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SPACE-ENABLED CAPABILITIES FOR CONNECTING AND COLLABORATING IN THE ARCTIC

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Executive Summary

In the Arctic region, space capabilities that support navigation and timing, communications, and remote sensing will be vital in establishing persistent situational awareness while connecting and informing defense, commercial, and civilian interests.

The analysis in this chapter is structured around a more complex Arctic with:

- Increased geopolitical rivalry, overlapping territorial claims, shifting alliances, and growing polarization among and between major global powers.
- A strong need to achieve multinational interoperability and multistakeholder cooperation for shared Arctic missions.

Specific missions in the Arctic region, such as border security, sovereignty protection, vessel assistance, fisheries monitoring, environmental and oil spill response, search and rescue, and science and research, will demand greater cooperation and connectivity as activities continue to expand.

Over the past few years, a proliferation of existing and proposed commercial space capabilities in the High North have offered connectivity services across multiple orbits. The White House has taken notice and has included an objective in the *Implementation Plan for the 2022 National Strategy for the Arctic Region* to achieve broadband communications to increase reliability of communications for U.S. military personnel operating in Arctic regions."[1]

This chapter recommends sharing capabilities and flexible architectures that offer economy, security, and user flexibility. A strategic path forward could also leverage innovations in space such as multi-orbit, multi-mission capable terminals, hybrid (multi-orbit) architectures, and satellite networks with robust data transmission capacities to meet the future needs of an advanced Joint Force and allies.

Introduction

The polar region is developing at a time when the expanding commercial space industry can provide persistent space-enabled connectivity, navigation, and increased surveillance. A combination of satellites in various orbits can provide the coverage and resilience necessary to meet national security, industry, and environmental goals. However, the Russian invasion of Ukraine has ripped up the "High North, Low Tension" script, a common Norwegian adage during more peaceful times. Geopolitical tensions are rising in the Arctic as Russia wages unprovoked war against Ukraine, and China continues to ramp up High North investments and activities. Now more than ever, the United States and its allies must project power in the sub-Arctic and Arctic regions to strengthen security and protect economic and environmental interests.

Today, cooperation is challenging as international forums and organizations, such as the Arctic Council and the North Atlantic Treaty Organization (NATO), are undergoing shifting alliances and membership. Beyond organizational alignments, specific missions, such as border security, sovereignty protection, vessel assistance, fisheries monitoring, environmental and oil spill response, search and rescue, and science and research will demand greater cooperation and connectivity as activities in the High North continue to expand.

During this time of increased competition and tension, the United States can partner and share space capabilities with allies and trusted partners across a range of missions. Space capabilities are uniquely qualified to address this dynamic and geopolitically stressed environment in the High North. Operations will advance using open systems with resilient architectures that offer economy, security, and user flexibility, supporting unified governance structures. Within the broader context, existing and emerging space capabilities will allow the United States to assert its influence as an Arctic nation.

Background

The area north of the Arctic Circle (66.3° latitude) includes 14.5 million square kilometers of ocean, ice, and land masses (see Figure 1). Arctic marine systems are warming at two to four times the global average rate, and many scientists view the region as a sentinel for climate change impacts on the world's oceans.[2] This rapid warming results in widespread permafrost thawing and negatively influences global carbon cycles, hydrology, and Arctic ecosystems. Additionally, melting sea ice is exposing two major sea routes for increased maritime traffic (see Figure 1), and harbors are becoming available year-round for shipping, resource extraction, and industrial development.

The Arctic is one of the most sparsely populated areas on the planet. Approximately four million people live above 65 degrees North, dispersed across eight Arctic countries, i.e., Canada, Denmark (via its autonomous territory, Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States (by virtue of Alaska). The following populations above the Arctic Circle include approximately:

- 400,000 Indigenous peoples from over 40 different ethnic groups
- 2,000,000 Russian inhabitants, or roughly half the Arctic population[3]
- 11,000 U.S. inhabitants on the north slope of Alaska[4]

The polar region is developing at a time when the growing commercial space industry can provide persistent space-enabled connectivity, navigation, and surveillance. A combination of commercial satellites in various orbits can provide the coverage and resilience necessary to meet national security, industry, and environmental goals. Fortunately, the U.S. government and other organizations, such as the Arctic Council, recognize the need to address connectivity and infrastructure gaps by encouraging greater use of commercial space services for civil and defense needs.

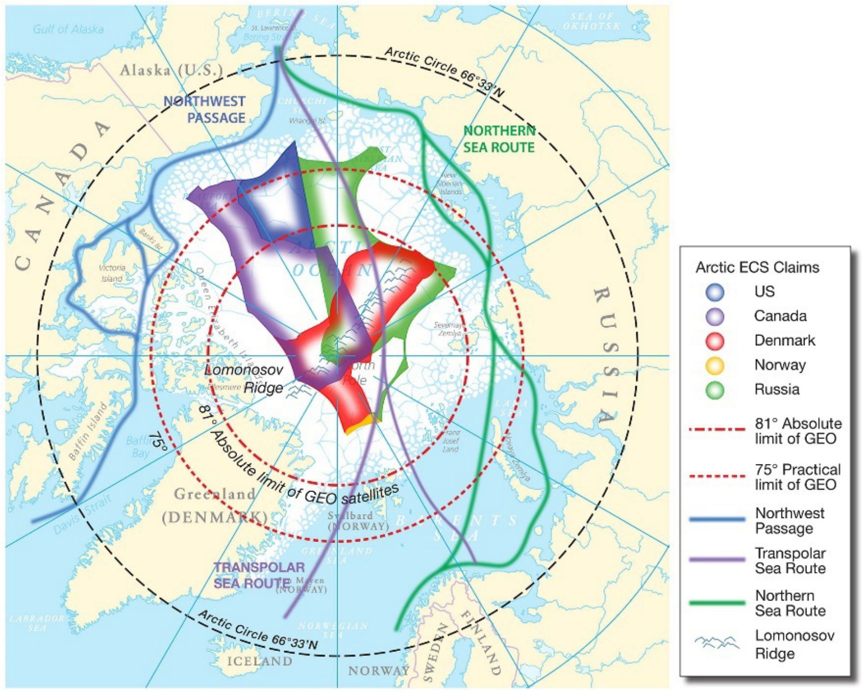

Figure 1: The Arctic Region – the area north of the Arctic Circle, 66°33' north latitude. *The areas intersecting over the North Pole illustrate that all five coastal Arctic States have made declarations of the extended continental shelf (ECS). The map shows areas of significant overlap between the countries, such as the Lomonosov Ridge, with Russia, Denmark, and Canada each claiming areas as extensions of their continental land mass.*

Governments and industry have historically optimized connectivity and satellite communications (or "satcom") for high population densities at mid-latitudes. Remote regions at extreme latitudes, such as the Arctic, struggle with adequate market demand, translating to higher network deployment costs per subscriber and escalating usage fees as connectivity providers seek a reasonable return on investment.[5] The result is that less populated areas are frequently overlooked, leaving residents without adequate access to broadband and communication services for distance learning, telemedicine, commerce, and general connectivity to the rest of the world. According to a nonprofit organization focused on Alaskan tribal members, small communities (estimated at 60,000 people) are unserved with no access to broadband, and an additional 200,000 people are "underserved" with low-end broadband download/upload speeds less than 10/1 Mbps.[6]

Arctic Governance and Cooperation

Arctic governance requires significant cooperation and relies on a foundation of various conventions and rules. The eight member countries of the Arctic Council and NATO (comprising 32 members in Europe and North America) are supranational governing bodies, with power and influence transcending national boundaries. In addition, the United Nations Convention on the Law of the Sea remains a prominent and binding framework for nations' maritime rights and responsibilities.[7]

Due to increasing commercial, civil, and defense activities in the High North, there is a pressing need among Arctic Council and NATO members to share data from space systems and collaborate operationally. However, both organizations have experienced recent changes, and the situation remains dynamic and geopolitically sensitive. Within this context, one must consider future space capabilities in the High North that allow for open systems with flexible architectures that offer economy, security, and user flexibility.

Arctic Council. The Arctic Council, established in 1996, is an intergovernmental forum that encourages cooperation, coordination, and interaction among the Arctic States, indigenous communities, and other inhabitants to address sustainable development and environmental protection issues.[8, 9] The council also looks to the United Nations' Sustainable Development Goals as a guiding framework for sustainability.

The United States is one of eight members of the Arctic Council, along with Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, and Sweden. These eight Arctic States,[10] with land inside the Arctic Circle, are permanent members of the Arctic Council. In addition, mid-latitude countries typically not associated with the Arctic, such as China, India, and Singapore, are accorded observer status.[11] Importantly, any issues related to national or international security are excluded from the mandate of the Arctic Council.

Russia is the largest geographical stakeholder in the Council, comprising 45 percent of the Arctic territory. The Kremlin continues to prioritize the Arctic due to strong vested economic interests, military, environmental, and national security goals; and historical ties to the region as part of its national identity.

Despite the council's 28-year history of cooperation, it comes as no surprise that following Russia's invasion of Ukraine, Russia was "iced out" of various international forums, including the Arctic Council, after seven member countries boycotted Russia's chairship. Conveniently, in 2023, Russia's chairship rotated out of the Arctic Council in a two-year planned cycle, making way for Norway's chairship from 2023 through 2025. After Norway's rise to the council chairship, the Biden administration acknowledged the need for scientific and practical cooperation. A senior White House official emphasized that "the Arctic Council should continue to serve as the premier forum for cooperation among Arctic states, including collaboration on sustainable development, protecting the environment, addressing the impacts of climate change, scientific research, and on other issues of importance to member countries."[12]

North Atlantic Treaty Organization (NATO). NATO, also referred to as the North Atlantic Alliance, remains strong and aligned with the Russian invasion of Ukraine driving expansion and an increased focus on NATO member defense budgets and burden sharing. Jens Stoltenberg, secretary-general of NATO, points out that as the organization celebrates its 75th birthday in 2024, NATO "is the strongest, most successful alliance in history because we have been able to change."[13] Adapting and changing also includes expanding the roster of NATO nations, most recently with two historically neutral countries, Finland and Sweden, joining in 2023 and 2024, provoked in part by Russia's military aggression in Ukraine.

NATO has years of experience exercising and training with allies and partners in the High North to prepare and respond to complex situations and crises that go beyond border defense.[14] U.S. Marine Corps Maj. Gen. Robert Sofge, commander of U.S. Marine Corps Forces Europe and Africa, stressed, "...now is the time to get our systems connected, our doctrine aligned, and to share our tactics to ensure we can sense and make sense in a complex battlefield, in the harshest of conditions, against a capable opponent."[15]

The North Atlantic Alliance relies heavily on space infrastructure to support its collective guarantee of freedom and security for member states. The Alliance has highlighted the criticality of space capabilities in multiple areas, "from weather monitoring, environment, and agriculture to transport, science, communications, and banking."[16] Space assets, both commercial and nationally owned, enable a strong backbone for deterrence and defense—in part due to satellite activities, including intelligence, surveillance, and reconnaissance (ISR); navigation; tracking forces; and missile launch and tracking.

To organize and manage these capabilities, the Alliance has dedicated a new organization called NATO SATCOM Services 6th Generation (NSS6G), which combines space resources and capabilities from France, Italy, the United Kingdom, and the United States to support NATO.[17] NATO Communications and Information (NCI) manages NSS6G and provides NATO with network core enterprise services, operational and exercise support, and program management. Due to advances in space technology and greater global participation, NATO increasingly relies on space and must ensure it can operate despite the growing emergence of Russia and China counter space-enabled threats.[*,18,19] As a result, U.S. allies and partners, supported by NATO NCI, must be prepared to operate in a contested environment to collaborate, connect, and share resources and capabilities.

U.S. Policy Responses. The United States has defined its strategic and commercial interests through a series of policy statements. Across four U.S. administrations, the policies have been mutually supportive and consistent. National and economic security, international cooperation, and environmental sustainability are enduring objectives from President Bush in 2009 to President Biden in 2022 (see Table 1).

Table 1: National Arctic Policies Across Four U.S. Administrations ***Policies build on common themes of national security, cooperation, and environmental sustainability.***	
Bush 2009	*National Security and Presidential Directive/Homeland Security Presidential Directive*
Obama 2013	*National Strategy for the Arctic Region*
Trump 2019	*Department of Defense Arctic Strategy*
Trump 2020	*Memorandum on Safeguarding U.S. National Interests in the Arctic and Antarctic Regions*
Trump 2020	*The Department of the Air Force Arctic Strategy*
Biden 2022, 2023	*National Strategy for the Arctic Region*, and *Implementation Plan for the 2022 National Strategy for the Arctic Region*
Biden 2024	*U.S. Department of Defense Arctic Strategy*

Need for Domain Awareness and Connectivity – From Seafloor to Space. In January 2023, a high-altitude Chinese balloon appeared to float aimlessly into the United States from Canada. Aside from the humorous press coverage, the incident sparked a more serious debate about why the U.S. Northern Command (NORTHCOM) did not spot the balloon earlier, despite awareness of China's balloon program.[20] Later, in March 2023, the commander of U.S. NORTHCOM and North American Aerospace Defense Command (NORAD) testified before Congress, stressing that "it is imperative that the United States and Canada move quickly to improve domain awareness from the seafloor to space and cyberspace for all approaches to North America." General VanHerck added that, as part of all domain awareness, over-the-horizon radars funded by the United States and Canada would improve the ability of USNORTHCOM and NORAD to detect threats to North America from "the Earth's surface to space." Additionally, U.S. Space Force investments in advanced space-based missile warning sensor capabilities are promising for the detection of hypersonic and advanced missile threats.[21]

Further, to increase domain awareness, more efforts are needed to "link existing platforms and sharing data with multiple commands, interagency and international partners" through existing innovative programs and new initiatives.[22] The Arctic presents unique security challenges as supranational organizations—NATO and the Arctic Council—hold key positions of trust and power. This type of organizational cooperation underscores the need for open and shared systems (for space, air, land, or marine-based data) to improve domain awareness and inform decisions.

[*]Various public media sources have indicated that electromagnetic pulses (EMP) may be used to disable communication systems by radiation and electronic damage and upsets.

The DOD's *2024 Arctic Strategy* goes further than platform connectivity and emphasizes the need for "robust transmission capacity" to support cooperation with U.S. allies and partners. Looking to the 2030s, the strategy suggests that large amounts of data will be needed for Joint Force demands and operation of "over 250 advanced multirole combat aircraft that could be deployed for Arctic operations."[23]

A National Call for Improved Satellite Services in Northern Latitudes. Until recently, Arctic policies lacked clear plans directing activities and steps. However, following the release of the *National Strategy for the Arctic Region* (NSAR) in 2022, the White House released the "NSAR - Implementation Plan" (NSARIP) in October 2023 to provide operational articulation.[24,25] The plan details more than 30 objectives and 200 discrete actions that advance the four mutually reinforcing pillars of the National Strategy, which are security, climate change and environmental protection, sustainable economic development, and international cooperation and governance. The 2023 NSARIP also outlines an objective to "improve communications, positioning, navigation, and timing (PNT) capabilities by developing communications and data networks capable of operating in the northern latitudes." According to Dr. David W. Allen of The Aerospace Corporation, the United States has a "close relationship with our allies to ensure we are in sync on radio frequency compatibility and interoperability between our GPS constellation and Japan's Quasi-Zenith Satellite System and Europe's Galileo PNT systems. We provide notification for any modifications to our GPS constellation." These multiple layers of cooperation between the United States and its allies remains important, particularly with signs of space-related cooperation between Russia, which has its own PNT system known as GLONASS, and China with its more modern and accurate BeiDou PNT network.[26]

Consistent with the NSAR, the DOD's *2024 Arctic Strategy* also underscores both the need for the DOD to pursue "technology through commercial partners and agreements with NATO Allies and partners" and to enhance command, control, communications, computers, cyber, intelligence, surveillance, and reconnaissance (C5ISR) capabilities with a "particular focus" on satellites providing Arctic coverage.[27] In short, both the White House and the DOD are encouraging greater consideration of commercial satellite capabilities for civil and defense activities.

Satellite Options: Commercial, Multi-orbits, International Cooperation

The 2023 NSARIP calls for maintaining "worldwide Satellite Communications for Presidential and DOD command and control over strategic forces."[28] In the future, such a system could include a secure mesh network of commercial solutions using satellites in numerous orbits to close the capability gap in the Arctic. Such a network could harness the strengths of each type of satellite orbit to optimize coverage, speed, resolution, latency, and cost trades for any one mission.

A satellite known as geostationary, a particular type of geosynchronous Earth orbiting (GEO) satellite that orbits at an altitude of 35,786 km (26,199 m), sits above the equator and is synchronized to the Earth's rotation. As a result, a GEO satellite can appear as a fixed point and provide persistent coverage for communications and sensing across a large swath of Earth. However, many parts of the Arctic are beyond line of sight for GEO coverage (see Figure 1). Due to the curvature of the Earth, 81 degrees is the maximum latitude beyond which a GEO is below the local horizon. Operationally, a GEO satellite's practical limit is approximately 75 degrees.[29] However, both low Earth orbit (LEO) and medium Earth orbit (MEO) satellites with adequate orbital inclination can provide polar coverage. A highly elliptical orbit (HEO) satellite also offers advantages for the Arctic region. From a spatial and temporal resolution perspective, two HEO satellites can provide continuous coverage. The oval-shaped orbit allows the first satellite to hang or "loiter" over the North Pole area before it tags the second satellite and returns to a much shorter time over the South Pole. Combined, the two satellites are optimized for coverage above 65 degrees north.[30]

Increasing LEO Popularity. More recently, due to technological advancements such as satellite cross-links, miniaturized parts, and high-volume satellite production, proliferated LEO constellations using small low-cost satellites are now introducing resilient global coverage and improved economies of scale. Over the past 10 years, the number of LEO satellites has increased dramatically from approximately 1,200 (before 2010) to almost 8,125 (June 2024), driven in part by the increasing demand for global internet coverage and other services.[31] Some of these LEO satellites occupy high-inclination orbits, thus contributing to polar region coverage, including some LEO satellites in sun-synchronous orbits, which provide consistent, daylight imaging conditions by synchronizing or maintaining a "fixed" position relative to the Sun. The popularity of high inclination and polar orbits provides a plethora of space sensors to monitor and observe dynamic areas of interest such as the Arctic Ocean, permafrost/land, cryosphere, infrastructure, and shipping traffic.

A Shift to Multi-orbit Networks. Accelerated in part by recent mergers of operators and the ability to cross-link between LEO, MEO, and GEO satellites, there is a strong shift toward multi-orbit networks. These hybrid networks offer perhaps the best method for providing resilient, fast, and affordable connectivity in the Arctic region. LEO satellites offer low latency, which is critical for remotely controlled sensors and unmanned platforms, while, at higher altitudes, MEO and GEO satellites can provide backbone connectivity and greater coverage with longer lifespans. Key space research and acquisition organizations such as the Defense Advanced Research Projects Agency (DARPA), the Space Development Agency, the Air Force Research Laboratory, and other government organizations are recognizing the benefits and need for hybrid constellations.

Commercial Connectivity: Proliferation of LEO and Emerging Hybrid Constellations. Historically, simple store and forward constellations, such as Gonets (Russia) and Argos (France), have served the polar regions using narrowband, unidirectional communications for scientific and meteorological purposes since the 1970s. By the late 1990s, Iridium Communications introduced global satellite communications, which provided coverage to both poles. Few new satellite services to the region were introduced until the past seven years or so, when a flurry of new commercial satellite offerings across LEO, GEO, and HEO emerged. The White House has taken notice and has included an implementation objective in the 2023 NSARIP to "[p]artner with the growing commercial space industry, Allies, and partners to achieve broadband communications to increase reliability of communications for U.S. military personnel operating in Arctic regions."[32]

LEOs with Arctic Coverage. While established constellations, such as Orbcomm, Iridium, and Globalstar, continue to operate, new proliferated LEO (pLEO) operators have emerged. SpaceX's Starlink has introduced the world's largest constellation, including satellites in polar or near-polar orbit. Meanwhile, Eutelsat's acquisition growth strategy has led to a hybrid GEO and LEO constellation. A future constellation to watch will be Telesat's (Canada) Lightspeed constellation, which will launch in 2026 with plans to cover the polar region. Current and future commercial satellite connectivity providers in the High North include:

- **Orbcomm** (USA). One of the first commercial LEO constellations offering services in 1996. Orbcomm operates 31 LEO satellites at 750 kilometers (km) altitude and a ground station network of 16 gateways in 13 countries to track and establish two-way satellite communications.[33] Its business focus is on Internet of Things (IoT), asset tracking, and monitoring systems across a range of industrial vertical markets. [†]

- **Iridium** (USA). Operates 66 satellites in polar orbits at 778 km altitude; uses inter-satellite links (ISLs) to route network traffic. Although Iridium replenished its first generation in 2019, it does not offer broadband speeds up to 25 Mbps and higher, as defined by the Federal Communications Commission. It offers commercial voice and data, IoT data, broadband, and hosted payload services.

- **Globalstar Inc.** (USA). Unlike Iridium with ISLs, Globalstar operates a "bent-pipe" constellation, with 48 satellites in a LEO at 1,414 km, inclined at 52 degrees to the equator. The constellation covers over 80 percent of the Earth's surface but does not cover areas above 70 degrees north latitude.[34] In 2022, a partnership was

[†]Iridium and Orbcom do not provide broadband speeds as defined by the FCC as 25 Mbps.

established with Apple, enabling Apple's iPhone to send distress signals using Globalstar's satellite network. Apple will spend $450 million, the majority to Globalstar, for satellite network capacity.[35]

- **Eutelsat Group** (France).[‡] Recently completed the deployment of its LEO constellation in 2023, with 634 satellites operating at 1,200 km. In September 2023, Eutelsat (France, focused on GEO) acquired OneWeb (the United Kingdom, focused on LEO). Existing customers must use different user terminals for each GEO and LEO network, but Eutelsat OneWeb plans to introduce a ruggedized hybrid GEO/LEO terminal with a phased-array antenna to allow connectivity to either a GEO or LEO satellite network.[36]

- **SpaceX – *Starlink*** (USA). Over 6,200 active satellites operating at 550 km altitude. The satellites use ISLs to connect to each other, forming a mesh network in space. SpaceX intends to serve the Arctic region and has invested in ground stations across Alaska (e.g., Nome, Fairbanks, and Kuparuk) for high-speed backhaul using terrestrial fiber optic cables.[37]

- **Telesat – *Lightspeed*** (Canada). Planning 198 satellites to be launched in 2026, from 1,315 to 1,335 km altitude in two orbital inclinations for complete global coverage, including polar areas,[38] while concentrating capacity over regions of highest demand. The constellation will use optical ISLs to create a mesh network in space and will use on-board data processing and routing for dynamic capacity delivery in regions with high demand.[39] The satellites will offer space relays for hosted government satellite missions.[40]

- **Amazon – *Project Kuiper*** (USA). New constellation. Under the terms of its FCC filings, Project Kuiper will be required to launch and operate half of its 3,236 satellites no later than July 30, 2026, and must launch and operate the remaining satellites no later than July 30, 2029.[41] Amazon Kuiper intends to provide internet to "tens of millions of people who lack basic access to broadband internet,"[42] but the constellation's coverage over the Arctic region is not yet known.[43]

Far North GEO Coverage. The current generation of GEO high throughput satellites (HTS) can also support high latitude regions, including a significant portion of the Arctic, with large amounts of capacity concentrated in small areas, using high power, multiple spot beams, and frequency reuse. The practical northern limit for GEO coverage is 75 degrees north (see Figure 1), well above the northern slope of Alaska. Therefore, assuming an unobstructed view, satellite dishes in Alaska can point at an angle of 10 degrees or higher to connect to a GEO satellite. Pacific Dataport (Anchorage, Alaska), for instance, launched their HTS satellite named *Aurora 4A*, a small GEOsat or "microgeo," designed to provide backhaul capacity in rural Alaska between last mile coverage options.[§] Despite the technical problems, this effort demonstrates the commercial sector's interest in solving a key challenge in the High North: fast and reliable satellite backhaul capacity.[44]

International and Commercial Cooperation Across Flexible Architectures. International partnerships are the key to U.S. deterrence and power projection by unifying global actions toward a common goal. Further, commercial space capabilities provide agility and connectivity to accomplish shared goals. The U.S. Space Force and trusted NATO and Arctic partners can collaborate, along with commercial partners, to deliver value. Beyond working across international partnerships, commercial space is also finding ways to deliver enhanced capabilities using the advantages of different orbits: LEO, MEO, GEO, and HEO. Two examples of leveraging space capabilities—the Arctic Satellite Broadband Mission (ASBM) and the Commercial Services for the Warfighter—are described below.

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‡During a September 2023 merger, Eutelsat combined its GEO satellite business with OneWeb's LEO constellation after shareholders voted on September 28 in favor of the all-share deal.

§The Aurora 4A satellite suffered a solar array drive malfunction, limiting its operations to 6 and 12 hours per day. The satellite will be replaced with UtilitySat 1 until a full replacement is available (source: Gunter's Space Page).

Arctic Satellite Broadband Mission (ASBM). Space Norway's[**] new HEO 2 satellite constellation launched in August 2024. The Arctic Satellite Broadband Mission (ASBM) intends to close the Arctic connectivity gap to provide continuous broadband coverage north of 65 degrees north latitude. Northrop Grumman built two large satellites, each weighing approximately two tons, to "speed up when over the South Pole and slow down above the North Pole, tagging each other to deliver persistent coverage of the northernmost region of Earth."[45,46] Both satellites are designed to operate for at least 15 years and will allow users to switch between GEO and HEO satellites.[47] Space Norway plans to cooperate with commercial satellite operator ViaSat and the Norwegian Ministry of Defense to offer mobile broadband coverage to civilian and military users in the Arctic.

Notably, a precedent has been set as Space Norway now claims the first operational U.S. DOD payload ever hosted on an internationally procured and operated space vehicle.[††] The following civilian and military payloads, are included:

- **Viasat.** A high-speed global network extension across the Arctic region with Ka-band payloads.[48]
- **U.S. Space Force – Enhanced Polar System Recapitalization (EPS-R).** A stopgap communications system using an extremely high frequency (EHF) extended data rate payload to fill a vital gap for defense operations in the Arctic region.[49,50]
- **Norwegian Ministry of Defense.** X-band payload.
- **European Commission.** A Norwegian radiation monitor payload.

Commercial Services for the Warfighter. Network convergence across GEO, MEO, LEO, HEO, and even terrestrial 5G cellular networks is happening now and will depend on interoperability standards and various existing spectrum regulations to ensure that there is no harmful interference. An emerging direct-to-device (D2D) market is also proving that unmodified cell phones can connect directly to orbiting LEO satellites for emergency services, texting, and, eventually, wider bandwidth applications.[51]

It comes as no surprise that military users seek to benefit from this connectivity convergence wave. In response, the Air Force Research Laboratory (AFRL) is prototyping and testing future satellite communications equipment so that warfighters can connect to a range of satellites that are in their field of view at any given time. AFRL's Defense Experimentation Using Commercial Space Internet (DEUCSI) contract, also known by the program name "Global Lightning," is now evaluating how hybrid SATCOM terminals can work across multiple constellations or satellite orbits with "highly capable, affordable antennas." In 2023, Global Lightning users conducted iterative tests across the globe, and the results are now being integrated into underserved areas such as the Arctic. [52]

Leveraging international partnerships and expanding commercial satellite capabilities can provide reliable and ubiquitous connectivity. These space capabilities can increase data-sharing to improve operations, provide greater transparency and accountability, and can be the means to "uphold international law, rules, and standards globally" as articulated in the *National Strategy for the Arctic Region*.[53]

Multi-missions Across a Range of Orbits and User Groups. In the future, SATCOM users can expect to see multi-orbit SATCOM operations working seamlessly to share information with a range of users.[54] Nowhere on the planet are these advantages more applicable than in the High North, where openness, flexibility, and interoperability are key to meeting

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[**]Space Norway, owned by the Norwegian Ministry of Trade, Industry and Fisheries, is a key part of the Norwegian Government's activities and assets in the space sector (source: https://spacenorway.no/en/about-us/).
[††]The pioneering commercially hosted infrared payload (CHIRP) mission was the first DOD-hosted payload on a foreign-owned satellite bus, SES (Luxembourg). The payload launched in 2011 and operated for 27 months.

mission requirements ranging from national security, to border protection, fisheries monitoring, search and rescue, and more (see Table 2).

Table 2: Arctic Missions

Persistent satellite imaging, continuous connectivity, and open data sharing will enable cooperation and magnify transparency in the Arctic region, to support various missions.

Arctic Missions	Benefits to Interoperability, Connectivity, and Data Sharing
National Security	Sharing satellite data with both allies and adversaries during military exercises, and detection of trespassing and other potential threats. Data sharing can mitigate mistrust and misperceptions among countries.
Border Security and Sovereignty Protection	Allows observation and border security enforcement, and territorial and natural resource protection. Includes responding to emergencies and safeguarding the free flow of commerce. Responsive communications can mitigate misunderstandings and support contingency operations.
Vessel Assistance and Management	Supports safe passage for ships in the Northern Sea Route, Northwest Passage, and other maritime routes.
Fisheries Monitoring	Supports and encourages compliance for fisheries management bodies and fishing moratoriums, and ensures ocean sustainability.
Environmental and Oil Spill Response	A multilateral treaty ratified by Canada in 2014, *Marine Oil Pollution Preparedness and Response in the Arctic* aims to increase cooperation and coordination among Arctic countries. Commitments include mutual assistance and information exchange to improve oil spill response success.
Search and Rescue	Supports coordination, cooperation, and response between Arctic nation coast guards called for in the 2013 *Arctic Search and Rescue Agreement*.
Science and Research	Supports the 2017 *Agreement on Enhancing International Arctic Scientific Cooperation*, which facilitates Arctic government data access by scientists, to support research, education, career development, and training opportunities.[55]

Recent mergers, such as the Eutelsat–OneWeb and Viasat–Inmarsat mergers, and agreements between Intelsat and SES with LEO operators OneWeb and Starlink are all pointing to a future where hybrid GEO, MEO, and LEO space networks will harness the strengths of each orbit to optimize utility for commercial, civil, and defense purposes.[56] Moreover, increasing the use of software-defined platforms can provide the levels of adaptability needed to work across multiple satellites and networks.

Next Steps and Key Decisions over the Next Four Years

The fallout from Russian aggression introduces increasingly urgent security challenges in the Arctic, particularly as the Arctic Council must reorganize itself around this new reality. During this new era of tension in the High North, the U.S. and NATO allies will need to assert their territorial, economic, and military interests. It is, therefore, a crucial time for satellite systems to support affordable and persistent connectivity, navigation, and observation by emphasizing open, available, and shared systems with trusted Arctic partners, to achieve multi-national interoperability and multi-stakeholder cooperation. Supranational alliances, such as the Arctic Council and NATO, have experienced recent changes, and the ongoing situation remains dynamic and geopolitically sensitive. Within this context, one must consider future space capabilities above 65 degrees north, including commercial services that allow for:

- Support and implementation of Arctic policies.

- Innovative collaboration with allies to share capabilities. The partnership between Space Norway and the U.S. military to bring broadband and other space capabilities to the Arctic region is a potential pathfinder for these types of partnerships.

- Incentivizing and use of open systems with flexible architectures that offer economy, security, and user flexibility.

- Development of multi-orbit, multi-mission capable terminals and hybrid solutions, which allow connections across various satellite constellations, including establishing interoperability standards for hybrid satellite architectures.

- Satellite networks that can handle robust data transmission capacities to meet the future needs of an advanced Joint Force.

These recommendations are structured around a more complex and less friendly Arctic with increased geopolitical rivalry, overlapping territorial claims, and growing polarization between major global powers. However, these same recommendations offer solutions for technical cooperation for search and rescue, environmental response, and other cooperative missions. Whatever the scenario in the High North, the United States and its allies will benefit from the enduring strategic value of space enabled capabilities.

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