McKinsey & Company

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

Discussion Materials

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Introductions

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Methodology and background on the development of insights

Joint research conducted by McKinsey and World Economic Forum

Informed by interviews with nearly 100 leaders

Breadth of perspectives incorporated:

- Representatives of 25 countries
- Heads of large and small national space agencies
- Leaders from ministries of defense
- More than 30 C-suite executives of new and established space companies
- Academics from 15 institutions
- Leading investors in the space industry

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth

The majority of the space-based economy today is data-driven

Estimated size of select space market segments today

Commercial satellite-based services (data)

$150B+

Satellite manufacturing

~$40B

Space tourism

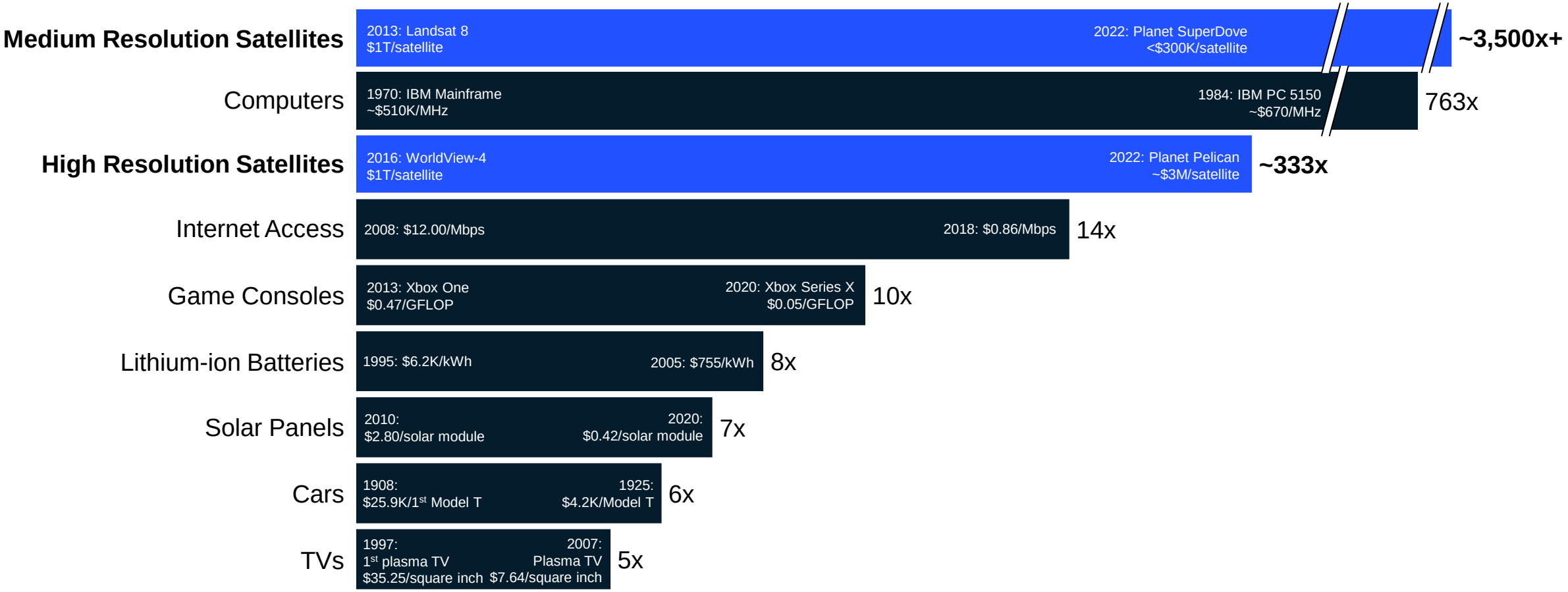
<$1B

Total commercial space economy today is >$350B

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Space Foundation; Northern Sky Research; Public Press

Satellite cost performance improvements within a 15-year horizon far surpass those seen in most other technologies

Increases in cost performance over time[1,2]



1. Prices are converted to 2022 dollars
2. Comparisons reflect products with similar end-markets; however, they are not meant to construe perfect substitutes. Products may not be comparable on other factors (e.g., satellites may not be comparable on data rates, signal to noise ratio, lifetime – however, increase is notable even on other dimensions such as dollar per bit)
3. Per kg of payload delivered to low-Earth orbit (LEO)

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Space Foundation; Northern Sky Research; Public Press; CPI Inflation Calculator; Center for Strategic and International Studies; National Renewable Energy Laboratory; NCTA; American Enterprise Institute; Expert Interviews

The space sector already plays a role in many non-space industries

Energy and mining

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.

Pharmaceuticals

Conducting experiments leveraging microgravity (e.g., protein crystallization) to improve pharmaceuticals

Telecom

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

Automotive

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

Transportation

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

Consumer

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

Finance

Leverage commodities geolocation tracking (e.g., vessels) to inform trades

Insurance

Using radar satellite-based flood monitoring capability to inform risk management and tailor solutions

Tech

Developing in-space computing offerings

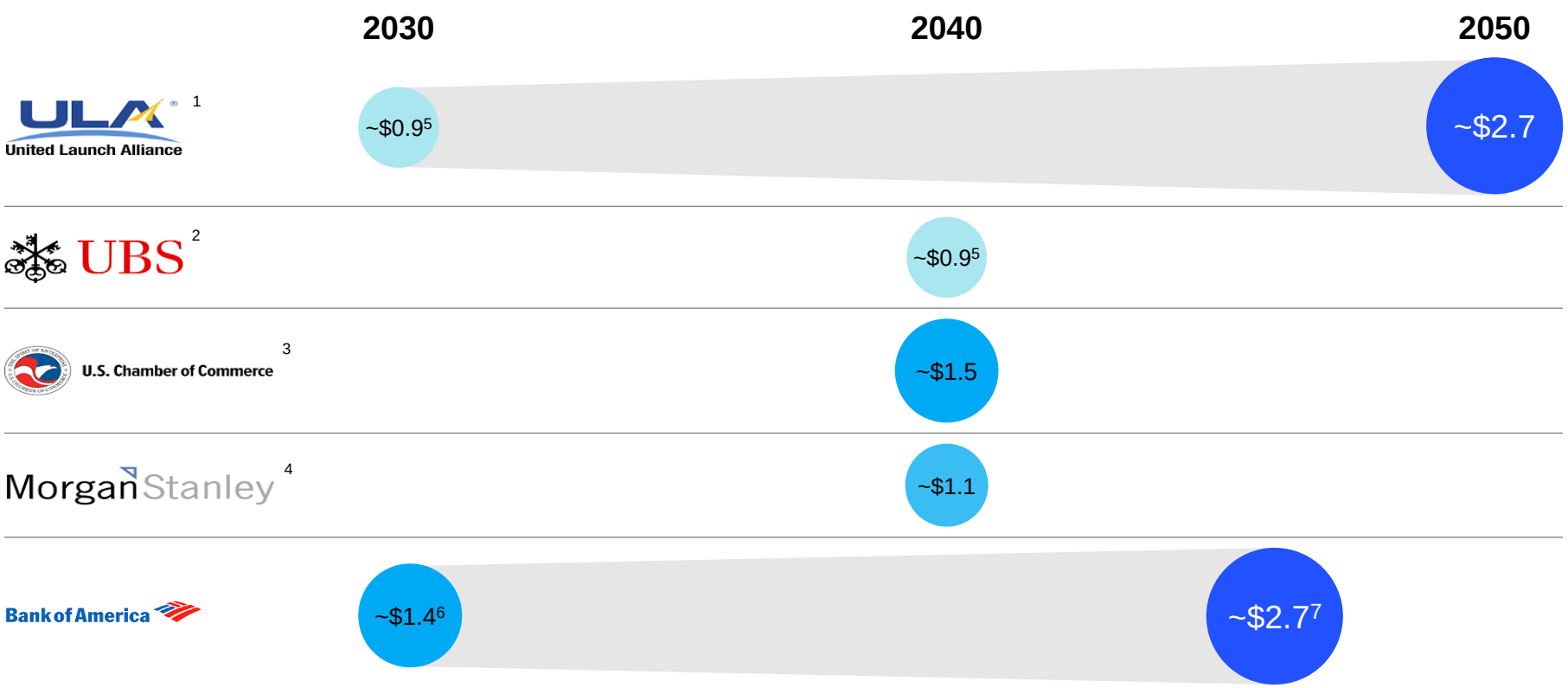
Media

Filming movies on International Space Station

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Public Press

There is wide divergence between forecasts of how large and how quickly the space economy will grow

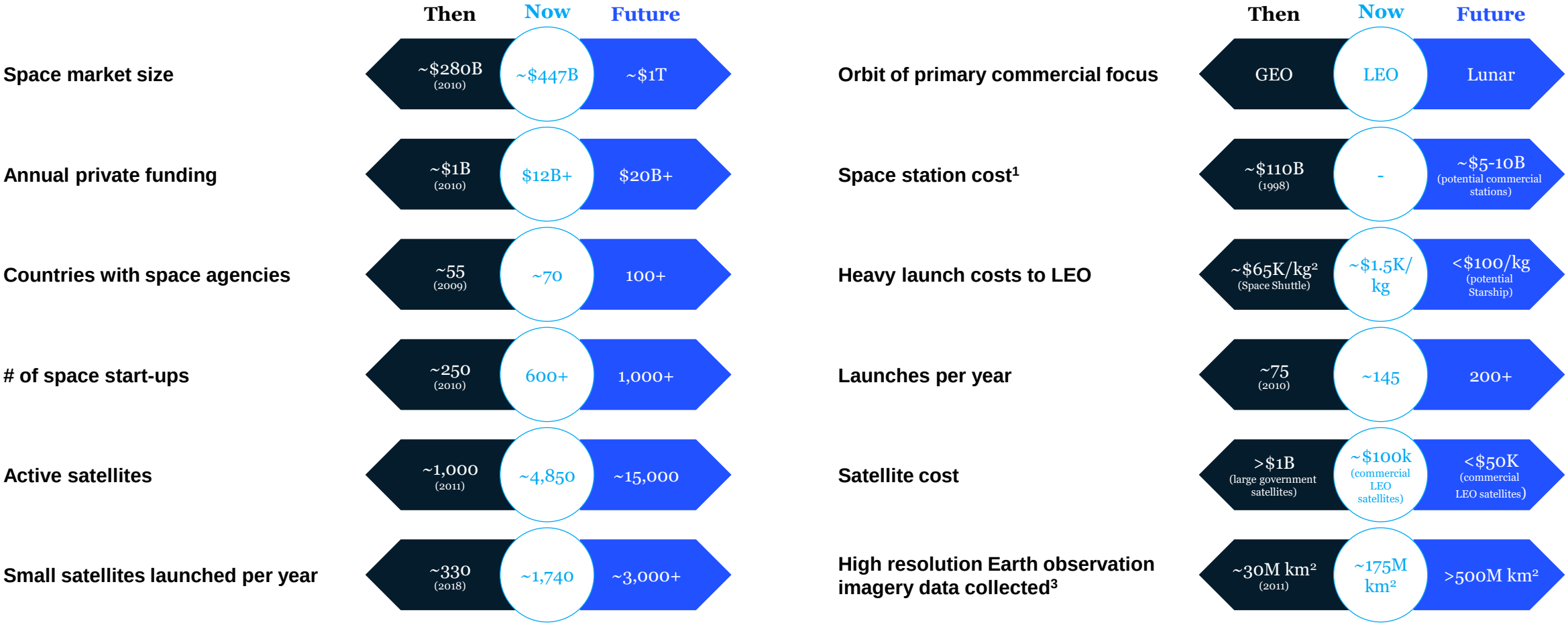
Estimated size of overall space market, $ Trillions



1. *ULA Innovation: Cislunar-1000*, United Launch Alliance, 2016; 2. "*Space Tourism: Ready for blast-off?*," UBS, 2019; 3. Higginbotham, Brian, *The space economy: An industry takes off*, US Chamber of Commerce, 2018; 4. "*Space: Investing in the final frontier*," Morgan Stanley, 2020; 5. Report anticipates a space gross product of $900B by 2032; 6. Sheetz, Michael, "Bank of America expects the space industry to trip to a $1.4T market within a decade," CNBC, 2020; 7. Sheetz, Michael, "*The space industry will be worth nearly $3T in 30 years, Bank of America predicts*," CNBC, 2017

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Northern Sky Research; Grand View; Mordor; The Space Foundation; Bank of America; Morgan Stanley; UBS; ULA; Public Press

The space sector has reached an inflection point



Note: Future reflects estimate by 2030

1. "Then" figure reflects cost of the International Space Station (ISS), for which the first module was launched in 1998; "Future figure reflects publicly estimated cost of planned US commercial space stations, planned to launch 2024-27
2. Inflation-adjusted
3. Earth observation imagery data reflects <1 meter resolution optical imagery (high and very high resolution)

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Union of Concerned Scientists; Center for Strategic and International Studies; Space Foundation; Pitchbook; Crunchbase; Euroconsult; Northern Sky Research; Organization Websites; Public Press

Why is this time different? (1/2)

		1990s-2000s space sector	Today's space sector
Technology advances	**Spectrum usage**	Satellites used **lower bandwidth** spectrum	Greater usage of **higher bandwidth spectrum** (e.g., Ka, Ku, V)
	Satellite throughput	**~5-10 gigabits/second**[1]	**>1 terabits/second** satellite planned for 2022 launch[2]
	Ground equipment	Ground antennas connected to a stationary GEO satellite (no LEO tracking ability)	Advancements enable ground antenna tracking of LEO constellations
	Launch frequency	**~15** launches/year was max observed frequency by a single vehicle	Average of **6.8** days between launches by SpaceX in 1H 2022
Cost decreases	**Launch cost**	**>$10K/kg** to LEO, inflation adjusted	As low as **~$1.5K/kg** to LEO (benefiting from reusability)
	Satellite costs	Predominately **large**, multi-billion-dollar exquisite satellites	Rise of small LEO satellites, some now being built for ~$100K
	High resolution earth observation (EO) imagery	Average cost of **~$20/km²** for **optical data** and **~$133/km²** for **synthetic aperture radar (SAR)**	Average cost of **<$15/km²** for **optical data** and **<$70/km²** **for SAR**

1. Limited by spectrum use, data compression, spot beams count; 2. Achieved via more spot beams, inter-satellite links, data compression improvements

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Public Press; Northern Sky Research; Center for Strategic and International Studies

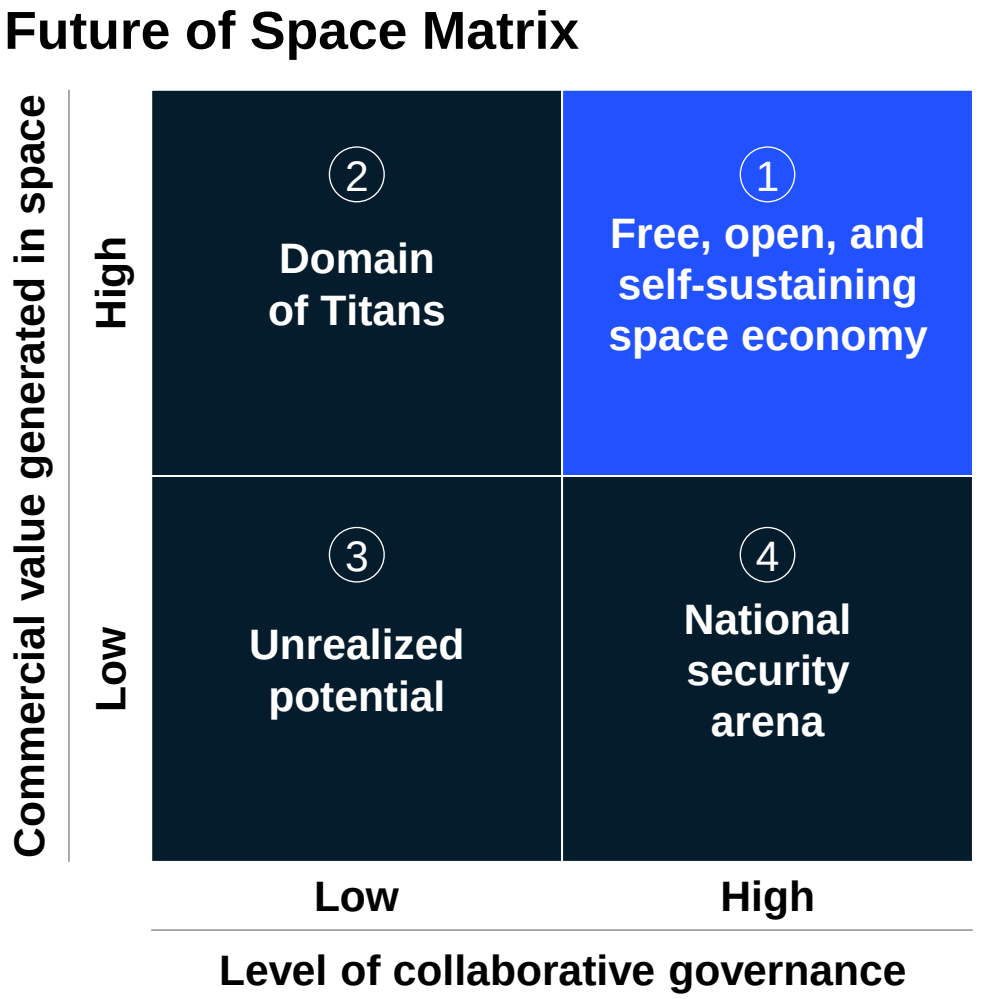
Why is this time different? (2/2)

		1990s-2000s space sector	Today's space sector
Applications and use cases	**Drivers**	Demand for **scientific exploration** drove development of the ISS, launch of Great Observatories, and planetary missions	Extensive development of **new or expanded space-for-Earth use cases** with pursuit of real commercial value generation potential Recognition of potential for **space-for-space applications** **Hosted payloads** enabled much expanded access
	Focus areas	Satellites primarily used for **military and personal communication purposes**: ~40% of satellites for comms, ~60% intended for non-LEO destinations	**~90%** of satellites launched in 2021 for **commercial use cases**; ~98% operate in LEO
Sources of capital	**Capital source**	**~$1B** in **private investor capital** from 2000-2010; capital primarily from **government programs and large OEMs/telcos**	**~$30B** in **private investor capital** from 2010-2020; represents 30% of space R&D funding
	Global govt. spend	**~$6B** per year	**~$92B** per year, with more nations participating
Global competition	**Global dynamics**	**Relaxation of international tensions** facilitated international collaboration on space initiatives (e.g., ISS, Cassini mission)	**Complex global dynamics** can hinder collaboration, but bolster resources for national security endeavors

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth; Union of Concerned Scientists; Gunter's Space Page; Public Press

Four scenarios for how the space sector could develop by 2050

Optimal outcome



Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth

Vision of a thriving space economy

Sense and communicate
E.g., expanded satellite comms for remote communities, remote sensing for climate condition monitoring

Protect and secure
E.g., EO could help deter large-scale drug trafficking or illegal shipping

Discover and Build
E.g., development of commercial space habitats to enable innovations in astrophysics, pharmaceuticals, and manufacturing

Survive and Thrive
E.g., diverse groups of people could work, live, and travel in space

Sustain and Manage
E.g., space infrastructure and services (e.g., satellite refueling), including in-space logistics networks enabled by advanced propulsion methods

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Five actions can help leaders chart the course towards an accessible, self-sustaining space economy

Detail follows

1. Create and implement effective space governance
2. Invest resources and effort in enabling technologies and capabilities
3. Incentivize collaboration among nations, sectors, and industries
4. Foster a self-sustaining industrial base
5. Leverage the space industry more to advance sustainability and security

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth

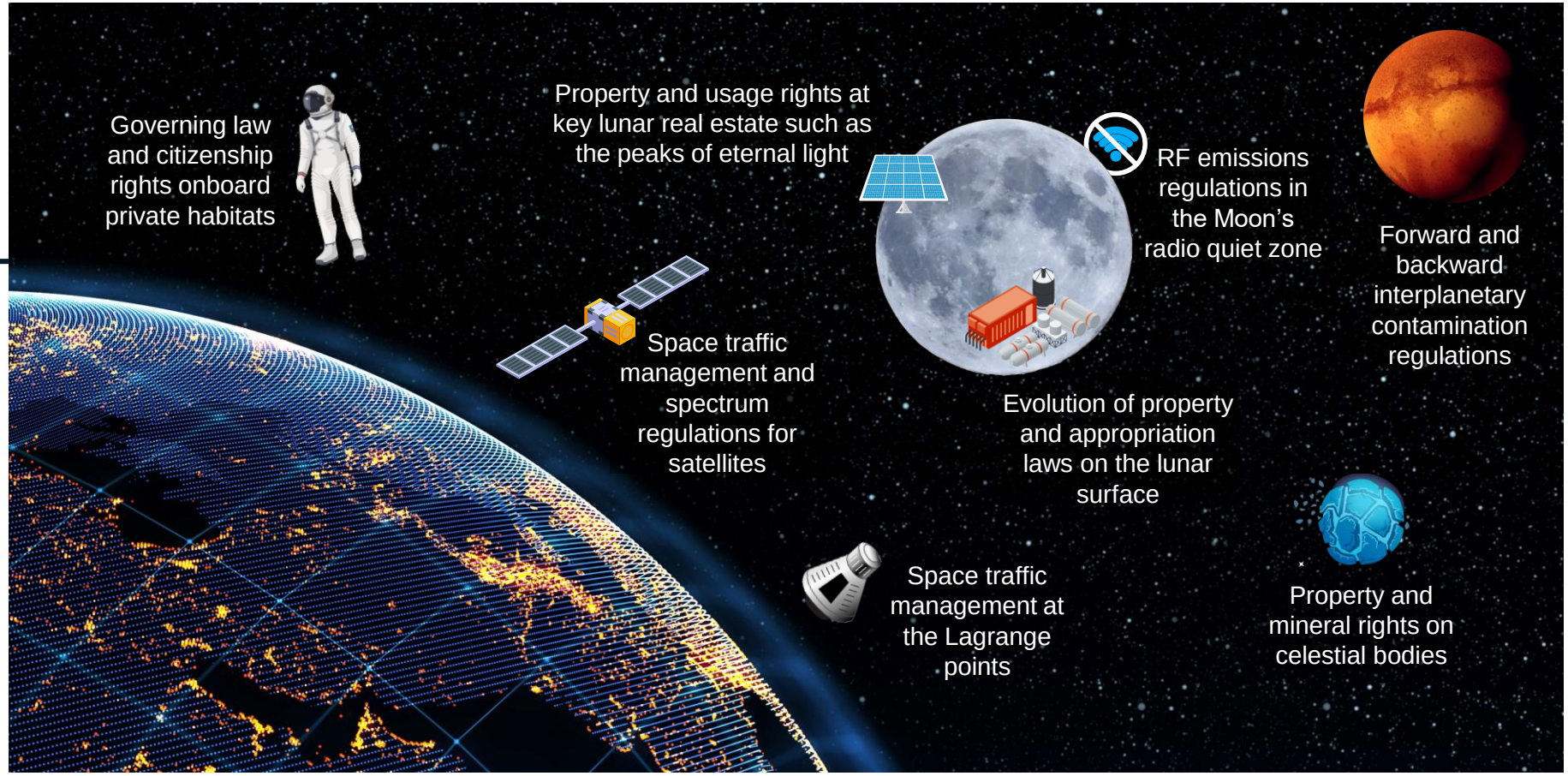
1. Create and implement effective space governance

Maintaining responsible behaviors in space

Defining property ownership, access, and usage rights

Developing and promulgating common standards

Protecting human life, infrastructure, and the environment



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2. Invest resources and effort in enabling technologies and capabilities

Experts named several technologies that will likely play a vital role in developing a self-sustaining space economy and expanding the benefits for Earth from the space ecosystem:

Advanced power and propulsion

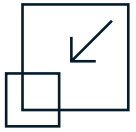
Downmass or re-entry capabilities

Cost-effective means of getting resources in space

AI/ML, cloud computing, robotics, and autonomy

In-situ utilization and life support

Enhanced cybersecurity



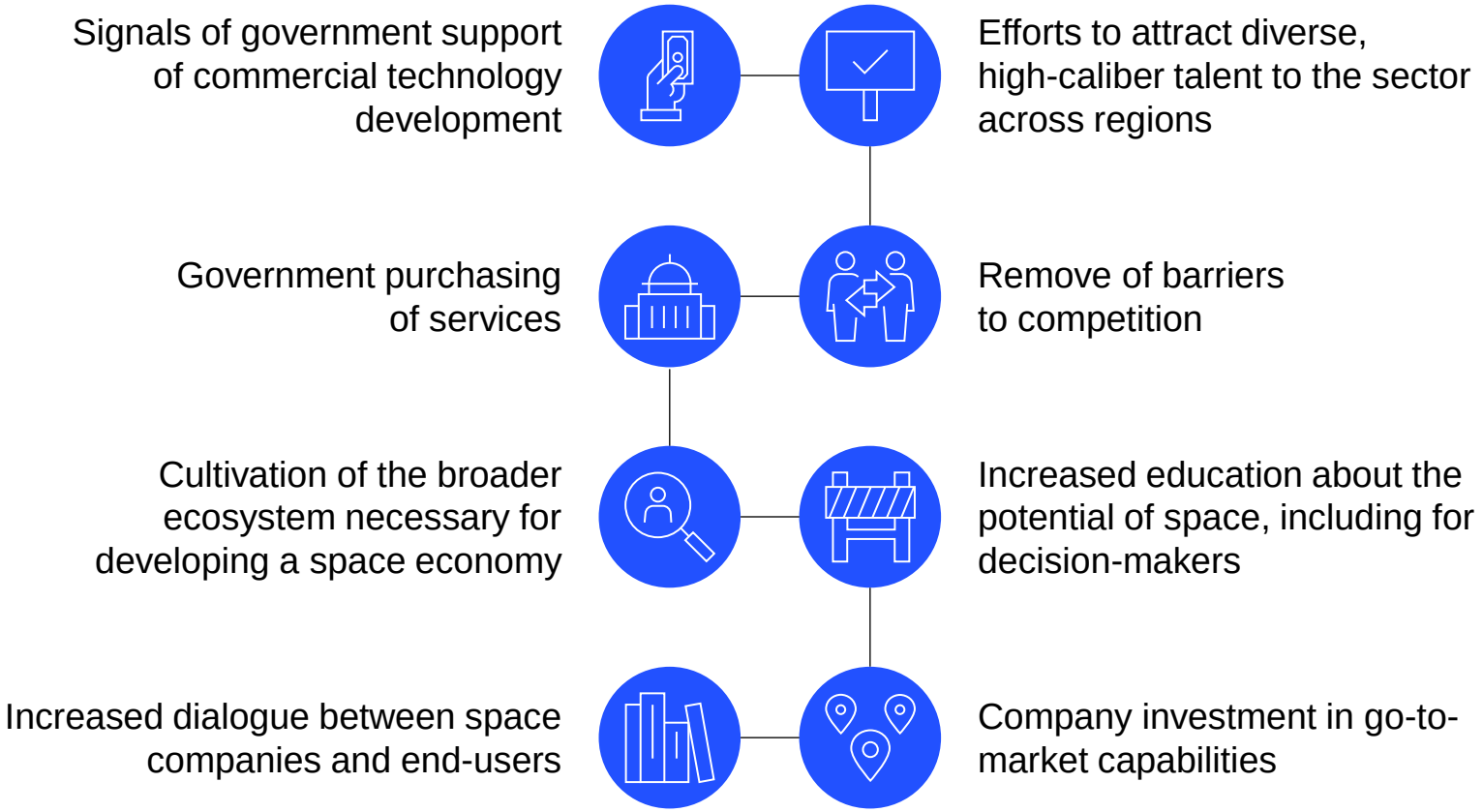
Component improvement and miniaturization

Mass production

Source: McKinsey & Company - The role of space in driving sustainability, security, and development on Earth

4. Foster a self-sustaining industrial base

What it would take – views from leaders we interviewed



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