Space Resilience and the Contested, Degraded, and Operationally Limited Environment

The Gaps in Tactical Space Operations

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The ability of space assets to deliver combat effects to theater operators is at a critical juncture. Over the past decade, not only have adversary counterspace capability and strategy surged markedly but also the number of objects occupying space have risen exponentially.[1] A significant proportion of US Air Force space systems were conceived and brought online during a much different operational landscape, and we have continued to operate a number of them well past their design life. Space is not the invulnerable high ground it once was. National security space leadership has recognized these challenges and describes our present environment as contested, degraded, and operationally limited (CDO).[2] Gen William L. Shelton, who recently retired after serving as commander, Air Force Space Command (AFSPC), has challenged the space operations and acquisitions community to reevaluate mission resiliency in light of these new circumstances. This appeal has manifested in the institution of new strategy and policy focused on bolstering space situational awareness (SSA), the disaggregation of system capability across new architectures, and the cultivation of international partnerships.[3]

While these initiatives may eventually result in the desired resiliency, they face implementation challenges in the form of tightened budgets and constrained manning. History has shown that the strategic advantages provided by technological capability are contingent upon their application by a well-trained, competent fighting force. These rules of warfare are no less applicable to space: the most effective defensive space control system will be the tactical crews and support personnel on whose shoulders mission assurance firmly sits. We assert that in a CDO environment, space operations squadrons are not prepared to provide global combat effects in support of joint force commander (JFC) objectives.

AFSPC's ability to deliver effects to JFCs while facing CDO threats requires timely and accurate characterization of the battlespace, rapid assessment and attribution of incidents, and precise prescription and employment of tactics.[4] In essence, this means achieving a fast and effective observe, orient, decide, act (OODA) loop. However, John Boyd's work indicates that as individuals make decisions, they often misunderstand their "relationship to the rapidly changing environment."[5] In light of this contextual misperception, we examine three common characteristics of tactical space operations that inhibit realizing the desired OODA loop:

1. Critical dependence upon on-call subject-matter experts (SME).
2. Inability to distinguish and attribute the source of mission degradation.
3. Limited awareness of the impacts of CDO events on supported operations.

These problems exist because current AFSPC training and operations frameworks are founded in past, pre-CDO space assumptions not sufficient for today's space domain. Since the operational environment has changed, AFSPC must reevaluate the assumptions it operates under and find a CDO-centered path to organize, train, and equip its forces. We propose that the following no- or low-cost solutions be promptly instituted throughout the administrative and operational chains of command:

1. Inaugurate a tiered certification paradigm that develops *true* expertise.
2. Establish and focus intelligence support for tactical mission planning and execution.
3. Integrate CDO space operations into Air Force and joint exercises.

These solutions will begin to lift the self-imposed fog and friction of war resulting from AFSPC's legacy training and operations methods. If AFSPC does not take action to resolve these issues, space operations will be inadequately equipped to respond to the crises inherent in the CDO environment. As a result, JFCs will not be guaranteed the asymmetric advantage that has been fundamental to US force projection for over two decades.

Train for the Fight

> *Know and use all the capabilities in your airplane. If you don't, sooner or later, some guy who does use them will kick your ass.*
>
> —Lt Dave "Preacher" Pace
> US Navy Fighter Weapons School Instructor

Winning the CDO fight will come down to "whoever can handle the quickest rate of change."[6] In their current state, space crews fall short of this axiom. Their ability to provide timely characterization, assessment, and mitigation of anomalous events is restricted to the content outlined in system checklists. Consequently, this limits operator reaction to known problems with strict, demand-response solutions. Even still, many of those actions lead to contacting or recalling on-call specialists for assistance, despite prior occurrence. Put plainly, the support elements (e.g., engineering, intelligence, tactics, and user support) required to "fight through" CDO events are not truly organic to 24/7 operations environments. In a 168-hour calendar week, experts are readily available for only 45 hours—meaning that less than 30 percent of operations are performed with full capability to sustain the mission. In terms of John Boyd's loop, more than 70 percent of the time the phenomena that shape accurate observation and orientation are greatly impeded (see fig. 1).[7] In a growing CDO environment, crews are more likely to face the type of complex historical, or even zero-day, anomalies that currently require SME resolution.[8] When JFC operations are under way, the response time associated with alerting experts can severely degrade the mission.[9]

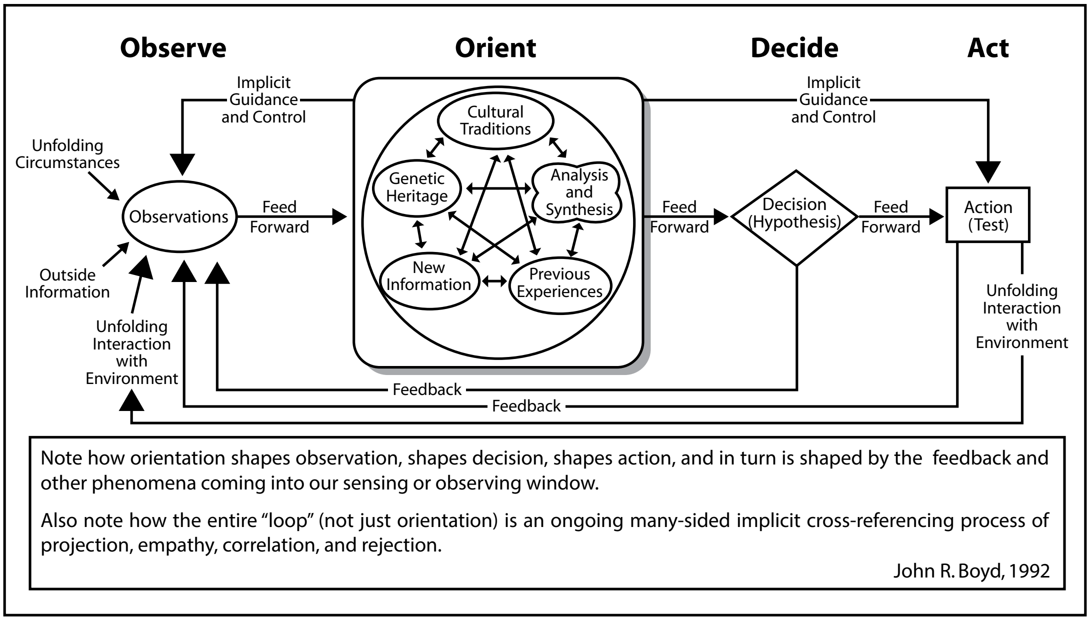

Figure 1. Boyd's OODA loop. (*Reproduced from* Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* [New York: Back Bay Books/Little, Brown and Company, 2002], 344.)

A heavy reliance on SMEs is predominantly a proficiency rather than a process problem. Space crews must turn to these experts because the skill sets are not inherent to operations certification programs.[10] AFSPC can reduce this dependency by codifying a new certification paradigm that does more than prepare operators to "fly" their systems through fair weather. Instead, the focus should shift toward developing experts who can operate in adverse conditions while facing enemy activity. This will require restructuring initial, mission, and continuation training around the on-call subject areas within a broader, CDO-focused curriculum. We propose a commandwide standard that completely integrates system capabilities, nominal and CDO space operations, and combat effects content within a single complementary and graduated syllabus emphasizing the relationships between the same core areas of study (see table 1).

Table 1. Proposed CDO-focused space operations certification program

Training	System	Mission Operations (Nominal vs. CDO)		Combat Effects / User Application
Emphasis	40%	40%	10%	10%
Initial Qualification	Basic system and subsystem capabilities, limitations, integration, and employment considerations	Introduction to mission area Basic position-specific tasks	Threats, impacts, and tactics fundamentals Basic degraded and operationally limited threats, impacts, and tactics	Singular missions or weapon systems
Emphasis	30%	25%	25%	20%
Mission Qualification	Advanced subsystem functionality and integration	Advanced position-specific tasks Graduated crew integration tasks	Advanced degraded and operationally limited threats, impacts, and tactics Graduated integration of controlled threats, impacts, and tactics Graduated mission planning	Integration of multiple missions or weapon systems
Emphasis	20%	10%	40%	30%
Continuation	Advanced subsystem case studies	System upgrade specifics	Advanced threat integration, impacts, and tactics within enemy COAs	Integration of multiple missions or weapon systems within JFC missions and objectives

In the proposed construct, the goal of initial qualification training (IQT) is the development of system expertise. It begins with an in-depth understanding of system and subsystem capabilities, limitations, and employment considerations through academic study and practical application. As is common today, this branch of study will focus on developing proficiency in nominal operations. However, this is not enough for fighting through CDO; thus, an introduction to CDO concepts and combat effects fundamentals is necessary to begin connecting nominal operations to the reality of today's challenging space domain and the potential impacts to supported operations.

With this foundation, operators will be prepared for a mission qualification training (MQT) curriculum that caps system expertise with study of subsystem relationships and in-depth case studies of real-world anomaly resolution actions. In parallel, nominal operations training will expand beyond position-specific tasks to focus on crew-wide integration. Additionally, combat effects and CDO modules will emphasize friendly system integration and multiple simultaneous-threat scenarios, respectively, with a gradual increase in CDO concept difficulty. This will begin to provide operators with an understanding of how joint war fighting relies upon space capabilities.[11] A graduate of MQT, as a certified mission-ready operator, will be able to respond to known adversary threats and system malfunctions while minimizing impacts to supported missions. They will lack the ability to completely mitigate zero-day events but will possess the necessary expertise to identify, assess, and troubleshoot a problem while awaiting on-call SMEs.[12]

The knowledge and experience gained in IQT and MQT must be reinforced by robust continuation training (CT) that simultaneously prepares operators for the challenges of CDO space and acts as the basis of a space cadre "upgrade" program. The CT curriculum would focus on three critical areas: (1) in-depth analyses of recent real-world anomalies and their resolution for maintaining troubleshooting currency, (2) comprehensive training on the broad impacts of CDO events to current and future JFC missions, and (3) mastery of significant system upgrades and/or changes. The rigorous nature of the proposed construct will require a tailored approach to training individuals at varying levels of expertise.

As suggested by Lt Col Phil Bauer, Lt Col Bill Woolf, and Maj Jon Slaughter in their briefing "USAF Warfare Center: 'How Can We Help?,'" this is an opportunity to institute an advanced space training construct similar to the "ready aircrew program." Unlike today's upgrade programs, a clearly documented, skills-based, and objective method of training and evaluation must be formalized to ensure only the most capable operators are in a position to develop, certify, and lead the next generation of crew members.[13] Colonel Bauer and company propose adapting the air operations "squadron letter of Xs" concept to track such progression. Their first draft drove our satellite operations–specific expansion (see table 2) that should be used by the command as a departure point to generate such a program.[14]

Combating CDO events requires frontline crews to conduct real-time analysis, synthesis, and problem solving of unfolding events. This starts with operators who possess the depth of system, operations, and combat effects proficiency currently expected of on-call SMEs. Current certification programs are not sufficient to this end since they develop only surface-level competence. To solve this problem, AFSPC must foster support personnel levels of expertise across all operator training curricula. The result would be a vast improvement in CDO-readiness capabilities over today's 30 percent availability rate. While enhanced mission-area expertise is certainly necessary for fighting through a CDO environment, it is not enough for a tactically advantageous OODA loop. Enhancing the fidelity of observation and orientation phenomena to drive more accurate and effective operator decisions and actions also requires a level of situational awareness (SA) that is largely absent from current space operations.

Table 2. Proposed satellite operations "letter of Xs"

NAME	CERT LVL	RANK	POSITION	EXP LVL	FLT LD	COMMAND SUPPORT	TRACK SUPPORT	BUS ALARM	PAYLOAD ALARM	UPLINK EMI	DOWNLINK EMI	STATIONKEEP	COLA STATIONKEEP	ANOMALY RESPONSE	EXERCISE	ADVANCED TRG	UPGRADE TRG	REMARKS
A	MR	Lt Col	MC															
B	MR	Capt	MC															
C	MR	1st Lt	SVO															
D	MR	2d Lt	SVO															
E	MR	SSgt	SVO															
F	MQT	2d Lt	SVO															
G	MQT	SrA	SVO															

You Can't Fight What You Can't See

The essence of information is the negation of uncertainties, or negative entropy. Entropy is disorder, thus negative entropy means order. This means that areas with the greatest uncertainties will have the greatest demands for information. Whoever can turn uncertainties into certainties will gain the upper hand under such conditions.

—Timothy L. Thomas, paraphrasing Shu Enze

When responding to mission degradation, tactics implementation is critically dependent upon an operator's ability to distinguish between incidents caused by system malfunction or environmental factors and those resulting from adversary activity. It is unlikely that present space operations crews and support personnel would be able to adequately make this distinction even if problems of proficiency were resolved. The source of this predicament is the lack of "capabilities that enable rapid threat identification and attribution, [which] facilitate a defensible architecture and provide a fundamental shift in space awareness."[15] Because operators are blind to their environment—physically, spectrally, and environmentally—they are confined to initiating OODA loops that lead to the execution of tactics focused solely on system malfunction.[16] The operational exigencies of CDO space make this an unacceptable risk. The solution is to provide space operations units with battlespace characterization for both ongoing operations and forecasted conditions, thereby leveraging and incorporating intelligence preparation of the operational environment (IPOE) and real-time, full-spectrum factor-threat identification in support of tactical-level mission planning and execution, respectively.[17]

Since IPOE is not standard in tactical space operations—there was no need for these functions below the operational level prior to the rise of a CDO space environment—AFSPC must start by assigning dedicated intelligence personnel to each space operations squadron. As unit representatives for the Joint Space Operations Center's operational intelligence functions, they would provide mission-specific "multidimensional understanding of the operational environment."[18] With this integrated IPOE support, crews will be able to "anticipate future conditions, assess changing conditions, establish priorities, and exploit emerging opportunities."[19] Accounting for adversary and environmental disposition and their associated indications and warning (I&W) can mean the difference between correctly attributing commanding anomalies to environmental perturbations caused by heightened solar activity, for example, as opposed to loosely speculating on ground system or spacecraft malfunctions. More importantly, it can provide operators the preliminary context for relating anomalies to enemy counterspace operations. However, complete attribution—and subsequent implementation of tactics—will be limited if crews are unable to perceive the threat environment in near real-time. As stated in Joint Publication 2-0, *Joint Intelligence*, "precise threat location, tracking, and target capabilities and status, in particular, are essential for success during actual mission execution."[20]

The uniqueness of the space domain requires SA tools that fuse all aspects of potential adversary attack vectors and environmental susceptibilities—spatial/orbital, spectral, and environmental, to name a few. While multiple tools currently available provide independent, unintegrated SA on some of these aspects, they are limited in capability. Their use for this function is not standard operational practice. Formalizing the use of Web-based Integrated SSA (WebISSA), Joint Spectrum Interference Resolution Online (JSIRO), and the Air Force Weather Agency's space environment global situational awareness chart will provide crews elementary physical, spectral, and environmental SSA, respectively. WebISSA can alert spacecraft operators of encroaching satellites.[21] JSIRO can be used, at best, for ad hoc spectral SSA to identify potentially related electromagnetic interference (EMI) incidents.[22] The space environment global situational awareness chart's stoplight table can provide a rough estimate of the space environment's contributions to CDO events.[23]

While these tools can provide a basic level of battlespace characterization, they are not sufficient for confident, near real-time attribution of external causes, nefarious activity, or environmental conditions, for example, over internal system malfunction. Instead, their shortcomings can easily lead to misattribution. What the command needs is a single tool that fuses physical, spectral, and environmental SSA into a tailorable common operating picture. Such a tool should be able to deduce the difference between a benign close approach and an intended attack vector simply based on relative orbital geometries and known adversary system capabilities. Additionally, it should leverage global electronic intelligence (ELINT) collection to report past and present EM threats, just as ELINT provides aircrews the ability to "locate adversary radars and air defense systems."[24] Finally, it must deliver orbit-, location-, spectrum-, and mission-specific environmental conditions, impacts, and probabilities just as air operations are supplied terrestrial weather status and impacts based on altitude blocks above an area of operations.

Just as "modern air, sea, and land commanders would never consider placing their highest valued assets into an essentially blind operating environment," space commanders must no longer accept the current gap in tactical SSA as adequate for mission accomplishment in CDO.[25] Taking the actions outlined above will ensure that the same fidelity of threat activity relished by air, sea, and land forces becomes a standard of tactical space operations centers. Although such SA is essential for crews to accurately attribute I&W and swiftly mitigate local threats, it does not provide the complete context needed to ensure tactical decisions and actions do not create undesired secondary and tertiary effects across multiple theaters and levels of war simultaneously. This necessitates that tactical integration of space operations with the other domains surpasses levels seen today at the operational and strategic levels of war.

Ramping Up Integration

> *The ordinary man is much more likely to do the right thing if he really understands why he is doing it, and what will probably happen if he does something else; and the best basis for sound judgment is a knowledge of what has been done in the past, and with what results.*
>
> —J. C. Slessor

As CDO matures and evolves, operational-level decision cycles will likely be unable to cope with rapid changes occurring concurrently across multiple systems and their distinct environments. Tactical space operations units executing timely and effective tactics will be increasingly fundamental to mission assurance. This presents a distinct challenge: the tactical OODA loops of space operations crews can have instantaneous consequences—both intended and unintended—to supported missions across numerous areas of operation (AO) at multiple levels of war. At present, space crews are largely oblivious to the missions and operations their systems are supporting at any given time. The result is a precarious situation in which tactic selection and execution are grounded in incomplete or faulty precepts. An appropriate solution requires that space crews are not only equipped with the requisite decision authority to execute potentially decisive tactics but also that they are seamlessly integrated into the mission planning and execution process of their supported AOs (which, in most cases, crosses multiple combatant commands [CCMD]).[26] AFSPC must begin this process by expanding space participation in CAF exercises like Red Flag and working with the CCMDs to integrate advanced CDO scenarios into their recurring combined large-force exercises.

A measure of space participation has occurred in exercises like Red Flag for a number of years. However, it is typically limited to space force enhancement products used to facilitate air planning and/or the simulated effects of deployable space forces. A more appropriate construct for the CDO environment would be the creation of a "collateral space package" (CSP) equivalent to the other Red Flag planning packages.[27] The CSP should be comprised of satellite operators whose nondeployable systems and capabilities are being leveraged for the exercise scenario.[28] As such, the CSP would be the focal point for synchronizing the tactical mission planning of geographically separated space operations units and integrating those efforts (to include collateral space asset disposition, threats, and contingencies) with the overarching air scheme of maneuver. They would identify the appropriate contracts necessary for notifying air players of the impacts of system degradation to successful accomplishment of the air mission (e.g., the consequences of overhead persistent infrared degradation to specific assets executing a "SCUD Hunt" or of the loss of protected military satellite communications to a B-2 strike mission).

The result of integrating planning and execution for the full spectrum of space capabilities used during Red Flag vulnerability windows is the insertion of critical observation and orientation phenomena into space crew OODA loops. Thus, space crews not only can execute tactics that benefit their "survival" but also can consider those that minimize impacts to terrestrial operating areas. The lessons learned developed from this integration will surely prove invaluable when crews are faced with real-world CDO events. In the end, however, not every OODA loop can be timely and/or effective. Red Flag is arguably the ideal initial testing ground for this construct of integration. However, the benefits described above come to fruition only when the space operations role is considered in the joint environment—both from the perspective of understanding the actual consequences of lost space capabilities to supported operations and to the development of courses of action at the tactical and operational levels of space command and control.

The benefits of the proposed degree of integration are not fully realized except in the context of joint exercises and the application of resulting lessons learned to actual operations. JFCs must integrate the consequences of potential CDO incidents into their OODA loops, just as space operations crews must incorporate one or more JFC's priorities into their tactics execution. In their 2010 "AirSea Battle" study, the Center for Strategic and Budgetary Assessments (CSBA) advocated that "the Air Force and Navy should rigorously train for and recurrently conduct exercises that simulate operations under conditions of lost or degraded space capabilities and capacities."[29] Introducing tactical CDO space operations into these heavily operational and strategic level-of-war exercises will highlight the importance for space crews and supported JFCs to examine "the world from a number of perspectives so that [they] can generate mental images or impressions that correspond to that world," thus preventing the mismatches between reality and their perceptions that ultimately generate incorrect response.[30]

Summary

There are no "battle management" magic bullets that will substitute for the ability of on-scene commanders, soldiers, and airmen to make appropriate decisions based on the ebb and flow of events.

—Richard P. Hallion

One of the widely known principles of the Chinese People's Liberation Army anti-access, area-denial (A2/AD) strategy is to impede US freedom of action by targeting space capabilities. The CSBA provides insight into how an A2/AD scenario might unfold:

> In the opening minutes of conflict, [the enemy would] seek to render US and allied forces "deaf, dumb and blind" by destroying or degrading US and allied Low Earth Orbit (LEO) [intelligence, surveillance, and reconnaissance], Space-Based Infrared System (SBIRS), third-generation Infrared System (3GIRS) sensors and communication satellites. This would be accomplished by employing directed-energy weapons, direct-ascent and co-orbital anti-satellite weapons, or terrestrial jamming, in concert with coordinated cyber and electronic warfare attacks.[31]

An instance such as this will reveal the true caliber of AFSPC's mission resilience. If the command continues to operate under legacy training and operations methodologies, mission resilience will be found wanting. Seventy years of air operations experience has shown that the ability to accomplish the mission and survive the return trip hinges upon an aircrew's weapon system and domain mastery. To answer the demands of CDO, AFSPC must adapt this axiom to the present environment and center its organize, train, and equip function on furnishing operators with the expertise, tools, and operational experiences necessary to do so. It must train operators who can characterize, assess, and respond to mission-impacting events; equip them with the tactical intelligence for comprehending the threat landscape; and clearly connect tactical tasks with supported commander operational objectives and priorities.

To accomplish this, the command must first adopt a certification program that creates and develops operators who are system, threat, tactics, and combat effects (user) experts. Second, intelligence personnel and functions should be integrated into all space crew operations centers, where spatial, spectral, and environmental intelligence can be fused to support active- and factor-threat identification. Finally, Air Force and joint exercises should expand the incorporation of space operations. This change would better characterize air component commander and JFC reliance on space capabilities, impacts to strategy when those capabilities are lost, and processes required to mitigate these losses. By enacting these remedies, AFSPC can ensure that the tactical initiative resulting from space crew OODA loops maintains operational and strategic harmony with supported operations.[32] ✪

Notes

1. Office of the Director of National Intelligence (ODNI) and Department of Defense (DOD), *National Security Space Strategy* (*NSSS*): *Unclassified Summary* (Washington, DC: ODNI and DOD, January 2011), 1–2.

2. In his briefing "Training for [CDO] Environments," Maj Patrick "Weezer" Slaughter, 561st Joint Tactics Squadron, establishes the following definitions and examples for CDO. *Contested operations* are defined by degradation caused by enemy action, for example, laser, direct ascent, and co-orbital antisatellite (ASATs) weapons, electronic warfare threats, cyber attacks, and foreign space object surveillance and identification. *Degraded system operations* are defined by degradation caused by failed systems or battle damage (e.g., uplink and downlink anomalies, bus and payload anomalies and malfunctions, ground system malfunction, and mission partner system failures. *Operational limitations* are defined by reduced mission effectiveness caused by the physical or operational environment (e.g., conjunctions and collision avoidance, terrestrial and space weather, classification, decision authorities, policy, and many others).

3. Gen William L. Shelton, commander, Air Force Space Command, "Space and Cyberspace: Foundational Capabilities for the Joint Warfighter and the Nation" (address, Air Force Association Air Warfare Symposium, Orlando, FL, 21 February 2014).

4. Hereafter the term *threats* is used to generically refer to any action or function that facilitates a CDO space environment and the term *tactics* to generically refer to any action taken to mitigate a threat.

5. Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (New York: Back Bay Books/Little, Brown and Company, 2002), 334–38.

6. Ibid., 328. While speed of the decision cycle is important, it is not—as is commonly espoused—the sole or even most important metric for evaluating effectiveness. Rapidly executing decision cycles with inaccurate input/feedback can exacerbate the confusion that is already inherent in conflict. Furthermore, imprecise interpretation of and orientation to those

phenomena can lead to execution of courses of action that are not adequate to the realities of the situation, leading to the collapse of the decision cycle and defeat. Prevailing through conflict results from the continuous effective, accurate, and rapid execution of the decision cycle, which creates an unmanageable uncertainty and ambiguity in an adversary's loop (ibid., 328). For a comprehensive study of the entirety of Boyd's work, see Frans P. B. Osinga's *Science, Strategy and War: The Strategic Theory of John Boyd*.

7. Observation is influenced by unfolding circumstances and interaction with the environment. Orientation, on the other hand, is influenced by new information, previous experience, and analyses and synthesis. As indicated by their required participation for anomaly response, the ability to fully comprehend these phenomena is currently resident with on-call SMEs.

8. *Zero-day*, common vernacular in cyberspace operations and security, refers to exploits or attacks that take advantage of previously unknown vulnerabilities in computer systems.

9. Depending on squadron or group standards, this varies between one and two hours.

10. Of course, in the case of contractor or civilian technical advisors, dependence cannot be completely avoided since these individuals have decades of hands-on experience with their particular space system. However, the instances when this depth of expertise is required are rare. This is illustrated by the fact that active duty personnel from different specialties, to include space operations, are regularly qualified as "on-call" experts.

11. A similar focus on air and space integration training was previously called for by Lt Col J. Christopher Moss, "Bridging the Gap: Five Observations on Air and Space Integration," in *Space Power Integration: Perspectives from Space Weapons Officers*, ed. Lt Col Kendall K. Brown, PhD (Maxwell AFB, AL: Air University Press, December 2006), 174–75.

12. The authors acknowledge that today's operations environment does not permit such cavalier dismissal of checklist discipline. However, they suggest that such adherence to legacy standards in a new, dynamic operating environment is equally as dangerous as delaying tactics by hours. Rest at ease; in the proposed construct, troubleshooting will be utilized only when the limitations of standing procedures are reached.

13. Each position must have a "basic" and "advanced" experience level. When operators complete all basic-level milestones, they will be eligible for advanced-level upgrade nomination by their squadron commander. When nominated, individuals will enter a training pipeline that will develop and test their ability to perform at the upgraded position. Completing upgrade training must be dependent on an individual demonstrating increased depth of knowledge and breadth of application to prevailing in a CDO environment. As operators surpass advanced-level milestones, they will be eligible for additional upgrades to crew leadership positions (e.g., crew chief for enlisted operators and crew commander for officers) and/or instructor or evaluator. Upgrades can no longer be a simple formality for the sake of career progression, as is often the case today. In particular, instructor and evaluator upgrades must go beyond an introduction to academic or evaluation techniques, product development, or simulator familiarization. Fighting through CDO events is critically dependent on certifying operators with the correct level of proven capability; this will not occur if our instructors and evaluators have not proven themselves as the most capable through a rigorous upgrade program.

14. Lt Col Phil Bauer, Lt Col Bill Woolf, and Maj Jon Slaughter, "USAF Warfare Center: 'How Can We Help?' " (briefing, 50th Space Wing, Schriever AFB, CO, May 2014).

15. Quoted in Lt Col Anthony J. Mastalir, *The US Response to China's ASAT Test: An International Security Space Alliance for the Future* (Maxwell AFB, AL: Air University Press, August 2009), 76.

16. In other words, crews lack adequate SSA. Air Force doctrine states that "SSA is crucial to accurately determining space system failures, whether from environmental effects, un-

intentional interference, or attack, giving decision makers and commanders information needed to pursue appropriate actions." LeMay Center for Doctrine, annex 3-14, "Space Operations," updated 19 June 2012, 34, https://doctrine.af.mil/download.jsp?filename=3-14-Annex-SPACE-OPS.pdf.

17. Air Force doctrine states that IPOE "is a process requiring detailed research, analysis, and knowledge of the adversary regarding topics such as force disposition, force sustainment, deployment of forces, weapon system capabilities and employment doctrine, environmental conditions, and courses of action." Ibid., 72, https://doctrine.af.mil/download.jsp?filename=3-14-Annex-SPACE-OPS.pdf.

18. Ibid.

19. Ibid.

20. Joint Publication 2-0, *Joint Intelligence*, 22 October 2013, I-25.

21. As AFSPC's Web-based, shared SSA tool, WebISSA is optional for satellite operators to determine safe-distance threshold violations in concert with collision avoidance analysis. For example, their "Neighborhood Watch" function can alert spacecraft operators to encroaching satellites and provide graphic representation of the associated orbital geometries.

22. As the DOD's Secret Internet Protocol Router Network (SIPRNET) portal for resolving EMI incidents, JSIRO is required for space crews to report EMI. Operators upload impacted frequencies, locations, and times of events into the JSIRO database. The database provides situational awareness to operational chains of command throughout resolution activities.

23. As the Air Force Weather Agency's environmental characterization status tracker, the space environment global situational awareness chart reflects observed events, probable impacts, and reported impacts for the previous two weeks, the current day, and a three-day forecast. The observed events include solar, charged particle, and geomagnetic activity. They are characterized generically as quiet, active, or very active. The probable impacts include high-frequency (HF) communications, satellite operations, space object tracking, high-altitude flight, and radar interference. They are characterized generically as favorable, marginal, or unfavorable. The reported impacts include HF communications, ultra-HF (UHF) satellite communications, satellite operations, space object tracking, high-altitude flight, and radar interference. They are characterized generically as favorable, marginal, unfavorable, or no report.

24. LeMay Center for Doctrine, annex 2-0, "Global Integrated Intelligence, Surveillance and Reconnaissance Operations, updated 6 January 2012, 56, https://doctrine.af.mil/download.jsp?filename=2-0-Annex-GLOBAL-INTEGRATED-ISR.pdf.

25. Lt Col Anthony J. Mastalir, *The US Response to China's ASAT Test: An International Security Space Alliance for the Future,* Drew Paper No. 8 (Maxwell AFB, AL: Air University Press, August 2009), 76.

26. In fact, the first steps in such changes to space command and control have already manifested in the delegation of emergency procedure execution to squadron commanders in standing orders from the United States Strategic Command's Joint Functional Component Command for Space. In the opinion of the authors, current authorities are inadequate, unbalanced, and ill-equipped. But that is a topic for another time.

27. While collateral space planning has been wrapped into the "nonkinetic package" previously, collateral space considerations are typically secondary to the effects created by deployable space assets.

28. Examples include the Global Positioning System (GPS), wideband military satellite communications (MILSATCOM), protected MILSATCOM, and space-based missile warning, for starters. Additionally, the authors are not demanding the physical presence of operators who would be geographically separated during real-world execution. Instead, exercising

with real-world, friendly-force disposition is essential to gaining the most complete lessons learned.

29. Jan van Tol et al., CSBA, *AirSea Battle: A Point-of-Departure Operational Concept* (Washington, DC: CSBA, 2010), 87.

30. Quoted in Lt Col David S. Fadok, "John Boyd and John Warden: Airpower's Quest for Strategic Paralysis," in *The Paths of Heaven: The Evolution of Airpower Theory*, ed. Col Phillip S. Meilinger, (Maxwell AFB, AL: Air University Press, 1997), 367.

31. Tol et al., *AirSea Battle*, 21.

32. Fadok, "John Boyd and John Warden," 365.

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