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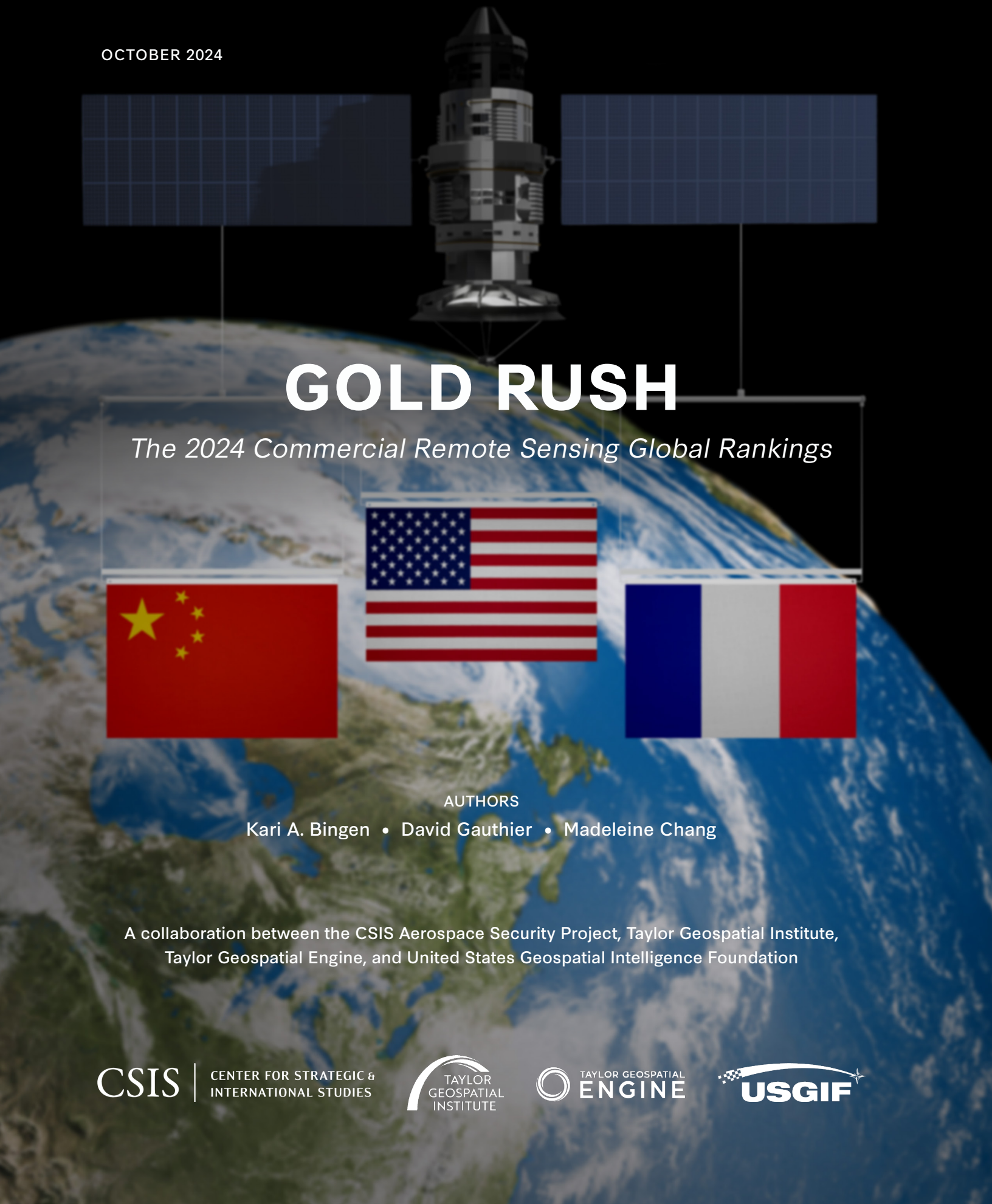

GOLD RUSH

The 2024 Commercial Remote Sensing Global Rankings

AUTHORS

Kari A. Bingen • David Gauthier • Madeleine Chang

A collaboration between the CSIS Aerospace Security Project, Taylor Geospatial Institute, Taylor Geospatial Engine, and United States Geospatial Intelligence Foundation

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This was an opportunity to bring together four independent not-for-profit institutions—that specialize in international security, space, and geospatial sciences and innovation—to assess an important aspect of U.S. technological, security, and economic competitiveness. We benefited from the scholarship and collegiality among the leaders and researchers within these world-class institutions.

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Executive Summary

Everyone loves a good competition. There is a reason the Olympic Games have been around for millennia. It is human nature to compete, compare performances, and strive for improvement. The commercial remote sensing arena is not immune. When the U.S. National Geospatial-Intelligence Agency (NGA) released a public product comparing the performance of commercial satellite imaging systems in 2021—what came to be known as the "Commercial Imaging Olympics" —the outcomes were surprising.[1] U.S. systems won "gold" in only three of the nine categories of performance, with Chinese systems also earning three gold medals.[2] The results informed discussion and elicited actions within both the U.S. space industry and the U.S. government to make changes in support of a stronger industrial base.

Following this, four leading institutions—the Center for Strategic and International Studies, Taylor Geospatial Institute, Taylor Geospatial Engine, and United States Geospatial Intelligence Foundation—collaborated to independently produce a "Top 3" ranking of the world's best commercial space-based remote sensing systems in 2024. The results should spur discussions on the state of U.S. leadership and global competition among commercial space providers and serve as an indicator of the relative strength of a nation's remote sensing offerings within the global space economy. While the project team developed a new and distinct research methodology and ranking system rooted in well-understood technical performance parameters, the format of the results honors both the spirit of the Olympic Games and the original product.

The 2024 assessment centers largely on advances in U.S. and Chinese remote sensing systems. Of 11 performance categories, Chinese systems garnered the gold medal in five areas and U.S. systems

in four areas, with Finland and South Korea each securing a gold medal. Nearly half of the podium spots went to satellite systems launched between 2021 and 2024, showing a large amount of dynamism within the last four years and the speed at which more advanced capabilities are being introduced in the global commercial marketplace.

Of 11 performance categories, Chinese systems garnered the gold medal in five areas and U.S. systems in four areas, with Finland and South Korea each securing a gold medal.

This report discusses actions the U.S. government should take as "a regulator, investor, and customer" to keep U.S. companies at the cutting edge of technology and globally competitive.[3] With a nascent commercial market, the government is the primary customer and market driver. It will need to take a more strategic and active role in advancing commercial capabilities that must endure and be competitive against Chinese commercial offerings, among others. This means building multiyear budget profiles for commercial remote sensing to create a stable demand signal, harmonizing government investment and private capital, aligning executive and legislative branch support, improving access to financial tools common in other economic sectors, and continuing to reform U.S. export policies and regulations. The report further highlights that U.S. national interests are also advanced through greater collaboration with allies and partners in commercial remote sensing, and explores the benefits of foreign companies establishing a greater presence in the United States and sharing their technological advancements and business innovations.

While the United States has long been the global leader in space, the 2024 medal winners spotlight the continued advancement of China's remote sensing capabilities and the expansion of its commercial space sector. Commercial remote sensing is one dimension of a broader space competition as Beijing continues to execute its vision of leading the world in space, among other key technology sectors.[4] The stakes are high. Should any one country dominate the commercial remote sensing market, not only could it gain economic advantages, but it would also control the information narrative about the entire planet, from the environment to natural resources to human conflict.

Introduction

While the United States has long been the global leader in space, that lead is being challenged as nations vie for the same economic, security, and industrial benefits from space capabilities that the United States has long enjoyed. The proliferation of space technologies, decreasing launch costs, diffusion of capital, and stimulating government policies are affording more nations the opportunity to compete in space, with some countries—in recent years—taking surprising new leadership roles in space-based remote sensing.[5] Further, the expanding privatization of the space-based remote sensing sector is creating increasing supply and competition in the international marketplace. Should any one country dominate the commercial remote sensing market, not only could it gain economic and security advantages, but it would also control the information narrative about the entire planet, from the environment to natural resources to human conflict.

The National Geospatial-Intelligence Agency (NGA) sought to understand trends in the global remote sensing marketplace. In 2021, it produced a ranking of commercial remote sensing systems across various categories of performance: a "satellite Olympics" that coincided with the 2021 Summer Olympics.[6] The NGA product was informative and well received by the government, industry, and academia. It challenged assumptions by policymakers, many of whom "assumed that U.S. companies would be industry leaders across the board."[7] Yet, U.S. systems won "gold" in only three of the nine categories. The 2021 product spurred important conversations about the importance of U.S. leadership in commercial remote sensing and, according to some U.S. companies, prompted new investments to accelerate developments in certain areas of remote sensing where the United States appeared to lag the rest of the world in technology.[8] The product also reinforced changes to

U.S. government regulatory policy and prompted an emphasis on a "competitive and burgeoning U.S. commercial space sector" that was described in the United States Space Priorities Framework.[9]

Should any one country dominate the commercial remote sensing market, not only could it gain economic and security advantages, but it would also control the information narrative about the entire planet, from the environment to natural resources to human conflict.

A lot has changed in just three years. To understand the latest trends, a collaborative team from the Center for Strategic and International Studies, Taylor Geospatial Institute, Taylor Geospatial Engine, and United States Geospatial Intelligence Foundation conducted an independent assessment of the world's best commercial remote sensing systems—shining a spotlight on those companies and nations that are leading the world in capturing knowledge of Earth and the activities upon it.

1

Methodology

To produce a ranking of the world's best commercial space-based remote sensing systems, the authors developed a methodology to quantitatively assess satellite performance using commonly understood and widely used technical performance parameters for remote sensing.[10] The assessment covered eleven categories of performance across electro-optical (EO), synthetic aperture radar (SAR), and infrared (IR) modalities. Nine categories are similar to those used by NGA in 2021, and two categories have been added.[11]

The performance parameters relevant to each category include technical factors such as spatial resolution, spectral resolution, number of imaging bands, and the number of operational satellites (or persistence of imaging), among others. The National Oceanic and Atmospheric Administration (NOAA) uses many of these parameters in evaluating commercial remote sensing license applications and in its benchmarking of foreign remote sensing systems.[12] In each category, the top performers were scored, ranked, and awarded gold, silver, and bronze medals. A company's national flag corresponds to the state or organization under which its satellite system is registered, as captured by the United Nations, and from where the majority of its satellite constellation and operations are regulated.[13] While the authors recognize that several foreign companies have established U.S. subsidiaries to pursue greater business opportunities within the United States, they were still attributed to a national team based upon satellite registration and licensing.[14] Foreign companies that have established U.S. subsidiaries are recognized for sharing their technical and business innovations with the United States, promoting greater alliance and partnership opportunities, and increasing the overall competitiveness of the market. The one exception made this year is for Satellogic, which is dual-flagged as both a U.S. and Uruguayan competitor due to

unique circumstances of redomiciling in the United States, maintaining Uruguayan registration with the United Nations, and subjecting its entire satellite constellation to NOAA licensing.[15]

To qualify for this assessment, only those space-based remote sensing systems that were privately owned and currently operating (i.e., not owned and operated by a government entity) and offering a product or service available to the commercial market as of July 1, 2024, were included in the dataset.[16] The authors relied on information that was publicly available and—recognizing that the accuracy and opacity of information can vary—sought to corroborate data across multiple sources, confirm technical specifications, and capture true performance data to the maximum extent possible.

This report makes comparisons to the 2021 NGA rankings, as provided in NGA's publicly released and discussed rankings chart.[17] While the methodologies may differ, the project team makes such comparisons buoyed by the fact that there are a limited number of key technical parameters needed to evaluate performance in categories such as EO imaging resolution and SAR revisit, and those technical parameters are often made publicly available in product specification sheets, press releases, and other information disclosed by companies. When necessary, companies were contacted directly to verify and fill in gaps in satellite system information, which in some cases was essential in determining podium rankings. The research team did not contact Chinese system owners, which could introduce both favorable and unfavorable effects for Chinese systems in the rankings.[18]

While striving to compare objective technical parameters with a repeatable methodology, the authors acknowledge that it is impossible to do so perfectly. Choices were made for how to score performance in each category and for selecting the definitions of the categories themselves. Challenges to this methodology and rankings are to be expected and encouraged, and the authors are receptive to engaging with companies and other experts to inform future iterations of the assessment.

Finally, the authors recognize that many U.S. and foreign commercial remote sensing systems are dual use, with companies selling data and services both in the commercial marketplace and to governments. Those companies may offer even higher-end capabilities to government customers that they do not make commercially available, but such capabilities were outside the scope of this assessment. Further, while including government systems might provide different outcomes at a different classification level (this project was completed based solely on non-classified, publicly accessible information), the purpose of this effort was to examine the state of competition among commercial providers alone as an indicator of the relative market strength of a nation's remote sensing offerings within the global space economy.

Table 1: Performance Categories and Assessment Factors

Performance Category	Assessment Factors
Electro-optical (EO) imaging	Based on ground sample distance (GSD) in native resolution and daily collection capacity at that resolution
EO revisit	Based on a constellation's ability to rapidly revisit targets, factoring in the number of operating satellites in the constellation and the orbital arrangement of those satellites
EO video	Based on spatial resolution, with "frames per dwell" (frames per second multiplied by dwell time) an additional performance factor
Synthetic aperture radar (SAR) X-band	Based on maximum "information density" calculated using the Radar Generalized Image Quality Equation (RGIQE), a parameter used by the NOAA Commercial Remote Sensing Regulatory Affairs (CRSRA), and the number of operating satellites (representing general collection capacity)[19]
SAR revisit	Based on a constellation's ability to rapidly revisit targets, factoring in the number of operating satellites in the constellation and the orbital arrangement of those satellites; currently only includes X-band SAR
SAR C-band*	Based on maximum "information density" calculated using the RGIQE, a parameter used by CRSRA, with the number of satellites (representing collection capacity) as a secondary metric[20]
Multispectral capability (4+ bands)	Based on GSD and number of operating satellites
Hyperspectral capability (20+ bands)	Based on spatial resolution (GSD) and "spectral information density," defined as the number of spectral bands divided by the average width of those bands
Short-wave infrared (SWIR)	Based on GSD as the dominant factor in determining system quality, with the number of satellites in orbit (representing collection capacity) as a secondary metric
Mid-wave infrared (MWIR)	Based on GSD as the dominant factor in determining system quality, with the number of satellites in orbit (representing collection capacity) as a secondary metric
Long-wave infrared (LWIR)*	Based on GSD as the dominant factor in determining system quality, with the number of satellites in orbit (representing collection capacity) as a secondary metric

Note: * New categories in the 2024 global rankings.
Source: Authors' research and analysis.

2

Medal Winners

Observations and Trends

This year's assessment centers largely on advances in U.S. and Chinese remote sensing systems. Of the eleven performance categories, Chinese systems garnered the gold medal in five and U.S. systems in four, with Finland and South Korea each securing a gold medal. Nearly half of the podium spots went to satellite systems launched between 2021 and 2024, showing a large amount of movement within the last four years and more advanced capabilities being introduced in the global commercial marketplace.

Electro-Optical (EO) Systems

Most notable in the EO categories is China's rise to gold in EO imaging capability, with its SuperView Neo-1 system, launched in 2022, offering a commercial product that combines high-resolution imagery with the largest constellation collection capacity. Because there is now a clustering of commercial systems able to capture native 30-centimeter (cm) imagery, additional performance factors such as collection capacity (at this resolution) provide further differentiation in the global market. While the U.S. WorldView-3 system (launched in 2014) still remains on the podium, Maxar's WorldView Legion constellation is likely to compete for the top spot in future assessments once its products become commercially available. The first two satellites in the Legion constellation were launched in May 2024, and two more launched in August 2024. Expected to launch in 2025 are the first commercial EO imaging systems going to very low Earth orbit—from Albedo Space and EOI Space—a move which will significantly improve their imaging resolution and enable them to be highly competitive.

2024 Commercial Remote Sensing Global Rankings

EO Imaging

1. China Siwei SuperView Neo-1
2. Airbus Pléiades Neo
3. Maxar WorldView-3

EO Revisit

1. Chang Guang Jilin-1
2. Satellogic Aleph
3. Planet SkySat

EO Video

1. Planet SkySat 16-21
2. Zhuhai Orbita Zhuhai OVS-2/3
3. Chang Guang Jilin-1 Video

SAR X-Band

1. Umbra Umbra SAR
2. Capella Space Acadia
3. ICEYE* Generation 3

SAR Revisit

1. ICEYE* Constellation
2. Umbra Constellation
3. Capella Space Constellation

SAR C-Band

1. SAST Gaofen-12
2. Spacety Chaohu-1
3. MDA Space RADARSAT-2

Short-Wave IR

1. Maxar WorldView-3
2. Satlantis GEISAT Precursor
3. SAST Gaofen-5

Mid-Wave IR

1. KARI KOMPSAT-3A
2. SAST Gaofen-5
3. Chang Guang Jilin-1 GP-01/02

Long-Wave IR

1. CAST Ziyuan-1 02E
2. SAST Gaofen-5
3. Chang Guang Jilin-1 GP-01/02

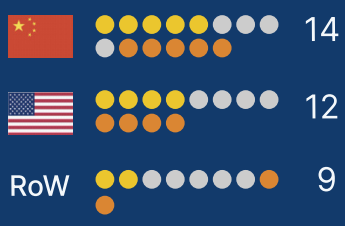
Multispectral

1. China Siwei SuperView Neo-3
2. Satellogic Aleph Mark V
3. Planet SkySat 16-21

Hyperspectral

1. Orbital Sidekick GHOSt
2. Pixxel* Anand/TD-1
3. Zhuhai Orbita Zhuhai OHS-2/3

Total Medals



*System also licensed in the United States.
Note: Information current as of July 1, 2024. Underlying data derived from open source and publicly accessible information.
Satellogic medals count for both the United States and Uruguay and are represented by a combined flag.
Source: Authors' research and analysis.

China's Jilin-1 EO systems hold the top spot in EO revisit, owing to its large constellation of over 100 operational satellites in orbit.[21] In the EO video category, the latest generation U.S. SkySat system earns gold when accounting for its enhanced product offerings tied to frame rate, dwell time, and spatial resolution. While not on the podium due to its products not being available on the commercial market, Japan's CE-SAT-1E system, operated by Canon Electronics and launched in 2024, receives an honorable mention for its high frame rate performance and innovative design. A noteworthy trend is a growing group of EO constellations offering sub 1-meter imagery at higher revisit rates. One such example is the U.S. BlackSky Global constellation that, while not on this year's podium, will be one to watch as it and other constellations optimize different performance parameters to increase the value of remote sensing to end users.

Figure 2: Total Medal Count

2024	Gold	Silver	Bronze	Total
China	5	4	5	14
United States	4	4	4	12
Finland	1		1	2
Uruguay		2		2
South Korea	1			1
France		1		1
India		1		1
Spain		1		1
Canada			1	1

Note: Information current as of July 1, 2024.
Source: Authors' research and analysis.

Synthetic Aperture Radar (SAR) Systems

SAR performance was the most challenging to assess, given the complexity of the data collected in radar pulses and the relative opacity of Chinese technical data. The authors used a benchmark that the NOAA Commercial Remote Sensing Regulatory Affairs (CRSRA) has adopted in its regulatory process, an equation to calculate information density contained in a SAR dataset called the Radar Generalized Image Quality Equation, and drew heavily on NOAA published data to rank the top foreign remote sensing systems.[22]

SAR X-band imaging performance saw a complete shake-up on the podium this year, with the three medalists being all new systems—U.S. Umbra SAR (gold), U.S. Capella Space Acadia (silver), and Finnish ICEYE Generation 3 (bronze)—launched in the 2022–2023 timeframe. Similarly, the same three companies were top performers in SAR revisit, with ICEYE outpacing the competition due to its larger constellation size. This is a stark contrast to just seven years ago when, as described in an Aerospace Corporation report, it was observed that "U.S.-based companies are not participants in the competition for commercial radar imagery due to domestic regulatory limitations that so far

have been an insurmountable barrier to entry."[23] With NOAA's regulatory reforms in 2020 and the removal of further restrictions on X-band SAR data sales in 2023, U.S. companies quickly become top performers in the market.[24]

While Chinese firms have made less progress in X-band SAR, they lead the pack in C-band SAR. C-band SAR provides lower-resolution radar imagery over larger areas and is particularly useful for environmental analysis, including global mapping, landform changes, and ocean monitoring.[25] The aging Canadian RADARSAT-2 satellite earned a bronze medal and its follow-on system, the CHORUS-C satellite from MDA Space, is expected to compete favorably in future rankings.

It is worth noting that all commercial SAR companies will approach a resolution limit based on spectrum constraints set by the International Telecommunication Union.[26] With resolution and dwell time approaching technical limits, where commercial SAR companies go next in offering differentiated performance and products over their competitors will soon make these comparisons more complicated and diverse.

Spectral Systems

The multispectral and hyperspectral podiums tell two different stories. In multispectral, China's SuperView Neo-3 received the gold medal, but the competition in this category was tight. All three podium winners appear to offer similar capabilities, with China's Siwei and the second-place finisher, U.S./Uruguay Satellogic, both launching their top performers in the last two years.

Hyperspectral capability was a category that, in NGA's 2021 assessment, showed no competitive U.S. system. In 2024, a U.S. system is now atop the podium with GHOSt satellites developed and operated by the U.S. company Orbital Sidekick. And an Indian system, Pixxel, is in receipt of the silver medal. Performance parameters for hyperspectral systems can often be in tension, making direct comparisons challenging. Some systems are designed for higher spatial resolution to aid in discovering smaller targets while others are optimized for finer spectral resolution (i.e., spectral density) to characterize specific materials and hydrocarbons and find them over larger areas. In future iterations of this analysis, it will likely be appropriate to separate hyperspectral systems into two unique categories.

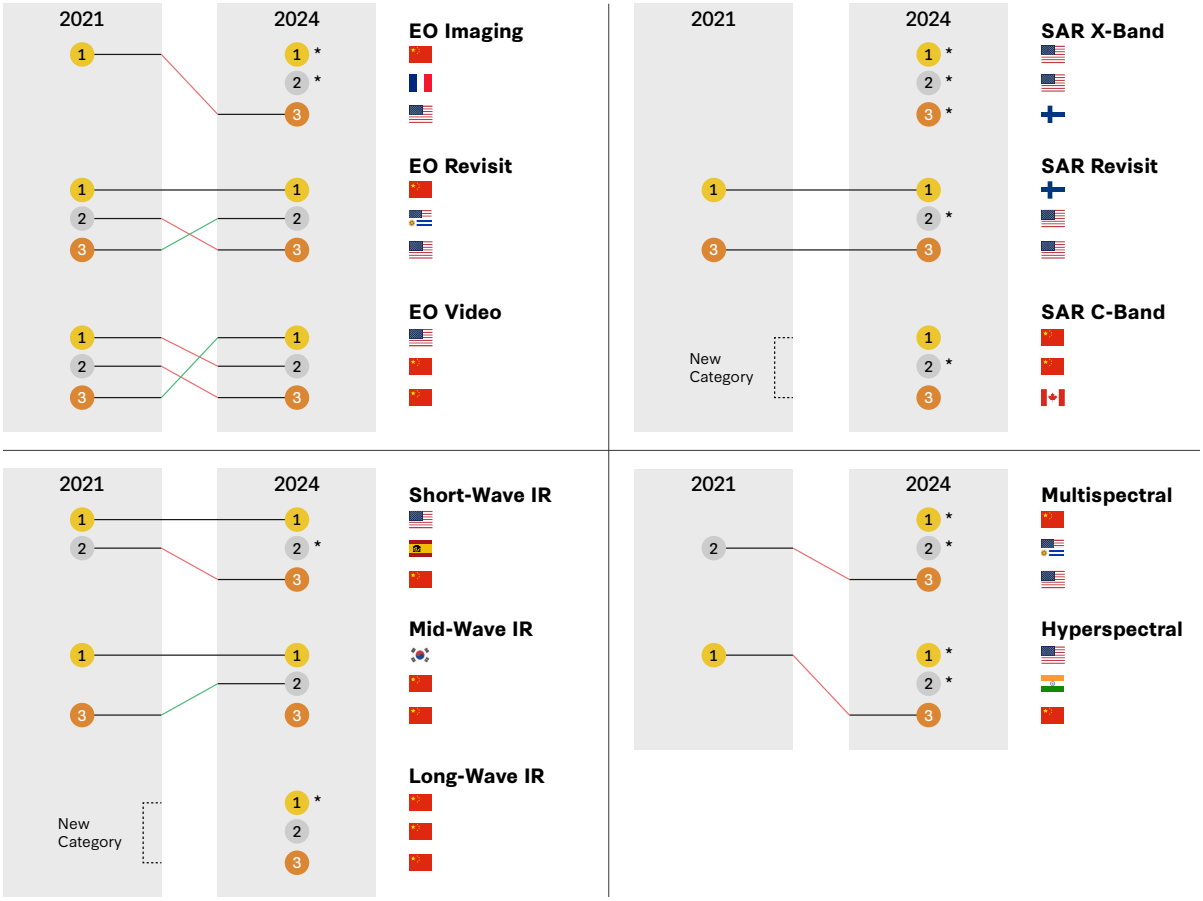
Infrared (IR) Systems

Across the IR remote sensing categories, short-wave infrared (SWIR) appears largely unchanged from NGA's 2021 rankings. WorldView-3 remains the leader, driven by its resolution performance, as many U.S. companies have shied away from SWIR offerings due to long-standing regulatory restrictions. While not reflected on the podium, several countries have or are developing commercial SWIR systems that could alter these results within the year. In contrast, fewer companies are pursuing mid-wave infrared (MWIR) remote sensing systems. The South Korean KOMPSAT-3A—a system launched in 2015—was then and still sits now atop the podium. Chinese systems launched in 2018 and 2019 took silver and bronze, respectively, with lower resolution

offerings than KOMPSAT-3A. Despite a smaller competitive pool at present, there are MWIR efforts by British, German, and U.S. companies worth watching.

In the category of long-wave infrared (LWIR), Chinese commercial systems are dominant. Much of the utility of LWIR remote sensing is in applications such as climate change, agriculture, and wildfire monitoring. Changes to U.S. regulatory restrictions on infrared imaging will enable U.S. companies to test this commercial market, with two U.S. companies planning to launch systems in 2025 capable of imaging in the LWIR spectral range: Albedo Space and Muon Space. Both could be future medal contenders.

Figure 3: Trends in the Medal Rankings

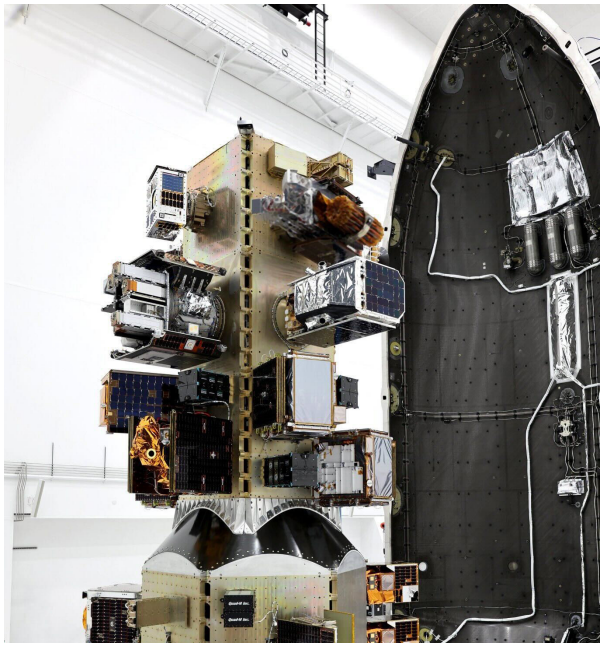


Note: Information current as of July 1, 2024. * System launched in 2021 or later; represents new entrants to the market within the last four years.
Source: Authors' research and analysis.

Neither the United States nor China has a clear across-the-board lead in commercial remote sensing.[27] In comparison to NGA's 2021 rankings, U.S. companies have made the greatest positive movement in X-band SAR, hyperspectral capability, and EO video. Government contracts,

strategic investments (from both private and U.S. government-related entities), and U.S. policy and regulatory relief appear to have played formative roles in the acceleration of these improved commercial capabilities over the last three years.

Meanwhile, Chinese companies moved up the podium in EO imaging and multispectral capabilities, and they hold dominant positions in LWIR and C-band SAR. The authors cannot definitively explain China's dominance and the absence of U.S. or other Western commercial entrants. However, space-based remote sensing using C-band SAR and LWIR instruments for environmental and scientific applications has long been a core competency of Western civil space agencies, such as NOAA's Geostationary Operational Environmental Satellite weather satellites and the European Commission-European Space Agency Copernicus initiative, with fewer commercial market opportunities.[28] Important to watch will be progress by U.S. companies like Albedo Space and Muon Space, and their ability to disrupt the IR results.



The payload stack for the SpaceX Transporter 11 mission launched on August 16, 2024, included new satellites from Planet, Satellogic, Capella, and Umbra, among others.

Photo: Planet Labs PBC

There are commercial remote sensing systems currently flying as demonstration systems or launched since July 1, 2024, that are on the cusp of operational capability and were not eligible for inclusion in these results. Established U.S. companies like Maxar and Planet launched WorldView Legion EO imagers and a Tanager hyperspectral system, respectively, and new-to-market companies will soon begin to offer commercial IR data and products. It is more difficult to predict new capabilities coming from Chinese aerospace companies, though they are expected to continue improving their commercial offerings.

Regarding China, are Chinese companies focusing efforts on assessed niches where little competition exists, or is their progress reflective of a broader strategy by Beijing to advance on myriad space-based remote sensing fronts? The authors believe it is both when looking holistically at the presence of Chinese companies across these categories, the numerous systems that did not medal but are in orbit or in development, and trends in other areas of commercial space. While U.S. analysts tend to focus on the People's Liberation Army's developments in space, China's commercial space sector is also rapidly expanding–enabled by leadership priority, national policy, government funding and incentives, and private capital.[29] China is likely intent on dominating this medal count in years to come.

3

Policy Discussion

"The fundamental goal of this policy is to advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry."

– U.S. Commercial Remote Sensing Policy, April 25, 2003[30]

This assessment considered worldwide commercial space-based remote sensing systems and produced a ranking of the world's best. As the overall medal count shows, the dominant front-runners are Chinese and U.S. companies. While the United States has long been the global leader in space, Beijing has declared its intent for China to lead the world in space. Commercial remote sensing is but one dimension of a broader space competition, from Earth to the Moon.

The questions for policymakers include the following:

- What issues will shape the long-term viability of these commercial remote sensing companies?
- What role should the U.S. government play in creating opportunities for U.S. companies that strengthen their overall viability and global competitiveness?
- What is at stake for U.S. national interests if the United States loses ground in this important area of technology and commerce?

The U.S. Commercial Remote Sensing Policy, unchanged since 2003, articulates the objective of "advanc[ing] and protect[ing] U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry." Furthermore, the first policy goal listed in the more recent 2020

National Space Policy is that the United States shall "promote and incentivize private industry to . . . strengthen and preserve the position of the United States as the global partner of choice for international space commerce."[31]

One might take away from these 2024 Commercial Remote Sensing Global Rankings that, in general, the U.S. remote sensing industry is performing well and that its position has improved from three years ago. Companies from the United States or its allies medal in nearly all categories, new systems are soon coming online (e.g., Maxar's WorldView Legion) that will be top contenders in the international marketplace, and U.S. companies are high performers in key categories that the U.S. government relies upon (e.g., EO and SAR). However, given the current global rankings, it is clear that the United States has not fully achieved its stated policy goals.

Moreover, there is also fragility and acute competition across the ecosystem with global security and economic consequences. The 2024 rankings provide a snapshot in time with mixed trends. Four Chinese systems and four U.S. systems each make their podium debut this year, having been launched in 2021 or later.[32] While U.S.-flagged companies gained in the rankings in several categories when compared to 2021 (e.g., EO video and hyperspectral capability), they lost ground in others (e.g., EO imaging). The 2024 Commercial Remote Sensing Global Rankings published here highlight the challenges ahead for the U.S. government to leverage all tools at its disposal to achieve U.S. national policy goals in space.

Government as a 'Regulator, Investor, and Customer'

Three government stimulants occurred in the past four years that appear to have played formative roles in the acceleration of U.S. commercial capabilities and, very likely, this year's podium results: government policy and regulation, strategic investments, and government contracts. This mirrors observations made by the Defense Science Board in a May 2024 report on commercial space access and integrity, where they see the role of government as "a regulator, investor, and customer."[33]

First in 2020 and later in 2023, NOAA implemented licensing reforms that removed several restrictions on the ability of commercial remote sensing companies to sell their more advanced and competitive products. For example, it removed all "temporary conditions" on X-band SAR, the practical effect being that U.S. companies could, according to the president of one U.S. SAR company, "offer customers the highest resolution images that our satellites are capable of capturing."[34] U.S. company Albedo Space, in 2021, was granted a first-of-its-kind NOAA license to sell 10 cm resolution EO imagery, a leap forward from today's 30 cm offerings.[35]

A philosophical shift is occurring, with U.S. government regulators accounting for the need to keep U.S. industry in the lead amid a tightening global competition. These global rankings show the speed at which the overall sector is moving and how both U.S. and foreign companies are seeking to push the performance envelope.[36] Roughly half of this year's top performers were systems launched in the last four years alone. While trends in U.S. policy and regulations are positive, they must continue to lead and pace, not lag. NOAA regulators should now work to remove the remaining technical restrictions on U.S. remote sensing systems and, like other nations, regulate more directly

to whom they can sell their data.[37] This would open a new era of technical innovation and dominant performance for the U.S. commercial remote sensing industry.

Second, the sector saw an influx of private capital in recent years that fueled many of the systems atop this year's podium. According to market analysis firm BryceTech, 2021 was a high watermark for private capital entering the commercial space sector, including through the use of special-purpose acquisition company vehicles, which raised capital for a few U.S. companies

Three government stimulants occurred in the past four years that appear to have played formative roles in the acceleration of U.S. commercial capabilities and, very likely, this year's podium results: government policy and regulation, strategic investments, and government contracts.

featured in this report.[38] The investment firm In-Q-Tel, whose aim is to transition intelligence and defense-relevant technologies from the private to the public sector, also made strategic investments in commercial remote sensing companies during this time. In 2022, In-Q-Tel invested in U.S. company Orbital Sidekick to advance its hyperspectral capabilities, with previous strategic investments including U.S. firm Capella Space (2017), Finnish firm ICEYE (2021), and British firm SatVu (2022).[39]

However, the investment landscape is becoming more challenging. Commercial space investments in North America are decreasing overall, with investors not seeing a return on their capital and the markets growing slower than they anticipated.[40] Without a continued influx of capital—satellite development and operations are capital intensive—U.S. companies will be hard-pressed to invest in further technological advancements, which could limit their future competitiveness.

Lastly, the U.S. government awarded a large contract for commercial EO imagery. In 2022, the National Reconnaissance Office (NRO) awarded "its largest-ever commercial imagery contract. . . . Valued at billions of dollars over the next decade" to three U.S. companies with commercial EO systems.[41] The NRO has also outlined plans to purchase other sensing modalities, like SAR, hyperspectral imagery, and radiofrequency mapping, but has not yet followed through with an expanded demand signal and program of record like it has for EO.[42] Meanwhile, the U.S. Space Force is beginning to acquire commercial remote sensing data and analytics to provide "tactical support of unified combatant commands as directed by the recent Tac ISR/SRT [intelligence, surveillance, and reconnaissance/surveillance, reconnaissance, and tracking] initiative," but also lacks clarity on scale, funding, and timelines.[43] Additionally, NGA plans to procure commercial analytic services through a program named Luno, creating a further market demand signal for geospatial data and value-added products.[44]

Projecting Ahead

Projecting ahead, one might read market forecasts with headlines that the space economy is "booming" and think there is no need for concern; the market is strong. After all, a 2024 World Economic Forum report projects the global space economy will grow to $1.8 trillion by 2035, with space-based Earth observation revenue more than tripling from $2 billion in 2023 to $9 billion annually by 2035, driven by increasing demand for value-added services like analytic insights and tailored products.[45] One firm noted that, "The demand for EO imagery remains the highest in the defence and intelligence (D&I) vertical."[46]

Yet, this forecasted demand signal from the U.S. government has not translated into sustained investment. U.S. companies are capturing small, initial government contracts but are finding it hard to secure substantial follow-on contracts. Without an ability to forecast long-term revenue, these companies will be challenged to attract capital to continue advancing their technology and product offerings. Even further, without a near-term demand signal, there is uncertainty about whether current companies will survive to realize the forecasted market opportunities in the decade ahead. It has already affected commercial SAR. Two U.S. SAR companies earned medals this year—Umbra and Capella Space—with ICEYE (headquartered in Finland with a U.S. subsidiary) also earning a podium spot. However, other U.S. companies have scrapped plans to deploy SAR satellites in the last three years.[47]

The U.S. government is still a powerful market actor with an ability to shape the commercial marketplace and assure the long-term sustainability of private industry, consistent with its policy goals. The Defense Science Board observed that "the government can be indispensable as an anchor tenant and source of a stable demand signal" for "nascent markets emerging from traditionally government missions . . . for which there may be limited early pure commercial demand."[48] To keep U.S. companies atop the podium and globally competitive, the government will need to wield its power as a customer, investor, and regulator more strategically.

Aligning government investment and private capital is a good place to start. Today's systems benefited from an influx of capital, including unprecedented private capital that entered the commercial space sector in 2021. Further investment now will determine the most advanced

To keep U.S. companies atop the podium and globally competitive, the government will need to wield its power as a customer, investor, and regulator more strategically.

systems on the podium three years from now. The government is the primary customer and market driver with a nascent commercial market. It will need to take a more active role in investing in commercial capabilities that must endure and be competitive against Chinese commercial offerings, among others. This means building multiyear budget profiles for commercial remote sensing to create a stable procurement demand signal and aligning executive and legislative branch support.

Such a demand signal should be used strategically to drive early capital investments that accelerate technological advancements and innovative solutions ahead of planned government contracts.

The government can also better integrate commercial capabilities into its architectures to increase the diversity of sources, add capacity, and improve mission resiliency. However, so long as commercial data and products are treated separately and perceived as costly to access, whereas government data is "free," users will not embrace it. The user experience should be seamless from tasking to delivery, whether they are accessing commercial or government-collected remote sensing information.

A closer partnership with investors can also seed advancements, whether to improve capabilities in existing areas of U.S. strength or nurture U.S. companies into new areas altogether. For example, new hyperspectral medal winner GHOSt, developed by U.S. company Orbital Sidekick, was bolstered by a strategic investment from the global security venture firm In-Q-Tel in early 2022 and a U.S. Department of Defense Strategic Funding Increase award in 2020, which private investment funds matched.[49]

Even for those U.S. companies atop the podium, revisions to U.S. export policies and processes—beyond NOAA's regulatory reforms—will continue to be necessary for selling their superior capabilities in the rapidly growing international marketplace. There is international demand, particularly from allied and partner governments that see procurement of commercial systems as a way to accelerate their own sovereign space capabilities. However, ITAR continues to hamper U.S. companies as they pursue these international business opportunities.[50] The ongoing U.S. government review of space export controls holds promise.[51] But, as this year's podium shows, it is important to recognize the global diffusion of remote sensing technology and speed of progress; U.S. export restrictions have not slowed advancements by Chinese firms, who, in some areas, lead U.S. companies.

As an example of international demand, Poland recently acquired two French Pléiades Neo satellite systems (the 2024 silver medalist for EO imaging).[52] Not only could such contracts expand revenue for U.S. companies, putting less pressure on the U.S. government as an anchor tenant, but they build opportunities for greater interoperability with allies and partners, and prevent China from further expanding its market reach. The U.S. government holds significant sway as an advocate of U.S. industry. It should aggressively promote its commercial remote sensing sector abroad, as it does for other areas of U.S. industry. Further, to expand international business opportunities, especially vis-à-vis China, greater use of investment and financing levers such as the Export-Import Bank of the United States should be encouraged within the commercial space sector.[53]

The United States regards its allies and partners as an "asymmetric advantage that our competitors can never hope to match."[54] Although Americans want to see U.S. flags atop the rankings, and beat their friends in competition, U.S. national interests are also advanced and U.S. leadership demonstrated through greater collaboration with allies and partners.[55] Notably, there is a lack of Five Eyes partners and NATO countries on the podium, despite Europe's long-standing space

aptitude. Japan is injecting capital into its space industry to advance capabilities for its security and economic benefit.[56] Many of these allies and partners possess cutting-edge technologies and are making investments in space-based remote sensing. Friendly countries looking to expand their commercial remote sensing capabilities should be encouraged, with this report being a helpful guide to put more friendly flags on the podium that complement U.S. systems and compete vis-à-vis China.

Finally, the government must be mindful that it can have a deleterious effect on the market as a competitor to industry. Mantras like "exploit what we have, buy what we can, and build only what we must" from the U.S. Space Force are encouraging, but the contribution of commercial capabilities and services must be integrated throughout requirements, acquisition, and operational processes to avoid the government pursuing systems that compete directly with what the commercial sector can offer.

What Are the Stakes?

"China's commercial space sector is growing quickly and is on pace to become a major global competitor by 2030."

– Annual Threat Assessment of the U.S. Intelligence Community, 2024[57]

This assessment shows the dynamism occurring in the sector and how rapidly the technology is advancing. Without deliberate actions by the U.S. government, as discussed above, it is not guaranteed that U.S. flags will remain atop the podium.

This image of China's newest aircraft carrier at the Jiangnan Shipyard was captured on August 2, 2024, by one of Maxar's new WorldView Legion satellites.

Photo: Satellite image ©2024 Maxar Technologies.

China is intent on being the world's leading space power by 2049.[58] Beijing is rapidly expanding its government and commercial space sectors, accelerated by political direction from President Xi Jinping himself, government-wide prioritization, large state and private investments, regulatory leeway, and technology theft.[59] Beijing sees its commercial companies as a way to bring technology innovation into the government and, consistent with its civil-military fusion strategy, to improve its military capabilities.[60] Its Belt and Road Initiative (BRI) is creating new markets for Chinese goods and services, and its commercial space companies "will continue attempts to undercut the price of Western firms in more competitive markets," according to the U.S. intelligence community.[61] Rising nations may look to acquire Chinese remote sensing systems, or data and services from those systems, for their own security, economic, and environmental needs and leverage already established BRI relationships and infrastructure. Should China take the mantle of global leadership in space, whether in remote sensing or communications, it is expected to spread its own techno-authoritarian norms and standards, grow its influence in international governance and standards bodies, and extend its surveillance model into orbit. Simply put, U.S. leadership here matters. The competition in commercial remote sensing is emblematic of the broader strategic interests at stake for the United States.

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4

Way Ahead

The intent of the 2024 Commercial Remote Sensing Global Rankings is to spur a discussion on U.S. leadership, take stock of the state of global competition, and consider ways in which the government tool kit can be used to keep U.S. companies at the cutting edge of technology and globally competitive. According to a recent article in the MIT Technology Review, a "country's economic security—its ability to generate both national security and economic prosperity—is grounded in it having significant technological capabilities that outpace those of its adversaries and complement those of its allies."[62] The authors want the results of the 2024 global rankings to generate deeper conversations across the public and private sectors on the importance of U.S. leadership in this area of economic, technological, and national security significance and the longer-term consequences should this leadership erode. These global rankings should also motivate closer discussions between the government and investment community on how government resources and private capital can work together to keep U.S. companies outpacing and out-innovating the competition.

This 2024 assessment is an initial effort to characterize the state of global commercial remote sensing capabilities. While this product focused strictly on the technical performance of remote sensing collection systems, the project team intends to expand the research effort to spotlight recent market advancements and technological trends that will impact the value of commercial remote sensing information delivered to customers. New collection modalities should be explored, including radio frequency, non-Earth imaging, and variations in hyperspectral remote sensing, as well as capabilities such as virtual constellations that aggregate multiple modalities of remote sensing information.

The intent of the 2024 Commercial Remote Sensing Global Rankings is to spur a discussion on U.S. leadership, take stock of the state of global competition, and consider ways in which the government tool kit can be used to keep U.S. companies at the cutting edge of technology and globally competitive.

Further, this study's repeatable, objective research methodology could be expanded to assess companies' efforts to move up the value chain, such as the timeliness of information delivery, the range of data sources used in multisource analysis, and the relative value of highly automated analytic products and services—focusing on outputs rather than inputs. As several market forecasts predict, demand in the Earth observation market will grow in value-added services, such as "data processing, data fusion and tailored products," to meet user demand for analytic insights.[63] Feedback and reader interest will help determine the future direction of this research.

Regardless of how the United States finds itself in this dynamic and highly competitive global landscape, tremendous commercial remote sensing capabilities have been created that are now ready to shine. Ideally, these companies will continue to spend capital to improve their capabilities. Doing so will enable a new community of private multisource analytics companies who will create even greater economic success and information value in the form of fused products and services that reveal the many changes and behaviors on Earth and the gamut of human activities taking place upon it. The "gold rush" is on, and the future competitiveness of U.S. commercial remote sensing is no longer guaranteed. What happens next will be decided by U.S. government actions through regulation, investment, consumption, and competition.

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Endnotes

1 Theresa Hitchens, "After Satellite 'Olympics,' IC Rethinks Wary Stance on Foreign Commercial Data," Breaking Defense, October 8, 2021, https://breakingdefense.com/2021/10/after-satellite-olympics-ic-rethinks-wary-stance-on-foreign-commercial-data/.

2 Ibid.

3 The U.S. Defense Science Board released a report in May 2024, *Commercial Space System Access and Integrity*, that described the government's role as a regulator, investor, and customer in discussing its findings and recommendations. Defense Science Board, *Commercial Space System Access and Integrity* (Virginia: Defense Science Board, 2024), 12, https://dsb.cto.mil/wp-content/uploads/2024/07/DSB_Commercial-Space-Final-Report_ForPublicRelease.pdf.

4 Office of the Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community* (Washington, DC: Office of the Director of National Intelligence, 2024), 9, https://www.dni.gov/files/ODNI/documents/assessments/ATA-2024-Unclassified-Report.pdf.

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6 Debra Werner, "NGA plans annual survey of international Earth imagery leaders," *SpaceNews*, October 8, 2021, https://spacenews.com/nga-annual-olymmpics/. Note that the 2021 Summer Olympics were originally scheduled for 2020, but were postponed until 2021 because of the Covid-19 pandemic.

7 Hitchens, "After Satellite 'Olympics,' IC Rethinks Wary Stance."

8 Author conversations with multiple representatives from U.S. commercial remote sensing companies.

9 The White House, *United States Space Priorities Framework* (Washington, DC: The White House, 2021), https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.

10 For example, the National Oceanographic and Atmospheric Administration (NOAA) uses several of these performance categories, such as spatial resolution and information density, in its evaluation of commercial remote sensing license applications and in its benchmarking of "certain foreign and United States civil systems and their known capabilities that make available the finest unenhanced data across various types of imagery." National Environmental Satellite, Data, and Information Service, "Remote Sensing License Tiering Q1 2024," NOAA, March 1, 2024, https://www.nesdis.noaa.gov/s3/2024-03/(U)Q1-2024_AvailabilityBenchmarks-03-01-2024.pdf.

11 This project chose to update the nine categories ranked in 2021 plus two additional categories that are listed in "Remote Sensing License Tiering Q1 2024." New categories for long-wave infrared and C-band synthetic aperture radar were chosen due to recent market activity in these areas. Research on other categories listed in the NOAA report did not reveal sufficient market activity to warrant rankings. Commercial radio frequency constellations were also considered, although it proved too difficult to capture sufficient performance data to develop accurate rankings within the project timeline.

12 National Environmental Satellite, Data, and Information Service, "Remote Sensing License Tiering"; and Office of Space Commerce, "License Application Guide," NOAA, accessed August 30, 2024, https://www.nesdis.noaa.gov/about/regulatory-affairs/licensing/forms-references-workshops.

13 Registration per the Convention on Registration of Objects Launched into Outer Space. "United Nations Register of Objects Launched into Outer Space," United Nations Office for Outer Space Affairs, accessed September 2, 2024, https://www.unoosa.org/oosa/en/spaceobjectregister/resources/index.html. For satellite systems not accessible via United Nations Office for Outer Space Affairs (UNOOSA), the research team relied on aggregated publicly available information from sources such as the NOAA "Remote Sensing License Tiering," the Joint Agency Commercial Imagery Evaluation *Remote Sensing Satellite Compendium*, and the EO Portal website. ("Earth Observation Missions," eoPortal, European Space Agency, accessed September 9, 2024, https://www.eoportal.org/.)

14 Foreign remote sensing companies that have established a U.S. subsidiary with a minority portion of their constellation being operated/regulated in the United States by July 1, 2024, are denoted in the medals chart by an asterisk.

15 Satellogic is in the process of moving its headquarters to the United States. (Jason Rainbow, "Satellogic relocating to the United States in search of government growth," *SpaceNews*, September 22, 2023, https://spacenews.com/satellogic-relocating-to-the-united-states-in-search-of-government-growth/). It appears as an Argentinean company in the 2021 National Geospatial-Intelligence Agency (NGA) assessment. In 2023, Satellogic announced plans to redomicile to the United States by the first half of 2024, and in November 2023, it received a NOAA remote sensing license for its entire Aleph-1 constellation. (Satellogic, "Satellogic Receives NOAA License to Expand U.S. Government Business," press release, November 21, 2023, https://investors.satellogic.com/news-releases/news-release-details/satellogic-receives-noaa-license-expand-us-government-business.) This is a substantial business decision by Satellogic, as the redomiciling has also involved divesting its Chinese investors.

16 For the definition of a "private remote sensing space system or system," the authors use the definition contained in the U.S. Code of Federation Regulations, Part 960, Licensing of Private Remote Sensing Space Systems, meaning "an instrument that is capable of conducting remote sensing and which is not owned by an agency or instrumentality of the U.S. Government" ("Part 960—Licensing of Private Remote Sensing Space Systems" in Title 15, Code of Federal Regulations, September 5, 2024, https://www.ecfr.gov/current/title-15/subtitle-B/chapter-IX/subchapter-D/part-960). For all systems, the authors identified

multiple credible sources describing the system as commercial, noting the company sells imagery from the remote sensing system on the commercial market, and verifying that imagery can be purchased. In some cases, system owners were contacted to confirm commercial sales. Though it was not possible to contact Chinese companies, their imagery was found for sale through online resellers. However, the extent of Chinese commercial sales could still be a source of uncertainty.

17 Hitchens, "After Satellite 'Olympics,' IC Rethinks Wary Stance."

18 For example, on the favorable end, the authors took at face value that the Chinese Jilin electro-optical (EO) constellation has 108 operational satellites while confirming through resellers that at least 54 Jilin satellites were taskable for a high-revisit DailyVision service. With its constellation size far exceeding any other EO constellations, uncertainties regarding the specific number of operational satellites had little effect on Jilin's ranking as the gold medal winner in the EO revisit category. On the other hand, a new Chinese X-band SAR satellite was not considered a top contender for a medal since its bandwidth was not publicly available (though it is unlikely to have outperformed the other systems in contention). Also, while the Satellogic website lists 48 Aleph satellites have been launched, additional research using space-track.org and further data gathering revealed that only 25 Aleph satellites remain active.

19 In 2022, the NOAA Commercial Remote Sensing Regulatory Affairs (CRSRA) transitioned its quality benchmarks from simple synthetic aperture radar (SAR) imagery ground resolution to the Radar Generalized Image Quality Equation (RGIQE). CRSRA, "Calculation and use of the RGIQE metric for SAR Tiering," Guidance Circular 960.6-1, March 31, 2022, https://www.nesdis.noaa.gov/s3/2022-04/SAR%20RGIQE%20Metric%20guidance%20032321_0.pdf.

20 Ibid.

21 Ibid.

22 CRSRA, "Calculation and use of the RGIQE metric"; and National Environmental Satellite, Data, and Information Service, "Remote Sensing License Tiering Q1."

23 James A. Vedda, *Updating National Policy on Commercial Remote Sensing* (Virginia: The Aerospace Corporation), 3, https://csps.aerospace.org/sites/default/files/2021-07/CommercialRemoteSensing_0.pdf.

24 Satellogic, "Satellogic Receives NOAA License"; and Office of Space Commerce, "NOAA Eliminates Restrictive Operating Conditions From Commercial Remote Sensing Satellite Licenses," NOAA, August 7, 2023, https://www.space.commerce.gov/noaa-eliminates-restrictive-operating-conditions-from-commercial-remote-sensing-satellite-licenses/#:-:text=On%20July%2019%2C%202023%2C%20the,remove%2039%20individual%20temporary%20conditions.

25 Kelsey Herndon et al., "What is Synthetic Aperture Radar?" Earthdata, NASA, accessed August 28, 2024, https://www.earthdata.nasa.gov/learn/backgrounders/what-is-sar.

26 The maximum bandwidth of a spaceborne SAR system permitted by the International Telecommunication Union is 1,200 megahertz. Because SAR imagery improves with greater bandwidth, this regulation represents a constraint on SAR imagery quality. Brooks Cressman, "CRSRA SAR Benchmarking," lecture, November 3, 2021, https://www.nesdis.noaa.gov/s3/2021-12/3.%20New%20SAR%20Benchmark_ACCRES.pptx.pdf; and Jakob Van Zyl and Yunjin Kim, "Synthetic Aperture Radars (SAR) Imaging Basics" in *Synthetic Aperture Radar Polarimetry*, ed. Joseph H. Yuen (New York, NY: John Wiley & Sons, Inc., 2015), 8.

27 By selecting categories and nationalities, the research process influenced the total medal count. Without the new C-Band and LWIR categories there would be five less medals for China. Likewise, the United States would earn fewer medals if Satellogic were not chosen as a contributor to the U.S. total medal count. Therefore, it is difficult to conclude there is a clear leader in commercial remote sensing, but the closeness of the competition and speed of technological advancement in many areas of performance is apparent.

28 The Geostationary Operational Environmental Satellites (GOES) provide imagery and data on atmospheric conditions and solar activity. GOES-East, in particular—built by the National Aeronautics and Space Administration (NASA) and operated by NOAA—collects in the LWIR spectrum ("GOES East [GOES 16]," National Oceanic and Atmospheric Administration, updated June 28, 2023, https://www.noaa.gov/jetstream/goes_east). The Sentinel-1 satellites, part of the European Commission and European Space Agency Copernicus joint initiative, perform C-band SAR imaging ("S1 Mission," SentiWiki, accessed August 28, 2024, https://sentiwiki.copernicus.eu/web/s1-mission).

29 Kari A. Bingen, "2024: The Year That Launched China's Commercial Space Sector?" in *2024 Global Forecast: A World Dividing, Part I: The China Challenge*, ed. Craig Cohen and Alexander Kisling (Washington DC: CSIS, 2024), https://csis-website-prod.s3.amazonaws.com/s3fs-public/2024-01/240125_GlobalForecast_2024_ChinaChallenge.pdf.

30 National Environmental Satellite, Data, and Information Service, *U.S. Commercial Remote Sensing Policy Fact Sheet,* NOAA, April 25, 2003, 2, https://www.nesdis.noaa.gov/s3/2021-08/Commercial%20Remote%20Sensing%20Policy%202003.pdf.

31 Trump White House Archives, *National Space Policy of the United States of America* (Washington, DC: The White House, 2020), 5, https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf.

32 China's SuperView Neo-1, SuperView Neo-3, Chaohu-1, and Ziyuan-1 02E were all launched in 2021 or later, with the Jilin-1 constellation expanding significantly since 2021. U.S. constellations by Umbra, Capella Space, Orbital Sidekick, and Satellogic all include satellite systems launched in 2021 or later.

33 Defense Science Board, *Commercial Space System Access*, 12.

34 Office of Space Commerce, "NOAA Eliminates Restrictive Operating Conditions"; and Jeff Foust, "NOAA lifts many commercial remote sensing license conditions," *SpaceNews*, August 8, 2023, https://spacenews.com/noaa-lifts-many-commercial-remote-sensing-license-conditions/#:~:text=Those%20restrictions%20include%20a%20reduction,aperture%20radar%20(SAR)%20imagery.

35 Topher Haddad, "Approved for 10cm: Albedo Awarded First-Ever NOAA License to Sell 10cm Satellite Imagery," Albedo Space, December 30, 2021, https://albedo.com/post/approved-for-10cm.

36 Office of Space Commerce, "NOAA Eliminates Restrictive Operating Conditions."

37 While current U.S. regulatory policy does not restrict the sale of unenhanced data that is "substantially the same" as that available in the global market, it does place limitations on systems that perform better than those available from foreign entities. See "Part 960—Licensing of Private Remote Sensing Space Systems" in Title 15, Code of Federal Regulations, September 5, 2024, https://www.ecfr.gov/current/title-15/subtitle-B/chapter-IX/subchapter-D/part-960). The net effect of these limitations is that U.S. companies are still held back from offering their best-possible remote sensing data to differentiate themselves from foreign competitors in the global marketplace.

38 For example, in 2021, Planet conducted an initial public offering (IPO) through a special-purpose acquisition company (SPAC), and in 2022, Satellogic conducted an IPO through a SPAC. See BryceTech, Start-up Space: Update on Investment in Commercial Space Ventures (BryceTech, 2023), https://brycetech.com/reports/report-documents/Bryce_Start_Up_Space_2023.pdf.

39 "our impact: stories from the industries we champion," In-Q-Tel, accessed August 28, 2024, https://www.iqt.org/portfolio#full-portfolio; ICEYE, "ICEYE Opens New Spacecraft Production Facility in Irvine, California, Expands U.S. Manufacturing, Research and Customs Operation," press release, April 15, 2021, https://www.iceye.com/press/press-releases/iceye-opens-new-spacecraft-production-facility-in-irvine-california-expands-us-manufacturing-research-and-customer-operations#:~:text=ICEYE%20enters%20agreement%20with%20In,manufacturing%20facility%20in%20Irvine%2C%20California; and

SatVu, "Lockheed Martin invest in Satellite Vu to bring its world-first climate change technology to the US," press release, March 1, 2022, https://www.satellitevu.com/press/2022/03/01/lockheed-martin-invest-in-satellite-vu-to-bring-its-world-first-climate-change-technology-to-the-us. Note that the In-Q-Tel investment in Finnish firm ICEYE is to work with its U.S. subsidiary to deliver its SAR capabilities, manufactured in the United States, to U.S. government organizations.

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