SPACE RACE:
Commercialising the Path

Point-of-View

July 2021

BDO

Contents

Journey into space started 50 years ago with nations' race making first steps using moderate technology at hand…

Key elements of space journey 50 years ago

Nations' Space race

Industry drivers:
ideology & national pride

Single use rockets
& costly shuttles

First milestones achieved:
1st man in space
1st step on the Moon
1st space station

Source: BDO Centers analysis

…and continues with visionary leaders driving space into the era of affordable travel and game-changing projects

Key elements of space journey now

Billionaires' Space race

Industry drivers: commercialisation & business leaders' aspiration

Ambitious projects are about to come true: moon base, people on Mars & beyond, space tourism

Reusable, cheap, and big rockets

Source: BDO Centers analysis

Active exploration and rapid growth of the global space industry enable multilateral perspectives in the future

Key space players

SPACEX

Elon Musk

Enable the colonisation of Mars

BLUE ORIGIN

Jeff Bezos

Build the low-cost road to space to enable near-Earth colonisation

GALACTIC

Richard Branson

Build the Spaceline for Earth to make space travel available for everyone

Prospective in-space industries

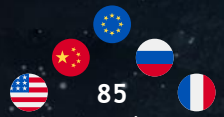
- Space mining
- Space logistics & Orbital transportation
- Space hospitality & Travel
- Space manufacturing & Construction
- Space farming

2020

315 Bn USD

2040

1,053 Bn USD



85 countries operating in space in 2021

Upcoming missions

	Governmental agencies	Private companies
MOON	Artemis	SpaceX, Rocket Lab
MARS	ESA, Roscosmos	SpaceX

Predictions of future development

- Asteroid settlements
- International Moon village
- Artemis Base Camp
- Greenhousing in space
- Sustainability in space

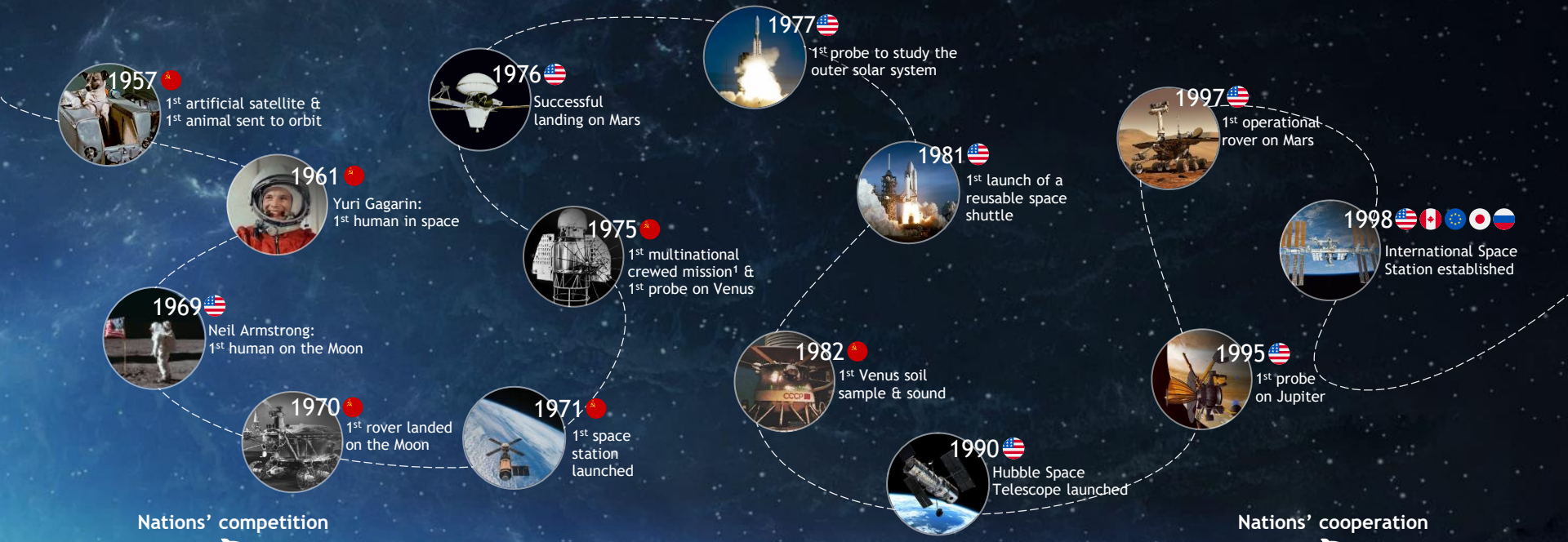
Source: BDO Centers analysis

FROM RACE OF SUPERPOWERS TO RACE OF BILLIONAIRES

Space exploration started more than 50 years ago from small steps in satellites assembly… 50 years ahead and the world observes a tremendous boost in space technologies and missions… Future of space exploration has become close to humanity like never before

BDO

In just 50 years of exploration, there was a tremendous boost in the space industry, starting from the Moon mission



Source: Space — The Timeline: 50 Years of Spaceflight — [2012]; John M. Logsdon, Britannica — Space exploration — [2021]
Notes: (1) Included members from the USSR and the USA

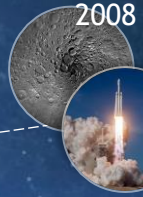
A New Space Age is boosted by big private companies entering the space, indicating commercialisation of industry

2001
Dennis Tito:
1st space tourist

2003
China's 1st manned earth orbiter

Space Columbia broke apart at landing

2004 GALACTIC
1st human spaceflight launched by a private company & 1st private astronaut



2008
Discovery of lunar water (ice)

SPACEX
1st successful launch of a privately developed rocket

First private companies

2012 SPACEX
1st privately owned company to carry cargo to ISS[1]

1st human-made probe reached interstellar space

2014
1st soft landing on a comet

2018
1st operating rover on an asteroid

ROCKET LAB
1st privately developed rockets launched from a private spaceport

2019
1st soft landing in the far site of the Moon & 1st germination of seed on another celestial body

2015 SPACEX
1st propulsive landing of an orbital rocket

BLUE ORIGIN
1st propulsive landing of a suborbital rocket

2020 SPACEX
1st orbital human spacecraft launched by a private company

2021 SPACEX
NASA picked SpaceX to land Americans on the Moon

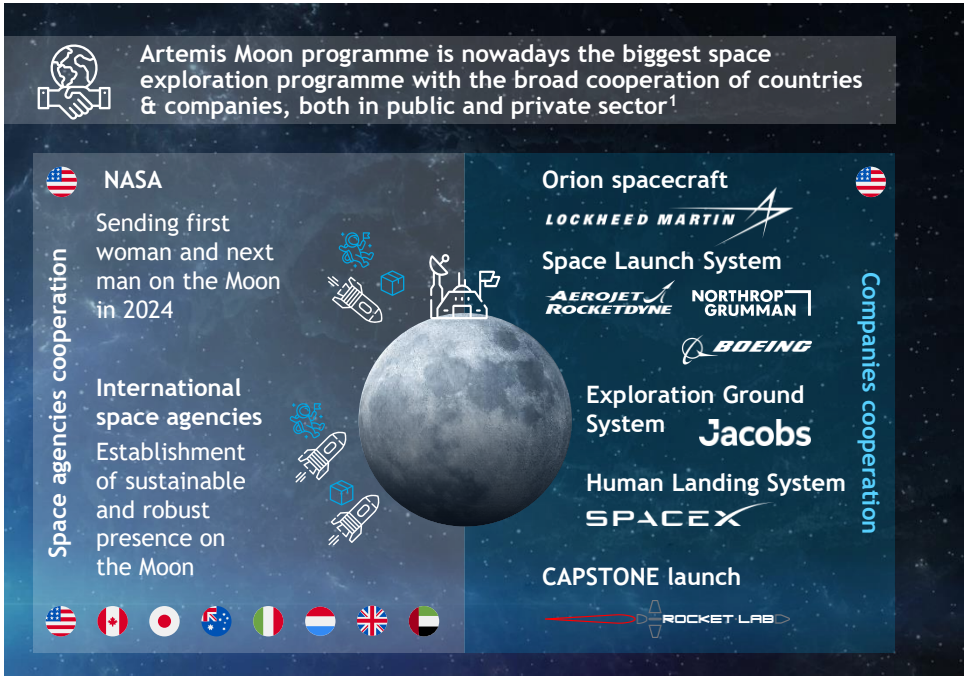
Abundance of private companies

Source: Space — The Timeline: 50 Years of Spaceflight — [2012]; John M. Logsdon, Britannica — Space exploration — [2021]
Notes: (1) International Space Station

In XXI century, the cooperation of countries & companies is the most effective approach to conduct space exploration

Humanity, governments, and big enterprises have common goals in space

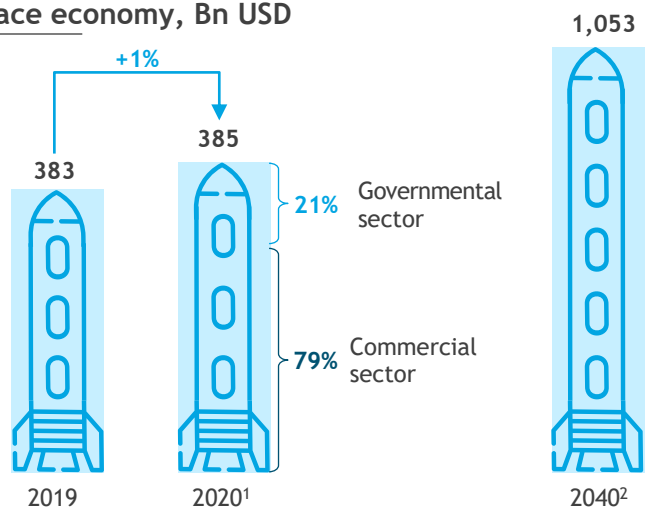
- **Increase capabilities and decrease costs** for future human and robotic space missions
- **Space-based research and observation of Earth** to improve life on Earth and deal with environmental problems
- **Extend human knowledge of space**, understanding of Earth, solar system, and the universe that may support life
- **Explore and expand human presence** beyond Earth and after that beyond the solar system
- **Stimulate economic growth** by the development of space-to-earth and space-to-space economy



Source: NASA — Exploration Mission Integral to 2020 National Space Policy — [January 2021]; NASA website
Notes: (1) Selected companies are shown on the scheme

The global space economy is projected to reach 1 Tn USD by 2040 with the commercial sector driving the market

Global space economy, Bn USD



85 countries operating in space[3]

NASA — leading space agency
Budget 2021: **23.3** Bn USD

466 spacecraft deployed
54% — by private companies[4]

Governmental investment on space exploration

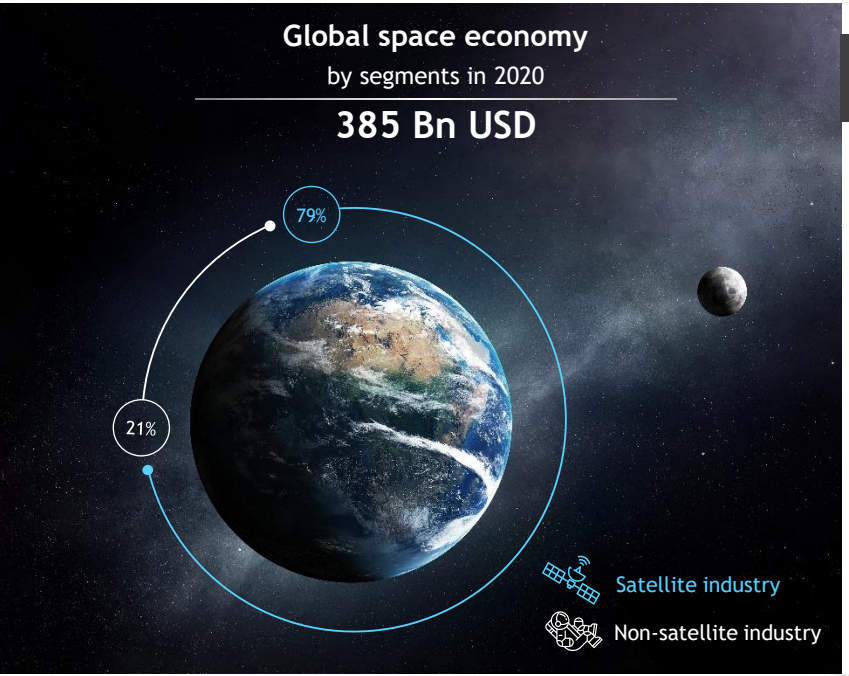
during 2019-2029, % of total

258 Bn USD

- Transportation
- Orbital infrastructure
- Astronomy, astrophysics & heliophysics
- Moon exploration
- Deep space exploration
- Mars exploration

Source: Space Foundation — The Space report — [Q2 2020]; Euroconsult — The Space economy report — [2020]; Statista website
Notes: (1) Based on the research of Euroconsult; (2) Based on the forecast of Morgan Stanley and Bank of America; (3) As of 2021; (4) In 2019

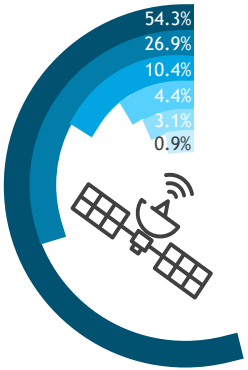
The satellite segment makes up 79% of the space economy with the USA as a leader in satellites quantity and launches



3,372 satellites are active in 2021[1,2]

56.3% **12.2%** **5.2%**

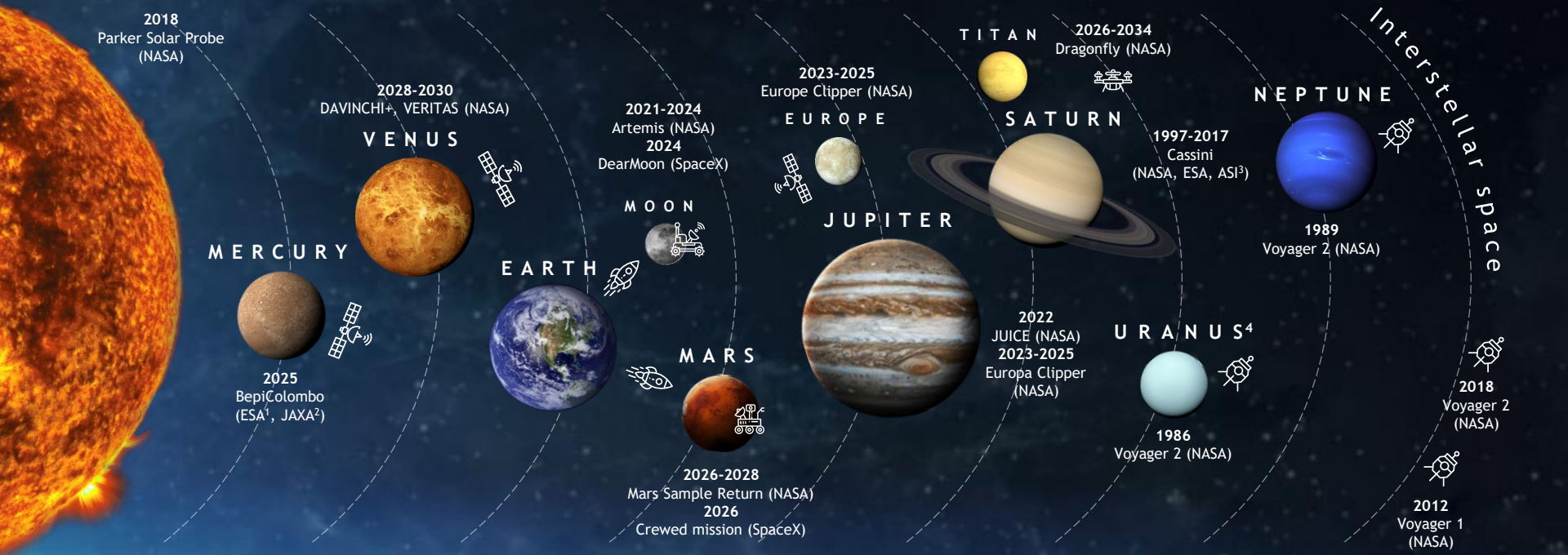
Satellite uses by operational purposes in 2021



- Communications
- Navigation / Positioning
- Earth observation
- Space science / Observation
- Technology development / demonstration
- Earth science & Other purposes

Source: Space Foundation – The Space report – [Q2 2020]; Union of Concerned Scientists website; Statista website
Notes: (1) As of May 2021, the private company SpaceX owns 1,500 satellites; (2) Top-3 countries by active satellites with a total share of 73.7%

Exploration of space is focused on finding new ways to unlock the mysteries of the solar system and beyond



Source: NASA website; SpaceX website
Notes: (1) European Space Agency; (2) Japan Aerospace Exploration Agency; (3) Italian Space Agency; (4) A number of dedicated exploratory missions to Uranus have been proposed, yet none have been approved as of 2021

Moon exploration started with the US mission in 1969, yet nowadays more private companies enter the Moon race

Nations landed on the Moon[1]

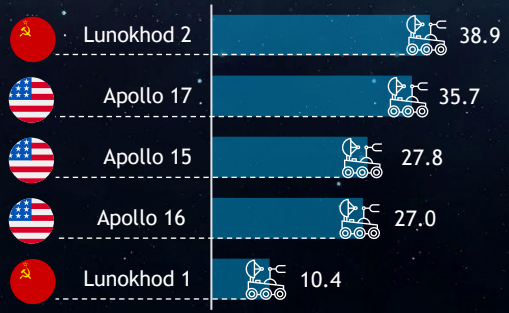
30 | 2
23 | 1
7 | 1

64 successful[2] Moon missions

Major upcoming moon missions of private enterprises

- 2024: Space X DearMoon
- 2023: Firefly Aerospace Blue Ghost; Blue Origin Blue Moon
- 2022: Masten Space Systems / Draper Lab XL-1 / Artemis-7
- 2021: PTScientists Alina; Rocket Lab Photon

Distance travel by Moon rovers, kilometres[3,4]



Key reasons to explore the Moon

- **Water and oxygen** to produce rocket fuel and establish a human base
- **Precious metals, rocks, and rare earths** to create building & raw materials
- **Helium-3** to create fuel suitable for fusion energy generation

NASA budget on the Moon missions

Project Apollo 1960-1973
25.8 Bn USD or 257 Bn USD[5]

Artemis programme 2021F-2025F
28.0 Bn USD

Source: NASA — NASA's Lunar Exploration Program Overview — [September 2020]; Statista website; National Geographic website
Notes: (1) As of 22 July 2019; (2) Successful and partially successful missions only; (3) As of July 2020; (4) Diameter of the Moon is 3,474.8 kilometres; (5) Brought to current prices and inflation adjusted

The first human-crewed mission is the main focus in Mars exploration for the space industry in the next years

Nations completed successful missions on Mars[1]

- 17
- 1
- 2
- 1
- 1
- 1

7-10 months average time of the trip to Mars

Major upcoming Mars missions

By countries

2022-2023

ESA / Roscosmos: ExoMars 2022 Rover and Surface Platform

2026-2028

NASA: Mars Sample Return with the aim to bring samples from the surface of Mars to Earth

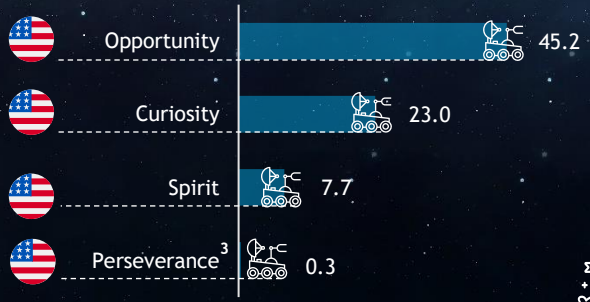
By private company

SpaceX:

2024 — uncrewed mission to Mars

2026 — crewed mission to Mars

Distance travel by Mars rovers, kilometres[2]



Key reasons to explore Mars

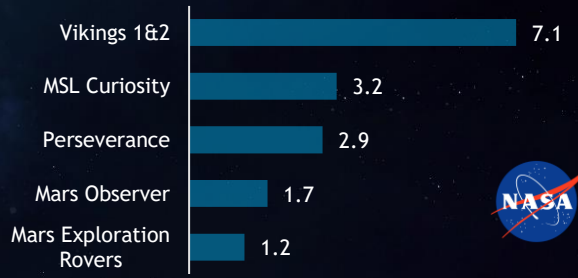
Mars's **land area** is almost equal to the surface area of Earth's continents

Water is locked into the Mars icy polar caps

Mars still has **decent sunlight** as it is about half as far from the Sun as Earth

Middle-term goal — human missions to Mars

Estimated life-cycle costs of Mars missions by NASA, inflation-adjusted, Bn USD[4]



Source: Deutsche Welle website; Statista website; NASA website; ESA website; CNBS website; SpaceX website; Media overview

Notes: (1) As of May 2021; (2) As of July 2020; (3) As of 20 May 2021; (4) As of February 2021

Except for the Moon & Mars, there are also other celestial bodies considered to be attractive to search for life

Venus

Key facts

225 Earth days
orbital period[1]

1.1 times
smaller than Earth

4 months
average time of the trip to Venus[2]

0.7 AU[3]
distance from the Sun

Current and past Venus missions by country[5]

8 | 3 | 2 | 1

Major upcoming Venus missions

VERITAS	DAVINCI+	EnVision
2028	2029-2030	2031-2033
Orbiter	Atmospheric probe	Orbiter

Key reasons to explore Venus

- Venus and Earth are alike in **size, density, and gravity**
- Astronomers detected **phosphine,** which is a possible sign of life
- In some areas, pressure and temperature are quite **Earth-like**

Europa[4]

Key facts

3.5 Earth days
orbital period[1]

4.1 times
smaller than Earth

>36 months
average time of the trip to Europa[2]

5.2 AU[3]
distance from the Sun

Current and past Europa missions by country[5]

9 | 2

Major upcoming Europa missions

JUICE	Europa Clipper
2022	2023-2025
Orbiter	Orbiter

Key reasons to explore Europa

- **Liquid water ocean** is present today and is in contact with the **rock**
- Atomic particles trapped by Jupiter crash into Europa and produce **compounds** that could be **used for living**
- Europa's seafloor could be heated by its **constant flexing** that could create **primordial life**

Source: NASA website; Media overview
Notes: (1) Length of the year; (2) Using existing humanity technologies; (3) Astronomical unit – approx. 149.6 million kilometres; (4) Moon of Jupiter; (5) As of June 2021

ROADS TO SUCCESS IN EXPLORING SPACE

Reaching the stars and beyond — ambitious plans and big dreams of key players are becoming the powerful engine of space industry development nowadays

BDO

Active involvement of private investors in the commercial space race could take the space industry to new frontiers

Elon Musk

SpaceX

2.9 Bn USD

Starship takes astronauts to the Moon

Jeff Bezos

Blue Origin

579.0 Mn USD

Design a human-landing system

Peter Beck

Rocket Lab

10.0 Mn USD

Launch a CubeSat into lunar orbit

Max Polyakov

Firefly Aerospace

93.3 Mn USD

Deliver science and technology payloads

Richard Branson

Virgin Galactic

45.0 Mn USD

Flight and integration services

Tim Ellis & Jordan Noone

Relativity Space

3.0 Mn USD

Place CubeSats into low Earth orbit

Red Whittaker

Astrobotic Technology

279.0 Mn USD[1]

Deliver payloads and VIPER to the Moon

Amount of recent contract with NASA

Source: AERTEC Solutions website; CNBC website; NASA website; Companies' websites
Notes: (1) Total amount of two contracts

Elon Musk, Jeff Bezos, and Richard Branson are pioneers of the commercial space race in the XXI century

Jeff Bezos

Net worth: 198.9 Bn USD[1]

Company: Blue Origin

Foundation year: 2000

BLUE ORIGIN

Space goal: Enable Moon and near-Earth colonisation

Key milestones

1st successful vertical landing of the suborbital rocket

16 successful test flights of the New Shepard suborbital rocket

July 2021 scheduled launch of the first commercial tourist space flight

Q4 2022 first test flight of the new heavy rocket New Glenn is scheduled

Elon Musk

Net worth: 155.5 Bn USD[1]

Company: SpaceX

Foundation year: 2008

SPACEX

Space goal: Enable Mars colonisation

Key milestones

1st private company to successfully launch a rocket into space

1st private company to bring humans to the ISS (10 astronauts)

May 2021 first full successful test flight of Starship

2026 cargo & crew missions to Mars

Richard Branson

Net worth: 5.0 Bn USD[1]

Company: Virgin Galactic

Foundation year: 2004

GALACTIC

Space goal: Build the Spaceline for Earth

Key milestones

>600 Seats booked on the commercial space flight

Collaboration of the development of supersonic jet

May 2021 spacecraft successfully completed the crewed suborbital test flight

Early 2022 start of the first scheduled commercial tourist flight

Source: Aerospace security website; SpaceX website; Blue Origin website; Virgin Galactic website; The Financial Times — Jeff Bezos's Blue Origin says it will take a civilian to space in July — [May 2021]; BBC — Virgin Galactic rocket plane flies to edge of space — [May 2021]

Notes: (1) As of 22 June 2021

Jeff Bezos, the richest man in the world, applies his ‘slow and steady’ approach to building a solid space business

Jeff Bezos
and his main companies

amazon BLUE ORIGIN The Washington Post

Origin

Born on 12 January 1964

Albuquerque, New Mexico, USA

Worth and ranking

Net worth: 198.9 Bn USD[1]

in Forbes Billionaires List (2021)

in Forbes Innovation Leaders (2019)

Social media[1]

2.4 million followers on Twitter

241 tweets

Space goal

Build the low-cost road to space to enable near-Earth colonisation

Road to success through making slow but relentless progress

1994	1997	1998	2000	2015	2018	March 2020	May 2020	Starting from 2021
Amazon foundation	**Amazon goes public**	**Amazon expansion**	**Blue Origin foundation**	**Blue Origin first milestone**	**The richest man**	**Amazon record capitalisation**	**Blue Origin contract with NASA**	**Space is in focus**
Online bookshop set up	54 Mn USD raised on NASDAQ	Amazon product range was expanded. Revenue reached 600 Mn USD	Space company founded, yet remained low profile until 2006	New Shepard space vehicle successfully rocketed into space and landed back	Bezos became the richest man in the world with net worth of 112 Bn USD	Amazon reached 1 Tn USD market capitalisation	NASA awarded Blue Origin 579 Mn USD to develop a potential lunar lander	Bezos plans stepping down as Amazon CEO and focus on Blue Origin

Source: Biography — Jeff Bezos [2021]; Business insider — After Amazon, Jeff Bezos will devote his time to building multi-billion dollar rockets — [2021]; Forbes website
Notes: (1) As of 22 June 2021

While performing test flights & competing for Moon mission contract, Blue Origin is yet to become commercially viable

KEY FACTS BLUE ORIGIN

Founded
2000

Headquarters
Kent, Washington, USA

CEO
Bob Smith

19 patents and **54** trademarks[1]

Funding[2]
Bezos intends to fund Blue Origin with 1 Bn USD per year from sales of his equity in Amazon

Number of employees
3,390[3]

KEY PROJECTS

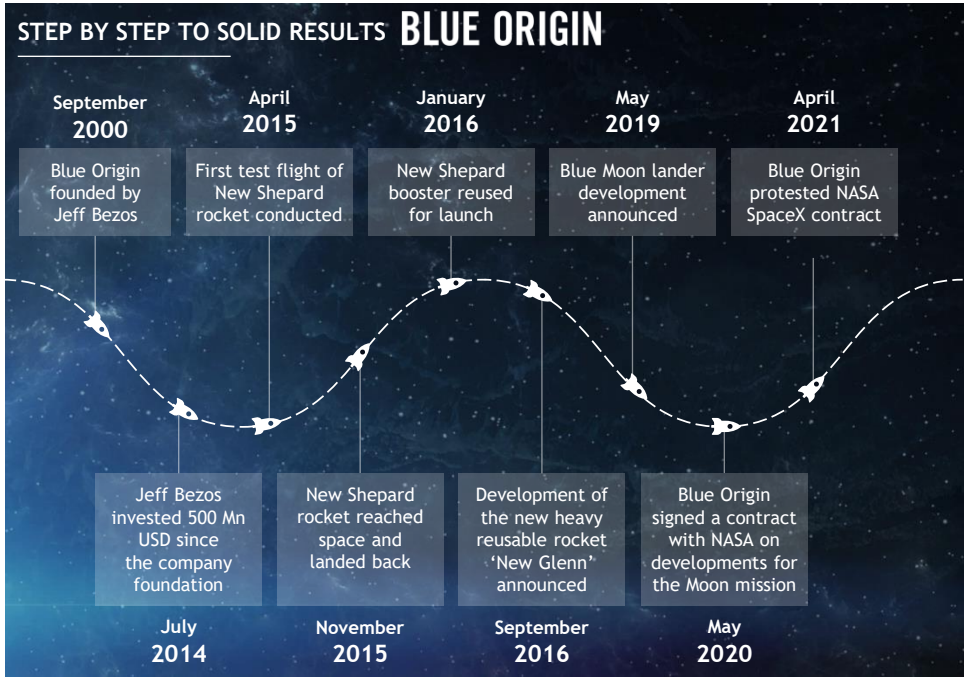
Contract with NASA on Earth observation missions, planetary expeditions, and satellite launches

Contract with NASA on the initial design of a human-landing system for the 2024 Moon mission Artemis

amazon | project kuiper

Participation in the Amazon Project Kuiper — a launch of 3,236 satellites constellation to provide high-speed internet to people around the world

STEP BY STEP TO SOLID RESULTS BLUE ORIGIN



Source: Craft website; Spacenews website; MIT Technology Review — Blue Origin could definitely use more Jeff Bezos in the next decade — [2021]
Notes: (1) As of January 2021; (2) In 2017-2018; (3) As of June 2021

Preservation of the planet and near-Earth space colonies are at the heart of Bezos' vision for civilisation evolution

Bezos' concern:

In the XXI century, humanity will face a shortage of energy resources as well as an ecological crisis

10.9 billion Global population in 2100[1]

124% Growth of global energy demand in 2100 vs. 2015[2]

Fossil fuel reserves will run out by[3]:

2052 Oil **2060** Gas **2090** Coal

+2.9°C Global warming by 2100[4]

1.1 m Sea level rise by 2100[5]

Bezos' vision:

Transfer of heavy, dirty manufacturing to space and development of near-Earth colonies will help humanity deal with the potential crisis

Colony design inspired by O'Neill cylinders[6]

Size and shape
Milewide spheres or cylinders

Gravity
Artificially created by spinning

Energy
Continuous sunshine

Resources
From Earth, Moon, and asteroids

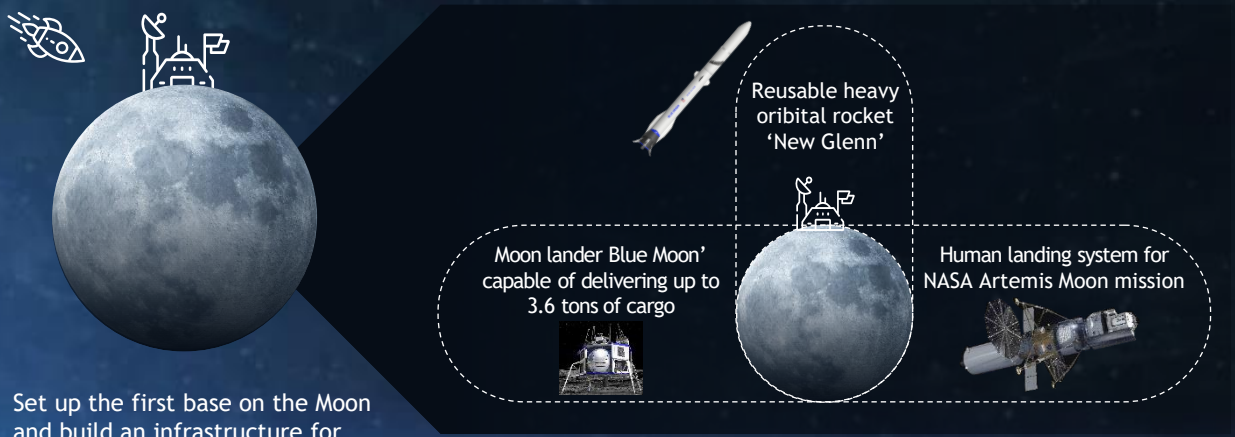
Specialisation
Industrial, residentional, farming, recreation, etc.

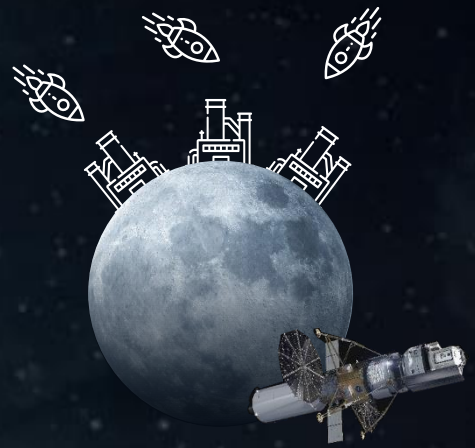
Source: UN website; Climate Action Tracker website; IPCC website; Arstechnica — Jeff Bezos unveils his sweeping vision for humanity's future in space — [2019]
Notes: (1) According to the World Population Prospects 2019 by the UN; (2) Under the medium scenario of population growth by the UN; (3) According to the Millennium Alliance for Humanity and Biosphere website; (4) Global temperature increase compared to the pre-industrial level, projected under current policies; (5) According to IPCC special report 2019; (6) Space settlement concept proposed by American physicist Gerard K. O'Neill in 1976

According to Jeff Bezos, base on the Moon is the first step to building an infrastructure for space colonisation

Idea of the Moon colonisation by Jeff Bezos

It is time to go back to the Moon — this time to stay.
Jeff Bezos





1 Set up the first base on the Moon and build an infrastructure for space travel and space economy

2 Transform the Moon into the manufacturing sector of the universe

22 Source: Media overview

Elon Musk's out-of-the-box thinking made him one of the most influential businessmen in the space industry

Elon Musk
and his main companies

SPACEX · TESLA · SolarCity · NEURALINK · OpenAI · THE BORING COMPANY

Origin

Born on 28 June 1971 in Pretoria, South Africa

Worth and ranking

Net worth: 155.5 Bn USD[1]

- in Bloomberg Billionaires Index (2021)
- in Forbes Billionaires List (2021)

Social media[1]

- 57.3 million followers on Twitter
- 14.5 thousand tweets

Space goal

Enable the colonisation of Mars

Road to success through pursuing his technological passions

1999	2002	2003	2006	2008	2010	2013	2016	2021
Sale of Zip2[2]	**Sale of PayPal[3]**	**Tesla foundation**	**Investment in SolarCity**	**SpaceX contract with NASA**	**Tesla went public**	**Introduction of Hyperloop[5]**	**Plans of Mars colonisation**	**GPS satellite launch**
Compaq bought Zip2 for 307 Mn USD	eBay purchased PayPal for 1.5 Bn USD	Musk started the mission to bring electric cars to the masses	Musk invested 10 Mn USD in solar technology company SolarCity	NASA signed a 1.6 Bn USD contract for Falcon 9 carrying the Dragon spacecraft to the ISS	Tesla's IPO[4] on NASDAQ with issuing 13.3 million shares at a price of 17 USD	Musk rose interest in the Hyperloop concept with his 'Hyperloop Alpha' paper	Musk announced his plans at the 67th annual International Astronautical Congress	SpaceX launched a GPS satellite for US Space Force

Source: Britannica — Elon Musk — [May 2021]; Observer website; Inc website; Forbes website; Media overview
Notes: (1) As of 22 June 2021; (2) Provided and licensed online city guide software to newspapers; (3) Provides online payments system; (4) Initial public offering; (5) Ultra-high-speed ground transportation system for passenger and cargo proposed

SpaceX is a game-changing aerospace manufacturer that designs and launches advanced rockets and spacecraft

KEY FACTS SPACEX

Headquarters
Hawthorne, California, USA

Revenue
1.2 Bn USD[1]

Number of successful launches: 15[1]

Value
74 Bn USD[2]

Funding
7.5 Bn USD over 39 funding rounds

Number of employees
9,500[3]

KEY ROCKETS of SpaceX

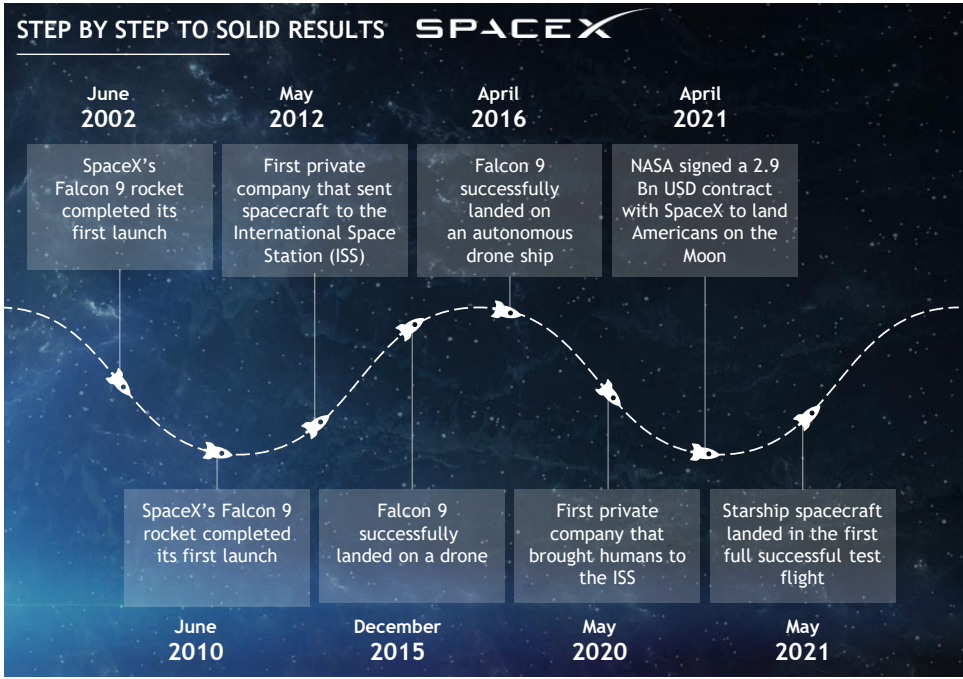
Faclon 9 is a reusable, two-stage rocket designed for transportation of people and payloads into Earth orbit and beyond.

Faclon Heavy is the most powerful operational rocket globally with the ability to lift ~64 metric tonnes into orbit.

Dragon spacecraft is capable of carrying up to 7 passengers to and from Earth orbit and beyond.

Starship is a fully reusable transportation system designed to carry both crew and cargo to Earth orbit, the Moon, Mars, and beyond.

STEP BY STEP TO SOLID RESULTS SPACEX



Source: SpaceX website; Trefis website — What Is Driving SpaceX's Revenues & Valuation?; Forbes — Is SpaceX Really Worth 74 Bn USD?— [April 2021]; Crunchbase website; NASA website; Media overview
Notes: (1) As of 2020; (2) As of February 2021; (3) As of February 2021

Musk aims to make life multiplanetary by launching the 1st civilian mission to the Moon and establishing a Mars colony

First civilian passengers on a lunar Starship mission

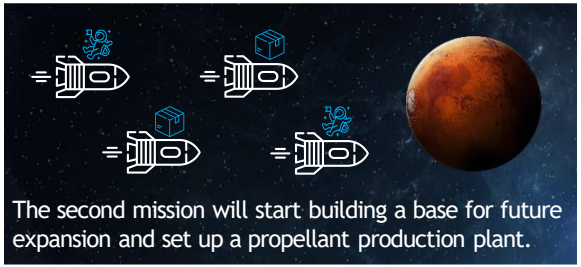
Yusaku Maezawa

The **dearMoon project** is the first civilian mission to the Moon that was first introduced in 2017. In 2018, Japanese entrepreneur **Yusaku Maezawa bought all seats for a lunar Starship mission.** The journey will happen in **2023** and continue for one week.

2024 — Cargo missions to Mars

The first mission will confirm water resources, identify hazards and build support infrastructure.

2026 — Cargo & Crew missions to Mars



The second mission will start building a base for future expansion and set up a propellant production plant.

Mars colony by 2050

1,000,000 people will live on Mars

100 Starships per year will be built

1,000 Starship flights per year, **3** flights per day

Cost of a single launch — **2 Mn USD**

The Mars colony should be a **self-sustaining city**, a ‘back-up drive’ for civilisation

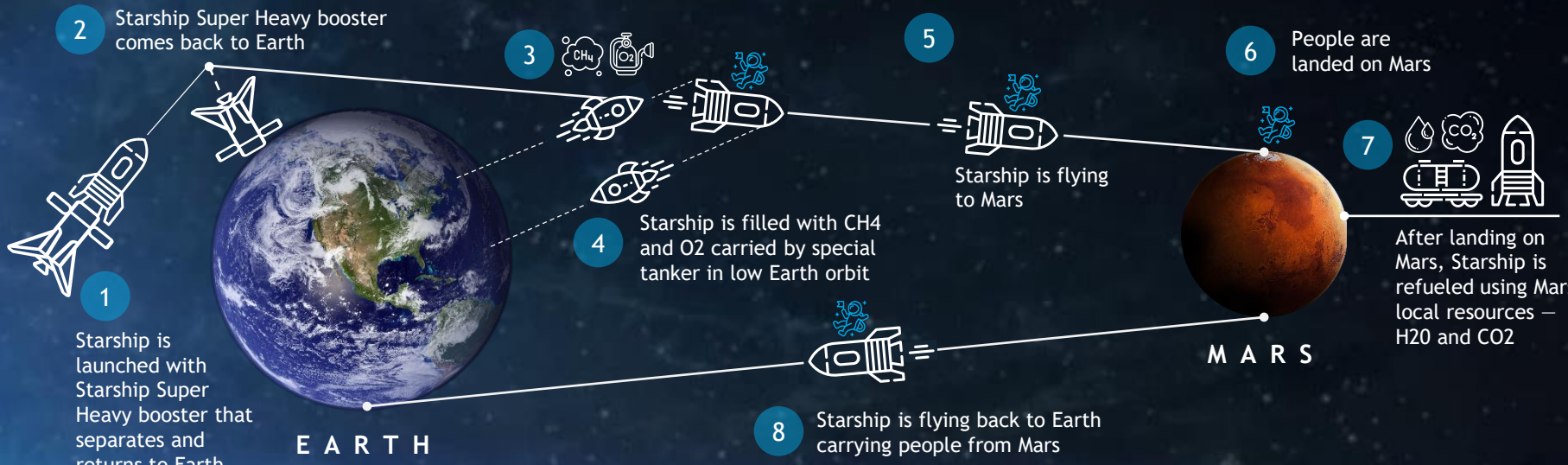
The **first human colony** on Mars will be built inside glass domes

Direct democracy will be implemented on Mars — the inhabitants will make decisions for themselves and there will be fewer and less complicated laws

Source: SpaceX — Transcript: Making life multiplanetary — [2017]; SpaceX — Presentation: Making life multiplanetary — [2017]; SpaceX website; DearMoon website; CNET website; CNBC website; Guardian website

Musk plans to set up a permanent human base on the red planet, with Starships carrying people to and from Mars

Road to Mars by Elon Musk



Source: SpaceX — Transcript: Making life multiplanetary — [2017]; SpaceX — Presentation: Making life multiplanetary — [2017]; SpaceX website

Richard Branson, the world's famous entrepreneur and adventurer, aims at pioneering and leading space tourism

Richard Branson
and his main companies[1]

Virgin · Virgin Start Up · Virgin Mobile · Virgin Atlantic · Virgin Galactic · Virgin Hyperloop · Virgin Hotels

Origin

Born on 18 July 1950

London, England, UK

Worth and ranking

Net worth: 5.0 Bn USD[2]

most admired business leader over the past five decades (2014)[3]

in the 100 Most Influential British Entrepreneurs (2018)[4]

Social media[2]

12.4 million followers on Twitter

25,6 thousand tweets

Space goal

Build the Spaceline for Earth to make space travel available for everyone

Road to success via the implementation of an adventurous approach to business and diversification

192-1980	1981-1987	1998-2000	2004	2006	2012	2015-2016	2017	2021
Foundation of Virgin Records	**Entering air transport & tourism**	**Expansion into telecom & rail transport**	**Virgin Galactic foundation**	**Expansion in media and entertainment**	**Virgin Startup foundation**	**Expansion in leasure and tourism**	**Investing in transportation technologies**	**Virgin Galactic reached space for the 3rd time**
First commercial success	Virgin Atlantic & Virgin Holidays foundation	Virgin Radio, Virgin Trains & Virgin Mobile foundation	The first commercial spaceline	Foundation of Virgin Media, Virgin Comics and Animation	First rocket-powered flight by Virgin Galactic spaceship	Virgin Hotels and Voyagers foundation	Virgin Orbit foundation and investment in HyperloopOne	First successful flight by Virgin Galactic since 2018

Source: Virgin Group website; Virgin Galactic website; Forbes website; Media overview
Notes: (1) Virgin Group operates more than 40 companies as of 2021; (2) As of 22 June 2021; (3) According to The Sunday Times; (4) According to UK-based company Richtopia

Despite several downfalls, Virgin Galactic is at the final stage of spacecraft development to enable tourist flights

KEY FACTS

Founded
2004

Headquarters
Kent, Washington, USA

CEO
Michael Colglazier

Market capitalisation
Value
8.7 Bn USD[1]

Funding
100 Mn USD by Virgin Group[2]
390 Mn USD — Aabar investments[3]
450 Mn USD — merger with Social Capital Hedosophia[4]

Number of employees
823[5]

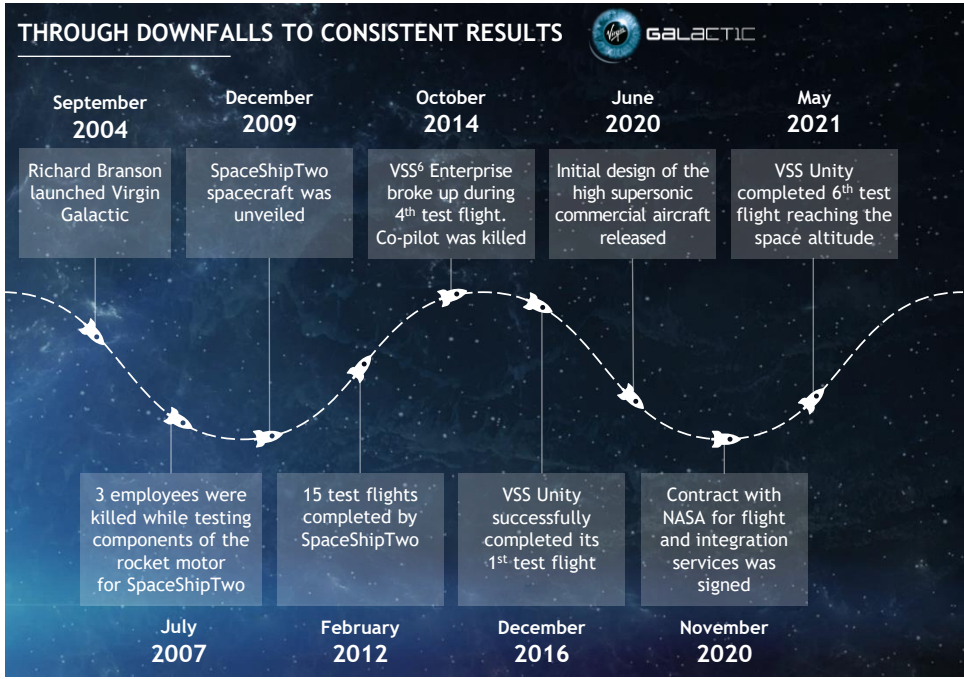
KEY PROJECTS

Commercial flights to space to start from early 2022

Contract with NASA for flight and integration services until July 2023. The total amount of the contract is 45 Mn USD

Participation in the launch of satellite constellation by OneWeb satellite venture

THROUGH DOWNFALLS TO CONSISTENT RESULTS

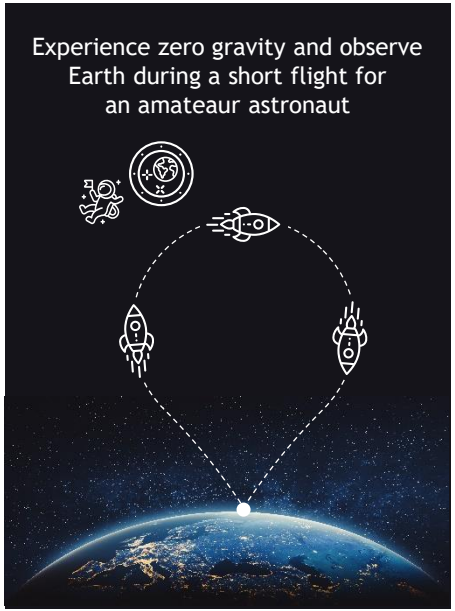


Source: Virgin Galactic website; NASA website; The Guardian — Virgin Galactic launches — [October 2019]; CNBC — Virgin Galactic shares jump after next spaceflight test is set for Saturday — [May 2021]; Bloomberg website
Notes: (1) As of June 2021, listed on NYSE; (2) During 2004-2010; (3) During 2010-2011; (4) In 2019; (5) As of December 2020; (6) Virgin space ship

As an adventurer himself Branson sees an opportunity in opening space for explorers who are ready to pay for it

Demand

Opportunity



Virgin Galactic offer

Offer:
Suborbital flight to 100 km altitude and back to Earth

Price:
250,000 USD

Spacecraft:
- Fully reusable spacecraft system, incl. carrier and spaceship
- Capacity for 8 people, incl. 2 pilots

Launch site:
Spaceport America, New Mexico, USA

Customer experience:
- Safe and enjoyable high acceleration flight
- 6 minutes of weightlessness
- Spectacular view on Earth from space

Virgin Galactic benefits:
- Regular and frequent schedules
- Flights for tourists and researches
- Expected cost decline driven by the economy of scale

 Source: Virgin Galactic website

Branson aims to establish the Spaceline with regular suborbital flights executed by a reusable spacecraft system

Reusable spacecraft system

WhiteKnightTwo carrier aircraft

SpaceShipTwo

Spaceport America
Virgin Galactic
operational hub

New Mexico, USA

Source: Virgin Galactic website; The Guardian — Richard Branson's Virgin Galactic prepares to go public — [July 2019]
Notes: (1) WhiteKnightTwo carrier aircraft and SpaceshipTwo

NASA actively cooperates with space companies to achieve maximum success in its Lunar mission — Artemis

Peter Beck
Rocket Lab

Foundation: 2006

Mission: open access to space to improve life on Earth

Key products: rockets — Electron & Neutron; Photon Lunar spacecraft

Launch complexes: 2 — in New Zealand and the USA[1]

In 2021, Rocket Lab will launch a CubeSat[2] into lunar orbit for **NASA** using an **Electron rocket** and **Photon Lunar spacecraft**. The contract for the dedicated launch is valued at 10.0 Mn USD.

Name: Electron

First launch: 2017

Total number of launches: 19

Delivered satellites: 104

Peculiarity: the only reusable orbital-class small rocket

Name: Photon Lunar spacecraft

First launch: June 2020[3]

Usage in missions: operational payloads, hosted payloads, science research, technology demonstrations, exploration

Tim Ellis & Jordan Noone
Relativity Space

Foundation: 2015

Mission: provide shift toward software-defined manufacturing by using 3D printing, AI, and autonomous robotics in space manufacturing

Key products: Terran 1, Aeon 1, Terran R

Relativity Space has a 20-year use agreement for a factory building at **NASA Stennis Space Center** that it uses to house one of Stargate factories. In 2020, **NASA selected Relativity Space to place CubeSats into low Earth orbit** as part of its VCLS Demo 2 contract. The launch will take place **by June 2022**. The contract value is 3.0 Mn USD.

Name: Terran 1

Planned first launch: September 2021

Total number of components: 600[4]

Time to print: 60 days[5]

Maximum payload: 1,250 kg to 185 km low Earth orbit

Peculiarity: world's first entirely 3D printed rocket

Source: AERTEC Solutions website; Rocket Lab website; Relativity Space website; NASA website; Media overview
Notes: (1) The launch rate of the base in New Zealand is 120 flights per year, while the launch complex in the USA provides up to 12 missions per year; (2) Small satellite developed by NASA; (3) Aboard an Electron rocket; (4) Compared to 60,000 parts in other rockets; (5) All rockets are printed on the Stargate factory

Griffin and Blue Ghost landers will be used by NASA as part of the Artemis programme to carry payloads to the Moon

Red Whittaker
Astrobotic Technology

Foundation: 2007

Mission: develop space robotics technology for lunar and planetary missions

Key products & services: Peregrine Lander, Griffin Lander, planetary mobility services, DHL MoonBox

NASA selected Astrobotic to deliver **payloads to the Moon** in **2021** (contract for **79.5 Mn USD**) and **VIPER**[1] to the Moon's South Pole in **2023** (contract for **199.5 Mn USD**).

Peregrine Lander

Used for: delivering payloads to lunar orbit and surface

First launch: Q4 2021

Payload capacity: 90 kg

Griffin Lander

Used for: medium-class lander to accommodate a variety of rovers and other large payloads

First launch: 2023[2]

Payload capacity: 475 kg

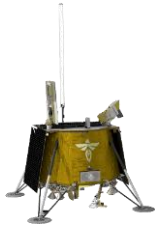
Max Polyakov[3]
Firefly Aerospace

Foundation: 2014[4]

Mission: provide economical access to space for small payloads through the manufacture of launch vehicles

Key products: Alpha, Blue Ghost, Beta, Gamma, Space Utility Vehicle, Launch Facilities, DREAM 0

In 2021, Firefly Aerospace signed a **93.3 Mn USD** contract with NASA to **deliver 10 science and technology payloads** to the Moon surface. This mission is a part of the Artemis programme.



Lunar lander Blue Ghost

Used for: carry instruments to study several aspects of the lunar surface in preparation for future human missions to the Moon

First launch: 2023

Payload capacity: 94 kg — NASA payloads

50 kg — remain available for commercial use

Source: Astrobotic Technology website; NASA website; SpaceFlightNow website; Firefly Aerospace website
Notes: (1) Volatiles Investigating Polar Exploration Rover; (2) Griffin Lander will be launched from the Kennedy Space Center on a SpaceX Falcon Heavy rocket; (3) Ukrainian and American space technology and IT business entrepreneur; (4) Formerly Firefly Space Systems. After going bankrupt in March 2017, Firefly Space Systems was bought by Noosphere Ventures (owned by Max Polyakov) and renamed to Firefly Aerospace

FUTURE OF IN-SPACE ECONOMY

What is waiting for us out there in the stars… And how the development of the space industry will impact big corporations on Earth… To succeed in the next 50 years, many businesses will need to combine space romanticism with innovative commercialisation stories

BDO

Active space exploration extends the space ecosystem and encourages the future development of the space industry

- Space mining
- Space logistics & Orbital transportation
- Space manufacturing & Construction
- Space hospitality & Travel
- Space farming

- Space waste handling
- Earth monitoring satellite
- Space renewable energy
- Space resource development
- Space green engineering

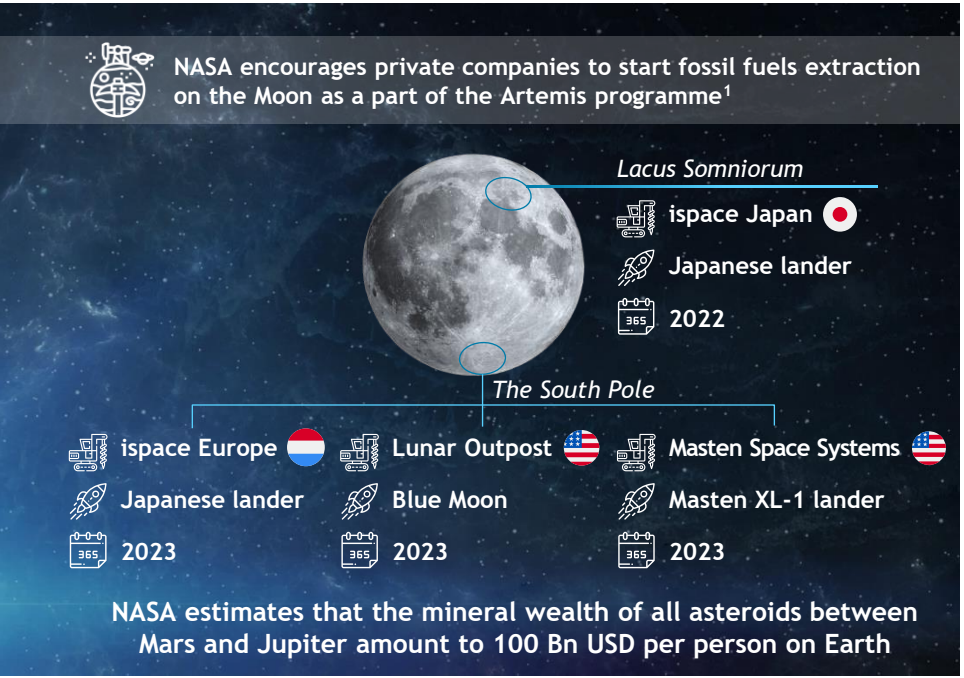
SPACE ECOSYSTEM

- Space bioengineering
- Space telecommunications
- Space medicine & Genetics
- Space nanotechnologies
- Space propulsion[1]

- Space fuels
- Space robotics
- Space habitation
- Interstellar colonies
- Orbital lab

Source: NASA website; Global Space Fund website
Notes: (1) Systems for spacecraft which are used to accelerate the spacecraft for orbit-insertion, station-keeping, or attitude control

Space mining opens new opportunities for deep space exploration, however, it demands further legal regulation



The space mining industry value is estimated to reach 3.9 Bn USD by 2025

Top-3 opportunities

- **Rare metals / minerals** extraction might boost the **complementary industries** on Earth as the supply will be increased
- Space mining could **increase the decarbonisation** of Earth, since fewer extraction activities will be provided on Earth
- Space refuelling might substantially **decrease costs in space exploration** and travel activities

Top-3 challenges

- Outer Space Treaty of 1967 **excludes possession of any celestial bodies by any country,** which may put legal constraints on mining
- **Propulsion systems** are the major limitation factor of the **payload mass** that could be transported by the spacecraft
- Minerals extraction with **minimal area contamination,** which might possess the scientific interest, could be a limitation factor

Source: NASA website; Statista website; The Washington Post website; Milken Institute — Mining in Space Is Coming — [2021]; Frontiers in space technologies — Current Challenges and Opportunities for Space Technologies — [2020]
Notes: (1) The programme is less focused on the financial incentive (25 K USD only), with more focus on establishing the legal precedent that private companies can collect and sell celestial materials

Space hospitality & travel possess high potential in the luxury segment with the first hotel at the project stage

Space hotels are becoming more realistic as Orbital Assembly Corporation (OAC) announced to build the first low orbital hotel

Station structure

24 modules (12x20 metres)

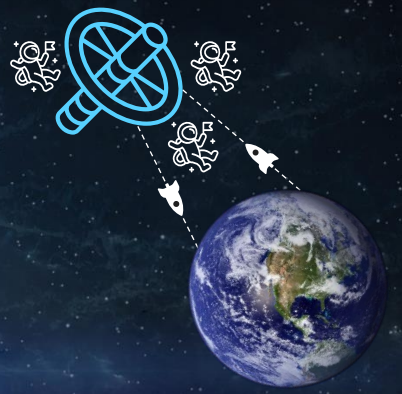
SPA Gym Living rooms
Cinemas Restaurants

Possible station capacity
~400

Possible construction period
2025-2027

Price per night
~1.7 Mn USD

The Voyager Station



The space travel industry value is estimated to reach 2.2 Bn USD by 2026

Top-3 opportunities

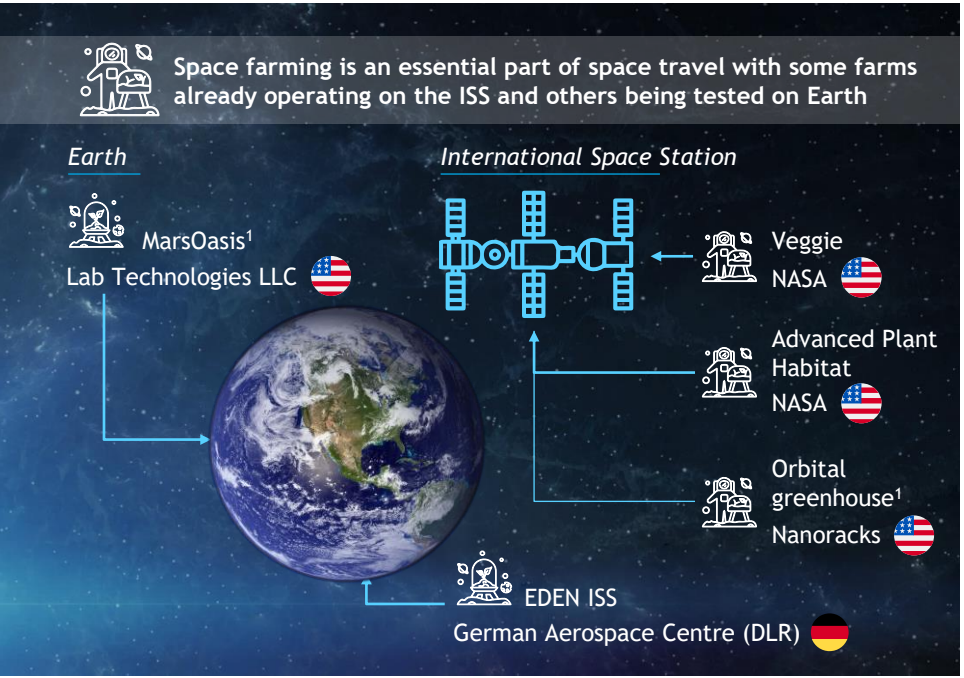
- **Real estate development** in space is one of the core points for the **successful colonisation** of other celestial bodies
- **Space real estate** development might assist with Earth's **overpopulation**
- Space real estate might **highlight the space theme** for the **high-income class**, as they are the target audience

Top-3 challenges

- **Space radiation** is still a big challenge, since there is no solid solution developed to fully tackle the space radiation issue
- Bases and hotels on Earth orbit will face **zero gravity**, which negatively impacts **human health**
- **Space farming technology** is still under development, hence ensuring a permanent food supply is challenging

Source: Daily Mail website; Wired website; Insider website

Space farming demonstrates large potential both for deep space travel and Earth, albeit still demanding exploration



The vertical farming industry value is estimated to reach 21 Bn USD by 2028[2]

Top-3 opportunities

- Space farming technologies are applicable **on Earth** allowing to grow plants in the arid climate, hence assisting the **food shortage issue**
- Space farming would lower the **costs of space hospitality**, **long-term flights**, since there will be less need in **food supply** from Earth
- Fresh food will allow to make **longer flights** into **deep space** as the astronauts will stay healthier and resilient

Top-3 challenges

- **Microgravity** is the major challenge for growing crops in space as delivering water to the plant is problematic
- High **Solar radiation** exposure could be harmful to a **crop's DNA** and may affect germination, growth, and reproduction
- **Space settlers might face a low yield harvest**, as the lunar or Martian soil is infertile due to the absence of organic compounds

Source: NASA website; E&T website; Horti daily website
Notes: (1) At the planning stage; (2) Technologies that are used in vertical farming might be used as a basis for space farming development in the future

Space manufacturing and construction are especially attractive due to favourable microgravity space conditions

Companies developing their in-space manufacturing & construction technologies

Space Tango

Current Good Manufacturing Practice. Capabilities to manufacture products in automated laboratories on the International Space Station

Tethers Unlimited

MakerSat. Technology device that will demonstrate in-space manufacture of antennas, solar arrays, and telescopes larger than can be fit into a space rocket

Made In Space

Archinaut. Combination of additive manufacturing with robotic assembly for remote in-space construction of large complex structures

NASA awarded 73.7 Mn USD for Archinaut demonstration

Varda Space Industries

Orbital manufacturing. Start-up focused on in-space manufacturing of specialised products that are difficult to produce due to material volatility or Earth's gravity

KLEOS

FUTRISM. First in-orbit method of producing large-scale, carbon composite, 3D structures in space

The space manufacturing industry value is estimated to reach 5.5 Bn USD by 2027

Top-3 opportunities

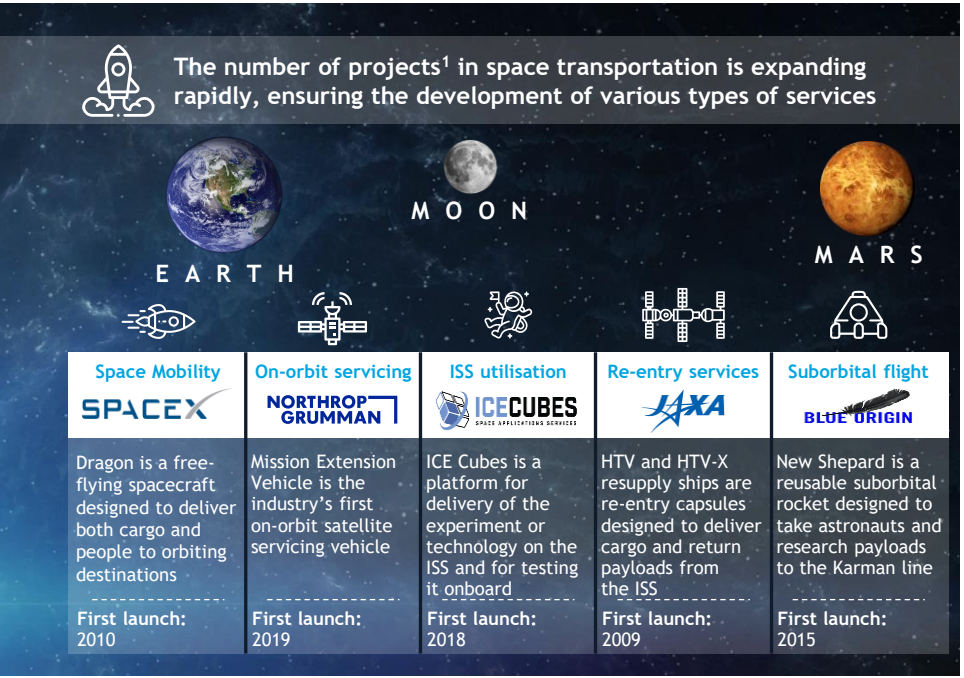
- In-space manufacturing and construction could benefit from the **advantage of microgravity and vacuum conditions**
- In-space manufacturing would enable **sustainable space exploration missions at a reduced cost** compared to launching from Earth
- **Space manufacturing facilities would be able to become self-sustaining**, requiring only minimal imports from Earth

Top-3 challenges

- **Extreme environmental conditions** requiring innovative building materials and the adoption of work in the weightless vacuum
- Significant costs in **overcoming the energy hurdle** for boosting equipment and materials into space orbit
- **Shortage of high skilled labour force** able to be engaged in in-space manufacturing and construction processes

Source: NASA website; Global Space Fund website; Companies' websites

Space transportation is expected to develop enormously, enabling the growth of all the other space industries



The space launch services market[2] is expected to reach 32.4 Bn USD by 2027

Top-3 opportunities

- In-space, lunar and planetary warehousing of satellites, equipment and food rations will create **the demand for stable supply chains**
- The chance to set **standards and trends** for the future of space logistics (for example, service expectations)
- The space logistics market is currently **open to private operators** for testing of technologies and business models

Top-3 challenges

- **Extreme physical conditions** create special requirements for modes of transports as well as for people and cargo
- Launch vehicle dimensions and weight restrictions **undermine the cost benefits** of economies of scale
- Commercial cost-benefit offers for space transportation providers **are untested** and a legal framework **is not yet created**

Source: Factories in Space website; DHL — Making the Moon more accessible to mankind — [2021]; Allied Market Research; Companies websites
Notes: (1) Cases presented below are selected among projects with 'active' and 'demonstrated' status; (2) The launch services market is a part of the space transportation & logistics market

In the next 2-3 decades, space exploration will be driven by both existing and futuristic technologies

3D Printer

Advanced 3D printers can **manufacture objects out of plastic, metals, and other materials** (like regolith) both on Earth and in space.

High Performance Spaceflight Computing

Flight computing technologies will deliver a computational capacity that is more than **100 times higher** compared to current analogues.

RASSOR[1] Robot

The Robot allows to **excavate extraterrestrial soils on the Moon, Mars, and asteroids** that could be converted into oxygen, water, and other products.

Delay / Disruption Tolerant Networking

The technology allows to provide space missions with **reliable internetworking,** avoiding the loss of data when transferring it across extreme distances.

Present

Future

Portable Magnetic Highway (FLOAT[2])

The project of the robotic **magnetic-based transport system**, which will allow to perform durable payload operations **on the Moon**.

Micro-swimmers (SWIM[3])

The concept of **swimming micro-robots** deployed from a single robot mothercraft that will explore the **Ocean Worlds of Enceladus, Europa, and Titan**.

Making Soil for Space Habitats

The concept implies the **creation of soil from carbon-rich asteroid material**, using **fungi** that will degrade toxic substances and initiate soil formation.

Light Bender

The concept for the **generation and distribution of power on the Moon** through capturing and redirecting of sunlight with the use of telescope optics.

Source: NASA website

Notes: (1) Regolith Advanced Surface Systems Operations Robot; (2) Flexible Levitation on a Track; (3) Sensing with Independent Micro-swimmers

30 years ahead — humanity reaching new horizons and overcoming challenges in the solar system and beyond

Bases on Moon & Mars

Permanent bases will be created on the Moon surface — e.g. International Moon Village (ESA), Artemis Base Camp (NASA) with some bases on Mars as well.

Space agriculture & manufacturing

Greenhouses will be constructed on humans' bases on the Moon and Mars. The resources mined at asteroids will be used by orbital factories to construct space bases.

Innovations

Multiple innovations in the space industry will boost the world's economy. New propulsion space engines will be created and widely used[4].

Settlements on asteroids

Temporary settlements for asteroid mining activities will be built. The value of all Near Earth asteroids[1] is estimated to be around ~100 Tn USD.

Space technologies on Earth

Long-haul flights will be conducted via spaceships instead of planes. Technologies in farming will allow to achieve high yields despite the arid climate.

Space transportation

Space transportation will be cheaper than the best currently available technologies[5], advanced refuelling stations will be available in space.

Sustainability in space

Space-solar power arrays will generate 24/7 clean energy for the households on Earth using microwave arrays, hence lowering carbon emissions.

Pinwheel space stations

Manned space stations could be worth about 50 Bn USD between 2030-2050[2]. Pinwheel space stations on LEO[3] will be used as a gateway for space travel.

Space leisure

Suborbital and orbital flights will be affordable for the middle-class together with lunar tourism. Space tourism is expected to generate 850 Bn USD by 2030.

Source: NASA website; Interesting engineering website; BBC website; Media overview

Notes: (1) Near Earth asteroids whose orbits are within 1.3 astronomical units of Earth; (2) According to SpaceWorks forecast; (3) Low Earth orbit; (4) For example electric ion, solar, and nuclear propulsion; (5) Compared to Falcon Heavy — 1,410 USD per kg

BDO CENTERS

A Kyiv based consulting practice with a focus on professional services, BDO Centers develops and scales innovations in support of the largest and most diversified group of strategy, consulting, digital, audit, tax, and operations professionals in the world. Drawing on a combination of industry and functional expertise, the company supports service processes for Marketing, Sales Enablement, Corporate Communications, Social Media, Events, Strategy and Business Consulting. Engineered to facilitate an increase in client centricity, the agile and cross-functional BDO Centers team provides strategic and operational value creation to accompany the full client journey.

CONNECT WITH US

www.linkedin.com/company/bdo-centers

www.facebook.com/bdocenters

www.instagram.com/bdocenters

nicolai.kiskalt@bdo.de

BDO