Operational Understanding of Positioning, Navigation, and Timing

A Monograph

by

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Abstract

Operational Understanding of Positioning, Navigation, and Timing, by MAJ Robert H. Tugurian, 47 pages.

This monograph pursues a determination of how the US Army can create a shared operational understanding of positioning navigation and timing. Planners, analysts, and strategists must understand how to implement space enablers and capabilities to address challenges in a contested operational environment. Most importantly this monograph seeks to answer the question of how the US Army will mitigate the adverse effects of positioning navigation and timing (PNT) during future multi-domain operations. Space enablers are paramount to successfully bridging the space operations gap at the BCT level in order to address near-pear threats during PNT warfare. Understanding how the US Army will conduct operations during MDO against near peer adversaries is vital to future mission planning that will allow the US Army to address operational challenges and maintain operational dominance during multi-domain operations. The monograph will provide background information that identifies the current problem the US Army faces with GPS in a denied, degraded, and disrupted space operational environment (D3SOE), current literature that is applicable to PNT, and analyzes current PNT capabilities and limitations. Finally, it concludes with recommendations on how the US Army must recognize the future implications of MDO and identify vulnerabilities that will impede any execution of future US Army operations.

Contents

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Abbreviations

A2AD	Anti-Access/Area Denial
ADP	Army Doctrine Publication
AFAT	Assured Functional Area Transfer
AFB	Air Force Base
AFSPC	Air Force Space Command
ARSST	Army Space Support Team
ASAT	Anti-Satellite
ASCC	Army Service Component Command
ASPDO	Army Space Personnel Development Office
BCT	Brigade Combat Team
C2	Command and Control
CAPDEV	Combat Capabilities Development
CGSC	Command and General Staff College
CO	Cyberspace Operations
D3SOE	Denied, Degraded, and Disrupted Space Operational Environment
DoD	Department of Defense
DSS	Defense Space Strategy
FFT	Friendly Force Tracking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IO	Information Operations
IPB	Intelligence Preparation of the Battlefield
JNWC	Joint Navigation Warfare Center
JP	Joint Publication
LOE	Lines of Effort

MA	Mission Analysis
MATDEV	Materiel Development
MDMP	Military Decision-Making Process
MDO	Multi-Domain Operations
NAVWAR	Navigation Warfare
NDAA	National Defense Authorization Act
NSPUSA	National Space Policy of the United States of America
NSSS	National Security Space Strategy
PNT	Positioning Navigation and Timing
SASC	US Senate Armed Services Committee
SATCOM	Satellite Communications
SSA	Space Situational Awareness
USASMDC	US Army Space and Missile Defense Command
USSF	US Space Force
USSPACECOM	US Space Command
USSTRATCOM	US Strategic Command
UTC	Coordinated Universal Time

Figures

Section 1: Introduction

In the current age of information and technology, the world's population has become increasingly reliant on real-time data. Whether it be cell phones, television, or even electricity, technology has become a staple to provide real-time information in everyday lives across the planet. As this globalization of technology increases, so do challenges to US national security and the complexity of protecting US interests at home and abroad. The United States continues to project power into contested operational environments. The ability of America to project power enabled by space capabilities in a denied, degraded, and disrupted operational environment must not remain solely in the strategic realm, but must also extend to the operational and tactical levels.

Today, near pear adversary threats, specifically China and Russia, are in an ever-increasing complex technological race with the United States. The Defense Space Strategy (DSS) summarizes that China and Russia present the greatest strategic threat due to their development, testing, and deployment of counterspace capabilities and their associated military doctrine for employment in conflict extending to space.[1] It is not so much the race to create the most dominant and lethal weapon, but a race more focused on how to deny adversary capabilities. Understanding the strategic benefits of these space-enabled operations, foreign governments are developing capabilities that threaten others' ability to use space. China and Russia each have weaponized space as a means to reduce United States and allied military effectiveness and challenge US freedom of operation in space.[2]

This technology race to deny adversary capabilities may cause a paradigm shift in both "the what" and "the how" for the delivery of information. Denying the delivery of information is at the forefront of information operations (IO) and multi-domain operations (MDO). The current

[1] US Department of Defense (DOD), *Defense Space Strategy* (Washington, DC: Government Publishing Office, June 2020), 1, accessed March 15, 2021 https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_defense_space_strategy_summary.pdf.

[2] DOD, *Defense Space Strategy*, 1.

problem facing the US Army at the operational level is the absence of a shared understanding in how positioning, navigation, and timing (PNT) and space capabilities enable mission planning and execution in a degraded, disrupted, or denied operational environment. The US Army must understand how PNT warfare may occur in an operational environment and also how to mitigate adversarial use of PNT warfare across all echelons during future MDO.

A combination of three distinct and essential capabilities defines PNT. *Positioning* is the ability to determine one's location and orientation accurately and precisely in two-dimensions, or three-dimensionally when required, in a standard geodetic system, such as the World Geodetic System 1984, or WGS84). *Navigation* is the ability to determine current and desired position (relative or absolute) and apply corrections to course, orientation, and speed to attain a desired position anywhere around the world, from sub-surface to surface and from surface to space. *Timing* is the ability to acquire and maintain an accurate and precise time from a standard (Coordinated Universal Time or UTC) anywhere in the world and within user-defined timeliness parameters. Timing also includes time transfer.[3]

Timing is the key to PNT. It is the foundation for both positioning and navigation. GPS derives its positioning and navigation data from timing signals by receiver devices. Users globally depend on a US Air Force maintained constellation of satellites solely for timing information.[4]

As the civilian population relies on PNT, the present backbone of modern technology, the US Army is also extremely reliant on PNT and its capabilities. Broad dependence upon satellite signals for navigation and timing places US critical infrastructure and economic activity at risk.[5]

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[3] US Department of Transportation, "What is Positioning, Navigation and Timing (PNT)?" last modified June 13, 2017, accessed July 15, 2019, https://www.transportation.gov/pnt/what-positioning-navigation-and-timing-pnt.

[4] Tom Hawkes and Blake McMahon, "Time Warfare: Threats to GPS Aren't Just About Navigation and Positioning," Defense One, May 10, 2017, accessed July 19, 2019, https://www.defenseone.com/ideas/2017/05/time-warfare-anti-gps-arent-just-about-navigation-and-positioning/137724/.

[5] Resilient Navigation and Timing Foundation, "The Facts …," accessed July 15, 2019., https://rntfnd.org/wp-content/uploads/RNT_FactSheet_Mar_16.pdf.

From an infantryman conducting a foot patrol at the tactical level to a naval ship conducting a joint exercise, and even a B-52 Stratofortress dropping a precision guided bomb at the strategic level; the calculation of exact locations required for successful execution for each of these operations uses PNT. The disruption of PNT may have the ability to halt US Army operations. There is an increasing concern about the ways and means adversaries can disrupt GPS signals and thereby deny US forces the positioning and navigation information that enables the "American Way of War."[6] The US military must counter these adversarial measures to effectively operate in a denied, degraded, and disrupted space operational environment (D3SOE).[7]

Operating effectively in D3SOE relies on several space-based systems that maintain a network of connectivity. Space-based systems and unhindered access to space are increasingly critical to the nation's economic well-being and linked to America's national security.[8] The US Army depends upon space capabilities to enable and enhance land warfare; virtually every Army and joint operation benefits from these capabilities.[9] Understanding the risk to these complex systems involved will generate a sense of urgency for preventative action to protect US interests.

Space-based capabilities are an integral component of the military, commercial, and civilian sectors. Current US space policy articulates foundational activities to improve space system development and procurement by strengthening interagency and commercial

[6] Hawkes and McMahon, "Time Warfare."

[7] Center for Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), iii, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

[8] Gene McCall and John H. Darrah. "Space Situational Awareness. Difficult, Expensive—and Necessary" *Air and Space Power Journal* 28, no. 6 (November – December 2014): 7, accessed September 15, 2020, https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-28_Issue-6/ASPJ-Nov-Dec-2014.pdf.

[9] CALL, CALL Handbook 18-28, iii.

partnerships.[10] Longstanding technological and cost barriers to space are falling, which enable more countries and commercial firms to participate in satellite construction, space launch, space exploration, and human space flight. Space X, a private commercial company, recently publicized its space program. This may facilitate new market opportunities for United States commercial space capabilities and services, including commercial applications that rely on US government-provided space systems.[11] Facilitating commercial application reliance on assured PNT may leverage the United States ability to augment and encourage civ-mil interoperability of emerging technology and space capabilities. Given the above overview, this monograph will address the criticality of understanding PNT during US Army operational planning.

Research Question

How will the US Army mitigate the effects of PNT warfare during future multi-domain operations (MDO)?

Hypothesis

The US Army requires a focus on supporting assured PNT and mitigation techniques that may allow the US Army to address operational challenges and maintain operational dominance during MDO. To counter near-peer challenges to assured PNT, the US Army must find new and comprehensive ways to reduce threats to timing systems, by simultaneous use of other warfighting domains, such as cyber and electronic warfare. It also means crafting a defensive time infrastructure and network to maintain, and improve friendly timing sources and timing distribution, with a focus on the wide-range of uses for precision timing.[12] In GPS-denied environments, ensuring accurate PNT information is delivered to the warfighter is absolutely

[10] Donald J. Trump, *National Space Policy of the United States of America* (Washington, DC: The White House, 2020), 11, accessed March 15, 2021, https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf.

[11] Ibid., 13.

[12] Hawkes and McMahon, "Time Warfare."

critical.[13] To incorporate these techniques, and effectively counter near-peer threats the US Army must increase the shared understanding of space capabilities and enablers across the force at the operational level.

Significance

The US Army must recognize the future implications of MDO and identify vulnerabilities that will impede any execution of future US Army operations. Understanding how the US Army will conduct operations during MDO against near peer adversaries is vital to future mission planning. MDO approaches will be tantamount to how the US Army will reduce its current overreliance on PNT while continuing to conduct and achieve mission success.

Methodology

Through the lenses of doctrine, history, and theory, research will focus on open-source unclassified archival material, current and historical military doctrine, and theoretical frameworks to generate a prescriptive recommendation to answer the research question. Access to personnel resources at Joint Navigation Warfare Center (JNWC), US Army Space and Missile Defense Command (USASMDC), US Strategic Command (USSTRATCOM), and US Space Command (USSPACECOM) at Peterson Air Force Base (AFB), Colorado will provide historical and current context along with information relevant to the research question. This will assist in guiding research, any findings, and provide additional context that pertains to this topic. The monograph will identify current MDO doctrine, including current space operations doctrine, to understand identified PNT vulnerabilities, mitigated where possible, and unmitigated where space enablers can bridge any operational gaps. Space enablers are paramount to successfully bridging the space operations gap at the BCT level in order to address near-pear threats during PNT warfare.

[13] Curtis Wright, "A-PNT: Assured Positioning, Navigation and Timing," accessed August 10, 2020, https://www.curtisswrightds.com/technologies/open-architecture/assured-position-navigation-timing.html.

This monograph will focus specifically on addressing the process through which the US Army should implement a centralized system approach to understanding PNT. This process will increase the operational understanding of PNT warfare by implementing space enablers and space capabilities across Brigade Combat Teams (BCT). Space capabilities are critical enablers to projecting land power and winning in close combat.[14] This monograph is divided into four major sections: the first section provides the introduction which consists of background information that identifies the current problem the US Army faces with GPS in a D3SOE; the second section provides current doctrine that is applicable to PNT warfare, and understanding of current PNT warfare capabilities and limitations; the third section provides an analysis on how the US Army currently plans and executes MDO; the fourth section concludes with implications, recommendations, and what additional research must be conducted.

Section 2: Literature Review

> The Army's warfighting functions, weapons, and battle systems are vitally dependent on space. We must fully leverage allied, national, and joint space capabilities to enable our warfighting functions and provide space support to all ground component forces.
>
> —2013 Army Strategic Planning Guidance, Field Manual 3-14, *Army Space Operations*

The United States is currently the world leader in space-based military capabilities. As competition drives innovation while simultaneously driving down operational costs, how will the United States maintain its status as the world leader in Space and provide the US Army with adequate space enablers at all echelons? With more nations, primarily China, Russia, Japan, and India, looking to develop their own innovative capabilities, the United States must also foster

[14] US Department of the Army, Army Regulation (AR) 900-1, *Department of the Army Space Policy* (Washington, DC: Government Publishing Office, 2017), 1-1, b.

multilateral cooperation when using these capabilities.[15] Understanding what compels these other nations to develop their own capabilities will ensure the United States remains two steps ahead to avoid the historical Thucydides's trap.[16] This section will review literature to provide a familiarization of the challenges in the space domain, current US space policy, US space strategy, US Army space doctrine, and the US Army's current space force structure, and alternative capabilities to GPS that can support PNT.

Few technologies have as broad an impact on national security and military operations as PNT. Timing threats to technology and Americans' daily lives must receive the appropriate priority. Yet, even as the Department of Defense (DoD) currently works on innovative systems to spread the risk, it must also think more broadly about timing's future place in warfare.[17] A centralized system approach must be employed to ensure the US Army can be cross-functional to provide interoperability. Without deliberate, comprehensive, coherent, and comprehensive guidance and policy now, the DoD risks replacing one well-functioning but vulnerable timing component—GPS—with dozens of disparate, non-interoperable, and possibly still vulnerable timing systems.[18]

FM 3-14, *Army Space Operations*, is the Army's foundational space doctrine. Operations conducted in the Space domain are a significant force multiplier because of their cross-domain

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[15] Vivienne Machi, "Air Force's Joint Forces Space Component Command Missions to Move to U.S. Space Command," Via Satellite, June 13, 2019, accessed August 10, 2020, https://www.satellitetoday.com/government-military/2019/06/13/air-forces-joint-forces-space-component-command-missions-to-move-to-u-s-space-command/.

[16] Thucydides's Trap – The Peloponnesian War (431-404 BCE) ostensibly arose because of the fear that a rising Athens would threaten Sparta's power in the Mediterranean. The idea of Thucydides's Trap warns that all rising powers threaten established powers. As China increases its power relative to the United States, the theory argues, the two nations are inevitably set on a collision course toward war. Steve Chan, "Thucydides's Trap? Historical Interpretation, Logic of Inquiry, and the Future of Sino-American Relations." University of Colorado Boulder, June 16, 2020, accessed March 31, 2021, https://www.colorado.edu/polisci/2020/06/16/thucydidess-trap-historical-interpretation-logic-inquiry-and-future-sino-american.

[17] Hawkes and McMahon, "Time Warfare."

[18] Hawkes and McMahon, "Time Warfare."

connectivity and the asymmetric advantage provided. Space operations are integral to successfully conducting large scale combat operations as part of unified land operations.[19] The frequency of conducting operations in a contested, degraded, and sometimes operationally limited space domain is increasing. FM 3-14 also addresses D3SOE as a composite of those conditions and influences in which hostile threats or non-hostile means impair space-enabled capabilities.[20]

US Army and joint forces must anticipate operating in a contested Space domain. The threat to US Army and joint operations from a contested, degraded, and operationally limited Space domain may create critical vulnerabilities for threat actors to exploit against unified land operations. These perceived vulnerabilities make contesting the Space domain attractive to threat actors. Threat actors may execute Anti-Access/Area Denial (A2AD) actions in an attempt to create multiple effects against United States and allied forces. Army forces must be prepared to conduct operations against A2AD actions.[21] Preparation can leverage space capabilities in a denied, degraded, or disrupted environment.

Maintaining dominance has several challenges in the space domain. Space is the only physical domain capable of achieving a globally persistent and legal overflight military perspective of any location on the earth.[22] Freedom of maneuver in space is required to maintain this dominant perspective. Maneuver in the space domain is similar to maneuver conducted in the physical domains, but much more complex.[23] Maneuver in space can also be physical or virtual, as well as its desired effects. Military forces at every echelon of war capitalize on this perspective to share information beyond their line-of-sight, synchronizing global power projection across all

[19] US Army, FM 3-14, 1-53.

[20] Ibid., 1-51.

[21] Ibid., 1-50.

[22] US Space Force, *Space Capstone Publication: Space Power, Doctrine for Space Forces* (Washington, DC: Government Publishing Office, June 10, 2020), 21, accessed March 31, 2021, https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf.

[23] US Army, FM 3-14, 1-50.

warfighting domains.[24] Maintaining freedom of maneuver in space requires the ability of soldiers to adapt or adjust operating parameters such as frequency, power, or modulation to gain a relative advantage over the enemy.[25] Maneuver in the space domain puts the US Army and joint force in a position of relative advantage over the enemy and may help counter the effects of a D3SOE.[26] Seizing this perspective presents opportunities to implement space capabilities during PNT warfare that will enable physical operational and tactical maneuver. By controlling this ultimate perspective, military forces can monitor and rapidly respond to any contingency around the world before establishing a large in-theater footprint.[27]

Precise timing, navigation, and synchronization have been a few of the most important technological advancements of mankind. The United States has sought to monopolize GPS as means of strategic defense and national security. This strategy has been dominant for decades as the United States has led in the PNT field of technology; however, the US Army has become overly reliant on its use. As time passes, near-peer threats are progressing in their technological capabilities that now compete with or may currently exceed the United States in the realm of multi-domain warfare. US Army operations, which heavily rely on continuous PNT, may be rendered inoperable and in turn leave the US Army defenseless if interrupted or degraded during operations. With this context in mind, a closer examination of US Army and joint doctrine is vital to understand how the US Army will maintain superiority during future multi-domain operations.

FM 3-14 defines PNT as the space-based Global Positioning System (GPS) that is a satellite-based radio navigation system operated by the Department of Defense to provide all military, civil, and commercial users with precise PNT.[28] GPS provides essential, precise, and

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[24] US Space Force, *Space Capstone Publication*, 22.

[25] US Army, FM 3-14, 1-51.

[26] Ibid., 1-51, 1-52.

[27] US Space Force, *Space Capstone Publication*, 22.

[28] US Army, FM 3-14, 1-52.

reliable timing information which enables forces to effectively execute unified land operations. GPS enables precision attack from stand-off distances, reducing collateral damage and allowing friendly forces to avoid threat areas.[29] Assured PNT information is a mission essential element in nearly every modern weapon system.[30]

Assured PNT through GPS allows ground units to maneuver expeditiously and efficiently. Based on Colonel John Boyd's concept of maneuver warfare, this formulation recognizes speed as the rapidity of action while focus represents the convergence of effects on an objective.[31] Real-time GPS information is tantamount to a unit's ability to fire and maneuver. GPS also enables friendly force tracking (FFT) to avoid specific areas and aid in rescue operations; it increases tactical operating ranges by providing specific location coordinates, fosters precision movement and maneuver, enables unmanned aerial systems which provide situational understanding, and many other functions.[32] Precision timing provides the US Army the ability to synchronize tactical digital networks and communications capabilities. Ensuring GPS connectivity and assured PNT is tantamount to mission success.

The loss of GPS may yield a decrease in the efficiency to conduct mission operations in a D3SOE. All Soldiers must understand the extent their forces and equipment rely on PNT information and how degraded or denied GPS information may impact US Army operations.[33] GPS degradation and loss impacts PNT, which as stated above supports several C2 capabilities. Neutralizing C2 capabilities will create proverbial fog of war distorting and limiting the commander's visualization of the operational environment.

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[29] Ibid., 1-20.

[30] Ibid., 1-20.

[31] US Space Force, *Space Capstone Publication*, 53.

[32] US Army, FM 3-14, 1-20.

[33] US Army, FM 3-14, 1-20.

What is a US Army Space Enabler and Space Professional?

The Space professionals (Functional Area – FA 40A) are career space specialists, who plan, develop, resource, acquire, integrate, or operate space forces, concepts, application, or capabilities.[34] As MDO comes to the forefront by 2028, the US Army must ensure the right organizations have an adequate number of positions for space professionals and space enablers are available across all echelons. Space enablers are US Army personnel who perform unique space tasks or functions or may require specialized skills to apply space capabilities.[35] Space enablers ensure proper planning of military operations in space enable activities such as intelligence collection; early warning; environmental monitoring; satellite communications (SATCOM); and PNT.[36] A significant question to ponder is how will the US Army recruit the appropriate talent and retain these personnel with these specialized skills? Most recruits often stay for their initial contract requirements and then migrate to the more lucrative private sector.

Space professionals work "space" full time, while Space enablers view "space" as supplemental to their respective career field. Space Professional Soldiers are currently only FA40 officers who follow a defined career path for training, education, and assignment.[37] Increasing the awareness of the FA40 career field and its benefits may increase recruiting efforts to fill currently vacant positions, as well as enable the US Army to increase space billets across the force, allowing for future space enabler implementation at the brigade level.

Joint Publication 3-14 defines space operations as those operations impacting or directly utilizing space-based assets to enhance the potential of the US and multinational partners.[38] US

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[34] US Army Space and Missile Defense Command, "The Army Space Cadre: Space Professionals (FA40) and Space Enablers," US Army, September 27, 2010, accessed February 5, 2021, https://www.army.mil/article/45767.

[35] US Army Space and Missile Defense Command, "The Army Space Cadre."

[36] US Department of Defense, Joint Staff, Joint Publication (JP) 3-14, *Space Operations* (Washington, DC: Government Publishing Office, 2018), I-2.

[37] US Army Space and Missile Defense Command, "The Army Space Cadre."

[38] US Joint Staff, JP 3-14 (2018), vii.

Army space operations and its personnel are separate from the newly founded US Space Force (USSF). US Army space operations utilize the fundamental principles of mission command to create a shared understanding of space enablers and space capabilities. Army Doctrine Publication (ADP) 6-0 articulates the US Army doctrine of mission command and accurately states that "a defining challenge for commanders and staffs is creating shared understanding of their operational environment, their operation's purpose, its problems, and approaches to solving them."[39]

The enactment of the FY20 National Defense Authorization Act (NDAA) redesignated the Air Force Space Command (AFSPC) as the USSF on December 20, 2019. The Secretary of Defense provided direction and guidance to establish the USSF under the Department of the Air Force, meaning the Secretary of the Air Force has overall responsibility for the USSF.[40] And the USSF mission is to organize, train, and equip space forces in order to protect US and allied interests in space and to provide space capabilities to the joint force.[41] This new mission protects US strategic interests in the space domain. USSF responsibilities include developing Guardians, acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to combatant commands.[42] The USSF is working with the US Army to ensure US Army space operations and USSF entities have a joint unity of effort while working in the space domain.

US Army activities conducted in the space domain support freedom of action throughout the operational environment (OE), and operations in other domains may create effects in the

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[39] US Department of the Army, Army Doctrine Publication (ADP) 6-0, *Mission Command: Command and Control of Army Forces* (Washington, DC: Government Publishing Office, 2019), 1-8.

[40] US Space Force, "About Space Force," Accessed March 1, 2021, https://www.spaceforce.mil/About-Us/About-Space-Force/.

[41] Ibid.

[42] US Space Force, "USSF Mission," accessed March 1, 2021, https://www.spaceforce.mil/About-Us/About-Space-Force/Mission/.

space domain.[43] It is imperative that commanders and planners, including the BCT level, understand the activities, capabilities, and operations that the space domain is able to provide. This understanding promotes the commander and staff's ability to have an inherent vantage point when visualizing the operational environment. An operational understanding of PNT will improve the commander's ability to adequately visualize, describe, direct, lead, and assess.

Commanders want to hold the high ground for the greatest visualization in any operational environment. Holding the high ground offers an elevated and unobscured field of view over the battlefield, providing early warning of enemy activity and protecting fielded forces from a surprise attack.[44] The space domain is the ultimate high ground and gives users the advantage of a global, persistent perspective of the strategic, operational, and tactical situation.[45] Satellites are well suited for communications, PNT, weather, reconnaissance and surveillance, imagery, mapping, and intelligence operations because of the access and perspectives they provide.[46] These space capabilities provide the high ground that enables the commander's visualization of the operational environment. Military spacepower is a critical manifestation of the high ground in modern warfare.[47] These space capabilities also provide freedom of action, global reach, responsiveness, and insights to A2 and AD, and geographic borders or denied regions do not constrain them.[48] Each domain within MDO has a unique set of challenges and vulnerabilities.

Within MDO, there is often conflation between space and cyberspace operations. Space operations and cyberspace operations (CO) are distinct, operations in space that enable many CO

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[43] US Joint Staff, JP 3-14 (2018), I-2.

[44] US Space Force, *Space Capstone Publication*, 16.

[45] US Army, FM 3-14, 1-55.

[46] Ibid., 1-55.

[47] US Space Force, *Space Capstone Publication*, 16.

[48] US Army, FM 3-14, 1-55.

and space systems' control segments require use of cyberspace.[49] Yet, each informs the other. Cyberspace provides a means for satellite control and spacecraft data transport.[50] A unity of effort between space systems and cyberspace requires streamline processes to relay information in a timely manner. Without this unity of effort, it could delay operations, ultimately preventing mission success.

This streamlined connectivity ensures that the DoD maintains a relative advantage with constant space superiority or even space supremacy. Space superiority is the degree of control in space of one force over any others that permits the conduct of its operations at a given time and place without prohibitive interference from terrestrial and space-based threats.[51] Space superiority is imperative to support strategic, operational, and tactical mission success. Space supremacy implies that one side could conduct operations with relative impunity while denying space domain freedom of action to an adversary.[52] To have space superiority or space supremacy a commander must have space situational awareness (SSA). US Army space policy states SSA is knowledge of the space environment, space objects, space-related activities.[53] SSA only exists during assured PNT.

SSA is the requisite foundational, current, and predictive knowledge and characterization of space objects and the OE upon which space operations depend (JP 3-14).[54] Maintaining SSA allows freedom of action in the space domain. SSA also combines the output of a wide variety of products and sources, including intelligence and cyberspace sources, to provide insight into

[49] US Joint Staff, JP 3-14 (2018), I-2.

[50] Ibid., I-2.

[51] US Joint Staff, JP 3-14 (2018), I-3.

[52] US Space Force, *Space Capstone Publication*, 30.

[53] US Army, AR 900-1, 2-2, e.

[54] US Army, FM 3-14, 1-19.

adversary use of space capabilities and their potential to threaten friendly space capabilities.[55] This insight is extremely useful during the reverse intelligence preparation of the battlefield (IPB) in the) step of the military decision-making process (MDMP). SSA contributes to a commander's ability to understand adversary intent.[56] Understanding adversary intent informs and shapes the commander's strategy. SSA is a key component for space control because it is the foundation for accomplishing all space control tasks.[57] Assured PNT must be present in order to have the SSA that sustains space control and superiority and supports US Army operations.

To assure PNT, the JNWC provides subject matter experts in deployable teams to support geographic combatant commanders.[58] These teams provide expertise in planning and executing Navigation Warfare (NAVWAR). The JNWC defines NAVWAR as the deliberate defensive and offensive action to assure PNT information through coordinated employment of space, cyberspace, and electronic warfare operations.[59]

National Space Policy

The National Space Policy of the United States of America (NSPUSA) recently created space guidelines that address current US national security interests in space. The United States seeks a secure, stable, and accessible space domain, which has become a warfighting domain as a result of competitors seeking to challenge United States and allied interests in space.[60] The US government created this policy to deter adversarial aggression and strategically shape the future space environment.

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[55] Ibid., 1-19.

[56] Ibid., 1-19.

[57] Ibid., 1-19.

[58] "Joint Navigation Warfare Center," Kirtland Air Force Base, accessed March 1, 2021, https://www.kirtland.af.mil/Units/Joint-Navigation-Warfare-Center.

[59] Ibid.

[60] Trump, *National Space Policy*, 11.

Three emerging patterns drive the current and future strategic environment. Space is becoming increasingly *congested*, *contested,* and *competitive*. Growing global space activity and testing of China's destructive anti-satellite (ASAT) system have increased congestion in important areas in space.[61] Commercial entities are also adding to the congestion with frequent satellite launches into orbit. There are well over one hundred thousand pieces of man-made debris orbiting the Earth, some of which are too small to track with current sensor technology. These smaller pieces of debris can damage satellites in orbit.[62]

Space is becoming increasingly contested in all orbits around the earth. Today's space systems and their supporting infrastructure face a range of man-made threats that may deny, degrade, deceive, disrupt, or destroy assets.[63] The NSPUSA addresses the importance of safeguarding space components or critical infrastructure against potential adversaries seeking to exploit perceived space vulnerabilities.[64] Safeguarding these space capabilities are of fundamental importance to space security. As more nations and non-state actors develop counterspace capabilities over the next decade, threats to US space systems and challenges to the stability and security of the space environment will increase.[65] Space Security protects these interests by establishing conditions for the safe and secure access to space for civil, commercial, intelligence community and multi-national partners.[66] NSPUSA strategies create an approach that allow the US to maintain space superiority and respond to these increasing space threats on its

[61] US Department of Defense (DOD) and Office of the Director of National Intelligence (ODNI), *National Security Space Strategy* (Washington, DC: Government Publishing Office, 2011), 3, accessed March 1, 2021, https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_national securityspacestrategy.pdf3.

[62] DOD and ODNI, *National Security Space Strategy*, 3.

[63] Ibid., 3.

[64] Ibid., 3.

[65] Ibid., 3.

[66] US Space Force, *Space Capstone Publication*, 35.

terms. Irresponsible acts against space systems could have implications beyond the space domain, disrupting worldwide services upon which the civil and commercial sectors depend.[67]

Space is becoming increasingly competitive. Although the United States still maintains an overall edge in space capabilities, the US competitive advantage has decreased as market-entry barriers have lowered.[68] To counter this decrease, the US is strengthening its position by increasing areas for international cooperation through the Secretary of State. In return, US partners bolster US space capacity while sharing vital information that increases space domain awareness.[69] The NSPUSA places emphasis on developing expertise and retaining space professionals. International advances in space technology and the associated increase in foreign availability of components have put increased importance on the US export control review process to ensure the competitiveness of the US space industrial base while also addressing national security needs.[70]

US National Space Strategy

The National Security Space Strategy (NSSS) draws upon all elements of national power and requires active presence of US leadership in space. The NSSS states that the United States will pursue a set of interrelated strategic approaches to meet national security space objectives to promote responsible, peaceful, and safe use of space; provide improved US space capabilities; partner with responsible nations, international organizations, and commercial firms; prevent and deter aggression against space infrastructure that supports US national security; and prepare to defeat attacks and operate in a degraded environment.[71]

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[67] DOD and ODNI, *National Security Space Strategy*, 3.

[68] Ibid., 3.

[69] US Space Force, *Space Capstone Publication*, 35.

[70] DOD and ODNI, *National Security Space Strategy*, 3.

[71] DOD and ODNI, *National Security Space Strategy*, 5.

Defense Space Strategy

The Defense Space Strategy (DSS) nests within the NSSS and seeks to achieve desired conditions of which the space domain is secure, stable, and accessible. The United States and its allies and partners underpin the use of space by sustained comprehensive US military strength. The United States is able to leverage its use of space to generate, project, and employ power across all domains throughout the spectrum of conflict.[72] To advance US space power the DoD will pursue the following defense objectives to maintain space superiority; provide space support to national, joint, and combined operations; and ensure space stability.

The DSS also articulates its prioritized lines of effort (LOE) to achieve these desired conditions, specifically to build a comprehensive military advantage in space.[73] The DoD has created specific objectives to achieve this LOE. Separately from building the USSF, the DoD objectives are to develop and document doctrinal foundations of military space power; develop and expand space warfighting expertise and culture; field assured space capabilities develop and field capabilities that counter hostile use of space; and improve intelligence, and command and control (C2) capabilities that enable military advantage in space.[74]

The US Senate Armed Services Committee (SASC) has ordered the Pentagon to provide an alternative to GPS by 2023.[75] In Section 1601 of the 2021 National Defense Authorization Act (NDAA), SASC states that the two-year deadline is "consistent with" urgent needs, and the Pentagon must prioritize and rank order the mission elements, platforms, and weapons systems most critical for the operational plans of the combatant commands. Section 1601 tasks the Pentagon to mature, test, and produce sufficient equipment for such prioritized mission elements

[72] DOD, *Defense Space Strategy*, 2.

[73] Ibid., 1.

[74] Ibid., 7.

[75] Theresa Hitchens, "SASC Wants Alternative GPS by 2023," Breaking Defense, June 29, 2020, accessed September 16, 2020, https://breakingdefense.com/2020/06/sasc-wants-alternative-gps-by-2023/.

that will generate resilient and survivable alternative positioning, navigation, and timing signals; process resilient, survivable data provided by signals of opportunity and on-board sensor systems; and integrate and deploy such equipment into the prioritized operational systems, platforms, and weapons systems.[76]

Section 1601 goes on to say, the United States will develop, acquire, field, operate, and sustain space capabilities to deliver timely and accurate space services to a variety of customers, from soldiers to national decision-makers.[77] The United States will enhance interoperability and compatibility of existing national security systems, across operational domains and mission areas, to maximize efficiency of national security architecture and ensure these characteristics are built into future systems.[78]

Department of the Army Space Policy

The Department of the Army space policy defines how the US Army accomplishes its service-level responsibilities and integrates space capabilities into Joint Combined Arms Operations.[79] It also addresses identifying future US Army challenges in the space domain by creating policy objectives and the implementation of space capabilities.

The US Army will integrate space capabilities across the force, provide needed space capabilities and support, and develop capabilities needed to provide space effects in support of US Army requirements.[80] To do this, the US Army must ensure combatant commanders can utilize space capabilities in the most effective manner. This requires a foundation built to maintain a trained and ready cadre to execute space operations. This cadre will develop and

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[76] Jeff Shepard, "eLORAN a Terrestrial Alternative to GPS." Microcontroller Tips, October 26, 2020, accessed February 5, 2021, https://www.microcontrollertips.com/eloran-a-terrestrial-alternative-to-gps/.

[77] DOD and ODNI, *National Security Space Strategy*, 6.

[78] Ibid., 6.

[79] US Army, AR 900-1, 1-1, a.

[80] Ibid., 2-1.

acquire necessary space force structure and systems by actively participating in defining space relates capability needs in coordination with the Joint community.[81] The US Army employs collaborative efforts centered on the operational and tactical needs of land forces to shape space-related combat capabilities development (CAPDEV) and materiel development (MATDEV).[82]

The Department of the Army Space Policy also articulates how integration of space capabilities relates to PNT. It states the US Army will integrate and synchronize US Army with Joint and Combined PNT and Navigation Warfare capabilities to create and sustain PNT overmatch as required by the land force. The US Army will also leverage and integrate space-based PNT services, such as global positioning system, into fixed and mobile systems and platforms. These fixed and mobile systems will provide PNT augmentation employment capabilities to enhance or extend coverage when operating in either permissive or degraded environments.[83]

Current US Army Space Force Structure

When viewing the current US Army force structure, understanding its systems helps provide context to how strategic echelons orchestrate nested operational and tactical actions. Space enablers are an important piece of this complex system. Understanding the imperatives of interdependency, the necessity of reducing complexities, and the need to produce manageable simplicities require a workable systems methodology.[84]

Each echelon depends on the capabilities of space enablers whether they know it and understand it, or not. Those personnel within each echelon that are unaware of what and how space enablers support their operations. Adding space enablers to lower levels reduces the

[81] US Army, AR 900-1, 2-1, a-d.

[82] Ibid., 1-1, b.

[83] Ibid., 2-2, a, 1-3.

[84] Jamshid Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business Architecture*, 3d ed. (Burlington, MA: Morgan Kaufmann Publishers, 2011), xix.

complexity of sending requests for space capability support to higher and can simplify system management at the level of a BCT and below. Implementing this idea can create a paradigm shift in how a staff conducts operational planning that can assure PNT and retain space access.

The distinct space capabilities, effects, and products used by the Army, joint, allied forces, and partner nations are planned, developed, prepared, and made available to the force by Soldiers conducting Army space operations and space-enabled operations.[85] Not only are space operations global, they are also multi-domain.[86] The Soldiers conducting space operations and space-enabled operations may be assigned to space operations, signal, cyber, electronic warfare, intelligence operations, and other military operations specialties.[87] However, not all Army Soldiers who configure and use equipment reliant on space capabilities are designated as space operators.[88]

> Army space operations, duties, and responsibilities are centered on these eight codified joint space capabilities: space situational awareness (SSA), PNT, space control, SATCOM, satellite operations, missile warning, environmental monitoring, and space-based intelligence, surveillance, and reconnaissance. There are two other codified joint space capabilities—nuclear detonation detection and spacelift—but the Army is not involved with those.[89]

> Army space-enabled operations are not specifically codified in joint doctrine as space capabilities, but are combined, derived, or second order tasks and actions enabled by space capabilities. These include, but are not limited to, joint friendly force tracking (FFT), network transport of Department of Defense information network, commercial imagery, National Reconnaissance Office overhead systems, Army tactical exploitation of national capabilities (TENCAP) program, National-to-Theater program interfaces, geospatial intelligence, integrated broadcast service, and common interactive broadcast.[90]

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[85] US Army, FM 3-14, 1-15–17.

[86] US Space Force, *Space Capstone Publication: Space Power, Doctrine for Space Forces* (Washington, DC: Government Publishing Office, June 10, 2020), vii, accessed March 31, 2021, https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf.

[87] US Army, FM 3-14, 1-15–17.

[88] Ibid.

[89] Ibid., 1-15–17.

[90] US Army, FM 3-14, 1-15–17.

Preserving freedom of action becomes an operational imperative in peace and war, and space security becomes a critical mission across the conflict continuum.[91] Space Control is the operations to ensure freedom of action in space for the US and its allies and deny an adversary freedom of action in space (JP 3-14). The Army conducts space control by using globally deployable units to conduct surveillance and assessment of space systems in support of US Army operations.[92] Space control supports freedom of action in the space domain for friendly forces, and when necessary, defeats adversary efforts to interfere with United States or allied space systems and negates adversary space capabilities. The current US Army task organization of space support nests within the force structure required to support national strategic and policy objectives.

Current US Army Task Organization of Space Support

Soldiers and civilians make up the Army's strategic level space cadre at the ASCC. Army operational echelons, primarily division and corps, also have documented training and experience in the space domain and conduct daily missions of the US Army Space Force..[93]

[91] US Space Force, *Space Capstone Publication*, 28.

[92] US Army, FM 3-14, 1-15–17.

[93] US Army Space and Missile Defense Command, *Army Space Personnel Development Office (ASPDO)* (Huntsville, AL: US Army Space and Missile Defense Command, n.d.), 2, accessed March 31, 2021, https://www.smdc.army.mil/Portals/38/Documents/Publications/Fact_Sheets/ASPDO.pdf.

Division

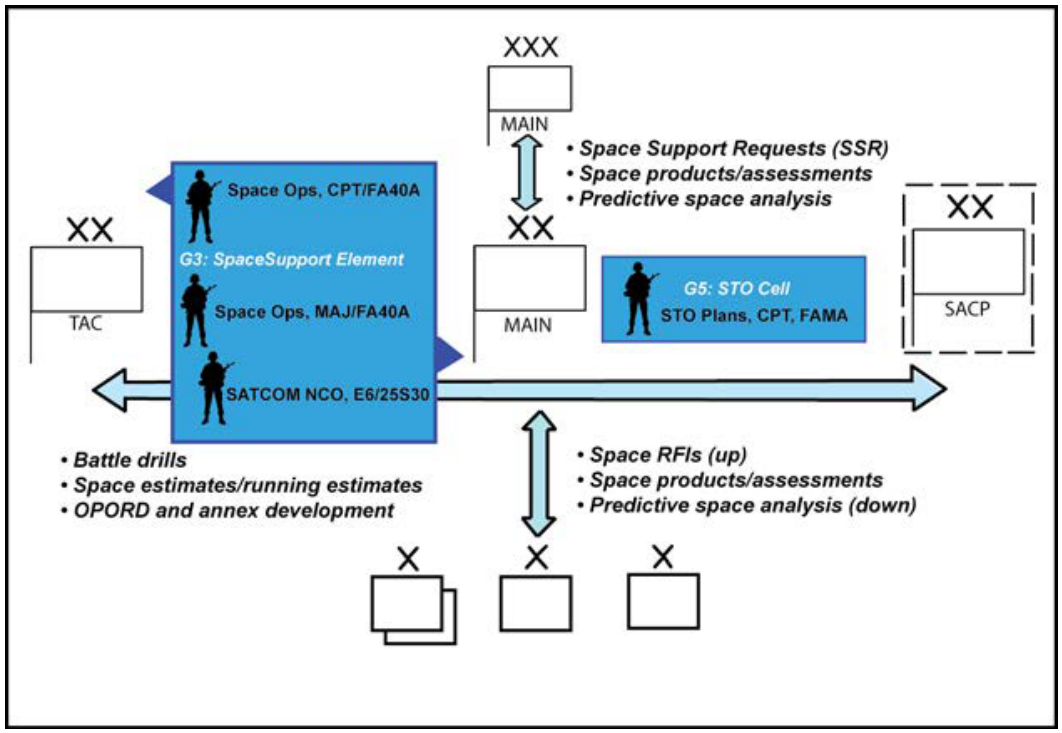

Figure 1. Organic Division Space Support. Center For Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), 53, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

Currently, the division Modified Table of Organization and Equipment (MTOE) the lowest level that authorizes space operations personnel. Current Division MTOE authorizes 1 x Major (O-4), 1 x Captain (O-3), and 1 x Staff Sergeant (E-6) to the G3 (Space Support Element), and 1 x Captain (O-3) to the G5 (Special Technical Operations (STO) Cell).[94] The mission of the SSE is to serve as the assigned unit's chief proponent of Space.[95] The division MTOE nests with its higher corps MTOE. MTOE is an Army acronym that stands for Modification Table of Organizational Equipment - an MTOE unit is a deployable, go-to-war unit, it is the units that

[94] CALL, CALL Handbook 18-28, 53.

[95] Eric N. Strom, "Space Support for the Warfighter: Determining the Best Way to Provide Space Capabilities at the Army Division and Brigade Levels" (master's thesis, Naval Postgraduate School, June 2009), 43, accessed March 31, 2021, https://apps.dtic.mil/sti/pdfs/ADA501554.pdf.

deploy, or can deploy.[96] This MTOE provides the Division with Space (and special technical operations [STO]) support across all warfighting functions/staff elements and through all planning horizons (plans, future, and current operations [FUOPS and CUOPS]).[97]

Corps

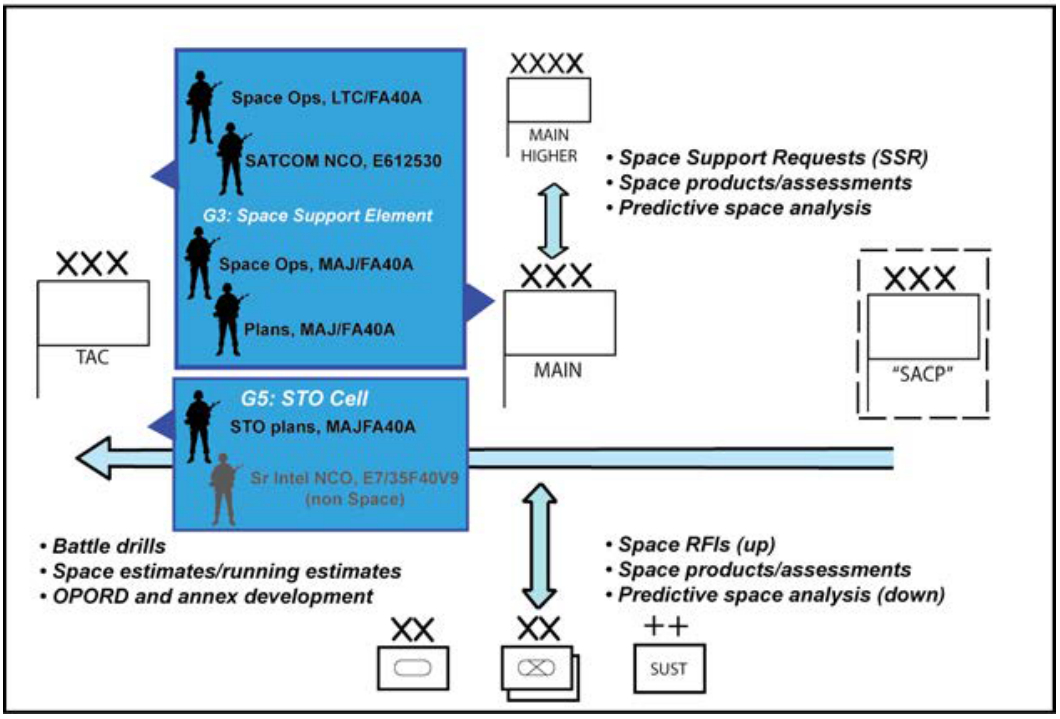

Figure 2. Organic Corps Space Support. Center For Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), 54, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

The corps is the focal point for the planning and execution of space operations.[98] The Corps MTOE authorization depicts space operations personnel as follows. Current Corps MTOE authorizes 1 x Lieutenant Colonel (O-5), 2 x Majors (O-4), and 1 x Staff Sergeant (E-6) to the TAC and Main CPs in the G3 (Space Support Element), and 1 x Major (O-4) and 1 x Sergeant

[96] Chuck Holmes, "Army MTOE and TDA Unit Information," Part-Time-Commander.com, accessed January 13, 2021, https://www.part-time-commander.com/army-mtoe-tda-unit-information/.

[97] CALL, CALL Handbook 18-28, 53.

[98] US Army, FM 3-14, 4-16.

First Class (E-7) to the tactical (TAC) FUOPS G5 (STO cell)..[99] This MTOE provides the Corps with Space (and STO) support across all warfighting functions/staff elements and through all planning horizons (plans, FUOPS, CUOPS)..[100] The corps MTOE provides space support to subordinate units and links to higher/lower space support channels.

Army Service Component Command (ASCC)

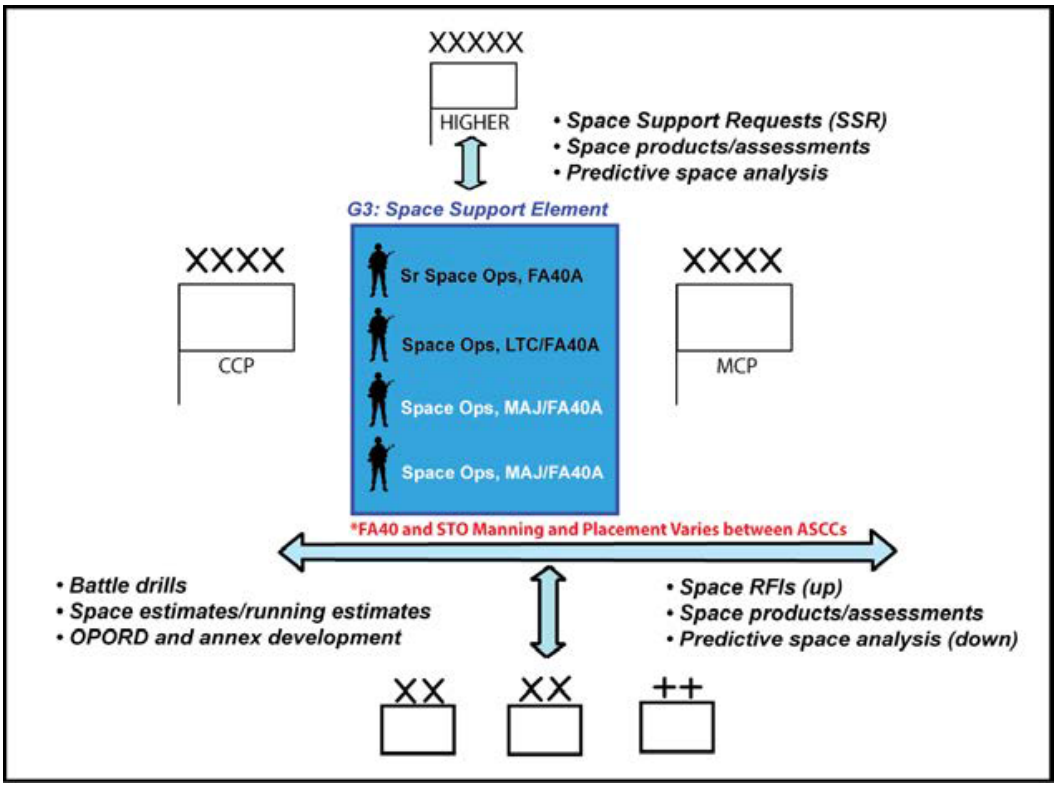

Figure 3. ASCC Space Support. Center For Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), 55, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

ASCC MTOE authorization depicts space operations personnel as follows. The ASCC MTOE authorizations vary significantly between ASCCs but generally include 1 x Colonel (O-6)/ Lieutenant Colonel (O-5) and 1 x Lieutenant Colonel (O-5)/ Major (O-4) at the main command post (MCP), and 1 x Lieutenant Colonel (O-5)/ Major (O-4) at the contingency command post

[99] CALL, CALL Handbook 18-28, 54.

[100] Ibid., 54.

(CCP).[101] The ASCC MTOE provides space support across all warfighting functions/ staff elements and through all planning horizons (plans, FUOPS, CUOPS), to subordinate units and to the theater director space forces (DIRSPACEFOR), or "DS4" at the Combined Air Operations Center/Joint Air Operations Center (CAOC/JAOC).[102] USASMDC currently serves as the ASCC to USSTRATCOM and conducts space and missile defense operations and provides planning, integration, control and coordination of Army forces and capabilities in support of USSTRATCOM missions (strategic deterrence, integrated missile defense, and space operations) and serves as the Army force modernization proponent for space, high altitude and global missile defense.[103]

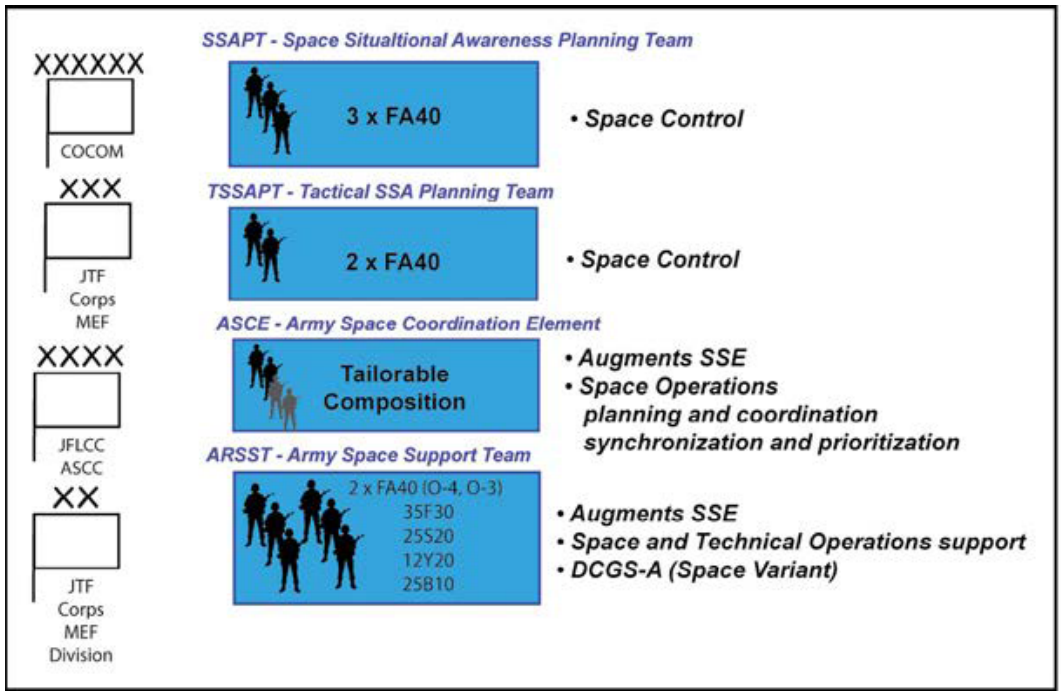

Figure 4. Current Space Support Augmentation. Center For Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), 56, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

[101] CALL, CALL Handbook 18-28, 55.

[102] Ibid., 55.

[103] "Functional Components," US Strategic Command, accessed March 31, 2021, https://www.stratcom.mil/components/.

These division and higher-level space augmentation forces provide space situational awareness (SSA), Space Force Enhancement (SFE), or Space Control (SC). To do so, space elements and teams integrate for support. Space Situational Awareness Planning Teams (SSAPTs) support corps commander-level headquarters, augmenting the Joint Space Control Coordination Element, and provide space and space control planning and coordination.[104] Tactical Space Situational Awareness Planning Teams (TSSAPTs) support tactical level headquarters, Joint task force, corps, with planning, requesting, and coordinating space control capabilities.[105] Army Space Coordination Element (ASCE) supports Joint Force Land Component Commander (JFLCC)/ ASCC headquarters with planning, synchronizing, coordinating, and prioritizing space operations.[106] The Army Space Support Team (ARSST) provides space-based capabilities to units with either no existing or insufficient organic capability of their own.[107]

Army Space Personnel Development Office (ASPDO) currently tracks 1,776 space enabler billets allocated across the US Army, ARNG, and USAR for fiscal year 2020. Of those, ASPDO assigned 1,435 to Compo 1. Two hundred and five of the space enabler billets are allocated for Compo 2. And lastly, The Compo 3 has 136 allocated space enabler billets.[108] The large majority of these billets are located in Air Defense Artillery, Engineer, Military Intelligence, and Signal branched units. The ASPDO Assured Functional Area Transfer (AFAT) program

[104] CALL, CALL Handbook 18-28, 55.

[105] Ibid., 55.

[106] Ibid., 55.

[107] Strom. "Space Support for the Warfighter, 391.

[108] Army Space Personnel Development Office, "FY 2020 Space Cadre Billets" (Colorado Springs, CO: US Army Space and Missile Defense Command (USASMDC), August 20, 2020).

provides future Army officers the opportunity to become Functional Area-40 Space Operations Officers after successful service within a basic branch.[109]

Section 3: Analysis

This section analyzes current and proposed US Army space capabilities, which provide maneuverability during PNT warfare. This section also identifies how the US Army currently integrates space capabilities and its impact across the force due to any operational limitations created by PNT warfare. Identifying when and how integrating space domain capabilities into mission planning is extremely salient. This analysis will also cover the adequacy of current requirements for space enablers and capabilities, their understanding, application at the operational and tactical levels, and alternatives that may provide additional breadth and depth to assist the US Army in defeating D3SOE.

The US Army must develop and sustain a cadre of skilled military and civilian space personnel through effective space-related training and education.[110] This cadre should strive for space mastery. The term space mastery refers to a technical understanding of the physical, network, and cognitive dimensions of space operations.[111] As the USSF has primarily harvested its initial talent from the US Air Force, it is also looking to bolster its ranks with members from other branches of service. The US Army must also acknowledge that many US Army FA40 and space enabler personnel may request to transfer to the USSF, further hindering future recruitment and retention for the US Army. Having an operational planner that is space enabler qualified (3Y) is always a benefit, but the likelihood of finding one is rare. The underlying problem lies in the US Army's ability to provide operational brigades with planners who understand US Army space

[109] Cecil Longino, "Growing tomorrow's Army space operations officers," US Army, May 19, 2020, accessed March 31, 2021, https://www.army.mil/article/235757/growing_tomorrows_army_space_operations_officers.

[110] US Army, AR 900-1, 2-3, c, 4.

[111] US Space Force, *Space Capstone Publication*, 49.

operations and capabilities. The number of FA40s across the US Army is fairly limited. Therefore, recruiting and retention of FA40 space enablers must become a priority for US Army Forces Command (FORSCOM) and US Army Training and Doctrine Command (TRADOC).

Integrating space enablers within a BCT will provide planners at the operational level with an increased space situational awareness of the battlefield. Sound space doctrine and superior space capabilities are of little use without personnel who have the expertise and empowerment required to wield them.[112] While there are clear benefits to having the "highest ground" physically and theoretically in space, understanding the nature and characteristics of space, its threats both natural and man-made, will allow planners at the BCT level to incorporate space capabilities into their planning considerations. The Army's warfighting functions are all enhanced by incorporating space capabilities.[113] This enhancement only comes with knowledge, training, and experience.

Current US Army battalion and brigade planners receive their professional military education while attending Command and General Staff College (CGSC). The CGSC curriculum only provides 1 hour of education related to US Army space operations during the 12-month curriculum. A one-hour block of space education at CGSC is simply inadequate as effective education to cover the vast amount of relevant information that pertains to space, space enablers, space capabilities, and their incorporation into MDO and the planning process. CGSC offers two elective courses that provide an orientation to space, but classes are limited due to schedules and the qualified faculty available to instruct. CGSC students that successfully complete the two elective space courses become space enabler qualified and receive the 3Y additional skill identifier.

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[112] US Space Force, *Space Capstone Publication*, 46.

[113] US Army, AR 900-1, 1-1, b.

The modern American military also depends on GPS to navigate, to track the position of friendly units, and even to provide the microsecond timing required to link up its radio communications networks.[114] Tracking the position of friendly units occurs at the lowest levels while also pushing the information up through the organization. This real-time awareness is vital for operational units to provide C2 during MDO. It is imperative that operational units receive the training and support necessary to utilize space capabilities to maintain tempo on the battlefield. Space enablers embedded at the BCT level will require dispersion throughout the sections within the S3 Operations. Both Current Plans (CUOPS) and Future Plans (FUOPS) staff sections will require space enablers that provide SSA training to the BCT staff. Understanding SSA for current space operations and available space capabilities will assist in planning for future operational requirements and space capability requests. BCT commanders must ensure their staffs understand how to access and plan for space capabilities to determine whether the capabilities are continuously available or require special authorization and coordination.[115]

To establish and maintain space superiority, commanders require resilient space capabilities, with forces that have the skill and the experience to operate and defend their space systems across the range of military operations and to deny the same to the opposing force.[116] This reinforces the notion that space enablers are required to not only ensure space superiority, but also operate alternative space systems to communicate, and provide a shared understanding at multiple echelons, including the BCT. Implementation of training at the operational level will

[114] Sydney J. Freedberg Jr., "Army Fields Anti-Jam GPS in Germany This Fall," Breaking Defense, June 06, 2019, accessed July 19, 2019, https://breakingdefense.com/2019/06/army-fields-anti-jam-gps-to-germany-this-fall/.

[115] US Army, AR 900-1, 1-1, b.

[116] US Joint Staff, JP 3-14 (2018), I-3.

prepare and enable US Army forces to successfully fight and win future conflicts in a D3SOE while protecting the US homeland, warfighters, and way of life.[117]

As assured PNT has the potential to be the difference between victory and defeat, it must be akin to military power in any other domain.[118] GPS redundancy to assure PNT will allow the US Army to effectively conducting MDO. eLORAN, inertial navigation systems (INS), high-tech celestial navigation, quantum compasses, and Mounted Assured Positioning Navigation and Timing System (MAPS) are different GPS capabilities that provide alternative PNT signals, while dismounted assured PNT and Nett Warrior provide additional breadth and depth required to defeat D3SOE.

eLORAN

Terrestrial-based hyperbolic navigation technologies predate today's satellite-based global positioning system (GPS). Starting with developments in the 1930s and 1940s, land-based long-range navigation (LORAN) systems using hyperbolic navigation. Today, the enhanced LORAN (eLORAN) system offers a more secure alternative to GPS. Hyperbolic navigation technologies were independently developed in the US and the UK during World War II. The first hyperbolic navigation system was to be used operationally, entering service with RAF Bomber Command in 1942.[119] Continuous breakthroughs in technology have led to enhanced LORAN (eLORAN), the evolution of LORAN-C.

Just as equipment required to spoof and jam GNSS and GPS must mimic relatively low powered transmissions, spoofing and jamming eLORAN requires very high-powered transmissions. eLORAN towers substantially improve PNT accuracy by the method they use to communicate data. These data commands can penetrate buildings, underground significantly, and

[117] CALL, CALL Handbook 18-28, iv.

[118] US Space Force, *Space Capstone Publication*, 26.

[119] Shepard, "eLORAN.

underwater, providing a unique and powerful command and control capability. eLORAN capabilities include signals 3-5 million times stronger than GPS/GNSS, 99 percent reliability and availability, a 1,200-mile signal range, and uses a transmission up to 1MW of power while encryption and authentication prevent disruption, jamming, or spoofing. eLORAN also utilizes the EMS 90kHz to 110kHz which is internationally protected. It is usable anywhere and can penetrate buildings, structures, tunnels, underground, and underwater. eLORAN is versatile and synchronizes to the Universal Coordinated Time (UTC) and also can support unmanned and autonomous operations.[120]

LORAN is a tried-and-true robust GPS system that has evolved into eLORAN over time to provide accurate PNT. eLORAN currently exceeds the accuracy, availability, integrity, and continuity performance requirements for all modern PNT applications. Lastly, eLORAN is difficult to spoof or jam, and it is nearly impossible to do so at a distance which could be an advantageous option for the US Army to integrate into its current GPS systems and create redundancy required to maintain PNT during MDO.

INS

The US Army and sister services currently utilize INS in some scenarios. As INS uses accelerometers and gyroscopes to dead reckon positioning rather than rely on external signals such as GPS. These components work together to calculate position, orientation, and velocity to deliver critical navigation information in GNSS-denied areas like urban canyons, bridges, tunnels, mountains, parking garages and dense forests.[121] INS is a readily available and successful alternative to GPS.

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[120] US Space Force, *Space Capstone Publication*.

[121] Jon Thorland, "What is An Inertial Navigation System?" Honeywell Aerospace, accessed February 5, 2021, https://aerospace.honeywell.com/en/learn/about-us/blogs/2020/04/what-is-an-inertial-navigation-system.

High-Tech Celestial Navigation

Mariners have used various celestial navigation techniques for hundreds of years. Two stars, the local altitude, and a clock are all that one needs to determine a position using a sextant.[122] Celestial navigation is surprisingly accurate. Today's advanced optics and high-speed microelectronics can enable celestial navigation with an accuracy of 15 meters, without the need to know the altitude, even in a moving aircraft or missile.[123]

Skymark, a high-tech celestial navigation system, uses a database of visible satellites – both working satellites and space junk – and has a claimed accuracy of 15m (49ft), making it almost as good as GPS. Skymark provides a system position fix through a unique combination of advanced optics, sensors, and algorithms to triangulate off of known positions of stars and satellites. And its accuracy depends on knowledge of the atmospheric density profile to provide a refraction estimation that replaces the vertical measurement in earlier celestial navigation systems.[124] High tech celestial navigation can correct an emerging problem common to INS when access to GPS is denied: they tend to drift and lose accuracy over time, making them imprecise on their own for long-distance navigation.

Quantum Compasses

A quantum compass, is somewhat similar to INS. It is an instrument that measures relative position using the technique of atom interferometry. And includes an ensemble of accelerometers and gyroscopes based on quantum technology to form an inertial navigation unit. A quantum compass contains clouds of atoms frozen using lasers, and by measuring the

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[122] Jeff Shepard, "Quantum Compasses and Optical Imaging for Global Positioning and Navigation," Microcontroller Tips, October 27, 2020, accessed February 5, 2021, https://www.microcontrollertips.com/quantum-compasses-and-optical-imaging-for-global-positioning-and-navigation/.

[123] Shepard, "Quantum Compasses.

[124] Ibid.

movement of these frozen particles over precise periods of time, the device's motion can be calculated. The device would then provide a tamper-proof accurate position in circumstances where satellite navigation is not possible.[125] A quantum compass may be an excellent GPS alternative for the US Army as it does not require communication to external systems. It could provide tamper-proof positioning in a D3SOE and allow freedom of maneuver for any US Army operations.

MAPS

Mounted Assured Position Navigation and Timing System (MAPS) is a program that ensures soldiers know their location and direction they are moving even if the enemy is jamming GPS. MAPS simplifies the Army's mounted PNT capability by distributing PNT data to multiple systems, eliminating the need for multiple [GPS] devices on a single platform, while allowing multiple users to access an assured GPS signal, and other sources of PNT, from one central point.[126] "This is an important capability for the Army and proof that [AFC]'s mission to accelerate the development and fielding of modernized Soldier capabilities is working," said Willie Nelson, Director of the Assured Positing, Navigation and Timing (APNT) Cross-Functional Team (CFT).[127]

While MAPS GEN I represents an initial "Fight Tonight" capability, Gen II will have more advanced features, such as the ability to receive M-Code - a more accurate, jam resistant GPS code built for military use. It will also feature alternate navigation, anti-jam antenna, sensor fusion, inertial measurement unit, and PNT threat line of bearing. Following Gen II, MAPS

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[125] Ibid.

[126] Jaspreet Gill, "Army Approves First Assured PNT Requirement," Inside Defense, September 16, 2020, accessed November 24, 2020, https://insidedefense.com/insider/army-approves-first-assured-pnt-requirement.

[127] Nathan Strout, "Collins Aerospace to Build GPS-Jamming Solution for the Army," Battlefield Tech, C4ISRNET, Sightline Media Group, October 7, 2020, accessed December 2, 2020, https://www.c4isrnet.com/battlefield-tech/2020/10/07/collins-aerospace-to-build-gps-jamming-solution-for-the-army.

incorporates into the C4ISR/EW Modular Open Suite of Standards, or CMOSS. CMOSS is a common chassis the Army is building as part of their new plug-and-play approach to capabilities. Instead of having to install MAPS onto vehicles with each upgrade, CMOSS will allow MAPS to install by simply plugging a chip into the chassis.[128]

Dismounted Assured-Positioning, Navigation and Timing (A-PNT) will provide a single source of A-PNT to support communications, command and control, logistics, targeting and effects as a stand-alone capability. It will also optimize power to leverage shared Conformal Wearable Battery when employed with Nett Warrior.[129]

Nett Warrior (NW) is an integrated dismounted leader Situational Awareness (SA) system used during combat operations. The system provides unparalleled SA to the dismounted leader, allowing for faster and more accurate decision-making in the tactical fight. With advanced navigation, SA and information-sharing capabilities, leaders are able to avoid fratricide and are more effective and lethal in the execution of their combat missions.[130] NW employs a system-of-systems approach, optimizing and integrating capabilities while reducing the Soldier's combat load and logistical footprint. It also provides overmatch operational capabilities to all ground combat leaders and small-unit operations.[131]

Dismounted A-PNT will provide accurate and trusted PNT information to the US Army's dismounted soldiers under limited or denied PNT conditions.[132] MAPS, CMOSS, and dismounted A-PNT will drastically reduce operational and tactical level navigation capability

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[128] Strout, "Collins Aerospace."

[129] US Army Acquisition Support Center (USAASC), "Assured-Positioning, Navigation and Timing (A-PNT) — Dismounted," accessed February 5, 2021, https://asc.army.mil/web/portfolio-item/a-pnt-dismounted/.

[130] US Army Acquisition Support Center (USAASC), "Nett Warrior (NW)," accessed February 5, 2021, https://asc.army.mil/web/portfolio-item/soldier-nw/.

[131] Ibid.

[132] USAASC, "Assured-Positioning."

gaps by its ability to create a real-time shared understanding with adjacent units on the battlefield. Below is a graphic that illustrates how to acquire alternative sources of APNT during D3SOE.

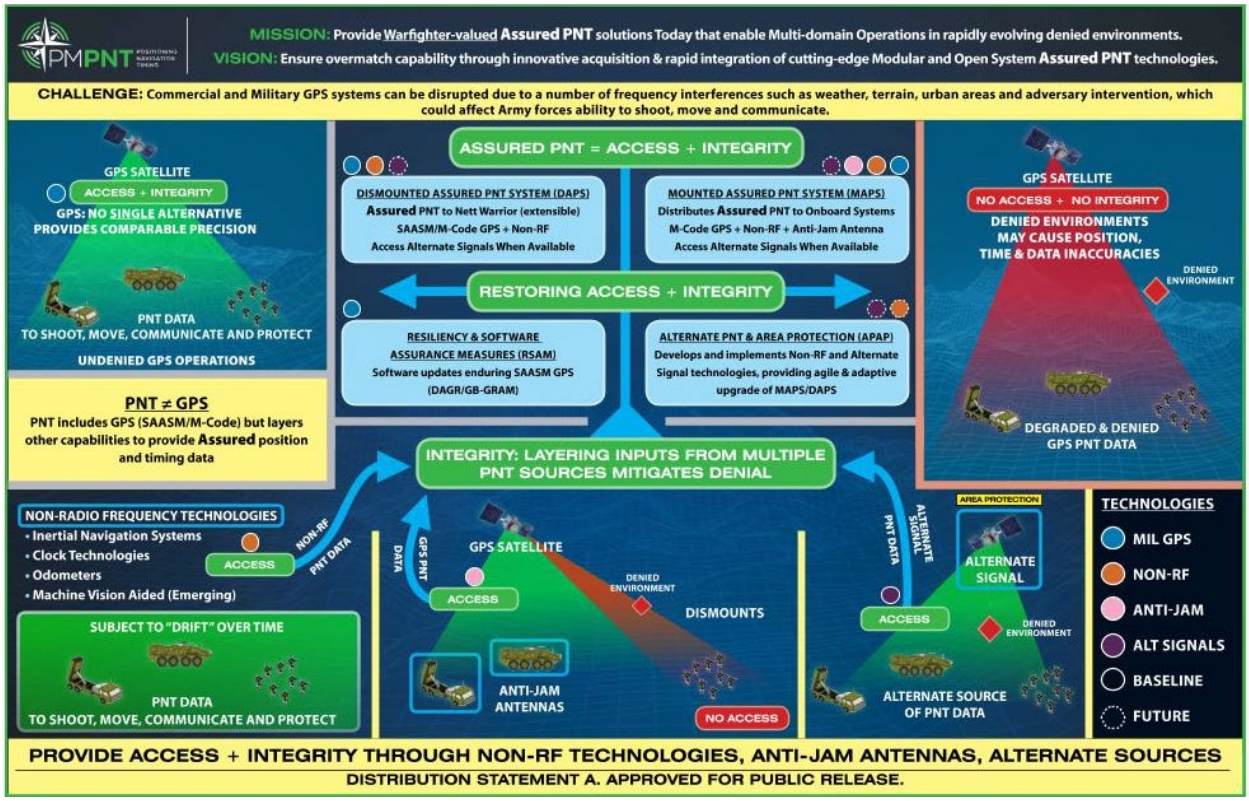

Figure 5. Army Concepts for Assured Positioning, Navigation, and Timing When GPS May Be Unavailable. Sydney J. Freedberg Jr., "Army Fields Anti-Jam GPS in Germany This Fall," Breaking Defense, June 06, 2019, accessed July 19, 2019, https://breakingdefense.com/2019/06/army-fields-anti-jam-gps-to-germany-this-fall/.

Lastly, the Defense Advanced Research Projects Agency (DARPA) has several PNT-related projects under way, intended to improve accuracy, allow fast integration of PNT sensors across multiple platforms, and even go beyond GPS. These programs are developing PNT capabilities that do not use the satellite system, but instead use arrays of sensors and new types of signal processing that can function in difficult environments, ad hoc networks of separate nodes, and new architectures that would allow integrate other domains such as communications,

electronic warfare or ISR systems into PNT.[133] PNT capabilities that do not use satellite would provide additional alternatives for the US Army to operate when in a D3SOE.

Execution of a synchronized, robust science and technology program can lead to procurement and fielding of space capabilities, to include technologies designed to operate in and through permissive D3SOE.[134] US Army implementation of these alternative capabilities will ensure BCT commanders can conduct operations during D3SOE. US Army space operations must remain flexible to commanders' needs and stay agile in response to threat actor exploitation efforts to place US Army and joint forces into a D3SOE, which is the results of a threat actor implementation of A2 and AD strategies.[135] Flexibility provides commanders the ability to orchestrate and exercise operational art. D3SOE is the most recognizable impact to space capabilities from threat actors such as China and Russia.

These alternative capabilities provide additional breadth and depth that assure PNT while operating in D3SOE. Breadth helps understand the enduring nature of PNT while providing insight on how PNT warfare's character will evolve in the future.[136] Depth provides the ability to better forecast the pressures high-intensity conflict will place on PNT.[137] Additional breadth and depth are necessary to ensure uninterrupted situational awareness during operations in D3SOE. This uninterrupted real-time situational awareness provides the operational understanding necessary for the US Army to mitigate the effects of PNT warfare during future MDO.

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[133] Kevin McCaney, "DOD Puts Emphasis on Navigation Warfare, Accurate GPS Signals," Defense Systems, February 9, 2015, accessed July 15, 2019, https://defensesystems.com/articles/2015/02/09/dod-directive-navigation-warfare-pnt-tools.aspx.

[134] US Army, AR 900-1, 2-3, c, 8.

[135] McCaney, "DOD Puts Emphasis on Navigation Warfare."

[136] US Space Force, *Space Capstone Publication*, 54.

[137] Ibid.

Section 4: Recommendations and Conclusions

Recommendations

Recommendations that support creating an operational understanding of PNT parallel objectives nested in the DSS. To support the objectives of LOE 1 listed in the DSS, doctrinal foundations of military space power must have swift distribution across the force and implementation in professional military education (PME). This will support the second objective of the DSS, by expanding space warfighting expertise and culture.

Expanding organizational space warfighting expertise and culture recognizes the importance of US Army space enablers and space capabilities. Space enablers with PNT expertise must integrate into the BCT in order to inform and educate BCT forces. PNT education will provide the BCT staff with the understanding required to plan with available space capabilities and inform future planning considerations. Creating a shared understanding of operational PNT will improve intelligence and C2 capabilities that enable military advantage in space. A brigade must also incorporate a space support cell and a STO cell which will provide the necessary space support at the operational to reinforce improved intelligence and C2 capabilities.

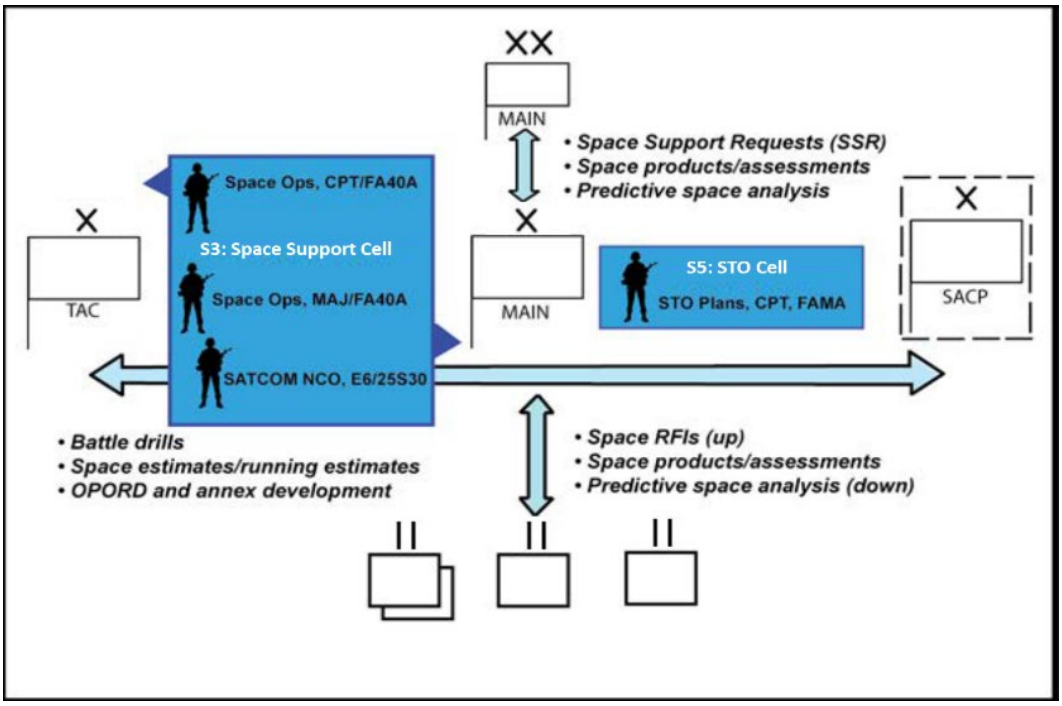

Figure 6. Brigade Space Support Cell and STO Cell Structure Recommendations. Created by author based on illustration taken from CALL Handbook. Center for Army Lessons Learned (CALL), CALL Handbook 18-28, *Operating in a Denied, Degraded, and Disrupted Space Operational Environment* (Fort Leavenworth: US Army Combined Arms Center, June 2018), 19, accessed September 15, 2020, https://usacac.army.mil/sites/default/files/publications/18-28.pdf.

BDE space support cell and STO cells, in the respective S3 and S5 staff sections, parallel the current DIV space cell structure. Mirroring the Division cell will create a streamlined connection between the DIV and BDE that will improve the dissemination of information and also create the necessary understanding of space enabler capabilities at the BDE level by including the BDE in space battle drills, space running estimates, space annex development, space RFIs, space products and assessments, and create a predictive space analysis which can all be disseminated to subordinate battalions to further the space knowledge at the tactical level within the organizations. Recommend the BDE MTOE approval to authorize 1 x Major (O-4), 1 x Captain (O-3), and 1 x Staff Sergeant (E-6) and also create the S3 Space Support Element (SSE), and 1 x Captain (O-3) to create the S5 (STO) Cell.

Presently, there are a limited number of space enabler billets currently in combat arms corps and divisions. As identified during the analysis, Active-duty Compo 1 combat arms

divisions only have three space enabler billets authorized per division. These billets must remain in place, and also be expanded, to provide continuity between echelons. Recommend that current BCT billets be recoded for space cadre and enabler personnel instead of authorizing ADCON, OPCON, or TACON to BCTs. This will eliminate the "red tape" that is often associated with ADCON, OPCON, and TACON personnel. Expanding the AFAT program will increase the number of available space enablers and recruit the appropriate talent to adequately support the need for space enabler billets at the BCT level. With ASPDO's assistance to expand the scope and scale of space enablers across BCTs will fundamentally increase the incorporation of space assets in planning, training, and execution of missions under a denied, degraded, and/or disrupted operational environment.

Recommend senior leaders push to foster additional leader development for junior leaders to acquire an understanding of space enablers and space capabilities. Exposure to US Army space operations while attending PME will increase this understanding. By incorporating space operations into the military education, US Army personnel can apply their new understanding of space enablers and capabilities the planning process within scheduled operational exercises. A specific example of this is allocating time for additional space blocks of instruction throughout CGSC held at Fort Leavenworth, Kansas. The field grade officers attending CGSC can receive a foundational understanding of US Army space operations and implement their newfound knowledge during the planning process of the Advanced Operations Course (AOC). Providing qualified space cadre to participate in US Army space-related training, education, and exercises can also familiarize field grade officers with space enablers and capabilities and give them the tools necessary to increase space knowledge and understanding at their future assignments, which are typically at the operational level in brigades and battalions. This can also increase recruitment for soldiers who want to transition to the US Army space professional functional area.

Recommend developing and fielding capabilities that counter hostile use of space and fielding future assured space capabilities. A US Army space policy objective is to execute space-related CAPDEV, METDEV, and technology development activities responsive to land force needs and validated requirements.[138] Implementing several alternative options to GPS that ensure PNT availability such as eLORAN, Inertial Navigation Systems (INS), High Tech Celestial Navigation, Quantum Compasses, and Mounted Assured Positioning, Navigation & Timing (MAPS) will provide the US Army with alternative PNT signals by creating redundancy and assurance during MDO. Fielding DARPA programs in conjunction with adding space enabler personnel to a BCT can heighten the space situational awareness of the BCT staff when planning for future operations. Implementation of these innovative space capabilities will support the real-time situational awareness BCT commanders require to conduct operations in and through D3SOE. This additional situational awareness of the operational environment is invaluable to the BCT commander and staff.

Additional Research

Additional research considerations may need to focus on how PNT warfare may push future warfare out of the physical dimension and into the virtual dimension and how the US Army can achieve and maintain an advantage in preparedness within the next decade. Identifying and forecasting future technological shortfalls, how to improve/correct these future problems, and research to address additional US Army doctrine shortfalls. Additional questions to consider are will the US Army require partnerships with private industry to maintain its competitive advantage in space? How does the US Army prepare to meet the future challenges of evolving adversaries in space? What capability development, doctrine improvement, force structure changes, and training will be required to support MDO at the ever-increasing speed of innovation? How will AI and machine learning innovation change the operational environment for the US Army by 2035?

[138] US Army, AR 900-1, 2-3, c, 7.

What space capabilities and emerging technology will be required to support the Multi-Domain Army of 2035?

Conclusion

The US Army must recognize the future implications of PNT and continue to identify vulnerabilities that will impede execution of future military operations, supported by space power, during D3SOE. Space power cannot unilaterally win wars, but like land power, sea power, air power, or cyber power, its success, absence, or failure could prove catastrophically decisive in war.[139] There cannot be only one. It is a continuous synchronization of joint and all domain efforts to accurately visualize the operational environment.

With regards to space, as new technology continues to develop, the primary challenge in the foreseeable future for the US Army is assuring PNT and the space-based capabilities that are essential to conducting MDO. The near-universal reliance on PNT information has led militaries to explore "deliberate defensive and offensive action to assure friendly use and prevent adversary use of PNT information through coordinated space, cyberspace, and electronic warfare (EW) capabilities".[140] Forecasting future technology and alternative options for assured PNT to support MDO will be tantamount to how the US Army will reduce its current overreliance on PNT and mitigate vulnerabilities while continuing to conduct operations and achieve mission success.

PNT vulnerabilities will impede execution of future US Army operations during MDO. US Army space enablers are paramount to successfully bridge the space operations gap, mitigate PNT vulnerabilities, and address near-pear threats during PNT warfare. Anticipating the future operational environment that the US Army will operate in requires additional US Army space enablers implemented at the BCT level. US Army echelons must significantly enhance the number of space enabler personnel in order to bridge the space operations gap. Educating,

[139] US Space Force, *Space Capstone Publication*, 26.

[140] US Joint Staff, JP 3-14 (2018), II-3.

developing, and training soldiers and leaders of the US Army about space operations and capabilities will create the operational understanding necessary to effectively plan and execute operations in future MDO.

Understanding how the US Army must utilize space capabilities to assure PNT while conducting operations during MDO against near peer adversaries is vital to future operational planning. Future MDO will require the US Army to focus on supporting assured PNT and mitigation techniques that will address operational challenges and maintain operational dominance. It reinforces the role space plays in the larger conflict spectrum and prepares us for what the future might hold.[141]

[141] US Space Force, *Space Capstone Publication*, 54.

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