

SPACE AND WAR IN UKRAINE

Beyond the Satellites

ROBIN DICKEY

MICHAEL P. GLEASON

Much of the international attention on the use of space in Russia's war in Ukraine—commercial space services in particular—has focused on satellite capabilities while ignoring the significance of other aspects of space systems, such as ground infrastructure, software, and information-sharing practices. Although Russia has numerous military satellites while Ukraine has none, international and commercial space information sharing and innovations in terrestrial hardware and software have allowed Ukraine to exceed Russia in the use of space at the operational, strategic, and diplomatic levels. The US armed forces can learn policy, strategy, and doctrine lessons including the importance of robust space doctrine; decentralized, strategic information sharing; and the need to protect the ground and communications segments of space systems.

Space has played a highly visible role in Russia's war in Ukraine since and even before Russia's invasion in February 2022. Satellite images of Russian troop convoys and destroyed Ukrainian buildings have provided the backdrop informing international perspectives of the war, while space data and services have directly supported warfighters on the ground. Many observers have begun to refer to the war in Ukraine as the "first commercial space war," paralleling descriptions of the 1991 Gulf War as the "first space war."¹

Satellites themselves are usually the focus in discussions on military uses of space. Yet, satellite ground systems, satellite data processing software, decentralized information sharing, and novel applications of data from existing satellite capabilities by troops on the ground have transformed the value and use of space, especially for Ukraine and its allies. Russia has failed to capitalize on a clear lead in number and

Robin Dickey, a member of the technical staff at The Aerospace Corporation's Center for Space Policy and Strategy, holds a master's degree in international studies, concentrating in strategic studies, from the Johns Hopkins School of Advanced International Studies.

Dr. Michael Gleason is a national security senior project engineer in The Aerospace Corporation's Center for Space Policy and Strategy.

1. Sandra Erwin, "On National Security: Drawing Lessons from the First 'Commercial Space War,'" *SpaceNews*, May 20, 2022, <https://spacenews.com/>; and Jonathan Beale, "Space, the Unseen Frontier in the War in Ukraine," BBC, October 5, 2022, <https://bbc.com/>.

quality of satellites over Ukraine, which owned and operated no national satellites when Russia invaded. The underwhelming effects of Russia's initial, perceived space superiority indicate that space lessons learned from its war in Ukraine should also include the importance of space doctrine, information-sharing processes, and ground-based enabling segments beyond the satellites—whether commercial or government-owned.

The networked, distributed approach to using and sharing information from space pursued by Ukraine and its allies has demonstrated the asymmetric advantages of this approach compared to the centralized, hierarchical structure used by Russia. Russian forces have struggled to both collect sufficient tactically useful information from satellites and disseminate that information to warfighters in a timely manner, due to their rigid command structure.

Ukrainian forces on the other hand have been able to innovate and adapt with more decentralized command and control (C2) and more direct communications and coordination between tactical units. This has increased the demand for data processing architectures able to process and disseminate much larger amounts of data to a much larger number of recipients, a burden that could be considered and addressed in future US architectures and strategies. This article explores the uses of space in Russia's war in Ukraine and how innovations beyond those involving the satellite performing the mission have shaped the battlefield, providing some preliminary lessons for the United States' uses of space across the Joint force in future conflicts.

Components of Space Systems

Space systems can typically be broken down into three segments: (1) the space segment, or the satellites performing the mission; (2) the ground segment, or the systems and personnel on Earth that operate the satellites and the facilities that receive, process, and distribute data from satellites; and (3) the "link" segment, or the signals that connect the satellites to each other and to users and operators on the ground through data uplinks to the space segment and data downlinks back to the ground segment.² Each of these segments is vital to the collection and dissemination of data so that neglecting any one segment diminishes the value of the others.

While satellites—the space segment—are usually what come to mind when thinking about space systems, the ground segment, link segment, and enabling software expand the definition of space systems far beyond the objects in orbit. The ground segment can be subdivided into satellite command and control (C2) on the one hand and the end-user segment on the other. For satellite C2, ground stations send commands to and can receive updates and data from satellites, and for the end-user segment, individual-level systems such as mobile terminals, antennas, receivers, and transmitters can provide interfaces between satellites and users in the field. Figure 1 represents the three major segments.

2. Air Command and Staff College Schriever Space Scholars, Air War College West Space Seminar, *AU-18 Space Primer* (Maxwell AFB, AL: Air University Press, 2023), <https://www.airuniversity.af.edu/>.

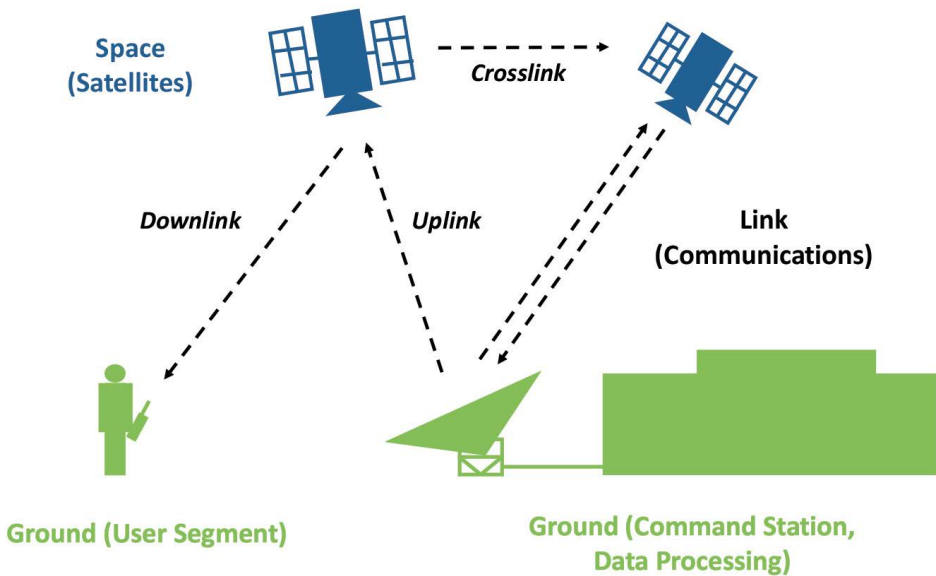


Figure 1. Space system segments

Satellite Capabilities Supporting Ukraine and Its Allies

At the onset of the Russian invasion, Ukraine did not own or operate any satellites; however, the United States and its NATO Allies have made space support available in various forms. Commercial actors have also provided a historic degree of space services to Ukraine. As a result, Ukraine has been able to leverage space systems far beyond expectations based on its capabilities prior to February 2022, which did not include independent access to space. While significant public attention has been directed at Ukraine's success in using commercial space services at the tactical level, space-based systems have also had notable operational- and strategic-level effects.

Position, Navigation, and Timing

Ukraine uses satellite services provided by the US military, most notably, GPS position, navigation, and timing (PNT) signals. GPS signals enable a wide range of precision strike rockets, bombs, and artillery shells used by Ukrainian forces.³ At the operational and strategic levels, GPS has been the NATO standard for PNT for decades.⁴ As Ukraine depletes its stocks of Soviet/Russia-sourced military equipment, and as NATO countries rearm Ukraine with NATO standard weapons,

3. Beale, "Unseen Frontier."

4. Tim Vasen, "Is NATO Ready for Galileo?," *Journal of the JAPCC* [Joint Air Power Competence Centre] 28 (December 2019), <https://www.japcc.org/>; and Michael P. Gleason, "Galileo, Power, Pride, and Profit" (Ph.D. diss., George Washington University, January 31, 2009), 97, 215, <https://apps.dtic.mil/>.

Ukraine may rely more upon GPS. Although there are alternatives to GPS, such as the European Galileo system, open-source reporting on the conflict does not suggest if or how they are being used.

Electro-optical and Synthetic Aperture Radar (SAR) Imagery

Before the February 2022 invasion, Ukraine benefited in several ways from US national security satellites. Imagery satellites provided intelligence to US national-level leadership, enabling the Biden administration to confidently raise the alarm globally about Russia's intentions and alert Allies to the threat. US-furnished strategic intelligence made its way to NATO field commands prior to the invasion, and the Alliance deployed additional forces in the region.⁵ Once the fighting began, US national security Earth observation and electronic signals intelligence helped fill the intelligence gaps as the US military pulled its surveillance planes back from international airspace near Russia's borders and the Black Sea.⁶

Commercial remote-sensing satellites include those capable of collecting high-resolution, electro-optical imagery and synthetic aperture radar (SAR) imagery. SAR imagery, although not collected by as many satellites and operators as electro-optical imagery, has the unique benefit of functioning even in low-visibility conditions, such as nighttime or cloudy weather. Commercial satellites help track buildups of Russian forces and troop movements within Ukraine and in Russia and Belarus. The availability of various kinds of imagery has helped Ukraine accurately locate, track, and target Russian forces prior to strikes and conduct battle damage assessments afterwards, which has in turn helped improve the efficiency and conservation of ammunition.⁷

Journalists and nongovernmental organizations have used satellite imagery creatively to reveal war crimes committed by Russia. Commercial companies such as Maxar, Planet, and BlackSky have directly contributed to this activity by providing images to these entities.⁸ These collaborations have been used to map mass graves, the systematic looting and destruction of cultural heritage sites, the forced adoption and re-education

5. Garrett Reim, "Lessons from War in Ukraine from Former USAF Commander," *Aviation Week Network*, December 6, 2022, <https://aviationweek.com/>; and W. J. Hennigan, "U.S. Deploys Forces in Response to Putin's Ukraine Moves," *Time*, February 22, 2022, <https://time.com/>.

6. Reim.

7. David Ignatius, "How the Algorithm Tipped the Balance in Ukraine," *Washington Post*, December 19, 2022, <https://www.washingtonpost.com/>; Steve Rosenberg and Jaroslav Lukiv, "Ukraine War: Drone Attack on Russian Bomber Base Leaves Three Dead," *BBC*, December 26, 2022, <https://www.bbc.com/>; Anna Ahronheim, "Russian Bombers Capable of Carrying Nukes Detected near Finland," *Jerusalem Post*, September 30, 2022, <https://www.jpost.com/>; and Egle E. Murauskaite, "U.S. Military Assistance to Ukraine in 2022: Impact Assessment," Strategic Multilayer Assessment (SMA), SMA EUCOM Speaker Series, livestreamed presentation, March 15, 2023, YouTube recording, 1:01:47, <https://www.youtube.com/>.

8. Denise Chow and Yuliya Talmazan, "Watching from Space, Satellites Collect Evidence of War Crimes," *NBC News*, May 3, 2022, <https://www.nbcnews.com/>.

of Ukrainian children in camps, the systematic destruction of food production and storage capacities, and the targeted destruction of health and education facilities.⁹

Satellite Communications

Ukraine uses several commercial satellite communication (SATCOM) systems for a wide variety of purposes. In the opening days of the conflict, Ukrainian President Volodymyr Zelensky stayed in regular contact with the United States even while mobile, using a secure satellite phone that the White House had given the Ukrainian government before the invasion occurred.¹⁰ Iridium, Globalstar, and Inmarsat all have capabilities in that sector.¹¹

Zelensky also uses Starlink satellites to directly address Ukrainians, national parliaments, and international organizations around the world. Commercial telecom satellites enable Ukrainians to stay connected with each other as well. The Luxembourg-based satellite operator SES broadcasts most Ukrainian TV channels and has provided space-based emergency internet and phone services to refugee camps along the Ukrainian border.¹²

Starlink provides broadband internet connectivity for a wide range of military and civilian users across Ukraine and has been crucial to Ukraine's battlefield successes. Starlink satellites provide connectivity enabling secure communication and situational awareness from top echelons to command bunkers and units in the field.¹³ On the battlefield, Ukrainian warfighters have used internet connectivity provided by Starlink as a key communication method for a wide range of activities as they find, target, and destroy enemy forces.¹⁴

Starlink also enables "tele-maintenance" of US and NATO weapon systems in Ukraine. When something breaks and Ukrainian forces lack the expertise to repair it, Ukrainian forces have used Starlink to reach back to US maintenance specialists at a base in Poland.

9. "Recent Reports," Conflict Observatory, accessed on March 1, 2023, <https://hub.conflictobservatory.org/>.

10. Kylie Atwood and Zachary Cohen, "US in Contact with Zelensky through Secure Satellite Phone," CNN, March 1, 2022, <https://www.cnn.com/>; "The Phone That Zelensky Uses to Avoid Being Found by Russia," *Marca*, March 16, 2022, <https://www.marca.com/>; and "Iridium 9575A for U.S. Government," Iridium (website), accessed March 2, 2023, <https://www.iridium.com/>.

11. Ben Gran, "What Is a Satellite Phone?," *SatelliteInternet.com*, June 12, 2023, <https://www.satelliteinternet.com/>.

12. Pierre Weimerskirch, "SES Supports Ukraine from Space," *RTL Today*, March 2, 2022, <https://today.rtl.lu/>.

13. Beale, "Unseen Frontier."

14. Sam Skove, "How Elon Musk's Starlink Is Still Helping Ukraine's Defenders," *Defense One*, March 1, 2023, <https://www.defenseone.com/>; Nick Allen and James Titcomb, "Elon Musk's Starlink Helping Ukraine to Win the Drone War," *Telegraph*, March 18, 2022, <https://www.telegraph.co.uk/>; and Alexander Freund, "Ukraine Using Starlink for Drone Strikes," *DW (Deutsche Welle)*, March 27, 2022, <https://www.dw.com/>.

These specialists diagnose the problem via video, walk the Ukrainian forces through the recommended fixes, or help put a new part on order directly from the field.¹⁵

There have been several challenges involved in relying on Starlink, including public incidents where SpaceX founder and CEO Elon Musk questioned on social media whether Starlink services should continue to be provided to Ukraine.¹⁶ SpaceX's growing restrictions on Starlink services within Ukraine have caused concern and driven some exploration of alternatives.

Other commercial satellite companies provide Ukraine internet connectivity from space, including Viasat, OneWeb, SES, Iridium, Inmarsat, Eutelsat, and Avanti.¹⁷ Viasat, OneWeb, and SES are all working to build more capacity, including through new constellations and new agreements with Ukrainian telecom operators.¹⁸ Nevertheless, Starlink remains the most visible provider of mobile satellite communication services in Ukraine.

Radio Frequency Monitoring

Some commercial satellites have another relevant capability: the ability to monitor radio frequency (RF) signals. Commercial space-based RF sensing is useful to detect jamming of GPS and communication signals and geolocating the jamming's source.¹⁹ GPS jamming can disrupt many basic services, including transportation networks, air travel, logistics, and telecommunication. Tracking this interference can help operators come up with alternatives and work-arounds.²⁰ For example, in March 2022, the company HawkEye 360 publicly announced it had "the capability to detect and geolocate Global Positioning System (GPS) interference, with analysis of data over Ukraine revealing extensive GPS interference activity."²¹

The United States, the European Union (EU), and like-minded nations also use commercial satellites to help enforce the sanctions imposed on Russia and Russian individuals. For example, the yachts of individually sanctioned Russian oligarchs have

15. Patrick Tucker, "US Soldiers Provide Telemaintenance as Ukrainians MacGyver Their Weapons," *Defense One*, September 18, 2022, <https://www.defenseone.com/>.

16. Isabelle Khurshudyan et al., "Musk Threatens to Stop Funding Starlink Internet Ukraine Relies on in War," *Washington Post*, October 14, 2022, <https://www.washingtonpost.com/>.

17. Theresa Hitchens, "A Musk Monopoly? For Now, Ukraine Has Few Options outside Starlink for Battlefield Satcoms," *Breaking Defense*, October 19, 2022, <https://breakingdefense.com/>.

18. Hitchens; "OneWeb Confirms Successful Deployment of 40 Satellites Launched with SpaceX," *Eutelsat OneWeb*, press release, January 10, 2023, <https://oneweb.net/>; Martin Coulter and Supantha Mukherjee, "Telecom Operator Veon Confirms Deal with British Satellite Firm OneWeb," *Reuters*, March 1, 2023, <https://www.reuters.com/>; and Courtney Albon, "SES Launches Advanced Broadband Satellites As Military Demand Grows," *C4ISRNet*, December 16, 2022, <https://www.c4isrnet.com/>.

19. Tracy Cozzens, "HawkEye 360 Tech Reveals Early GPS Interference in Ukraine," *GPS World*, April 29, 2022, <https://www.gpsworld.com/>.

20. Cozzens.

21. "Hawkeye 360 Signal Detection Reveals GPS Interference," *Hawkeye 360*, press release, March 4, 2022, <https://www.he360.com/>; and Cozzens.

been tracked globally using RF monitoring of onboard ship automatic identification system transmitters from companies such as Hawkeye 360, Spire, and Kleos Space.²² Such tracking has enabled the seizure of the yachts when they reach foreign ports.²³ Likewise, the same commercial space companies contribute to tracking cargo ships that are evading sanctions, documenting the theft of Ukrainian grain and enabling subsequent enforcement actions and future reparations.²⁴

Space Capabilities beyond Satellites

The robust and diverse satellite capabilities coming to bear in Russia's war in Ukraine, especially from the commercial sector, are only a third of the story. Every service provided by a satellite in orbit is made usable by hardware and software on Earth. Innovations in these terrestrial aspects of space systems as well as novel policies and practices for sharing satellite information have done just as much, if not more, than the satellite capabilities themselves to provide Ukraine an advantage in the war.

The Ground Segment

Russia's war in Ukraine has demonstrated both the value and the vulnerability of the Earth-based aspects of space systems. Modems, terminals, and other ground-based receivers of satellite communications signals have been highly visible in the conflict. One of the reasons Starlink has been so broadly used at the tactical level is because the antennas are the size of a pizza box, smaller than those of many other commercial satellite systems, making them easy to carry by mobile, tactical teams.²⁵ Mobile satellite ground systems have been vital for replacing the telecommunications ground infrastructure destroyed by Russia.

Ground segments of space architectures have also become targets. In the hour before troops moved into Ukraine in February 2022, Russia conducted a cyberattack that disabled Viasat modems, including terminals used for Ukrainian command and control. This attack also had international and strategic effects, disabling tens of thousands of ground-based terminals throughout Europe and disrupting wind turbines

22. Tim Fernholz, "Satellites Are Hunting 'Dark Vessels' That Evade Sanctions at Sea," Quartz, November 8, 2022, <https://qz.com/>.

23. Alessandra Bonomolo and William McLenna, "Inside the Capture of a Russian Oligarch's Super yacht," BBC, November 11, 2022, <https://www.bbc.com/>.

24. Simão Oliveira, "Grain Laundering: Seeing Who's Hiding in the Dark Shipping," *Spire* (blog), October 26, 2022, <https://spire.com/>; Michael Biesecker et al., "Russia Smuggling Ukrainian Grain to Help Pay for Putin's War," AP, October 3, 2022, <https://apnews.com/>; Fernholz, "Satellites"; and Jérôme Weiss, "Sanctions on Russia As It Presses In on Ukraine," *Spire*, April 14, 2022, <https://spire.com/>.

25. Admin, "David, Goliath, & Space – Is This How Future Wars Will Be Fought?," *Downlink, Produced by US Defense & Aerospace Report*, podcast, 37:12, February 12, 2023, <https://defaeroreport.com/>; and Hitchens, "Musk Monopoly?"

and internet services.²⁶ Russia's action showed how many aspects of infrastructure and communications in Ukraine and Europe relied on the terminals, while also highlighting a major cyber vulnerability in these ground systems.²⁷

Unlike the similarities between the threats posed by cyberattacks to ground and space segments, physical threats can play very different roles against the ground segments of space systems than against the space segments. While physical threats to satellites are still somewhat limited to either direct-ascent missiles or co-orbital weapons capable of reaching specific orbits, satellite control centers or terminals traveling with military units can be just as vulnerable to physical attack as any other facility or materiel on Earth.

Conversely, Ukrainian armed forces have sometimes taken advantage of some of Russia's unwitting uses of data from space systems. For example, GPS PNT receivers are commercially available and ubiquitous around the world, embedded within innumerable commercially available products, such as smartphones. Some smartphone photos taken by Russian forces and posted on social media had embedded GPS-enabled geolocation data.²⁸ Ukrainian forces were able to target those GPS coordinates and destroy Russian forces with precision, using GPS-enabled munitions.²⁹

The Link Segment

Space does not just connect people to other people; it also connects people to systems that sense and shoot. Autonomous vehicles and remotely piloted drones are often guided through satellite communications links, allowing much greater drone range. At the unit level, Ukrainian forces have leveraged Starlink to relay drone video feeds directly to artillery batteries in real time, allowing artillery batteries to observe precisely where their artillery rounds are landing and adjusting fire as needed.³⁰ Reconnaissance drones using Starlink satellite relays have also enabled coordination of other ground forces, such as directing soldiers with shoulder-fired, antitank weapons where to position themselves for an attack.

Attack drones that directly target Russian tanks, positions, and other objectives are also enabled by Starlink.³¹ One example is the coordinated drone attack on the Russian navy at Sevastopol on October 29, 2022. Drones provided real-time intelligence, confused the enemy by creating chaos at the base, and enabled the main explosive-laden

26. Anthony J. Blinken, "Attribution of Russia's Malicious Cyber Activities against Ukraine," US Department of State, press release, May 10, 2022, <https://www.state.gov/>.

27. Katrina Manson, "The Satellite Hack Everyone Is Finally Talking About," Bloomberg, March 1, 2023, <https://www.bloomberg.com/>.

28. Stavros Atlamazoglou, "Deadly HIMARS Strikes Show How Ukrainian Forces Are Turning Cell Phones into 'Force Multipliers,'" *Business Insider*, January 15, 2023, <https://www.businessinsider.com/>.

29. Beale, "Unseen Frontier."

30. Skove, "Starlink"; and Tamir Eshel, "Coordinated Drone Attack Targets the Russian Black Sea Fleet at Sevastopol," *Defense Update*, October 30, 2022, <https://defense-update.com/>.

31. Skove; and Freund, "Ukraine."

autonomous strike boats to close in on the intended targets. This targeting included a precision hit on the *Admiral Makarov*, reportedly the Black Sea Fleet's new flagship after the missile cruiser *Moskva* sank.³²

Yet the direct use of space to enable drones and other military systems has raised concerns from the commercial operators of such satellite communications networks. In February 2023, following complaints to the UN by Russia about Starlink's support to Ukraine, SpaceX Chief Operating Officer Gwynne Shotwell expressed opposition to certain "offensive" uses of Starlink by Ukrainian forces and stated actions were being taken to restrict those uses.³³

Although the effects or follow-through on that statement are not yet clear in open sources, this dynamic raises questions of whether certain commercial satellite operators, without US government input, will begin unilaterally restraining themselves around activities they deem "off limits" in a conflict. Ukraine's precedent-setting use of commercial space services, providing commercial links that enable kill chains on a scale never seen before, may make some commercial satellite companies uncomfortable and cause them to reevaluate their interests.

The Role of Data

While the data and services collected and processed by space systems have been invaluable in Ukraine, one reason why the impact has been so significant has been the underlying policy and doctrinal environment that enabled or encouraged data to be shared quickly with key stakeholders. In addition, along with innovations in hardware, the software and applications allowing units to rapidly process and disseminate information have proven invaluable to Ukrainian military efforts against Russia. Ukrainian forces have also benefited from receiving raw rather than processed data, along with requisite training on how to exploit the raw data. The timeline for transferring data from space to warfighters has dropped from days to hours or, in some circumstances, fewer than ten minutes.³⁴

The "Uber for artillery" application, GIS Arta, allows units collecting information on potential targets, including from satellites, to share that information directly with units that could fire on the targets.³⁵ This pairs sensors with shooters in a decentralized network instead of having to funnel specific information up and back down through centralized command nodes.

As another example, Palantir software can draw imagery from a total of 306 commercial satellites. Soldiers in battle can use handheld tablets to request more satellite coverage if they need it. Western military and intelligence services work closely with

32. Eshel, "Drone."

33. Adela Suliman, "SpaceX Questions Ukraine's Use of Starlink for War," *Washington Post*, February 9, 2023, <https://www.washingtonpost.com/>.

34. David Sandy (former chief of staff, UK Ministry of Defence Space Directorate), interview by Mick Gleason, virtual, February 2023.

35. David Burbach, comments, in "David, Goliath, & Space."

Ukrainians to facilitate this information sharing.³⁶ Cloud-based environments have also helped remove data stovepipes and minimize the need to translate between systems.³⁷ Ultimately, sharing data is less expensive than collecting it, so pursuing new models for dissemination of data allows for a wider range of possibilities to add value and utility.³⁸

The encouragement of information sharing and decentralized data dissemination has helped counter Russian narratives and reveal Russia's activities and war crimes, while also increasing the resilience and effectiveness of Ukrainian armed forces. The availability and relative ease of sharing commercial satellite imagery were key factors in generating the international support for sanctions against Russia.

In 2022, a US Intelligence Community leader noted that the US Intelligence Community more than doubled its procurement of commercial satellite imagery leading up to the conflict.³⁹ According to the official, the imagery from companies "was able to flow directly to those who need [it], EUCOM, NATO, and directly to Ukrainians."⁴⁰ In some cases, the soft power enabled by sharing imagery from satellites manifested into hard power advantages, including more war materiel provided to Ukraine. Much of this was hard to anticipate. For example, Germany changed its longstanding Russia policy, *Ostpolitik*, to offer heavy arms to Ukraine, including sending advanced battle tanks to the country.⁴¹

In sum, even without satellites Ukraine has been able to use space systems to great effect, highlighting that satellites are only one part of the equation. This does not diminish the importance of satellites but should elevate appreciation for the importance of the ground and link segments. Russia's use of space in its war in Ukraine provides another useful case.

Strategic and Operational Use of Space by Russia

Russia has used satellites for intelligence, surveillance, and reconnaissance (ISR) and communications while attempting to interfere with space assets supporting Ukraine. Yet the constraints imposed by Russia's highly centralized military C2

36. Ignatius, "Algorithm."

37. Todd Harrison and Matthew Strohmeyer, "Commercial Space Remote Sensing and Its Role in National Security," Center for Strategic and International Studies, February 2, 2022, <https://www.csis.org/>.

38. Josef Koller, "The Future of Ubiquitous, Realtime Intelligence: A GEOINT Singularity," Aerospace Corporation Center for Space Policy and Strategy, August 8, 2019, <https://csps.aerospace.org/>.

39. Sandra Erwin, "As Russia Prepared to Invade, U.S. Opened Commercial Imagery Pipeline to Ukraine," *SpaceNews*, April 6, 2022, <https://spacenews.com/>.

40. Erwin.

41. Frank Jordans, Kirsten Grieshaber, and Samya Kullab, "US, Germany to Send Advanced Tanks to Aid Ukraine War Effort," AP, January 25, 2023, <https://apnews.com/>; and Isabel Muttreja and Bernhard Blumenau, "How Russia's Invasion Changed German Foreign Policy," Chatham House, November 18, 2022, <https://www.chathamhouse.org/>.

methods and an aging space architecture have resulted in a perceived underwhelming contribution of Russian space capabilities to the fight.

Russian Military Space Capabilities

In early 2022, at the onset of its war in Ukraine, Russia had numerous but somewhat limited space capabilities. The Russian PNT system, GLONASS, enables deployments, force movement, and precision-guided munitions. Russia uses a small number of highly capable ISR satellites, with more than 30 satellites providing electro-optical imagery as well as a new radar observation platform, systems for missile warning, and electronic and signals intelligence satellites.⁴²

But this still leaves significant gaps in its space-based ISR coverage. Russian military SATCOM is insufficient as well. One expert indicated: “Russian troubles apparently hinge on a shortage of open optical and synthetic aperture radar satellites. Whereas its deficient command, control, and communications (C3) systems are the result of having too few satellite communication channels and terminals.”⁴³ Russia’s communications infrastructure had such low battlefield performance that Russian forces turned to unsecure means of communication such as mobile phones.

Whatever the limitations of Russia’s military space capabilities leading up to the Russian invasion of Ukraine, Ukraine was at a clear disadvantage in terms of satellite capabilities, as mentioned above. Yet, Russia has largely failed to capitalize on its advantage. The reasons why span well beyond the satellite capabilities themselves and involve both the ground and link segments and the problem of data management.

Even in cases where Russia is collecting information or communicating via space systems, it has faced difficulty in disseminating the information and data to Russian forces in an efficient or timely fashion. An assessment of Russia’s space capabilities from 2019 indicated that even its new ISR systems had issues: “In addition to the high failure rate of the satellites, the products and services that they do provide often fail to meet the requirements of end users and are not competitive with equivalent foreign capabilities.”⁴⁴ While the Russian SATCOM architecture appears to be more robust than space-based ISR, military communications operate under a very hierarchical, slow, and vertically organized structure in contrast to the more network-centric approaches used by the Ukrainian armed forces and their allies.⁴⁵

Russia’s highly centralized command structure limits its utilization of information from space, as demonstrated by the combat operations of Russian battalion tactical groups in Ukraine in 2013 and 2015. A review of the failures and vulnerabilities of

42. *Challenges to Security in Space: Space Reliance in an Era of Competition and Expansion* (Washington, DC: Defense Intelligence Agency, 2022), <https://www.dia.mil/>.

43. Pavel Luzin, “Russia’s Space Satellite Problems and the War in Ukraine,” *Eurasia Daily Monitor* 19, no. 76 (May 24, 2022), <https://jamestown.org/>.

44. Anatoly Zak, *Russian Military and Dual-Purpose Spacecraft: Latest Status and Operational Overview*, CNA Occasional Paper (Arlington, VA: Center for Naval Analyses, June 2019), <https://www.cna.org/>.

45. Luzin, “Satellite Problems.”

these units found C2 was centralized so that there was no networked common operating picture (COP), making changes to it difficult to disseminate quickly and efficiently. Moreover, intelligence collection tended to be narrowly focused without general coverage beyond a specific objective.⁴⁶ It is not entirely clear if Russia has corrected these deficiencies, suggesting that in the near term, Russia will not be able to effectively use its space capabilities for tactical warfighting to an extent comparable to the United States, its Allies and partners, and Ukraine.

While several commercial satellite firms support Russia's military activities, Russia has made less use of commercial space capabilities than Ukraine and its allies have.⁴⁷ This is partially because many commercial companies have now locked Russia out of their services, and face sanctions from the United States and others if they allow Russia to use these services. For example, the Russian companies TerraTech and AO BARL provide satellite imagery of Ukraine to Russia, and the Chinese company Spacety and its Luxembourg-based subsidiary provided SAR imagery to the Wagner Group, according to the sanction announcement.⁴⁸ But Russia's less-than-robust use of commercial satellite services is also due to its military structure, which is not conducive to the decentralized, networked approach favored by these commercial technologies.⁴⁹

Beyond technical, doctrinal, and commercial challenges, human factors may be playing a significant role in Russia's limited uses of space in Ukraine. As with other industries across Russia, the space industry has struggled with incompetence, corruption, and mismanagement for decades, with "unqualified or unmotivated personnel responsible for human errors," contributing to major quality control issues.⁵⁰ These problems are paired with personnel issues on the battlefield, especially regarding inexperienced Russian conscripts and convicts.⁵¹ It is hard to decentralize data and decision-making if there is no trust or distribution of competency.

Counterspace Systems: Not Just Countersatellites

The Russian military focuses heavily on electronic warfare capabilities, including a range of ground-based and mobile systems to counter GPS, communications, and radars.⁵² Other counterspace capabilities pursued by Russia include cyber systems,

46. Nicolas J. Fiore, "Defeating the Russian Battalion Tactical Group," *Armor* (Spring 2017), <https://www.moore.army.mil/>.

47. Luzin, "Satellite Problems."

48. "Treasury Sanctions Russian Proxy Wagner Group As a Transnational Criminal Organization," US Department of the Treasury, press release, January 26, 2023, <https://home.treasury.gov/>.

49. "David, Goliath, & Space."

50. Zak, *Russian Military*.

51. Victoria Smolkin, "One Reason Russia Is Struggling in Ukraine," *Politico*, March 3, 2022, <https://www.politico.com/>; and Isabelle Khurshudyan and Kamila Hrabchuk, "As Morale Suffers, Russia and Ukraine Fight a War of Mental Attrition," *Washington Post*, October 13, 2022, <https://www.washingtonpost.com/>.

52. *Challenges to Security*.

directed-energy weapons like the Peresvet laser weapon system, and the direct-ascent antisatellite (ASAT)-capable Nudol system.⁵³ These systems have been put to use both in the lead up to and during Russia's invasion of Ukraine. The Nudol system, for example, was used to destroy a defunct Russian satellite in an ASAT test in November 2021, three months before the invasion of Ukraine.

Russian forces have actively interfered with space systems supporting Ukraine. In UN meetings, Russian delegates have publicly called out numerous commercial space companies, claiming that the companies were supporting the Ukrainian armed forces in a way that could make them "legitimate targets for retaliation."⁵⁴ In practice, many Russian counterspace activities have focused more on communications links and ground architectures than on satellites.

The Russian cyberattack on Viasat in February 2022 was able to deny Ukrainian forces the use of key space capabilities by exploiting a vulnerability in ground systems.⁵⁵ Russian interference with global navigation satellite system (GNSS) signals has disrupted targeting and troop coordination as well as carried the potential to disrupt air travel, logistics, and other basic services.⁵⁶ Yet Russia's efforts to jam Starlink satellites have faced resistance as Starlink operators have been able to adapt code to counter the interference, a countermeasure referred to as "fantastic" and "eye-watering" by Office of the Secretary of Defense Director of Electronic Warfare Dave Tremper.⁵⁷

Lessons for the United States

Asymmetric Advantages

The US Joint Force may gain many insights from Ukraine that highlight both US asymmetric advantages and potential gaps or areas for improvement. For example, military planners, strategists, and analysts should recognize that the satellite capabilities themselves are not the stars of this show. Instead, the ground and link segments

53. *Challenges to Security*.

54. "Statement by the Head of the Russian Delegation K.V. Vorontsov at the Second Session of the Open-Ended Working Group Established Pursuant to UNGA Resolution 76/231 (Unofficial Translation)," UN Office for Disarmament Affairs, September 12, 2022, <https://documents.unoda.org/>; "First Committee, 22nd Plenary Meeting – General Assembly, 77th Session," UN Web TV, October 26, 2022, video, 3:12:22, <https://webtv.un.org/>; "5th Meeting, 3rd Session Open-ended Working Group on Reducing Space Threats," UN Web TV, February 1, 2023, video, 2:57:58, <https://webtv.un.org/>; and "4th Meeting, 3rd Session Open-ended Working Group on Reducing Space Threats," UN Web TV, January 31, 2023, video, 2:47:48, <https://webtv.un.org/>.

55. "Russia behind Cyberattack with Europewide Impact an Hour before Ukraine Invasion," United Kingdom Foreign, Commonwealth & Development Office, press release, May 10, 2022, <https://www.gov.uk/>.

56. Cozzens, "HawkEye 360."

57. Kate Duffy, "Interference: Elon Musk Reported Russia Was Increasing Efforts to Jam Starlink Satellite Internet in Ukraine, But Hasn't Succeeded," *Business Insider*, May 11, 2022, <https://www.businessinsider.com/>; and Duffy, "A Top Pentagon Official Said SpaceX Starlink Rapidly Fought Off a Russian Jamming Attack in Ukraine," *Business Insider*, April 22, 2022, <https://www.businessinsider.com/>.

that facilitate networked data dissemination methods and innovative application of the data from satellites have allowed Ukraine, with no satellites of its own, to make better use of space than Russia. As well, planners, strategists, and analysts should consider how threats have manifested against these ground segments and links rather than to satellite capabilities.

Ukraine has demonstrated that what matters is not only what satellite data or services are provided, but also how they are delivered to the warfighter. In April 2023, then-Major General David Miller—who at the time was director of operations, training, and force development for US Space Command—indicated that warning, surveillance, and targeting information ultimately has no value if it cannot get to the user.⁵⁸ Trained, motivated, and innovative warfighters themselves are a further force multiplier, as shown by how Ukrainian forces have leveraged space capabilities.⁵⁹

Similarly, Chief of Space Operations General B. Chance Saltzman stated that a key goal of the US Space Force going forward is “making sure that not only do we have the systems to do the mission, but that our operators have the training, the experience, and we have validated tactics that actually enable those capabilities.”⁶⁰

The use of space in Ukraine has shown that commercial data sources provide effective alternatives to classified space-derived information, enabling more efficient information sharing across partners and Allies. Information-sharing policies and practices combined with the space-derived information itself have allowed the United States and its Allies and partners to coordinate a comprehensive response to Russia’s invasion of Ukraine across military, diplomatic, and economic sectors.

Moreover, the war is a reminder of the competitive advantage the United States and its partners and Allies achieve from the strength of open, transparent societies compared to closed autocracies. The sheer volume and variety of sources and means of dissemination facilitated by space services and used by Ukraine to share information, particularly about the movements and potential war crimes of Russian forces, have helped keep Russia from controlling the narrative on the international stage. Russia’s centralized structures have largely prevented it from being able to use space effectively in Ukraine. As a result, the Kremlin has failed to shape the perception of the invasion in a way that favors Russia. These dynamics could play out similarly in a crisis involving other countries that try to tightly control the flow of information, such as China.

Areas for Improvement

One of the most significant challenges demonstrated by Russia’s war in Ukraine is the vulnerability and threat toward ground components and software related to space

58. “Spacepower Security Forum 2023: A Mission to Protect and Defend Assets in Space,” transcript of conference proceedings, Mitchell Institute for Aerospace Studies, April 5, 2023, <https://mitchellaerospacepower.org/>.

59. “Spacepower Security Forum.”

60. Theresa Hitchens, “Ukraine Spotlights ‘Criticality’ of Space in Conflict: Saltzman,” *Breaking Defense*, January 13, 2023, <https://breakingdefense.com/>.

systems. Several leaders across industry and the military have indicated that ground systems and software, such as cloud environments, can be particularly vulnerable in conflict.⁶¹ Accordingly, the hardening of ground systems, software, and cloud environments may be a key investment in securing space systems as a whole. Distributed architectures in ground systems, not just in space, have been put to the test for several commercial actors throughout the war. The US Space Force may be able to derive direct lessons for future architectures, particularly for SATCOM.

General Kevin Chilton, the former commander of US Strategic Command, has pointed to the challenge raised by this dynamic for the Joint force writ large. The Army, Navy, Air Force, and Marines—not the Space Force—typically buy the user equipment and therefore “need to step out and make sure they have the proper user equipment, or the space capabilities are for naught.”⁶² This statement highlights how a satellite’s value is dependent on the usability of its data by warfighters and decision-makers. Therefore, Joint force investments in user equipment play a key role in the effectiveness of Space Force capabilities. Coordinating across organizational seams among end users, satellites, and data processing and dissemination can pose a complex task requiring sound policy and doctrine, not just capable technology.

The Joint force will also need to consider the challenge of balancing the hierarchical needs of a military with the potential benefits of decentralization of information and decision-making. Although decentralization has aided Ukraine’s use of space in many ways, legal, policy, and operational requirements will require a degree of centralization to ensure the US military is able to achieve its objectives in an effective, responsible manner.

Conclusion

The space enterprise is not confined to satellites in orbit. As impressive as satellite capabilities may be, Russia’s war in Ukraine has demonstrated their operational and strategic impacts are magnified vastly by terrestrial hardware and software, and by the networked, distributed approach to using and sharing information.

It is also clear that merely possessing satellite capabilities is not enough to ensure space support for the warfighter. Increasing opportunities to make use of space information and services developed by others have enabled Ukraine to close the gap in space capability while Russian forces have apparently struggled to provide sufficient space-derived information to their warfighters in a timely fashion. This dynamic indicates that doctrine, policy, information-sharing structures, and data-processing capabilities, while not always the most visible components of space strategy, can be a driving force for competitive advantage in war.

Russia’s war in Ukraine spotlights many trends and patterns that the Joint force should watch closely for future implications to the role space may play in war. The war

61. “Spacepower Security Forum.”

62. “Spacepower Security Forum.”

demonstrates the value of space to terrestrial forces while also highlighting the value of links—interconnectivity—and terrestrial systems for space forces. Even as the US Space Force develops an independent identity and structure as a service, it must continue to strengthen the ties to and interoperability with the rest of the Joint force. Æ

Disclaimer and Copyright

The views and opinions in *Æther* are those of the authors and are not officially sanctioned by any agency or department of the US government. This document and trademark(s) contained herein are protected by law and provided for noncommercial use only. Any reproduction is subject to the Copyright Act of 1976 and applicable treaties of the United States. The authors retain all rights granted under 17 U.S.C. §106. Any reproduction requires author permission and a standard source credit line. Contact the *Æther* editor for assistance: aether-journal@au.af.edu.