Metrea

UNDERSTANDING THE THIRD SPACE AGE

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THE OPPORTUNITY

A new wave of expansion in space activity is underway that is arguably unlike anything experienced before, creating what some have called a third space age. It is defined in large part by the proliferation of mega-constellations and a corresponding increase in launch rates and launch capacity. And unlike the first two space ages, it is driven almost entirely by commercial space companies. This paper examines the quantitative trends behind the third space age and explores the potential for these trends to reduce the cost of access to space, relax design constraints for future space missions, and enable a host of new space missions and capabilities for both commercial and military applications.

DEFINING THE FIRST TWO SPACE AGES

In a 2015 paper, NASA's Tom Cremins framed developments in the space domain as falling into two distinct periods—what he labeled as the first space age and the second space age.[1] The first space age began with the launch of Sputnik in 1957 and continued through the end of the Cold War and dissolution of the Soviet Union in 1990. The United States and Soviet Union dominated this era, accounting for 96 percent of orbital launches and 93 percent of satellites placed in orbit during this period. Beyond the competition in civil space to achieve many "firsts" (e.g., the first to orbit a satellite, the first to put a human in space, and the first to land a person on the moon), military and intelligence space missions quickly became an important element of the competition in space. Of the more than 4,100 satellites launched during the first space age, 65 percent were for military and intelligence missions.[2]

The second space age began in 1991 and was a period of diversification and commercialization. While the United States and Russia continued to dominate in the number of launches and satellites orbited, other nations began to increase their relative share of overall space activity. In the waning years of this era (2011-2015), nations other than the United States and Russia represented 56 percent of launches and 49 percent of satellites orbited. Notably, commercial space systems began to play a larger role, comprising 30 percent of all satellites launched in the second space age, compared to just 5 percent in the first space age.[3]

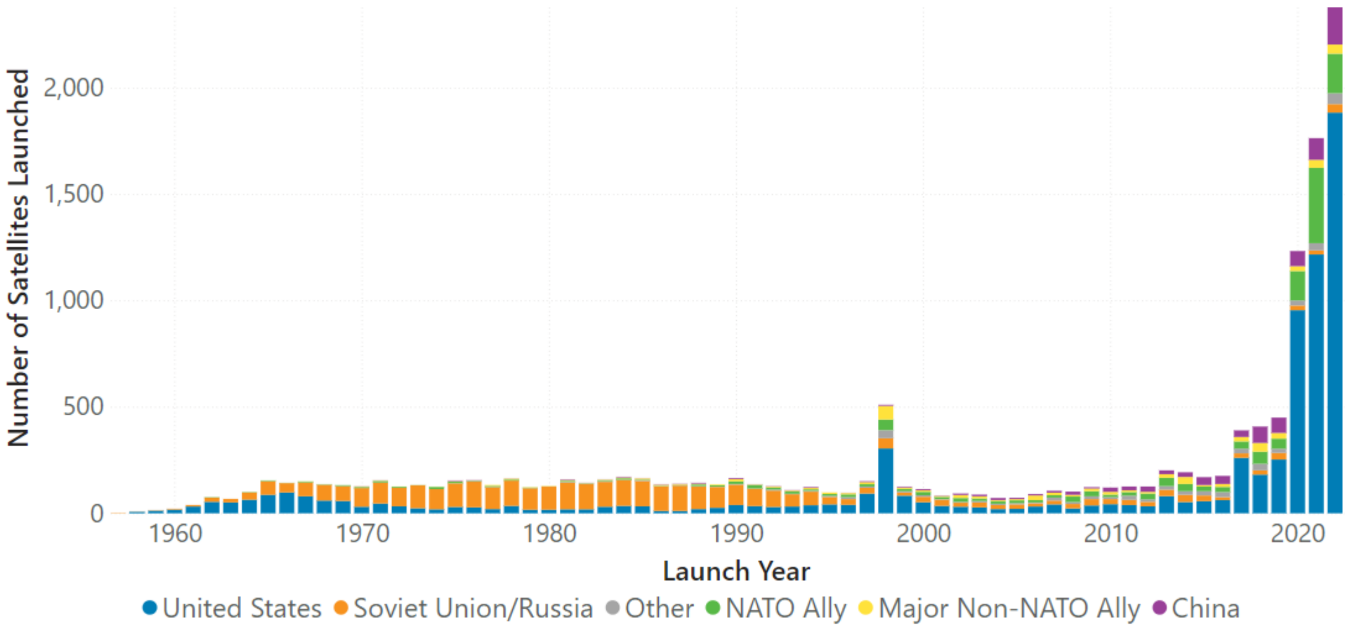
TRENDS DRIVING THE THIRD SPACE AGE

In more recent years, others, such as U.S. Space Force Lt. Gen. John Shaw, have extended Cremins' framing to include a third space age.[4] The third space age arguably began in 2016, although there is not as clear of a dividing line as exists between the first and second space ages. One of the defining characteristics of the third space age is the deployment of mega-constellations by commercial space companies. These mega-constellations are driving a higher launch rate and a sharp increase in effective launch capacity to support their deployment. For example, the number of satellites launched per year soared from 176 in 2016 to 2,380 in 2022, and commercial satellites represent more than 83 percent of all satellites launched during this period. If these trends continue as expected, and especially if new launch vehicles like SpaceX's Starship begin commercial service in the coming years, it could significantly drive down launch costs. Because launch costs often represent a large fraction of overall space system costs, especially for commercial space systems, a significant reduction could spur additional investments and innovations in space capabilities, creating a positive (and potentially exponentiating) feedback loop.

Mega-Constellations

The most telling indicator that a third space age has begun is the rate at which new satellites are being launched. As shown in Figure 1, the total number of satellites launched has set new records each year since

Figure 1: Number of Satellites Launched Annually by Nation



2020. To date, this trend is primarily, but not exclusively, driven by SpaceX and its rapid deployment of the Starlink constellation for satellite communications. To put the scale of this in perspective, the total number of Starlink satellites launched in the past two years exceeds the total number of satellites launched by all U.S. entities (including commercial, military/intel, civil, and academic) in the first and second space ages combined. As of May 2023, SpaceX has launched more than 4,300 Starlink satellites.[5]

The second largest satellite constellation on orbit belongs to United Kingdom-based company OneWeb. It began launching its constellation of communications satellites in 2019, but it experienced a setback in 2020 when the company filed for bankruptcy protection. By November of that same year, it emerged from bankruptcy with $1 billion in equity investment from the UK government and an Indian company.[6] The Russian invasion of Ukraine also created a problem for the company in 2021 because it had booked several launches on Russian launch vehicles. Russia refused to launch any additional OneWeb satellites, and the company was forced to rebook the launches on other launch vehicles.[7] Despite these difficulties, in March 2023, OneWeb surpassed the threshold needed to begin global coverage with a total of 618 satellites launched to date.[8]

Beyond the LEO broadband mega-constellations, several other commercial firms are deploying large constellations for a variety of purposes, including space-based electro-optical imagery, synthetic aperture radar, weather monitoring, and radio frequency signal detection and geolocation. For example, since 2016 Planet Labs has launched nearly 400 satellites, and Swarm Technologies and Spire Global have launched more than 130 satellites each.

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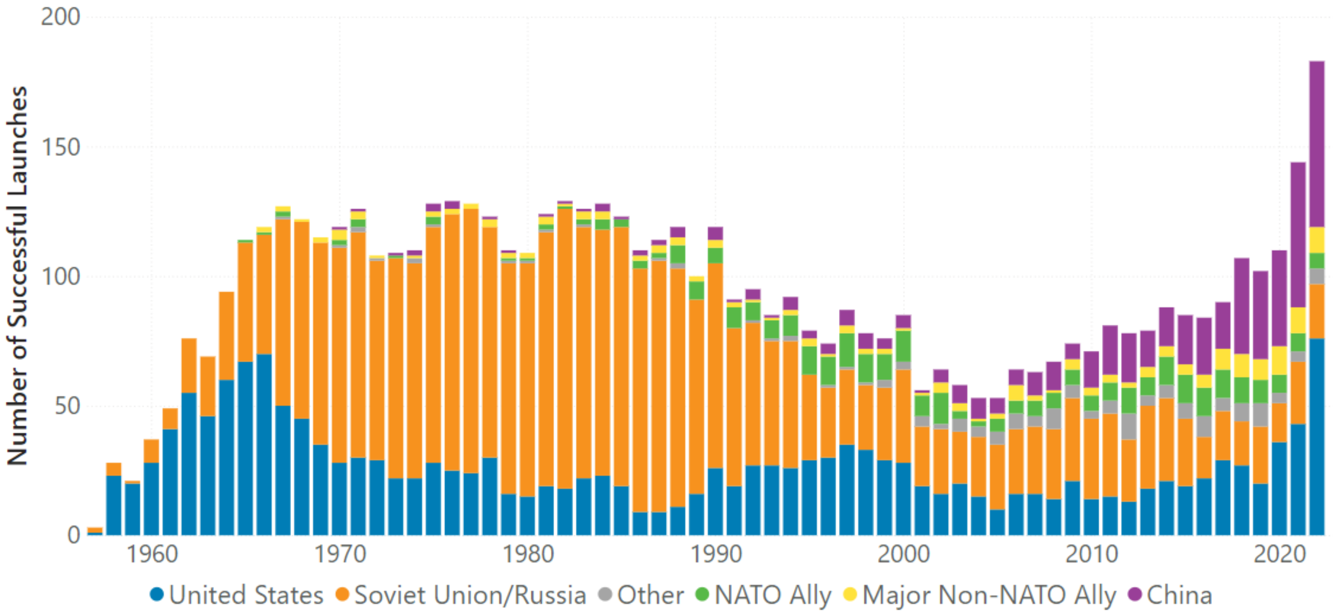
Launch Rate

The frequency of space launches has surged in recent years to support the deployment of large satellite constellations. As shown in Figure 2, the annual number of launches set an all-time record in 2022, with 176 successful launches globally. The growth in launch rate is driven almost entirely by the United States and one company and launch vehicle in particular: SpaceX and its Falcon 9. In 2022, the Falcon 9 logged 58 launches. In the first quarter of 2023, it launched at a rate of almost twice per week, putting SpaceX on pace to double the number of launches it logged in 2022. The global launch rate for 2023 is on track to top 200.

Figure 2: Successful Orbital Launches by Nation

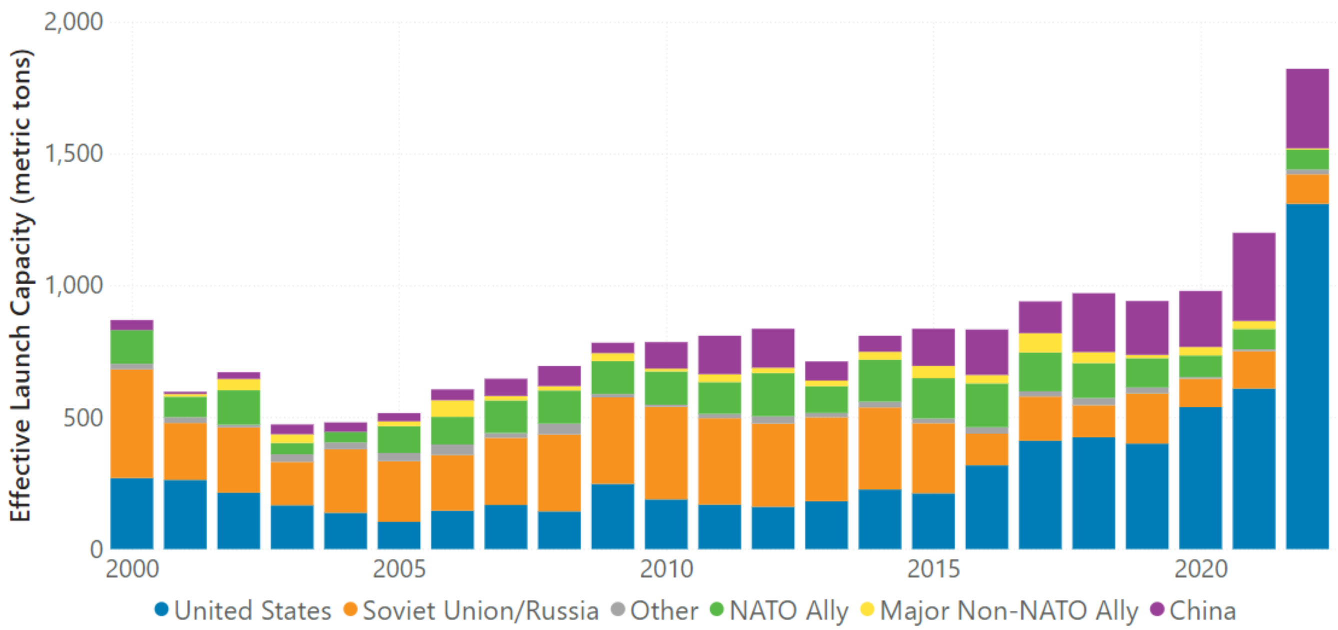


Medium-sized launch vehicles, defined as having a mass to LEO capacity of between 2,000 and 20,000 kg, made up 76 percent of launches from 2016 through 2022. Small launches (less than 2,000 kg) have increased somewhat in recent years, driven in part by a wave of new small launch vehicles entering service, such as Rocket Labs' Electron and China's Kuaizhou-1A. To date, heavy (20,000 to 50,000 kg) and super-heavy (more than 50,000 kg) launches have been less common, comprising just 8 percent of all successful launches since 2016.[9] While NASA's Space Launch System (SLS) is the largest capacity launch vehicle currently in service, its recurring cost of $2.2 billion per launch limits the number of missions it can support.[10]

Launch Capacity

Another useful metric for understanding the changes taking place as part of the third space age is effective launch capacity, shown in Figure 3. This is a theoretical measure of the equivalent mass that would have been launched if all the launches that occurred were used to deliver each vehicle's maximum payload to LEO. The

Figure 3: Effective Launch Capacity (Equivalent Maximum Mass to LEO) by Nation



actual mass launched is far less than this because many vehicles are used for missions less than their maximum capacity and to deliver payloads to higher energy orbits than LEO. However, effective launch capacity is a useful metric because it provides a common basis for aggregating launch capacity in a single value for tracking over time.

Global effective launch capacity surged to record levels within the past two years. It rose from an average of 800 to 900 metric tons annually in the 2010s to an all-time high of over 1,800 metric tons in 2022. Extrapolating data from the first quarter of 2023, it appears likely that effective launch capacity will likely exceed 2,100 metric tons for the current year.

WHAT TO WATCH

This is not the first time a wave of large satellite deployments and a corresponding reduction in launch costs has been forecasted to fundamentally disrupt and transform the space industry. In the late 1990s, a similar wave of activity was underway, with large constellations being planned by companies like Teledesic, SkyBridge, OrbComm, Iridium, and Globalstar. While the latter three deployed what were then among the largest satellite constellations on record, they quickly fell into financial troubles and filed for bankruptcy.[11] Teledesic and SkyBridge never deployed the massive constellations they once envisioned.

> It is not yet clear if the market for LEO broadband services can support the on-orbit capacity these mega-constellations are building.

The difference in the current wave of large satellite deployments is that the trend appears to have more staying power. As shown in Figure 1, the wave of space activity in the late 1990s looks more like a blip in the data in hindsight, whereas the current wave is larger and sustained. Moreover, some of the companies driving current trends already have a substantial number of satellites on-orbit or in the production pipeline to be launched in the coming months and years, meaning much of the capital required has already been committed. However, it is not yet clear if the market—primarily the market for LEO broadband services—can support the on-orbit capacity the mega-constellations are building. If the market does not fully materialize as anticipated, it could lead to one or more of the companies involved reconsidering their plans for deployment or replenishment, merging with a competitor, or ceasing operations completely.

Continued Mega-Constellation Deployments

Perhaps the most important factor to watch in the progression of the third space age is the continued deployment of mega-constellations. The constellation that is the farthest along also appears to have the farthest to go in terms of reaching its ultimate size. According to its FCC license, SpaceX plans to deploy 7,500 Starlink v2 satellites, half of which must be launched by December 1, 2028.[12] While SpaceX recently began launching some Starlink v2 "mini" satellites, the full-size Starlink v2 satellites require Starship's more than 8-meter diameter payload fairing.[13] The company will likely need more than 100 Starship launches to deploy the full quantity of Starlink v2 satellites planned. SpaceX hopes to eventually have as many as 42,000 Starlink satellites on-orbit in total.[14]

OneWeb is nearly complete in deploying its initial constellation of 648 satellites, but it has proposed a follow-on phase two constellation of 6,372 satellites.[15] A key difference from Starlink is that OneWeb has already experienced several setbacks, including bankruptcy. Given its recent financial troubles, it is not clear if the company will have the resources to move forward with the second phase of its constellation.

A third company is also planning to begin launching a LEO broadband mega-constellation in the coming years. Amazon's Kuiper program has approval to deploy a 3,236-satellite constellation, half of which must be launched by July 2026. The company has already contracted for 37 launches on Blue Origin's New Glenn rocket, 38 on United Launch Alliance's Vulcan, and 18 on Arianespace's Ariane 6.[16] Notably, none of these launch vehicles have flown to date (as discussed in more detail in the following section).

Not to be outdone, both Europe and China plan to get into the LEO broadband market as well. A Chinese company known as SatNet has filed with the International Telecommunications Union (ITU) to deploy a 12,992-satellite LEO constellation.[17] Little is known about the company, which was founded in April 2021, and it is not clear if it has the resources to follow through on its ambitious plans.[18] Likewise, it is not clear if the European Union will follow through on its recently announced plans to build what it calls the Infrastructure for Resilience, Interconnectivity and Security by

Satellite (IRIS2) constellation. IRIS2 is intended to provide a sovereign network for secure communications that would rival Starlink, OneWeb, Kuiper, and others.[19]

The U.S. military plans to deploy its own fleet of roughly 1,000 satellites in LEO by 2026 as part of the Space Development Agency's data transport and missile sensing constellations.[20] In the most recent budget request, SDA projects $20.2B in funding over the next five years to make this vision a reality.[21] On April 2, 2023 it launched the first ten Tranche 0 satellites, with a second launch planned for June 2023.[22]

New Heavy Lift Launch Vehicles

Another potentially disruptive factor to watch is progress with the new space launch vehicles that are expected to begin operations in 2023 or 2024. Perhaps the most significant of these is Starship. SpaceX conducted its first test launch of the Starship spacecraft with the Super Heavy booster on April 20, 2023.[23] Although this test was terminated due to loss of vehicle control before the upper stage could separate, it marks the beginning of a concerted test campaign to complete development of the vehicle and begin regular commercial service. NASA is depending on the upper stage Starship spacecraft for its Artemis program and the first crewed lunar landing scheduled for no earlier than December 2025.[24] The cargo version of Starship is expected to carry more than 100,000 kg to a 500 km sun synchronous orbit (SSO), which is the equivalent of roughly ten reusable Falcon 9 launches to the same orbit.[25] Starship is designed to be fully reusable (both stages), and SpaceX is promising a high launch cadence.[26]

The other major new launch vehicle expected to debut in 2023 is ULA's Vulcan. Vulcan is a replacement for the Atlas V, which is being retired due to its dependence on the Russian RD-180 engine for its first stage.[27] The Vulcan uses Blue Origin's BE-4 engine for its first stage and a modified version of the existing Centaur upper stage. In 2020, United Launch Alliance won 60 percent of the launches on the National Security Space Launch Phase 2 competition using its Vulcan rocket.[28] The contract requires two successful certification flights before it can begin launching payloads for the military and intelligence community.[29] The first flight was originally planned for 2022 but was pushed to early 2023. More recently, an explosion during testing of the Centaur V upper stage appears to have delayed the first flight again.[30] Because of these delays, the Space Force has already moved the first national security mission scheduled for the Vulcan to a different launch vehicle, and with further delays it may need to move other missions as well. This could cause a ripple effect of bumping payloads and launch schedules across the space industry. The fully expendable Vulcan is not expected to be cost competitive with Falcon 9 or Starship.

Blue Origin continues development of its New Glenn launch vehicle, which uses the same BE-4 engine as the Vulcan for its first stage and the BE-3 engine from its suborbital New Sheppard human-rated launch vehicle for its second stage.[31] New Glenn would be able to lift 45,000 kg to LEO (or approximately 25,000 kg to SSO)—roughly a quarter of the reported capacity of Starship and the equivalent of about 2.5 Falcon 9 launches. The first stage of New Glenn is designed to be reusable, but the second stage is not. In February 2023, NASA awarded Blue Origin a contract to launch a mission on New Glenn in late 2024, implying that it expects the vehicle to be operational by that time.[32]

The European Space Agency is also in the process of developing a new European launcher, Ariane 6. The agency formally decided to move ahead with the program in 2014 as a replacement for the Ariane 5, and the first launch was initially planned for 2020.[33] The program has encountered multiple delays; the first launch has slipped to late 2023 and may slip into 2024. The vehicle will come in two variants, depending on whether it uses two or four solid rocket boosters, and it is expected to have a payload capacity of up to 15,500 kg to SSO. Given its launch location in French Guiana near the equator, this vehicle will likely be mainly marketed for launches to geostationary orbit (GEO) or geostationary transfer orbit (GTO). It is expected to be able to deliver up to 5,000 kg directly to GEO or 11,500 kg to GTO. Ariane 6 will be a fully expendable rocket.[34]

By some estimates, the space launch market has over 100 companies in various stages of developing or operating launch vehicles, with the vast majority of these efforts focused on small to medium-sized launch vehicles.[35] Many of these companies are in the early stages of development and may never become commercially viable. Rocket Lab is one of the leading small launch vehicle companies, logging 31 successful launches of its Electron rocket and 3 failures to date.[36] It is facing stiff competition from SpaceX's ride share service, which has a much lower cost per kilogram than an Electron launch. It remains to be seen how much of a premium companies are willing to pay for a dedicated launch to a specific orbit rather than using a less expensive rideshare launch. This dynamic is beginning to play out with some of the setbacks small launch companies have already encountered. For example, after a launch failure earlier in 2023, Virgin Orbit ceased operations and laid off 85 percent of its staff when it failed to secure additional investment.[37] Startup Astra canceled development of its Rocket 3 small launch vehicle after multiple failures, and it is instead focusing on an entirely new vehicle, Rocket 4, with an uncertain timeline.[38]

WHAT IT MEANS

Current trends are by no means a reliable predictor of the future. Rather, the trends observed in the formative years of the third space age are best viewed as indicators of the opportunities and challenges that lie ahead. Whether current trends continue depends in large part on the economic success of SpaceX's Starlink constellation and the technical success of its Starship launch vehicle. If Starlink proves to be economically viable and the Starship development and test program continues at its current pace, global effective launch capacity could exceed 5,000 metric tons annually in the next two to three years, regardless of what happens with other launch vehicles and mega-constellations.[39] The addition of other medium and heavy lift vehicles to the space launch market, such as New Glenn, Vulcan, and Ariane 6, would further bolster launch capacity. An increase in launch capacity of this magnitude could reduce launch prices significantly, especially if capacity is driven by reusable vehicles. For example, Elon Musk has speculated that the price of a Starship launch could eventually cost $10 million or less.[40] Even if the price fell to $50 million per launch, that translates into a price per kilogram of ~$500, which is an order of magnitude reduction from current prices. For many commercial space missions, where launch costs are sometimes a third to a half of total recurring costs, an order of magnitude reduction in launch costs would be revolutionary. Not only would it greatly reduce constraints on satellite designs, but it would also make new space missions economically feasible that otherwise might not be. As one space investor recently noted, "Starship has such high importance to the space sector that probably almost everyone who has a space company has to war game what that means for their business."[41]

> For many commercial space missions, an order of magnitude reduction in launch costs would be revolutionary.

This scenario would also have significant impacts on national security space in terms of both resiliency and threats. Lower costs and reduced design constraints would allow the U.S. Space Force to deploy proliferated LEO constellations more efficiently and replenish them more regularly, and it could allow more military missions to move or expand into space.[42] However, this scenario could lead to greater proliferation of space capabilities in general, making space traffic management and space domain awareness more challenging.

On the other hand, it is also possible that current trends will moderate in the coming years and launch prices may not fall precipitously or at all. Progress on Starship may be slower than expected, or the market for LEO broadband may prove to be much smaller than anticipated. Delays in Starship combined with delays in the development of other new vehicles, particularly Vulcan and New Glenn, could lead to a tightening in the space launch market, driving up prices and making launch opportunities scarce, especially for rideshare missions. This could slow progress in national security space, particularly in efforts to deploy more resilient proliferated LEO constellations. Moreover, a slowdown could have broad effects across the space industry and lead to a third space age that is more akin to the latter years of the second space age.

The next two years will be pivotal to understanding the ultimate trajectory of the third space age—whether it's a boom or a bust. For this reason, MSI has created the Space Dashboard to track space developments in near-real time. The dashboard pulls data from a variety of public sources, particularly Jonathan McDowell's *General Catalog of Artificial Space Objects* and T.S. Kelso's *Celestrak Satellite Catalog*. It allows one to filter and visualize both launch and satellite data to better understand the trends as they evolve. While the future of the third space age remains uncertain, it promises to be interesting.

ABOUT THE AUTHOR

Todd Harrison is the Managing Director of Metrea Strategic Insights. Prior to joining Metrea in May 2022, Mr. Harrison was a senior fellow and the director of Defense Budget Analysis and the Aerospace Security Project at the Center for Strategic and International Studies (CSIS). He joined CSIS from the Center for Strategic and Budgetary Assessments (CSBA), where he was the senior fellow for Defense Budget Studies. At both CSIS and CSBA, Mr. Harrison authored numerous publications on trends in the defense budget, military space systems, threats to space systems, civil space exploration, defense acquisitions, military compensation and readiness, and military force structure, among other topics. Before joining the think tank community, Mr. Harrison worked as a consultant to Air Force Space Command while at Booz Allen Hamilton, as a program and product manager at space startup AeroAstro Inc., and as a management consultant at Diamond Cluster International. Mr. Harrison served in the U.S. Air Force Reserves and is a graduate of the Massachusetts Institute of Technology with both a B.S. and an M.S. in aeronautics and astronautics. He is currently a non-resident senior associate at CSIS, a member of the National Security Space Association Board of Advisors, and an adjunct faculty member at the Johns Hopkins School of Advanced International Studies where he teaches classes on the defense budget and military space systems.

ABOUT METREA STRATEGIC INSIGHTS

Metrea Strategic Insights (MSI) specializes in pathfinding studies that look beyond the typical five-year planning horizon at long-term trends, threats, opportunities, discontinuities, and asymmetries in national security. MSI is led by Managing Director Todd Harrison and is supported by a team of experts with a variety of experience in government, industry, think tanks, and academic institutions. MSI does not take institutional positions, and any views expressed in this publication are solely those of the author(s).

MSI's parent company, Metrea, provides effects-as-a-service to national security partners in four domains and over a dozen mission-centric solution areas, including airborne ISR, aerial refueling, electronic warfare, communications, space-based ISR, and advanced simulation. Metrea leverages commercial business models to unleash innovation cycles that anticipate emerging threats. Metrea is headquartered in Washington, DC with facilities across the United States, the United Kingdom, and the European Union.

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Cover photo credit: SpaceX, April 20, 2023.

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