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# The Commercialization of Low Earth Orbit

The promise of human spaceflight stands to transform our economy by leveraging the untapped power of LEO

## **Volume 1: The Time is Now**

**Spring 2022**



# 1

## Volume 1: The Time is Now

This work is the first volume in a series of Deloitte Consulting publications on the commercialization of low Earth orbit (LEO) and its associated economic impact. Through this series, we hope to provide more resolution into this unique and rapidly evolving industrial sector and explore the key market segments that will drive growth over the next decade and beyond. We begin the series with our holistic vision for the industry, based on our cumulative analysis of each key market segment within the LEO economy. Succeeding volumes will bring depth to this vision by exploring the key market forces, barriers, and business case metrics driving each LEO economy market segment.



## Mission summary

A vibrant, commercialized low Earth orbit (LEO) is coming. For over 175 years, Deloitte has worked through the commercialization and industrialization of markets, nations, and humanity. From the building of the transcontinental railway to the industrialization of the automobile and the commercialization of the Internet, we have been there. Looking back, the signs of the transformation to come were clear, but in that moment, the path forward was less certain. Today, we observe many of the same pre-commercialization conditions present in the commercial LEO economy. We are on the cusp of enabling a vibrant LEO economy – provided the right investment, incentivization, and intervention efforts occur.

As we look toward the future of LEO, we recognize that the commercial potential of human spaceflight and on-orbit servicing have yet to be realized. Unlocking this commercial potential requires concerted efforts to 1) deliver lower cost, higher cadence human-rated access to space; 2) significantly increase down mass capacity; 3) establish multiple on-orbit destinations, human-rated, depot-centric, and otherwise; and 4) develop the ability to access LEO and execute missions and activities at the speed of business. For this to become a reality, industry must avoid the “field of dreams” model and the pitfall of “if we build it, they will come.” Breaking the cycle is possible – it has happened already in launch and commercial remote sensing – and is required if NASA and others want to transition to be one of many customers for commercial human spaceflight and LEO destinations in the future.

We believe that a vibrant LEO economy includes all on-orbit, LEO-centric activities and operations including commercial remote sensing, satellite communications, on-orbit servicing, and commercial human spaceflight. Supporting these activities are the commercial launch services and ground systems providers that also create and receive economic

benefit from LEO operations. Over the past decade, or since the dawn of the “new space” age, commercial remote sensing, satellite communications, and commercial launch services providers have grown substantially as private investment, commercial innovation, and public-private partnerships have rapidly reshaped the industry.

Our team views the future of the LEO economy and the commercial potential of LEO human spaceflight with optimism – if enabling strategies are implemented to continue pushing the market forward. Public and private infrastructure and capability investments are critical to supporting and growing the LEO economy. For instance, the Commercial Crew and Commercial Cargo programs have invested in the first commercial International Space Station (ISS) airlock and attached commercial modules to actualize US ambitions in space. When viewed holistically, the emerging commercial architectures inclusive of human-rated capsules, next-generation space station modules, satellite servicing vehicles, and ground infrastructure present an optimistic picture - one in which several coherent pathways of investment and returns open pockets of untapped commercial potential that can lead to sustainable commercial LEO activity.

By 2035, our team’s vision for a vibrant LEO economy includes multiple on-orbit destinations, regular human-rated access to space, the industrialization of on-orbit manufacturing, and robust on-orbit services. Realizing this vision could result in an annual market of \$312 billion, creating a nearly 8-fold increase in the economic value derived from LEO today. Like the railroad, automobile, and internet industries that came before it, infrastructure investment, demand incentivization, and additional intervention are still required to get us from today to a vibrant LEO economy. The time and the opportunity to act is now.





## Pre-launch countdown

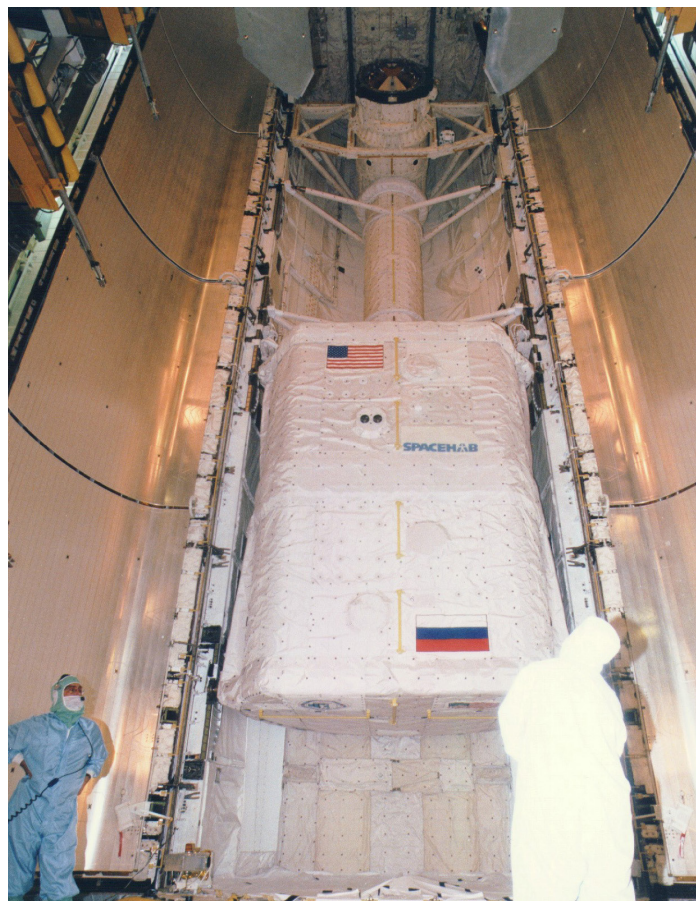
### What has happened over the last 30 years?

Over the past 30 years, human activity in LEO has changed dramatically: first from regular human access to LEO, next to the construction and early commercial operation of the ISS, and finally to the advent of commercial space companies providing on-orbit services, as shown in Figure 1 below.

The Space Shuttle provided regular access to LEO and was instrumental in the assembly of the ISS and continuous human presence in LEO that has been maintained for over 20 years. Nascent commercial activities that started in the Spacelab and Spacehab modules migrated to the ISS where more robust capabilities were available. As the Space Shuttle was retiring, NASA co-invested with industry to establish commercial cargo and crew delivery capabilities. The cargo systems have been operational for several years and the commercial crew delivery systems are demonstrating their capabilities today. Commercial space operations are becoming widely viewed as “normal,” thereby increasing the confidence of other commercial interests to extend operations to space.

As we look forward, the commercial cargo and crew launch systems are available for commercial missions and represent the initial segment of the infrastructure needed for commercial activities that are truly independent of NASA and other US Government entities. What is lacking are multiple commercial platforms, or “destinations” where private entities can “rent” a location and other resources needed to operate. NASA’s NextStep program is supporting the attachment of a commercial module on the ISS to increase the infrastructure available for commercial operators to contract with the module owner, Axiom, to conduct their operations independently from NASA’s oversight. However, the Axiom module will have limited access to scarce resources on the ISS, such as electrical power and communications bandwidth, and thus will be limited in what can be accomplished. NASA’s Commercial LEO Destinations program is providing some “seed money” to stimulate the development of a commercial LEO space station, but their contributions will subsidize only a small fraction of the investment needed to design, develop and deliver to orbit a commercial platform.

For the LEO human spaceflight economy to flourish, there needs to be ample “space to rent” with robust resources available so as not to impose too many limitations on the art of the possible. The most significant barrier to the emergence of a robust economy operating in LEO is a “chicken and egg” cycle that must be overcome. To-date, commercial entities have not raised investment large enough to finance a fully commercial space station, lacking the guarantees of a demonstrated market appetite for the platform. Our research has shown a potential user group unwilling to commit to the costs of developing space-based commercial systems without the existence of a destination that could support them. This market stand-off must be resolved to fully unleash the potential of the market.



In recent history, there has been slow, stuttering commercial growth in the LEO human spaceflight economy, however some players are excited to make the push.





## Understanding the market

### Limiting factors for market growth

Our analyses suggest the following conditions are inhibiting the investment in, and growth of, a self-sustaining LEO human spaceflight market:

- **Market perception**, in our view, is one of the most pervasive barriers to commercial success in LEO. Based on our market segment analysis, we believe there are significant “blind spots” among industry leaders about the potential value of on-orbit activities and pathways to achieve them.
- **Market size** remains a factor due to lack of a diverse set of demand forces as suppliers focus foremost on fulfilling public sector needs. Further, the number and type of potential buyers have historically been served by niche suppliers, making the true market size difficult to ascertain. Until companies feel confident that the potential LEO human spaceflight market is significantly larger than just the funding that NASA is willing to provide, they will not see a need to risk investing in the market.
- **Capital constraints** remain significant, primarily when compounded by the complex landscape of business, financial, and regulatory risks that can lead potential investors to prematurely dismiss LEO investment opportunities as capital intensive, high risk, and low ROI.
- **Physical infrastructure constraints** impose hard limits on capacity, scalability, and ultimately, economic viability for various markets within the LEO Human Spaceflight industry. For example, because there is a limited supply of human habitats in LEO and a limited capacity for on-orbit activities like manufacturing and R&D on the ISS, only a select few companies can participate in the R&D portion of the LEO human spaceflight market at any given time. These constraints will need to be addressed through capital investment to unlock growth potential through 2035.
- **Operational barriers** imposed by current supply-side limitations, such as prohibitive launch operations and maintenance costs linked to “low run” production, are preventing companies from fully participating in the growth of the LEO human spaceflight market. For example, the time to initiate on-orbit activities, disparities in up-mass and down-mass capacities, and on-orbit astronaut availability, are all factors contributing to constrained utilization of on-orbit infrastructure and the microgravity environment.
- **Minimal commercial participation** by the broader US economy, such as the Fortune 500 members, threatens the long-term viability of the LEO human spaceflight industry because startup companies backed by venture and angel investors do not have the economic buying power to drive the industry forward while simultaneously growing it on a sustained basis.



FIGURE 1

## The pace and the growth of commercial space operations has increased continuously in the last 30 years

### 1990

The Hubble Space Telescope was released into orbit to start astronomical observations in space.

Spacehab and Orbital Sciences delivered commercial services primarily to government customers.

1990

### 1995

In preparation for deployment of the International Space Station, the crew of the Space Shuttle began a series of dockings and crew exchanges with the Russian space station, Mir. US astronauts spent months acclimating themselves to living and working in space.

### 1998-2009

On-orbit assembly of the main ISS platform and modules. Continuously crewed since 2000, the platform established the initial location for space-based commercial activity

The Space Shuttle program fundamentally transformed human access to LEO and dramatically increased our ability to establish on-orbit infrastructure.

Establishment of the ISS provided critical infrastructure for value-creating activities on-orbit, as well as advancing life support, power and thermal control, earth observation, and other in-situ scientific capabilities.

### 1991

The Spacelab Life Sciences (SLS-1) mission was the first mission dedicated entirely to understanding the physiological effects of spaceflight on humans and animals.

### 2001

Limited tourism occurred from 2001 to 2009 with services by Roscosmos. From this point on, over 50 other companies/agencies were enabled to complete commercial activities on the ISS.

2000

## 2010

Through the Commercial Crew Development Program, NASA invested in sequential rounds of funding to stimulate development of new commercial crew transport capabilities. Since 2014, NASA has awarded two companies associated with the Commercial Crew nearly \$7 billion, equating to anywhere from \$50-350 million per mission.<sup>iii, iv</sup>

## 2020

NASA selected Axiom from proposals submitted through Appendix I of the Next Space Technologies for Exploration Partnerships (NextSTEP) program.

## 2021

CLD Phase 1 procurement was formally released July 12, 2021 to establish Space Act Agreement(s) for free-flyer station.

## 2011

ISS has provided a platform for US commercial industry research and technology demonstrations via CASIS ISS National Laboratory program.

2010

The end of the Space Shuttle program in 2011 necessitated commercial contracts from NASA and other international partners.

NASA has committed to the Commercial LEO Destinations (CLD) mission to continue developing technologies enabling a focus on deep space missions (lunar orbit, return to lunar surface, and Mars expeditions).

## 2010

ISS has been an accelerator and a test bed for additional on-orbit technologies that will enable the LEO market, including expandable habitats, medical research and life support, and interoperability standards for avionics, docking, and more.

## 2010

Commercial resupply services were quickly established by US-based providers SpaceX and Northrop Grumman (formerly Orbital Sciences, then ATK). The first commercial supply launch took place in 2010. Meanwhile, the only human-rated launches were on the Soyuz, leading to reliance on Roscosmos.

2020





## Understanding the market

### The strategic significance of human spaceflight

Despite these barriers, our projections indicate that the LEO human spaceflight market currently generates approximately \$40 billion in value annually and that the market continues to move toward commercialization, particularly with respect to satellite remote sensing and launch services activity. These trends are demonstrated by several examples of recent announcements that are lowering key barriers on both the supply and demand side to enable increased market activity.

On the supply side, the LEO human spaceflight market has observed a significant increase in competition among service providers in recent years. With the commercial crew program slated to provide NASA with astronaut launch services, the number of potential seats available to NASA and commercial passengers has expanded from zero seats in 2019 to a projected 450 seats between 2020 and 2030 when accounting for capsule reuse. In recent years, individual seat costs have fallen to \$55 million<sup>v</sup>, down from a prior price of \$70 million per seat<sup>vi</sup>, and the continued success of the Commercial Crew program and additional private astronaut demand could push per-seat costs below \$30 million by the end of the decade. Additionally, other competitors in launch services have established new un-crewed capabilities, which is helping to further grow the LEO human spaceflight market. Fueling both crewed and un-crewed technologies are emerging companies such as Relativity Space, which has developed a large-scale additive manufacturing printer that has significant implications for the advancement of all launch services.

On the demand side, space tourism providers are accelerating their efforts to bring consumer space access to market. For example, Blue Origin and Virgin Galactic have elicited interest from consumers and provided an initial assessment of demand. As of November 2021, roughly 700 people have reserved tickets up to \$450,000 each to fly to the edge of space on Virgin Galactic<sup>vii</sup>, while nearly 7,600 people registered to bid to fly alongside Jeff Bezos on the first commercial flight of Blue Origin's New Shepard vehicle.<sup>viii</sup>

This level of demand raises the question of how much the industry will grow in the coming years. While year-over-year growth in the total space economy from 2015 to 2020 has been modest at 4.4%<sup>ix</sup>, our analysis suggests that with new investment from both public and private sector players, more rapid acceleration is possible within the LEO human spaceflight market. Specifically, based on our cumulative modeling of the LEO economy segments, our models indicate that in a scenario involving higher annual investment the industry could achieve upward of 17%

compound annual growth from 2022-2035. This would translate to a significant increase in market size from approximately \$40 billion in 2022 to as high as \$312 billion in 2035.<sup>x</sup> Such growth demonstrates a compelling case for public sector efforts directed at stimulating new economic activity in the industry.

Read more in *Volume 2: An orbit for everyone*





## Understanding the market

### Choosing a destination: a vision for 2035

When imagining a future for a commercialized low Earth orbit, we look to the Zoom In, Zoom Out framework to identify near-term actions most likely to achieve an end-state vision. Our research into strategic planning efforts across US public companies reveals that a 10–20-year timeframe is the ideal timeline for a desired end state. As such, we have centered our vision for the future around the art of the possible in 2035.

When looking towards the future of LEO, the 2035 target end-year is useful given that it is sufficiently beyond the Artemis return to the Lunar surface, the retirement of the ISS, and the introduction of multiple crewed launch systems and potential commercial LEO destinations. By 2035, we expect that much of the technological, industrial, and economic transformation that we are imagining today has the potential to occur. Even with wildly varying rates of maturity, the synergistic maturation that needs to happen to enable high-growth market outlooks can occur over this timeline.

By 2035, our vision for a vibrant LEO economy includes multiple on-orbit destinations, regular human-rated access to space, the industrialization of on-orbit manufacturing, and robust on-orbit services. Our analysis indicates that realizing this vision could result in an annual market of \$312 billion, creating a nearly 8-fold increase in the economic value derived from LEO today.

This publication is just the start of our *Commercialization of Low Earth Orbit* series. In succeeding volumes, we will bring depth to our vision by exploring the key market forces, barriers, and business case metrics driving each LEO economy market segment. Our approach is presented in more detail, along with the Zoom In, Zoom Out framework and our method for scenario planning, in *Volume 2: An Orbit for Everyone*.

Given the rapid pace of change and investment within certain segments of the commercial space industry, we acknowledge that the outlook for 2035 will require continual analysis and reassessment. We believe that this is best done collaboratively and invite you to join us in imagining the future and incentivizing today.

## Let's Talk.

# Let's Talk

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Deloitte is confident that we have and will continue to demonstrate a strong understanding of the space enterprise. Our 360-degree perspective underscores our fresh and holistic thinking about challenges in space. We possess differentiated knowledge of New Space, as well as outside perspectives on the United States Department of Defense, Government, open architecture, and enterprise transformation. Our experts have launched rockets, deployed satellite remote sensing systems, implemented global telecom solutions leveraging commercial satcom, analyzed the commercial space economy, and secured private investment for space technology companies. An advantage we have over our competitors is the broad array of resources available at any given time, allowing us to leverage experience, expertise, eminence, skills, credentials, and – most importantly – perspectives that very few can match.

**For more information on Deloitte Space services and solutions, contact our team:**



**Brett Loubert**  
Principal  
US Space Leader  
Deloitte Consulting LLP  
[bloubert@deloitte.com](mailto:bloubert@deloitte.com)  
+1 240 994 5861



**Kathleen Purtill**  
Principal  
Civil Sector Leader  
Deloitte Consulting LLP  
[kpurtill@deloitte.com](mailto:kpurtill@deloitte.com)  
+1 571 331 2423



**Diane Ashley**  
Managing Director  
Defense Space Leader  
Deloitte Consulting LLP  
[diashley@deloitte.com](mailto:diashley@deloitte.com)  
+1 703 944 1355



**Keith Pfromer**  
Managing Director  
Civil Space Leader  
Deloitte Consulting LLP  
[kpfromer@deloitte.com](mailto:kpfromer@deloitte.com)  
+1 703 939 0011



**Bill Bastedo**  
Specialist Executive  
Space Mission Systems Engineering  
Deloitte Consulting LLP  
[wbastedo@deloitte.com](mailto:wbastedo@deloitte.com)  
+1 713 982 3648

## Key contributor

Jeff Matthews, Specialist Leader, Deloitte Consulting LLP

## About the production of this report

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# Endnotes

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- <sup>ix</sup> "The Space Report." *The Space Report Online*, Space Foundation, 2021, <https://www.thespacereport.org>.
- <sup>x</sup> Based on Deloitte proprietary analysis including modeling of all LEO economy market segments.

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