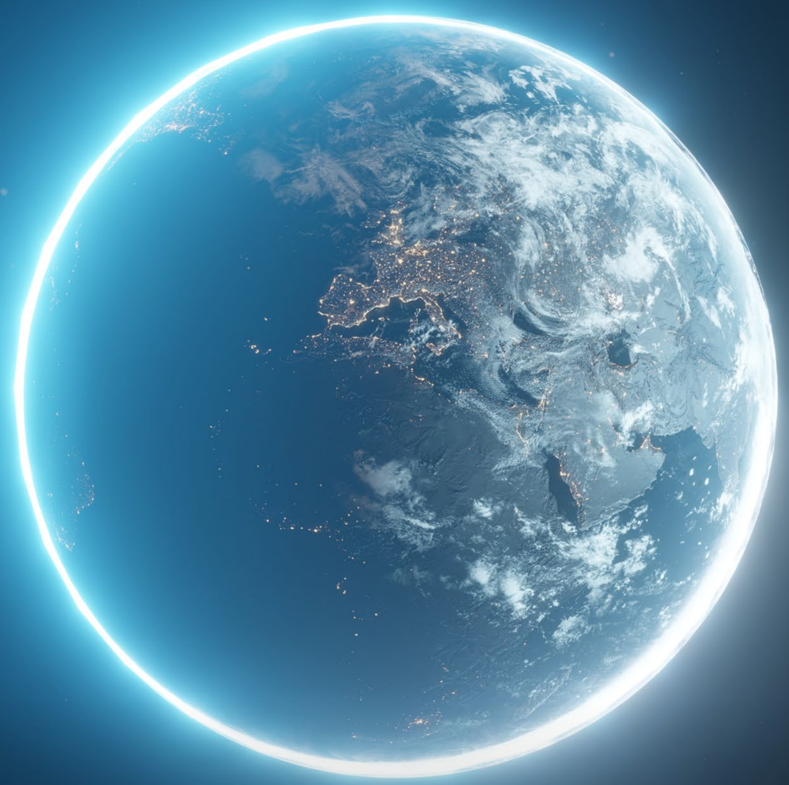


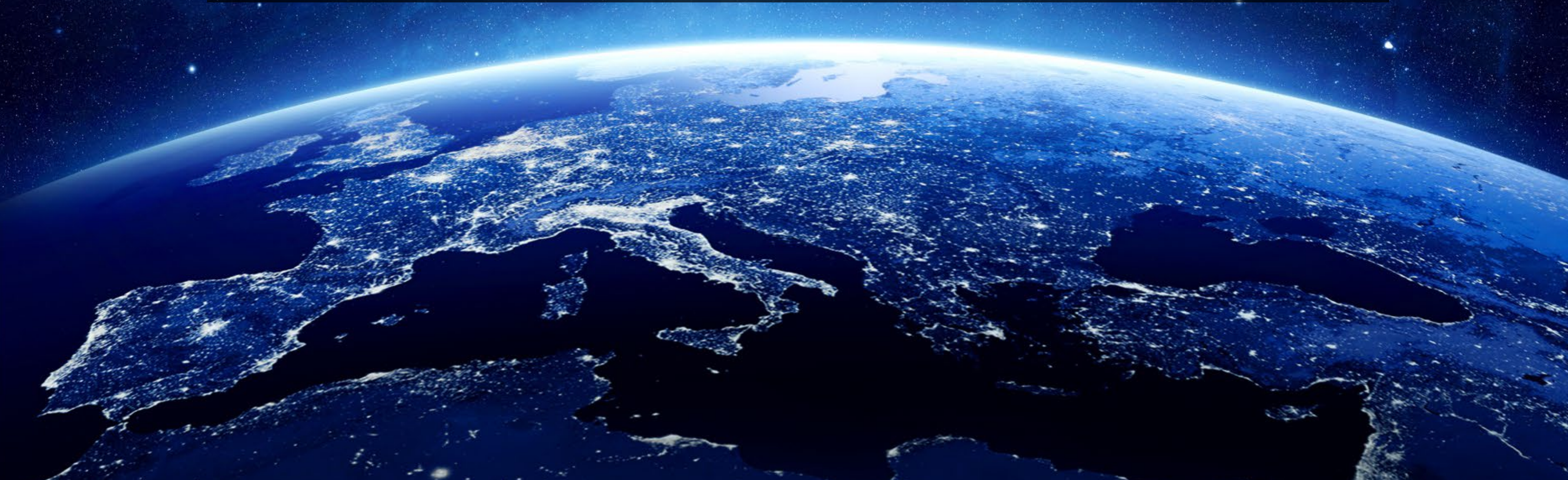
The Future of the Space Economy

Potential Implications for the Intelligence Community

By Thomas Cortez, Brendan Omana, and Dr. Philip Ritcheson

Introduction

The strategic importance of U.S. space capabilities cannot be overstated. These capabilities are integral not only to the daily lives of Americans but also to the functioning of modern social and economic systems. From water and agricultural systems to information technology, communications, finance, and media, space-based satellites are critical. The future space economy is expected to increase in key areas, such as launch, data, and communications. New economic areas may be created, such as space sustainability. But for all its potential economic benefit, advancing space capabilities also pose challenges for the U.S. Intelligence Community (IC). To better position itself in a crowded and competitive space environment, the IC must accelerate its mission modernization efforts.



The Future Space Economy

The space economy will likely grow significantly over the next decade. Space-based capabilities are expected to become more accessible, thereby transforming how industry, government, and society use space in day-to-day activities. In 2022, the global space economy grew by 8%, and some predict it could reach a trillion dollars by 2040.[1] In the global satellite industry, spacecraft manufacturing increased by 9%, global launches by 2%, and satellite ground equipment revenue grew by 4%.[1]

Launch

Growth in the launch market is driven in part by the continuing reduction in launch costs, spurred by private capital and rocket reusability, coupled with technological advances in satellite manufacturing that enable the production of cheaper satellites.[1] The rapid development of commercial space companies has decreased launch costs as well, lowering the barriers to entry for satellite companies, which, in turn, creates demand for more launches and further reduces costs. From 1980 to 2019, the cost of heavy launches to low-Earth orbit (LEO) dropped from $65,000 per kilogram to $1,500 per kilogram—a decrease of over 95%. This significant reduction has led to an exponential increase in the number of satellite launches in recent years compared to the previous seven decades.[1] Looking ahead, the next five to ten years could see an eightfold increase in the number of satellites in orbit, with tens of thousands expected to be in orbit worldwide by 2032.[2] By 2030, most planned satellite launches will focus on establishing communication constellations in Low Earth Orbit (LEO), due to its accessibility and cost-effectiveness, coupled with its significant potential for capability expansion and application.

Data

With more space-based assets, public and private sectors gain greater access to space-based data, services, and capabilities. This “democratization of space” allows space-driven operations to permeate various parts of the economy, government, and society.[3] The demand for space data, products, services, and capabilities will likely continue to grow as they become more accessible and applicable across industries.[4] In one example, improvements in remote sensing algorithms are enhancing satellite capabilities, enabling them to transmit crucial information to the ground rapidly, thereby improving our awareness and ability to understand quickly.[5] Going forward, the expansion of LEO constellations is expected to allow for real-time data that can be transmitted for use in supply chain management, agriculture, forestry, natural disaster mitigation, sustainability, and intelligence applications.[6] As space technology continues to evolve and data becomes more accessible, additional use cases are likely to emerge as more sectors adopt space data capabilities. The development of laser communication systems, which can transmit and receive more data, will further enhance the use of space data.[7] Moreover, advances in edge computing and artificial intelligence (AI) are expected to enable more data to be collected, analyzed, and shared in space, speeding up both awareness and decision-making.[8]

Communications

Beyond space launch and data, the future space economy is expected to extend terrestrial operations into the space domain and further integrate the two. The proliferation of satellites and advancements in space technology will likely create a flexible, adaptive environment, altering how we interact with orbital infrastructure. On-orbit servicing, Assembly, and Manufacturing (OSAM) capabilities involving advanced robotics for satellite maintenance could lead to cost savings and sustainability benefits.[9] The proliferation of LEO constellations will facilitate the development of multi-orbit communication networks that integrate satellites in LEO, Medium Earth Orbit (MEO), and Geosynchronous Earth Orbit (GEO), thereby enhancing the reliability and scope of satellite communication (SATCOM) services for both commercial and governmental stakeholders.[10] As space-derived data becomes increasingly pivotal for terrestrial operations and as space infrastructure is more deeply integrated into economic and government frameworks, multi-orbit SATCOM architectures will be essential for enabling the sophisticated bidirectional communications required for the future space economy. Related, the deployment of 5G satellite constellations, which promise high-speed, low-latency connectivity, has the potential to mitigate digital divides and foster significant economic competition among major powers.[11]

Sustainability

Space sustainability has emerged as a new sector, offering significant potential for economic and environmental value. According to a recent study, Earth observation data could add as much as $700 billion in economic and environmental value by 2030, potentially contributing over $3 trillion to the global gross domestic product. Moreover, environmental actions informed by this data could reduce greenhouse gases by two gigatons,[12] while the European Commission is exploring whether orbiting data centers could reduce the greenhouse gas emissions associated with ground-based data centers.[13] Space-based technologies may well play a key role in addressing global challenges and promoting sustainable development.

Potential Implications for the Intelligence Community

The criticality of space and expected advantages of the space economy are recognized by our adversaries.[14] According to the U.S. Defense Intelligence Agency, "Between 2019 and 2021, the combined operational space fleets of China and Russia [grew] by approximately 70%".[15] During this period, China doubled its number of remote sensing satellites in orbit and has increasingly developed satellites leveraging AI-enabled, cloud-based, edge solutions.[16] The ability of some countries to rapidly manufacture and launch proliferated constellations, including rapid replacement during a crisis or conflict, will likely stress U.S. ground and space-based capabilities to identify, characterize, and track these satellites. As other countries develop cyber weapons, jammers, and other tools, the risk increases that these technologies could be used to hack and control U.S. military and commercial satellites. These tools could also inhibit the satellites' ability to communicate with other satellites within their clusters.[17] Looking to the Moon and beyond, in cislunar orbit, at least a dozen countries are already planning at least 50 deep space missions.[18]

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Artificial Intelligence

Current and projected developments in data analytics and edge computing, facilitated by AI, will continue to transform how the IC gathers, processes, and uses the enormous amounts of space data, further improving U.S. intelligence capabilities.[19] Governments and private companies are projected to spend billions of dollars to integrate AI, machine learning, and cloud computing into their space technologies over the next decade. For instance, the market size of AI in space exploration is expected to reach $1.8 trillion by 2030, reflecting a 35.6% annual increase.[20] AI is already being used to control satellite constellations, with plans to expand this technology to larger constellations of smaller satellites, making launches more cost-effective and maneuverability easier. One company recently announced a new operations center that will use machine learning, automation, and AI to manage its satellites, enhancing the monitoring of thousands of objects in Earth's orbits.[21]

Accelerating Mission Modernization: Tasking and Collection

The rapid evolution of the space economy presents an opportunity for the IC to accelerate its mission modernization in key areas, including collection, edge computing, ground infrastructure, and cyber.

The traditional process of tasking and managing satellite constellations must be more flexible and adaptable. Currently, the tasking process is predominantly manual and centralized, requiring extensive human intervention and coordination across multiple agencies and domains. This approach is becoming increasingly inefficient, time-consuming, and prone to errors and delays. With the future government architecture projected to be four times larger and collect ten times the data of today's systems,[22] the inefficiencies of the current process will only be exacerbated.

The current system is ill-equipped to keep pace with the evolving threat environment and the exponential growth in data and operational complexity. To maintain strategic superiority, a future U.S. tasking and collection system must support cross-cueing and multi-domain operations while adapting seamlessly to advanced space operations. This includes greater maneuverability, increasingly threatening rendezvous and proximity operations, and simultaneous activity in multiple orbits, including cislunar space beyond the Moon. The future tasking process should be automated, integrated, and responsive, leveraging AI, cloud computing, and data analytics. This system should analyze intelligence requirements, prioritize relevant data sources, and coordinate collection and onboard analysis tasks across government and commercial assets. It will also need to monitor and adjust the tasking process based on collection and analysis outcomes. This approach should enable faster, more accurate, and efficient intelligence collection and analysis, reducing the manual workload and cognitive burden.

Edge Computing

The need to process enormous amounts of data to support decisions in a complex security environment will likely increase. As space-based intelligence-gathering capabilities mature with the evolution of AI, big data analytics, and edge computing, a greater portion of the intelligence cycle could be conducted in the space domain. AI and edge computing can enable the processing and analysis of space data directly on-board satellites,[23] reducing decision-making latency due to transmission and analytic speeds. This advancement allows for ubiquitous sensing, where space-based intelligence resources can constantly monitor for threats without direct human involvement. By leveraging these technologies, satellites will be able to autonomously gather data, identify and analyze threats, and communicate relevant information to specialists on the ground.[24] AI will enable autonomous spacecraft to adapt to rapidly changing conditions, enabling them to avoid, analyze, and respond to hazards and threats.[25]

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Multi-orbit satellite constellations and laser communications technologies can revolutionize the transfer of massive amounts of data between satellites, reducing the need for downlinks to ground-based systems. These multi-orbit communications networks can provide efficient, low-latency transmission of data. This creates an intelligence network with a very low risk of dropped signals, even in communication-denied areas. To fully leverage these advancements, hybrid space architectures should be normalized, and barriers to "Allied by design" collaboration, removed.[26]

Ground Infrastructure

While the autonomy of the intelligence process may increase, the necessity for investment in ground capacity, particularly for data storage and processing, must be carefully reviewed. Currently, hundreds of terabytes of data are transmitted back to Earth daily by thousands of satellites in orbit.[27] With an anticipated tenfold increase in data from U.S. government satellites, the urgency for ground modernization and investment becomes increasingly evident. The rapid adoption of AI and cloud computing will continue to place significant demands on data centers and their developers. Increased investment in ground infrastructure will be essential to construct the advanced facilities required to power and sustain the technology behind AI and other modern data collection equipment.[28] It is estimated that the world will produce 147 zettabytes of data in 2024, potentially increasing to 181 zettabytes by 2025. (One zettabyte is the equivalent of 250 billion DVDs worth of data.[29]). Investing in large-scale, reliable, and advanced data centers will be critical to maintaining the integrity of our information security.[30]

Cyber

In the future space-based environment, the vast amounts of data flowing to and from space will remain vulnerable to attempts to compromise this information. Historically, constraints on space systems—such as physical size and weight, radiation hardening, and power limitations—have left little room or budget for integrating robust cybersecurity measures. Most current space cybersecurity efforts use encryption to secure data transfers between space and ground. However, advancements in cyber warfare are rendering these measures increasingly insufficient to protect the growing volume of space data flowing between ground and space, as well as within space itself. Consequently, building cyber-resiliency into space systems, ground stations, and data centers will be a crucial component of the future space economy and the IC.[31] One mitigating factor is the implementation of Zero Trust Architecture, which authorizes every interaction between a data source and those accessing it, even from trusted users. Experts believe that "new spacecraft architectures and communication networks will need Zero Trust principles built in from the start to enable real-time end-to-end security between ground and space."[32] In the event of a cyberattack on a satellite or a group of satellites, incorporating redundancies into space systems can help maintain the system's functionality. Additionally, disaggregating space data architectures can mitigate the scale of potential data leaks by complicating an adversary's ability to access, block, or corrupt data during a cyberattack.[33]

Conclusion

Space is a critical domain for the United States, whether for public services, economic growth, innovation, or national security. And as with other domains, it will be imperative that the United States protect and advance its national interests in and through space, unilaterally if necessary, and with allies and partners preferably. The future space economy will increase economic value in key areas and create other sectors. But these advances are not for the United States alone. Adversaries will have the same opportunities, will seek to exploit vulnerabilities. In an era marked by strategic instability and the thickening alignment of four adversaries, the U.S. IC has much to do to maintain strategic advantage.The proliferation of satellites and continuing surge of space-based data requires accelerated mission modernization. Streamlined processes and increased automation for planning, tasking, collection management, and processing will enable the IC to keep pace with a rapidly expanding government and commercial architecture and to produce and deliver analytic insights more rapidly. Keeping pace with the increase in collection and data will also improve the likelihood of the IC to persistently sense and defeat adversarial use of denial and deception.

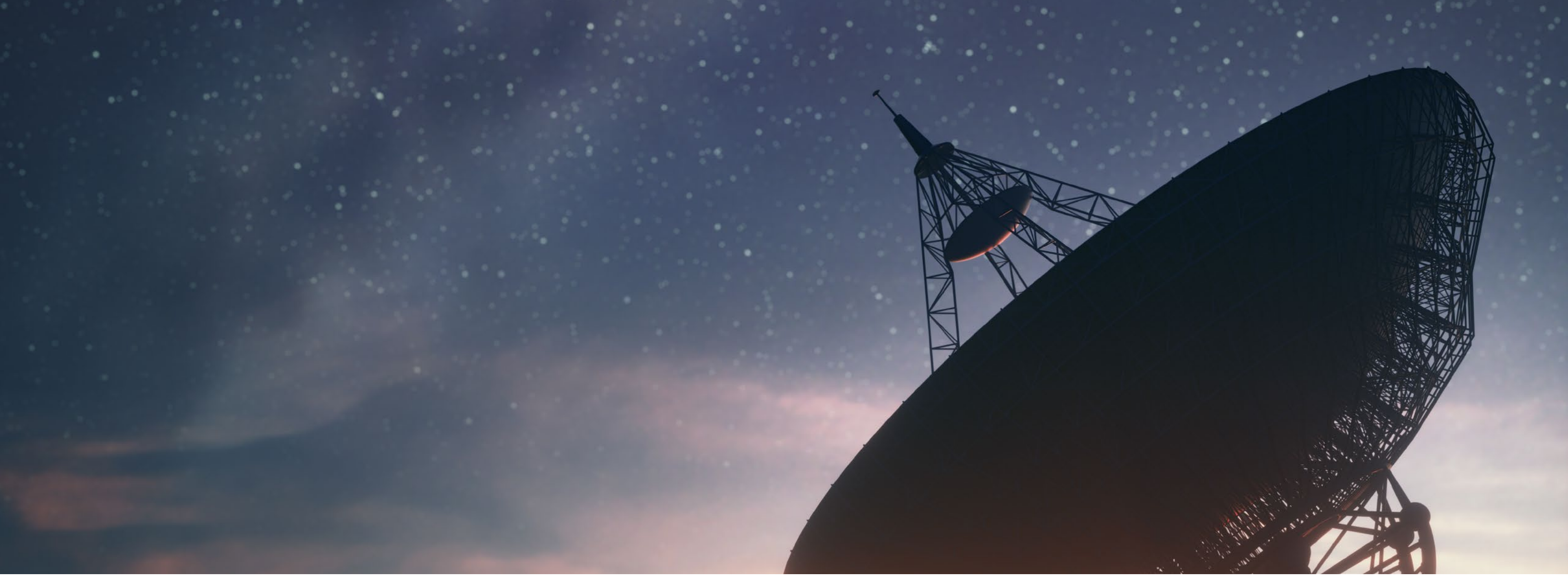
Significant investments in AI, data storage, and computing capabilities will be necessary to process, analyze, and disseminate the massive amounts of raw data collected by satellites. These data solutions need to be scalable to accommodate the growth in depth and scope of intelligence data requirements and operations. Legacy hardware and software at operations centers will need to be upgraded in tandem to fully harness the capabilities of AI-driven intelligence collection and analysis.

As the space community continues to integrate AI, machine learning, and cloud computing into its operations, the barrier to entry in the field will continue to decrease. This will enable more entities to participate in space activities, fostering innovation and collaboration as well as increased competition. Both industry and government will need to rethink strategies to unlock its future.[34] For the IC, it is in a race to shape its modernization efforts and prepare for ongoing competition in, from, and through space. Improvements in automation, AI, and edge computing could enable more effective intelligence operations, reduce the burden on intelligence officers, and allow a redistribution of manpower and resources to other areas.[35] An appropriate human-machine balance should be prioritized – one that accelerates sensing, informs decisions, and enables action. Current and future intelligence officers will need to develop the skills to effectively engage and leverage these powerful tools, presenting recruiting and retention challenges. The IC will likely need to devise new strategies to attract and retain top talent in a competitive candidate pool.[36]

The future space environment will place a premium on adapting capabilities and processes to multi-domain and agile operations. Rapid replenishment and other advanced space operations will challenge U.S. space and intelligence capabilities. So, too, will adversarial development and deployment of AI, machine learning, and cloud computing in space. The risk of cyberattacks, electronic warfare, and other malicious activities in space, on space systems, and across the space ground infrastructure is increasing.

For the IC, it is in a race to shape its modernization efforts and prepare for ongoing competition in, from, and through space.

In this environment, keys to success include the rapid investment in, and adoption of, advanced technology enablers. While the U.S. government's increasing reliance on commercial space companies for remote sensing and Earth observation could put some economic and intelligence activities at risk,[37] the IC should further deepen its integration with commercial entities and private enterprises. This will tap into a U.S. strategic advantage – industry's innovation excellence – enable IC missions, facilitate joint and combined space operations, and complicate adversary decision making.[38] Speed will be essential, reinforcing the need for integration and interoperability, between the Department of Defense and the IC and with U.S. allies and partners, as more resilient, flexible, and adaptable capabilities are developed and fielded.



Let’s Talk

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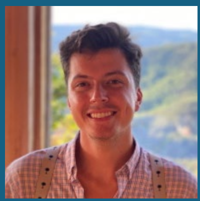

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