Unleashing Resilient Space

Creating a More Flexible, Adaptive, and Resilient Space Architecture to Guarantee

Space Superiority

Proposal Paper for Team “Heather's Hooligans”

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Executive Summary

The U.S. faces a rapidly evolving threat landscape in space, with adversaries like China and Russia actively developing counter-space capabilities to exploit US reliance on space-based assets. These threats range from reversible jamming and cyberattacks to destructive ASAT missiles and on-orbit manipulation, potentially crippling US military operations and national security. To counter this, the US must achieve decision superiority by operating inside the adversary's OODA loop, requiring resilient and responsive space systems. The "Golden Dome" initiative aims to establish a next-generation missile defense shield, but its success hinges on resilient space architectures capable of providing timely data to decision-makers.

Current US space systems suffer from stove piped command and control (C2) and outdated survivability/endurability requirements hindering rapid acquisition and deployment of new capabilities. Overcoming policy barriers, leveraging commercial technologies and international partnerships, and embracing rapid reconstitution are crucial for achieving resilience. The Tactically Responsive Space (TacRS) program exemplifies the potential for rapid reconstitution, while initiatives like FORGE and GRIFFON demonstrate a shift towards modern, flexible software-defined ground systems.

Key recommendations include streamlining acquisition processes, embracing risk-taking in program management, fostering closer collaboration with allies and commercial partners, and prioritizing the development of robust, distributed, and cloud-based Space C2 architectures. These efforts are essential to ensure data path diversity, enhance cybersecurity, and enable rapid data processing and dissemination to decision-makers at all levels. By prioritizing resilience in space, the US can effectively deter aggression, maintain space superiority, and safeguard national security in the face of evolving threats.

Problem Statement

The U.S. needs the ability to react to adversary attacks quicker than the adversary can counterattack (i.e. "Getting inside the enemy's OODA loop"). This will require robust, distributed command and control systems to pass, store, process, and synthesize data in quick timelines across various platforms so decision-makers can determine the action needed against adversaries on demand. Space systems will provide the first indications and warning of an attack. Thus, the data from those sensors must be transported and processed in, from, and to all areas of conflict at the speed needed to help decision-makers at tactical levels. Unfortunately, current systems have stove-piped command and control (C2) systems, and workaround integration attempts may not result in decision-making at relevant timelines to thwart new threats. However, having a space command and control system (Space C2) enabled by data/communications path diversity (i.e., resilience) will increase the speed of data flow and accessibility to allow decision-makers to make and act on decisions faster.

Threat Landscape

The U.S. requires flexible and adaptive methods to reconstitute space-based capabilities as competitor nations are developing and deploying various means to challenge the U.S. position in the space domain. Our adversaries view U.S. dependence on space-based capabilities as a potential weakness to exploit and are developing concurrent and accelerating capabilities to target terrestrial, on-orbit, and cyberinfrastructure. Unfortunately, actions in space have a direct effect on our National Security. "Our air, land, and sea forces rely on critical capabilities delivered by systems in orbit. Our adversaries know this, and it is why they are fielding weapons capable of destroying U.S. satellites that deliver intelligence, navigation, missile warning, and global communications for our forces. Failure to address these threats would be catastrophic to our soldiers, sailors, airmen, and marines in a conflict, let alone the outcome of a war." (Chilton, 2023)

This rapidly evolving and strategic environment threatens U.S. space infrastructure with a range of capabilities from China and Russia that span from reversible effects that are non-destructive and temporary through the continuum of permanent effects that result in permanent degradation or physical destruction across an infrastruc-ture that encompasses both terrestrial and space domains. Additionally, the expanding relationships between China and Russia with the proliferation of technology and growing cooperation with Iran and the Democratic People's Republic of Korea (DPRK) create emerging challenges as each continues to develop its space programs. Ultimately, the most stressful scenario for U.S. National Security is the ability to operate through a first strike from an undeterred adversary against our space enterprise. The first steps to any confrontation with our adversaries will initiate in space.

Both China and Russia have consistently viewed U.S. actions in space as threatening, with the intent of demonstrating hostile intent, and have worked to exploit the American "Space Pearl Harbor." (Blanc, Beauchamp-Mustafaga, Holynska, Bond, and Flanagan, 2022). China and Russia promote strategic communication to limit the militarization of space. However, both countries are developing toward the contrary. China's first revelations of the U.S. dependence on space-based capabilities emerged through the U.S. military's performance, starting with the first Gulf War and carried forward through actions in the second Iraq War leveraging space-based assets to guide munitions to increase lethality. (Cheng, 2011) "Chinese military analysts have noted the dependence of the U.S. military on space and have concluded that the degradation of U.S. space capabilities may result in decisive losses for the U.S. military." (Pollpeter, Anderson, Wilson, and Fang, 2015) As a response, Chinese defense academics have promoted the need to develop space and counter-space capabilities to impede U.S. intervention in regional conflicts.

Chinese space and counter-space capabilities are being fielded at a breathtaking pace and are designed to "blind and deafen the enemy" (DoD, 2020). "Space has become a new domain for contemporary military conflicts and is a key factor in determining military reforms. It will significantly impact the evolution of future warfare's forms, methods, and rules. Therefore, paying attention to the situation of military conflicts in space and strengthening the research on issues of military conflicts in space are critical subjects of military strategy." (CASI, 2020) To this end, China has developed various capabilities to target U.S. and allied support. (ODNI, 2024)

China's use of electronic warfare (EW) emphasizes suppressing, degrading, disrupting, or deceiving enemy electronic equipment to deny multiple types of communications, radar systems, and GPS navigation to hinder enemy movement and the use of precision-guided munitions. (DoD, 2020) Cyberspace capabilities could be used against space-based assets to support military operations. (DoD, 2020) A likely scenario would be the Chinese employment of a cyber-attack during the initiation of a conflict to disrupt an adversary's actions by targeting network-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), logistics, and commercial activities. (DIA, 2022)

Over the last 20 years, Chinese defense research has proposed the development of Directed Energy Weapons (DEW) spanning reversible and non-reversible counter-space effects. (D. I. (DIA, 2022) These include dazzling (temporally blinding) electro-optical sensors to destroy imaging components potentially. (DIA, 2022) Chinese ground-based laser weapons vary in power to disrupt and degrade satellites, which can provide a variety of adverse effects. China is potentially fielding higher power systems that extend the threat to satellite structures. (DIA, 2022)

China has likely continued the development of its anti-satellite (ASAT) capabilities following the 2007 destruction of one of its defunct weather satellites in low earth orbit (LEO) with an ASAT missile. (DIA, 2022) China's military units have continued training with ASAT weapons. They probably intend to pursue additional capabilities as they "… launched an object into space on a ballistic trajectory with a peak orbital radius above 30,000 kilometers, near GEO altitudes". (DIA, 2022) The launch profile did not match traditional space launch vehicles (SLVs), ballistic missiles, or other scientific testing vehicles and suggests a Chinese capability to use ASAT technology against one of the farthest satellite orbits. (DoD, 2020)

Satellite inspection and repair is another capability China is developing that could serve as a means and method to turn off adversary satellites. (DIA, 2022) Launched to conduct experiments for on-orbit space maintenance and space debris cleanup, these satellites have the potential to be used as weapons. (DIA, 2022) The Chinese Shijian-17 satellite launched in 2016 into GEO raised concerns due to its curious maneuvers and robotic arm, while the Shijian 21 towing of the Chinese non-functioning Beidou navigations satellite into a high GEO graveyard orbit in January 2022 showcased the dual-use nature of these capabilities. (DIA, 2022)
China has also continued research and development on space-based kinetic weapons, including various delivery vehicles, payload separation, and re-entry techniques for targeting purposes. (DIA, 2022) China's 2021 fractional orbital launch of an ICBM with a hypersonic glide vehicle 2021 demonstrated "… the most significant distance flown (~40,000 kilometers) and longest flight time (~100+ minutes) of any Chinese land attack weapons system to date. (D. I. (DIA, 2022)

As the pioneer of space flight, Russia has a long-established understanding of the benefits of access to the space domain. Russia, like China, views space as a critical enabler for the U.S., labeling it an "Achilles Heel" to be exploited. (Sputnik News, 2016) Furthermore, Russian defense academic writings and doctrine identify space as a war-fighting domain and a significant factor in achieving Russian military objectives. (Chekinov, 2013) (AFP, 2014) "Slowly but surely, we are heading toward [mili-tarization of space]. Roscosmos has no illusions about this. Everyone is working on it." —Dmitry Rogozin, then Chief of Russian State Corporation Roscosmos (Cole, 2019). Russia remains committed to improving its ability to access and operate in space by modernizing its military and integrating space capabilities; however, it is within a more limited scope than China. After years of neglect, Russia is limited by its budget and competing priorities. (Bodner, 2017)

Additionally, technology sanctions imposed by the West have exposed weaknesses in the Russian use of space as a military asset, as seen in the unsuccessful interventions in Syria and the ongoing war in Ukraine. However, the Russian desire to diminish U.S. prestige should not be underestimated, with space being a primary target for erosion. (Swope and Young, 2024)

Russia seeks to seize the operational initiative by disrupting its adversary's Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance with the full spectrum of EW capabilities. It has fielded ground-based systems to counter tactical communications, satellite communications (SATCOM), GPS, and radars. (DIA, 2017) Russia's capabilities have been honed and refined as Syria has become "the ultimate testing ground" as they were able to employ EW capabilities to undermine adversary capacities in the region. (Varfolomeeva, 2018) (Rane, 2017) Russia's development of forces and capabilities to include cyberspace operations supports a holistic concept that weaponizes information that can be employed in times of peace, crisis, and war to include the targeting of space-enabled information collection and transmission. (DIA, 2017)

Russia's use of DEWs threatens adversary space operations with several ground-based lasers that could be used to blind satellite sensors. (DIA, 2022) The Peresvet, named after an orthodox monk who was killed in single combat, is a laser weapon system that has been fielded to Russian forces and has been indicated by the Russian leadership to have an ASAT mission. (O'Connor 2018) (Nebehay, 2018) (Hitchens, 2022) In public statements, Russian President Vladimir Putin called the Peresvet a capability that "…until just recently only figured in science fiction." (Associated Press, 2019) Russia will probably field more capable lasers to damage various satellite structures, not just electro-optical sensors. (DIA, 2022)

Russia is developing ASAT missiles that can destroy adversary space systems in LEO. (DIA, 2022) The Nudol is a Russian mobile missile defense complex capable of destroying ballistic missiles and low-orbiting satellites. (Thomas, 2019) In late November 2021, the Nudol weapon system destroyed a defunct Russian satellite in LEO and created tens of thousands of pieces of lethal, non-trackable debris. Russia will likely continue to develop ASAT capabilities, looking to expand into other orbital regimes. (DIA, 2022)

Russia's launch in May 2024 of the COSMOS 2576 followed up on a growing orbital capability for inspection and servicing satellites that can closely approach satellites to inspect and repair malfunctions or conduct an attack resulting in temporary or permanent damage. (Paroozi 2024) In addition, Russia likely continues to build upon space-based ASAT capabilities, as demonstrated in July 2020 when the COSMOS 2543 ejected an object at high speed, characteristic of a weapon. (USSPACECOM, 2020) Russia will likely continue the development of other co-orbital ASAT capabilities. (DIA, 2022)

The ability to anticipate, defend against, recover from, and respond to a wide range of threats will depend on our integrated space enterprise's resilience and defensive capabilities. We must build resilience into the plans and architectures for capability development and resourcing. However, regulatory hurdles and antiquated interpretations threaten the implementation of the Proliferated Warfighter Space Architecture (PWSA). Additionally, it is incumbent to modernize our ground systems and installations to ensure our systems meet dependability, availability, and reliability standards. These investments in resiliency will be necessary to sustain capability in the face of advancing quality and quantity of adversary threats.

Current NC3 space architecture is driven by the ICBM threat that consumed the U.S. during the Cold War. At the time, the systems needed to be survivable through a nuclear detonation and operate for a certain period after an attack. With the deterrence strategy in full effect, the country had time to develop large, exquisite satellites and ground systems to address these survivable and endurable requirements. Due to limited access to launch vehicles, it was expensive to launch satellites; thus, the DoD would pile hundreds of these requirements on a satellite and launch on massive rockets to get to the highest orbits. The nation had clear space superiority and had the luxury of time to develop and launch new capabilities.

In the last decade, the threat landscape has changed significantly from the sole focus on ICBM attacks to the homeland. Open sources show hypersonic glide vehicles (HGVs) pose a new asymmetric threat. These weapons are highly maneuverable, can go anywhere globally, and can carry a variety of payloads. These weapons have a dimmer, faster signature, challenging today's on-orbit and ground-based sensors. Additionally, threats such as heavy intercontinental ballistic missiles, nuclear-powered cruise missiles, or newer, harder-to-qualified threats are emerging to increase complexity in the space domain, such as cyber warfare, hybrid threats, and advanced technologies like artificial intelligence used by adversaries. All these threats make it imperative that the nation fields capabilities faster than before. The U.S. no longer has the luxury of time, especially given that the size of specific adversary's arsenals exceeds our defenses.

Golden Dome for America

The Iron Dome for America effort (now called “Golden Dome”) kicked off by President Trump early in 2025 is energizing the missile defense community to action. "The Executive Order directs the implementation of a next-generation missile defense shield for the U.S. against ballistic, hypersonic, advanced cruise missiles, and other next-generation aerial attacks. To provide for the common defense of American citizens, this order accelerates the development and deployment of Hypersonic and Ballistic Tracking Space Sensor Layers, proliferated space-based interceptors, a Proliferated Warfighter Space Architecture, capabilities to defeat salvoes prior to launch, non-kinetic missile defense capabilities, and underlayer and terminal-phase intercept capabilities." – Iron Dome for America Fact Sheet.

Within 60 days, an all-encompassing report of the missile defense kill chain will be created, explaining the feasibility and affordability of fielding current and future systems in an accelerated manner. The Executive Order directs:

"(a) Submit to the President a reference architecture, capabilities-based requirements, and an implementation plan for the next-generation missile defense shield. The architecture shall include, at a minimum, plans for:

(i) Defense of the U.S. against ballistic, hypersonic, advanced cruise missiles, and other next-generation aerial attacks from peer, near-peer, and rogue adversaries;

(ii) Acceleration of the deployment of the Hypersonic and Ballistic Tracking Space Sensor layer;

(iii) Development and deployment of proliferated space-based interceptors capable of boost-phase intercept;

(iv) Deployment of underlayer and terminal-phase intercept capabilities postured to defeat a counter value attack;

(v) Development and deployment of a custody layer of the Proliferated Warfighter Space Architecture;

(vi) Development and deployment of capabilities to defeat missile attacks prior to launch and in the boost phase;

(vii) Development and deployment of a secure supply chain for all components with next-generation security and resilience features and

(viii) Development and deployment of non-kinetic capabilities to augment the kinetic defeat of ballistic, hypersonic, advanced cruise missiles, and other next-generation aerial attacks;" - Iron Dome for America Executive Order

The Executive Order also requires that "The U.S. continues to cooperate on missile defense with its allies and partners to aid in defense of all populations and troops and of forward-deployed U.S. troops. Following the submission to the President of the next-generation missile defense reference architecture under section 3(a) of this order, the Secretary of Defense shall direct a review of theater missile defense posture and initiatives to identify ways in which the U.S. and its allies and partners can:

(a) Increase bilateral and multilateral cooperation on missile defense technology development, capabilities, and operations;

(b) Improve theater missile defenses of forward-deployed U.S. troops and allied territories, troops, and populations; and

(c) Increase and accelerate the provision of U.S. missile defense capabilities to allies and partners." – Executive Order for Iron Dome for America

Space systems, whether on-orbit or on the ground, provide the first indicators of an attack "left of launch." Increasing the resiliency of existing systems will directly contribute to the Golden Dome for America effort by ensuring U.S. decision-makers act quicker than adversaries and ensuring the Golden Dome "Systems of Systems" has the capacity and bandwidth to endure the long fight without being oversaturated.

The Answer to Golden Dome: Increase Resiliency of Space Systems

Systems that are fielded in the future must focus on sensing these new, more likely threats and providing data to decision makers faster than the enemy can respond in a variety of environments and conditions. John Plumb, Assistant Secretary of Defense for Space Policy, said, "We have to be resilient because the adversary is coming for us. And so what we need is a constellation that allows me to take a punch, fight through, absorb a blow and kind of degrade the ability of an adversary to take a shot." (Erwin, 2022) Resiliency is a way to challenge threats by increasing overall system performance and robustness. It can be implemented in many ways, such as orbital diversity (e.g., sensors in LEO, MEO, and GEO), proliferating smaller and cheaper sensors in lower orbits to track and maintain custody of hypersonic weapons as they travel through all phases of flight. Having more satellites requires keeping the costs of the satellites low so the constellation can be reconstituted (i.e., satellites launched and deployed quickly) in the event of system failure or attack. Other ways to implement resiliency in a system are through diverse communications paths and expanding ground operations command and control architecture.

We must depend on allied and commercial support to get after resiliency quickly. In an interview with the Missile Defense Advocacy Alliance, General Michael Guetlein, VCSO, stated, "We are all good at operating in our stovepipes, but we are not good at integrating across organizational boundaries. The other thing that has changed from a space perspective, a significant change from a space perspective, is we used to believe we had to own and operate our own kit. I needed to build everything myself, and I needed to operate it myself. That was primarily because we owned the corner of technology. We had the best technology on the planet. However, at the same time, I didn't think I could trust my allies and my commercial partners to always be there during times of crisis or conflict when I needed them without debate. The last thing that has changed slightly from a space perspective is that we didn't want to integrate with our commercial partners because we didn't want to put a target on their backs. We didn't want to make them a combatant. We are learning from Ukraine: first, the allies will be there. Commercial partners will be there. They will protect and defend their own kit. But then Russia came out and said everybody in space is a target. I don't care if you're commercial. I don't care if you're DoD, allied, or civil. You're all a target. Well, if we're all operating in the same domain, we're all integrated and networked together, and we're all going to be shot at together, we'd better learn how to collaborate and cooperate together. So, we are able, from a space perspective, to leverage all that innovation coming out of industry today to field capabilities faster, more capable, and at a better price point than we have ever been able to do in history of space." (Elison 2025)

Barriers to Achieving Resiliency

Policy Barriers- Survivable/Endurable

The missile warning/tracking (or NC3) architecture's ability to improve resiliency is hampered by the interpretation of Presidential Policy Directives that drive challenging survivability and endurability requirements. It is questionable if the solution being dictated will mitigate today's most relevant threats. Solving survivability and endurability through resiliency will be more cost-efficient and technically feasible.

Survivable and endurable requirements were written into the Capability Description Documents of these systems since the Cold War and have been passed down into our systems today. These requirements were written with a nuclear attack lens to be ready in the event of a nuclear ICBM attack on the United States. Survivability means a system must operate during an attack. In contrast, endurability means the system must be able to operate in the aftermath. These requirements have been interpreted to require hardening to these systems, and the solutions can be implemented in satellite or ground systems.

Technology Barrier- Hardening

The sensors and satellites must have triple redundancy with "rad-hard" (radiation-hardened) parts for on-orbit systems. Because of the extensive testing and development, these generally triple the cost of the satellite and significantly increase the spacecraft's SWAP (Size, Weight, and Power). When the U.S. government has taken years to field new satellites, this dilemma is often one of the main contributors to schedule delays and significant cost growth.

For ground systems, hardening means having facilities on the ground that can withstand the impact of an incoming missile. This requires enormously thick walls and a sustainment tail that can support the isolation of personnel for a significant period. Communication nodes also must be secured in this manner, often with triple redundancy, causing significant cost growth. For endurability requirements, mobile and transportable systems are fielded, often with a large sustainment and training tail and, in some cases, requiring it to be pre-staged with international partners at a high cost of time and money.

All these requirements contribute to declaring a system an ITW/AA (Integrated Tactical Warning Attack Assessment) certified system. As of late, ITW/AA has become a scalable process, allowing proliferated on-orbit sensors to contribute to the ITW/AA network without the prohibitive survivable and endurable requirements to slow down fielding. This process demonstrates that the NC3 community is open to looking at new sources and ways of flowing data to ensure a better sense of the threat climate. Policy must reflect this new approach to achieve alignment across the entire community.

Classification Barrier- Sharing data with Allies, Commercial

Due to classification barriers, we are hindered from truly integrating with our Allied partners. The Joint Capabilities Office (JCO) has figured a way around that barrier. It is an organization fusing commercial sensor data and delivering to Allies for a threat picture. General Guetlein states, "We're in the dozens of allies today collaborating in the data lake primarily for space domain awareness. We have what we call a JCO, a joint commercial office right now, that is operating in New Zealand, the UK, and the U.S. We have 15-plus countries already sitting on all those ops floors, passing data in and out of the data lake and giving us exquisite space situational awareness." (Elison 2025)

Sharing data with our trusted international partners and commercial industry is another barrier to achieving resiliency that must be overcome to achieve our national security goals.

Inconsistent U.S. policies on disclosing classified information are a critical barrier to space collaboration with allies and the commercial industry. RAND Project Air recently investigated how to better integrate allies, partners, and industry into space collaboration and identified six key issues (RAND 30 January 2024).

1. The DoD space enterprise (U.S. Space Force, U.S. Air Force, U.S. Space Command, and the Office of the Secretary of Defense for Policy) does not have a cohesive vision and desired goalpost for partnering.
2. DoD space enterprise roles and responsibilities of key offices with a space remit remain contested or blurred.
3. DoD regulations, processes, and architecture limit the ability to integrate with allies and partners fully.
4. The U.S., its allies, and partners lack suitable, interoperable communications standards and structure across classification levels.
5. The issue is that the U.S. says what it wants to do but cannot follow its promise regarding space collaboration, which is dangerous for the entire coalition.
6. The U.S. space community lacks direction from the top about what we want out of cooperation to improve our overall space force design, and worse, the U.S. space enterprise cooperation process is ineffective.

A fight against a common adversary can only be won with international cooperation. Integration with international partners cannot indeed occur when data is withheld. We are making strides when it comes to space security cooperation. As of 1 April 2025, the Office of the Secretary of the Air Force, International Affairs (SAF/IA) International Agreements Data Base (IADB) indicated that The Department of the Air Force has developed, negotiated, and concluded 38 international agreements (and 14 amendments), across 17 different partner countries, spanning all space mission areas and classification levels, with an overall value of $54.737b ($48.85b U.S.; $5.88b Partners). The USSF Space Systems Command (SSC) International Affairs office has received 67 new Foreign Military Sales requests since the standup of space FMS in 2021. Thus far, SSC has 812 implemented FMS Case Lines valued at $876.3M, with 81 case lines implemented in FY24 valued at $223M. More cooperation is on the horizon, and the DAF must be poised to accept and deliver on this collaboration where it makes sense for U.S. national security.

Achieving Resiliency: Responsive Acquisition, Rapid Reconstitution, Resilient Space C2

Responsiveness in Space Acquisition

The forward to DoD's Planning, Programming, Budgeting, and Execution (PPBE) Reform Implementation Report states that the plan "reflects a shared commitment across the Department to addressing the urgent need for flexibility when the world changes overnight." (Department of Defense 2025) Notably, the potential likelihood for an overnight change is a defining characteristic underpinning the DoD's focus on PPBE reform. The connotation here for overnight change is that the conflict we will face with potential adversaries will not be static. It will likely be a dynamic and evolving conflict with emergent threats driving new requirements. While we can pursue resilient space systems today based on known and predicted threats, resiliency and responsiveness also require agility and speed by both government and industry to rapidly reconstitute degraded systems after attacks, fight through a protracted conflict, pursue new tactics, techniques, and procedures, rapidly modify existing space systems, and pursue new materiel solutions when necessary. Current space doctrine defines responsiveness as "the ability to react to changing requirements and meet combatant commander needs to maintain support."

(Blore, 2023) One need only look at the myriad game-changing threats encountered amid conflict throughout the 20th Century and into the 21st Century to see evidence of this phenomenon. A prominent example of the need for rapid development and fielding of materiel solutions to counter emergent battlefield threats was the unexpected impact of improvised explosive devices (IEDs) by both Iraqi and Afghani insurgents in the early 2000s. The U.S. military was left without an answer, and the Mine Resistant Ambush Protected (MRAP) vehicle program was born to counter these rapidly evolving IED threats. With 75 percent of casualties in Iraq and Afghanistan attributable to IEDs, the MRAP quickly became DoD's most important acquisition program. (U.S. Government Accountability Office, 2009) The urgency to develop the MRAP solution in months, not years, led the DoD to allow for a tailored acquisition approach. "It is the only time in my 42 years in the industry that all bureaucratic silos in the government procurement process were broken down, and there was a single-mindedness of purpose among all involved," said now-retired Pentagon Comptroller Robert Hale. (Judson, 2016) The urgency drove the Army's Requirement Integration Directorate (RID) to cast the net widely in search of prototype solutions, including commercial, government, and allied sources. A subsequent GAO report on key acquisition program attributes for MRAP highlights several themes that still ring true today for the pursuit of urgent operational needs, including reliance on existing/available technologies, commercially available sources, assuming concurrency risk between development, production, testing, and fielding, minimal operational requirements, leveraging multiple suppliers through flexible contracting strategies, incremental deliveries, and priority resourcing. (U.S. Government Accountability Office, 2009)

Fast forward to today, and we continue to see emphasis on speed and agility in acquisition. Recall that a central premise of this paper regarding the definition of resilience is that our ability to fight through a protracted conflict with a thinking adversary will involve more than just the protection of existing capability. It will require both rapid reconstitution of capability, which will be discussed later using the example of Tactically Responsive Space (TacRS), and new material solutions delivered in an operationally relevant timeline. As discussed earlier in this paper, threats to our Space-based capabilities are proliferating. USSF acquirers must leverage rapid acquisition authorities and processes, particularly those aligning well with recent acquisition and PPBE reform efforts. For those weary of seeing the same acquisition reform initiatives played again and again without success, do not expect them to taper off. An examination of key recurrent themes will follow shortly, with some evidence of forward progress. Furthermore, concerns over historical timelines in space programs from authority to proceed (ATP) to availability for launch (AFL) should not be seen as showstopper issues.

Attributes of Rapid Acquisition

As evidenced in the keys to MRAP success noted earlier, successful pivots towards urgent operational needs drive acquisition strategies that do not point to material solutions requiring significant investment in non-recurring engineering (NRE). The former Service Acquisition Executive (SAE) for Space Acquisition acknowledged the importance of limiting NRE for speed in his Space Acquisition Tenets, explicitly highlighting that space system acquirers needed to "…use existing technology to minimize non-recurring engineering in order to shorten development timeliness." (Calvelli, 2022) The cost-estimating community understands this relationship between NRE and acquisition timelines. It is so predictable that many acquisition schedulers focus on the amount of NRE as a predictor for most likely schedule duration. So, if we must avoid NRE-intensive materiel solutions for urgent operational needs, what other attributes of the acquisition process require tweaking? There are many, including but not limited to the following introduced briefly below:

- Leverage commercial capability and international agreements where possible and appropriate. A former SSC Commander, General Mike Guetlein established the mantra "Exploit what we have, buy what we can, and build only what we must.". (Satnews, 2023) This sets the expectation for commercial and allied partnering before searching for government-developed material solutions. Leveraging commercial and international capabilities is covered in greater detail elsewhere in this paper.
- Make significant investments in technology maturation and risk reduction before introducing these technologies into programs of record (PoR), thus increasing the likelihood and availability of mature technology from a broader industry base. While the so-called "valley of death" between technology efforts and Program Executive Offices (PEO)--managed programs and funding is still very much a problem, there are ways to tackle this problem. With an explosion of technological advances in space capability being driven by industry, not government, bridging the valley of death is more about capitalizing on areas where industry investment overlaps with Space Force priorities and avoiding the valley altogether through constant communication and utilizing Other Transaction Authority agreements vs. Federal Acquisition Regulation (FAR)-based contracts to facilitate this goal. (Easley, 2022) In addition, there is increased emphasis on the role of SpaceWerx (responsible for allocating the Small Business Innovative Research (SBIR) funds) in allocating resources towards promising technology, and enhanced involvement from space operators facilitates early and focused technological maturation before initiating new programs.

- Utilize flexible and streamlined acquisition, funding, and contracting mechanisms available through approved Rapid Acquisition Authority (RAA), Middle Tier Acquisition, use of "Quick Start" authorities, and expanded use of Other Transaction Authority (OTA) agreements. OTAs are being increasingly used to facilitate speed in capability delivery. With the 2016 NDAA expanding the use of OTAs beyond prototypes into production, this tool expanded substantially in space systems acquisition. The bill enabled movement directly into production without requiring a competitive award. OTA Agreements offer greater flexibility and fewer constraints than FAR-based contracting. (Obis, 2025)
- Solve THE problem with a minimum viable product (MVP) solution. During a conflict, speed takes precedence over traditional requirements process rigor. A recommendation from the Sec 809 panel regarding expanded authorities given to portfolio acquisition executives enables this approach and is addressed further below.
- Clearly articulate the effort's priority and the need to assume risk where necessary. This concept trickles down to the program management office, where aversion to assuming cost/funding risk and award of "protest proof" contracts are the norm. Addressing the culture of aversion to risk is discussed further below.
- Invest now in the ability to reconstitute space-based capabilities in space and on the ground rapidly. A section on Tactically Responsive Space (TacRS) is provided later in this paper as an example.

Congressional Efforts to Enable Rapid Acquisition

Of the speed enablers noted above, flexible and streamlined rapid acquisition processes and approvals have garnered the most attention in recent years. A few key legislative and policy provisions are as follows:

- FY03 NDAA, Section 806, Rapid Acquisition and Deployment Procedures – directed the SECDEF to establish rapid acquisition procedures. DoD 5000.78, RAA implements RAA procedures as directed.
- FY09 NDAA, Section 801, Assessment of Urgent Operational Needs Fulfillment – directed study and report on the effectiveness of fulfilling urgent operational needs. Led to internal controls for fulfillment through non-DoD agencies.
- FY16 NDAA, Section 804 - provided DoD with a new acquisition pathway for rapid prototyping and rapid fielding of capabilities referred to as Middle Tier Acquisition
- FY16 NDAA, Section 809, Advisory Panel on Streamlining and Codifying Acquisition Regulations - Extensive report with 98 recommendations, including many to simplify acquisition, leverage the marketplace, and improve resource allocation
- FY22 NDAA, Section 1004, Commission on Planning, Programming, Budgeting, and Execution Reform—The final report was delivered in March 2024. It highlighted the need to "respond effectively to emerging threats."
- FY24 NDAA, Section 229 (under Sec 3601)—"Quick Start" allows service secretaries to use specific authorities to initiate urgent or emerging operational development activities for up to one year.

The succession of expanded rapid acquisition authorities provided through legislation and/or recommendations from the Sec 809 Panel and the PPBE Commission have created momentum towards the more incredible speed of delivery. However, the challenge goes deeper than law and policy into acquisition culture and processes, often incentivizing risk-averse behaviors that lead to lengthier acquisition timelines. In addition, there are several tradeoffs involved with shortening acquisition cycle times. Often, these are illustrated as "ceding" oversight and control from both Legislative and Executive Branch stakeholders. In other words, deliberate streamlining or eliminating various checks and balances that characterize traditional major capability acquisitions (MCAs) are sacrificed for speed. Concerns from stakeholders warrant "faster together" solutions that avoid erosion of oversight/insight where possible. However, another tradeoff is with program scope and risk management practices. Cultural impediments and "off-target" PM incentives that support risk-averse behavior undermine the potential to exploit rapid acquisition efforts.

Faster Together

As one sifts through the hundreds of acquisitions and PPBE reform proposals captured in the last few decades, the authors of this paper recommend specific attention towards those proposed reforms that offer novel methods to preserve authorities and oversight, but with everyone moving faster together. There are various instances where role players have acknowledged that we need to move faster, only to be followed with the statement, "But we are not the ones holding things up." When Space and Missile Systems (SMC) personnel were asked to assist the Congressional Sec 809 Advisory Panel on Streamlining and Codifying Acquisition Regulations, perceptions of timely coordination were tackled head-on. The panel, created by the 2016 National Defense Authorization Act (Public Law 114-92), was charged with the task of offering recommendations to transform the DoD acquisition system in ways that would address the challenges of the 21st Century, including the need for our acquisition system to "adopt a wartime footing" and improve delivery timelines. Regarding misperceptions over contributing factors associated with lengthy coordination, the Department of Air Force and SMC personnel gave the panel insights into the typical processing cycle times for an out-of-cycle "New Start" approval. Cumulatively, the process took 182 days on average from DAF submission to

Congressional approval, but over half of that time involved simply "getting it out of the building (i.e., Pentagon)." Nevertheless, subsequent discussions with Congressional professional staff members (PSMs) uncovered a perception among them that approval from the four Defense Subcommittees was happening "quickly." An example provided by SMC that was included in the Sec 809 Volume 3 report was the near failure to secure New Start approval on the Enhanced Polar System Recapitalization (EPS-R) in time to exploit the proposed partnership between space Norway and the U.S. government and meet Space Norway's constrained schedule. The last defense subcommittee approval was secured with no time to spare. (Section 809 Panel, 2019)

So, what is an example of faster together? One that relates directly to the example above is New Start notification procedures. While "Quick Start" authorities enabled the service secretaries to initiate urgent programs without following routine new start notification procedures, not every Congressional stakeholder is a fan of "ceding" this authority. Ceding new start approval authority is not the only option for Rapid Acquisition. An idea that the DoD initially put forward in response to a Congressionally directed report on an Alternate Acquisition System (AAR) for USSF was to pursue 30-day coordination of "prior-approval New Starts" through the Defense Subcommittees. The New Start would be approved if 30 days elapsed without a subcommittee response. In other words, silence is consent. (Anderson, 2019) Similarly, coordination through DoD channels would have strict timelines for coordination, with silence serving as consent. This approach preserves Congressional, OMB, and OSD oversight but makes timely coordination of new starts a time-bound priority.

An example of faster togetherness that already exists for rapid acquisition is the provision in RAA policy (DoD Manual 5000.78), allowing for a flexible resourcing strategy. In the case of an approved RAA, the SecDef or DepSecDef may use "any funds available to the DoD…" to enable a flexible and rapid deployment of funding against the project. However, Congressional oversight is maintained because the SecDef must notify the Congressional Defense subcommittees of the resourcing strategy. (Office of the Under Secretary of Defense for Acquisition and Sustainment, 2019)

Aversion to Taking Risks at the Program Level

Even if you secure RAA or Quick Start approval to meet an urgent operational need, that program is being handed to a workforce that has been trained and incentivized to avoid risk. Little attention is given to differentiating between operational risk and "business risk" – the latter being much more acceptable when mission capability is gapped or in jeopardy. The problem is that program managers are expected to manage risk at the program level, and their performance is scored by their ability to balance performance, schedule, and cost-effectiveness. SAF/FM (Financial Management) and SAF/AQC (Contracting) are beginning to acknowledge the downsides of "risk-averse" behavior when business risk is managed at the program level. Recent analysis of the ~$3B per year in DAF appropriated funding that "cancels" each year without resulting in an outlay from the Treasury highlights the wasted opportunity in spending these funds. One of the root causes behind this missed opportunity is the risk-averse behavior of program managers when it comes to program funding. (Wood, 2024) PMs are incentivized to cover their financial risks, often at the expense of funding that could be used to secure mission effects. Suppose the risk of program overruns is seen as an exercise in enterprise risk management, and PMs are incentivized to accept more cost/funding risk to fund an urgent operational requirement. In that case, they can focus more on delivery schedules and system capabilities. Similarly, and with an even more significant impact on program schedules, is the culture and expectation to award "protest proof" contracts. An interview with a USSF Senior

Materiel Leader highlighted this as a significant factor in delayed contract award timelines. (Wood, Interview with SSC SML, 2025)

There are no easy answers to address our risk-averse acquisition culture, even when limited to business risk, but messaging of support from acquisition leaders, policies, training, and other communication that sets the tone for PM performance should seek to encourage risk-taking where appropriate and even reward PMs who end up needing additional resources to cover cost overruns. The Sec 809 Panel recommended " Transitioning from a program-centric execution model to a portfolio execution model." (Section 809 Panel, 2019) They further characterized the problem as:

- A compliance-heavy culture driven by fear of failure.
- A workforce believes failures will be punished rather than celebrated, despite leadership pronouncements to take risks and fail fast.
- Until recently, a highly centralized organizational structure under which sequentially made decisions, and a long coordination process led to unacceptable timelines, causing program delays and administrative inefficiencies.
- Milestone decisions that require excessive program documentation, multiple program reviews, and protracted coordination.
- Individual program-centric thinking and decision-making versus mission and kill-chain-centric thinking.
- A rigid funding environment that stifles agility.
- Lack of decision authority commensurate with management responsibilities.

The Sec 809 panel's proposed remedy to these problems is to expand the authorities of a PEO into that of a Portfolio Acquisition Executive (PAE) who "…would be delegated a substantial level of acquisition, requirements, and budget decision authority. PAEs' ability to integrate, manage, and execute programs within the portfolio would provide the flexibility, agility, and increased lethality required for responding to evolving threats and technology." Unfortunately, that recommendation has not been adopted. However, USSF's efforts to involve operators more closely with acquirers continue. The point is that the culture of compliance, bureaucracy, excessive oversight, and aversion to risk-taking undermines the ability to develop an acquisition workforce that knows how to pivot toward rapid acquisition. A remedy to this condition will require a more pervasive application of the tenets of rapid acquisition within an acquisition cadre poised to pivot away from the rigor of major capability acquisitions (MCAs).

Resiliency Through International and Commercial Partnerships

The USSF, specifically SSC International Affairs (IA) mission-critical function, is executing U.S. Space Force Foreign Military Sales (FMS) and leading international space security cooperation, essential to deliver warfighting space capabilities to our allies and partners. SSC/IA is one of the DoD entities executing space security cooperation, ensuring allied space capabilities strengthen U.S. military operations. Current efforts include leading Missile Warning/Missile Tracking (MW/MT) partnerships, NATO's NORTHLINK for Arctic defense, and STARLIFT for allied spaceport access. In addition, SSC/IA fields mission-critical FMS capabilities within days to respond to real-world combat operations. These efforts enhance deterrence, resilience, and U.S. force projection. Iron Dome for America, a follow-on to Regans Strategic Defense Initiative 33 years ago, nicknamed "Star Wars" depicted below in the exhibit, will begin to be studied and kick off shortly, per the recent Executive Order.

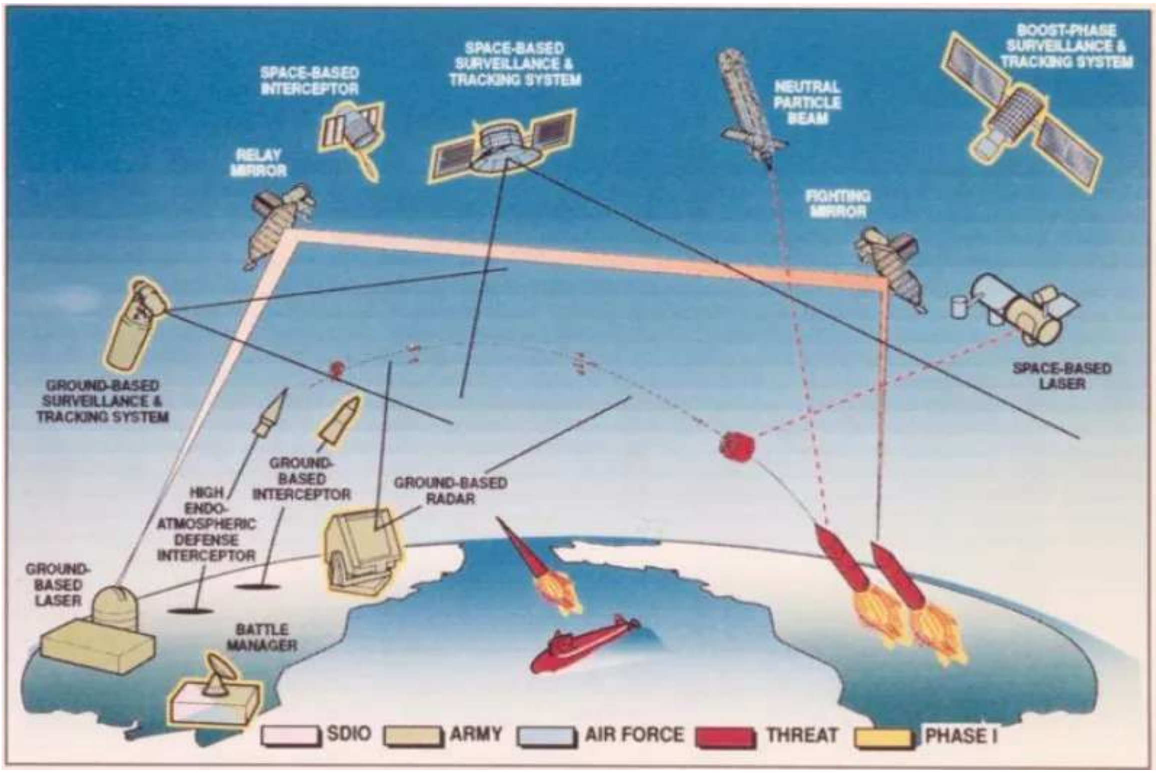

Figure 1- SDI Concept of Operations

Without SSC/IA, missile tracking, SATCOM, PNT, and other space domain capabilities would be degraded, increasing operational risks and weakening the U.S. military's ability to respond effectively to global threats. Disrupting SSC/IA's space security cooperation efforts with allies and partners would have significant consequences and stall current efforts to align with the CSO's Lines of Effort (LOE) 3, "Partnering to Win."

SSC/IA alone will generate approximately $13B in international sales revenue for the USSF in response to critical allied requests, directly bolstering the U.S. defense industrial base and funding innovation. Cooperative international agreements reduce the financial burden on U.S. taxpayers by ensuring allies invest in shared capabilities. Without SSC/IA's space security cooperation efforts, the U.S. risks weakening domestic industry, losing strategic financial advantages, and ceding global market influence to adversaries like China and Russia, which aggressively promote their space industries to foreign partners as alternatives to American systems.

USSF Space Security Cooperation enhances warfighter readiness by integrating allied space capabilities for intelligence, navigation, and secure communications. Aligning international assets with U.S. defense operations improves response speed and situational awareness in contested environments. Without SSC/IA, U.S. forces would face slower decision-making, reduced operational reach, and diminished access to international space infrastructure, weakening their ability to operate effectively in future conflicts where space superiority is critical to mission success.

Rapid Reconstitution via Commercial

While Rapid Acquisition Authorities and acquisition teams armed with the authorities, capabilities, and culture to deliver fast helps us address the "unknowns" of future conflicts, our ability to reconstitute on-orbit capabilities is just as compelling of an approach to achieving resilience and responsiveness within our current space architecture. Historically, the idea of "launch on demand" capability was cost prohibitive. Furthermore, long satellite useful lives reduced the frequency of recapitalization rates (e.g., new programs), which drove a propensity towards pursuing state-of-the-art requirements, driving significant NRE and adding to the development schedule time. Finally, the high launch cost combined with these expensive satellites drove a "no fail" culture. Thankfully, competition among space launch providers, significant technological advancements, the emergence of a truly viable and growing commercial space market, and other factors combined to open opportunities for lower-cost, prominent constellations of low earth orbiting satellites with shorter valuable lives, higher recapitalization rates and more significant opportunity for incremental development and capability on-ramps. It also afforded an opportunity to affordably purchase spares or leverage "just in time" availability from a satellite (SV) production line for rapid enclosure, fueling, launch vehicle (LV) integration, launch, and on-orbit checkout in very short order. The Tactically Responsive Space (TacRS) program, which came online in 2021, has steadily advanced the goal of rapidly delivering capability on orbit in a matter of days.   There are multiple goals with TacRS. In addition to demonstrating the ability to place an SV into an assigned orbit rapidly, it is a tool to inject purpose-built SVs to surveil enemy satellites with offensive counter-space potential placed into unique orbits intended to evade U.S. surveillance assets.   This capability will serve as a deterrent to adversaries seeking to place offensive counter-space assets in orbit.

In 2023, a mission titled VICTUS NOX demonstrated the ability to rapidly mate an SV with an LV, fuel, launch, and place the SV into an orbit unknown to the operators until the day before launch. (Plumb, 2024) Following the success of VICTUS NOX, the USSF is pursuing a mission titled VICTUS HAZE in 2025 that will launch two separate SVs on two different LVs to accelerate testing and learning opportunities. Early in 2025, the USSF awarded a contract to Firefly Aerospace for a launch service mission titled VICTUS SOL. While an SV provider has not yet been determined, this mission will serve as a third opportunity to advance TacRS goals. (SSC Public Affairs, 2025)   Two additional missions are expected in 2026: VICTUS SURGO and VICTUS SALO.

Building Resilient Space Command and Control (C2)

Space Systems Command (SSC) says in it is "Race To Resilience" that "resiliency is the capacity to withstand or to recover quickly from difficulties." (Space Systems Command, 2025) To Breaking Defense in 2022, the first Chief of Space Operations (CSO) relayed, "What we are trying to do is just like you do with your financial portfolios, where you diversify your financial portfolio so you do not go broke if one stock takes a tumble. We want to do the same thing with our satellite architecture." (Hitchens, 2022) It is used interchangeably to describe people and systems. When focused on systems, it is a concept that describes the strength in numbers, technical redundancy, and increased capacity to ensure an operation will continue and the system can keep driving toward a successful conclusion. "The Defense Department has placed a greater emphasis on the need for space system resilience over the last five years, as adversaries like Russia and China have increased their aggression in the domain. Moreover, as the Chinese government eyes a possible invasion of Taiwan by 2027, the space Force is working to ensure its satellites and ground systems can operate through disruption should they be targeted." (Albon, 2024)

The SDA and SSC hybrid architecture approach to orbital diversity will ensure resiliency for the on-orbit sensors. By fielding hundreds of small satellites, the sensor systems account for some being inoperable, whether through an environmental issue, technical anomaly, or adversary threat. The system will adapt and recover, ensuring operational availability is maintained as a system rather than an individual satellite. On-orbit data processing and streamlined data transport will ensure there are many communications paths to get information to receivers on earth.

Regarding the latest for HBTSS, "SDA is interested in industry's perspective on implementing the Golden Dome for America architecture and is particularly interested in building on and integrating PWSA's current contributions to global kill chains and missile defense," the agency wrote in an 11 February solicitation. The agency is asking for "novel architecture concepts, systems, technologies, and capabilities that enable leap-ahead improvements for future [PWSA] tranches, capability layers, or, enable new capability layers to address other emerging or evolving warfighter needs," it adds. "The fate of HBTSS and authority over how such high-precision sensors are pursued has been a bone of contention between the two agencies and driven some concerns from Capitol Hill. Two prototypes were launched last February, but MDA and SDA said the birds would not be integrated into SDA's PWSA. Instead, technology advances and lessons learned from the HBTSS program were being migrated into sensors developed by SDA for its Tracking Layer of missile warning/missile tracking satellites." (Hitchens, 2025)

Missile Defense Kill Chain "OODA Loop" Evolution to F2T2EA

Col. John Boyd was an Air Force strategist who understood the need to think and act quickly as adversaries developed new technologies. He designed a commonly used term called the "OODA Loop," which stands for "Observe, Orient, Detect, and Act. " These four steps repeat in a "loop," ensuring a repeatable way to conduct combat operations. Senior leaders note that wars decide who can think and act quickly; thus, "getting inside the enemy's OODA loop" means acting quicker than adversaries.

When precision bombing technology became a significant part of combat operations, the OODA loop needed to be refined to ensure all the systems required in the kill chain had understood roles. Find, Fix, Track, Target, Engage, and Assess became the new vernacular when describing the integration of systems of systems in a complex kill chain. Find refers to detecting a threat. Fix requires sensors to lock into the threat. Track requires sensors to monitor the threat continually. Engage is when kinetic effects are delivered to the threat. Assessing is understanding the levels of the effects delivered to the target and if they were delivered as planned.

In a scenario such as a missile defense kill chain, the "intercept" of the missile defense systems comes at the Engage step. When F2T2EA is displayed sequentially from left to right, the steps that precede Engage are considered "left of launch." Systems performing the steps "left of launch" must be able to sense a launch of an enemy missile, understand what type of missile it is, track it through all phases of flight, and deliver data at warp speed to aid decision-makers in how to engage those missiles. The incredible amounts of data needed to perform these steps can easily consume bandwidth and increase latency if the systems are not correctly architected for resiliency.

While global coverage and data transport will be achieved in orbit, that does not account for how the data will be transported from orbit to the ground and across various weapon systems to close the kill chain. Deliberate investment needs to be made in data architecture, data transport, and operations to ensure ground path diversity is resilient and will guarantee that the "Left of launch" phase of the missile defense kill chain will be closed.

Resiliency through Orbital Diversity

The Department of Defense (DoD) has committed to the success of the Proliferated Warfighter Space Architecture (PWSA), the small satellites in Low Earth Orbit being developed, launched, and operated by the Space Force's Space Development Agency (SDA). This constellation of satellites is designed to provide communications capabilities via a data transport layer in orbit alongside missile tracking sensors in their missile custody layers. The approach to buying these layers is in blocks (called "Tranches") with various vendors who adhere to similar standards for data integration. SDA is launching their Tranche 1 transport layers, and despite the prototype nature of the system, their performance is met with skepticism mainly because the entire constellation has not been fielded. (Hitchens, 2025) Space Systems Command follows a similar approach to the PWSA by fielding layers of missile tracking sensors in the Medium Earth Orbit. Hadley states, “Space Force leaders have touted proliferation as a way to make targeting harder for potential adversaries, challenging them to find different ways to attack objects in different orbits and narrowing the target window as spacecraft move relative to the Earth.” (Hadley, 2025). The Space Force's overall approach to fielding orbitally diverse sensors will ensure global coverage for missile warning and tracking will be achieved.

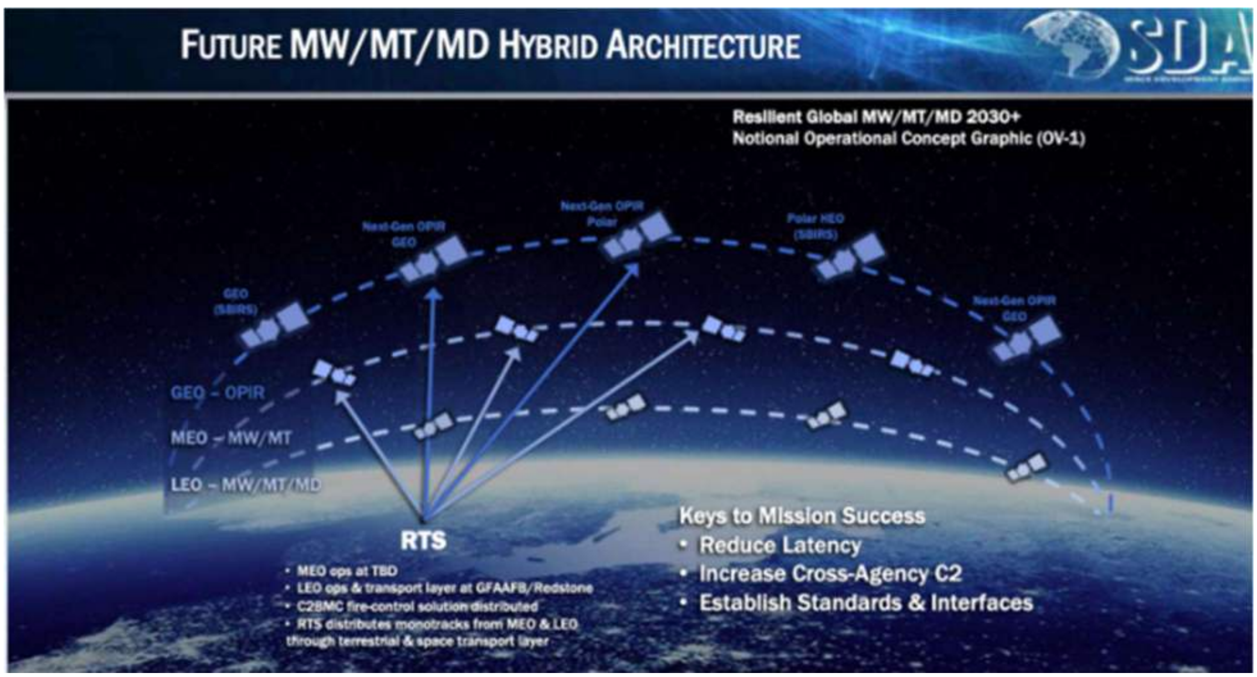

Figure 2- Operational View of Proliferated Warfare Space Architecture (Hitchens, 2022)

Resiliency in Data Architectures

The current missile warning data architecture processes large amounts of data from exquisite sensors for strategic warning purposes. These sensors have the capability to provide additional data that that would be helpful for decision-makers, but operators are limited in what they can generate, dropping potentially important pieces of information “on the floor”. Creating a Tools, Applications, and Processing Laboratory dedicated to missile warning data aims to exploit all this unused data for battlespace awareness purposes and make it more operational.

Flash forward to when the PWSA and the MEO missile tracking systems will be fielded. Hundreds of sensors mean an exponential growth in the data that will be available and needed to track the relevant hypersonic glide vehicle threats that are described in the Iron Dome for America Executive Order. The ground systems currently being fielded are prototypes to operate and process the data from these early Tranches and Epochs. However, once the entire system is operational, it is questionable how resilient the ground architecture will be in processing all this sensor data.

An approach for consideration is using cloud-based systems to process and store the data. This will enable data to be retrieved from any point or operations floor in the world, assisting theater Combatant Commanders to make decisions quickly for their area of operation. It will alleviate the burden of one or two operations floors as the sole "bell ringer" for finding, fixing, and tracking missile threats. It will enable better storage of raw data, ensuring more capability can be exploited from the sensors and allowing greater awareness of a situation.

A solid data architecture will enable artificial intelligence in the missile defense kill chain. While humans need to make the ultimate call to engage on a target, the "left of launch" steps (Find, Fix, Track) can benefit from using artificial intelligence to gather, store, process, and assess the data from hundreds of on-orbit sensors. Human operators will need artificial intelligence to note patterns, integrate data from ground sensors, and make action recommendations for engagement. This can only be accomplished by having a well-understood, robust, and diverse data architecture. Investment and fielding of cloud-based data systems for the missile tracking architecture are a must to close the kill chain in relevant timelines.

Missile Warning is moving towards a new and improved data processing structure in its system called FORGE. As noted in an interview by Breaking Defense with SciTech President David Simenc, "The way to think of these efforts is as delivering 'mission processing applications.' We are fielding a suite of software services that perform all the manipulations required to turn raw sensor data from all our national missile detection and tracking sensors into actionable tracks. The apps also provide the warfighting interfaces necessary for our Guardians to operate the system 24-7-365 to provide clear, unambiguous, assured, and timely warnings. Think of it as a real-time, fully interactive picture of every missile launch in the world and several other classified missions. FORGE processing is completely rearchitecting and modernizing missile warning data exploitation to provide superior performance today and a firm foundation for the future. This is the first major missile warning software modernization effort in 20 years, and there are many cobwebs. The larger FORGE program is a full modernization effort for missile warning-ground. Within mission data processing, our FORGE processing apps leverage a software platform built by Raytheon. Think of the platform as a private cloud architecture that provides a key cybersecurity layer. FORGE also delivers a consolidated command and control system for 14 satellites through a separate acquisition." (Breaking Defense, 2024)

Evolved Strategic SATCOM (ESS), another NC3 program, will be employing commercial-like data processing framework called the Ground Resilient Integration & Framework for Operational NC3, or GRIFFON. Colonel AJ Ashby, Senior Materiel Leader for ESS states, "You kind of liken the framework to your cell phone, and then you have different applications that would ride on that framework." This approach, like that of FORGE for Missile Warning, utilizes the software acquisition pathway. It is a pivot from previous space systems programs where they developed the ground and space systems in a stove-piped manner with one major defense contractor and cost-plus contracts, resulting in extreme delays in delivering capabilities to operators. (Hadley, 2025)

The Space Domain Awareness mission heavily utilizes the Unified Data Library (UDL) to command and control on-orbit assets and data processing. It is a cloud-based architecture for which the space Force's best artificial intelligence (AI) prototype algorithms are being developed. The missile tracking architecture could benefit from leveraging the UDL or mirroring the UDL to ensure a robust data construct that can easily integrate with other sensor data to obtain full awareness of an adversary threat. Another ground system being prototyped by the Space Force is R2C2, a ground system in development by the space Rapid Capabilities Office. "R2C2 is a cloud-based and software-enabled ground infrastructure that would provide more flexibility to command and control assets to take action in scenarios that would unfold during a conflict such as maneuvering or re-routing networks." (Erwin, 2024) The complexity of dynamic space operations is on par with the complexity of missile tracking; thus, a similar ground architecture approach should be widely adopted.

Reluctance to use cloud-based systems stems from a fear of cyber controls and being able to keep the data secure against adversary or insider threats. Implementing zero-trust controls can alleviate the concern of adversary infiltration and decrease technical debt, the indirect cost of additional work sometime in the future resulting from choosing a quicker solution over a more robust one. Resistance to cloud-based systems also comes from needing on-site processing with the operations centers to ensure operational availability. A counterargument is that the resiliency of cloud-based systems guarantees operational availability because any operations center globally would have the ability for command and control in addition to data processing.

Resiliency through robust, diverse ground data transport pathways

Combatant Commanders are concerned about communication isolation from the U.S. during wartime. Combatant commands' resiliency of operations should be enhanced by ensuring that on-orbit data can be downlinked and processed directly to the theater. Current policy inhibits the free passing of raw mission data to any international allies.

Investment in communications path diversity on the ground will guarantee operational availability and data throughput. MeshOne-T is a conglomeration of the DoD and commercial antennas and fiber lines that can receive on-orbit data and push it anywhere globally. Antennas need to accept a variety of signal bands and encrypt and decrypt data for security.

Resiliency through distributed operations

Theater commanders require missile warning operations and processing in their area of responsibility. The current construct primarily has strategic missile warnings in one location, followed by threat information being shared globally. Mobile and transportable systems are in place and under development to coordinate warnings across all combatant commands. The concern is that if communication were ever broken, the theater commanders would be unaware of incoming attacks.

Current strategic missile warning systems operations require a large footprint of uniformed members to command and control them. An extensive apparatus of shift workers, satellite planners, evaluators, instructors, and testers maintain these systems.

Commercial providers have proven that satellite command and control operations can occur in small, discreet locations. As automation is built into new satellites, the manpower footprint is significantly reduced.

Movement into distributed, permanent operations centers for missile tracking across all combatant commands should be considered. The cloud-based architecture will ensure that data from all the sensors globally will be available to all the operations floors. This will require allied support to stand up operations centers in other countries. An agreement to share data with Five Eye partners would ensure allied partnership and integration in times of conflict. Operations manpower can be shared by training personnel from international partners to work alongside U.S. operators. In doing so, the manpower footprint from the US-based strategic operations centers can be reduced.

Recommendations for Unleashing Resilient Space

The current administration has proven successful in issuing Executive Orders to pivot into a new mindset. Clear direction should be given to ensure all missile defense stakeholders understand the appropriate system levels to implement survivability and endurability requirements. This process can be done through updates to Presidential Policy Directives, the National Defense Authorization Act (NDAA), the National Security Space Strategy (written in 2011), or through an Executive Order, which will ensure a more resilient architecture on both the ground and on-orbit.

Employ Rapid Acquisition Mechanisms at All levels of Government

USSF acquirers must leverage rapid acquisition authorities and processes, particularly those aligning well with recent acquisition and PPBE reform efforts. This extends beyond leveraging rapid acquisition or “quick start” authorities into the tools and techniques that correlate with effective rapid acquisition. The Section 809 Panel recommendation to convert PEOs into PAEs, with delegation of a substantial level of acquisition, requirements, and budget decision authority should be pursued. Acquisition community leadership should pursue a broad initiative to address and reverse historically risk averse behaviors. Incentives should be developed to encourage PMs to assume financial and other business risks when necessary to improve delivery timelines. This can be done by having a strong leader heading the effort, and having specific delegations to program managers with authorities that clear the bureaucracy currently encountered in the Pentagon. USSF Science and Technology budgets should focus on efforts that capitalize on industry investments, particularly where they overlap with Space Force priorities. The use of Other Transaction Authority agreements and "commercial-like" acquisitions should be expanded to enable more streamlined and flexible acquisition strategies. Less NRE-intensive efforts are essential to delivering capability in operationally relevant timeless. Finally, in order to deliver capability in a timely manner, when coordinating an acquisition strategy or looking for congressional vectors, the U.S. should follow the "silence is consent" philosophy, whereas a notification is delivered to Congress and they have 30-days to provide feedback else concurrence will be assumed.

America First is not America Alone…Integrate International and Commercial Capabilities

Resiliency improvements could also be made through international cooperation and commercial partnerships. Using the lessons from having a high value Memorandum of Understanding with other countries (such as the Iron Dome with Israel) will be beneficial in future efforts with desired interoperability between two states. Some examples of international partnerships include increasing interoperability with coalition networks and standing up OCONUS operations centers processing raw mission data that has been downlinked directly from on-orbit sensors. Lifting this policy for specific allies (e.g., primarily the UK and Australia) could enable operations centers to be located outside the U.S. and directly in theater.

Having distributed operations centers with mission processing capabilities will provide a backup to current operations centers in the U.S.

The nation can leverage commercial capabilities by reconstituting satellites (TacRS), establishing diverse ground communications links, and implementing a secure cloud and edge computing infrastructure similar to what current commercial vendors are utilizing. Standing up a commercial consortium of international and domestic vendors aimed at developing a consolidated solution would be a creative way to kick start driving commercial capabilities in sensor platforms.

Field new capabilities to ready the architecture for decisive decision making

By eliminating or reducing the hardening requirement on orbit, investments can be diverted into proliferating our on-orbit NC3 systems, fielding systems in various orbits, and ensuring that the U.S. can reconstitute these constellations in tactical timelines. There can be a greater focus on on-orbit processing to enable space data networking, allowing mission data to be passed between satellites and opening opportunities to download mission data anywhere in the world. The service is on track with fielding capabilities such as MEO Missile Warning/Tracking and the Hypersonic Ballistic Tracking Space Sensor. Continuing to field these systems will ensure that system survivability and endurability is measured by the number of sensors that can be re-constituted quickly.

By eliminating or reducing the hardening requirement on ground systems, investments can be diverted to building new operations centers globally, capitalizing on commercial antenna capabilities, and making communications lines more robust in theater. There can also be more emphasis on strengthening the cyber security of all these ground and space systems.

Increase Ground Communications Paths and Operations Centers

In day-to-day operations, having ops floors in 2 other locations will allow operators to work 8-hour shifts instead of 24-hour shifts through a "follow the sun" principle where command and control are seamlessly handed off to other operations floors. Quality of life and human factors for operators can improve because they are working fewer hours and training for distributed ops, supported by doctrine that supports distributed ops. Manpower can be freely shared with trusted international partners, reducing the burden of having only U.S. operators. International relations can improve by sharing critical data that affects their homelands.

During wartime, having multiple operations centers will enable triple backups if one site takes a hit. More communications paths will allow data to flow and be processed quicker and directly to the theater, giving theater commanders insights on the region in tactical timelines.

Implement Cloud C2 architectures with robust Cybersecurity

A resilient space command and control (C2) architecture requires deliberate efforts to strengthen and secure communications infrastructures. A sound, secure data library is required to get the most from sensor and warfighter performance, and it will be critical for implementing artificial intelligence or autonomy for mission data processing. Utilizing existing contracts and vendors such as Amazon Web Services for the National Reconnaissance, would be a quick win to field capability and make room for tremendous amounts of missile warning and tracking data that will need to be stored and processed. Programs such as Plantir's WarpCore which leverages the Unified Data Library will enable artificial intelligence to utilize critical data from various sensor sources. AI programs like these will create courses of action that can help decision makers act quickly, thus "getting inside the enemy's OODA Loop".

Conclusion

The rapid evolution of adversary threats requires the United States to get inside the enemy's "OODA" loop to counter potential attacks to the homeland. Space systems will be first to detect launches and track flights of these threats, thus it is imperative to invest in methods and technologies that will aid in fusing data from various sources and present effector options to decision-makers in relevant timelines.

To obtain a genuinely resilient space architecture, policy barriers must be lifted. Removing policy, technology, and classification barriers will unleash the potential of the systems that are being developed and fielded. Inconsistencies and policies regarding disclosure and sharing of information should be rectified. Improve acquisition such that goals are achievable and can be followed through.

Investing in systems that guarantee seamless operations from anywhere area of operation globally will ensure resiliency across the systems of systems required to make Golden Dome successful. Investments must be made in fielding technically achievable, secure, diverse, and integrated systems with international partners. Follow through with "Allied by Design" whereby the space enterprise develops a consistent approach to bring allies and partners in at the beginning for all space-related activities and collaboration.

References

AFP. (2014). *New Russian Military Doctrine Labels NATO as Main Threat.* Paris: Agence France-Presse. https://www.defensenews.com/global/europe/2014/12/28/new-russian-military-doctrine-labels-nato-as-main-threat/

Albon, C. (2024). How the Space Force is Making its Systems More Resilient. *C4ISRnet.* https://www.c4isrnet.com/battlefield-tech/2024/04/18/how-the-space-force-is-making-its-systems-more-resilient/

American Institute of Aeronautics and Astronautics. (2021). Hypersonic vehicles and technologies. https://www.aiaa.org/hypersonic-vehicles-and-technologies

Anderson, S. S. (2019). Alternate Acquisition System for USSF - Draft. Washington, D.C.: DoD Working Paper.

Associated Press. (2019). *Putin hails new Russian laser weapons*. https://apnews.com/general-news-ff03960c48a6440bacc1c2512a7c197a

Blanc, Alexis A. and Beauchamp-Mustafaga, Nathan and Holynska, Khrystyna and Bond, M.Scott and Flanagan, Stephan A. (2022). *Chinese and Russian Perceptions of and Responses to U.S. Activities in the Space Domian.* Santa Monica: Rand Corporation. https://safe.menlosecurity.com/doc/docview/viewer/docNE2E9C42036F99797db5480e0af620b8f2ec937e21db7346235648e6b133df01b41095e88736b

Blore, A. T. (2023). Responsiveness Is Not Operational - Aligning Strategy in the Newest Service. Colorado Springs: Air University.

Bodner, Matthew. (2017). *60 years after Sputnik, Russia is lost in space.* Space News. https://spacenews.com/60-years-after-sputnik-russia-is-lost-in-space/

Breaking Defense. (2024). A Major Overhaul Is Coming In Software For Missile Warning. https://breakingdefense.com/2024/04/a-major-overhaul-is-coming-in-software-for-missile-warning/

Calvelli, F. (2022). Memorandum For the Department of the Air Force Space Acquisition Workforce - Space Acquisition Tenets. *Washington, D.C.: Office of the Assistant Secretary.*

CASI. (2020). In Their Own Words: *Science of Military Strategy 2020.* China AeroSpace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Translations/2022-01-26%202020%20Science%20of%20Military%20Strategy.pdf

Chekinov, S.G. and Bogdanov S.A. (2013). *The Nature and Content of a New Generation War.* Moscow: Military Thought.

Cheng, Dean. (2011). *Chinese Lessons from the Gulf Wars*. In *Chinese Lessons from Other Peoples; Wars.* U.S. Army War College Strategic Studies Institute.

Chilton, Kevin. (2022). *Empower Our Space Force, Just As We Do For The Other Services*. Defense News. https://www.defensenews.com/opinion/commentary/2022/01/28/empower-our-space-force-just-as-we-do-for-the-other-armed-services/

Cole, Brendan. (2019). *Russia Reacts to Trump's Space Warfare Command Launch, Says Militarization of Space Is Inevitable.* Newsweek. https://www.newsweek.com/russia-rogozin-deep-space-trump-1456923

Department of Defense. (2025). Planning, Programming, Budgeting, And Execution Reform Implementation Report. *Washington, D.C.: Office of Prepublication and Security Review.*

DIA. (2017). *Russia Military Power Building a Military to Support Great Power Aspirations.* Defense Intelligence Agency. https://www.dia.mil/Portals/110/Images/News/Military_Powers_Publications/Russia_Military_Power_Report_2017.pdf

DIA. (2022). *Challenges to Security in Space.* Defense Intelligence Agency. https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf

DoD. (2020). *Annual Report to Congress, Military and Security Developments Involving the People's Republic of China 2020 Annual Report to Congress. D*epartment of Defense. https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF

Easley, M. (4 March 2022). JUST IN: Space Force Looks to Bridge the "Valley of Death". *National Defense.*

Elison, R. (2025). Space and Missile Defense Virtual Discussion with General Michael Guetlein. *Missile Defense Advocacy Alliance,* podcast transcript, page 20. https://safe.menlosecurity.com/doc/docview/viewer/docN6864321137B38b3c59d3ba7f4bab0c08fb75b22db3602b05a7d7420173ab8f0a6b3b548a5506

Erwin, S. (2022). U.S. National Security Space Strategy Emphasizes Resilient Systems, responsible behavior. *SpaceNews.* https://spacenews.com/u-s-national-security-space-strategy-emphasizes-resilient-systems-responsible-behavior

Erwin, S. (2024). Space Force takes another swing at modernizing satellite ground systems. *Space News.* https://spacenews.com/space-force-takes-another-swing-at-modernizing-satellite-ground-systems/

Hadley, G. (2025). Space Force Brings Acquisition Reforms to New Nuclear Command and Control Program. *Air and Space Forces Magazine.* https://upcontent.link/kpaa3y

Hitchens, T. (2022). *Breaking Defense*. https://breakingdefense.com/2022/05/space-force-targets-2027-for-resilient-on-orbit-posture-initial-capability/

Hitchens, T. (2025). *Breaking Defense.* https://breakingdefense.com/2025/02/exclusive-dod-memo-seeks-review-of-space-development-agencys-independent-status-plans/.

Hitchens, T. (2025). SDA asks industry to propose 60-day studies of 'novel' capabilities for Iron Dome. *Breaking Defense.* https://breakingdefense.com/2025/02/sda-asks-industry-to-propose-60-day-studies-of-novel-capabilities-for-iron-dome/

Hitchens, Theresa. (2022). Don't be dazzled by Russia's laser weapons claims: Experts. Breaking Defense. https://breakingdefense.com/2022/05/dont-be-dazzled-by-russias-laser-weapons-claims-experts/

Judson, J. (2016). 30 Years: MRAP - Rapid Acquisition Success. *Defense News.*

MILSAT Magazine, September 2022. "Space Systems Command: Tactically Responsive Space, SSC's Space Safari prepares for the next TacRS mission". http://www.milsatmagazine.com/story.php?number=1719801667

National Academies of Sciences, Engineering, and Medicine. (2018). Hypersonic weapons: Background and issues for Congress. https://www.everycrsreport.com/reports/R45441.html

National Defense Magazine. (2024) Proliferation Provides Space Force Resilience, New Challenges. https://www.nationaldefensemagazine.org/articles/2024/5/16/proliferation-provides-space-force-resilience-new-challenges

National Infrastructure Advisory Council. (2016). Cybersecurity: Ensuring the resilience of the nation's critical infrastructure. https://www.dhs.gov/sites/default/files/publications/niac-cybersecurity-report-final.pdf

Nebehay, Stephanie. (2018). *U.S. Warns on Russia's New Space Weapons*. Euronews. https://www.euronews.com/2018/08/14/us-warns-on-russias-new-space-weapons

Obis, A. (2025, 12 Mar). How the 2016 NDAA transformed OTAs into a key defense contracting tool. *Federal News Network.*

O'Connor, Tom. (2018). *Russia's Military Has Laser Weapons That Can Take Out Enemies In Less Than A Second*. Newsweek. https://www.newsweek.com/russia-military-laser-weapons-take-out-enemies-less-second-841091

ODNI. (2024). *Annual Threat Assessment of the U.S. Intelligence Community.* Office of the Director of National Intelligence. https://www.dni.gov/files/ODNI/documents/assessments/ATA-2024-Unclassified-Report.pdf

Office of the Director of National Intelligence. (2016). National intelligence priorities:2016. https://www.dni.gov/files/documents/National_Intelligence_Priorities_FY2016.pdf

Office of the Under Secretary of Defense for Acquisition and Sustainment. (2019). DoD Manual 5000.78, "Rapid Acquisition Authority". Washington, D.C.: Directives Division at https://www.esd.whs.mil/DD/.

Paroozi, Daniele. (2024). *Kosmos 2576: Russian Spacecraft Suspected to be an 'Inspector Satellite*. Space Voyaging. https://www.spacevoyaging.com/news/2024/05/25/kosmos-2576-russian-satellite-suspected-to-be-an-inspector-satellite/

Plumb, J. (2024). Tactically Responsive space: An Emerging New Deterrence Tool—*Center For Strategic & International Studies.*

Pollpeter, Kevin and Anderson, Eric and Wilson, Jordan and Yang, Fan. (2015). *China Dream, Space Dream China's Progress in Space Technologies and Implicatons for the United States A Report Prepared by the U.S.-China and Economic Security Review Commision.* U.S.-China and Economic Security Review Commision. *https://www.uscc.gov/sites/default/files/Research/China%20Dream%20Space%20Dream_Report.pdf*

RAND. (2024) Charting a Path to Thoughtful Allied Space Power- Allied by Design Research.

Rane. (2017). *In Syria, the Russian Military Found the Ultimate Testing Ground*. Rane Worldview. https://worldview.stratfor.com/article/syria-russian-military-found-ultimate-testing-ground

Satnews. (2023, April). "Exploit what we have, buy what we can, and build only what we must.". *MilsatMagazine.*

Section 809 Panel. (2019). *Report of the Advisory Panel on Streamlining and Codifying Acquisition Regulations, Volume 3 of 3.* Arlington, VA: https://Section809panel.org.

Space Systems Command Public Affairs. (2025). Space System Command Advances Tactically Responsive Space capabilities to enable faster, more agile responses to on-orbit threats. *Space Systems Command Press Release.*

Space Systems Command. 2025. https://www.ssc.spaceforce.mil/About-Us/Race-To-Resilience

Sputnik News. (2016). *This is the Achilles Heel of Washington's Military Power.* Moscow: Sputnik News. https://sputnikglobe.com/20160130/us-space-satellites-1033971479.html

Swope, Clayton and Young, Makena. (2024). *Is There a Path to Counter Russia's Space Weapons?* Center for Strategic Studies. https://www.csis.org/analysis/there-path-counter-russias-space-weapons

Thomas, Timothy. (2019). *Russian Combat Capabilities for 2020: Three Developments to Track.* MITRE Corporation. *https://www.armyupress.army.mil/Portals/7/Legacy-Articles/documents/Thomas-Russian-Combat-Capabilities.pdf*

U.S. Government Accountability Office. (2009). *Defense Acquisitions: Rapid Acquisition of MRAP Vehicles.* Washington, D.C.: GAO.

USSPACECOM. (2020). *Russia Conducts Space-Based Anti-Satellite Weapons Test.* *https://www.spacecom.mil/Newsroom/News/Article-Display/Article/2285098/russia-conducts-space-based-anti-satellite-weapons-test/* Varfolomeeva, Anna. (2018). *Signaling strength: Russia's real Syria success is electronic warfare against the US.* The Defense Post. https://thedefensepost.com/2018/05/01/russia-syria-electronic-warfare/

Varfolomeeva, Anna. (2018). *Signaling strength: Russia's real Syria success is electronic warfare against the US.* The Defense Post. https://thedefensepost.com/2018/05/01/russia-syria-electronic-warfare/

Wood. (2024). Canceling Funds Root Causes - MOCAS contracts. *Los Angeles, CA: Briefing to DAF leaders.*

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