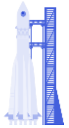
McKinsey Technology Trends Outlook 2022

Future of space technologies

August 2022

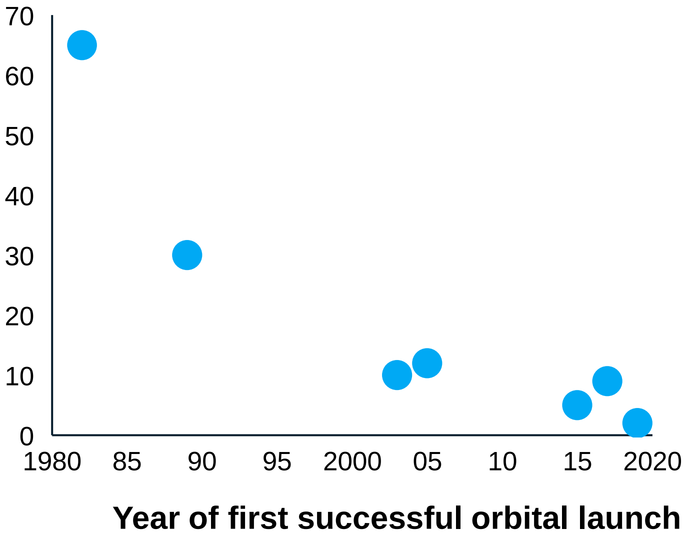
What is this trend about?

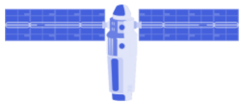
Moving down the cost curve has unlocked use cases that were previously cost-prohibitive



Heavy launch[1]

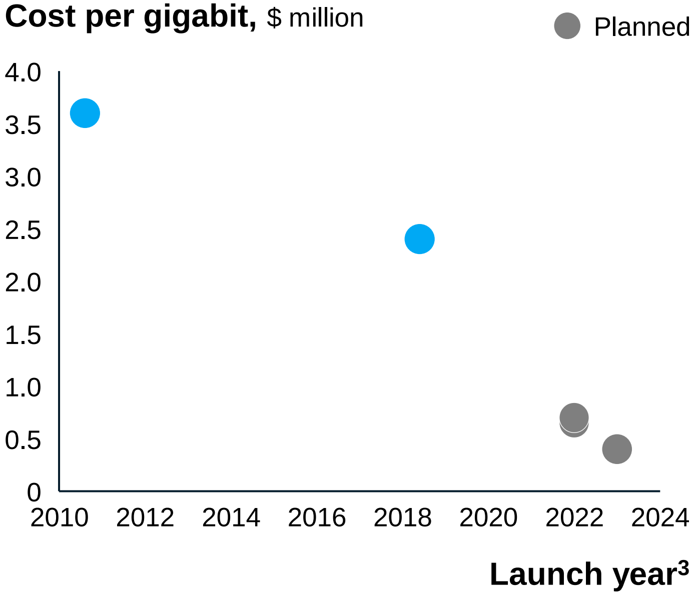
Cost per kg to low-Earth orbit (LEO), $ thousand





GEO[2] communications satellites[1]

Cost per gigabit, $ million



1. Figures reflect estimates only, based on analysis using publicly stated information and expert estimates. Satellite lifetime not factored into cost per gigabit.
2. Geosynchronous equatorial orbit.
3. Launch years are actual or planned per company announcements.

Source: Ryan Brukardt, Jesse Klempner, Daniel Pacthod, and Brooke Stokes, “The role of space in driving sustainability, security, and development on Earth,” McKinsey, May 2022

Key trends

1. The **largest shift in space tech** over the past 5–10 years has been the **acceleration down the cost curve**, which is **increasingly unlocking new capabilities**, **use cases**, and **users** for space tech and satellite data and **scaling accessibility**
2. One of the **drivers of cost-effectiveness** has been the **reduction of size, weight, power, and cost (SWaP-C)** of satellites and launch vehicles
3. SWaP-C reduction has **led to architectural shifts**, eg, from individual, **large GEO** satellites to **smaller, distributed LEO satellites**

Why should leaders pay attention?

>$1 trillion estimated market

>10% estimated annual growth by 2030 in the space market from a value of ~$447B today

~15% CAGR up to 2030 estimated for Earth observation information products, data analytics, data downlink, and space tourism and travel, all of which are expected to drive long-term demand[1]

Increased partici-pation globally

>1,400 companies involved in the new space industry, from governments to start-ups, which are expected to grow from 600+ today to 1,000+ in 2030

New entrants are moving faster than legacy players by focusing on first-mover advantages and commercial opportunities

Significant cost reductions

Significant cost reductions are already occurring, and **further reductions in launch and return-to-Earth costs** could **enable even more disruptive applications**, such as space mining and commercial human spaceflight

New business models

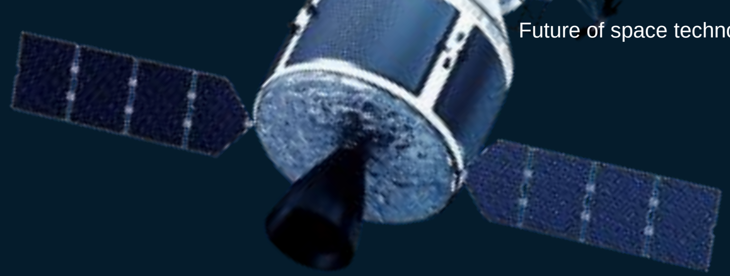
New business models, including **vertical integration** required to meet increased demand, are driven by **movement toward value-added services,** given higher margins

Increased focus on software

Value-added services necessitate a higher degree of digital applications (eg, autonomous landing of launch vehicles, AI delivering real-time insights to clients)

[1]"NSR's global space economy report projects $1.25 trillion in revenue by 2030," Northern Sky Research (NSR), January 2022.

Source: "The role of space in driving sustainability, security, and development on Earth," McKinsey, May 2022



What are the most noteworthy technologies?

Nonexhaustive

Technological advancements and the reduction of size, weight, and power of satellites and launch vehicles have contributed to cost-effectiveness, making new space applications more economically feasible

Satellites

Application of new technologies

Higher computing power leveraging consumer processor tech across distributed satellite networks to support data collection from increasingly high-resolution sensors

Less expensive, higher-resolution sensors that conduct observation of their targets (eg, Earth, planets), typically using passive observation in several spectrums (eg, optical, infrared) and active sensors (via radar)

Less costly, more efficient power systems using smaller, lightweight solar panels and more efficient batteries, allowing small (cube) satellites to have greater power availability for expanded missions

Greater capabilities in a smaller size, weight, and power (SWaP) package, enabling new missions

Industrialization of assembly

Design for modularity: Manufacturing approach that enables faster design, development, and assembly via cube-sat architectures (built using standard dimensions, ie, units of 10 × 10 × 10 cm) used as extendable building blocks

Shift from job shop to assembly line: In response to increased demand (for proliferated constellations) and investment in facilities, changes in satellite production from one-off, hand-built examples to a more industrial process

Democratization of production: Lower costs due to new manufacturing processes, including additive manufacturing and modular designs, enabling market entry of new players

Enabled a shift in architecture from individual GEO satellites to proliferated architectures in LEO

Architectural shift

LEO constellations

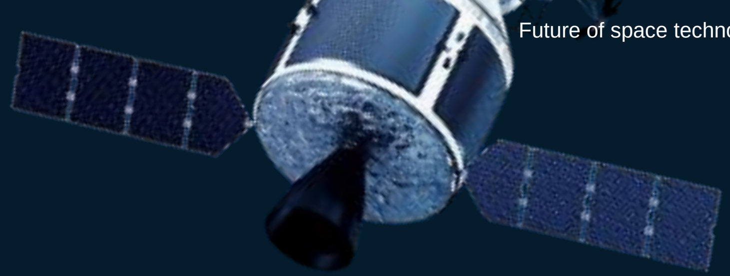
Low-Earth-orbit (LEO) satellites, which orbit close to Earth's atmosphere (altitude 300–2,000 km)

Proliferation in number of active satellites, from ~4,100 in 2021 to ~2,700 in 2020, with a focus on mega-constellations using smaller satellites

Pros: Increasingly dense coverage and capacity globally, lower latency, higher flexibility and revisit

To learn more about this technology, see "Advanced connectivity," *McKinsey Technology Trends Outlook 2022*, August 2022

Source: Evangela Rodgers, "With satellite internet, network capacity is key," Viasat, Sept 2021; Katja Lenz, "Smartphone technology provides satellites with increased computing power," German Aerospace Center (DLR), June 2022



What are the most noteworthy technologies? (continued)

Nonexhaustive

Other emerging technologies will build on the sector's transformation over the previous decade

Communications

Laser communications

Laser links would allow satellites to **communicate using pulses of light** for data transmission

Potential exists **to increase data transfer speeds** by 100x–1,000x vs traditional radio frequency

Ability to direct laser emitted to very specific locations (both to satellites in space and ground stations on Earth), which **mitigates coverage overlap and interference**

Digital capabilities

Edge computing and AI

With the growing launch of satellites and spacecraft for activities such as Earth observation, **higher volumes of data will be collected**, introducing a **need for edge computing**

Edge computing allows for **processing data closer to** the **point of collection** in the **cloud**, **leveraging AI and machine learning capabilities**, reducing latency, and saving bandwidth to deliver **near-real-time insights**

Deep-space exploration

Nuclear propulsion

Nuclear thermal/electric propulsion could propel spacecraft at higher speeds for longer distances, enabling deep-space exploration[1]

Technological advancements are optimizing performance and reliability while improving affordability to enable a cadence of more frequent launches

Currently in R&D; may carry safety risks, and most missions don't have a need for rapid transit that would justify it

Operations

In-orbit servicing

Satellite refueling/mods: Satellites refuel or modify satellites in orbit to extend mission lifetime and capabilities and to reduce replacement costs

Orbit Fab developed end-to-end refueling using its Rapidly Attachable Fluid Transfer Interface (RAFTI), a fueling port that can also be used as a drop-in replacement for existing satellite fill-and-drain valves

Orbit repositioning involves raising the orbit or changing the inclination of a satellite

Launch: Reuse of booster structures, engines, or otherwise, coupled with technology advancements (eg, material sciences, computer-aided design, 3-D printing) and increases in launch rate, are contributing to a reduction in operational costs and an increase in accessibility to space

End-of-life disposal is pulling space debris to reenter Earth's atmosphere for disposal, reducing collision risks

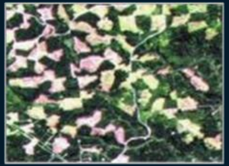
[1]As opposed to current chemical and solar electric propulsion technologies, which suffer from significant energy inefficiencies.

Source: Stew Magnuson, "Laser communications to thwart jamming, interception," National Defense, Nov 2014; Daniel Baird, "LCRD: Your Questions Answered," The Invisible Network Podcast, NASA, Apr 2022

What disruptions could the trend enable?

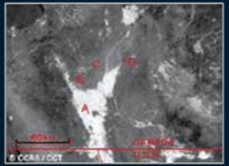
Enabled by remote sensing

Advancements in applications of Earth observation data



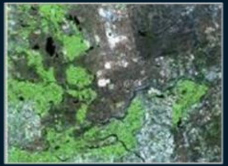
Forestry

- Commercial forestry (inventory and mapping applications)
- Reconnaissance mapping
- Environmental monitoring



Hydrology

- Soil moisture estimation
- Flood mapping and monitoring
- Irrigation scheduling and leakage detection

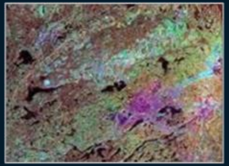


Agriculture

- Crop type classification, condition assessment, yield estimation
- Mapping of soil characteristics and management practices
- Compliance monitoring (farming practices)

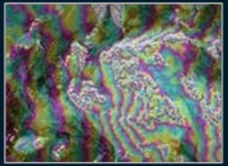
Land cover and use

- Routing/logistics planning (eg, seismic activities, urban expansion, resource extraction)
- Target detection
- Damage delineation



Geology

- Mapping (eg, structural, terrain, geologic unit)
- Exploration/exploitation (eg, mineral, sand, and gravel)
- Baseline infrastructure



Mapping

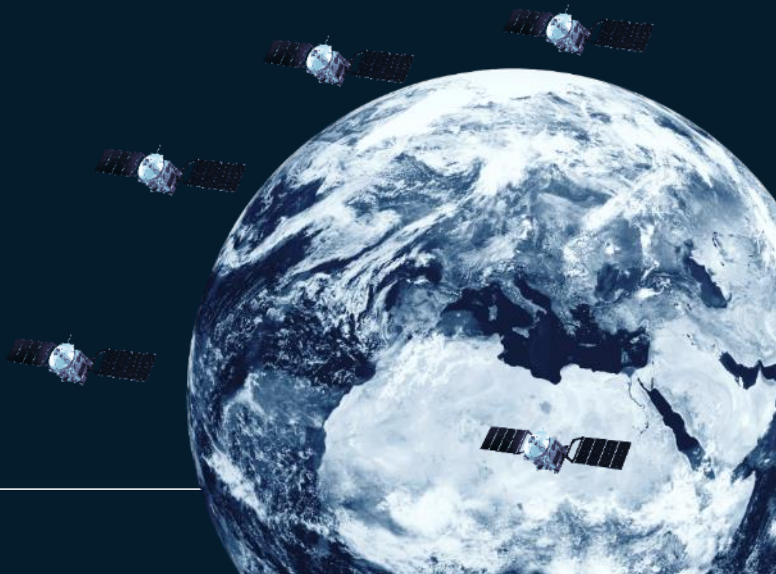
- Planimetry/surface geometry
- Digital elevation models
- Baseline thematic/topographic mapping

Oceans and coastal monitoring

- Ocean pattern identification
- Storm forecasting
- Environmental evaluation (eg, fish stock and marine mammal assessment, oil spills)

Sea and ice assessment

- Tactical identification (eg, detection, tracking, navigation)
- Shipping/rescue routes
- Global-change monitoring (eg, ice conditions, pollution indexing)



Source: McKinsey analysis

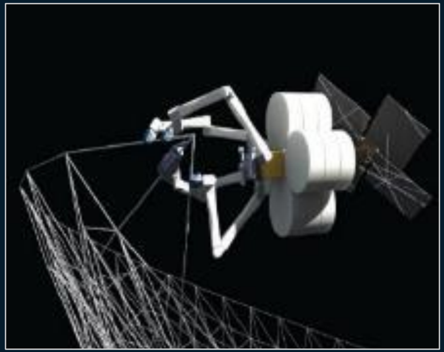
What disruptions could the trend enable? (continued)

The future space economy and human spaceflight could consist of activities not currently employed in space today, enabled by drastic reduction of launch costs, AI applications in space, and advancements in power transmission

Space economy

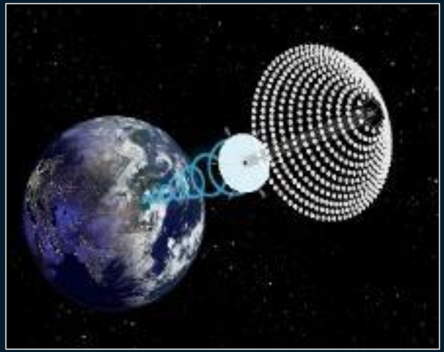
Space mining

Mine asteroids and space objects for materials to return to Earth



In-orbit construction and manufacturing

Seeks to capitalize on the benefits of zero gravity and supply future space travel



In-orbit power generation

Build space-based solar power generator leveraging 24/7 exposure to sunlight to offset emissions on Earth

Cislunar activity

Public- and private-sector exploration missions and development of infrastructure on the surface and in orbit

Scaling human spaceflight

Commercial tourism

Scale paying customers to space for short experiences of zero gravity and Earth views

Source: McKinsey analysis

What industries could be most affected by the trend?

While applications for space technologies are being developed across all industries, two are primarily impacted:

Telecommunications

Providing broadband internet to planes and remote areas, including emergency backup coverage

Aerospace and defense

Providing satellite imagery for navigation and monitoring to achieve security and intelligence objectives

Emerging use cases are being built across other industries, especially as costs decline and accessibility increases

Electric power, natural gas, and utilities

Monitoring methane emissions; informing development of sustainable energy services; providing imagery of mining sites

Agriculture

Monitoring soil, rainfall, and snow cover to inform irrigation plans, predictions of agricultural output, etc

Information technology and electronics

Developing in-space computing offerings

Automotive and assembly

Collaborating on lunar rovers; enabling autonomous driving and in-car entertainment

Aviation, travel, and logistics

Tracking moving shipping containers; providing positioning and navigation information; monitoring temperature of sensitive containers and road congestion

Financial services

Using radar satellite-based flood-monitoring capability to inform risk management and tailor solutions; leveraging commodities geolocation tracking (eg, vessels) to inform trades

Consumer packaged goods

Experimenting in space under specific space environment conditions to inform design and manufacturing of sneakers, soccer balls, etc

Pharmaceuticals and medical products

Conducting experiments leveraging microgravity (eg, protein crystallization) to improve pharmaceuticals

Source: "The role of space in driving sustainability, security, and development on Earth," McKinsey, May 2022

Who has successfully created impact with space technologies?

McKinsey deployed remote-sensing analytics to unlock new insights across industries

Case examples (nonexhaustive)

A Field-level insights for agriculture input players

Used local agronomic data and various satellite imagery to inform marketing strategy, identify growth opportunities, match offerings to grower needs, adjust to changing conditions

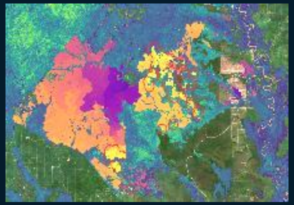
B Vegetation detection for utility players

Optimized vegetation-trimming cycles around major utility grids by combining lidar and high-resolution optical images to map vegetation attributes

C Commodity tracking and procurement

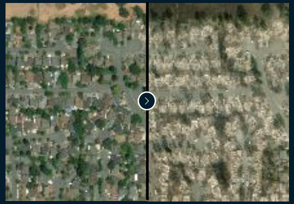
Helped companies that trade/process commodities to enhance their purchasing/trading activities through earlier insights on drivers of supply and demand (eg, by predicting and monitoring refinery shutdowns or port congestion)

D Supply chain traceability and forest carbon



Helped consumer packaged goods (CPG) companies verify their zero-deforestation or sustainable-sourcing commitments by monitoring natural assets in key production areas

E Building and construction detection



Supported NGOs and public organizations by tracking urbanization and building-level features (eg, to identify unreported property development or, in post-disaster relief effort, to identify damaged buildings via high-resolution satellite images

F Oil and gas shale activity monitoring

Helped oil and gas companies monitor the life cycle of shale oil exploration and production, including drilling and fracking events

Source: McKinsey analysis

What are unresolved risks related to space technologies?

Cost-effectiveness

Space technologies must be cost-effective for space services and human spaceflight to be scalable

Trade-offs exist between more cost-effective (higher-risk) commercial technologies and higher-performance, more reliable “space qualified” technology

Careful risk assessment is required on the importance of mission assurance/ accomplishment (eg, extensive use of commercial tech in constellations increases the risk of satellites dying prematurely and adding to the space debris challenge)

Governance

Governance should encompass usage rights and space activities

Uncontrolled proliferation of all possible space concepts increases the risk of spectrum interference, physical collisions, etc

Governance mechanisms need to better define allocation of spectrum and orbit usage rights in order to accommodate the increasing number of players, satellites, and applications

Cyberrisks

Risk and complexity of cyberthreats are growing

As dependency on space tech increases across different use cases, the potential damage resulting from exploitation of a cyber vulnerability also increases

Proliferation of commercial players raises a question of whether all services will be well protected from cyberrisks

Source: McKinsey analysis

What are some topics of debate related to the trend?

Nonexhaustive

1 Space militarization

How can leaders define rights and norms?

Governments recognize space as a war-fighting domain (eg, GPS jamming, antisatellite weapons), as demonstrated by recent organizational changes (eg, space commands established in France, Japan, UK, US)

2 Legal conflicts between states

How can leaders define ownership and access rights?

A key need for the sector is to reach a **common understanding about access rights and usage of properties and resources** (eg, for Lagrange points, spectrum, and minerals found in space); such rights can help create a democratized setup whereby all can participate in the benefits of space

3 Space debris and traffic management

Should LEO have limits?

As more companies access space, **concern arises** regarding **space debris, space traffic management, and congestion** (eg, uncertainty about what the ~27,000 pieces of debris in space might hit and when)

Source: McKinsey analysis

Additional resources

Related reading

The role of space in driving sustainability, security, and development on Earth

The potential of microgravity: How companies across sectors can venture into space

The future of space: It’s getting crowded out there

Expectations versus reality: Commercial satellite constellations

Look out below: What will happen to the space debris in orbit?