Space Industrial Base Report written by Air Force, Space Force, Air Force Research Laboratory, and Defense Innovation Unit officials, the United States lacks a "North Star" to orient the government and commercial space sectors. The country needs a clear and comprehensive long-term vision to guide a "whole-of-nation" strategy over the coming decades—to ensure that China does not overtake the United States and become the dominant player in this vital arena.[107]

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[107] Michael Marrow, "U.S. still lacks 'whole-of-nation' vision for space, report warns," *InsideDefense.com*, August 24, 2022.

A clearly articulated vision will lead to solutions for protecting U.S. space systems from attack and providing reassurance to the commercial sector. For example, a clear vision will help to remove the bureaucratic obstacles (discussed above) to more responsive launch operations.

Overclassification problems also continue to hinder space program advocacy and important collaboration with allies.[108] If we want deterrence to be effective, then the nation's leaders must be able to talk about existing and planned capabilities as well as the threats posed by adversaries. U.S. capabilities that are not brandished cannot contribute to deterrence. Yet the Biden Administration has not released an unclassified version of the recently finished *Space Strategy Review*. The National Defense Strategy released in October 2022 states the following: "Deterrence depends in part on competitors' understanding of US intent and capabilities. The Department must seek to avoid unknowingly driving competition to aggression. To strengthen deterrence as well as manage escalation risks, the Department will advance its ability to operate in the information domain—for example, by working to ensure that messages are conveyed effectively."[109] Indeed, overclassifying programs, by placing them in "special

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[108] Lambakis, *Space as a Warfighting Domain*, pp. 82-89. Theresa Hitchens, "'Out of control': DoD reviews use of super-secret SAP classification, for space programs and beyond," *BreakingDefense.com*, February 14, 2023, available at https://breakingdefense.com/2023/02/out-of-control-dod-reviews-use-of-super-secret-sap-classification-for-space-programs-and-beyond/; Sandra Erwin, "Pentagon working with Congress on unclassified space strategy," *SpaceNews Online*, February 15, 2023, available at https://spacenews.com/pentagon-working-with-congress-on-unclassified-space-strategy/.

[109] Theresa Hitchens, "U.S. Strategic Space Review signed out, but no unclassified version is coming," *BreakingDefense.com*, November 1, 2022, available at https://breakingdefense.com/2022/11/exclusive-us-strategic-space-review-signed-out-but-no-unclassified-version-is-coming/.

access program" status, for example, makes it difficult to integrate space capabilities across other domains and restricts access to industry innovations and ideas. The over-classification trap also limits interaction with partners on space sensor development efforts and interoperability with allies.[110] These deficiencies should be expected to degrade or hinder the development and timely deployment of missile defense tracking space sensors.

Despite the fact that space sensors are not weighed down by the baggage associated with space-based kinetic kill systems, political problems stemming from the absence of a coherent vision still may hinder their development and deployment.[111] Arguments for space arms control could unduly restrain important sensor development, particular as those sensors could be used to help execute counterspace operations. Missile defense is a force application mission that takes place in space, and changes in international norms or restrictions could be introduced and reduce the ability of the United States to protect itself against missiles.

The absence of a clear, coherent, national vision is also a drag on the political momentum needed to support space, which will necessarily impact funding of these important programs. Yet as these threats are not expected to go away or diminish, a vision will be needed to fund the Space Force

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[110] TN Science Desk, "Japan eyes a Space-based missile defense system with 50 satellites tracking enemy missiles," *Times Now*, November 16, 2022, available at https://www.timesnownews.com/technology-science/japan-eyes-a-space-based-missile-defense-system-with-50-satellites-tracking-enemy-missiles-article-95556333; Erwin, "New guidance from Space Force acquisition boss."

[111] Space has been used for decades to enhance and facilitate military operations on Earth. Over the past four decades there has been significant political turmoil around: 1) deployment of terrestrial- or space-based kinetic or non-kinetic weapons to terminate or destroy a satellite, or, 2) deployment of weapons in orbit for missile defense, space control, or striking targets on Earth. Decisions for or against the deployment of space-based sensors have not had to factor in the highly intense political arguments that typically charge space weapon debates.

at the appropriate level and maintain stable programs. Given the serious China challenge in space alone, one would expect to see significant increases in the coming budget years.[112] Along with that funding, Space Force must continue to fund the missile defense mission work that is not necessarily in its mission portfolio. Should attention to the missile defense mission wane in the Space Force or the DoD, funding and authority to continue the necessary space sensor development work without having to do bureaucratic gymnastics will become compromised.[113]

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[112] Sandra Erwin, "Space Force to seek budget boost beyond 2023, China's capabilities are 'close to ours,'" *SpaceNews Online*, October 25, 2022, available at https://spacenews.com/space-force-to-seek-budget-boost-beyond-2023-chinas-capabilities-are-close-to-ours/ and Thomas Novelly, "Citing Growing Threat from China, Space Force Leaders Say They Need More Money," *Military.com*, October 28, 2022, available at https://www.military.com/daily-news/2022/10/28/citing-growing-threat-china-space-force-leaders-say-they-need-more-money.html.

[113] Courtney Albon, "Space Force budget presents a bridge strategy for missile warning, tracking architecture," *C4ISRNET.com*, April 19, 2022, available at https://news.yahoo.com/space-force-budget-presents-bridge-165954127.html.

# Chapter 5
# Implications of the Space-based Missile Defense Sensor Network for Other Mission Areas

The deployment of missile defense tracking sensors in space will benefit three other missions that belong to the Department of the Air Force and the Space Force: Missile Warning, Space Domain Awareness (or what used to be called Space Situational Awareness), and counterspace operations (or defense of friendly space assets). The overlap and synergy of MDA's HBTSS and Space Force Tranche tracking sensor deployments and these Space Force mission areas are significant. Policymakers and those responsible for funding the development, deployment, and operation of the missile defense space tracking capabilities should be aware that these investments will have mission-multiplying effects that benefit other mission areas critical to U.S. space superiority and Joint Force operational agility.

Multi-mission capabilities, including space surveillance, warning, tracking, intelligence collection, and fire control for missile defense, are the way of the future. The idea that the nation can leverage these capabilities to perform many missions is desirable. Because the United States has demonstrated space sensor tracking capabilities over the last couple of decades and is pushing to deploy operational sensors in space over the next several years, the nation's leadership has realized that the data from these satellites can serve other purposes, transforming single-purpose satellites to do more than one job. This, moreover, appears to be the vision of the Commander of the U.S. Space Command, who is looking for ways to get the most out of what we have today.[114]

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[114] Amanda Miller, "Dickinson: U.S. Space Command Is Studying New Ways to Use Existing Satellites," *Air & Space Forces Magazine*, November

## The Space Threat

Adversary counterspace capabilities, especially those under development or already developed by China and Russia, increase the chances that U.S. sensors on satellites, as well as other satellites the United States relies on for its military operations and economic prosperity, can and may be targeted during hostilities.[115] Multiple threats have emerged to U.S. space systems in recent years. Indeed, China and Russia have conducted live anti-satellite tests in space and are building capabilities that can damage or destroy U.S. space assets.[116]

China has a robust network of space surveillance sensors capable of searching, tracking, and characterizing satellites in all Earth orbits. It also has and continues to further develop electronic warfare, cyberthreat capabilities,

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29, 2022, available at https://hypeaviation.com/story/dickinson-us-space-command-is-studying-new-ways-to-use-existing-satellites/83331/.

[115] Sandra Erwin, "U.S. Space Force chief: The use of space technology in Ukraine 'is what we can expect in the future'," *SpaceNews Online*, December 4, 2022, available at https://spacenews.com/u-s-space-force-chief-the-use-of-space-technology-in-ukraine-is-what-we-can-expect-in-the-future/.

[116] Defense Intelligence Agency, *Challenges to Security in Space*, 2022, p. IV, available at https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf Sandra Erwin, "Space Force nominee sees growing threats to U.S. satellites from rival powers," *SpaceNews Online*, September 13, 2022, available at https://spacenews.com/space-force-nominee-sees-growing-threats-to-u-s-satellites-from-rival-powers/; Sandra Erwin, "Space Force briefing on military space race catches Jeff Bezos' attention," *SpaceNews Online*, October 19, 2022, available at https://spacenews.com/space-force-briefing-on-military-space-race-catches-jeff-bezos-attention/; Department of Defense, *Defense Space Strategy Summary*, June 2020, p. 1 available at https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_DEFENSE_SPACE_STRATEGY_SUMMARY.PDF. See also Gen. John W. "Jay" Raymond, "Space dominance requires taking technology and policy risks," *Defense News Online*, September 14, 2020.

sophisticated on-orbit capabilities, kinetic energy weapons (such as ground-based anti-satellite weapons), and possibly directed energy weapons in addition to other counterspace technologies.[117]

China began its ASAT tests in 2005 and in 2007 destroyed a satellite that created significant space debris in Low Earth Orbit. Since then, it has conducted more than a dozen additional tests, including some in higher orbit, demonstrating that it can place most U.S. satellites at risk. It has fired lasers at satellites and has five military bases capable of firing light to blind or destroy satellite optics, and is expanding its space facilities around the globe, which could further enhance this threat. China is developing other sophisticated space-based capabilities, such as satellite inspection and repair, which could function as a weapon.[118] China has an unmanned, reusable space plane program.[119] It also has incorporated cyberattack plans.[120] U.S. policymakers have declared that China is doubling down

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117 Defense Intelligence Agency, *Challenges to Security in Space*, p. 17. Alasdair Pal, "China poses increasing threat in military space race, top U.S. general says," *Reuters*, November 27, 2022, available at https://www.reuters.com/world/us/china-poses-increasing-threat-military-space-race-top-us-general-says-2022-11-28/.

118 Defense Intelligence Agency, *Challenges to Security in Space*, p. 18.

119 Trefor Moss, "Both the U.S. and China have secretive programs to develop unmanned, reusable spaceplanes," *Wall Street Journal Online*, September 4, 2020, available at https://www.wsj.com/articles/china-launches-experimental-spaceplane-11599217896.

120 For a summary of the growing China space threat to U.S. systems, see Lambakis, *Foreign Space Capabilities*, p. 19-26, and; Lambakis, *A Guide to Thinking About Space Deterrence and China*, (Fairfax, VA: National Institute Press, 2019), pp. 11-22, and Sandra Erwin, "Raymond on China's space program: 'It's alive, well and concerning,'" *SpaceNews Online*, December 17, 2020, available at https://spacenews.com/raymond-on-chinas-space-program-its-alive-well-and-concerning/.

on the use of space for warfare.[121] It has also explored technologies to use space for purposes of force application. A warhead released from a Fractional Orbital Bombardment System, demonstrated by China in 2021, would be difficult for early warning systems to track.

Russia is expanding its space capability by investing significantly in a full range of capabilities, including ASAT kinetic weapons, lasers, jammers, and cyber weapons.[122] Early in 2020, the commander of U.S. Space Command at the time, General Jay Raymond, highlighted the concerning behavior of two new Russian satellites with distinct similarities to other Russian satellites that launched a high-speed projectile in 2017.[123] Russia continued its ASAT development activities in 2019 and 2020.[124] In November

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[121] Courtney Albon, "Pentagon leaders discuss China's space ambitions at classified meeting," *Defense News Online*, September 8, 2022, available at https://news.yahoo.com/pentagon-leaders-discuss-china-space-154830430.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuYmluZy5jb20v&guce_referrer_sig=AQAAAH6nPE3Xu5_TarNVEXX8_WTZhZBc1v_UON7uNof-iZUBKXKPFtEYaGtttBpqcrYWLJY65piWcc1mrQzBnFZaAZ3XKEKvrh98XXgAhFhdCZgIF5JhB81nK6xZvDbznYbWMXyt3GwNzaaj1OcyNP9KNKgMEYiPFuszrkEl3Cnwt6YF.

[122] Pavel Luzin, "Cosmos ASATs and Russia's Approach to Space Weapons," *Eurasia Daily Monitor* Vol. 17, Iss. 121, August 14, 2020. Russia has demonstrated two different types of space weapons. See Greg Norman, "Russia tests anti-satellite missile in pursuit to make space a 'warfighting domain,' US officials say," *Fox News*, December 16, 2020, available at https://www.foxnews.com/world/us-space-command-russia-tests-anti-satellite-missile. Defense Intelligence Agency, *Challenges to Security in Space*, pp. 27-29.

[123] Stephen Kitay, DASD (Space), "Defense Official Briefs Defense Space Strategy to Reporters," June 17, 2020, Transcript at: https://www.defense.gov/Newsroom/Transcripts/Transcript/Article/2225281/defense-official-briefs-defense-space-strategy-to-reporters/.

[124] Sandra Erwin, "Space Force official: Russian missile tests expose vulnerability of low-orbiting satellites," *SpaceNews Online*, December 16, 2020, available at https://spacenews.com/space-force-official-russian-missile-tests-expose-vulnerability-of-low-orbiting-satellites/.

2021, it destroyed its own satellite with a ground-launched missile, which produced an estimated 1,500 pieces of debris and reportedly forced astronauts aboard the International Space Station to take shelter.[125] Related to the execution of its war against the Ukraine, Moscow officials gave the impression that Russia would be willing to attack commercial spacecraft supporting the Ukrainian military (e.g., the Starlink communication satellites).[126] Russia is developing space inspection systems that could be used as a weapon.[127] Like China, Russia is honing its cyber-attack skills.[128]

Space systems, which are part of the information network that relies entirely on digital systems and data flow and on software and radio-frequency links, are especially vulnerable to electromagnetic pulse (EMP) attacks.[129] An

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[125] Defense Intelligence Agency, *Challenges to Security in Space*, p. 28; Lee Ferran, "Space Force commander cannot 'forgive' Russia for 'reckless' ASAT test," *BreakingDefense.com*, October 14, 2022, available at https://breakingdefense.com/2022/10/space-force-commander-cannot-forgive-russia-for-reckless-asat-test/.

[126] Ann M. Simmons and Micah Maidenberg, "Moscow Threatens U.S. Satellites," *Wall Street Journal*, October 28, 2022. Joey Roulette, "Russia's anti-satellite threat tests laws of war in space," *Reuters*, October 27, 2022, available at https://kfgo.com/2022/10/27/russias-anti-satellite-threat-tests-laws-of-war-in-space/#:~:text=Oct%2027%2C%202022%20%7C%2011%3A10%20PM%20By%20Joey,executives%20about%20the%20safety%20of%20objects%20in%20orbit.

[127] Defense Intelligence Agency, *Challenges to Security in Space*, p. 29.

[128] See Steve Ranger, "US intelligence: 30 countries building cyber attack capabilities," *ZDNet*, January 5, 2017, available at http://www.zdnet.com/article/us-intelligence-30-countries-building-cyber-attack-capabilities/.

[129] High Altitude Nuclear Explosions in LEO pump up the Van Allen radiation belts and cause failure of unhardened satellites while an atmospheric EMP would affect activities on Earth and limited effects in space. Kitay "Defense Official Briefs Defense Space Strategy," June 17, 2020. For a good summary of the EMP threat, see Mitre, *Electromagnetic Pulse: The Dangerous but Overlooked Threat, September 2020*, available at

EMP might create havoc not only on Earth but also within satellite systems. The United States has a variety of systems, including Nuclear Command and Control and missile warning capabilities, whose survival might be challenged by a nuclear detonation in space.[130] The threat of a cyber-attack on U.S. space assets is being viewed as the likely form of attack, at least in the near term.[131]

## Bolstering Missile Warning

Both the MDA HBTSS and the SDA Tranche (LEO) tracking satellites will be part of the nation's Unified Overhead Persistent InfraRed (OPIR) enterprise architecture. As such, they will have inherent missile warning capabilities to supplement the dedicated missile detection Space Based InfraRed System (SBIRS) spacecraft in geosynchronous earth orbit (GEO) and High Earth Orbit. The missile warning and tracking data gathered in Low Earth Orbit, in turn, will be integrated with the DoD's nuclear command, control, and communications (NC3) network following certification in the NC3 Integrated Tactical Warning & Attack Assessment (ITWAA) system.[132] Once integrated into the system later this decade, these satellites will work synergistically with SBIRS in support of the missile warning

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https://www.mitre.org/publications/project-stories/electromagnetic-pulse-the-dangerous-but-overlooked-threat.

[130] See Kitay, "Defense Official Briefs Defense Space Strategy."

[131] Ferran, "Space Force Commander cannot 'forgive' Russia for 'reckless ASAT test." See also Theresa Hitchens, "Cyber Attack Most Likely Space Threat—Maj. Gen. Whiting," *BreakingDefense.com*, September 16, 2020, available at https://breakingdefense.com/2020/09/cyber-attack-most-likely-space-threat-maj-gen-whiting/.

[132] Theresa Hitchens, "Space Development Agency missile tracking data will inform NC3," *BreakingDefense.com*, November 11, 2022, available at https://breakingdefense.com/2022/11/space-development-agency-missile-tracking-data-will-inform-nc3/.

mission to enhance warning reliability, reducing, for example, the likelihood of false alarms that might trigger the activation of the country's retaliatory nuclear strike forces.

The presence of missile warning satellites in LEO also will improve the resiliency of the entire early warning and missile launch detection system. It is much harder to completely take out a satellite network consisting of scores of orbiting space platforms when the system is fully operational and satellites are continuously on the move. This resiliency will go a long way toward ensuring that the nuclear warning the country relies on will be available during a crisis. According to Derek Tournear, the SDA Director, resiliency in a satellite network "gets a little easier with the proliferated systems because just by nature you should have multiple detections at a given time. And you should have multiple detections from the given layers, the LEO layer and the MEO layer. It cuts down [false warnings] and gives you higher confidence."[133]

## Enhancing Space Domain Awareness

As the nation moves to space to improve missile defense tracking capabilities, it will also be improving capabilities for space domain awareness. Counterspace capabilities could blind our eyes in space, a domain where we have the greatest opportunity for viewing other nations' space operations up close.[134] It will become increasingly important that U.S. defense planners and operators understand what is happening in space in real time so that timely actions can be taken to deter aggression there and to evade or respond to counterspace activities. The current approach to tracking space objects is one of leveraging

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[133] Hitchens, "Space Development Agency missile tracking data will inform NC3."

[134] DIA, *2022 Challenges to Security in Space*, p. 4.

many different platforms, whether deployed in space or on earth, including even ships at sea.[135] As the nation moves its missile defense tracking sensors to space, a new opportunity will arise to expand the number of space-based platforms capable of increasing our knowledge of what is happening in Earth's orbits.

The missile warning and tracking missions are tied very closely to the space domain awareness mission. In his confirmation hearing, the Space Force Commander, General Saltzman, explained that missile warning and tracking, in space and on earth, will be vital capabilities in this security environment, in part because of what these sensors can tell us about what is happening in space. He explained that "the more data that we can collect from the sensors on the planet, the better we're going to have for space domain awareness and, I think, the better we're going to be able to do our mission."[136] The Chief of Space Operations also expressed in his answers to advanced policy questions prepared for the hearing that the availability of missile tracking sensors in space and on the ground will be essential to knowing what is going on in space, the very capability

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[135] Jason Sherman, "MDA readies missile defense destroyers for new 'big deal' mission: tracking space objects," *InsideDefense.com*, June 14, 2022.

[136] General Saltzman, *Hearing to Consider the Nomination of Lieutenant General Bradley C. Saltzman to be General and Chief of Space Operations,* Before the Senate Armed Services Committee, Hearing Transcript, September 13, 2022, available at https://www.armed-services.senate.gov/imo/media/doc/22-63_09-13-2022.pdf. Not only will we need the terrestrial and space platforms to do this mission, significant work also needs to be done in the software arena: "When I think about space domain awareness and the number of sensors worldwide that we are going to need in order to effectively evaluate and determine what is on orbit and where it is and what it is doing and then have the tools—the software tools—on the ground to take all that data in and turn that data into information and decision-quality information, those are some near-term issues that I think we are going to have to address from a software and a hardware standpoint."

that will enable him to “do his job.” Transitioning the intelligence mission to space is critical to military operations given the need for the Joint Force to utilize capabilities in all domains. According to Space Force Lieutenant General Michael A. Guetlein, Commander of Space Systems Command: "The days of us focusing only on maintaining the space catalog of knowns is over. Not only are we focusing on what we know is out there, we're searching for new objects. We are identifying where those objects came from, why they are there and what their intents are."[137] This would also give the Joint Force the data it needs to be able to defend against those objects if necessary.

Utilizing space assets for greater efficiency is a priority for U.S. Space Command. If this is to be achieved, then greater emphasis must be placed on the development of satellites that are multi-purpose and on transforming single-purpose satellites to do more than one job. One of the ways that the defense space community can achieve this is to support the full deployment of currently planned missile defense space tracking sensors, because these sensors have an inherent capability to be multi-mission. Indeed, the Commander of U.S. Space Command confirmed this by emphasizing the close working relationship he has with the Missile Defense Agency. General James Dickenson cited MDA as having “done work in terms of looking at sensors that do solely missile defense, but [could] do space domain awareness. A lot of times people say, ‘Well, it was never designed to do space domain awareness.’ But it has the ability to do so, and so we are ... actively pursuing that.”[138]

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[137] Jeff Foust, “Guetlein: improved space domain awareness essential for national security,” *SpaceNews Online*, September 28, 2022, available at https://spacenews.com/guetlein-improved-space-domain-awareness-essential-for-national-security/.

[138] Amanda Miller, “Dickinson: U.S. Space Command Is Studying New Ways to Use Existing Satellites,” *Air & Space Forces Magazine Online*,” November 29, 2022, available at

The need to expand space domain awareness capabilities extends also to better exploitation of the space prowess of the commercial sector. The Space Force wants to supplement its own data on space activities retrieved by government satellites with data and artificial intelligence algorithms from commercial companies to help satellite operators identify potential space threats.[139] In addition to having greater space domain awareness, one should also expect a need to develop the software and algorithms required for commanders to understand what is happening in their areas of responsibility. Activity in space will be on the rise, leading to confusion on the battlefield. Accounting for what is up there and identifying it will be very similar to tracking activity during a close-in air battle. There will be a requirement to do combat identification: Is it an inbound missile or a commercial airliner? Is it a threat? Will there be sufficient time to do that?

## Countering Adversary Counterspace Capabilities

The growing reliance of the U.S. on its space assets increases the incentive of the adversary to attack them. According to the Chief of Space Force Operations General Saltzman:

> Unfortunately, our adversaries are investing heavily to close that gap and supersede us. I'm worried about the pace with which they are making those changes. China first amongst them, but Russia is also committed to investing heavily in the kinds of capabilities that are going to disrupt, degrade and even destroy our on-orbit

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https://www.airandspaceforces.com/dickinson-us-space-command-is-studying-new-ways-to-use-existing-satellites/.

[139] Sandra Erwin, "Space Force in discussions with industry on future market for space surveillance data," *SpaceNews Online*, October 4, 2022, available at https://spacenews.com/space-force-in-discussions-with-industry-on-future-market-for-space-surveillance-data/.

> capabilities. And so it's that pace of change and their commitment to disabling it, that's most concerning to me.[140]

An attack on U.S. space systems might involve attacking the space ground control systems that talk to military communications satellites, disrupting their ability to send data to U.S. and allied forces around the world. They also may involve direct attacks on spacecraft. The United States relies on satellites that offer a range of protections against reversible interference tactics, such as highly secure, jam-free, and hardened communications satellites. Missile launch warning satellites—such as the U.S. Space Based InfraRed System (SBIRS), High Earth Orbit (HEO), and GEO satellites—operate 37,000 kilometers above Earth and higher. Aside from the passive protections they have from lasing to blind or dazzle the infrared sensors, the vast distances from Earth afforded by operation in GEO and HEO complicate counter-space aggression. Yet, as discussed earlier in this chapter, there are increasing challenges to security in space, perhaps the most alarming of these being the development and deployments by China and Russia of multiple ASAT weapons and other systems that can put current U.S. space-based missile warning sensors at risk in their undefended and highly predictable orbits.

Given the threats to satellites in GEO and HEO, the Space Force over the past several years has decided to adopt

[140] Sandra Erwin, "Space Force nominee sees growing threats to U.S. satellites from rival powers," *SpaceNews Online*, September 13, 2022, available at https://spacenews.com/space-force-nominee-sees-growing-threats-to-u-s-satellites-from-rival-powers/#:~:text=Space%20Force%20nominee%20sees%20growing%20threats%20to%20U.S.,the%20Senate%20Armed%20Services%20Committee%20Sept.%2013%2C%202022.

a different approach to ensure operational resiliency.[141] According to General Saltzman:

> The most serious issue I expect to address is the urgent need for resiliency in our space and ground architectures in support of this emerging architecture. The USSF completed a critical Force Design analysis last August that resulted in our request for a pivotal mission area architecture shift from a geosynchronous and highly elliptical force presentation to a proliferated low and medium earth orbit design. This approach allows for resiliency and detection of new and emerging threats, such as hypersonics.[142]

Spacecraft in LEO and MEO, of course, are even more at risk of attack. On the one hand, satellites in LEO are particularly vulnerable, as they are closer to possible attack from ground-launch systems. On the other hand, if satellites are deployed in a large numbers as part of a networked constellation in LEO, the nation can

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141 Sandra Erwin, "DoD to end procurements of geosynchronous missile-warning satellites," *SpaceNews Online*, September 21, 2022, available at https://spacenews.com/dod-to-end-procurements-of-geosynchronous-missile-warning-satellites/ See also Courtney Albon, "Next Space Force chief should focus on resiliency, Raymond says," *C4ISRNET.com*, November 3, 2022, available at https://news.yahoo.com/next-space-force-chief-focus-145539085.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuYmluZy5jb20v&guce_referrer_sig=AQAAAH6nPE3Xu5_TarNVEXX8_WTZhZBc1v_UON7uNof-iZUBKXKPFtEYaGtttBpqcrYWLJY65piWcc1mrQzBnFZaAZ3XKEKvrh98XXgAhFhdCZgIF5JhB81nK6xZvDbznYbWMXyt3GwNzaaj1OcyNP9KNKgMEYiPFuszrkEl3Cnwt6YF.

142 Lt Gen Bradley C. Saltzman, *Advance Policy Questions for Lieutenant General Bradley C. Saltzman, US Space Force Nominee for Appointment to be Chief of Space Operations of the Space Force Advanced Policy Questions*, prepared for the Senate Armed Services Committee nomination hearing for Lt. Gen Bradley C. Saltzman, September 13, 2022.

dramatically reduce that vulnerability.[143] The sheer number of satellites the enemy would have to defeat would be daunting. The missile tracking satellites currently under development, if deployed in the proliferated numbers envisioned by Space Force today, would have such an inherent defensive capability. There is a clear advantage to having more than one or two satellites to perform a critical mission (such as missile launch warning). The fact that they are deployed in small numbers makes these satellites high-value assets—worthy of the enemy's investment in technologies, systems, and effort to attack or interfere with them.[144]

If the nation can proliferate those satellites, however, it will become significantly harder to punch an operationally significant "hole" in the constellation despite the fact that they are deployed at lower altitudes. The enemy would have to hit a significant number of satellites over a period of time in order to make a "hole" that will affect the performance of the Missile Defense System. And if they do create a hole, it is going to move around the Earth, which means tracking sensor coverage would not be eliminated entirely. This lack of certainty about the continued operation of missile defense tracking sensors increases the doubt in the enemy's mind that it can achieve its military objective, and may thereby act as a deterrent.

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[143] Resilience is not just about what is in orbit. There are also ground systems that require protection. Greg Hadley, "Keys to Space Resilience: It's More Than Orbits, Says DOD's Plumb," *Air & Space Forces Magazine Online*, February 15, 2023, available at https://www.airandspaceforces.com/keys-to-space-resilience-its-more-than-orbits-says-dods-plumb/.

[144] Patrick Tucker, "Space Force Trying to Prep Old Satellites for New Threats by 2026," *DefenseOne.com*, April 20, 2022, available at https://www.defenseone.com/threats/2022/04/space-force-trying-prep-old-satellites-new-threats-2026/365917/ See also Testimony of Dr. Plumb, *Before the House Armed Services Committee,* March 8, 2023, p. 13.

Similarly, tactics for combatting the counterspace threat include increasing the number of sensors in orbit (many targets are harder to take out) and diversifying the orbits used by space sensors (putting satellites in LEO, MEO, and GEO, for example, to multiply the counterspace challenges facing the potential adversary). As has been proposed in Space Force and elsewhere, distribution of satellites among different orbits can also significantly enhance the security of missile warning and tracking satellites. As Assistant Secretary Calveli, head of space acquisition for the Department of the Air Force stated, "resiliency means our systems can be counted on during times of crisis and conflict. The four things that we need [are] proliferation, diversified orbits, integrating commercial capabilities and then the ability to reconstitute. That is how I would define resiliency."[145]

With SBIRS and data transport satellites spread across GEO, MEO, and LEO, there would be a significant cost. It would be a worthwhile cost, however, considering the resilience gained in the entire missile warning architecture.[146] A distribution of missile warning and

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[145] Theresa Hitchens, "Space acquisition office weighs mission priorities in case satellites go down," *BreakingDefense.com*, January 18, 2023, available at https://breakingdefense.com/2023/01/space-acquisition-office-weighs-mission-priorities-in-case-satellites-go-down/#:~:text=Space%20acquisition%20office%20weighs%20mission%20priorities%20in%20case,Hitchens%20on%20January%2018%2C%202023%20at%202%3A20%20PM.

[146] The ability to pass data between assets in different orbits using optical crosslinks would allow defenders to maintain custody of the target missile without ever having to communicate with the ground, which is what current warning satellites in GEO do. Sandra Erwin, "Lockheed Martin proposes multi-layer space network for missile defense," *SpaceNews Online*, April 18, 2022, available at https://spacenews.com/lockheed-martin-proposes-multi-layer-space-network-for-missile-defense/. See also Theresa Hitchens, "Newest sats launched by DoD include jammer-evading, classified payloads," *BreakingDefense.com*, July 6, 2022, available at https://breakingdefense.com/2022/07/newest-sats-launched-by-dod-

tracking satellites among the three major Earth orbits also would allow a reduction in the number of satellites that need to be deployed to have a resilient architecture. Reliance on a proliferated LEO constellation, for example, might require hundreds of satellites in that orbit, whereas diversification among different orbits would require fewer satellites deployed in LEO and still would introduce enough complexity into attack operations to improve deterrence and protect the missile tracking network.[147]

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include-jammer-evading-classified-payloads/#:~:text=Newest%20sats%20launched%20by%20DoD%20include%20jammer-evading%2C%20classified,Hitchens%20on%20July%2006%2C%202022%20at%201%3A30%20PM.

[147] According to CSO General Saltzman, "If you can just take out a few satellites and radically degrade the capabilities, you don't have a resilient architecture." This has to be the "starting point of a discussion that we need to build a new type of space capabilities with resiliency baked in from the beginning." Sandra Erwin, "U.S. Space Force chief: The use of space technology in Ukraine 'is what we can expect in the future," *SpaceNews Online*, December 4, 2022, available at https://spacenews.com/u-s-space-force-chief-the-use-of-space-technology-in-ukraine-is-what-we-can-expect-in-the-future/; Greg Hadley, "Study: Combine Missile Warning, Tracking Constellations Into One Multi-Orbit System," *Air Force Magazine Online*, June 7, 2022.

# Chapter 6
# Summary and Recommendations

The U.S. has made great strides in defending against ballistic missile threats posed by lesser powers, such as North Korea, and against theater-range missile threats to U.S. forces deployed abroad and U.S. allies and partners. It is generally recognized that missile defenses can help deter an attack, provide leaders options and additional time to respond to attacks or stabilize a crisis situation, assure U.S. allies and reinforce alliance unity, and provide a measure of protection in the event deterrence fails.[148] Against increasingly diverse threats, the effectiveness of the U.S. Missile Defense System will hinge on the agility, persistence, and precision of its sensors—especially the space-based sensors that allow the system to reach its highest performance capacity.

Yet it is not clear that the Biden Administration is committed to the advancement of the nation's missile defense capability, let alone the full deployment of missile tracking sensors in space. Despite supportive statements by the top policy officials in the Pentagon,[149] the administration's publication of high-level strategy

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[148] U.S. Department of Defense, *2022 National Defense Strategy of the United States of America*, "Missile Defense Review," p. 8, available at https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

[149] Colin Kahl, Office of the Secretary of Defense for Policy: "We need a missile warning, missile tracking and integrated air and missile defense that accounts for all of those [developments], which is why we're making significant investments—not just in things like updating our interceptors for ballistic missiles or cruise missile defense, but also significant investments in space-based missile warning and tracking," Courtney Albon, "Pentagon leaders discuss China's space ambitions at classified meeting," *DefenseNews Online*, September 8, 2022, available at https://news.yahoo.com/pentagon-leaders-discuss-china-space-154830430.html.

documents, at least, do not demonstrate such a commitment. The only vision for missile defense in the *2022 Missile Defense Review* (MDR), which is an addendum to the 2022 *National Defense Strategy* (as opposed to its own independent publication), is that there must be less emphasis on it. Strategic nuclear and conventional retaliatory capabilities, passive defenses, and the strategy of "missile defeat" (to include destroying missiles before they launch) receive significant attention in this report.

In the unclassified version of the MDR, the version most people will see, advocacy for missile defense and space-based tracking sensors is underwhelming. The 2022 MDR leans heavily on non-missile defense elements for defending the U.S. homeland, deployed forces, and international partners against missile attacks. It offers no vision for enhancing missile defense, either through system or technology investments or consideration of different basing modes (moving some missile-defense capabilities to space, for example). The 2022 MDR does not call for any major shift (through, for example, acceleration of system development efforts or the proposal of new starts) from the capabilities the Defense Department has previously advanced.[150] While this MDR reiterates the historically proven idea that deterrence *can* fail, it does not advocate for the investments required to provide protection once deterrence *has* failed.

Other than a passing mention of military requirements for "sensor capabilities to detect, characterize, track, and engage current and emerging advanced air and missile threats regionally, and to improve early warning, identification, tracking, discrimination, and attribution for

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[150] See also Doug Lamborn, "Reagan's Vision and the State of U.S. Missile Defense Today," *The Ripon Forum*, December 12, 2022, available at https://riponsociety.org/article/reagans-vision-and-the-state-of-u-s-missile-defense-today/.

missile threats to the homeland,"[151] the MDR ignores the revolutionary contributions that global and persistent missile defense tracking sensors currently under development can make. Among the most significant, force-multiplying advances in missile defense today are MDA's development of Hypersonic and Ballistic Tracking Space Sensor satellites and the Space Force's development of Tranche missile-tracking satellites. The MDR should have been used to explain why these satellite deployments and the objective sensor architecture are critical to future defense against hypersonic and ballistic missiles.

To leverage some of the obvious advantages space offers missile defenders, the U.S. is adding missile-tracking satellites to its current constellations of dedicated early warning spacecraft. The MDR misses a critical opportunity to tell its readers that these ongoing satellite development efforts promise to significantly improve the ability of the United States to defeat existing and emerging missile threats. With Space Force and the SDA now in place and pursuing these development efforts along with MDA, the country has an architectural foundation for moving the country's missile tracking sensor center of gravity to space—a plan and vision that should have been emphasized in the 2022 MDR.

The country must move beyond development and initial deployments that will occur over the next few years to fill out the entire architecture that is envisioned. This not only will require continued funding and advocacy for satellite- and ground-system development but also will require the country to put new emphasis on the development of responsive launch capabilities. If the missile tracking and discrimination capability is to be fully

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[151] U.S. Department of Defense, *2022 National Defense Strategy of the United States of America*, "Missile Defense Review," p. 8, available at https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

realized, the satellites to be deployed will need to be placed in orbit in sufficient numbers and then incrementally and periodically replaced with follow-on satellites.

There is a growing warfighter requirement for integrated space sensors, not simply to meet the newest missile and space threats but also to replace increasingly obsolete terrestrial sensors.[152] A space-based sensor layer would enable the United States to use its interceptor inventory more efficiently and effectively to counter a broad array of threats, including hypersonic missile threats.[153] Yet efforts to deploy eyes in space to enable global and persistent tracking of even the less challenging in-flight ballistic missile threats have been on-again off-again and, in the end, have not resulted in the deployment of a new operational constellation. While the absence of a cohesive missile defense vision affects the entirety of the mission, the lack of focus on the long-term purpose of the mission will stunt the growth of missile defense efforts in space.

Space sensors are not weighed down by the baggage associated with space-based interceptors, but political problems stemming from the absence of a coherent vision still may hinder their development and deployment. The lack of vision and advocacy could derail programs currently under development, prevent them from reaching their full potential, and stunt long-term acquisition efforts and strategy development. The arguments for space arms control could unduly restrain important sensor developments, particularly since those sensors could be used to help improve Space Domain Awareness and execute counterspace operations.

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[152] Lieutenant General John E. Shaw, Deputy Command U.S. Space Command, *Testimony before the House Armed Services Committee, Strategic Force Subcommittee*, May 11, 2022 [draft].

[153] VADM Jon A. Hill, *Written Statement: Hearing before the House Armed Services Committee, Strategic Forces Subcommittee,* June 15, 2021.

The absence of a clear, coherent, national vision is a drag on the political momentum needed to support defense activities in space, which will necessarily impact funding of these important programs. A vision will be needed to fund the Space Force at the appropriate level and maintain stable programs. Space Force also must continue to fund the missile-tracking sensor development and production work that is not necessarily in its mission portfolio. Should attention to the missile defense mission wane in Space Force or the DoD, funding and authority to continue the necessary space sensor development work may be compromised.[154]

The Biden Administration should lean into the vision for missile defense and the role of space outlined above, and forcefully shift the missile-tracking center of gravity from Earth to space.

## Implement the Vision through Education

A clearly articulated vision will put the nation on the best path to protecting its space systems from attack and providing reassurance to the commercial sector. Leaders should use the opportunity of a newly published directive, or perhaps a Space Defense Review, to publicize broadly the U.S. vision for space in forthcoming policy and strategy documents. The Biden Administration also should make a concerted effort to persuade leaders throughout government, especially in Congress, of the merits of its vision and new policy. It must work to make that vision a reality by preparing the public mind (domestic and foreign) for the possible introduction of new Defense Department

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[154] Courtney Albon, "Space Force budget presents a bridge strategy for missile warning, tracking architecture," *C4ISRNET.com*, April 19, 2022, available at https://news.yahoo.com/space-force-budget-presents-bridge-165954127.html. See also Sandra Erwin, "Space Force official: To beat China, U.S. has to spend smarter," *SpaceNews Online*, January 11, 2023, available at https://spacenews.com/space-force-official-to-beat-china-u-s-has-to-spend-smarter/.

programs. Implementation of the vision must involve moving the center of gravity for missile-defense tracking sensors to space.

In addition to education, relentless advocacy within the government is needed. There is a constant battle within the Pentagon bureaucracy for resources, and battles to save or terminate programs take place every year. The risk of termination is always there. One advantage that missile-tracking satellites have today, which midcourse tracking satellites lacked in the past, is that they are part of a military service committed to the development and maturation of U.S. spacepower. Today, the Space Force, within an Air Force Department that has given spacepower development critical support, and U.S. Space Command have a special charge that can naturally evolve into advocacy for space assets required to protect the country against emerging threats. Yet all federal departments and agencies as well as the Congress need to be educated and enabled to carry out this policy direction. Whatever approach is taken, the adoption of a vision within national-security policy will invariably require a whole-of-government approach.

## Ensure Adequate Funding of Tracking Space Architecture

Without strong advocacy in high-level public documents for missile defense, the DoD may be tempted to forgo costly investments in critical space technologies, missile-defense-related weapons, sensors, and Command and Control Battle Management and Communications systems. The question is whether HBTSS satellites and Tranche LEO tracking satellites survive to become an acquisition program that leads to an operational constellation. Adequate funding of early warning and tracking satellites is vital to realizing the objectives of the National Defense Strategy.[155] Congress, the source of appropriations, is supportive now. One must ask, however, whether other spending priorities will arise that undermine the place of a Missile Defense System and its needed satellites in the nation's defense arsenal.[156]

If a new administration arrives in 2025, the next President may not put the weight of the office behind satellite programs. Unless the Biden Administration and its Defense Department put a major emphasis *now* on educating stakeholders in the Administration and in Congress, the American public, and American allies on the critical importance of missile-tracking satellites to the hypersonic and ballistic missile defense missions, it would be naïve to assume that these programs will survive.

[155] Secretary Frank Kendall and Gen. John W. Raymond, "The U.S. Space Force Is Your Eye in the Sky," *Wall Street Journal Online*, June 8, 2022.

[156] For a good example of what can happen in the world of compromise, see Courtney Albon, "Lawmakers chart 'middle course' on space-based missile warning funding," *C4ISRNET.com*, January 13, 2023, available at https://news.yahoo.com/lawmakers-chart-middle-course-space-162738016.html.

### *About the Author*

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