Deloitte.

xTech Futures:
SpaceTech

Launching the ultimate emerging market

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INTRODUCTION

PREFACE

From InfoTech to xTech

Fifteen years ago, our small band of rebels published a report called Deloitte *Tech Trends*. The idea was simple, but not simplistic: Chronicle pioneering client case studies from around the globe that, taken together, traced a trendline toward our shared tomorrow. Somebody, in some other sector, in some other country, is very likely building pieces of your tomorrow, today. Or, as William Gibson said best: "The future is already here—it's just not very evenly distributed." As an organization delivering myriad professional services in just about every industry sector, we take that truism more literally than just about anyone.

Today, Deloitte *Tech Trends* is our most widely read annual report globally. It's required reading for business leaders who are keen to get beyond the buzzwords du jour and on to enduring business value; those who aspire to graduate from best practices to next practices and play leapfrog instead of catch-up.

But here's the catch.

If we're being honest with ourselves, *Tech Trends* doesn't really chronicle "tech" so much as a subset of tech. Specifically, information technology. Which makes sense, because InfoTech has indeed been the primary engine powering business acceleration and digital transformation for the last 50+ years. But as it turns out, there's a whole lot more going on in "tech" than IT. In distinctively Deloitte fashion, we've gotten busy studying the evolution of undergraduate majors, PhD programs, grant funding, patent activity, venture funding, and liquidity events. In doing so, we've realized something material.

SpaceTech. BioTech. RobotTech. EnergyTech. These upstart technology domains are beginning to graduate from the laboratory to the boardroom, because they stand to propel the next wave of business value creation. Some call them hockey sticks.

Others, S-curves or rocket ships. We call them xTech—"x" in the sense of an arithmetic variable—because there are many—and in the sense of exponential, insofar as each of these domains might feel inconsequential to your business today, or even tomorrow, but prove to become table stakes for your business strategy the day after tomorrow. We're grateful you're spending some time with us exploring what's NExT (i.e., Novel & Exponential Technologies).

"When you're dealing with exponential growth, the time to act is when it feels too early."

—Paul Graham,
co-founder of Y Combinator[1]

Billions have been made by 20th-century pioneers who helped their customers realize value from InfoTech. Trillions will be made by 21st-century pioneers who will help their customers realize value from xTech.

For starters, x = space.

Onward,
~!mb

Mike Bechtel
Chief Futurist
Deloitte Consulting LLP

Here's to the future,
Raquel

Raquel Buscaino
NExT SpaceTech Lead
Deloitte Consulting LLP

WHY SPACE? WHY NOW?

Space beckons. From our species' earliest days, a desire to explore beyond the boundaries of our known world has driven human expansion. Why else would we have set sail in canoes—without a known destination—through the mighty Pacific on our way to settle the islands of Oceania? There is a distinctly human quality that pulls at our hearts as we consider unknown frontiers, quietly convincing us that they, too, must be explored.

Those earliest sea explorers looked to the stars to guide them on their journeys, but the sea and stars are connected in more ways than this. The driving motivations that led prior humans to explore the sea are remarkably similar to those of today's space pioneers—from creating new sources of wealth and economic opportunity to deepening our understanding of our world and universe. Enabled by advancements in technology, and fueled by government and commercial cooperation, the ages of sea and space exploration have shaped—and will continue to shape—the trajectory of humanity.

Space is at the same inflection point as the sea during the Age of Exploration in the 16th and 17th centuries. We are at the dawn of a new era of space exploration. Space has never been more accessible, and, in turn, the untapped potential for breakthrough discoveries has never been greater. In this report, we'll chronicle this inflection point in space *access* and *opportunity*. Space exploration is no longer a venture only for government agencies or space companies.

In previous decades, a thoughtfully developed tech strategy became a competitive imperative; similarly, over the coming decades, companies across all industries will increasingly need to consider whether a space strategy will be a key component of their future. We hazard a guess that in the future, every company will likely be a space company. However, they will probably participate at varying levels. Some businesses may be *creators* of products and services in the space economy while others will be *purveyors* that support space-based activities; still others will be *consumers* of space services.

This may seem like hyperbole, but like *Tech Trends*, this report aims to help companies maintain a competitive edge by forecasting into the future. From agriculture companies using satellite data to optimize crop yields to pharmaceutical companies using the advantages of microgravity to develop life-saving solutions, we'll demonstrate how industries can leapfrog to the next opportunity by leveraging space-based technology advances and providing products and services to the growing space industry.

This new era will present profound challenges—many in number, and major in scale. But these issues will, in turn, present opportunities for leading organizations to leverage their existing expertise in space, as they might for any new market here on Earth. If we've learned anything in researching this report, it's that space is indeed the ultimate emerging market.

We must be careful, however, that in our pursuit of progress we strive to mindfully avoid the pitfalls of our past. Just as seafaring expeditions resulted in unforeseen biological and environmental changes, we need to ensure that our exploration of space does not follow suit. We must learn from our past, even as we yearn for our future, and aim to build a space ecosystem that is responsible and safe; sustainable and efficient; inclusive, equitable, and accessible; and economically viable.

Hyperbolic headlines and Hollywood hijinks notwithstanding, we aspire to make one thing clear: We do not build our presence in space to escape Earth, but to enrich it. We may not yet recognize how the direct and indirect scientific, economic, social, and other benefits of space exploration will manifest themselves, but we anticipate that there will be many.

What will be your organization's role in space? For those who are willing to claim their seat in the cockpit and buckle in, an abundance of opportunity awaits. The future is not ours to receive, but ours to create. And the countdown has already started.

ABOUT THE REPORT

The space industry is rife with jargon and acronyms. Our aim is to break down the complexity of technical space terminology and illustrate the cross-industry opportunities that space presents. There are certainly engineering and business barriers to be overcome, but our hope is to paint a picture of the possibilities if and when these challenges are addressed. For organizations that live and breathe in the space sector, there are still insights to glean from the report, but we also recommend referring to additional *Deloitte Space* eminence that dives deeper into specific space topics.

Readers may notice that much of the discussion is related to the American space sector. Compared to its peers, the United States is in a unique position due to long-term and ongoing government investment in its space economy, and this was reflected in the research we conducted. However, our audience is global; the business opportunities described likely will be available to organizations regardless of geographic boundaries.

INTERVIEWS WITH INDUSTRY EXPERTS

Some of our greatest insights came from speaking with leading industry experts. We'd like to thank the following individuals for their time and contribution:

- **Greg Autry**, space policy expert
- **Tory Bruno**, CEO of United Launch Alliance
- **Sarah Cruddas**, space journalist and author
- **Maureen Haverty**, VP at Seraphim Space
- **Roger Launius**, former chief historian at NASA
- **Mike Lewis**, chief innovation officer at Nanoracks
- **Dan Lockney**, Technology Transfer Program executive at NASA
- **Jeff Matthews**, director of strategy at Radian Aerospace
- **Nobu Okada**, founder and CEO of Astroscale
- **Rod Pyle**, editor-in-chief, *Ad Astra*
- **Scott Rodriguez**, VP of Government Programs at Nanoracks
- **Tom Vice**, CEO of Sierra Space

STRUCTURE

To help you understand your organization's potential role in space, we structured this report into three chapters, as described here and shown on the next page in our **SpaceTech frontiers** framework.

HERE
Right here, on Earth, the space economy's historical barriers to entry are being decreased, de-risked, and democratized.

NEAR
Very near, in Earth's orbits, entrepreneurs and enterprises alike are turning possibility into profitability, today.

THERE
Out there, in deep space, a new frontier for human health, wealth, and wisdom awaits.

A myriad of opportunities and issues are relevant across the ***Here***, ***Near***, and ***There*** chapters. We've sprinkled callouts on these topics—regulatory and ethical considerations; cybersecurity and defense; sustainability; and media, entertainment, and marketing—throughout the report, signified by the heading ***Everywhere***.

SpaceTech frontiers

HERE

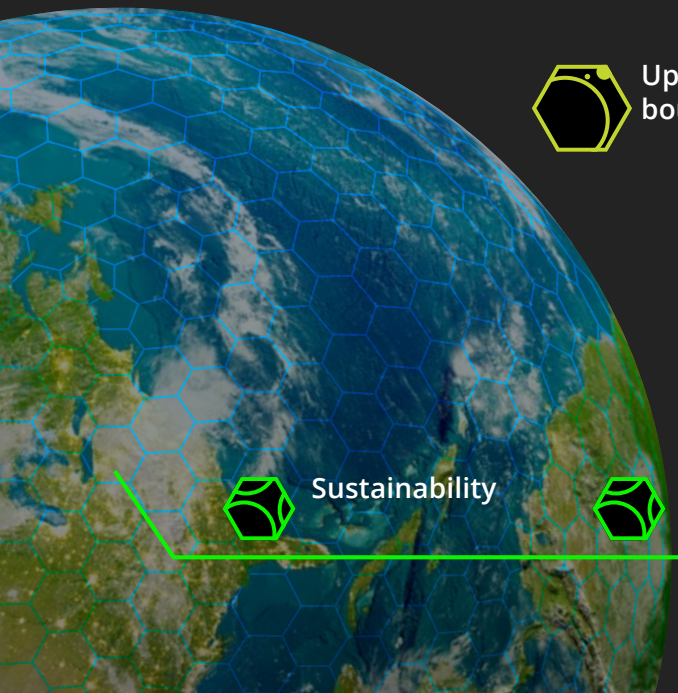
Reducing barriers to entry and exploration

NEAR

Capturing higher-value business cases in Earth's orbits

THERE

Exploring new frontiers for health, wealth, and wisdom



Upward bound

Gateways to the galaxy

New constellations

Defying gravity

Cosmic cleanup

Offworld production

Lunar redux

The human problem

Destination: Space

The new gold rush

The Red Planet

EVERYWHERE

Sustainability

Cyber and defense

Media, entertainment, and marketing

Regulation

Ethics

Diagram is not to scale


HERE
Reducing barriers to
entry and exploration

HERE

Right HERE, on Earth, the space economy's historical barriers to entry are being decreased, de-risked, and democratized.

The US space shuttle flew its final mission in 2011, and at the time, it felt like the end of an era. Apollo astronauts Neil Armstrong, Jim Lovell, and Eugene Cernan addressed an open letter to then-President Barack Obama, saying "For the United States, the leading spacefaring nation for nearly half a century, to be without carriage to low Earth orbit and with no human exploration capability to go beyond Earth orbit for an indeterminate time into the future, destines our nation to become one of second or even third rate stature."[2]

But America's space ambitions didn't end with the termination of the shuttle program, as some had feared; they instead entered a second stage—one in which commercial and government capabilities are growing in tandem. With government agencies providing financial support and sharing workloads, space is now accessible to both governments and private companies alike.

As a result, it's easier than ever before for many businesses—not only in the United States, but globally—to access the opportunities that exist beyond Earth's surface and across the space value chain. These opportunities are not only for traditional space industry organizations, but also for end markets including transportation, finance, manufacturing, pharmaceutical, and research organizations, in addition to others. We'll discuss these in further detail in this and in other report chapters.

Here on Earth, opportunities and activities include those related to launch vehicles, spaceport development, supply chain and logistics, data processing, and ground terminals, among others. In this section, we'll focus on how innovative launch vehicles and spaceport infrastructure are helping drive the commercial space flight revolution. We'll explore the growth in these two areas and learn how they're providing companies in all industries the ability to access space's exciting business opportunities.

UPWARD BOUND

Novel launch vehicles open new avenues to space

Basic rocket functions remain unchanged from the earliest days of space exploration, as shown in the timeline on the next page. But new advancements are making the process more affordable and leading to innovative (i.e., new and improved) ways of leaving our planet.

In 2015, SpaceX demonstrated the ability to successfully land a rocket back on Earth intact for use in future launches.[3] Reusable rockets—along with advancements in materials science and spacecraft manufacturing—are dramatically lowering the cost for private companies to launch payloads and people into space. Today, the

cost per kilogram of upmass—the payload mass carried from Earth into orbit—varies substantially depending on launch provider, the type of rocket used, and how deep into orbit you want to go but, in general, has declined substantially.[4]

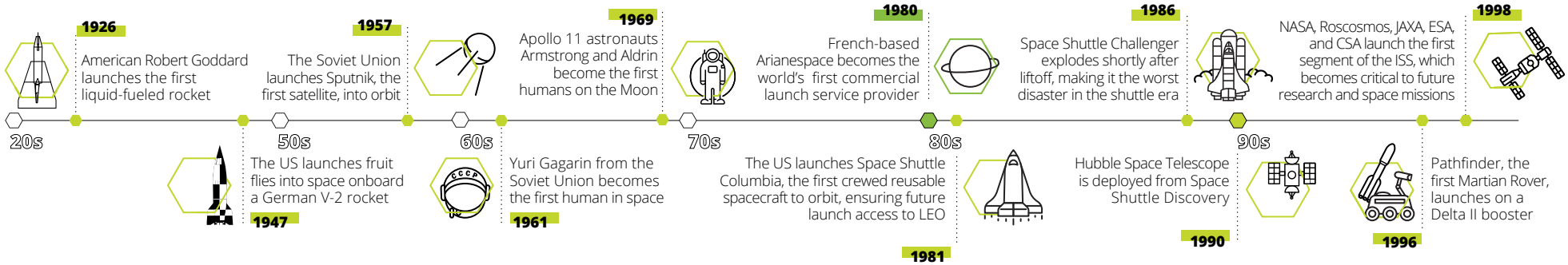
As costs decrease, the launch business model is also evolving. Rideshare missions, in which multiple payloads from different customers are hosted on a single launch vehicle, can help businesses get payloads to orbit in a more cost-efficient, timely, and sustainable manner.

Reusable rockets and payload-as-a-service business models have opened a wide market of private demand, leading to unprecedented growth of commercial space activity and global commercial competition. "I joined the space industry five years ago and it has been completely, fully transformed," says Maureen Haverty, vice president at Seraphim Space, an investor in space startups.[5] "It's now a very vibrant ecosystem with high customer demand."

A host of future-facing innovations could soon supplement existing rocket capacity.

A HISTORY OF LAUNCH

How innovation in rocketry made space accessible



Source: Deloitte analysis

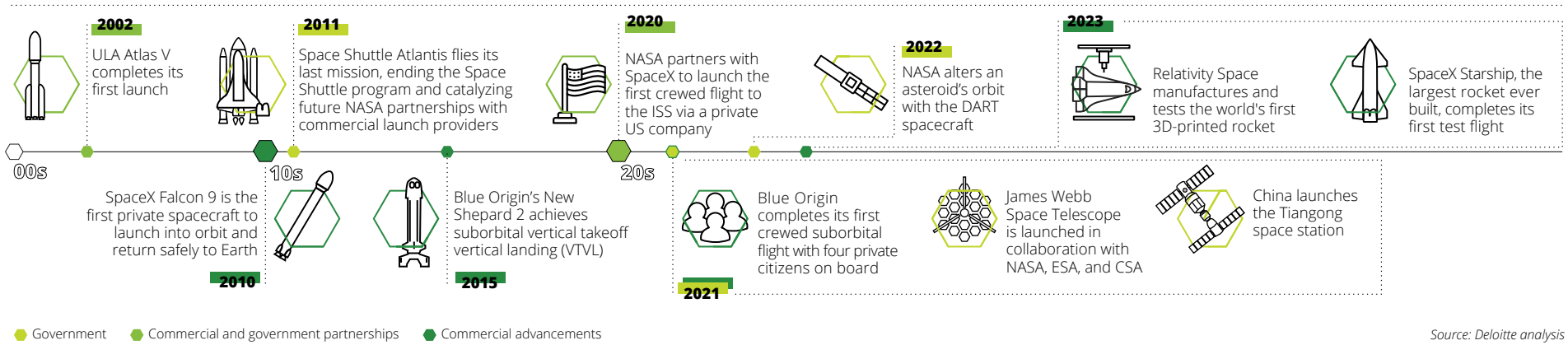
Currently in development are lighter-touch techniques that lower costs, including rockets manufactured primarily from 3D-printed parts,[6] containerized launch solutions that fit in shipping containers,[7] and centrifugal launch systems that fling payloads into orbit without using rockets at all.[8]

Shuttle-like vehicles that operate like airplanes will further democratize entry to space: Horizontal takeoff and landing capabilities will allow them to launch from and land on both airport and spaceport runways, which will help extend space access to companies and governments in countries without spaceports.[9]

Together, these developing innovations have the potential to dramatically lower costs and increase opportunities for companies in nearly every industry to participate in the space economy. A competitive launch ecosystem is already thriving, and in turn, creating new business opportunities in areas as divergent as space logistics; exploration; resource extraction; in-space servicing, assembly, and manufacturing (ISAM); and space tourism. (We'll cover each of these in the *Near* and *There* chapters).

EVERYWHERE
Media, entertainment, and marketing

Space is a new sandbox for experimenting with advertising and brand positioning. Like they did during the first space race, products and brands can build positive and futuristic customer perceptions using space-based motifs. For example, to highlight their brand's dedication to creative education, LEGO created a STEM education program with NASA and the Artemis Moon mission to bring space education to the classroom.[10]



Source: Deloitte analysis

GATEWAYS TO THE GALAXY

Spaceport development is critical for meeting launch demand

Putting a rocket into space is no trivial endeavor. A host of infrastructure and services is necessary for safe launches—equipment to pack payload onto rockets, air and space traffic management, refueling services, advanced vehicle testing, and emergency responders, to name just a few.

This concentrated infrastructure is known as a spaceport. Think of it like a seaport, which is more than just a place to launch a ship—it's also where all the commercial activity related to shipping organizes itself. Similarly, spaceports are gateways, providing countries and, increasingly, companies with assured access to space's commercial, scientific, or defensive capabilities.

In the past, spaceports have typically been controlled by government agencies like NASA or ESA.[11] That will likely continue to be the case for the most part, but a more local, distributed group of entities, including private companies, is now supplementing space infrastructure and services capacity—either through the creation of new spaceports or the modernization of existing spaceport capabilities. "We're building these superhighways, these bridges, these hubs, that will connect Earth and space in a very unique way," says Tom Vice, CEO of Sierra Space.[12]

At this writing, there are at least 28 active spaceports worldwide that have been used to launch satellites into orbit, with more planned to come online in the next few years.[13] The capacity is needed: The number of objects launched into orbit has increased dramatically in the past several years, and this surplus of demand is expected to strain existing launch infrastructure.[14]

Spaceports can function as hubs for research and development, STEM skills training, transportation, and manufacturing, not to mention jobs and tax revenue.[15] National, state, and local governments have an opportunity to build the infrastructure to help meet this demand while creating centers for burgeoning space launch activity. Some government officials, such as those in the US states of Michigan and Arkansas, are already considering proposals to work toward this goal.[16] Sweden opened mainland Europe's first spaceport in early 2023[17] and the United Kingdom is proposing to build several in Scotland,[18] while Africa's first spaceport will be developed in Djibouti.[19]

It's worth noting another caveat: Just as location is important in developing a seaport, so, too, it is with spaceports. To help minimize fuel consumption, rockets typically launch in an eastward direction, with most spaceports tending to have sparsely populated areas or oceans to their east. Additionally, some latitudes on Earth are better for launching into different Earth orbits than others.[20]

EVERYWHERE
Sustainability

As the number of rocket launches and spaceports increases, noise and pollution could negatively impact Earth's ecosystems.[21] It will be critical to continue developing technologies that reduce environmental impact, such as reusable rockets (which are more environmentally friendly because they reduce the amount of raw material needed), alternative launch approaches, and responsible fuel sources. In addition, developers will need to build buy-in from communities that may be most impacted by spaceports. For example, Michigan officials are currently facing backlash over their plans to build a spaceport from local residents who fear a crash or explosion could cause major damage to Lake Superior.[22]

Right now, limited launch capacity is a major bottleneck in our ability to venture off-world. Yet with massive launch vehicles under development—such as SpaceX's Starship, which is being designed to have a payload of up to 150 tons and carry 100 passengers[23]—we anticipate this choke point may eventually be reduced. When that happens, we can imagine a future in which spaceports dot the spacefaring nations, like seaports in cities with the natural features to support them. There are plenty of challenges, but as we discovered in the age of sea exploration, overcoming them opens new frontiers. As the pace of launches picks up, nations, cities, and states with the appropriate location and features that support spaceport infrastructure may benefit from this emerging trend.

FINAL THOUGHTS

An increase in payload capacity, launch frequency, and spaceport capabilities is opening up access to Earth's orbits and beyond—and the space industry's shifting business model for reaching space is further enabling this transformation. In the same way that computer processing and storage has moved from on-premises to the cloud, launch capabilities are transitioning to an as-a-service model. Space launch is no longer a do-it-yourself end-to-end initiative, nor a project to be outsourced to a single contractor. Instead, the as-a-service business model is transforming space launch in the same way that the cloud democratized IT: making it increasingly accessible, responsive, and affordable. It is now easier than ever before for organizations to take advantage of opportunities along the space value chain. But for these nontraditional space companies, it will be important to have a plan anchored securely on *terra firma*.

For many businesses, the space economy's greatest value will come in the form of satellite communications, navigation, and data—which, as we're about to explain, already plays a significant role in most, if not all, businesses.


NEAR
Capturing higher-value
business cases in Earth's orbits

NEAR

Very NEAR, in Earth's orbits, entrepreneurs and enterprises alike are turning possibility into profitability, today.

In pop culture lexicon, space is often termed the "final frontier," evoking images of a vast, empty region to be discovered and chartered. Far from Earth, in deep space, these images can ring true. But in the major orbits of our planet, space is anything but empty. Rather, an energized ecosystem of satellites, space stations, and services already exists, and it's flourishing.[24]

For instance, satellites in geosynchronous orbit (GEO, above 22,000 miles from Earth) and medium Earth orbit (MEO, above 1,200 miles from Earth), enable much of the telecommunications equipment and GPS systems we take for granted today. However, recent innovation and investment have been focused on exciting possibilities within low Earth orbit (LEO, below 1,200 miles from Earth)—the primary focus of this chapter.[25]

Lower launch costs have led to a space "gold rush," as corporations race to fill LEO with services, infrastructure, and research. For example, agricultural equipment manufacturer John Deere is aiming to increase rural connectivity using LEO satellites to enable smart farming, while biotech firms are keen to explore tissue engineering in microgravity conditions.[26]

A new kind of space race is on. But unlike the original sprint to the Moon, the race to LEO is a marathon, occurring over an extended period with many phases, as companies and governments build on past experiments and determine their capabilities and constraints in space. As organizations compete to launch new satellites and commercial space stations, others are developing expertise in service and repair to extend the life of objects already in orbit, while a select few are concerned with enabling the first wave of space tourism. "The last 60 years were focused on exploring space. The future is now how to harness space to benefit life on Earth—how to extend cities and factories into low Earth orbit," says Sierra Space's Vice. "We are on the cusp of a profound industrial revolution."

NEW CONSTELLATIONS

Satellites are powering a smarter, more connected Earth

Dating apps, gas stations, and stock trades surprisingly have one thing in common: They're enabled by satellites.[27] Satellites across Earth's orbits uniquely solve business use cases that require precise location, exact timing, and/or enhanced connectivity and imaging. As such, the market for satellites

is showing impressive growth: In 2022 alone, the total number of active satellites increased by 44% to nearly 7,000, with roughly 3,800 in LEO, and Deloitte estimates the number in LEO could grow to more than 40,000 by 2030.[28]

Today, thanks to the breakthrough technology advancements and diminishing launch costs that we discussed in the previous chapter, a nanosat—a miniaturized satellite weighing between 1 and 10 kilograms—can be deployed to LEO for under US$100,000. In comparison, traditional satellites are often much larger—some the size of a bus—and cost tens or hundreds of millions of US dollars to launch into orbit.[29] With a constellation of small satellites orbiting and communicating together, similar to a Wi-Fi mesh network, a company can mimic the coverage offered by large satellites in GEO while taking advantage of the lower latency and sharper image resolution afforded by being closer to Earth.[30]

By combining the increased access to satellites with existing tools like edge computing and AI, early adopters are finding major improvements in their ability to trace, measure, and predict throughout their supply chains. Some businesses may want to stand up their own capabilities for custom configuration, while others may partner with satellite-as-a-service companies such as Planet or Spire to access high-frequency data and foundational analytics.[31] In either case, companies keen to tap into LEO's economic opportunities have begun leveraging these advances in three main areas: satellite communications (satcom), satellite navigation (satnav), and earth observation (EO) and remote sensing.

SATELLITE COMMUNICATIONS

The largest market share in satellite opportunities belongs to satcom. Roughly 80% of satellite launches from 2020 through April 2022 have been communications satellites, up from 40% in 2019, and major telecom providers are capitalizing on this growth to expand internet access for customers.[32]

Recent activity in the business-to-business-to-consumer market centers on partnerships. For example, T-Mobile and Starlink have joined forces to eliminate cellular dead zones,[33] and Verizon has teamed up with Amazon's Project Kuiper to expand global 5G coverage.[34] Meanwhile, Apple's[35] landmark Emergency SOS satellite communications feature was made possible by its partnership with Globalstar.[36] And Qualcomm and Iridium Communications are collaborating to offer direct-to-satellite communication—no Wi-Fi or cellular data needed—on select Android phones.[37]

EVERYWHERE
Regulation

Competition for prime orbital positions could create a demand rush that places stress on the "first come, first served" policy that the International Telecommunications Union has relied upon to coordinate geosynchronous orbit satellite frequency services.[38] This dynamic could one day lead to a "landless land grab" in lower orbits if updated regulation doesn't pave the way to new global rules of engagement for nation-states and private organizations.

In the business-to-business market, broadband providers are partnering with transportation companies such as Hawaiian Airlines and Royal Caribbean to provide their customers with high-speed internet access.[39] Finally, in the business-to-consumer segment, Starlink supplies broadband internet to more than 1 million active subscribers, while Amazon's Project Kuiper has plans to launch its own direct-to-consumer service.[40]

Such innovations can bring reliable internet access to rural areas and developing countries without ground-based infrastructure. When satellite internet is no longer cost-prohibitive, the possibilities for developing communities are immense: Deloitte estimates that the increase in GDP driven by affordable worldwide internet could lift 160 million people out of poverty, while improved, reliable coverage is likely to keep customers loyal to their mobile operators.[41]

Increased internet connectivity also empowers use cases in the rapidly growing Internet of Things (IoT) market, especially when devices are out of reach of traditional networks. For instance, Starlink subsidiary Swarm uses satellite constellations to support data transmission to and from IoT devices, so customers can track asset locations in real time instead of waiting for updates from a shipping provider.[42] Edge computing extended to remote areas can also improve mining equipment maintenance, livestock tracking, and smart utility metering.[43] In short, the declining cost of leveraging data anywhere can lead to new economies of scale for digital transformation and real-time insights.

Companies are moving quickly to utilize satellites and leverage the benefits of LEO-based communications for their customers, but they'll need to collaborate to succeed. A crowded orbital environment raises the risk of collision, and, as we detail later on, new partnerships and providers will be required to protect the commons of space and harness its opportunities.

EVERYWHERE
Cyber and defense

Like on Earth, satellite data and transmissions are susceptible to theft, jamming, and corruption; governments have already begun targeting their rivals' satellites.[44] As more organizations find value in leveraging space-based assets, the risk of malicious actors will likely increase. Cyber readiness will be of the utmost importance for governments and companies alike.[45]

SATELLITE NAVIGATION

While the market for satcom is rapidly expanding, many of us have already become accustomed to another major use case for satellites without even realizing it: navigation services. Global navigation satellite systems (GNSS), typically based in MEO, provide location with an accuracy of seven meters, 95% of the time.[46] This high degree of accuracy, enabled by atomic clocks on satellites, leads to use cases far beyond road-trip directions, such as guiding missiles, enabling modern air travel, and more.[47] The market for GNSS was valued at more than US$220 billion in 2021, and is projected to reach US$547 billion by 2031.[48]

The first uses of satellite navigation originated from the US Navy's need to track its nuclear submarines.[49] Today, GNSS includes US GPS satellites as well as systems launched by Russia, China, and the EU that enable precise location and timing across industries, from remotely guiding mining machinery to tracking animals for biodiversity and time-stamping financial transactions.[50] Consumers are already accustomed to GNSS data-enabling fitness apps and social networks, and organizations are expected to increase the use of GNSS applications in the coming years. For instance, as AI improves the capabilities of robotics and autonomous vehicles, these devices will employ GNSS sensors to navigate farms and roads[51] and even measure the shifts in volcanic land to predict which areas to evacuate first.[52]

As smartphone and IoT usage continue to grow, more and more devices can be tracked and guided through satnav, leading to an increasingly digital world. Together, satnav and Earth observation could help businesses unlock a new paradigm of data collection and analysis in every step of their supply chains, as outlined below.

EARTH OBSERVATION AND REMOTE SENSING

Just as reliable GNSS data led to downstream business innovations such as integrated storefront information and ubiquitous customer reviews, EO and remote sensing satellites stand to help businesses and consumers see almost every aspect of the planet as a high-fidelity data point to be analyzed and optimized. For example, retailers can monitor foot traffic and parking lot activity to assess their performance against competitors' stores.[53] Considering the possibilities, the EO market, which accounts for approximately 10% of the total space market, is forecasted to grow from US$3 billion today to US$8 billion in 2030 and US$25 billion by 2040.[54]

Businesses eager to apply data-driven decision-making are likely to find that EO data can enable new levels of transparency throughout an entire supply chain.[55] For instance, as shown in the illustration on page 20, the journey from farm to table can be tracked from end-to-end, enabling new paradigms for financial planning, consumer expectations, and industry standards around food sourcing.

FROM FARM (TO SPACE) TO TABLE

Satellites are used throughout the agricultural supply chain to improve crop yields, tracking, and transparency

SATELLITE TECHNOLOGY

Earth observation: Satellite remote sensing provides near-real-time global hyperspectral imagery

Communications and navigation: Satcom and satnav are available at every step of the supply chain

FARM

Weather monitoring: Soil sensors receive weather predictions from satellites for irrigation

Equipment tracking: Farm equipment is guided by spatially accurate satellite imagery

GROCERY

User research: Assess trends across stores by measuring parking lot activity

Demand forecasting: Send real-time sales data to suppliers and distributors for collaborative planning

FINANCE

Crop yield: Price discrepancies are mitigated by accurate forecasts of crop yield ahead of harvest

Insurance: Insurance underwriters remotely assess crop or infrastructure damage

LOGISTICS

Traceability: Enhance tracking consistency of trucks, planes, and ships in-transit

Navigation: Ships evade storms, oil spills, and pirates that are not visible on marine tracking systems

Source: Deloitte analysis.

The potential for similar disruption across industries is broad:

- **Sustainability**. The World Economic Forum estimates that EO data could benefit Africa to the tune of US$2 billion per year by helping reduce environmental damage from gold mining, increasing agricultural productivity, and more.[56] In addition, according to ESA and other space agencies, EO data is essential to climate change modeling efforts, including the stark discovery that the Arctic Ocean could be stripped of sea ice by 2050.[57]

- **Health care**. Satellite imagery combined with AI can help scientists monitor pollution and diseases to better track and anticipate population-level needs.[58]

- **Hospitality**. High-resolution satellite imagery can help businesses assess traffic at attractions such as resorts or sports arenas and provide customers with up-to-date navigation or wait times.[59]

- **Defense**. Governments can strengthen their surveillance capabilities on borders and in remote locations through EO imagery.[60]

- **Energy**. Advanced imagery inputs to AI algorithms can pinpoint ideal sites for oil and gas exploration, provide live feeds to remotely operated robotic drills, and monitor pipelines.[61]

- **Security**. Satellite tracking of movement can help law enforcement counter human and drug trafficking and coordinate emergency response.[62]

- **Industrials**. Businesses can verify the observed progress of construction projects against reported progress by contractors.[63]

As access to satcom, satnav, and EO data scales and becomes more affordable, space analytics could be used to create digital twins of Earth—a global spatial web.[64] When combined with AI and IoT devices, a digital twin of the planet could better help users track, monitor, and predict the movement of organic and inorganic assets. For example, EO data combined with AI can help identify optimal routes for cargo ships, enabling them to avoid storms, oil spills, and pirate activity; meanwhile, edge computing devices connected via satcom can provide real-time updates on the vessel's engine health. Similarly, satellite data can help predict wildfire patterns in California or Australia and provide reliable, constant tracking and communication with response teams.[65]

EVERYWHERE
Ethics

Monitoring the entire Earth through EO satellite data raises ethical concerns over individual privacy and data ownership, especially as image resolution continues to improve. If a company captures images to monitor attendance at its theme park, should consumers have a right to consent or ensure their images are scrubbed? Guardrails that protect and respect consumer privacy can ensure trust in satellite technology.

Travelers who have witnessed the progression from printed road maps to current navigation apps can vouch for the benefits of ubiquitous and accessible satellites. The integration of satcom, satnav, and EO data, along with advances in AI and IoT, can fully unlock a new way of monitoring our world, and in turn, doing business in it. In fact, in an increasingly global world embracing remote work and remote access to devices, we may one day wonder how we ever functioned without the expanded connectivity and transparency offered by satellites. Space may be getting crowded, but the future promises to be clearer.

DEFYING GRAVITY

Space stations provide a new sandbox for experimentation

Space stations are no longer the sole domain of governments. The International Space Station (ISS), the largest international hub for space operations and experiments for more than two decades, is set to be retired around 2030, and governments and corporations alike are interested in the commercial options that will replace it.[66] The only other station currently in orbit is China's Tiangong, which is already open to commercial activities.[67]

Going forward, government space agencies hope to allocate more funding toward research and major missions like the Artemis Moon exploration program instead of maintaining the ISS. And commercial players can benefit from having more flexible space destinations.[68] Companies like Axiom Space, Blue Origin, Nanoracks, and Northrop Grumman have begun partnering with consortia to design mixed-use stations for commerce, research, and even tourism.[69]

Purpose-built for modularity and multifunctionality, the next generation of space stations will likely offer rentable spaces, advanced robotics, and the opportunity to conduct a wide range of experiments, from bioprinting life-saving kidneys to manufacturing silicon crystals. While R&D grows in the near term, manufacturing is also poised to be a high-growth industry in space. By the end of the decade, businesses may count space as an integral part of their supply chain. Some may endeavor to launch their own projects, while others might rely on experimentation-as-a-service companies, such as Nanoracks or Offworld Biotech, to design, prototype, and launch their ideas.[70]

EVERYWHERE

Media, entertainment, and marketing

Satellite data can support groundbreaking reporting from warzones and areas of conflict without risk to journalists' lives. With live data transmitted from satellites, journalists can instantaneously gather high-definition imagery and global intelligence to synthesize insights. This was the case when the New York Times won the Pulitzer Prize with reporting that used satellite images of Syrian medical facilities reportedly bombed by Russian aircraft.[71]

MANUFACTURING IN SPACE

The unique conditions of space present new opportunities for manufacturing in ways that are not possible on Earth

SEMICONDUCTORS

Silicon carbide wafers have fewer impurities, leading to improved performance

PHARMACEUTICALS

Microgravity allows for higher-quality protein crystals and more effective drug development

FIBER OPTIC CABLES

Higher-quality cables lead to improved data transmission and reduced costs

ORGANS

Organs printed in microgravity are more accurate and functional for research on Earth

STEM CELLS

Slower growth of stem cells in space enables higher production for use in personalized medicine

Source: Deloitte analysis.

Space experimentation offers companies the ability to build and test unique products, as shown in the adjacent illustration.[72] For instance, space's unique conditions can eliminate some of the typical defects found in complex metal alloys, such as those used for medical implants, and allow researchers to engineer delicate human tissues such as blood vessels.[73] Companies could also leverage space environments to test thermal management and radiation on equipment that must operate reliably in harsh Earth environments.[74]

> *"The thing about space is that we at any moment could have a massive discovery that changes life for everybody."*
>
> **—Mike Lewis, chief innovation officer, Nanoracks[75]**

In addition to manufacturing products in space for use on Earth, opportunities exist to build products in space for use in space. Microgravity permits greater precision in producing parts like mirrors and lenses for spacecraft, and cryogenic temperatures in space are optimal for building bulk metallic glass (BMG) materials used for rovers. And more basic needs can be met as well: NASA has started a garden, known as Veggie, on the ISS to study plant growth in microgravity while enhancing astronauts' diet and well-being.[76]

History offers several examples of industries where government research laid the groundwork for commercial development, including biotechnology, agriculture, and transportation. In the same vein, commercial space stations may soon unleash a disruptive new paradigm for R&D and manufacturing. Costs will likely continue to decrease while microgravity-as-a-service offerings make experimentation more accessible. Considering NASA has already invested more than US$545 million to accelerate the development of commercial space stations,[77] state-of-the-art companies in the next decade could be building their products and services not only in London or Tokyo but also in LEO.

COSMIC CLEANUP

Groundbreaking solutions can create a sustainable orbital ecosystem

It's every launch provider and satellite operator's worst nightmare: Speeding through LEO at about 17,500 miles per hour,[78] a bit of debris or another satellite tears through their cutting-edge equipment, jeopardizing human lives, millions of dollars' worth of technology, or critical communication services. Littering in orbit may be just as hazardous as littering on Earth. Fortunately, debris remediation and mitigation can also be good business.

At present, there are more than 25,000 pieces of debris larger than 10 centimeters in orbit, and many millions more smaller particles, resulting from prior launches, decommissioned satellites, and collisions or explosions.[79] There have been seven known collisions between objects in orbit, and ESA expects that number to increase.[80] Even the ISS, which is heavily shielded, must be moved once per year on average to avoid a potential impact.[81] A critical mass of such collisions could lead to the dreaded Kessler Syndrome: A chain reaction in which every in-orbit collision creates new space debris that leads to further collisions faster than objects can be removed.[82]

> *"The space industry has had a throw-away culture. They've just used rockets and satellites once, then disposed of them."*
>
> **—Nobu Okada,**
> **founder and CEO of Astroscale[83]**

EVERYWHERE
Cyber and defense

Several countries have conducted testing of direct-ascent anti-satellite weapons (ASATs), affecting the amount of debris in LEO. For example, Russia's 2021 test created more than 1,500 trackable shards and potentially hundreds of thousands of smaller pieces. Fragments from the test headed toward the ISS, forcing its seven crewmembers to implement emergency measures until the danger of a collision had passed.[84]

For these reasons, debris remediation and mitigation has become more important than ever, and innovative businesses are tackling this issue in three major areas:

- **Navigating the debris field**. To navigate the debris field, satellite operators are turning to space situational awareness (keeping track of objects in orbit and predicting their movements) and space traffic management (preventing those objects from colliding). Government bureaus such as ESA, JAXA, and NASA have dedicated teams in these fields, and a growing crop of startups including AstriaGraph, Kayhan Space, and Vyoma offer software to help launch providers track, map, and model the location of objects in LEO.[85]

- **Preventing the creation of future debris**. Satellite explosions and collisions are the main source of large orbital debris—a risk that's heightened by more than 1,800 defunct satellites in LEO that can't be maneuvered like active satellites.[86] To combat this, satellite providers are improving design and operations to reduce such malfunctions, and several UN member states have voted to refrain from ASAT tests that cause satellite explosions.[87]

- **Removing debris in orbit**. Some companies are developing experimental methods of capturing floating debris—for example, using magnets or large claws—and escorting it down to Earth to burn up in the outer layers of the atmosphere.[88] Space debris cleanup solutions are in the experimental phase, but many companies are rushing to address the issue given the scale and criticality of the problem. Additionally, government agencies are aiming to shorten the timeline for mandatory de-orbiting of inactive satellites.[89]

LEO is full of business opportunities, yet the trash still needs to be taken out. Tech companies or waste management specialists could seize a lucrative piece of the growing space market by developing solutions that enhance current remediation and mitigation measures. For instance, quantum computing could empower constant and robust space situational awareness optimization, and AI built into satellites and spacecraft can aid in autonomous collision avoidance. Optical (laser-based) communications could also improve response times as organizations share information. If the road to such exponential opportunities in space is to remain safe, organizations will need to clear the litter.

OFFWORLD PRODUCTION

A self-sufficient space economy is underway

Imagine driving from New York to Los Angeles without a single gas station en route. Perhaps the car trunk could hold enough gas to make the journey, but what if a detour is needed? What if a minor engine issue requires a wrench and there's not a repair shop in sight? Historically, space mission planning has been based on such scenarios. The need to transport fuel, repair equipment, and other components and materials can severely restrict mission length and objectives.

In-space servicing, assembly, and manufacturing (ISAM) is set to revolutionize space operations by changing what's possible in space, from extending satellite life spans to building new environments and habitats in orbit. To be continuous, convenient, efficient, and ultimately profitable, space operations should be self-sustaining.

ISAM consists of three categories that enable organizations to think of space as a long-term destination:

- **Servicing** to refuel, repair, replace, or augment existing assets, reducing the expensive and unsustainable replacement of spacecraft every few years.
- **Assembly** of components, which enables organizations to build objects in space that can't be sent from Earth due to launch constraints, or can't be built on Earth at all due to gravity.
- **Manufacturing** in microgravity, in which raw materials are transformed into usable components through additive manufacturing and other processes.

Companies that conduct servicing, assembly, or manufacturing activities on Earth could consider which existing markets or clients might soon appear in the space economy, and how they might adapt and apply current assets to the space market. They can also prepare now to meet the unique challenges and requirements of operating in orbit, as every aspect of the mission life cycle requires a skilled provider.

For example, the ability to repair deep-sea oil leaks under harsh conditions could provide oil and gas companies with a synergistic opportunity to retool existing technologies for use in space. Additive manufacturing companies could 3D-print parts and structures in space, while robotics firms can further reduce the need for human intervention in space repairs.

Those outside the space industry can also study existing efforts by space companies to prepare for the emerging on-demand ISAM economy. For instance, Northrop Grumman is building on its existing mission life extension technologies by first developing robotic satellite servicing vehicles, and further down the road, refueling pods and depots and in-orbit assembly and repair vehicles.[90] And startups like Orbit Fab are already developing in-orbit refueling technologies and services and have tested their hardware on the ISS.[91]

As ISAM providers scale to address the thousands of spacecraft in orbit, the space economy is poised to move away from single-use components toward a more sustainable future. While the market is still nascent, businesses outside the space industry have a strong opportunity to adopt advances in technologies like robotics and AI to reduce the need for human involvement in space repair and assembly. As ISAM also reduces reliance on Earth, future missions should be free to push the boundaries of what can be achieved in space.

DESTINATION: SPACE

Space tourism creates adjacent industry opportunities

If the open road continues to serve as a metaphor for space, then today's space tourism is the equivalent of a Bugatti driving through the countryside. In other words, it's exceedingly rare and attainable by only a select few with extreme financial means. Still, Deloitte estimates that demand for space tourism could reach an annual market of US$3.3 billion by 2035.[92] As this market grows, so, too, will opportunities for Earth-based companies to capitalize on adjoining niches and serve wealthy consumers:

- **Space travel agencies.** Companies like Space Adventures have pioneered early commercial visits to the ISS.[93] As space becomes a more common destination, highly specialized travel agencies will likely develop to help their clients discern the best orbital flight options and negotiate a good price.

- **Accommodations for commercial activity.** As an increase in commercial LEO activity requires hosting more engineers, builders, and tourists in space, hospitality companies have an opportunity to pair their expertise with space providers. For example, Hilton is collaborating with Voyager Space to design communal spaces and crew accommodations for astronauts aboard the Starlab space station.[94]

- **Space insurance.** Space tourism companies are not currently required to offer insurance to passengers, and most life insurance policies exclude space tourism coverage. Existing insurance providers may have an opportunity to tap into a network of high-net-worth individuals likely willing to pay higher premiums for apt coverage. Early movers like Battleface are already offering insurance to space tourists.[95]

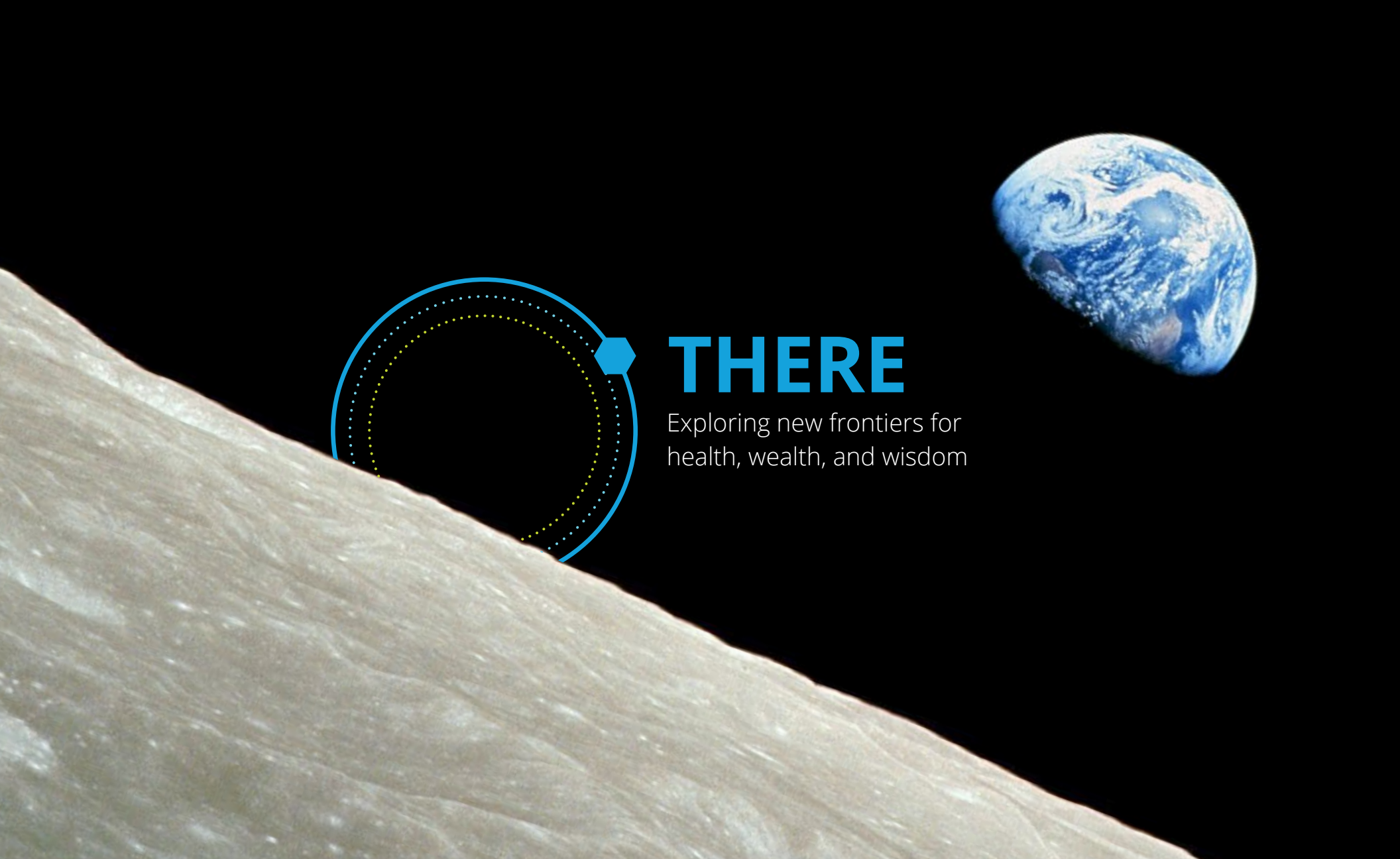
- **Using space travel for Earth travel.** Projecting forward into the future, companies could also explore the potential of point-to-point space travel: flying through space to travel at record speed from one point on Earth to another. For example, SpaceX is designing flights that can travel from New York to Shanghai in under an hour or quickly deliver cargo anywhere on Earth to support disaster relief.[96] Such capabilities, though still far from reality, could offer a new option for global travel.

While space tourism is still years away from being a common occurrence, the opportunities expand well beyond those listed above. Companies in the food industry have already prepared beverages and snacks for consumption in orbit, while specialty clothing and merchandise serve as status symbols signifying a flight to the stars. Italian coffee manufacturer Lavazza partnered with the Italian Space Agency on an experimental microgravity espresso maker and coffee capsules, and Under Armour partnered with Virgin Galactic to design bespoke spacesuits for future space tourists.[97]

Actor William Shatner, who flew to space aboard a passenger flight with Blue Origin in 2021, provides a guide to thinking about the power of space tourism, especially as it becomes more accessible. "I had thought that going into space would be the ultimate catharsis of that connection I had been looking for between all living things—that being up there would be the next beautiful step to understanding the harmony of the universe," he said. "I had a different experience, because I discovered that the beauty isn't out there, it's down here, with all of us. Leaving that behind made my connection to our tiny planet even more profound."[98]

FINAL THOUGHTS

As we discussed in the previous chapter, groundbreaking innovations have opened up space to a broad array of enterprises and serve as a launch pad for the burgeoning LEO economy. Commercial players have a clear opportunity to establish market share in a sector that shares many similarities with Earth and has attracted over US$250 billion in private investments over the past decade. Companies have historically adapted their business models for globalization by knowing what and where to outsource and by tailoring their products and services to different markets. Now, they will need to do the same for the next phase of globalization: post-globalization, or beyond the globe itself.


THERE
Exploring new frontiers for
health, wealth, and wisdom

THERE

Out THERE, in deep space, a new frontier for human health, wealth, and wisdom awaits.

At the beginning of 2023, four NASA crewmembers climbed into a round capsule measuring just over 19 feet in diameter. They had little human contact—except with each other—for 45 days, and any communication with NASA operations was subject to a 10-minute delay. Their survival was entirely dependent on the supplies they packed and the technology inside the capsule.

But the crew was not heading off to some distant planet. Part of NASA's Human Exploration Research Analog mission, they were testing capabilities for a potential future mission to the Martian moon Phobos.[99] During the 45 days of isolation, NASA kept tabs on their physical and mental health to see how astronauts handled a lengthy mission confined to close quarters with their fellow crewmembers. While the crew traveled no farther than the Johnson Space Center in Houston, Texas, their mission is laying the groundwork for a much longer journey.

NASA and other international space agencies, as well as private companies, are actively testing technologies that will be needed to send astronauts back to the Moon and beyond.[100] The first stop is a return to the Moon, as several nations have laid out ambitious plans to head to Earth's natural satellite. From there, it's onward to Mars.

Building long-term habitations off Earth, venturing to distant planets, and mining celestial objects are becoming more plausible with each passing day. Those nations able to crack the challenges that come along with deep space travel—and private companies that support or even lead their own missions—stand to reap substantial rewards in terms of scientific advances, economic activity, and potentially valuable natural resources.

THE HUMAN PROBLEM

How do we solve for space exploration's weakest link?

Global space agencies have already sent robotic probes across our solar system, and, indeed, to interstellar space.[101] Probes can provide a lot of information about the conditions on distant planets and in deep space, but humans have always wanted to explore new frontiers firsthand.

"If our objective is to learn about the universe, we have robot emissaries that do that exceptionally well, and we don't care whether or not they return," says Roger Launius, former chief historian of NASA.[102] "If our objective is to become a multi-planetary species, then the human element is critical." The challenge, however, is that space presents unique threats to human life, such as increased radiation exposure and adapting to different levels of gravity.

People evolved for life here on Earth, but the conditions we will encounter in space are completely alien. “Humans are the weakest link in space,” says Scott Rodriguez, vice president of government programs at Nanoracks, a company contributing to the development of one of the first private space stations.[103]

Irregular sunrises and sunsets disrupt astronauts’ circadian rhythms, making it difficult for them to get deep, restful sleep.[104] Communication delays between space and Earth—only a couple of seconds on the Moon but between 5 to 20 minutes on Mars—can make connecting with loved ones a challenge, leading to feelings of intense isolation.[105] Astronauts receive comprehensive training for dealing with stressful conditions, but space travel is still a dangerous and high-pressure activity.

Space agencies and private companies are tackling some of these challenges as they plan for missions farther out into space. One promising approach is to build more inviting habitats than the utilitarian environments we’ve previously deployed.

Future innovation could provide new solutions. For example, NASA, in partnership with the Translational Research Institute for Space Health, is developing a machine learning algorithm that will read astronauts’ various biomedical markers to predict changes in behavioral health.[106]

Further out, we may see artificial gravity in space: University of Colorado researchers have given credence to age-old science fiction tropes by proposing practical spacecraft with rooms that spin, using centrifugal force to simulate gravity.[107] One speculative concept, O’Neill cylinders, consists of living structures in which large rotating cylinders mimic gravity by taking advantage of centrifugal force. The idea is purely theoretical, in part due to its massive imputed size: 5 miles in diameter and 20 miles long.[108]

While the challenges of radiation and microgravity are very real, the proposed solutions remain very much in development, as shown in the adjacent illustration. Business and technological expertise is needed to develop solutions for some of these unique challenges, be they AI-based counseling services, radiation-shielding clothing and vehicles, or novel preventive medications. In the distant future, perhaps gene editing technologies could be used to create a new generation of astronauts who are more resistant to the perils of long-term space travel.

THE PHYSICAL TOLL OF SPACE TRAVEL

Humans spent billions of years evolving to live here on Earth. What happens when we leave Earth behind?

KEY CHALLENGES

1

MICROGRAVITY

can cause astronauts to lose as much as **50% OF THEIR MUSCLE MASS,** & **1.5% OF THEIR BONE MASS,** as well as contribute to kidney stones

2

TIME IN SPACE

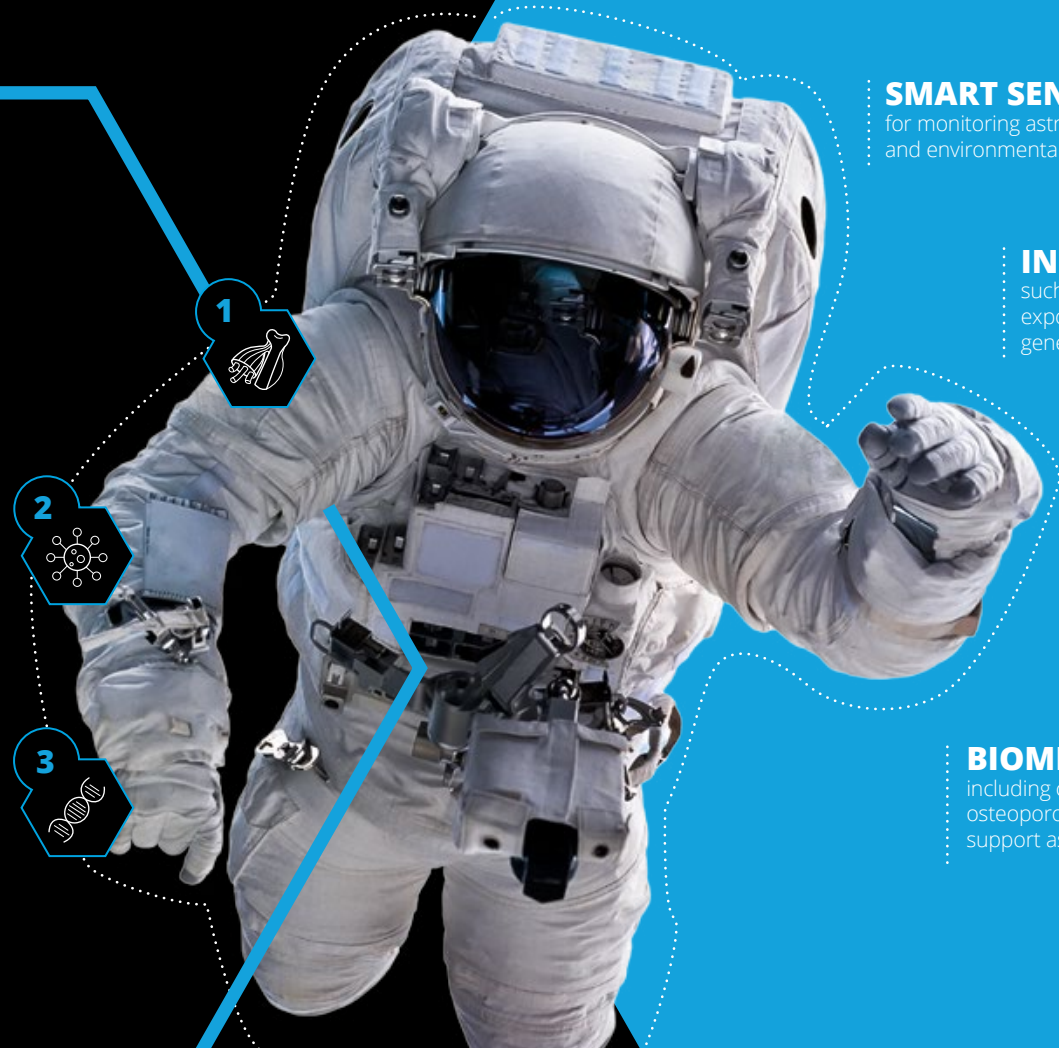
causes immune cells to become overactive, **leading to rashes and allergies**

3

RADIATION

from the sun and deep space damages astronauts' DNA, **causing cataracts, cancers, and other health problems**

Source: Deloitte analysis.



INNOVATION-DRIVEN COUNTERMEASURES

SMART SENSORS

for monitoring astronaut health and environmental risks

INFRASTRUCTURE

such as radiation shielding, light exposure controls, and artificially generated gravity

AI

is poised to provide on-demand mental and physical health counseling to astronauts on long missions

BIOMEDICAL SOLUTIONS

including common medications for osteoporosis and kidney stones could support astronauts' health

**Not an exhaustive list*

LUNAR REDUX

Returning to the Moon is a quantum leap for humankind

The last time a human walked on the Moon was 1972, when two NASA astronauts spent about 75 hours on the lunar surface.[109] In the intervening decades, lunar capsules have been relegated to museum halls. But that's about to change: Government agencies, with contributions from private companies, are planning ambitious missions to head back to the Moon. "The possibility of permanent and sustainable occupation and development on the Moon—that is the most exciting thing over the next decade," says Greg Autry, an American space policy expert and author.[110]

To start, space agencies are ramping up robotic exploration. More than a dozen countries are eyeing the Moon as a near-term destination, with many others planning missions by 2030.[111] Most aim to land robotic rovers, joining a landed rover from China that is already exploring the lunar surface.[112]

But space agencies' plans are more ambitious than just robotic exploration. The goal of the Artemis program—led by NASA in partnership with CSA, ESA, and JAXA—is to build a space station that orbits the Moon and provides support for missions to the Moon's surface as well as to points farther out in space, such as Mars. Known as the Gateway, the space station could even support long-term settlements on the Moon.[113]

There are many reasons to shoot for the Moon. Though it may look barren and desolate, the Moon holds significant deposits of valuable resources (see section "*A new gold rush*"). "If we want to see humans on Mars, if we want to do all the things that are intrinsically human and explore further, we need to go to the Moon," says Sarah Cruddas, space journalist and author. "The Moon is only three days away from Earth, so if something goes wrong you can get back quickly. But it is there that we can learn how to survive on a world that isn't our own."[114]

Landing or sustaining a human presence on the Moon presents many environmental challenges, such as high levels of solar radiation from the lack of a protective atmosphere and magnetosphere.[115] But many of the challenges stem from how we become self-sufficient in space and how different nations and companies cooperate.

Self-sufficiency includes a variety of activities from producing food to creating sustainable energy sources. A wide range of organizations are seeking to tackle these and adjacent problems. For instance, scientists working with the ISS National Lab genetically modified tomato seeds so they could more easily be grown aboard the ISS (and, in turn, on a Moon base),[116] while Rolls-Royce recently announced plans to build a nuclear reactor intended to power a future Moon base by 2029.[117]

Becoming self-reliant in space is one challenge, and cooperation across spacefaring nations may be another. For example, with so many countries planning Moon missions, competition for the best locations on the lunar surface could be fierce.

EVERYWHERE
Regulation

While the comprehensive lunar governance proposed in the Artemis Accords and Moon Treaty (1979) have yet to gain broad support, more targeted regulations that protect the lunar environment from destruction and debris will be critical.[118] These policies would ensure that countries represented by the 10 space agencies currently planning lunar missions "avoid harmful contamination" as mandated by the Outer Space Treaty (1967) and preserve equitable access to settlement sites, research stations, and other lunar resources for countries that are not yet spacefaring.[119]

The challenges of establishing a sustained presence on the Moon will range from the massive to the miniscule, and sometimes it will even be both: For example, lunar dust can be a serious problem for astronauts on the Moon as it can clog machinery, tear away at spacesuits, and have detrimental effects if inhaled.[120] If we are to create long-term habitations on the Moon or Mars one day, mitigating dust—among many other challenges—will be critical to our success.[121]

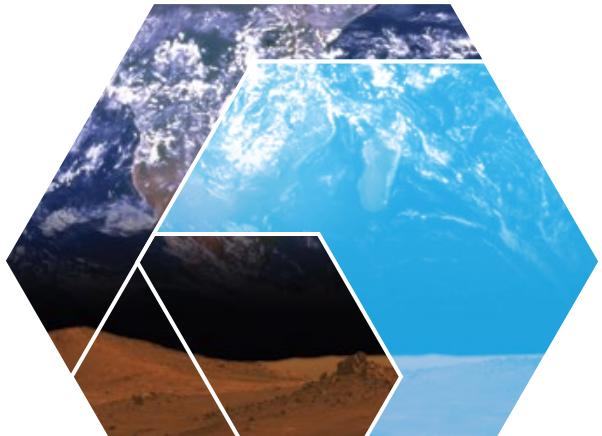
A lunar settlement could become for astronauts what the ISS is today: a center for research and experimentation. It could also host other boundary-pushing activities and serve as a staging ground for trips to Mars or beyond. But there's value to a lunar base beyond those activities: Settlement would likely inspire future generations of space pioneers in ways that are hard to predict. And as for the innovations that could accrue from such a mission, the sky is no longer the limit.

A NEW GOLD RUSH

A universe of valuable resources is ripe for extraction

Whether it's the Moon or more distant asteroids, celestial bodies are often composed of materials that could aid in our exploration of space.[122] "We now understand how the tremendous wealth of natural resources that exist on the Moon, near-Earth objects, and asteroids just beyond the reach of the Moon could completely change the destiny of the human race," says Tory Bruno, CEO of United Launch Alliance, which manufactures and operates rockets.[123]

The Moon holds many resources that could be harnessed to improve life up in space or down here on Earth. From water ice at the dark lunar poles to water molecules embedded in lunar soil on sunlit regions, the presence of H_20 could sustain longer missions as a source of drinking water or be converted to fuel, eliminating the need to transport a full mission's worth



of replenishments from Earth.[124] The Moon also contains helium-3, a rare-to-Earth isotope that has the potential to one day power safe, clean nuclear fusion reactors,[125] as well as rare earth elements (REEs) that could be important to the ongoing electrification of earth's transportation systems.[126]

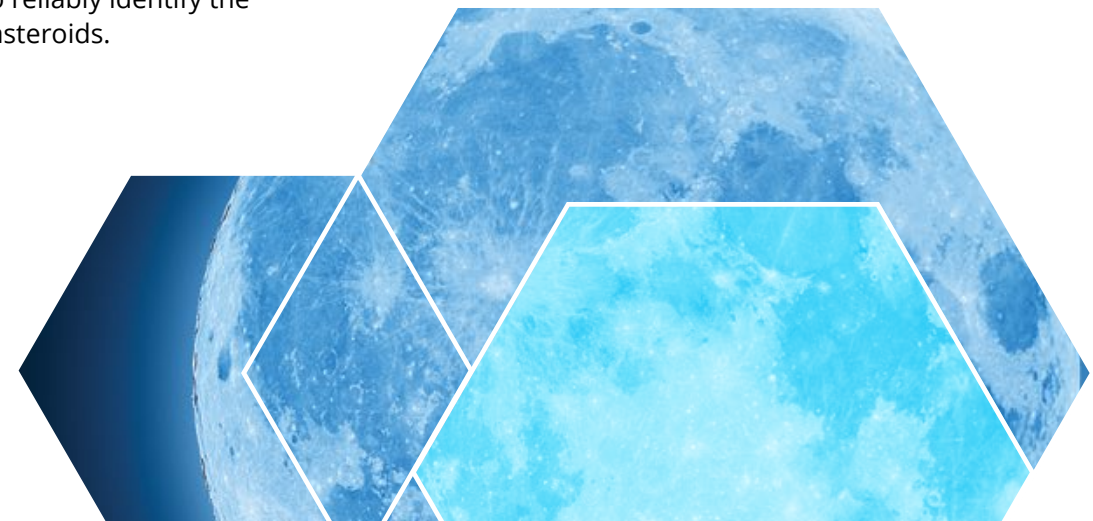
Resource extraction on the Moon isn't just theoretical—successful experiments have proven the concept. China's Chang'e 5 mission has already retrieved rock samples containing helium-3 from the Moon's surface and returned them to Earth.[127] NASA, in turn, is working to devise a business model for the extraction, sale, and use of space resources.[128] As part of this effort to spur commercial activity, the agency recently awarded contracts to four private companies to collect samples of lunar regolith—rocky soil that covers the surface of the Moon—to be used as part of the Artemis program.[129]

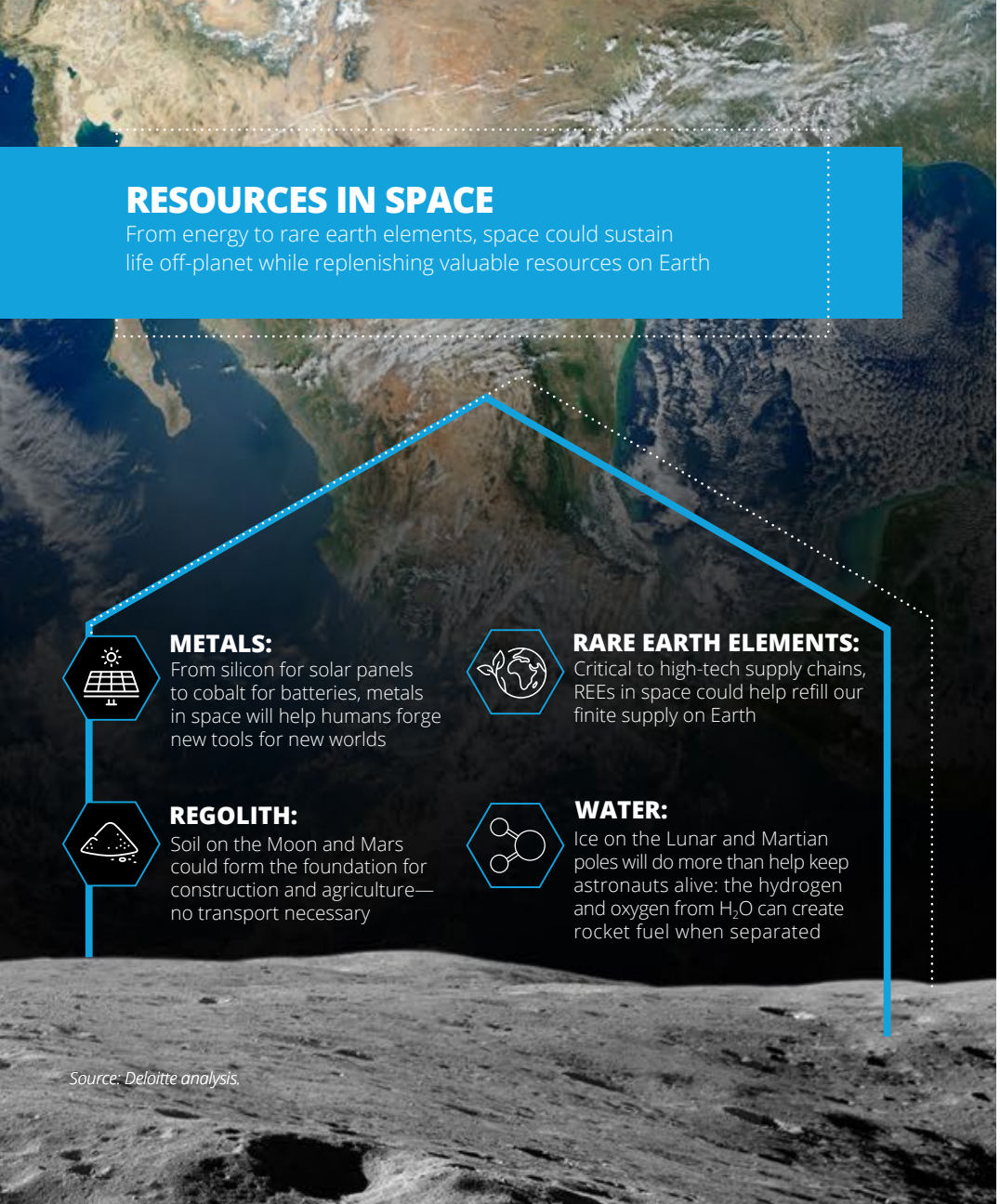
Although the Moon's resources are valuable, asteroid mining tends to grab the headlines. Many asteroids hold significant deposits of REEs and other elements that would be useful for expanding human presence in space. And the concept has proved plausible: Both JAXA and NASA have successfully used landers to collect material from asteroids in deep space, albeit less than a kilogram of material.[130]

Still, asteroid mining at scale remains many years away from commercial viability. A few companies have tried without success due to a number of challenges yet to be addressed, such as the cost of launching equipment to the far reaches of the solar system where asteroids are typically found, and the ability to reliably identify the composition of asteroids.

EVERYWHERE
Regulation

The United States is encouraging private space mining investors with business-friendly regulations, such as the 2015 Commercial Space Launch Competitiveness Act, which gives US companies the right to commercially explore and recover space resources.[131] These policies are aligned with international laws: Existing treaties prevent states from claiming ownership over land in space but do not explicitly forbid them from keeping the resources that they extract there.[132]





THE RED PLANET

Human exploration of Mars is on the horizon

The Red Planet has always inspired people's imaginations. Ancient civilizations from the Babylonians to the Romans named it after their gods of war because they associated its red appearance with blood.[133] The Greeks reviled it for this connotation, while the Romans revered it.[134] Today, though, we know it's neither the bringer of war that the Greeks feared nor the protector that the Romans celebrated—it is one of the next stops in human exploration.

While there may be no warring deities waiting for us on Mars, there's still plenty to be wary of—for starters, getting there. A trip to Mars will likely take at least seven months,[135] and during that time, astronauts will be subjected to cramped spaces, weightlessness in microgravity, and radiation. Humans will need to meet basic safety and physiological needs, and self-sufficiency will likely be a challenge. "What are you going to eat? What are you going to drink? What are you going to wear? How are you going to live?" asks Rod Pyle, editor-in-chief of *Ad Astra*. "Basically, anything that coddles people in some way could be a huge opportunity."[136]

Despite these challenges, credible efforts are underway to land people on the Red Planet. There are many reasons why humans may want to explore Mars. For one thing, pushing the bounds of what's possible and raising the bar for future generations is part of our human DNA—expanding human presence to Mars is no exception. Mars is the second closest planet to Earth, but the most hospitable relative to our other planetary neighbors, so a Mars settlement could also serve as a useful waypoint for long missions to deep space, providing astronauts a place to refuel and relax before heading back out to explore other planets or mine asteroids. At a more distant point, a Mars settlement could be a hedge against extinction events on Earth, increasing the odds that our species won't join the 99.9% of all organisms that have previously gone extinct on our home planet.[137]

There's still a host of technologies that need to be developed before a Mars mission becomes reality. For example, NASA deployed an instrument on the Perseverance rover called the Mars Oxygen In Situ Resource Utilization Experiment, or MOXIE. The goal is developing technology that can create oxygen from the Martian atmosphere and enable a completely self-supporting space settlement. MOXIE has already demonstrated the ability to pull small amounts of oxygen from the atmosphere, but the technology will need to scale to provide mission support.[138] Many of NASA's goals for the Artemis lunar program are intended to develop and prove technologies that will eventually support missions to Mars, with examples including robotic mining equipment and advanced power storage gear.[139] Lunar missions will also test habitation and living conditions, which help prove the feasibility of landing people on Mars.[140] There are many challenges to be solved before humankind can take its first steps on Mars, but pioneering organizations see these challenges as opportunities to overcome orthodoxies and push our species further into the future.

EVERYWHERE
Ethics

As humankind ventures further into space, it's impterative we implement planetary protection procedures for all missions so as not to cross-contaminate organic matter between solar system bodies. Planetary protection refers to the control and prevention of both "forward contamination" (i.e., terrestrial organisms from Earth making their way to another celestial body) and "backward contamination" (i.e., extraterrestrial life making its way back to Earth). Regulating the former is imperative to making sure that, if we do discover life outside of Earth, we remove doubts that the discovered life came from contamination.[141]

FINAL THOUGHTS

Even as humans venture further into the "final frontier," uncertainties remain. The technologies necessary for building and sustaining a presence beyond Earth are in their infancy, and the rules that would govern off-Earth peoples are embryonic. There are many difficult challenges yet to be overcome—but overcoming challenges is one of humanity's strong suits. Surely, settling Mars would have some practical and immediate benefits. But even more so, it would serve as a symbolic victory, marking homo sapiens' arrival as an interplanetary species and heralding the fulfillment of the new space age. It would also signal a new beginning—because once we've settled Mars, the inevitable question is, "what's next?"

CONCLUSION

THE SPACES BETWEEN

The space economy has reached an inflection point in terms of both access and opportunity. This new space age offers a launch window for pioneering companies of all sizes, and in all sectors, to establish sustainable competitive advantages by reimagining themselves, for the first time, as space companies—not as a radical pivot, but as an intentional extension of their core business models.

That said, SpaceTech is just one of *many* exponential technology domains that stand to significantly impact the way we work and live in the next 30 years. Other xTechs, such as BioTech, RobotTech, and EnergyTech, just to name a few, will have similarly profound trajectories. We anticipate that many of tomorrow's most lucrative investment opportunities will lie at the intersections of these technology categories. Leaders willing and able to capitalize on the "spaces between" these domains won't just be market-takers, but market-makers—not just betting on the future, but building it.

As mentioned earlier, we humans are uniquely evolved for life here on Earth but aren't biologically equipped to survive off-planet. Enter synthetic biology, which offers us the rarified opportunity to engineer *in vivo* just as we do *in silico*. Whether through developing lab-grown food to provide self-sufficiency on ever-longer space missions, or utilizing CRISPR gene editing to manufacture an "evolutionary step change" in our human capacity to survive in space, the future of human space travel and biotech is inextricably linked.

And what's a space story without robots? From probes to landers, robots have dutifully served as the intrepid first explorers of space, prepping the most perilous paths so that we humans might one day venture there ourselves. Just as physical robotics are used here on Earth to augment human capabilities and complete work too hazardous for human hands, so, too, will they continue to be used in space.

But how will we power this party? In a world of energy scarcity, space offers us untapped abundance. From space-based solar power (where satellite arrays collect solar power, convert it to microwaves, and transmit it to Earth-based ground stations that turn it into electricity) to helium-3 extraction for nuclear fusion reactors, the keys to unlocking a clean energy revolution on Earth could very well be hiding in the skies above.

The upshot: Today's leading companies, be they in health care or hospitality, energy or entertainment, are just small steps away from making giant leaps into tomorrow's space economy.

And the day after that tomorrow, our successors will look back with admiration at those of us who raised our sights—who recognized that our organizations' futures lay among the stars, and who realized that, by galactic standards, even global enterprises would one day be considered "small businesses."

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Our insights can help you take advantage of emerging tech trends.

If you're looking for fresh ideas to address your business challenges, let's talk.

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Prior to joining Deloitte, Bechtel led Ringleader Ventures, an early-stage venture capital firm he co-founded in 2013. Before Ringleader, he served as CTO of Start Early, a national not-for-profit focused on early childhood education for at-risk youth.

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