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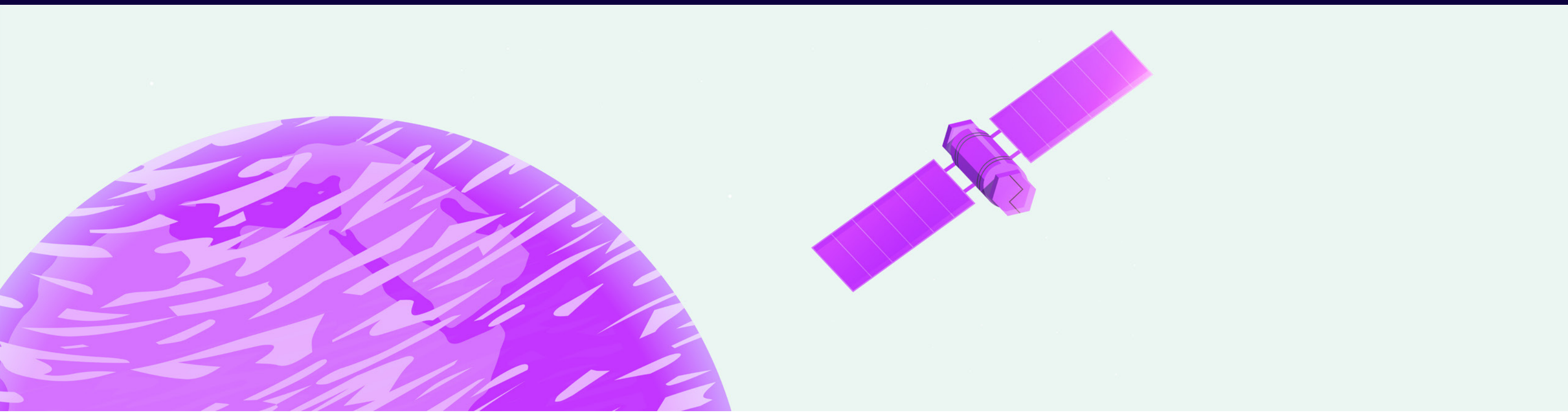

Vol. 37, No. 4, 2024

ACCELERATING SPACE EXPLORATION: THE CONFLUENCE OF TECH & COMMERCIALIZATION

Curt Hall

We are entering a new era in space exploration — one that is not primarily fueled by geopolitical rivalries (although geopolitics certainly play an important role) but more by advances in key technologies and commercial trends, including AI and robotics, 3D printing, pharmaceutical and biotechnology research, materials science, and, perhaps most significantly, the commercialization of space. Together, these technological and economic developments are accelerating the exploration of the cosmos and leading to the formation of a next-generation space economy that promises to significantly impact life on Earth and in outer space. This *Amplify Update* examines commercial developments in conjunction with key trends in emerging technologies and how they are helping to accelerate space exploration.

COMMERCIALIZATION & THE RUSH TO SPACE

GLOBAL SPACE ACTIVITY IS ON TRACK FOR 259 LAUNCHES TO TAKE PLACE IN 2024

In 2023, there were a record 223 attempted space launches worldwide (211 were successful). This is an increase of almost 20% over the 186 launches conducted in 2022. To put this growth into perspective, there were 145 attempted launches in 2021, 114 in 2020, and 102 in 2019. These numbers include both successful and unsuccessful attempts.

This year promises to be even busier: global space activity is on track for 259 launches to take place in 2024. This projection is based on the rate of successful launches conducted in January, which averaged a liftoff every 33 hours and 49 minutes. However, don't be surprised if this number is eclipsed as the year progresses.

MORE COMPANIES + NEW PLAYERS = MORE INNOVATION & DISTRIBUTED RISKS

Today, private sector involvement is helping drive the rush to space. The "opening up" of space exploration to a host of players has led to an explosion in innovation fueled by competition among companies designing and manufacturing spacecraft and those offering related equipment/services and conducting missions.

For example, the development of reusable vertical-launch-and-landing rockets by companies like Blue Origin, SpaceX, Relativity Space, and others is lowering the cost of launches and helping reduce the amount of space debris from discarded rocket components. Reuse also extends to crewed spacecraft. For example, SpaceX's Endeavour Crew Dragon spacecraft has flown five missions (the maximum number currently allowed for the spacecraft); however, NASA and SpaceX are investigating the possibility that these crafts could eventually be allowed to fly more missions.

Companies are leveraging advancements in materials sciences to develop new, innovative spacecraft. For instance, Sierra Space's LIFE (Large Inflatable Fabric Environment) space station is constructed of specially designed ultra-strong fabric materials, which allows it to launch onboard a conventional rocket yet inflate in orbit to a structure that is three stories tall, 27 feet in diameter, and can accommodate four astronauts and their science experiments.

The commercialization of space is creating opportunities for companies not traditionally participating in the space industry. For example, the Japanese mini lunar rover Sora-Q, which landed on the Moon on January 2024, was developed by the toy company Takara Tomy (maker of the "Transformers" toy line) in partnership with the Japan Aerospace Exploration Agency (JAXA). Takara Tomy leveraged its considerable experience in building flexible children's toys to implement a tennis ball–sized shape-shifting rover that can crawl along the lunar surface, snap pictures, and transmit them back to Earth.

Commercialization is helping distribute the risk associated with space exploration and development among more participants. Consider recent moon missions by Astrobotic Technology's Peregrine Lunar Lander and Intuitive Machines's Odysseus. Peregrine's lander never reached lunar orbit due to a fuel leak. But just 45 days later, Odysseus successfully landed on the Moon — essentially returning the US to the lunar surface for the first time in over 50 years. Both companies are participants in NASA's Commercial Lunar Payload (CLPS) initiative intended to establish (through funding) commercial programs to deliver goods and services to space stations, the Moon, and beyond.

PRIVATE SECTOR INVOLVEMENT ON THE RISE

The space industry is experiencing a surge in private sector involvement in four key areas:

1. **Launch services.** Commercial launch activity in 2023 increased 50% from 2022. Much of this activity is attributed to commercial satellite launches. According to the Space Foundation's 2023 "The Space Report," more than 2,800 satellites were deployed into orbit last year (23% more than in 2022). Regarding the number of payloads, the report states that "the commercial sector dominated: 90%, or 2,507 of the known satellites deployed, were commercial."

2. **Satellite manufacturing.** The global satellite manufacturing market is projected to reach an estimated US $18.2 billion by 2028 with a CAGR of 5.8% from 2023 to 2028. Major drivers include more programs targeting space exploration, a growing need for satellites to support communications, and an increasing need for satellite equipment for collecting space-related data.
3. **Space data.** Demand for space data and related products and services like imaging, navigation, environmental, agriculture, defense, and national security is accelerating. Demand for space data is tightly linked to the growing use of satellites. Expect demand to grow considerably for the foreseeable future as more satellites are placed into orbit.
4. **Space tourism.** Companies like Blue Origin, SpaceX, and Virgin Galactic have successfully demonstrated that they have the technical expertise and administrative capabilities to send citizens into space. Opening up space travel to non-astronauts represents the beginning of a space tourism market, which was valued at $851.4 million in 2023 and is expected to grow at a CAGR of 44.8% from 2024 to 2030.

NEW, ADVANCED & EMERGING TECHNOLOGIES WILL PLAY A KEY ROLE IN THIS NEW SPACE ECONOMY

NEXT-GENERATION SPACE ECONOMY

The growing commercialization of space will eventually result in more companies providing a broad range of prebuilt space offerings and services. This will help mitigate the need for custom-designed space equipment, lowering the cost of entry for space exploration and eventually leading to a shift from government-led to commercial-led space exploration, resulting in the creation of a 21st-century space economy. How fast this happens remains to be seen. But one thing is certain: new, advanced, and emerging technologies will play a key role in this new space economy. In the words of Prasun Desai, Deputy Associate Administrator of the Space Technology Mission Directorate at NASA: “Technology drives space exploration.”

AI & ROBOTICS IN SPACE EXPLORATION

AI and robotics are having a profound impact on space exploration. Applications are varied and numerous. They range from systems intended to help engineers with designing spacecraft and equipment and assisting astronauts and mission control in conducting missions to enabling autonomous navigation of spacecraft and the robotic exploration of extraterrestrial environments. AI is also used to analyze the vast amounts of data generated by space missions.

AUTONOMOUS SPACECRAFT & ROBOTIC EXPLORERS

AI plays a crucial role in spacecraft operations, including for:

- **Autonomous navigation and decision-making.** AI systems facilitate advanced autonomous capabilities in spacecraft, including delivery vehicles and robotic extraterrestrial explorers. Machine learning (ML) algorithms, working in conjunction with computer vision and advanced sensors (e.g., light detection and ranging [LiDAR], radar, inertial guidance systems) enable spacecraft to navigate autonomously in unknown environments by analyzing data collected from their surroundings and making real-time decisions. Autonomy is essential for deep space missions where real-time communication with Earth-based mission stations is limited due to radio and data transmission latency.
- **Collision avoidance.** Satellites and other spacecraft utilize ML algorithms to avoid collisions with other spacecraft in orbit. For example, SpaceX reportedly uses ML to analyze sensor data from satellite sensors (e.g., for positioning and velocity) to identify potentially dangerous maneuvers and take evasive action.
- **Terrain recognition and feature mapping.** AI serves to map extraterrestrial environments. Applications include algorithms for image and sensor data analysis that can create detailed maps of lunar and planetary surfaces and for identifying craters, rocks, and other potentially hazardous features. This capability is essential for enabling spacecraft (including robotic explorers) to land and move about safely and accurately. For example, the Odysseus lunar lander is primarily an autonomous vehicle. During its historic Moon landing, its optical navigation system's onboard ML algorithms processed more than 10,000 images for guidance.

- **Fault detection and recovery.** Modern spacecraft are smart. They utilize AI in various ways to monitor spacecraft systems for anomalies and to automate maintenance, including analyzing telemetry data to predict equipment failures (i.e., predictive maintenance). Should the AI system detect or predict a fault (e.g., failing battery or communication component), it can initiate automated recovery procedures. This helps reduce human intervention and ensures that the mission will continue.
- **AI-facilitated robotic exploration.** Modern robotic explorers employ AI and ML for object recognition, path planning, and sample collection. For example, NASA's Perseverance and Curiosity rovers rely heavily on AI for navigating the Martian terrain, avoiding obstacles, and autonomously selecting and prioritizing (based on scientific goals) interesting features, rocks, soil, and other samples to investigate. Perseverance's onboard AI application, called "AEGIS" (Autonomous Exploration for Gathering Increased Science), can autonomously target and select rocks on Mars for sampling with its robotic arm. It requires no direct instructions from mission control on Earth. This includes identifying suitable samples for caching and returning (in the future) to Earth. Developed by NASA's Jet Propulsion Laboratory (JPL), AEGIS works in conjunction with Perseverance's SuperCam laser instrument, directing the laser to zap specific areas on rocks.

WITH RECENT DEVELOPMENTS IN GENAI, ORGANIZATIONS ARE APPLYING AI TO FURTHER OPTIMIZE DATA ANALYSIS PRACTICES

ANALYZING SPACE DATA WITH AI

Government space agencies and commercial enterprises have used AI for decades to analyze the vast amounts of data generated by rocket launches, satellite operations, robotic exploration, and other space missions. With recent developments in generative AI (GenAI), these organizations are now applying this cutting-edge technology to further optimize their data analysis practices.

Satellites generate incredible amounts of data that must be analyzed to support mission goals and operations. But not everyone has the technical skills required to conduct complex data analyses. Last summer, NASA and IBM developed a large language model (LLM) to enable researchers to apply GenAI's advanced natural language processing (NLP) capabilities to analyze the vast amounts of data generated by NASA's Earth Science satellite operations. The application allows researchers and scientists — using natural language queries — to more easily analyze and track the effects of climate change. In developing the application, NASA sought to speed satellite image analysis, boost scientific discovery, and make the nearly 250,000 terabytes of satellite mission data accessible to more people. Consequently, the model was made public via the open source Hugging Face AI platform. This is the largest geospatial model hosted on Hugging Face. NASA/IBM reps claim it can analyze geospatial data up to four times faster than other state-of-the-art deep learning models.

GENERATIVE DESIGN OF SPACECRAFT EQUIPMENT & HARDWARE

Government space agencies and commercial enterprises are using GenAI to automate the design and development of spacecraft and other equipment. Generative design is an innovative approach to design and engineering that applies GenAI to enable human designers to explore a much wider solution space and generate novel and more efficient designs significantly faster than they could working on their own. It involves defining design goals and constraints and then using ML algorithms to generate a broad set of design alternatives, with the AI system iteratively learning and refining new designs based on the feedback and constraints provided.

For example, NASA uses generative design to automate the design and development of spacecraft equipment and hardware. This application integrates human-operated computer-aided design (CAD) tools and generative ML algorithms. In practice, an engineer uses a CAD tool to define the mission requirements and to draw the surfaces where a needed part will connect to a spacecraft or other piece of equipment. ML algorithms then use these inputs to generate complex structure designs. The GenAI system can reportedly generate 30-40 design iterations an hour, significantly simplifying the work of engineers. NASA uses these designs for various missions, including astrophysics balloon observatories, Earth-atmosphere scanners, planetary instruments, space weather monitors, space telescopes, and even for the Mars Sample Return mission.

Generative design allows NASA to accelerate the design and rapid prototyping process for spacecraft hardware and other equipment. The agency claims engineers can construct a prototype within about a week of completing the design, analysis, and production stages. Moreover, the designs are optimized: they are lighter and stronger than human-designed components, and they can also consolidate multiple parts into a single, more efficient part. These qualities have great value for space operations where every bit of weight saved and size reduction is of extreme importance when it comes to launch, weight, and capacity constraints.

3D PRINTING & SPACE

3D printing (aka "additive manufacturing") technology creates physical objects from digital models by depositing layers of material (e.g., plastic, metal, composites) on top of each other. Advancements in 3D printing have made it possible to rapidly manufacture parts and equipment for spacecraft and key space infrastructure on demand. The technology is widely used in the space industry, where it is helping to reduce spacecraft R&D and manufacturing costs on Earth. NASA, the European Space Agency (ESA), Blue Origin, Relativity Space, SpaceX, Intuitive Machines, and others use 3D printing to make key rocket and spacecraft components.

EFFORTS ARE UNDERWAY TO ADVANCE 3D PRINTING TO SUPPORT IN-SPACE MANUFACTURING

Efforts are underway to advance 3D printing to support in-space manufacturing, which could: (1) reduce the need for costly, resource-intensive resupply missions to space stations and other off-world bases and (2) lead to the establishment of in-orbit space-based manufacturing platforms, including in Earth's orbit, on the Moon, and on planets like Mars. In my recent *Amplify* article, we dive deep into 3D printing, given its significant importance to the future of space exploration.

PHARMACEUTICAL, BIOTECH & MEDICAL RESEARCH IN SPACE

Pharmaceutical, biotech, and medical research are playing crucial roles in addressing the challenges of human health in space and on Earth. Research ranges from studying the effects of microgravity on the human body and the production of food and medicines in zero-gravity environments to robotic-assisted surgery. National space agencies and biotech and pharma firms are all keenly interested in such in-space research because it could potentially lead to the development of new drugs, therapies, and medical devices that help combat diseases and repair the human body.

BIOTECH & PHARMA RESEARCH ON THE ISS

Several biotech and pharma experiments have been conducted on the International Space Station (ISS). An experiment in March 2020 successfully developed adult stem cells into differentiated organ-like structures, such as liver, bones, and cartilage, under microgravity conditions. This experiment originated from research at the University of Zurich with Airbus developing the necessary hardware.

A more recent experiment, conducted in February 2024, used biological materials that mimic DNA to create a scaffold for regenerating cartilage tissues and to study the effect of a specific RNA on cartilage growth in space. This project is important because microgravity causes cartilage degeneration that could damage astronauts' health and ability to perform on long-duration space missions and in lower-gravity environments like those found on the Moon and Mars. The research could also help in developing new drugs and therapies to treat patients suffering cartilage damage on Earth.

BIOPRINTING IN SPACE

One of the most innovative projects is bioprinting in space. Bioprinting employs techniques similar to 3D printing to combine cells, growth factors, and biomaterials to fabricate biomedical parts that closely mimic natural tissue characteristics. The experimental technology is currently used to create mini tissues and organs for studying disease and the effects of new drugs.

Space agencies like NASA and biotech and pharma firms are conducting bioprinting experiments in space. Basically, bioprinted materials in zero-gravity environments tend to retain their form and remain in a three-dimensional shape. This quality helps eliminate or reduce the need to use scaffolds or other support structures typically required for bioprinting on Earth; consequently, tissues can grow in three dimensions without such support, facilitating the fabrication process significantly.

For future space missions, bioprinting could make it possible to print food and medicine on demand, helping to reduce mission launch payloads and providing resources essential for maintaining the health of crew members during a mission. For biotech and pharma companies, in-space bioprinting could assist with the development of new drugs and therapies and breakthroughs in regenerative medicine and organ transplantation.

IN-SPACE BIOTECH & PHARMA MANUFACTURING PLATFORMS

The development of commercial space-based orbiting biotech and pharma manufacturing platforms utilizing various techniques, including bioprinting, is just getting underway. Such platforms are intended to leverage the benefits of zero-gravity environments for researching and manufacturing new drugs and therapies that are too complicated, if not impossible, to develop on Earth. Several companies have developed or are developing in-space manufacturing platforms and services, as described below.

SEVERAL COMPANIES HAVE DEVELOPED OR ARE DEVELOPING IN-SPACE MANUFACTURING PLATFORMS & SERVICES

REDWIRE'S PHARMACEUTICAL IN-SPACE LABORATORY

Redwire Corporation's Pharmaceutical In-Space Laboratory (PIL-BOX) in-space pharma manufacturing platform offers pharma companies and researchers services to grow small-batch crystals of protein-based pharmaceuticals and other key pharmaceutically relevant molecules for research. In October 2023, astronauts aboard the ISS conducted various experiments with PIL-BOX. One experiment, in partnership with Eli Lilly, was ADSEP-PIL-01. This study investigated how microgravity affects the production of various biocrystals used to treat cardiovascular disease, diabetes, and pain. This and subsequent research are intended to support the development of advanced treatments for these diseases.

SIERRA SPACE'S LIFE ORBITING MANUFACTURING FACILITY

Sierra Space and Redwire are jointly developing a commercial pharma/biotech R&D and manufacturing platform for deployment in low Earth orbit (LEO). Specifically, Redwire is integrating its PIL-BOX biotech and manufacturing technology into Sierra Space's LIFE habitat platform. The intention is to make the platform available (for licensing) to customers for pharmaceutical drug development and human health research.

In addition to biotechnology for large molecule crystallization for pharmaceutical structure determination and formulation, Redwire is contributing thermally conditioned storage lockers, manufacturing facilities for industrial crystals, and a gradient-temperature furnace. Redwire is also providing technical expertise to develop the robotic capabilities required to facilitate automated in-space manufacturing.

VARDA'S IN-SPACE PHARMACEUTICAL MANUFACTURING TECHNOLOGY

Varda Space Industries has taken a different approach to manufacturing drugs in space. Rather than conducting microgravity biopharma research on the ISS or other space stations, Varda's business model is based on using unmanned capsules acting as mini in-space factories and return vehicles. These capsules launch on conventional rockets and are inserted into LEO. Upon completing their zero-gravity bio-pharma experiments, they reenter the Earth's atmosphere and land.

In February 2024, Varda successfully completed its first mission to test its in-space manufacturing technology. Specifically, the spacecraft produced crystals of Ritonavir, an antiviral drug used to treat HIV and hepatitis C. Microgravity allowed these crystals to form more perfect structures than possible on Earth. Varda's capsule, after spending over seven months in space, returned to Earth, making it the third private company (after SpaceX and Boeing) to recover an intact spacecraft from orbit. The recovered capsule subsequently underwent post-mission analysis, with the Ritonavir vials undergoing analysis to assess their purity and other properties at Improved Pharma's pharmaceutical lab.

ROBOTIC-ASSISTED SURGERY IN SPACE

In February, an experiment was conducted on the ISS involving the use of robotic-assisted surgery technology developed by Virtual Incision Corporation. The goal was to assess the impact of zero gravity when performing simulated surgical tasks. During a portion of the experiment, a surgeon on Earth utilized remote-controlled technology to direct the movements of the robot in a simulated surgical operation. This experiment demonstrated that remote, robotically controlled surgery can be conducted in a zero-gravity environment even with latency.

The robotic device "spaceMIRA" (Miniaturized In Vivo Robotic Assistant) performed several operations on simulated tissue consisting of rubber bands remotely operated by surgeons residing about 250 miles below in the company's Nebraska, USA, headquarters. In the experiment, a remote surgeon manipulated the robotic hands to apply tension to a simulated tissue. Simultaneously, the surgeon used their other hand to precisely dissect the elastic tissue using scissors. Six surgeons participated in the tests, and each successful demonstration involved dissecting the correct tissue segment under pressure — a task made difficult due to the time delay experienced when sending a command from the surgeon (on Earth) to the robotic device on the ISS. According to Michael Jobst, a colorectal surgeon who participated in the experiment, the delay was about 0.85 of a second.

NASA IS INTERESTED IN DETERMINING THE FEASIBILITY OF EQUIPPING SPACECRAFT SENT ON LONG-DURATION MISSIONS WITH ROBOTIC SURGICAL DEVICES

Findings from this and follow-up experiments could potentially impact healthcare in space and on Earth. NASA is interested in determining the feasibility of equipping spacecraft sent on long-duration missions with robotic surgical devices that could be used should a crew member become ill and require surgery. For healthcare systems on Earth, such research could help with establishing access to surgical medical care in remote locations. This mission was backed by a grant awarded from NASA to the University of Nebraska through the Established Program to Competitive Research.

MATERIALS SCIENCE & SPACE EXPLORATION

Advances in materials science are leading to the development of new, high-performance materials designed to withstand the harsh conditions of space exploration. Of particular importance are multifunctional carbon fiber composites, synthetic fibers, materials with superior thermal management capabilities, self-healing polymers, and electromagnetic interference (EMI) shielding materials.

MULTIFUNCTIONAL CARBON FIBER COMPOSITES

The development of multifunctional carbon fiber composites is especially significant. Such materials have exceptional strength-to-weight ratios, which can help reduce spacecraft weight yet can withstand the extreme conditions encountered in space travel. These composites are used in various spacecraft components, including payload fairings, heat shields, and telescopes. They are also used to provide thermal protection for crewed spacecraft.

SYNTHETIC FIBERS MADE FROM LIQUID CRYSTAL POLYMERS

Synthetic fibers like Vectran, made from liquid crystal polymers, are prized for their exceptional strength, durability, and resistance to environmental factors. For example, Vectran boasts almost twice the strength of other synthetic materials like Kevlar.

Moreover, it performs well even at extremely low temperatures. Both qualities are crucial for space applications, and companies are now using such materials to develop new, innovative space vehicles.

For example, Sierra Space's LIFE inflatable space station is made of high-strength "soft goods" materials (i.e., sewn and woven fabrics, primarily Vectran) that become rigid structures when pressurized. This strong, flexible material allows it to launch onboard a conventional rocket yet inflate in orbit to form a three-story commercial space habitation and biotech/pharma manufacturing platform that can accommodate four astronauts and their experiments. The LIFE habitat has been tested to meet NASA micrometeoroid impact and thermal capability requirements. The company is also studying larger designs, including a 1,400-cubic-meter version, which, in a single launch, could inflate to form a space station larger than the ISS.

SUPERIOR THERMAL MANAGEMENT MATERIALS

Advanced materials possessing superior thermal management properties are being developed to help regulate temperatures and protect sensitive instruments and other equipment from damage due to the extreme temperature ranges encountered in space travel and planetary exploration. For example, the Sora-Q robotic lunar explorer is made with a special type of aluminum and plastic specifically designed to withstand the extreme temperature swings experienced on the Moon, which can range from -274 to 230 degrees Fahrenheit.

Materials with advanced thermal management capabilities are also being developed for 3D printing spacecraft components. For example, NASA's GRX-810 is an oxide-dispersion-strengthened alloy that can endure temperatures of over 2,000 degrees. And it reportedly can survive more than 1,000 times longer than existing state-of-the-art alloys, making it useful for 3D printing various spacecraft parts used in high-temperature applications like rocket engine components.

SELF-HEALING MATERIALS

Self-healing materials are especially appealing for space applications due to their ability to autonomously repair damage in the severe environment of space where manual repair can be difficult or impossible. Their use would provide the ability for spacecraft to repair themselves autonomously after experiencing micrometeoroid strikes, a collision with space debris, or from structural decline caused by aging. NASA is interested in such materials to protect spacecraft during long-duration flights as well as space stations and lunar and planetary bases to ensure mission continuity; however, such materials would also be beneficial for ensuring the survivability of commercial satellites in an increasingly cluttered Earth orbit.

WE ARE SEEING THE BEGINNING OF A NEW, COMMERCIAL SPACE INDUSTRY

EMI SHIELDING MATERIALS

EMI shielding materials are being developed to protect critical spacecraft components like communications, navigation systems, and other electronics from damage from electromagnetic interference encountered in space. EMI shielding materials are critically important for almost every form of space application, including satellites, space stations, rockets, telescopes, robotic rovers, and other vehicles. Consequently, a lot of research is underway. Of particular interest are lightweight nanomaterial composites due to their exceptional EMI shielding properties.

CONCLUSION & FUTURE DEVELOPMENTS

This *Update* highlights how technological and economic developments are coming together to accelerate space exploration. A huge amount of activity is taking place around space exploration; one could write a book on the industry and technological developments and really just scrape the surface of what is currently taking place and what is in store over the next decade.

We are just starting to enter a new era in space exploration. And we are seeing the beginning of a new, commercial space industry: one destined to benefit from the speed and innovation of free enterprise and its willingness to strive to capitalize on space for commercial reasons — in addition to the need to satisfy our seemingly insatiable human desire to explore new frontiers.

Emerging technologies — and changing business models — will help drive the revolutionary 21st-century space industry. The importance of AI and robotics, 3D printing, biological and pharma research, and the development of new, advanced materials for space exploration can hardly be overstated. We should expect the use of these technologies to increase significantly for the foreseeable future — not just to facilitate planned upcoming (government-led) deep space missions to destinations like the

Moon and Mars, but to allow enterprises to capitalize on space. In particular, the use of these technologies for establishing commercial space-based orbiting manufacturing platforms will prove especially valuable. Initially, these will be deployed in LEO; eventually, they will be deployed on the Moon and Mars.

But the rush to space and its commercialization faces challenges. Space is becoming more crowded, and there is a growing risk of collisions between satellites and other spacecraft and debris. Reusability efforts, like the development of reusable rockets and other spacecraft components, are promising, but if the industry takes off as expected, we are going to need new regulations mandating sustainability and pollution control to help ensure that the rush to space does not come at the expense of Earth and the cosmos.

Geopolitics — exacerbated by Russia's ongoing invasion of Ukraine — and, most worrying, the possible militarization of space, have once again raised their nasty heads. Indeed, the prospect of space-based weapons — including nuclear ones — threatening the world came to the forefront just recently with the revelation of possible Russian plans to develop nuclear anti-satellite weaponry. Such issues necessitate a pressing need to negotiate new treaties governing the use of space.

To end on more optimistic note, hopefully these issues will be solved through peaceful negotiations and international cooperation, resulting in a new space economy that will prove beneficial not just for those venturing into outer space but for everyone here on Earth as well.

About the Author

Curt Hall is a Cutter Expert and a member of Arthur D. Little's AMP open consulting network. He has extensive experience as an IT analyst covering technology and application development trends, markets, software, and services. Mr. Hall's expertise includes AI, machine learning, intelligent process automation, natural language processing and conversational computing, blockchain for business, and customer experience (CX) management. He also focuses on the Internet of Things, including platforms, architectures, and use cases; big data platforms and use cases; and business intelligence (BI), predictive modeling, and other analytic practices. Mr. Hall's research also includes mobile and social technologies in the enterprise as well as mobile BI and collaboration. He has conducted extensive research on how all these technologies are being applied to develop new advisory, decision support, customer engagement, and other enterprise applications. Mr. Hall is a frequent contributor to Cutter's Technology and Sustainability research deliverables as well as *Amplify*. He served as Editor of numerous Cutter journals, including *Intelligent Software Strategies, Data Management Strategies*, and *Business Intelligence Advisor*. His recent studies examining the enterprise adoption of key emerging technologies and practices delivered four series of in-depth, survey-based Cutter Consortium research: "AI & Machine Learning in the Enterprise," "Blockchain Rising," "CX Management in the Enterprise," and "IPA in the Enterprise. Mr. Hall also coauthored, with Cutter contributor Paul Harmon, *Intelligent Software Systems Development: An IS Manager's Guide* and contributed to James Martin and James Odell's *Object-Oriented Methods: Pragmatic Considerations*. His work has appeared in various technical journals and IT publications, including as a contributing author to *Pricewaterhouse-Coopers Technology Forecast Yearbooks*. Mr. Hall can be reached at experts@cutter.com.

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