CSIS BRIEFS

Extending the Horizon

Elevated Sensors for Targeting and Missile Defense

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THE ISSUE

- **Developing advanced sensing capabilities is a priority for the U.S. Department of Defense (DoD)** to overcome the targeting challenge for both strike and air and missile defense.
- **Terrestrial sensors are a critical backbone for air and missile defense architectures,** but they have inherent limitations that present known vulnerabilities.
- **Whether based on land, aerostats, aircraft, or in orbit, elevated sensors—each type of which has benefits and trade-offs**—can supplement targeting capabilities.

From the Gulf War Scud hunts to today's discussion of targeting missiles "left of launch," the challenge of countering missile threats has been defined by a competition of hiding and finding.[1] Prior to launch, missiles can be dispersed and hidden in shelters or otherwise camouflaged. After launch, modern missiles can evade detection through a variety of means, including speed, stealth, trajectory, and maneuverability through terrain or around radar coverage. With air and missile defense and strike capabilities alike, interceptors and guided munitions are only as good as the sensors that tell them where to go and what to kill.

During her Senate confirmation process, Deputy Secretary of Defense Kathleen Hicks highlighted the role of sensors for missile defense and defeat. "If confirmed," she wrote, the DoD "would assess 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."[2] Sensors, discrimination, and network modernization represent critical enablers for missile defense. Surveillance, tracking, and targeting capabilities also help strike assets find and target adversary missiles on the ground. When asked what one capability he would most like to develop and field, General John Hyten, vice chairman of the Joint Chiefs of Staff said, "overhead sensors that see everything, characterize everything that goes on . . . from a missile perspective, all the time, everywhere."[3] While such an ambitious vision is unlikely to ever be realized, it nevertheless points in the direction of how to fill gaps for integrated air and missile defense.

These two sets of capabilities, strike and air and missile defense, are especially complementary in today's strategic and threat environment. Overhead sensors can play a dual role in cueing defensive intercepts and fixing locations for counterattack, a concept termed offense-defense integration.[4] Active air and missile defense cannot conclude conflicts but can help set the stage for an advantageous termination of hostilities. In the words of retired rear admiral Archer Macy, the role of active air and missile defense is "protection of critical assets, capabilities, own and partner forces, and protected populations from damage caused by objects arriving in the atmosphere, regardless of flight path type, altitude or velocity spectra, and to do so long enough to end the air threat by other means."[5]

In order to target new generations of adversary ships, missile batteries, and the missiles themselves, the U.S. Joint Force should refocus its sensor architecture to include a more diverse set of basing domains, with particular emphasis on elevated platforms. The United States has built an effective backbone of surface-based radars, but evolving its sensor networks will require more distributed and mobile platforms that can direct precision-guided munitions over the horizon. Elevated sensors on a variety of platforms can fill critical capability gaps, enhance the U.S. sensor architecture, and make it more resilient to attack.

THE TERRESTRIAL BIAS

Today's missile defense sensor architecture evolved in part from the Cold War-era missile warning infrastructure. For this and other reasons, it exhibits a bias toward large, powerful surface-based radars.[6] To ensure strategic warning of Soviet bomber or intercontinental ballistic missile (ICBM) strikes, radars had to have enough power to cover large areas and to operate continuously to deter a surprise first strike.

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After the Cold War, policy and technology changes allowed the growth of missile defense systems. In developing a missile defense sensor architecture, the United States initially built upon the existing surface-based radars. The United States upgraded Early Warning Radars and Aegis ships that could be adapted from air defense roles to ballistic missile defense missions. As it accelerated the fielding of these new systems, the Missile Defense Agency (MDA) relied on surface-based radars, building systems such as the AN/TPY-2 radar for the Terminal High Altitude Area Defense (THAAD) system and the Sea-based X-band (SBX) radar platform. In recent years, MDA has continued on this path, moving to complete the Long Range Discrimination Radar in 2021 and working through siting issues for a potential land-based radar in Hawaii. These terrestrial radars provide an important foundation for ballistic missile defense through persistent coverage of key areas and the power to perform crucial functions such as discrimination.

Yet terrestrial platforms possess inherent limitations in today's more complex air and missile threat environment. The curvature of the earth presents an inherent problem for terrestrial radars, limiting their range against lower-flying threats such as cruise missiles, which remain hidden behind the horizon until they draw closer. Given their size and cost, they are few in number. Their fixed locations and energy emissions also make them potential targets. In many cases, these radars provide critical sensor functions for missile defense systems, so the effectiveness of the system disintegrates quickly if they are attacked.[7]

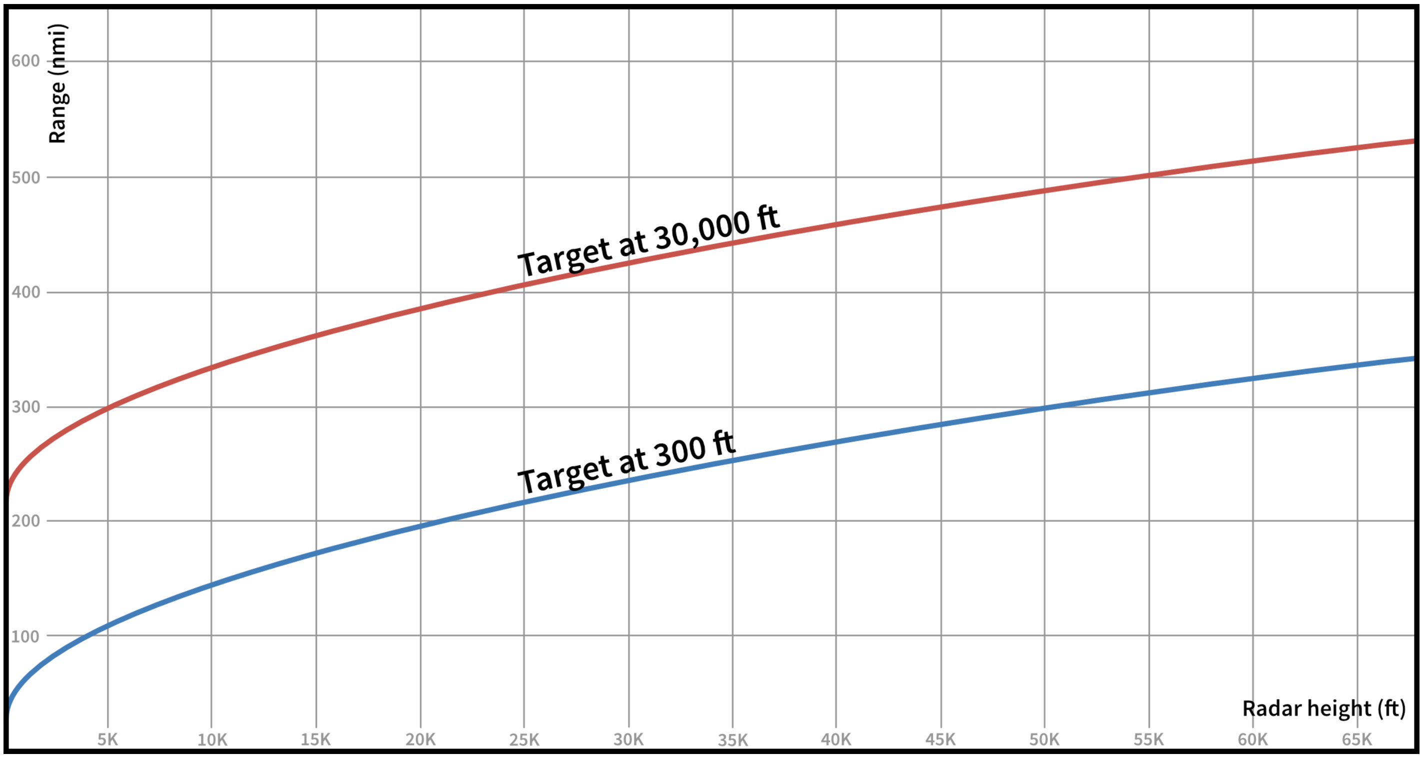
As air and missile threats become more diverse and maneuverable, a new type of sensor architecture is also necessary. Adversaries have not only developed a wide range of platforms for air and missile attack but have also worked to structure complex attacks. Countering these developments will require a sensor architecture rebalanced across multiple domains to provide resilient sensing options for both defensive systems and attack operations.

THE ADVANTAGE OF ELEVATION

One straightforward way to improve today's air and missile defense sensor architecture is to develop and deploy elevated sensors, whether on fixed platforms, aircraft, or even as payloads on satellites in space. Elevated sensors have at least three advantages over existing terrestrial-based systems. First, elevated sensors can detect ballistic, hypersonic, and cruise missile and other aerial targets at greater range (Figure 1). If a target is flying at a 300-foot altitude, for instance, a sensor 10 feet off the ground would have a range of about 25 nautical miles. A sensor in a tethered aerostat 10,000 feet off the ground would have a range of 144 nautical miles, and a high-altitude aircraft operating at 60,000 feet would have a range of about 323 nautical miles.[8]

Extending the horizon is particularly critical for cruise missile defense, countering unmanned aerial systems (UASs), and hypersonic defense. Unlike ballistic missiles, cruise missiles travel at lower altitudes and on unpredictable flight paths, which may be outside the field of view of terrestrial sensors. Figure 2 depicts how airborne sensors can overcome these limitations using the example of the Naval Integrated Fire Control-Counter Air (NIFC-CA) concept. Elevated sensors increase the engagement area by adding sensor coverage beyond the line of sight of terrestrial radars and by looking out, or down, over other terrain features that could obscure cruise missiles or small UASs from view. Earlier detection, in turn, buys time for dispersal, hardening, or other types of passive defense and increases engagement time for active defenses.

Figure 1: Relationship between Radar Height and Range



Source: Congressional Budget Office, CSIS Missile Defense Project.

Second, elevation creates the opportunity to field a more diverse architecture that leverages different phenomenology—such as infrared or lasers. More diverse sensing capabilities would allow the United States to detect incoming missile threats more reliably. These alternative data sources would also improve the ability of detection and tracking algorithms to isolate missile tracks and facilitate other missile defense operations.

Earlier detection, in turn, buys time for dispersal, hardening, or other types of passive defense and increases engagement time for active defenses.

Finally, airborne sensors, by virtue of their smaller size and mobility, may be easier to disaggregate, adding to their survivability over static terrestrial systems. Fielding smaller platforms in larger numbers could increase air and missile defense architectures' resilience by removing single points of failure and complicating adversaries' attempts to target critical nodes. Certain aircraft may also be substantially cheaper than additional terrestrial platforms, making them easier to field and replace in large quantities.

To be sure, elevated sensors come with trade-offs and limitations. More distributed sensor platforms require stronger and more resilient network capabilities to send their data where it is needed. Elevation can also reduce the resolution and fidelity of that sensor due to size, weight, and power limitations—which can, in turn, limit their ability detect, classify, and track their targets.

Increasing fidelity often requires increasing the size of both the sensor and the platform, affecting their procurement and operational costs. Placing sensors on multi-mission platforms can also create operational issues, with commanders competing to use them for different missions. Managing these trade-offs will require finding the right mix of terrestrial and elevated platforms.

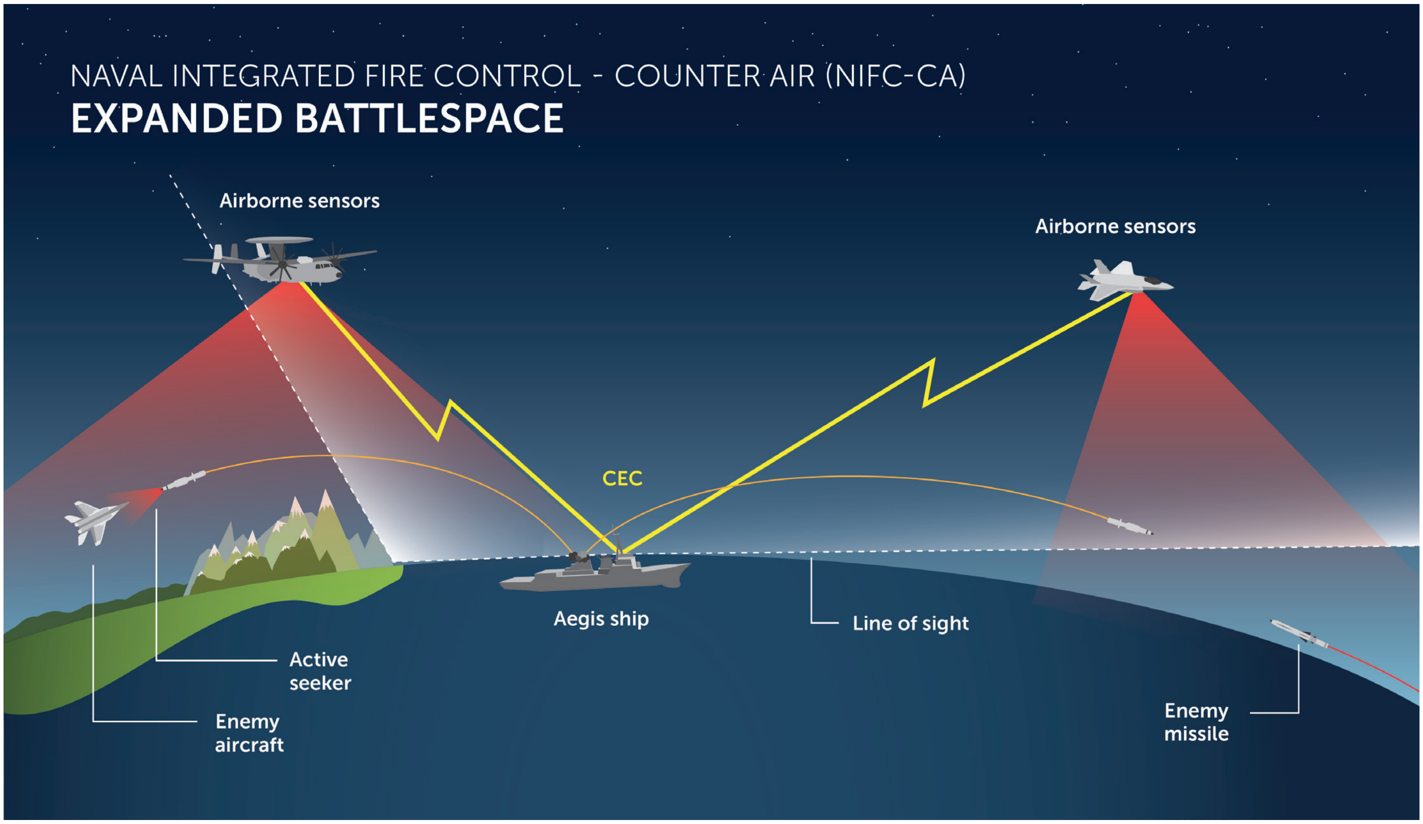
PLATFORM AND DOMAIN OPTIONS

Platforms for elevated sensors can be categorized into three distinct types: elevated ground-based radars and tethered aerostats; aircraft; and space-based satellites. Each carries benefits and operational challenges.

TOWERS AND AEROSTATS

One option to leverage the advantages of elevation is to place new sensor platforms on higher terrain, such as large hills or mountains, or on aerostats—lighter-than-air

Figure 2: Naval Integrated Fire Control-Counter Air (NIFC-CA) Expanded Battlespace



Source: CSIS Missile Defense Project.

platforms that are tethered to the ground. These basing options provide the smallest increase in range but could offer lower procurement and operating costs. Elevated ground-based sensors and tethered aerostats would be best suited to missions tracking lower-flying threats such as cruise missiles, which may not be detected by higher flying sensors.

Elevated land-based sensors have been used in tests to mimic sensor-equipped aircraft for cruise-missile defense. For example, the Navy used an elevated radar during its Mountain Top demonstrations in 1996 as a stand-in for an E-2C aircraft, serving as both a tracking device and a node in the Cooperative Engagement Capability network under development.[9] Where geography is conducive, topography alone could have significant operational utility, especially in areas where air traffic makes consistent deployment of military aircraft unfeasible. Hills or mountains on an island, such as Guam, present a ready advantage to expand the battlespace.

Homeland cruise missile defense is a mission ripe for the use of ground-based elevated sensors. This was the vision for the cancelled Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS) and the subject of U.S. Northern Command's recent request for funding for an elevated sensor for the National Capital Region.[10]

The demise of the JLENS program points to operational challenges. In a fateful 2015 incident, a prototype JLENS aerostat became unmoored in bad weather and traveled for hundreds of miles before crashing in rural Pennsylvania. The incident discouraged further investment in similar capabilities. Challenges of weather can be overcome, however, and such incidents can usually be managed, according to former Secretary of Defense Ashton Carter.[11] The United States has successfully deployed smaller aerostats to protect forward operating bases in Afghanistan and elsewhere. Deployment at lower altitudes, more attention to weather, and a different attitude toward attrition—as with installations at forward operating bases—can contribute to the return of aerostats.

AIRCRAFT

Fixed-wing aircraft can also contribute to the air and missile defense mission. Aircraft offer proven platforms that can get sensors closer to, and even within, contested airspace, but their operational costs can be higher. Aircraft are also limited in which sensors they can carry, depending on size, weight, and power requirements, and the aircraft's own payload capacity.

MDA has been investigating using dedicated aircraft for missile defense sensors for some time. In its fiscal year (FY) 2011 budget, for example, MDA requested over $500 million over the Future Years Defense Program to develop the Airborne Infrared sensor program, which would have integrated a ballistic missile defense sensor onto a UAS. In the 2016 Pacific Dragon exercise, MDA demonstrated the ability of UASs to contribute to the boost-phase tracking of target missiles.[12] According to its 2021 budget submission, the agency is exploring options to partner with the military services to integrate multispectral sensors into operational platforms for prototyping and development.[13] The reduced size and weight of gallium nitride radar technology could enable more airborne platforms to carry radars as well.[14]

Existing platforms could also be modified to contribute to missile defense sensing through interchangeable payloads or pods. This would allow theater commanders to use unmanned aircraft flexibly, configuring the same platform to perform different missions depending on need. This could include using separate sensor packages for separate missions, from air and missile defense to more traditional intelligence, surveillance, and reconnaissance for a precision strike. Airborne surveillance and tracking is also an area where allies could contribute. Japan is reportedly studying the role of UASs for detection and early warning of both ballistic and hypersonic missiles.[15]

Airborne platforms do not need to be dedicated air and missile defense assets to contribute to the mission. DoD's Joint All-Domain Command and Control (JADC2) strategy aims to develop the networks necessary to leverage sensors already mounted on manned and unmanned aircraft. In 2018, former MDA director Lieutenant General Samuel Greaves challenged missile defense organizations to do this, saying, "Our job is to look outside of the classic missile defense system. . . and look for sensors and shooters that would be able to contribute when integrated into the [Ballistic Missile Defense System]."[16] The Army and Air Force have already tested such a capability, with an F-35 aircraft supporting an Army Patriot engagement in July 2021 using the Integrated Air and Missile Defense Battle Command System (IBCS) network.[17]

Fixed-wing aircraft would also play a critical role in attack operations for missile defeat, either as a strike asset themselves or as a source of targeting data. In some ways, this would be an adaptation of current operations around the globe where unmanned aircraft have become the preferred strike platform for targeting terrorist leaders. Tactics and capabilities may need adjustments, however, to be appropriate for a more contested air domain. DoD seems to be making some of these investments already through programs such as the Defense Advanced Research Projects Agency's (DARPA) LongShot.[18]

Several recent events demonstrate the value of elevated sensors in supporting such strike missions. In Ukraine, Russia has used unmanned aircraft to fill critical intelligence gaps to direct rocket and artillery fire in the Donbas region.[19] In 2020, Azerbaijan used drones extensively to support its operations in the disputed Nagorno-Karabakh region, including to strike Armenia's high-end air and missile defense assets, such as the Soviet S-300 system.[20] Iran has also demonstrated the ability to use unmanned aircraft to provide targeting information for ballistic missile strikes during its Great Prophet 15 military exercises.[21]

"Our job is to look outside of the classic missile defense system. . . and look for sensors and shooters that would be able to contribute when integrated into the [Ballistic Missile Defense System]."

—former MDA director Lieutenant General Samuel Greaves

With sufficient networking, the range of support from aircraft could expand to direct long-range fires, including hypersonic strike. Such cueing will be especially important for time-sensitive missile defeat missions. In environments with thick air defenses, however, this would also be difficult, requiring either survivable aircraft or a sufficient number of less costly and attritable unmanned platforms.

SPACE

Some of the greatest benefits of sensor elevation can be realized from placement in space. The United States has long recognized the important role that satellite-based sensors can play in early warning and detection of missile launches, having deployed its first Defense Support Program (DSP) satellites in the early 1970s. Each of the past six administrations has established a plan to deploy a space-based layer of missile tracking satellites as well, but none thus far has deployed more than a few demonstration satellites.

The creation of the U.S. Space Force and Space Development Agency suggests a growing interest within

DoD in developing and deploying a new generation of space-based assets, including those for missile warning and tracking. The Space Force is in the process of replacing the legacy DSP and Space-Based Infrared System (SBIRS) satellites with the Next Generation Overhead Persistent Infrared (OPIR) sensors for initial missile warning. The sensor payload for these geosynchronous-orbit satellites passed a critical design review in August 2021.[22]

MDA, in collaboration with the Space Development Agency, is also working to deploy a constellation of lower-orbit tracking sensors for both hypersonic and ballistic missiles, called the Hypersonic and Ballistic Tracking Space Sensor (HBTSS). These satellites are planned to replace and expand upon the coverage of the Space Tracking and Surveillance System (STSS) satellites, which MDA plans to decommission in the next few years.[23] The Space Force also recently revealed plans to develop Ground Moving Target Indicator (GMTI) radar satellites for tracking moving terrestrial targets. These could also provide the data necessary to target mobile missile launchers.[24]

Constellations of space sensors offer the potential to track missiles from launch all the way through their flight. This "birth-to-death" tracking capability would allow the United States to track a maneuvering threat continuously, making space sensors particularly important for countering hypersonic and maneuvering ballistic missiles. This also reduces the need to be able to pass off the track between multiple terrestrial sensors, which ensures a consistent track quality.

These significant advantages also come with trade-offs. The primary barrier to deploying a constellation of space sensors is cost. Despite progress in reducing the price of satellite bodies, sensors, and associated space launches, the cost of their deployment generally increases as the capability of the sensor payload (and thus the weight) increases. These cost issues currently contribute to space-based assets' scarcity, which can also create competition over their missions and tasks.

EXTENDING THE HORIZON

In today's strategic environment, the ability to find hidden adversary missiles before and after launch will be increasingly critical to broad U.S. deterrence and defense goals. While General Hyten's aspiration of having all-seeing overhead sensors may never quite be realized, his choice to highlight elevated sensors underscores the importance of that feature in the sensor architecture of the future. Fielding new elevated sensors in space is a key component of moving toward that vision, but other suborbital elevation—from towers to high-altitude aircraft—will also be useful to significantly extend the practical horizon for the surveillance, tracking, and targeting needs of both strike and air and missile defense. ■

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