Atlas V rocket launches Navy's Mobile User Objective System 2 satellite from Space Launch Complex–41 at Cape Canaveral Air Force Station, Florida, July 19, 2013 (U.S. Navy/NASA/Patrick H. Corkery)

Space Operations
Lines, Zones, Options, and Dilemmas

By Jerry V. Drew

While there is considerable literature available on both the strategic and tactical aspects of space operations, there is surprisingly little that discusses the linkage of tactical space operations to the achievement of strategic objectives through operational art. In addition to government documents such as the National Security Space Strategy, influential academic works have largely focused on the strategic and political aspects of the space domain.[1] Much of the professional literature produced by military practitioners, on the other hand, has focused on the tactical exploitation of space systems.[2] While this collection of works sometimes hints at the possibility of synchronizing tactical action to achieve strategic ends, none provides a practical explanation of how commanders and staffs might achieve such a feat.

Furthermore, the doctrinal publications that bear some responsibility for this explanation—for instance, Joint Publication 3-14, *Space Operations* (2018), and U.S. Army Field Manual 3-14, *Army Space Operations* (2019)—tend to develop domain-unique language rather than language rooted in theoretical principles that is translatable across other warfighting domains.[3] As a result, the connective tissue of a common operational language between space operations and the rest of the joint force is largely missing. With the recent establishment of U.S. Space Command and the U.S. Space Force, the joint force stands poised to

Major Jerry V. Drew II, USA, is a Planner in the U.S. Army Space and Missile Defense Command.

expand its incorporation of the space domain into existing and future operations. To effectively accomplish this expansion, however, operational art as it applies to the space domain requires a deeper conceptual consideration—one that leverages and expands on existing warfighting concepts to enable multidomain integration.

The literature of operational art itself has a long history and provides much of the language necessary for such a consideration. In 1838, the Swiss general and theoretician Baron Antoine-Henri Jomini published *The Art of War*, a work that permeated the U.S. military of the 19th century and forms the basis for the modern doctrinal lexicon. Like his contemporary, the Prussian general Carl von Clausewitz, Jomini concerned himself primarily with land warfare, but his concepts remain relevant to applications of space systems in modern warfare. Indeed, they have served the theoreticians of warfare quite well over the past two centuries. Within the realm of military space literature, Everett Dolman's *Astropolitik* makes reference to the sea power theory of Alfred Thayer Mahan, himself a disciple of Jominian thought.[4] Furthermore, John Klein's *Space Warfare* leverages the writings of Sir Julian Corbett, whose *Some Principles of Maritime Strategy* was a reaction to Mahanian thought.[5] When taken as a whole, the existing body of theory provides rich source material from which to discuss the ways one might employ military space systems within the larger context of operational art. The operational artist may then apply these concepts to work toward an understanding of how space systems, along with systems centered in other domains, contribute to an overall strategic goal. From the perspective of space systems, the most important among these concepts are lines of communication (LOCs), lines of operation (LOOs), zones of operation (ZOOs), and zones of communication (ZOCs). While these concepts have theoretical, historical, and doctrinal precedent in the land, maritime, and air domains, they take on a new form in the context of the employment of space systems.

Lines of Communication

In *The Art of War*, Jomini simply defines *LOCs* as "the practicable routes between the different portions of the army occupying different positions throughout the zone of operations."[6] Clausewitz provided more detail. In *On War*, he writes that LOCs "lead from an army's main position back to the main sources of food and replacements."[7] They allow for the conduct of various functions, including resupply, troop movement, delivery of mail, transit of couriers, and the conduct of administrative action. The joint doctrinal definition of LOCs follows the vein of the Clausewitzian theory but falls short on two accounts. First, it acknowledges only the troop movement and resupply functions of an LOC. Second, it concedes the domain-specific or multidomain nature of LOCs insofar as they apply to the land, maritime, and air domains, but offers no consideration of the concept as it applies in the space (to say nothing of the cyber) domain.[8]

In an effort to expand these concepts into the space domain, Klein defines *celestial lines of communication* (CLOCs) "in and through space used for the movement of trade, materiel, supplies, personnel, spacecraft, electromagnetic transmissions, and some military effects."[9] Thus, Klein's CLOCs maintain similar functions to those of Clausewitz and include "physical CLOCs" that launch satellites or replenish constellations and the "nonphysical LOCs" of radio communications links.[10] While traditional LOCs can perform all the Clausewitzian functions, Klein's nonphysical CLOCs are a special type of nondoctrinal line in that they perform only the information transmission function. These communications links fulfill the courier functions mentioned by Clausewitz, but unlike the LOCs of 19th-century wars, nonphysical CLOCs are not tethered to supply routes.

In his effort to map warfighting concepts to the space domain through the creation of new terminology, Klein provides the joint force a great service. The downside of his approach, however, is that the language he creates is domain specific, rather than domain inclusive. Additionally, because of the specificity required to describe them, the terms themselves are somewhat cumbersome. If one considers the function of the lines rather than their physical location, however, one may arrive at terms that more easily translate to other components of the joint force. These functions, which Clausewitz defined and which Klein addresses, are the transfer of personnel and materiel (in the manner of the joint doctrinal definition of the concept) and data transfer. Klein's concept of physical CLOCs provides justification for the inclusion of space domain LOCs into the joint doctrinal definition of LOCs; like LOCs in other domains, the physical CLOCs perform the function of transferring personnel and materiel from one location to another. For this reason, one may simply consider Klein's physical celestial LOCs as LOCs per the doctrinal definition, retaining the modifier "celestial" when useful. Also, Klein's nonphysical CLOCs transfer data. As such, the term *data line of communication* (DLOC) seems more useful because it describes the function of the concept while remaining general enough to apply to other domains, including cyber. Thus, "nonphysical celestial lines of communication" simplify to "data lines of communication."

The concept of LOCs when applied to the space domain—both in its relation to theoretical notions and in its uniqueness from current doctrinal definitions—carries tremendous significance for the operational artist. First, space-specific LOCs are a concern to the military planner if constellation replenishment is a concern. Historically, constellations receive new satellites as older models fail—a very deliberate process that requires significant lead time. In a protracted conflict that witnesses the destruction or degradation of vital space systems, however, a belligerent may endeavor to launch replacement capabilities. Massive satellites require large rockets to lift them into orbit, which in turn necessitates significant infrastructure. In the case of the United States, large rocket launches occur either over the eastern coast of Florida or the western coast of California.

Crewman from 101st Airborne Division (Air Assault) stands beside AH-64A Apache helicopter armed with M-230A1 30mm automatic cannon and AGM-114 Hellfire missiles as it prepares for takeoff during Operation *Desert Shield,* January 23, 1991 (DOD)

In terms of LOCs, these launch sites represent a base, and the typical rocket flight and orbital path form the remainder of the LOC. As the trend toward smaller, more capable satellites continues, future constellation replenishment may not be dependent on traditional launch facilities but may employ ad hoc launch sites or launch-capable air and sea platforms. If ever realized, such launch options would give the operational artist greater flexibility in opening LOCs.

As for DLOCs, those provide tremendous flexibility to the operational artist. In a space domain context, such DLOCs allow for the control and use of the spacecraft. In support of multidomain operations, the DLOCs allow for communication not only with a military force's rear area (in the Clausewitzian sense of LOCs) but also with other units operating in the same zone (in the more Jominian sense of LOCs). In contemporary U.S. military operations, the force largely takes for granted the ability to talk to rearward and adjacent units via satellite, but an enemy with jammers or antisatellite missiles could threaten such access. DLOCs, then, provide a concept for the operational artist to use in the deliberate planning and employment of space systems and of communications systems in other domains.

Lines of Operation

In theory and doctrine, the LOC and the LOO are related concepts that center on the friendly military force. Generally, LOCs lead from the massed force rearward and connect terrain already traversed with rearward bases. LOOs, on the other hand, lay out the path that the force intends to follow to reach its objectives. In the words of Jomini, LOOs connect "the decisive points of the theater of operations."[11] As in Jomini, the doctrinal definition of *LOO* hinges on decisive points. In joint doctrine, a LOO connects actions "on nodes and/or decisive points related in time and [physical] space to an objective."[12] Whereas Jomini designates only physical locations as decisive points, the joint definition expands to include not only places but also events, critical factors, or functions.[13]

Whether adapting the concept of LOO from theory or doctrine, the employment of space systems through operational art requires consideration of LOOs and LOCs in and across multiple domains. Most obviously, space operations can occur *in* space. Just as

often—and sometimes simultaneously—space operations occur *to* or *from* space. DLOCs provide the electromagnetic connection between the ground station controlling the in-space action, between the satellite and the air or sea force executing along its LOO, or between the electronic warfare system and its satellite target. The penultimate operational artist would be capable of synchronizing the activity of LOCs and LOOs of all domains through integrated planning. For much of the joint force, however, space operations are not a familiar topic and require further explanation.

As in the other domains, an objective in space may be terrain based (attainment of a specific orbit or orbital slot) or enemy based (in the case of an antisatellite system that seeks to destroy another satellite). One terrain-based LOO might follow the mission's critical events: launch, attain orbit, transfer orbit, reach final orbit, begin proximity operations. With current technology, this LOO might take weeks or months to complete and significantly deplete the spacecraft's onboard fuel reserve. Any effort to synchronize the tactical actions of such a satellite, then, requires an understanding of these time-distance calculations and how those relate to operations in other domains. In the near future, one might imagine multiple satellites (or groups of satellites) executing independent LOOs. These formations may converge at their decisive point in space just as the air and land forces mass at their decisive points on Earth.

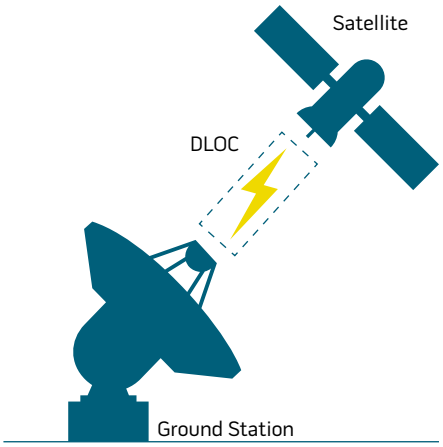
While the orbital aspect of space operations remains the most obvious, ground-based space operations forces may also execute along LOOs. The LOO of a satellite communications unit, for example, may begin with an intertheater deployment. Establishing an initial operating location follows. As the conflict escalates, the unit relocates to a more suitable position—either rearward, forward, or perhaps to an entirely different continent in order to maintain the DLOCs that are essential for the joint force to operate. Nondeployable space operations units (the so-called deployed-in-place units) may execute similar relocations, but because these units are less mobile, their potential set of LOOs contains fewer options; they may plan only to move from point to point and then possibly back again. Regardless of their relative complexity, operations would likely require execution of multiple LOOs to maintain the viability of multiple DLOCs. It is therefore useful to define a concept that groups multiple LOOs and LOCs into sets.

Zones of Operation and Zones of Communication

Since LOOs are possible both in space and in the employment of space systems from Earth, ZOOs are also possible in both locales. A ZOO consists of multiple LOOs, and like a LOO, a ZOO could exist in any single domain or across multiple domains. Indeed, a ZOO may be multidomain in nature, including the orbital and surface-based space operations LOOs along with land, maritime, or air LOOs. The previous example of multiple satellites converging simultaneously with air and ground forces provides such a case. A *ZOO* is not a defined doctrinal term but a Jominian concept, "a fraction of the whole theater of war which may be traversed by an army in the attainment of its objective."[14]

Just as multiple LOOs may coalesce to form a ZOO, multiple LOCs may coalesce to form a ZOC, and multiple DLOCs may coalesce to form a data zone of communication (DZOC). Within the context of contemporary space operations, it is difficult to define a ZOC because the personnel and materiel transport functions are isolated—that is, major launch facilities are widely separated and not employed as complementary assets in a warfighting sense. With the expansion of responsive launch capability, however, such ZOCs may be possible. Additionally, in the near future, orbital refueling or repair satellites may traverse groups of well-defined LOCs in a manner similar to how fuelers and maintenance vehicles traverse well-worn road networks on the ground. For the present, however, the DLOC is the operative principle of space operations, and the DZOC therefore requires a more expansive consideration.

Figure 1. DLOC Between Single Satellite and Single Ground Station



In the context of space systems, the simplest DLOC consists of the uplink or downlink signal between the ground and the satellite—in doctrinal terms, the link segment of the space system (figure 1). In modern military systems, however, the reality can be much more complicated.

A typical beam from a transmitting satellite (for example, a communications satellite) covers a large area on the ground. One need to think only of how many backyard satellite dishes a single communications satellite may service. Similarly, in military operations, one satellite may service many ground receivers within a single theater or even within multiple theaters. One may imagine radio waves linking the satellite transponder to each of the ground-based receivers within the footprint of the transmitted beam. This group of links forms a DZOC. Figure 2 shows a DZOC consisting of one satellite communicating with multiple receivers.

While one satellite may transmit to multiple receivers with a single transmitter, it is also possible for a satellite to have multiple transponders, each capable of servicing multiple receivers. In this situation, each transponder creates multiple links by transmitting to multiple receivers, each of which may be considered as separate DZOCs.

The visualization of DZOCs changes slightly depending on the orbital altitude of the satellite in question. For satellites in

Figure 2. DZOC of One Satellite and Multiple Receivers

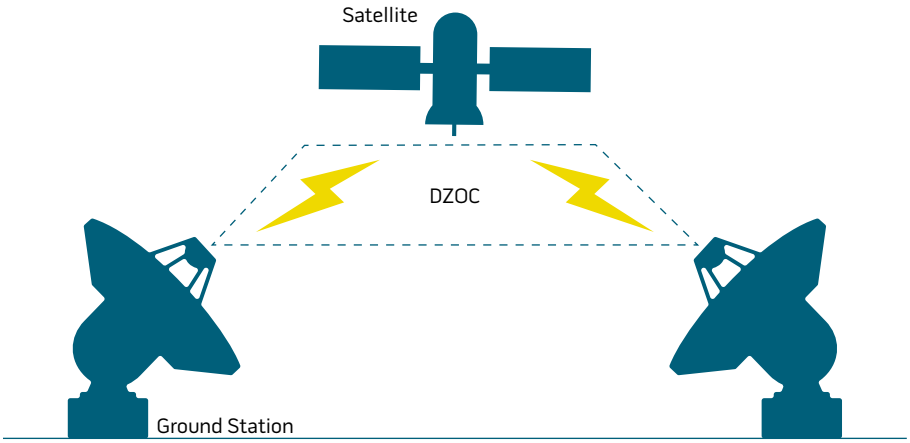
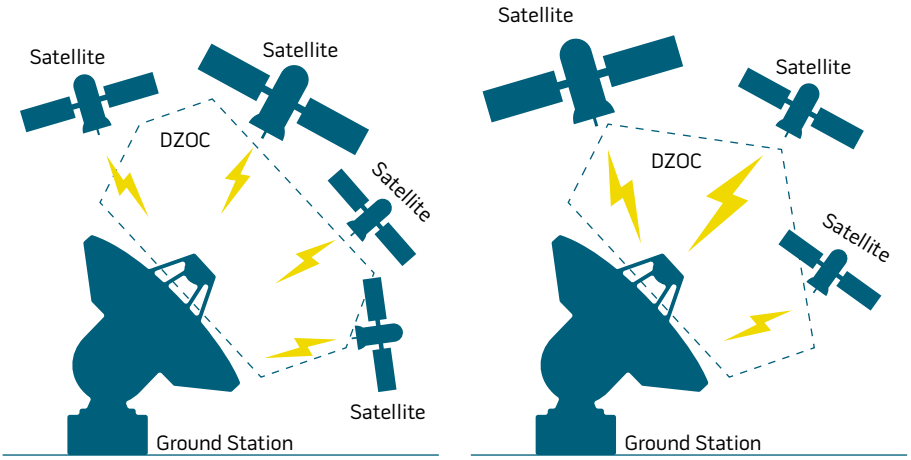


Figure 3. DZOC Changes as Satellites Move



geosynchronous earth orbit (GEO), the satellite remains in view of the same locations on Earth. Its orbital speed matches the rotational speed of Earth, giving an observer on the ground the perception that the satellite is stationary over that point. For satellites at this orbital altitude, the ZOC is continuously operational. As altitudes become lower, the speed of the satellite relative to the ground increases. For low-Earth orbit (LEO) satellites, a few hundred miles from the Earth, a ground receiver will be able to access the satellite only for a short period, perhaps only several minutes. In this situation, the DZOC is short lived; it comes into existence when the links are established and is not reestablished until the next satellite in the constellation comes along or until the original satellite returns.

Between GEO and LEO resides a wide expanse of space called medium-Earth orbit (MEO). The GPS constellation resides in MEO (approximately 12,000 miles from the Earth) and is designed to provide multiple links to handheld and vehicle-mounted receivers. As one might deduce from the in-between altitude, the windows during which to access GPS satellites are neither constant (as with GEO satellites) nor very brief (as with LEO satellites). Although access times vary depending on the location of the receiver relative to the constellation's configuration, a single GPS satellite typically remains in view for 3 to 6 hours. For an accurate solution, each receiver requires access to four satellites, but more than the minimum are typically in view. As one satellite dips below the horizon and out of view of the receiver, another will likely have risen above the horizon to offer its own link, thus providing a continuous solution to the receiver.

Unlike the typical receivers depicted in the first two DZOC illustrations, GPS receivers accept simultaneous input from multiple satellites. Thus, the DZOC involves multiple transmitters, not multiple receivers. Figure 3 shows the changing DZOCs as GPS satellites move relative to the ground observer.

As with missile warning, weather, intelligence, and communications satellites, GPS satellites enable tactical operations and have historically operated with little enemy interference. As long as these enabling means are working normally and the space domain remains relatively uncontested, the operational artist may be tempted to devote less consideration to the vulnerabilities of such space systems. However, when a system becomes degraded, the synchronization of operations with windows of system capabilities becomes a significant concern.

Options and Dilemmas

The line of communication and the line of operation serve as foundational concepts for joint force operations. In this sense, space operations are not different from operations in the other domains, but the application of familiar concepts to a different domain requires clarifying and expanding their application. With the building blocks of LOCs, DLOCs, LOOs, ZOCs, DZOCs, and ZOOs in place, one must consider how to employ them in a larger operational context. While one may apply these concepts within any number of operational frameworks, a historical example of large-scale combat—the Persian Gulf War—provides an illustration of how such concepts can apply, particularly in creating options for the friendly force and dilemmas for the enemy.

Jomini states as the first point of his fundamental principle that the aim of war is to mass combat power at the decisive point.[15] To do this effectively, even with a joint force operating in multiple domains, the complementary concepts of options

Navy's fourth Mobile User Objective System satellite, encapsulated in 5m payload fairing, stands mated to Atlas V booster inside Vertical Integration Facility at Cape Canaveral's Space Launch Complex–41, August 19, 2015 (Courtesy United Launch Alliance)

and dilemmas apply. One may imagine Napoleon arriving at the preordained time of battle with three corps converging on the enemy army. With three corps at his disposal, Napoleon had options. For example, he could have attacked with two while keeping the third in reserve. Alternatively, he could have used two for a turning movement while employing the third as a guard force. He also could have used two as an enveloping force while sending the third against a weaker enemy detachment.

An enemy commander with five corps could have parried every dilemma presented by Napoleon with forces to spare. In other words, he or she would have retained options in the face of multiple dilemmas. Retaining options in the face of dilemmas is the essence of flexibility.[16] All other things equal, an enemy with only two corps would have had fewer options: conduct a deliberate defense, withdraw, or split the force to risk a bold offensive—as Robert E. Lee did successfully at the Second Battle of Bull Run in 1862.[17] If employed with simultaneity, however, Napoleon's three corps could theoretically present more dilemmas than the enemy's two corps could absorb. When one force presents an enemy force with multiple, synchronized dilemmas along the depth of the enemy force, the enemy's entire ability to wage war effectively becomes overwhelmed; the friendly force has achieved operational shock.[18]

One way for the joint force to create dilemmas is to open multiple ZOOs that the enemy must address. As previously mentioned, these zones may or may not correspond to domains. In the case of the Gulf War, for example, U.S. Central Command opened land and air ZOOs from Saudi Arabia and a maritime ZOO in the Persian Gulf.[19] Arguably, the air assault of the 101st Airborne Division on the allied coalition's northern flank represented a cross-domain zone of operation.[20] The ability of allied coalition forces to open multiple ZOOs and effectively sequence operations within those ZOOs imposed on the Iraqi armed forces a state of operational shock. In essence, the allied coalition presented the Iraqis more dilemmas than they could effectively counter, and the advantages of space-based intelligence, communications, missile warning, and navigation directly contributed to the ability of the allied coalition to maintain an overwhelming operational tempo.

As far as the space domain is concerned, little unclassified information is available on how the United States did or did not open space zones during the Gulf War.[21] It is important to consider, however, that multiple LOOs had placed all the space systems into operation over a period of decades preceding the conflict, and it is possible that the U.S. Air Force adjusted satellites during the conflict to maximize their usefulness. While LOOs

Sodium Guidestar at Air Force Research Laboratory Directed Energy Directorate's Starfire Optical Range provides real-time, high-fidelity tracking and imaging of satellites too faint for conventional adaptive optical imaging systems, November 17, 2005 (DOD)

and ZOOs may not have been the operative concept for the planned use of space systems during the Gulf War, space systems did provide DLOCs for weather, intelligence, and missile warning, and DZOCs for communications and a not fully operational GPS constellation.[22]

Imagine now a similar scenario in which a near-peer belligerent is able to counter U.S. forces in the land, sea, and air domains and perhaps overmatch U.S. forces in the cyber domain. In such a scenario, how does the operational artist employ space systems? As in the Gulf War, the operational artist must consider possible and existing lines and zones and make provisions for opening and maintaining them through the deliberate placement of assets within the specific strategic context. While the employment of existing assets may be more or less straightforward, employing new satellites presents a difficult problem.

While it may be possible to accelerate or reprioritize launch and on-orbit testing timelines, military satellites typically require long lead times for operational employment. For this reason, the planning and employment of such constellations falls more within the realm of strategy, but the destruction of such assets poses immediate problems for both the operational artist and the tactician.[23] While the tactician must adjust procedures to the capability of the remaining resources, the operational artist must understand the strategy and work to readjust the means to enable the most effective strategy. Operational planners (particularly military space professionals), then, must understand the vulnerabilities of space systems and develop contingency plans to address their loss. Furthermore, with the limitations of satellite replenishment in mind, one may plan to counter the enemy's satellite replenishment capability by cross-domain attacks on launch facilities or by cyber action against the enemy's industrial base.

Unlike the operational employment of enabling means (satellites for communications, intelligence, among others), the operational employment of offensive orbital systems requires a different calculus. First, orbital antisatellite systems, inspector satellites, or manipulator satellites are niche capabilities that have existed since the Cold War—albeit in low numbers and largely in an experimental rather than operational capacity.[24] Still, a consideration of their potential is useful. Based on the desired target, the distance they are required to travel, and their design specifications, there is a tradeoff between how far an orbital asset could travel and how fast it could get there. As with the infantry Soldier, a satellite may travel a long distance slowly without expending all its fuel, or it may travel a short distance very rapidly with a greater expenditure. Satellite refueling, however, is not currently practicable, and any future LOO that involves offensive orbital means must bear the limitations in mind. Nonetheless, in theory, a belligerent may use multiple spacecraft-based robotic manipulators to open multiple LOOs, thus forming a zone of operation and presenting the enemy with an additional dilemma set.[25] A less complicated—and perhaps a more operationally useful—way of establishing a ZOO is from Earth through the employment of defensive space control (DSC) or offensive space control assets.

If an in-space ZOO is one type of space operation ZOO, a second type is a defensive space control ZOO. Given the fundamental importance of information transmission to the joint force, the

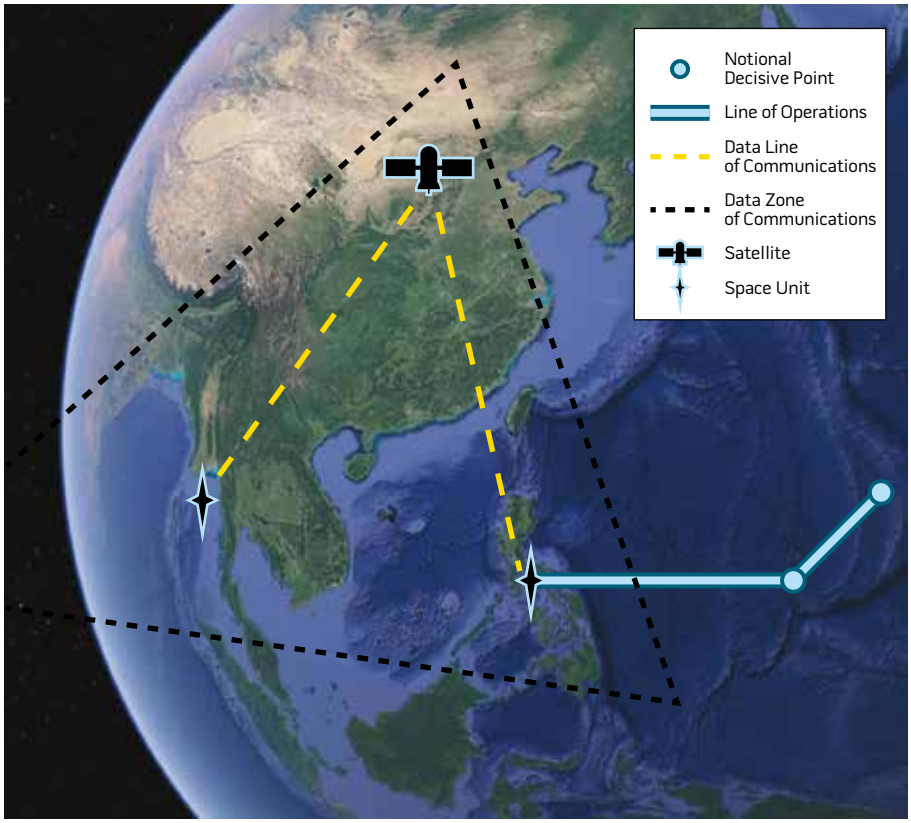
employment of DSC assets should be an early consideration for the operational artist. As mentioned, DSC assets may be placed outside or inside the theater of war to protect the most necessary data lines or zones. The effort to deploy, emplace, and operate these assets constitutes a contributing LOO, the ultimate goal of which is to establish a DLOC with the intent of monitoring an already existing link segment. The employment of multiple assets into multiple theaters represents additional LOOs and additional DLOCs that may, if mutually supporting, coalesce into data zones (figure 4).[26]

A third type of ZOO, a combination of offensive space control LOOs, involves the employment of satellite jammers. As with DSC assets, a force may develop multiple LOOs (or ZOOs) with the ultimate goal of establishing offensive LOCs in the theater of war, from an external theater or in multiple and mutually supporting theaters. The combination of multiple offensive DLOCs constitutes an offensive DZOC, and depending on the orbital motion of the target satellites, the operational artist must determine the appropriate sequencing of the tactical offensive actions to contribute to the overall strategic effect. Alternatively, if an enemy force is establishing offensive DLOCs, the operational artist must anticipate which friendly assets are vulnerable and take action to mitigate operational risk.

Conclusion

An understanding of space operations across the joint force is now more essential than ever, and achieving this understanding depends on a language that translates concepts across all domains. Necessarily, this effort must not focus on the creation of domain-unique language (as has the space doctrine of the past) but on making similar concepts relatable so that domain-specific practitioners across the joint force can communicate effectively with one another. The language of operational art—with some expansion of existing concepts like lines of operation and communication—provides the connective tissue to link the operations of all domains through theoretical ideas that enable practical application.

Figure 4. Multiple DLOCs Coalesce to Form DZOC



To begin addressing the practical questions of how operational artists may employ space systems, theory and doctrine provide a starting point from which to consider specific new concepts. Historical examples provide context and, in the case of ZOCs, suggests a useful concept neither in traditional theory nor in U.S. doctrine. That the ideas of Jomini come to the fore indicates his importance in creating the language of modern military operations as evidenced in the theoretical writings of Mahan, Corbett, and Klein. However, while each of these writers focused on a particular domain, in contemporary warfare, domains are inseparable, and domain-specific theories of warfare may be misleading. Theory, history, and doctrine all posit that it behooves a belligerent to present as many dilemmas as possible to an enemy across all domains (simultaneity) while maintaining as many options as possible for one's own force (flexibility). While it is possible that the forces of a single domain may be able to achieve the desired ends, it is unlikely—and perhaps even foolish—for any modern nation to operate in that way. Indeed, all domains are essential in modern warfighting, and the operational artist must approach the goal of victory through the establishment of ZOOs in as many domains as possible, the maximal use of ZOCs, and the synchronization of activity across all domains. ZOCs and ZOOs provide the friendly force options while forcing the enemy to confront multiple dilemmas, and the creative process of integrating multidomain ZOCs and ZOOs is fundamental to operational art. Indeed, the creative process that links the tactical actions to the strategic ends is ongoing and requires continuously revisiting one's understanding of operations in all domains.[27] For this reason, concepts—whether they come from history, theory, or doctrine—may be more important tools for an operational artist in the conduct of warfighting than any domain-specific means. JFQ

Notes

[1] See, for example, Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (Abingdon, UK: Frank Cass Publishers, 2002); Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007); James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests*, 2nd ed. (Stanford: Stanford University Press, 2011).

[2] Of note, the Air University's *Space Primer*, a decade's worth of *Army Space Journal*s published during the height of the Iraq War years, and multiple master's theses and monographs from both the Naval Postgraduate School and the Command and General Staff College endeavored to expound on the tactical usefulness of space.

[3] Joint Publication 3-14, *Space Operations* (Washington, DC: The Joint Staff, April 10, 2018); U.S. Army Field Manual 3-14, *Army Space Operations* (Washington, DC: Headquarters Department of the Army, October 2019)

[4] Dolman, *Astropolitik*, 33.

[5] John J. Klein, *Space Warfare: Strategy, Principles, and Policy* (New York: Routledge, 2006), 3.

[6] J.D. Hittle, ed., *Jomini's Art of War* (Harrisburg, PA: Stackpole Books, 1965), 78–79.

[7] Carl von Clausewitz, *On War*, eds. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 345.

[8] According to joint doctrine, a line of communication is "a route, either land, water, and/or air, that connects an operating military force with a base of operations and along which supplies and military forces move." See Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: The Joint Staff, November 8, 2010, as amended through February 15, 2016), 141.

[9] Klein, *Space Warfare*, 51.

[10] Ibid., 52–53. A celestial line of communication (CLOC) should be voiced as "clock" to avoid confusion with a sea line of communication (SLOC).

[11] Hittle, *Jomini's Art of War*, 78.

[12] JP 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 141.

[13] Ibid., 60.

[14] Hittle, *Jomini's Art of War,* 78.

[15] Ibid., 67.

[16] In Army doctrine, the tenets of unified land operations are flexibility, depth, synchronization, and simultaneity. Neither joint nor Army doctrine formally defines these terms. See Field Manual 3-0, *Operations* (Washington, DC: Headquarters Department of the Army, 2017), 5-5.

[17] Allan R. Millett, Peter Maslowski, and William B. Feis, *For the Common Defense: A Military History of the United States from 1607 to 2012* (New York: Free Press, 2012), 174.

[18] Shimon Naveh, *In Pursuit of Military Excellence: The Evolution of Operational Theory* (Abingdon, UK: Frank Cass Publishers, 1997), 18.

[19] Robert H. Scales, *Certain Victory: The U.S. Army in the Gulf War* (Fort Leavenworth: U.S. Army Command and General Staff College, 1994), 84, 390–391, figure 5-3. I also must acknowledge Dr. Bruce Stanley, associate professor at the School of Advanced Military Studies, for first explaining to me the concept of lines, zones, and dilemmas, which he did in the context of the Gulf War. The additional consideration of lines and zones in the space domain is my expansion of the concept.

[20] Ibid., 221.

[21] Except for three pages of overview on the general conclusions of the study, the portion of the *Gulf War Air Power Survey* regarding space operations remains classified. Eliot A. Cohen et al., *Gulf War Air Power Survey*, vol. 4 (Washington, DC: Government Printing Office, 1993), v–vii.

[22] James Walker, Lewis Bernstein, and Sharon Lang, *Seize the High Ground: The Army in Space and Missile Defense* (Washington, DC: U.S. Army Space and Missile Defense Command, 2003), 151–157.

[23] Dolman, *Astropolitik*, 61. Much of Dolman's discussion in *Astropolitik* engages this aspect of "astrostrategy."

[24] See, for example, Jim Sciutto and Jennifer Rizzo, "War in Space: Kamikazes, Kidnapper Satellites and Lasers," CNN, November 29, 2016, available at <www.cnn.com/2016/11/29/politics/space-war-lasers-satellites-russia-china/>; Andrew Ogilvie et al., "Autonomous Satellite Servicing Using the Orbital Express Demonstration Manipulator System," fact sheet, Defense Advanced Research Projects Agency, 2008, 25–29.

[25] A celestial zone of operation (CZOO) is voiced as "kazoo" not as "sea zoo."

[26] Although the tendency in the joint force is to view the deployment of forces *to* a combat theater as administrative—indeed, Service component commands perform this function through their administrative control authorities—planners should treat such moves as operational so as not to downplay the need for synchronization with the overarching scheme of maneuver or to negate the possibility of enemy interference. As the Marines state, a force must be able to "fight to the fight."

[27] Huba Wass de Czege, "Thinking and Acting Like an Early Explorer: Operational Art is Not a Level of War," *Small Wars Journal*, March 14, 2011; Naveh, *In Pursuit of Military Excellence*, 13.