SpaceTech Industry 2021 / Q2 Landscape Overview

May 2021

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SpaceTech Analytics

Introduction

SpaceTech Industry Landscape Overview summarizes key observations in the SpaceTech ecosystem, a rapidly evolving and exponentially growing industry. In it, we have assembled information about **key industry trends** and created an **unprecedented database** of more than **10 000** SpaceTech related companies, **5 000** leading investors, **150** R&D Hubs and Associations, and **130** governmental organizations.

By providing **insights into a number of public and private companies** engaged in various subsectors of the space economy, the Space Industry Database and SpaceTech Landscape deliver a comprehensive analysis of the area.

Apart from **exploring** the most interesting case studies and trends, including **space law** and **commercialization of space**, the overview also predicts **future developments** in SpaceTech.

The study pays special attention to space-related companies relying on **AI, DeepTech**, and **Longevity**. By using them, they can further stimulate space exploration, as well as increase the application of SpaceTech products for humanity's needs on Earth.

To sum up, SpaceTech has a **huge economic potential**. It has already resulted in the emergence of goods and services that have become an integral part of our lives.

Our Approach

Database

Identification of relevant:
- Companies,
- Investors,
- Hubs,
- Universities & Research Centres,
- Government Ministries, Departments & Agencies,
- Space Associations,

that operate, interact with or are somehow involved in the space industry.

Applied Research & Analytics Methods

- Descriptive Analysis
- Mixed Data Research
- Exploratory Data Analysis
- Comparative Analysis
- Qualitative Data Collection
- Data Filtering

Data Sources*

- Media Overview (Articles, Press Releases)
- Industry-Specialised Databases
- Publicly Available Sources (Websites)
- Industry Reports and Reviews

Relying on various research methods and analytics techniques, the report provides a comprehensive overview of the space industry.This approach has certain limitations, especially when it comes to the leveraging of publicly available data sources and secondary research. SpaceTech Analytics is not responsible for the quality of the secondary data presented herein; however, we do our best to eliminate the said risks by using different analytics techniques and cross-checking data. Please note that we did not deliberately exclude certain companies from our analysis. Nor was it due to the data-filtering method used or difficulties encountered. In fact, the main reason for their non-inclusion was incomplete or missing information in the available sources.

SpaceTech Landscape Framework

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Science and R&D

- Astronomy & Astrophysics
- Earth Science
- Astronautics
- Space Medicine
- Space Architecture
- Astrobiology

Frontier Technologies

- Engineering
- Robotics
- Software
- BIoTech
- Artificial Intelligence
- Machine Learning

Spacefaring

- Private Spaceflight
- Logistics
- Space Tourism
- Transportation

Satellites & Aerial Imagery

- Satellite Communication
- Satellite Manufacture
- Aerial Imagery
- Navigation
- Data Gathering
- Weather Forecasting

Spacecraft Construction

- Manufacture
- Repair
- Materials & Part Production
- Launch Infrastructure

Supporting Industries

- Training
- Consulting
- Research & Education
- HR

SpaceTech Industry Framework

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Stakeholders Groups

- Civil Society
- Scientists & SpaceTech Professionals
- Influencers & Media
- Investors & Founders
- Government Agencies
- Military & Defence

Market

- Space Exploration
- Spaceflight
- Space Medicine
- Security & Defense
- Satellites
- Data Gathering

Use Cases

- Science and R&D
- Tourism
- Spacecraft
- Military
- Healthcare
- Artificial Intelligence

Opportunities & Concerns

- Extraterrestrial Life
- Alternative Energy
- Internet Access All Around The World
- Mining In Space
- Militarization Of Space
- Moon As An Interplanetary Hub

SpaceTech Sector Classification Types

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By Type of Agency

- Civil
- Military
- Private
- International Collaborations

By Level of Development

- In Theory
- Testing
- Developed
- Advanced

Space Economy Sectors

- Downstream
- Upstream
- Spinoff

By Area of Operation

- Outer Space
- Medium Earth Orbit
- Low Earth Orbit

SpaceTech Technology

SpaceTech Analytics

Satellite Technologies

- Fixed Satellite Service
- Mobile Satellite Service
- Satellite Manufacturing
- Broadband Satellites

Non-Satellite Projects Funded by the US Government

- MDA
- NRO
- NDAA
- USAF

Ground Technologies

- GNSS Chipsets
- VSAT
- Navigation Devices

NASA Projects

- Space Exploration
- Space Operations
- Safety and Security
- Science

Satellite Industry Products

Satellite Ground Equipment

- Network Equipment
- Satellite Dishes
- Personal Navigation
- Mobile Satellite Terminals

GNSS Chipsets

- Agricultural
- Avionic
- Maritime
- Rail

Services

- Television
- MSS
- Broadband Internet
- VSAT Webs

Sensing

- Surveying Equipment
- Weather Analysis
- Remote Fire and Smoke Analysis

Executive Summary

Space-related technologies are being developed in an enormous speed nowadays. Launch vehicle, satellite, propulsion, manufacturing and other companies emerge every quarter. Big companies in spacetech share their innovations and breakthroughs every week. Several countries have already planned their Mars colonization projects, others have the clear vision of lunar scientific stations. Space tourism has finally become available and is on its way to becoming more and more accessible. In this sense, the present report is designed as an in-depth review of the state of the art in space technologies including space medicine and R&D to advise accurately the market, industry and public sectors.

In this report there are chapters that describe things like: how startups use modern technologies, such as mapping Earth from space and developing commercial micro/nano-satellites, new technologies and solutions for more advanced space research conduction, the timeline of the best recent SpaceTech Breakthroughs, including the most highly rated missions, air and spacecrafts and stations from all around the world, which made a great impact on space exploration, statistical analysis of the SpaceTech market such as Growth of the global SpaceTech economy, Impact of Crises, SpaceTech Stock Index, etc., comparative analysis of government space budget.

SpaceTech Analytics (STA) is a leading strategic and analytical agency focused on emerging markets in Satellite Technology, Advanced Startups, Space Law, and Economics and other industries of SpaceTech.

STA is producing regular analytical reports on major areas of high potential in the space industries, maintaining ratings of companies and governments based on their innovation potential and business activity in the SpaceTech sphere, and providing strategic consulting and investment intelligence services to top-tier clients, including major investment funds and banks, family offices, insurance companies, government organizations, and big companies among others.

Executive Summary

Report represents activity overview of space programs conducted by the major space powers, represented by such leading countries as the US, China, Russian Federation, Japan, United Arab Emirates, India, lists of the main challenges facing the space industry, explaining why it is important to solve them.

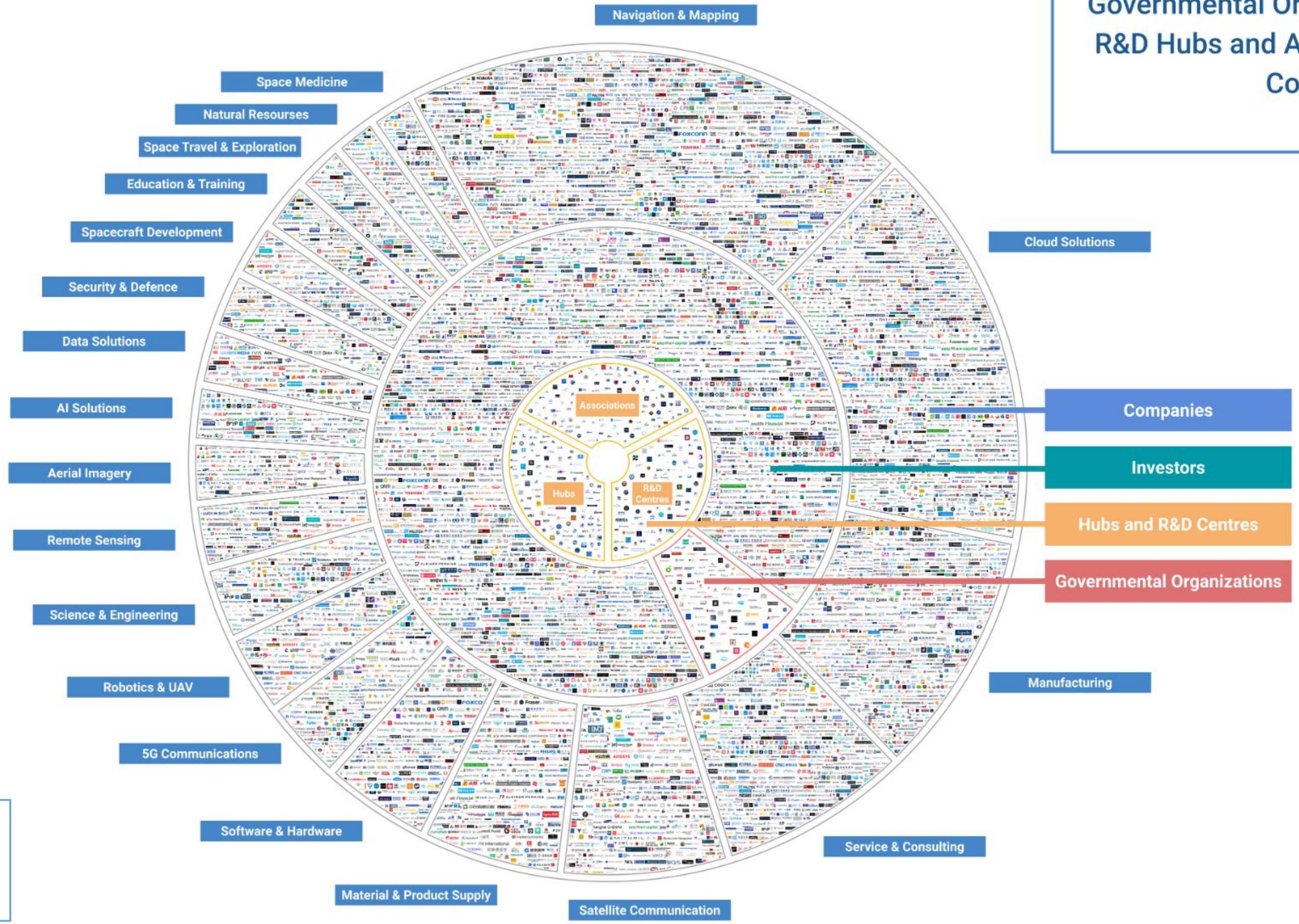
There are also chapters that explain the difference between different types of satellites placing the main emphasis on nanosatellites and describing their advantages and illustrates how small satellites could be used, space tourism and how it is supposed to work including an overview of the industry and a comparative analysis of 12 Space Travel companies, and describe the main obstacles of space exploration and colonization, such as cosmic radiation & zero gravity influence on the human body. The International Collaborations chapter focus on space agencies and private companies seeking to send manned missions to the Moon, establish permanent lunar settlements, explore the resources of the Moon and asteroids and travel to other planets.

In addition to their purely descriptive and analytical approaches, the report is designed to make key strategic recommendations and guidance regarding space-related technologies and techniques, within the reach of companies, other entities, and nations, in order to assist them in optimizing their action plans and strategies, providing specialized guidelines for business, and investment core decisions.

- Technological Analysis of the Best Startups
- Small Satellites
- Industry Trends & Technologies
- Space Travel Industry Overview
- SpaceTech Industry in Figures
- Space Medicine Industry Overview
- National Space Programmes
- International Collaborations on Space Exploration
- Technological Issues and Solutions
- Unidentified Aerial Phenomena and Artefacts

Global SpaceTech Ecosystem 2021

Governmental Organizations - 130
R&D Hubs and Associations - 150
Companies - 10 000
Investors - 5 000



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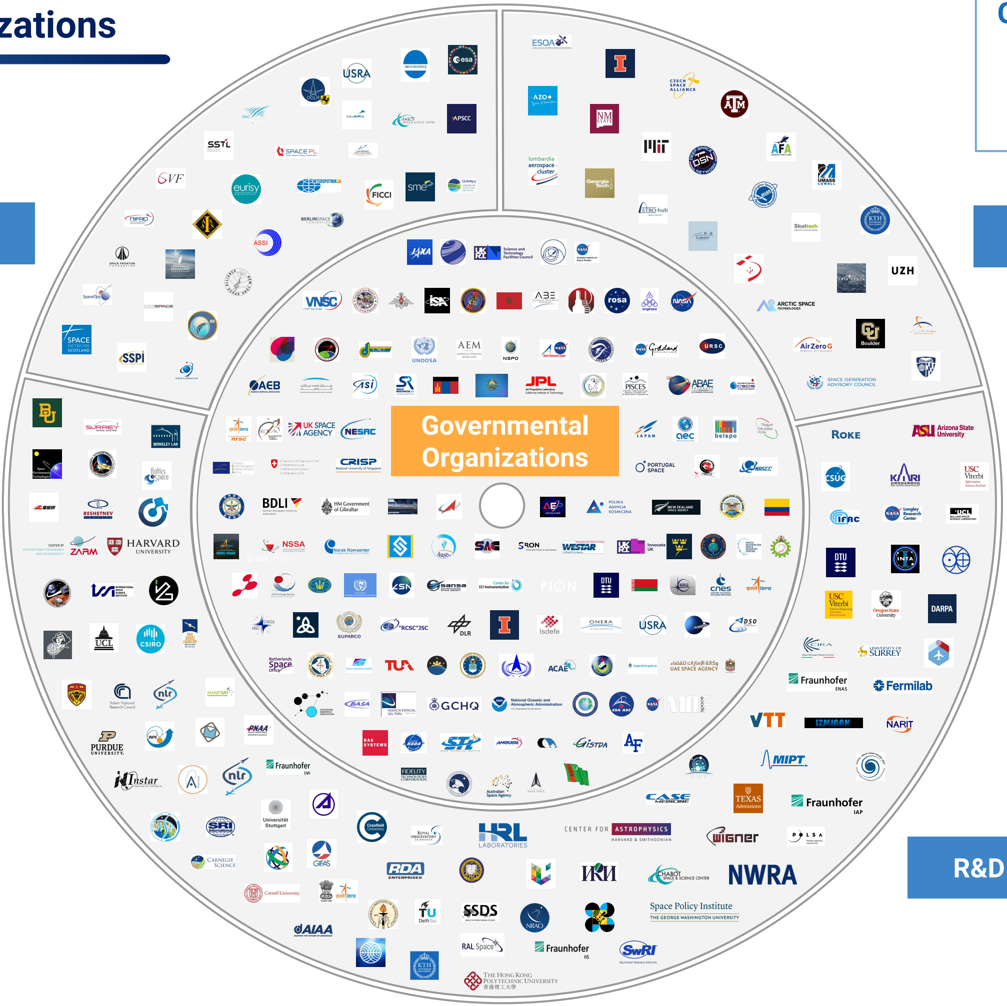
R&D Hubs, Associations and Governmental Organizations

Governmental Organizations - 130
R&D Centres - 93
Associations - 29
Hubs - 28

Associations

Hubs



R&D Centres

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SpaceTech Industry in Figures

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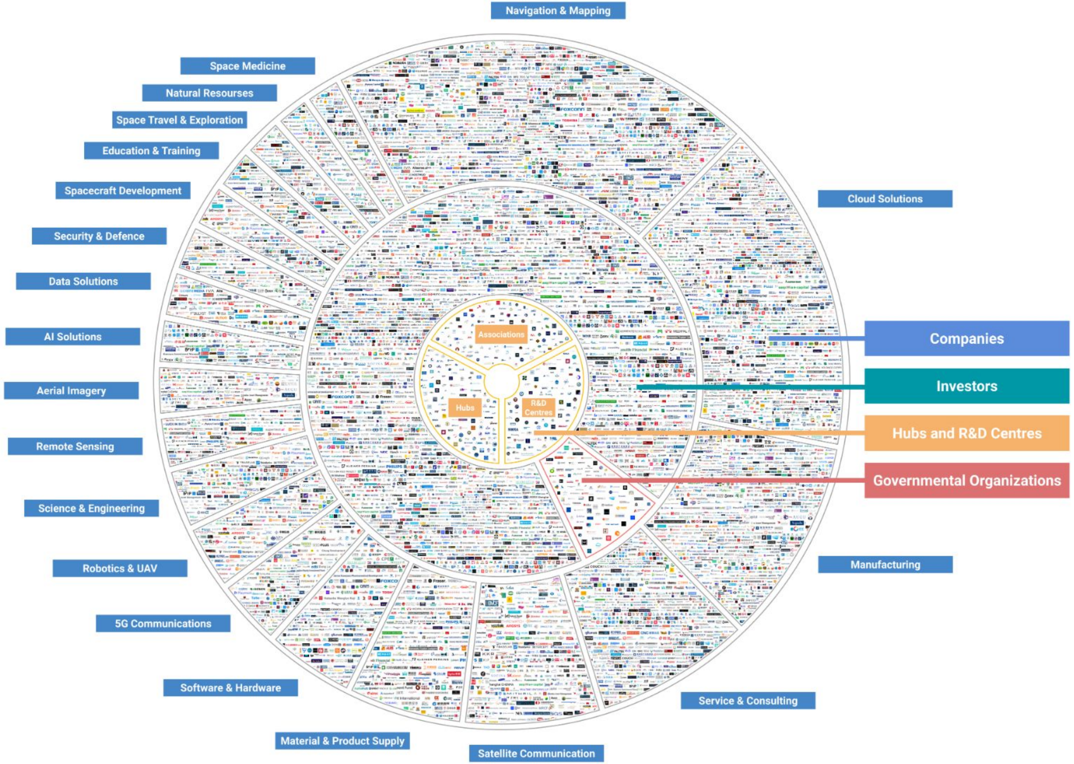
Global SpaceTech Ecosystem 2021

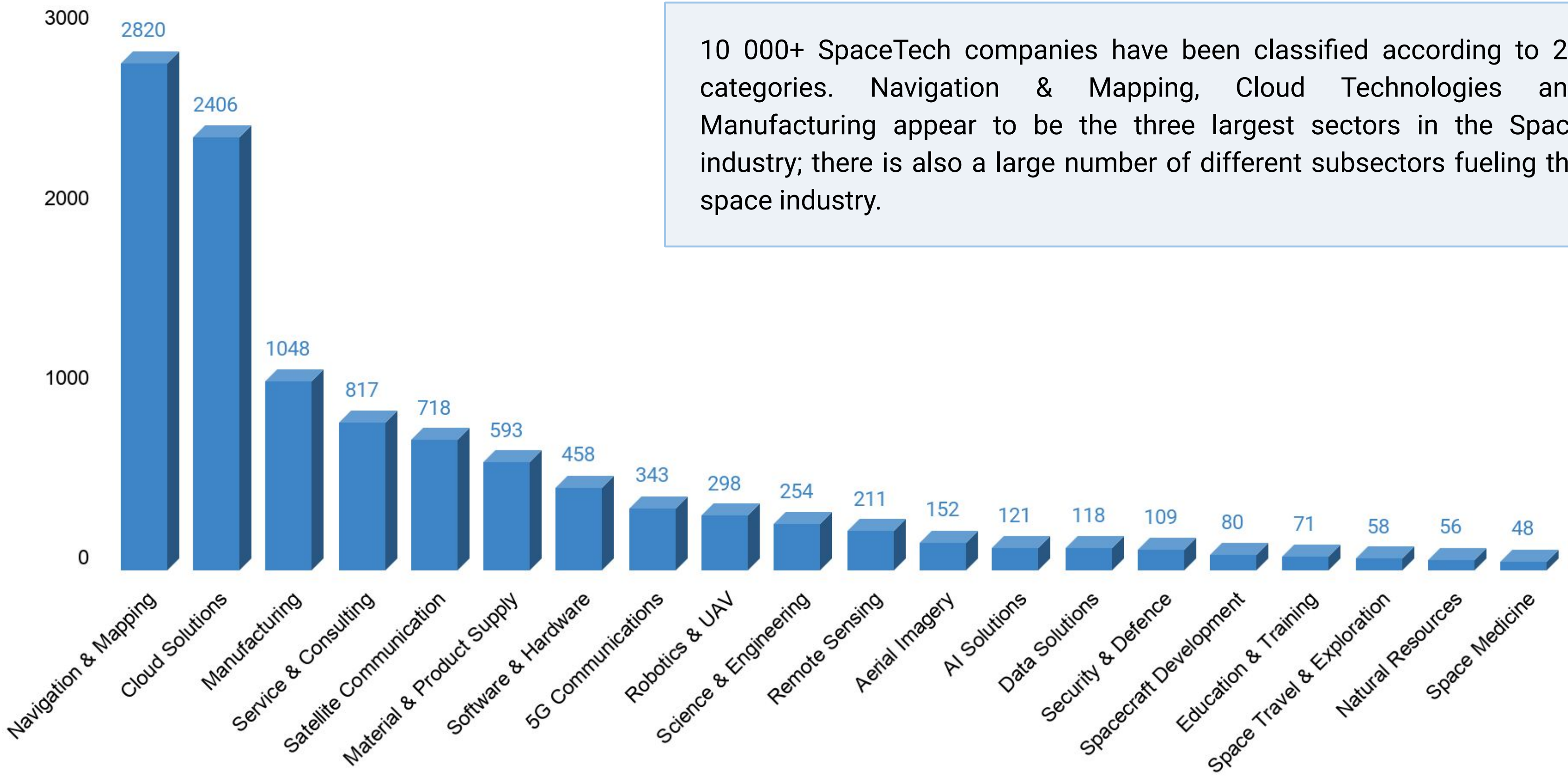
10 000 Companies | **5 000 Investors** | **150 R&D Hubs and Associations** | **130 Governmental Organizations**



USA	Canada
UK	Germany
China	France
India	Israel
Spain	Japan
Australia	CEE*
Singapore	France
Brazil	Ireland
Gulf Region	EU

* – Central and Eastern Europe

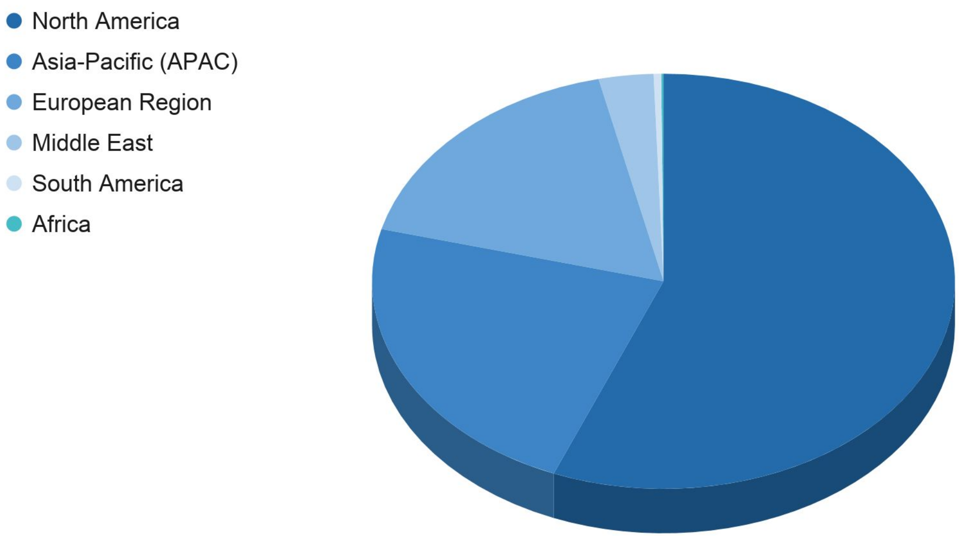
SpaceTech Sectors in 2021 (by Number of Companies)

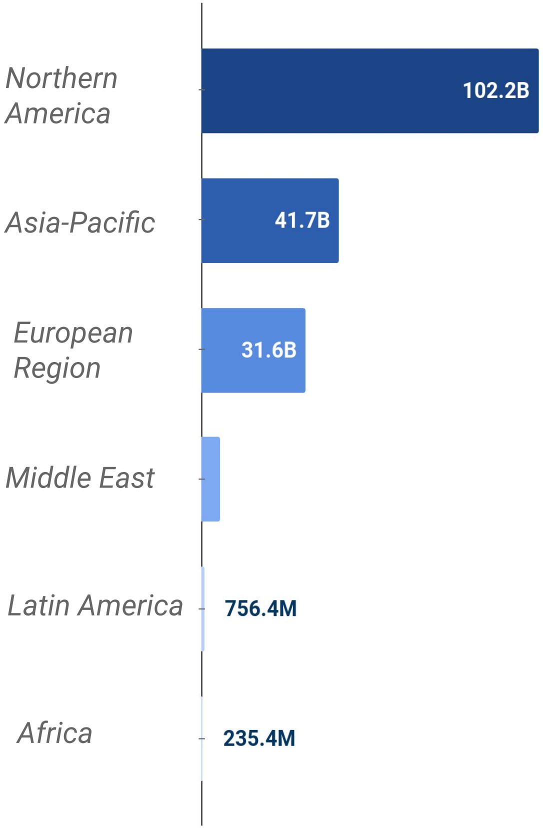


10 000+ SpaceTech companies have been classified according to 20 categories. Navigation & Mapping, Cloud Technologies and Manufacturing appear to be the three largest sectors in the Space industry; there is also a large number of different subsectors fueling the space industry.

Funding by Region

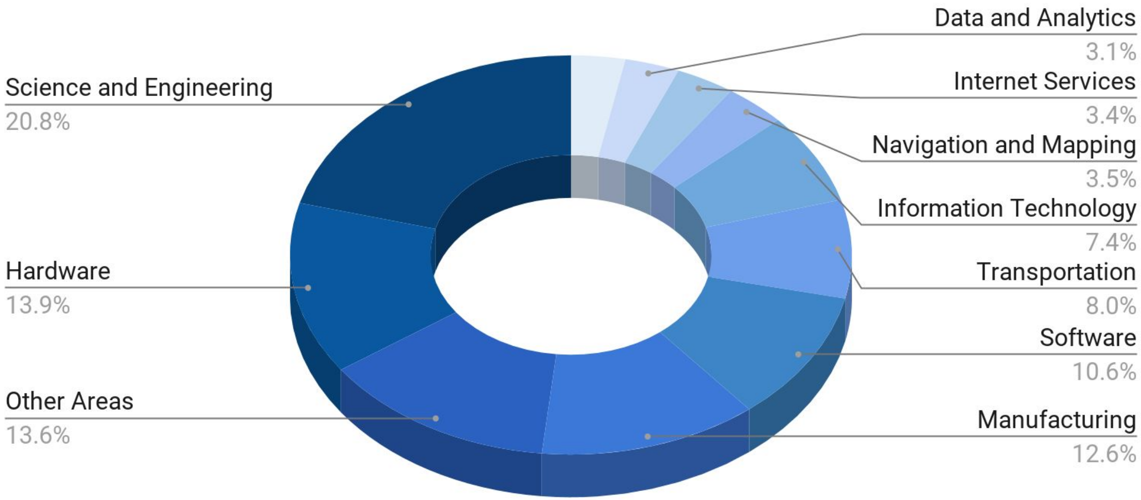
The US is a leader in the number of SpaceTech companies and the amount of investment they receive. However, Asia is confidently gaining momentum in the financing of companies in the industry. Thanks to the new space goals of the United Arab Emirates, the Middle East entered the race as well.



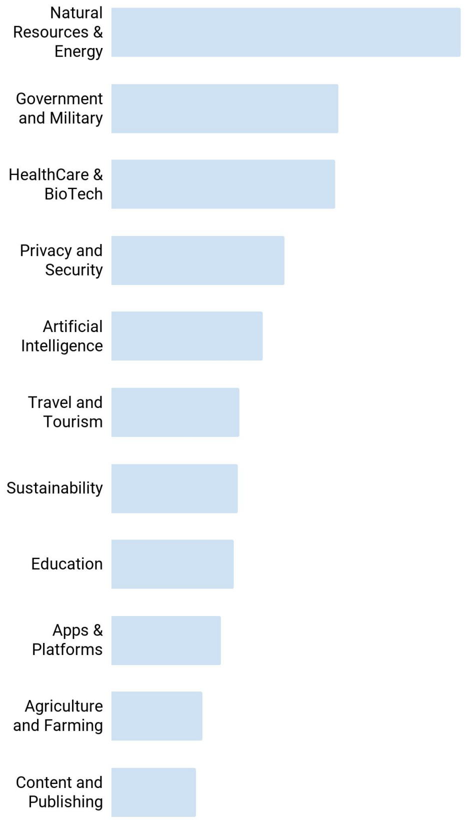


Areas of SpaceTech Usage

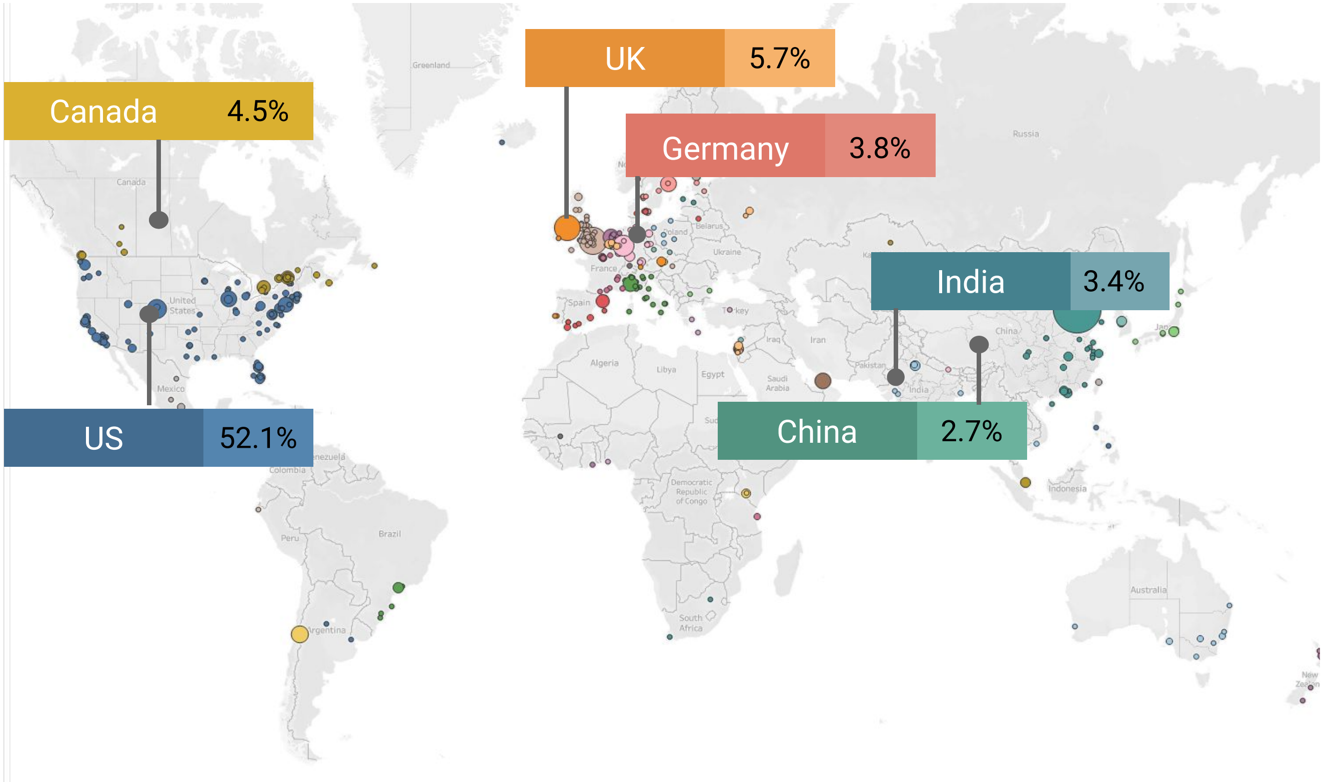
Over the past decades, space has attracted a large number of participants, with New Space and non-space companies entering various industry development chains. Mainly, the number of private space-related companies is prevalent in the United States, while Asian and European regions speed up the activity.



Other Areas of Usage



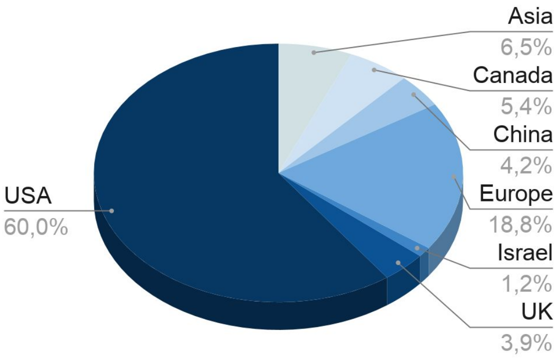
Company Regional Distribution (by Number of Companies) in 2021



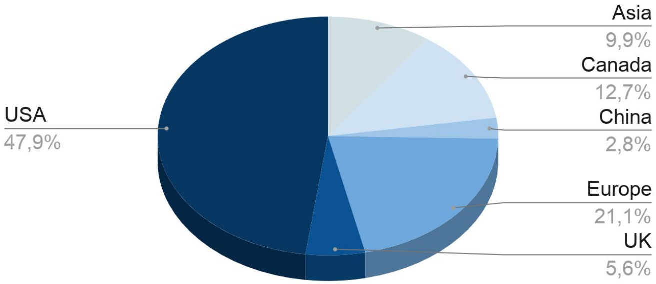
The US is still firmly in the lead in terms of the number of spacetech companies (52.1%). The UK ranks second (5.7%), while Canada, Germany, India and China are in the third place (with 4.5%, 3.8%, 3.4% and 2.7% respectively).

Company Regional Distribution (by Categories and Number of Companies) in 2021

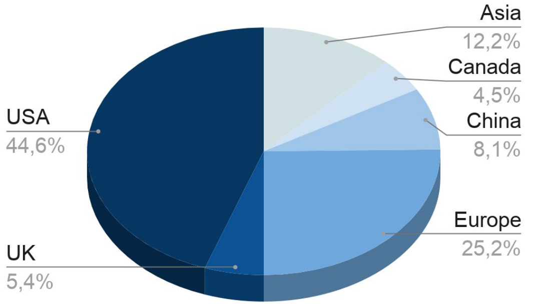
Manufacturing

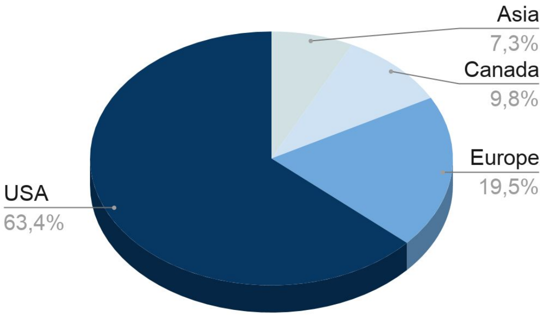


Spacecraft Development

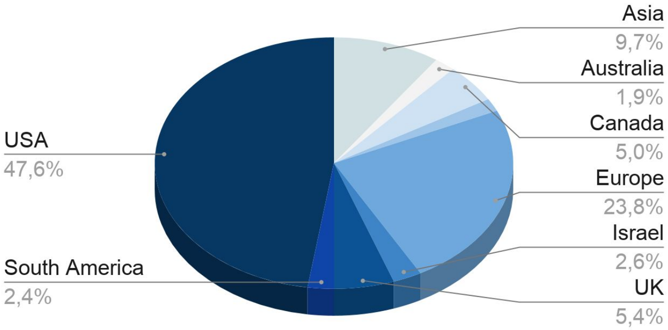


Science and Engineering

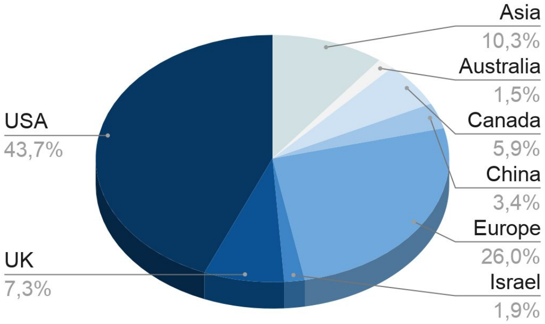




Space Medicine



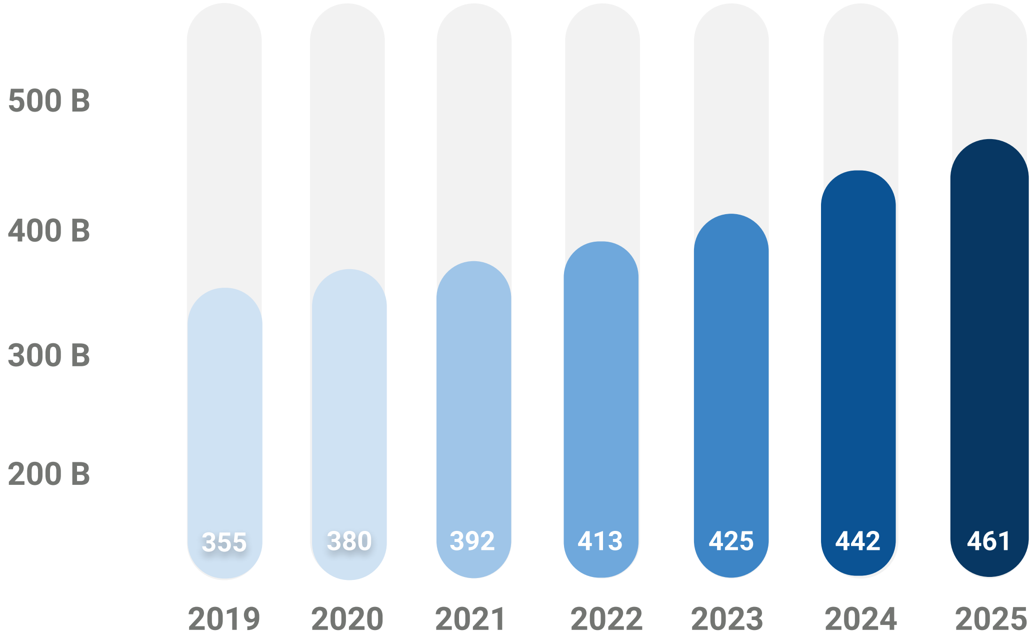
Software/Hardware



Satellite

The Global SpaceTech Economy

World SpaceTech Industry Size Projections, $B



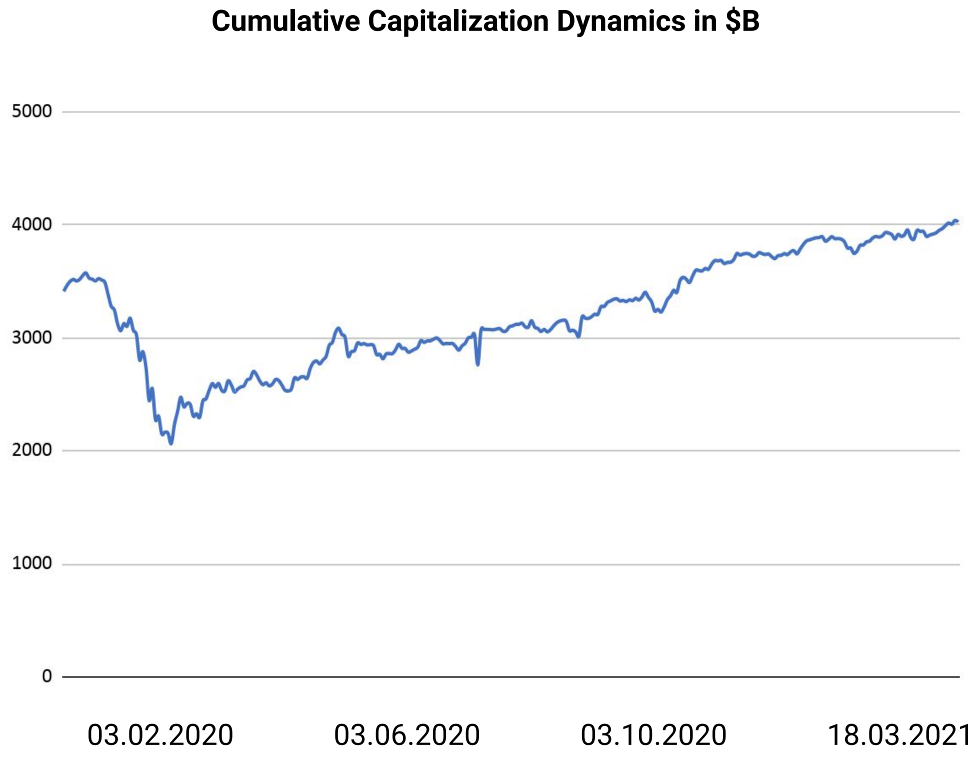
Showing stable growth, the global SpaceTech economy was valued at **$380B** in 2020 and is expected to grow to **$10T** by 2030.

According to the most conservative estimates, it accounts for 0.5% of the global GDP.

This will have a dramatic impact on the annual growth in the global SpaceTech market, and mainly because of the growth of the **Space Exploration** sector and advances in **IT**, **FinTech**, and other digital technologies.

Source: Haver Analytics, Morgan Stanley Research forecasts, 2020

SpaceTech Publicly Traded Companies



Despite the crisis and dramatic fall in companies' capitalisation in February 2020, capitalization of **376 publicly traded companies** grew from **$3,410B** on February 3, 2020 to **$4,030B** on March 18, 2021.

The largest companies by market capitalization are William Hills, MultiChoice Group Limited, Eli Lilly and Company, Danaher Corporation and Honeywell International.

SpaceTech companies are similar to other companies in the sector (i.e. the ones that reached series B or C funding rounds), which means that the **growth** in their market capitalization can be an approximation of the dynamics in the entire sector. Anticipated growth in the industry is expected to **impact** favorably market capitalisation of SpaceTech corporations.

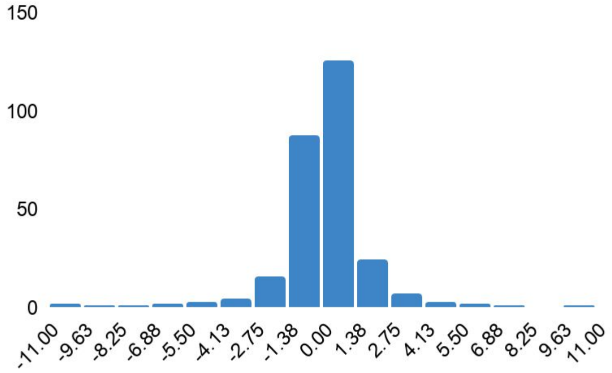
SpaceTech Stock Market

Our SpaceTech stock index includes more than **350** corporations operating in the space and IT sectors in 2021. Their market capitalisation demonstrates a significant growth, exceeding that of the entire market (represented as the **S&P 500 index**), as well as the general **SpaceTech industry** indices (ROKT and ITA). The SpaceTech stock market segment is, therefore, less volatile compared to them (as measured by standard deviation).

Interestingly, distribution of returns in the **SpaceTech** stock market segment is right-skewed - a demonstration of the low likelihood of left tail events (sometimes referred to as “black swan events”) happening. Despite the negative skewness, the value is small, which means that the likelihood of the so called “black swan event” is much lower in comparison to the **S&P 500**. A negative **Curtosis** means that the distribution is flatter than a normal curve with the same mean and standard deviation.

Index	Correlation with longevity market	Average daily return in 2020	Average daily volatility in 2020	Skewness	Curtosis
SpaceTech Index	-	0.08	2.07	-0.1	-0.98
ROKT	0.97	0.07	2.53	0.01	-0.96
S&P500	0.71	0.08	2.08	-0.41	-0.4
ITA	0.74	0.02	2.91	0.68	0.6

SpaceTech Stock Returns Histogram



Investments Overview

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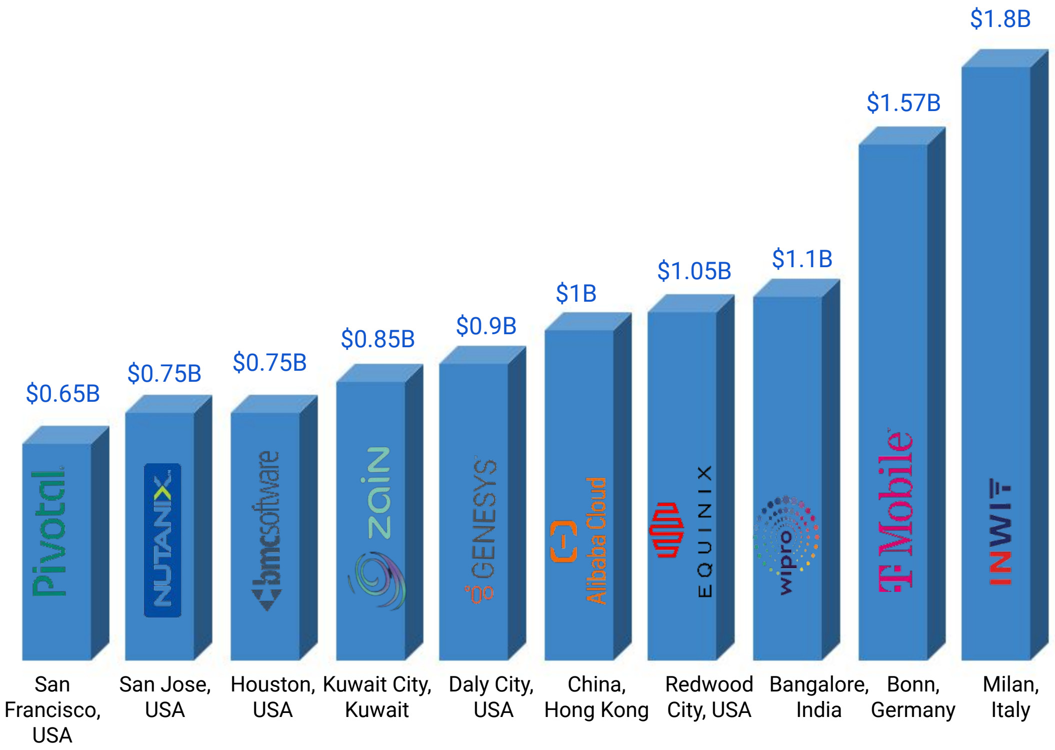
Top 10 Investment Deals

- Valued at **$1.8B,** the largest investment deal represents a post-IPO investment in Infrastructure Wireless Italiane.
- The second largest deal, valued at **$1.57B,** represents private equity investment in T-Mobile.
- Valued at **$1.1B,** the third largest investment involves Wipro Technologies.
- Valued at **$1.05B** and **$1B,** investments in Equinix and Alibaba are the 4th and 5th largest investments in the industry.
- Estimated at **$0.9B,** the 6th largest deal is private equity investment in Genesys.
- The 7th largest deal**,** worth **$0.846B,** is post IPO equity investment in Zain Group.
- **Valued at $0.75B,** investment in BMC Software is considered to be the 8th largest in the industry.
- Valued at **$0.75B** and **$0.65B,** deals involving Nutanix and Pivotal are the 9th and 10th largest in the industry.

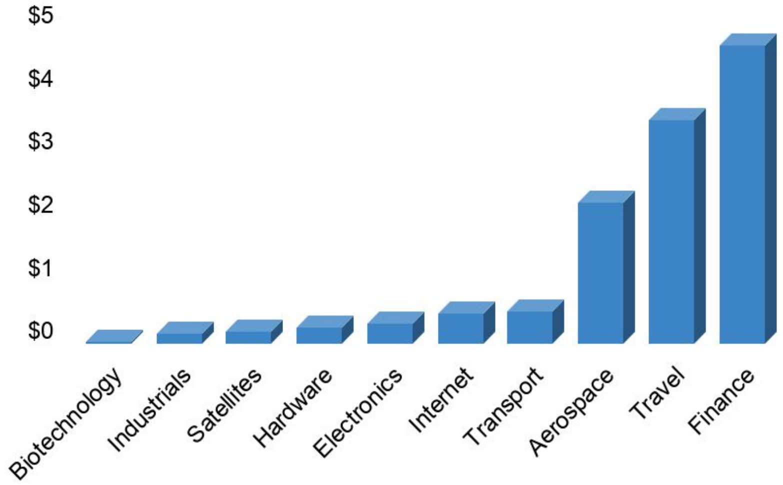
Investments in SpaceTech-Focused Companies Totalled $132.2B Globally in 2020



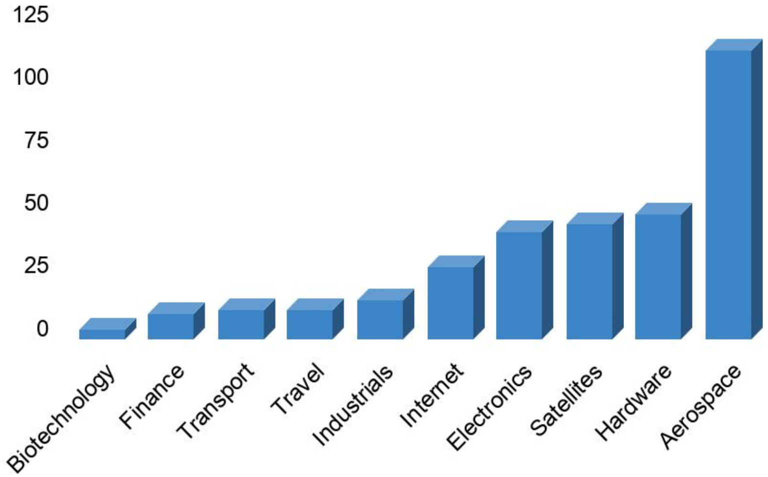
Dynamics of Investments in SpaceTech

Total Early-Stage Investments in Space Technologies in 2021:
$68B

Total Investments in $B

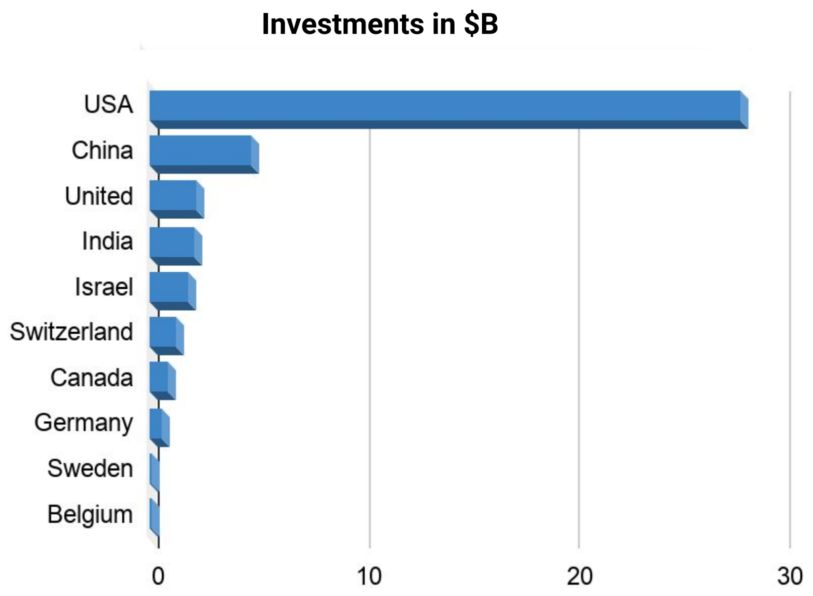


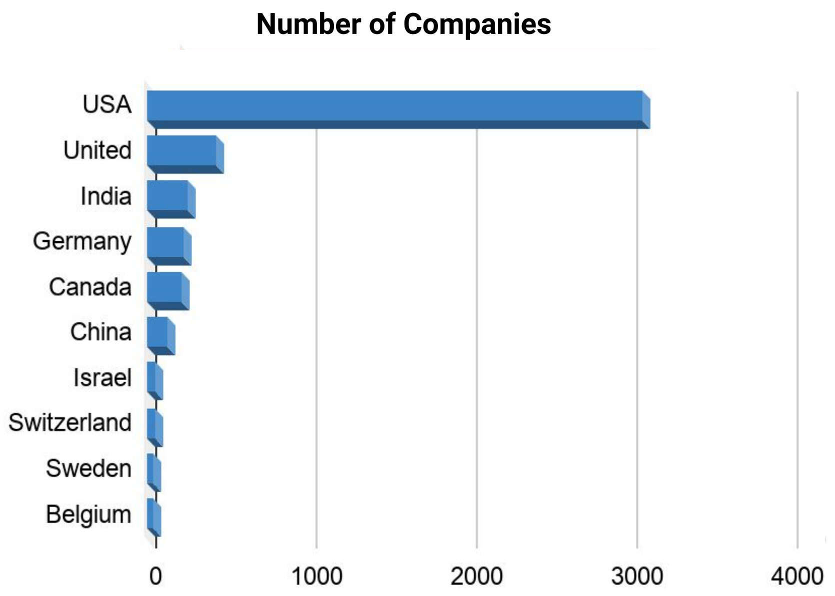
Number of Companies



Valued at **$4.75B, the SpaceTech financial services sector** is the largest in the SpaceTech Industry. Some of the most active **capital-raising sub-sectors** include **aerospace financial services**, **aerospace travel air transportation** and **aerospace Internet**.
The distribution of investments across different SpaceTech sectors demonstrates that most of the subsectors in the industry are rapidly growing. Summing up, both **governmental and private investors** are interested in the SpaceTech industry and determined to continue investing in it.

Top 10 Countries in SpaceTech Sector in 2021





With a total of **$28B** invested in **3,086 companies, the US** is an undisputed leader in terms of SpaceTech investments. This is approximately 6 times the amount invested in SpaceTech companies in **China** - the second largest country in terms of spacetech investment (**$4.786B** invested in **122 companies)**. China is closely followed by the **United Kingdom** where funding is mostly raised from public sources and IPOs, and not by way of private funding.

Top Manufacturing Companies

Funding Round	Parts	Hardware	Launch Vehicle
IPO	Ipsen, LATÉCOÈRE, PLEXUS, LOCKHEED MARTIN	Ball, SAAB, AXISCADES	BOEING
Rounds C-F		ECHODYNE, VORAGO TECHNOLOGIES (Opening up new possibilities)	LANDSPACE, ROCKET LAB
Round B	Swissto12		
Round A	NewRocket	国科天迅 TASSON	
Seed	FIREHAWK, MeghVaahan (Arrival of The Fittest), MILLE		PHANTOM SPACE CORPORATION

Manufacturing focus

The majority of manufacturing companies have already launched their IPOs; however, some of them are still growing

Top Satellite Companies

Total Funding	Aerial Imagery	Research and Development	Satellite Manufacturing
$15M-$2B	TRE ALTAMIRA (A CLS Group Company)	ST Engineering; bigblu broadband investor relations	TERRAN ORBITAL; AST SpaceMobile
$300K-$15M	MAXAR; gsi global surface intelligence; FluroSat	PIXXEL; Astroscale	BELLATRIX AEROSPACE Propelling Dreams
$5K-$300K	HYPERVERGE; EOS	planetek hellas	AAC CLYDE SPACE

Satellite Focus

The largest recipient of investment is Astroscale, followed by Flurosat, Maxar and AAC

100 Leading Companies in SpaceTech Sector

May 2021

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Introduction

Spacetech industry is made of a big variety of spheres. From companies that study propulsion and manufacture engines to the companies that develop medicine for astronauts. From those that only produce specific materials to those that design both software and hardware for the launch vehicles.

Since SpaceTech is a really broad industry tag, there are a lot of companies that touch upon space-related technologies, but don't quite reach the scale of space exploration, like television providers for example. However, there is still a huge number of companies, that are on the frontline of the space frontier and have formidable market capitalisations and investments.

There is a list of companies that fully manufacture unmanned and/or manned launch vehicles, that carry the payload to different levels of Earth orbit. They usually specialize and differ much. Some are good for launching nano-satellites, others benefit from being fully customizable.

Some leading companies manufacture the crucial parts of the launch vehicles. For example thrusters of space station modules. Some even assemble specialized satellites or develop new technologies, that can be capitalized on in near future. Most of them attach much investments.

100 Leading Companies in SpaceTech Sector (by Number of Employees)*

1	Advantech Wireless
2	Aerojet Rocketdyne Holdings
3	AirBorn
4	Airbus
5	ALCOA Inc.
6	Alliant Techsystems
7	Amgen
8	Analog Devices, Inc.
9	Anaren
10	Ariane Group
11	Arrowhead Products
12	Aselsan
13	Avcorp Industries
14	B/E Aerospace
15	BAE Systems, Inc.
16	Ball Aerospace
17	BGF Industries
18	Blue Origin
19	BlueHalo
20	Boeing
21	Carlisle Interconnect Technologies
22	CMC Electronics, Inc.
23	Cobham
24	Collins Aerospace
25	Crane Aerospace & Electronics
26	CS GROUP in SPACE
27	Curtiss-Wright Corporation
28	Daiichi System Engineering
29	Dassault Aviation
30	Dish Network
31	Draper
32	Ducommun, Inc.
33	DWG Holdings

*in alphabetical order as for 2020-2021

100 Leading Companies in SpaceTech Sector (by Number of Employees)*

34	Dynetics, Inc.
35	EaglePicher Technologies
36	ENSCO
37	Eutelsat
38	FDC Composites inc
39	Flexan Corporation
40	General Atomics
41	General Dynamics
42	General Electric
43	Gentex
44	GKN Aerospace
45	GMV in Space
46	Hamilton Sundstrand
47	Harris Corporation
48	Honeywell Aerospace
49	IEC Electronics
50	IHI Corporation
51	Inmarsat
52	JSC Information Satellite Systems
53	KBR, Inc.
54	Kratos Defense and Security Solutions
55	L3Harris Technologies
56	Leonardo
57	LMI Aerospace Inc.
58	Lockheed Martin
59	Maxar Technologies
60	Meggitt
61	Mission Essential
62	MIT Lincoln Laboratory
63	Mitsubishi Heavy Industries
64	Moog Inc.
65	Nortech Systems
66	Northrop Grumman

100 Leading Companies in SpaceTech Sector (by Number of Employees)*

67	OHB-System AG
68	ONERA
69	Orbital ATK
70	Orbital Sciences LLC
71	Precision Castparts
72	Qinetiq Canada
73	Raytheon Technologies
74	Rockwell Collins
75	Roketsan
76	Roscosmos
77	RUAG
78	Safran
79	Saint-Gobain Aerospace
80	SES S.A.
81	Sierra Nevada Corporation
82	Sifco Industries
83	SiriusXM
84	SpaceX
85	Spirit AeroSystems
86	Swales Aerospace
87	Teledyne Technologies, Inc.
88	TERMA Group
89	Tesat-Spacecom
90	Thales Defence
91	The Aerospace Corporation
92	TransDigm Group Inc.
93	Trimble Inc.
94	TRW Inc.
95	United Launch Alliance
96	United Technologies
97	UTC Aerospace
98	Victrex
99	Virgin Group
100	Yarde Metals

Leading Companies by Investment and Funding Stage*

Company	Total Investments in $B	Last Transaction in $B	Funding Stage	Headquarters
Infrastructure Wireless Italiane	1.80	1.80	Post-IPO Secondary	Milan, Italy
Dropbox	1.71	0.60	Debt Financing	San Francisco, US
Pivotal	1.70	0.65	Series C	San Francisco, US
T-Mobile	1.57	1.57	Private Equity	Bellevue, US
Equinix	1.44	1.06	Post-IPO Debt	Redwood City, US
Snowflake	1.37	0.48	Series G	San Mateo, US
Alibaba Cloud	1.20	1.00	Series B	Hangzhou, China
Nutanix	1.15	0.75	Post-IPO Debt	San Jose, US
Wipro Technologies	1.10	1.10	Post-IPO Equity	Bengaluru, India
QTS Realty Trust	1.09	0.50	Post-IPO Debt	Overland Park, US

- Having attracted $1.8B in investments, Infrastructure Wireless Italiane is considered the largest recipient of investment.
- It is followed by Dropbox ($1.71B), and Pivotal ($1.7B).
- T-Mobile and Equinix attracted $1.57B and $1.06B in 2021.
- Alibaba attracted $1B of investments on the series B funding stage.

*as for 2020

Leading Companies by Investment and Funding Stage

Company	Total Investments in $B	Last Transaction in $B	Funding Stage	Headquarters
Cloudera	1.04	1.04	Post-IPO Secondary	Palo Alto, US
Momo	1.00	0.65	Post-IPO Debt	Beijing, China
Genesys	0.90	0.90	Private Equity	Daly City, US
Zain Group	0.85	0.85	Post-IPO Equity	Safat, Kuwait
BMC Software	0.75	0.75	Debt Financing	Houston, US
OVHcloud	0.74	0.46	Debt Financing	Paris, France
Upland Software	0.72	0.19	Post-IPO Debt	Austin, US
Cohesity	0.66	0.25	Series E	San Jose, US
J2 Global	0.65	0.65	Post-IPO Debt	Los Angeles, US
Box	0.56	0.15	Series G	Redwood City, US

- Cloudera, Zain Group, BMC Software and J2 Global have attracted the largest amount of investments thanks to their most recent deal.
- Genesys attracted $0.9B thanks to private equity funding.
- The majority of the companies from this list have attracted investments by launching IPO and using debt financing.

Leading Companies by Investment and Funding Stage

Company	Total Investments in $B	Last Transaction in $B	Funding Stage	Headquarters
Rubrik	0.55	0.55	Secondary Market	Palo Alto, US
Getronics	0.55	0.55	Debt Financing	Reading, UK
Yimidida	0.54	0.14	Series D	Shanghai, China
DocuSign	0.54	0.54	Secondary Market	San Francisco, US
Deem	0.54	0.03	Venture	San Francisco, US
SolarWinds	0.53	0.32	Post-IPO Secondary	Austin, US
Pure Storage	0.53	0.06	Secondary Market	Mountain View, US
Wangsu Science & Technology	0.51	0.51	Post-IPO Equity	Beijing, China
Veeam Software	0.50	0.50	Private Equity	Baar, Switzerland
Fuze	0.49	0.01	Venture	Boston, US

- Rubrik, Getronics, Docusign, Wangsu Science & Technology and Veeam Software have attracted the largest amount of investments thanks to their most recent deal.
- Having attracted $0.55B in investments, Getronics is the undisputed leader in this list.
- Docusign attracted $0.54B of investments from the secondary market.

100 Leading Investors in SpaceTech Sector

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100 Leading Investors in SpaceTech Sector (by Number of Deals)*

1	500 Startups
2	Accel
3	Alchemist Accelerator
4	Almi Invest
5	Alumni Ventures Group
6	AME Cloud Ventures
7	Andreessen Horowitz
8	Bain Capital Ventures
9	Battery Ventures
10	Benchmark
11	Bessemer Venture Partners
12	Bpifrance
13	Business Growth Fund
14	Canaan Partners
15	Cisco
16	Creative Destruction Lab
17	DCVC
18	Dell Technologies Capital
19	Draper Associates
20	Dylan Taylor
21	Earlybird Venture Capital
22	Enterprise Ireland
23	Entrepreneurs Roundtable Accelerator
24	EASME
25	EvoNexus
26	Felicis Ventures
27	First Round Capital
28	Floodgate
29	Foundation Capital
30	Founder Collective
31	Founders Fund
32	FundersClub
33	General Catalyst

*in alphabetical order

100 Leading Investors in SpaceTech Sector (by Number of Deals)

34	GGV Capital
35	Goldman Sachs
36	Greylock
37	GV
38	Hercules Capital
39	High-Tech Grunderfonds
40	Horizon 2020
41	IDG Capital
42	Idinvest Partners
43	Index Ventures
44	In-Q-Tel
45	Insight Partners
46	Intel Capital
47	IVP
48	Keiretsu Forum
49	Khosla Ventures
50	Kleiner Perkins
51	Lighter Capital
52	Lightspeed Venture Partners
53	Lux Capital
54	Madrona Venture Group
55	MassChallenge
56	MassVentures
57	Mayfield Fund
58	Menlo Ventures
59	Microsoft
60	National Science Foundation
61	New Enterprise Associates
62	Nexus Venture Partners
63	Norwest Venture Partners
64	NYSERDA
65	OpenView
66	Partech

100 Leading Investors in SpaceTech Sector (by Number of Deals)

67	Plug and Play
68	Qualcomm Ventures
69	Redpoint
70	Right Side Capital Management
71	Salesforce Ventures
72	Samsung Ventures
73	Sapphire Ventures
74	Scale Venture Partners
75	Sequoia Capital
76	Shasta Ventures
77	Sierra Ventures
78	Silicon Valley Bank
79	Slow Ventures
80	SOSV
81	Start-up Chile
82	Startupbootcamp
83	StartX
84	Storm Ventures
85	SV Angel
86	TCV
87	Techstars
88	Techstars Ventures
89	Telstra Ventures
90	Threshold
91	True Ventures
92	U.S. Venture Partners
93	Venrock
94	Venture Kick
95	Vertex Ventures
96	Voyager Capital
97	Wavemaker Partners
98	Western Technology Investment
99	Wayra
100	Y combinator

30 Leading SpaceTech Investors / Portfolio Companies

Investors	Companies
European Commission EASME Executive Agency for SMEs	Eleaf, GeoVille, PIXXEL, FOOTMARKS, e4c eco4cloud, SKYSPECS, ARWAY, ADVENIAS YOUR IDEA OF SOFTWARE
techstars	lifebit, Astroprint 3D Print Cloud, mLab, CYCURO, Cypheme
Y Combinator	bioRender, PadMapper, IBM, BITMOVIN, KubeSail
intel	datto, ScienceLogic, panoply, Paxata, cisco, harmonic
500 startups	Keen, aureso, ATOMIONICS, BLOCKCYPHER, Dropsuite, FriendlyData
NEA	NEXTNAV, nodeprime, everactive, logikcull, tuya, Tintri
salesforce ventures	APPIRIO a wipro company, SHANON for Successful Business., Novidea, DocuSign, ZYLO, uhuru
Goldman Sachs	cellnex, CLOUDIAN, THOMSON REUTERS, Limelight NETWORKS, NASUNI
SEQUOIA	Mellanox TECHNOLOGIES, snowflake, Red Hat OpenShift, CUMULUS, druva, dolphin, MICROCHIP
RSCM RIGHT SIDE CAPITAL MANAGEMENT, LLC	Legalinc, vmw, DataBlade, CYCURO, TYFFON, Virgo, lynq

30 Leading SpaceTech Investors / Portfolio Companies

Investors	Companies
SVAngel	REDCAP, CUMULUS, DRONE BASE, ZYLO
Accel	ermetic, duetto, CLOUDERA, clockwise, ARISTA
PLUGANDPLAY	neteera, NGD systems, KODIAK DATA, envio, cinpost, ixlayer, Uber Cloud
CREATIVE DESTRUCTION LAB	NAVA, GEOCENTO, SPACE RYDE, CISLUNAR INDUSTRIES, PIXXEL, Benchmark Space Systems
Lightspeed	vmw, AVI Networks, CATO NETWORKS, PENSANDO, cohere technologies, Tintri
svb	VERVE GROUP, BIRCH, NASUNI, RingCentral, A10 Networks
MC	indigo, cirrus, bird.i, nextome, TapWalk, SMG
a16z	LOCOMOBI, Akamai, tidemark, CUMULUS, D2IQ
BESSEMER VENTURE PARTNERS	estimote, VONAGE, OKERA, verato, ctera
ALUMNI VENTURES GROUP	INTELITY, ARRIS, OPENPRISE, ANRA TECHNOLOGIES, PRENAV

30 Leading SpaceTech Investors / Portfolio Companies

Investors	Companies
DC>C Data Collective	solarwinds, FORTEM TECHNOLOGIES, RAPTOR MAPS, intel, KODIAK DATA, Keen
INSIGHT PARTNERS	Tintri, jedox., conga, MIRANTIS, Skytap, kasten
BainCapital VENTURES	Moveworks, clockwise, opsani, turbonomic, Datica, ARIA
NORWEST	celona, ORACLE, Qubole, WEKA, WORLD VIEW
KLEINER PERKINS	Miaozhen Systems, SPINLAUNCH, Viasat, D2IQ, RED HAT OPENSHIFT, looker
ALCHEMIST ACCELERATOR	Segmed, 3TEN8.AI AUTONOMOUS NETWORKS, QUANTIPLY, NDB, NFWare
foundation capital	LOFT ORBITAL, CLOUDKNOX, BLOCKCYPHER, SYNOPSYS, Stacklet
FOUNDER COLLECTIVE	now, indigo, asurion, Gig
NEW YORK STATE OF OPPORTUNITY. NYSERDA Supported	STARFIRE SYSTEMS, innoveering innovative engineering solutions, BLASCH, ELECTRON COIL INC, BAE SYSTEMS
canaan partners	zmanda A BETSOL COMPANY, JOHN ZINK HAMWORTHY COMBUSTION, WORLD VIEW, AMBRA, ASTRA

Top Publicly Traded Companies in SpaceTech Industry

May 2021

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Introduction

Publicly traded SpacetTech companies develop advanced technologies that will make Mars settlements, space stations and deep space researches possible. One can contribute to the space exploration effort by **investing in such companies**.

SpaceTech as one of the most advanced branches of science offers various opportunities for the exploring investor. Moon rockets and space stations are still expensive, however space is no longer the exclusive domain of national governments. Moreover, public and private companies are now involved in **satellites, research, mining, communications and space tourism. The space business has branched into several distinct sectors,** with hundreds of companies involved, and has even developed its own market index and specialized research sources. There are companies that provide network, navigation and Earth observation services to other industries of the world. As the SpaceTech sector is developing rapidly throughout the globe, public companies raise their stocks and private companies become public.

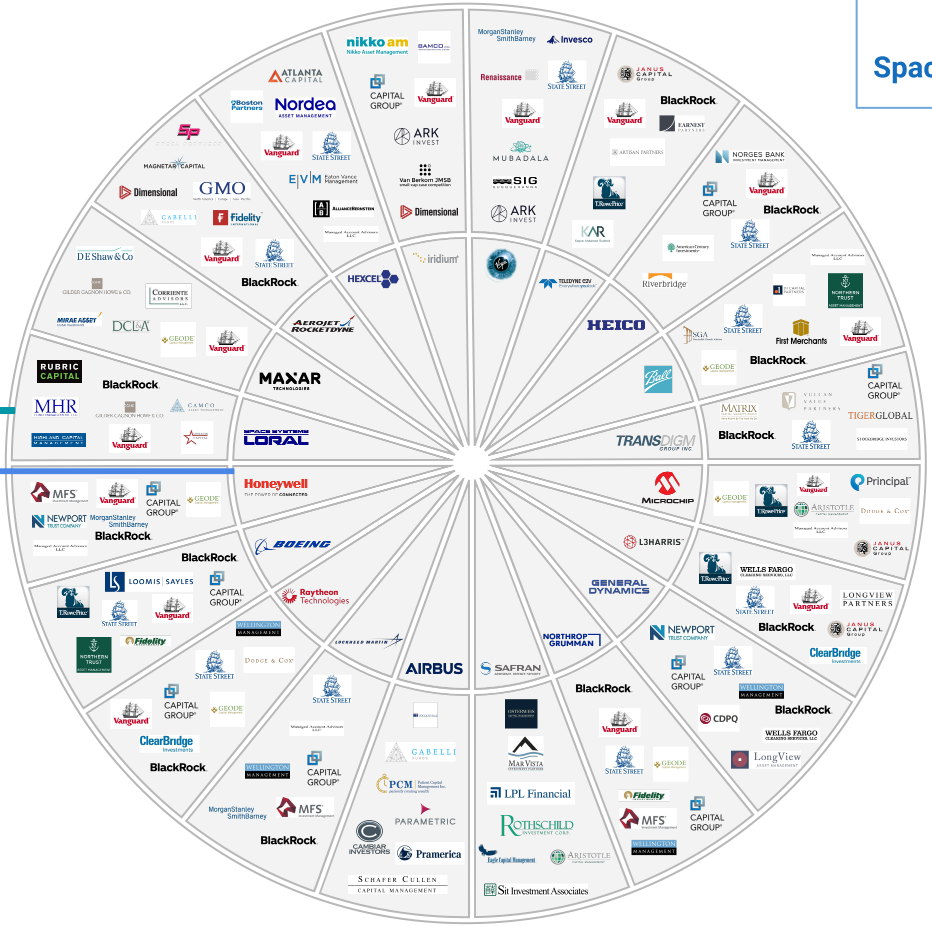
The estimated **$400 Billion space economy** is still largely dominated by large aerospace and satellite companies, serving government-funded interests.

SpaceTech Analytics has conducted the profound data analysis concerning the following sections:

- Top 20 Publicly Traded Companies by Capitalization
- Top Latest Companies by IPO
- Top Companies by Upcoming IPO
- Best Performing SpaceTech Companies 2020-2021

Investors of Top 20 Publicly Traded Companies

The Largest Shareholders of Top SpaceTech Publicly Traded Companies



Top 20 Publicly Traded Companies by Capitalization in 2021

1	Honeywell International Inc.	$160.3B
2	The Boeing Company	$144.5B
3	Raytheon Technologies Corporation	$134.4B
4	Lockheed Martin Corporation	$106.2B
5	Airbus SE	$102.6B
6	Safran SA	$64.1B
7	Northrop Grumman Corporation	$58.9B
8	General Dynamics Corporation	$53.7B
9	L3Harris	$44.7B
10	Microchip Technology Inc.	$42.9B
11	TransDigm Group Inc.	$35.6B
12	Ball Corporation	$26.97B
13	HEICO	$19B
14	Teledyne Technologies, Inc.	$15.5B
15	Virgin Galactic	$7.5B
16	Iridium Communications Inc.	$5.1B
17	Hexcel	$4.98B
18	Aerojet Rocketdyne	$3.9B
19	Maxar Technologies	$2.2B
20	Loral Space And Communications	$0.8B

Latest and Upcoming IPOs*

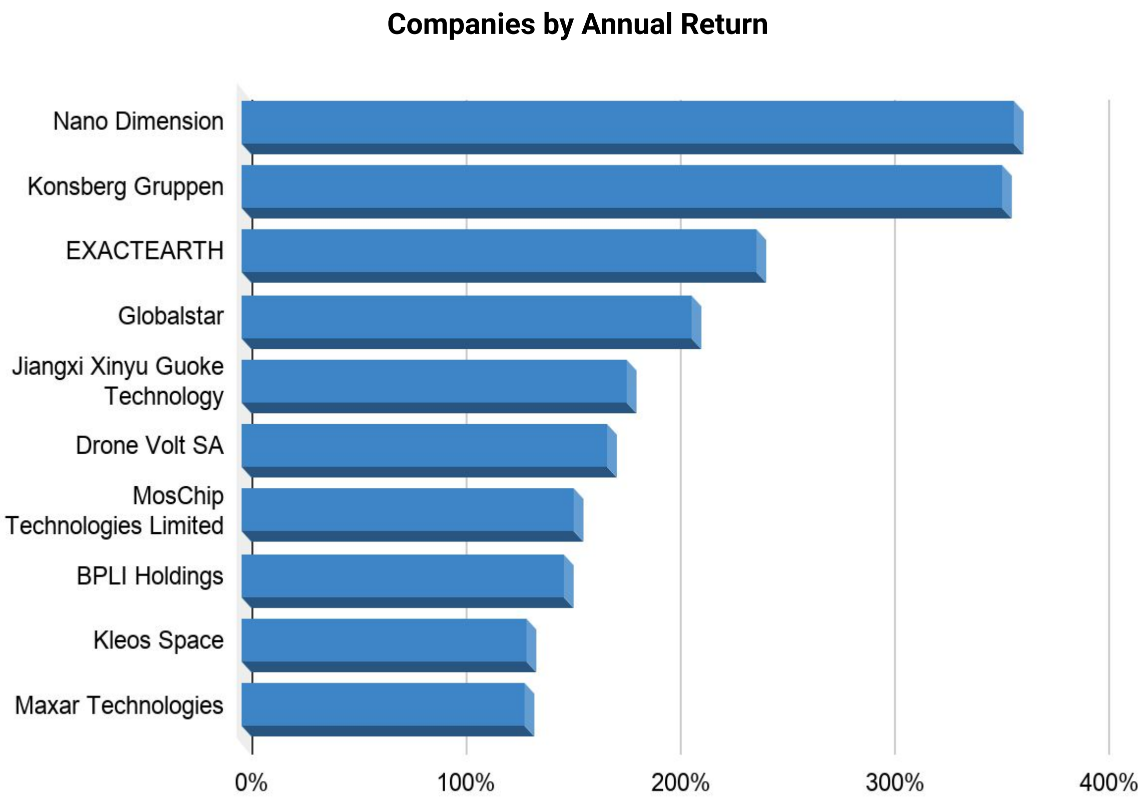
Company	IPO Date	Description
AAC Clyde Space	19.03.2019	AAC Clyde Space is advanced nanosatellite spacecraft mission services, & providing New Space solutions and services.
Virgin Galactic	28.10.2019	Virgin Galactic is the world's first commercial spaceline and vertically integrated aerospace company.
Nanjing Institute Of Surveying	03.04.2020	Nanjing Institute Of Surveying pays close attention to the development of surveying and geographic information technology.
VeriSilicon Holdings	21.08.2020	VeriSilicon Holdings is an IC design foundry that provides custom silicon solutions and system-on-chip turnkey services.
AmpliTech Inc.	17.02.2021	Amplitech Group is a manufacturer of custom and standard RF components for commercial, space, defense, and military markets.
Rocket Lab	upcoming	Rocket Lab delivers a range of complete rocket systems and technologies for fast and low-cost payload deployment.
Spire Global	upcoming	Spire Global Inc. is a space to cloud data analytics company utilizing satellites to provide maritime, aviation, and weather tracking.
BlackSky	upcoming	BlackSky Global is a satellite-imaging-as-a-service startup based in Seattle.
Astra Space	upcoming	Astra is a rocket launch startup that provides satellite delivery and launch services.
Momentus	upcoming	Momentus offers the infrastructure services necessary to enable enterprise and human existence to flourish in space.
Nanoracks	upcoming	Nanoracks is building tools to allow for the re-purposing of in-space hardware and turn it into agile space stations, which the company call Outposts.

*special purpose acquisition companies (SPAC) also included

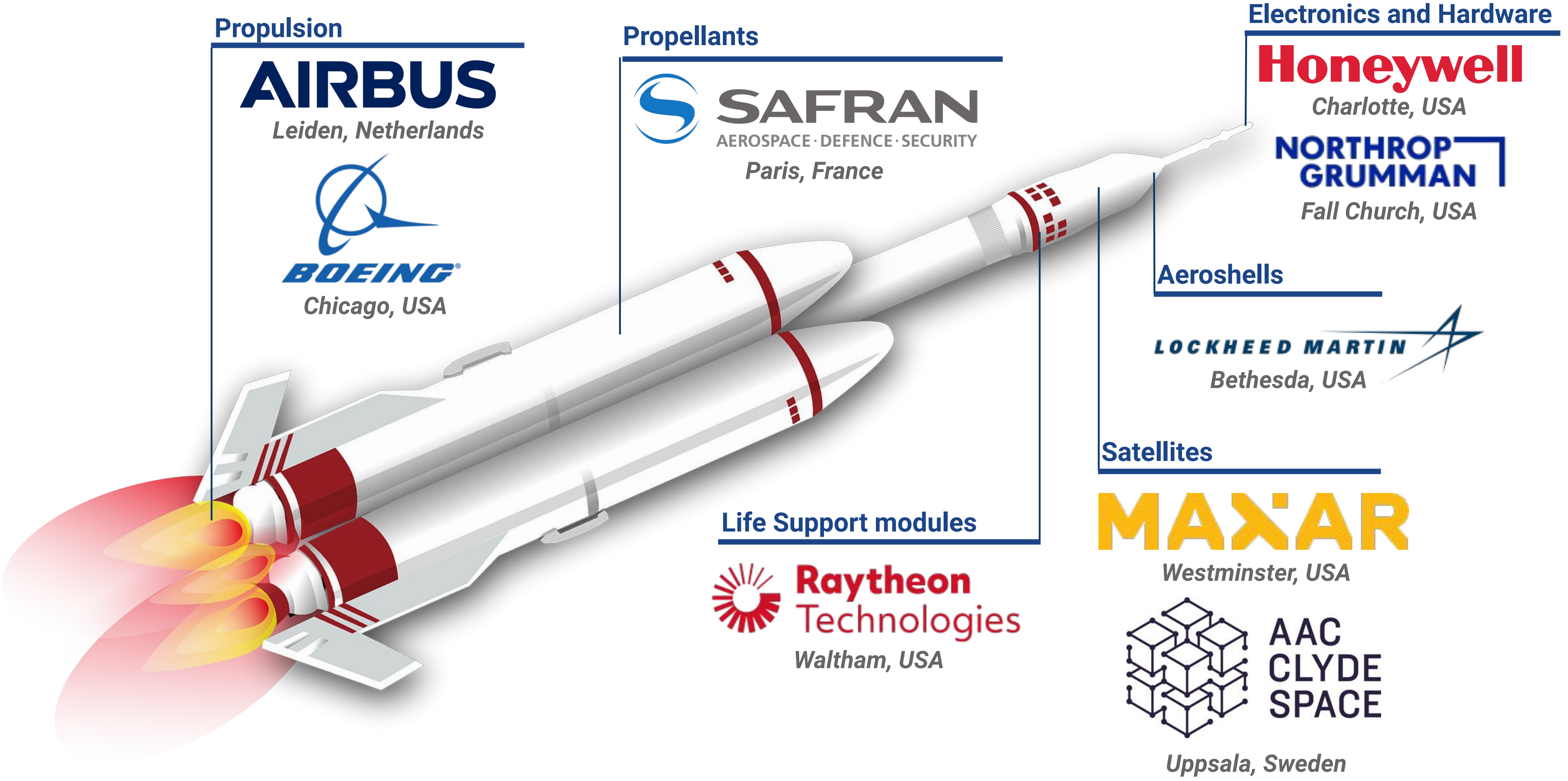
Best Performing SpaceTech Companies 2020-2021

There was a market trend toward an increase in **capitalization** of the majority of SpaceTech companies in 2021:

- With a rate of **return of 356%**, Nano Dimension experienced the largest growth. Its capitalisation increased more than **a 3.5 times** in 2020.
- With a growth rate of **354%,** Kongsberg is the second fastest growing company in 2020.
- The third largest company is Exactearth, whose **growth rate stood at 247%**.
- Other companies (seen on the right) also demonstrated a dramatic **growth** in 2020 and are, therefore, also worth looking at.



Public Manufacturing Companies



Schematic display of some rocket parts produced by several public companies.

Source: [PNGtree]

Space Exploration & Innovation ETF (ARKX)

ARK Space Exploration & Innovation ETF is an actively-managed exchange-traded fund incorporated in the USA and will invest under normal circumstances primarily (at least 80% of its assets) in domestic and foreign equity securities of companies that are engaged in the Fund's investment theme of Space Exploration and Innovation.

Space Exploration

The fund seeks to provide exposure to companies involved in space-related businesses like reusable rockets, satellites, drones, and other orbital and suborbital aircrafts. These innovations should transform logistics, observation, agriculture, telecom, drones, and may even put humans on Mars.

Strategy Description

This actively managed equity strategy seeks long-term capital growth by investing in domestic and foreign equity securities of companies focused on space exploration. What used to be a monopolistic and bureaucratic industry is being upended by both rocket and satellite cost declines.

Cathie Wood is a founder, CEO and CIO of Ark Invest, an investment management company.

Investment Focus

Reusable Rockets	Suborbital Aerospace	Orbital Aerospace
Aerial Drones	Enabling Technology	3D Printing

Space Exploration & Innovation ETF (ARKX Top 5 Stocks)

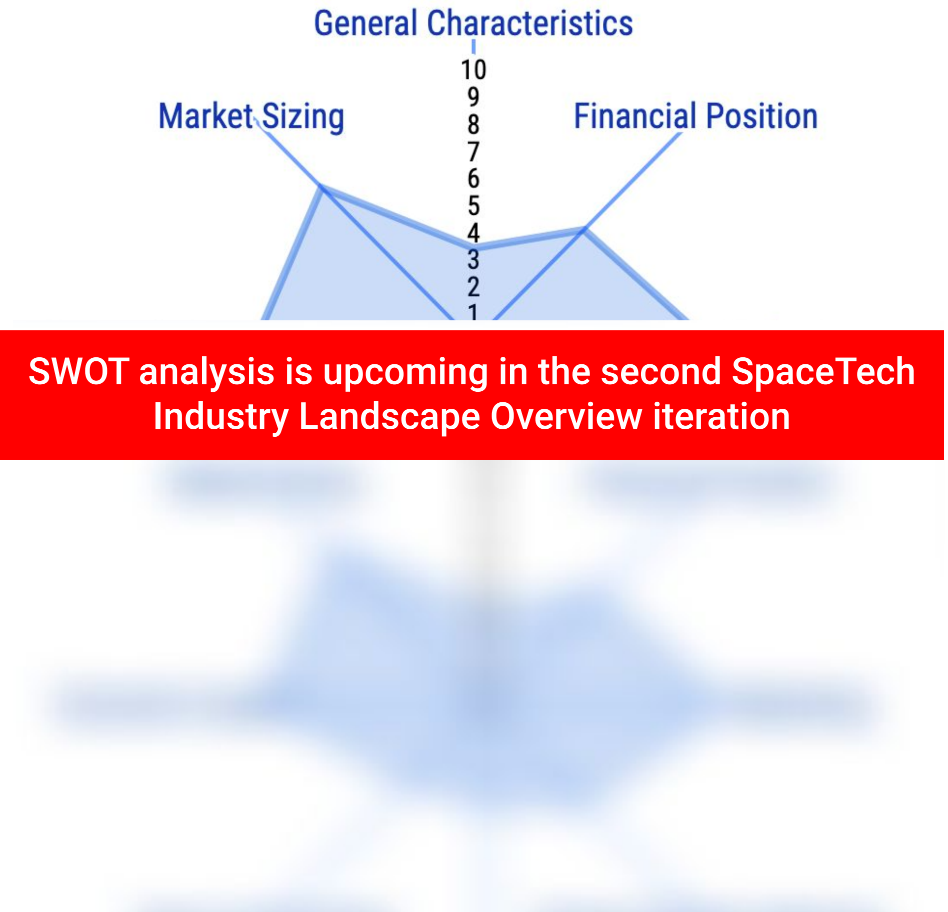
Trimble	Sunnyvale, California, US, 1978	Trimble is transforming the way the world works by delivering products and services that connect the physical and digital worlds. Core technologies in positioning, modeling, connectivity and data analytics enable customers to improve productivity, quality, safety and sustainability.
INVEST IN THE 3D PRINTING ETF PRNT	N/A 2016	The 3D Printing ETF (PRNT) seeks to provide investment results that closely correspond, before fees and expenses, to the performance of the Total 3D-Printing Index, which is designed to track the price movements of stocks of companies involved in the 3D printing industry.
KRATOS DEFENSE & SECURITY SOLUTIONS	San Diego, California, US, 1994	Kratos Defense & Security Solutions, Inc. operates as a defense contractor and security systems integrator for the federal government and for state and local agencies. The Company offers services in weapon systems lifecycle support, military weapon range, security and surveillance systems, and IT engineering.
L3HARRIS™ FAST. FORWARD.	Melborn, Florida, US, 2017	L3Harris Technologies is an American technology company, defense contractor and information technology services provider that produces C6ISR systems and products, wireless equipment, tactical radios, avionics and electronic systems, night vision equipment, and both terrestrial and spaceborne antennas for use in the government, defense, and commercial sectors.
JD.COM	Falls Church, Virginia, US, 1939	JD.com, Inc. also known as Jingdong and formerly called 360buy, is a Chinese e-commerce company headquartered in Beijing. It is one of the two massive B2C online retailers in China by transaction volume and revenue, a member of the Fortune Global 500 and a major competitor to Alibaba-run Tmall.

Space Exploration & Innovation ETF (ARKX Top 10 Holding According to Their Weight)*

Weight	Company	Ticker	Market Price	Market Values
8.72%	TRIMBLE INC	TRMB	$73.84	$53,468,430.08
6.60%	THE 3D PRINTING ETF	PRNT	$35.39	$40,478,728.10
5.49%	JD.COM INC-ADR	JD	$71.25	$39,805,950.00
5.64%	KRATOS DEFENSE & SECURITY	KTOS	$24.35	$34,589,832.45
5.50%	L3HARRIS TECHNOLOGIES INC	LHX	$211.06	$33,724,222.10
5.13%	IRIDIUM COMMUNICATIONS INC	IRDM	$35.29	$31,426,062.61
4.60%	LOCKHEED MARTIN CORP	LMT	$380.62	$28,169,305.58
4.57%	KOMATSU LTD	6301	$29.45	$28,010,071.41
4.28%	THALES SA	HO	$102.24	$26,263,667.80
3.31%	BOEING CO/THE	BA	$220.78	$20,302,487.24

* according to their weight as for 13.05.2021

Source: *(ARKX) HOLDINGS*



SWOT analysis is upcoming in the second SpaceTech Industry Landscape Overview iteration

Northrop Grumman Corporation operates as an aerospace and defense company worldwide. The company operates through four segments: Aeronautics Systems, Defense Systems, Mission Systems, and Space Systems.

Stock price (in B $)

Ticker	Mean Daily Return	Volatility of Daily Returns	Growth After IPO	Capitalization (B$)
NOC	-0.01%	2.39%	1179.11%	58.8

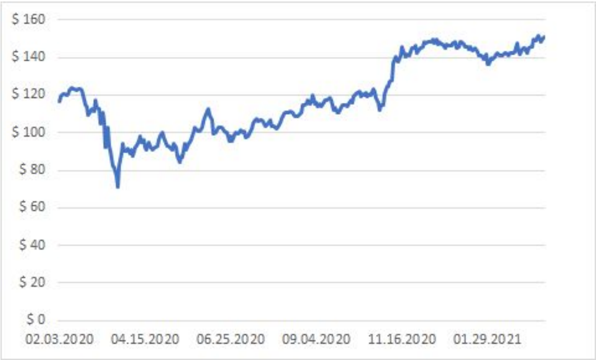
Honeywell International Inc.

Honeywell

SWOT analysis is upcoming in the second SpaceTech Industry Landscape Overview iteration

Honeywell International Inc. operates as a diversified technology and manufacturing company worldwide. Its Aerospace segment offers auxiliary power units, propulsion engines, integrated avionics, environmental control and electric power systems, engine controls, flight safety, communications, navigation hardware, data and software applications.

Stock price (in B $)



Ticker	Mean Daily Return	Volatility of Daily Returns	Growth After IPO	Capitalization (B$)
HON	0.13%	2.73%	2466.67%	160.38

TELEDYNE TECHNOLOGIES INCORPORATED

SWOT analysis is upcoming in the second SpaceTech Industry Landscape Overview iteration

Teledyne Technologies Incorporated provides instrumentation, digital imaging, aerospace and defense electronics, and engineered systems in the United States, the United Kingdom, Canada, Denmark, France, the Netherlands, and internationally. The company's Instrumentation segment offers monitoring and control instruments for marine, environmental, industrial, and other applications.

Stock price (in B $)

Ticker	Mean Daily Return	Volatility of Daily Returns	Growth After IPO	Capitalization (B$)
TDY	0.07%	3.16%	4338.56%	19.52

Aerojet Rocketdyne Holdings

SWOT analysis is upcoming in the second SpaceTech Industry Landscape Overview iteration

Aerojet Rocketdyne Holdings, Inc. designs, develops, manufactures, and sells aerospace and defense products and systems in the United States. It operates in two segments, Aerospace and Defense, and Real Estate. The Aerospace and Defense segment offers aerospace and defense products for the United States government.

Stock price (in B $)

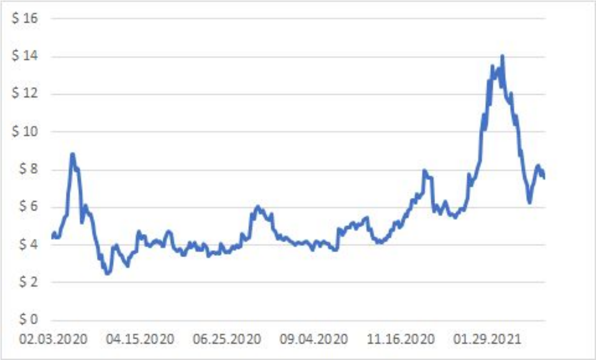
Ticker	Mean Daily Return	Volatility of Daily Returns	Growth After IPO	Capitalization (B$)
AJRD	0.06%	3.42%	661.8%	3.88

Virgin Galactic Holdings

SWOT analysis is upcoming in the second SpaceTech Industry Landscape Overview iteration

Virgin Galactic Holdings, Inc., an integrated aerospace company, develops human spaceflight for private individuals and researchers in the United States. It also manufactures air and space vehicles. The company's spaceship operations include commercial human spaceflight, flying commercial research, and development payloads into space.

Stock price (in B $)



Ticker	Mean Daily Return	Volatility of Daily Returns	Growth After IPO	Capitalization (B$)
SPCE	0.45%	7.23%	210.00%	7.52

Conclusions

The global SpaceTech industry is expected to generate revenue of **$10T** in 2030. That's up from the current **$350B**. In other words, this is a massive opportunity for private equity investors. The commercial SpaceTech sector is **extremely fast-growing**. The market could triple in the next few decades, creating a trillion-dollar opportunity for early entrants. Barriers to entry could restrict competition and enhance the value of market leaders. Tendencies in the sector investments are changing, and while the traditional space industry was once dominated by governments, the New Space industry is **dominated by private, emerging companies.** However, the collaboration between the private and governmental companies have proved its effectiveness, which boosts the growth rate of the whole industry.

SpaceTech is tightly regulated, and the most dominating subject at the moment is the US government. National security concerns and defence contracts of all developed countries complicate the common concerns further. Most of the upcoming IPOs are headquartered in US, but the numbers are growing and companies from other countries also emerge.

Relying on various research methods and analytics techniques, the report provides a comprehensive overview of top publicly traded SpaceTech companies. Our proprietary analytics is based on the following data sources:

- **Industry Reports and Reviews**
- **Publicly Available Sources (Websites)**
- **Media Overview (Articles, Press Releases)**
- **Industry-Specialised Databases**

Key Takeaways

1. The analysis demonstrated that the richest and most influential investors of the world expressed their interest in SpaceTech and consider the industry as perspective area of opportunities.
2. The global SpaceTech industry is expected to generate revenue of $10T in 2030.
3. The growing number of IPOs in the SpaceTech industry shows a high level of interest among investors in this sector. The number of IPOs in the SpaceTech industry rose from 2 in 2019 to 5 in 2020.
4. Collaboration between public and private agencies and companies proved its **effectiveness**. A synergy of public and private companies is considered to be the most efficient way to achieve goals and develop technological progress.
5. **Software, Manufacture** and **Satellite** communication are the **largest sectors** among public companies, which correlates with the whole industry. However public companies are now also involved in research, mining, communications and space tourism too.
6. Most of the leading publicly traded companies have an elaborated marketing, which means that advanced marketing is a required feature of a successful public company in SpaceTech.
7. With a total of $28B invested in 3,086 companies, the US is an undisputed leader in terms of SpaceTech investments. This is approximately 6 times the amount invested in SpaceTech companies in China - the second largest country in terms of spacetech investment ($4.786B invested in 122 companies).
8. Despite the crisis, publicly traded companies demonstrated rapid growth, as their market capitalisation increased from $3.41 trillion in February 2020 to $4.02 trillion in March 2021.
9. **Overall change of profit of companies that became public in recent decade is positive.**
10. The biggest annual returns of recent years are collected by Manufacture and Satellite companies.
11. However, the biggest capitalization is obtained by Space Medicine and Cloud companies.
12. **Utilization of developments in Air and Spacecraft, Space missions** in SpaceTech is significant.

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Top SpaceTech Breakthroughs

2010

Hayabusa

First spacecraft to return to Earth with samples from an asteroid. It was a Japanese spacecraft that explored asteroid Itokawa. The interesting thing is that the spacecraft was launched in 2003

2011

Messenger

First spacecraft to orbit Mercury. Messenger was a U.S. spacecraft that studied Mercury's surface and environment. The spacecraft crashed on the planet's surface after running out of fuel on April 29, 2015.

2014

Rosetta

First spacecraft to orbit a comet. Rosetta - European Space Agency spacecraft that carried Philae. The expectation was that the craft would help to decode the history of the solar system.

2014

Philae

First spacecraft to land on a comet. Philae took seven hours to descend to the comet's surface. The lander was to fire two harpoons and use three ice screws in its legs to anchor itself to the surface of the comet.

2015

Dawn

First spacecraft to orbit a dwarf planet (Ceres). Dawn was launched September 27, 2007 by U.S, and flew past Mars on February 17, 2009, to help reshape its trajectory toward the asteroid belt.

2015

New Horizons

First spacecraft to fly by Pluto. New Horizons observed a large, young, heart-shaped region of ice on Pluto and found mountains made of water ice that may float on top of nitrogen ice.

Top SpaceTech Breakthroughs

2015

Falcon 9

First rocket stage to return to its launch site. SpaceX did its first relaunch of a previously flown Falcon 9 first stage on March 30, 2017. The first Falcon Heavy test flight occurred on February 6, 2018.

2019

New Horizons

Farthest object (2014 MU69) explored by a spacecraft. The Kuiper Belt object MU69 has been officially named “Arrokoth”, a Native American term meaning “sky” in the Powhatan language.

2019

Chang'e 4

First landing on the Moon's far side. Eight chinese devices measured radiation emitted by naturally decaying heavy elements. These spectral data helped quantify the amounts of minerals on the lunar surface.

2021

Perseverance

First aircraft to attempt controlled flight on another planet. The rover has an onboard helicopter Ingenuity that will help in land surveying and probable landing areas.

2022

Artemis II

First stationary Moon station. NASA is planning to make a crewed flight to the Moon in order to establish a so called Gateway

2026

SpaceX Starship

First humans to land on Mars. It was originally planned to launch a crew to Mars in 2024, but in 2019 Elon Musk stated that the flight will be uncrewed.

National Space Programmes: Activity Overview

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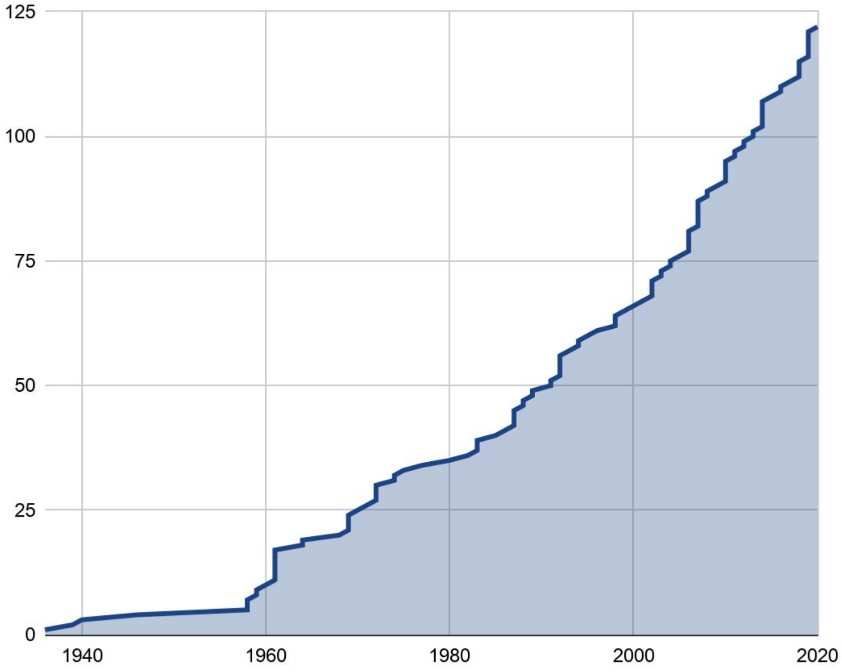
Introduction

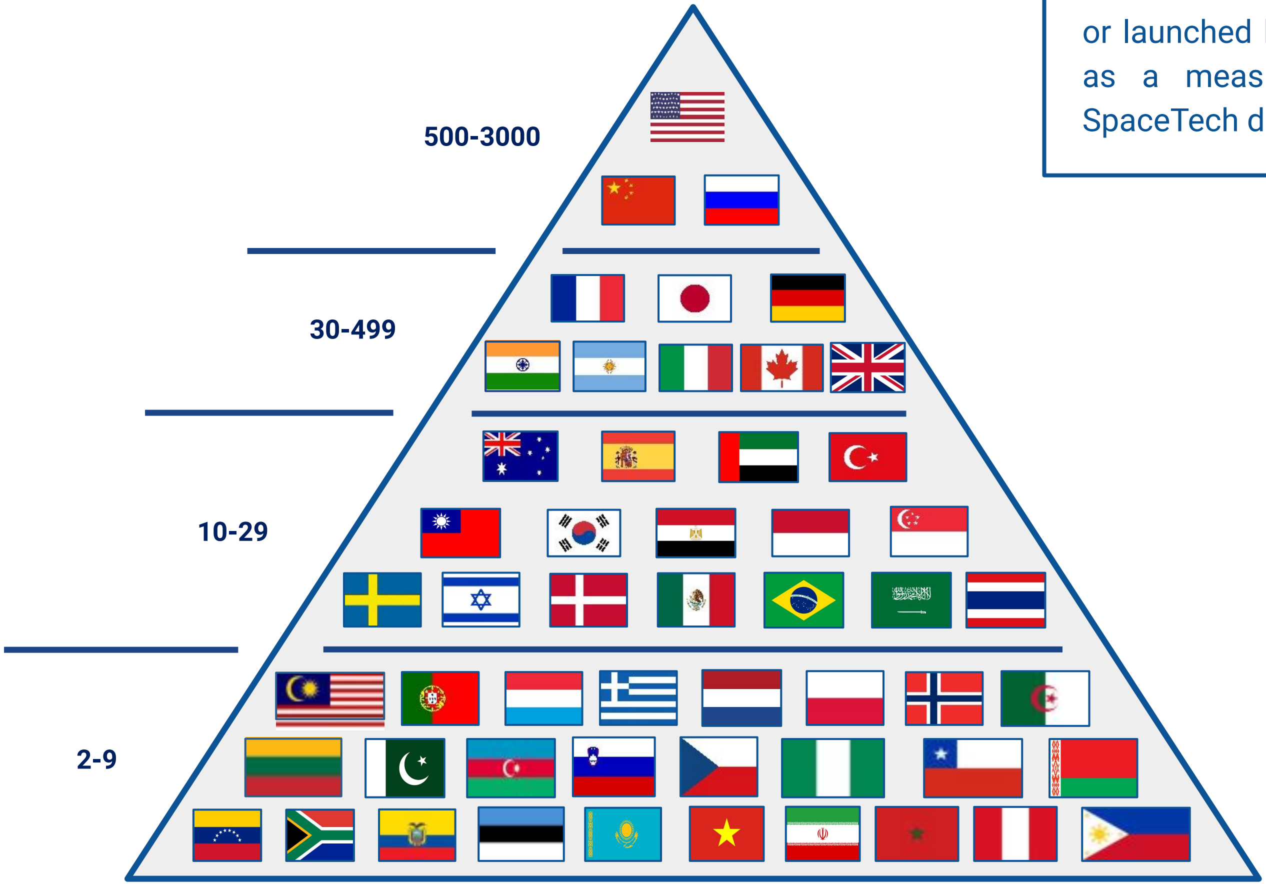
Since the very beginning of The Space Race back in 1957 different countries all over the world have been developing their space technologies with a massive effort. At first it was only USA and USSR, but then Europe and China joined with more than 120 governmental space agencies. There are also a number of space agencies, that are expected to be established in the following years. The development of the governmental agencies has accelerated during last 10 years, f.e. UAESA ran by United Arab Emirates was only formed in 2014, but has already sent a probe to Mars.

Governmental agencies have always been the ones to exclusively run manned and unmanned flights. At first it was about launching satellites into orbit and probes to other planets, but today we already have a set of rovers on Mars, a giant space station built with the cooperation of many different countries and the telescopes that have left Solar system and could look into the past of our galaxy. Much more is yet to come. Some agencies have concentrated on implementing high-precision Earth observation satellites, that will help with monitoring the conditions on the planet. Others are building the telescopes that will answer a broad variety of big questions about physics and space.

Number of Governmental Space Agencies Timeline



Number of Satellites by Country



Number of satellites either owned or launched by country used here as a measure of approximate SpaceTech development

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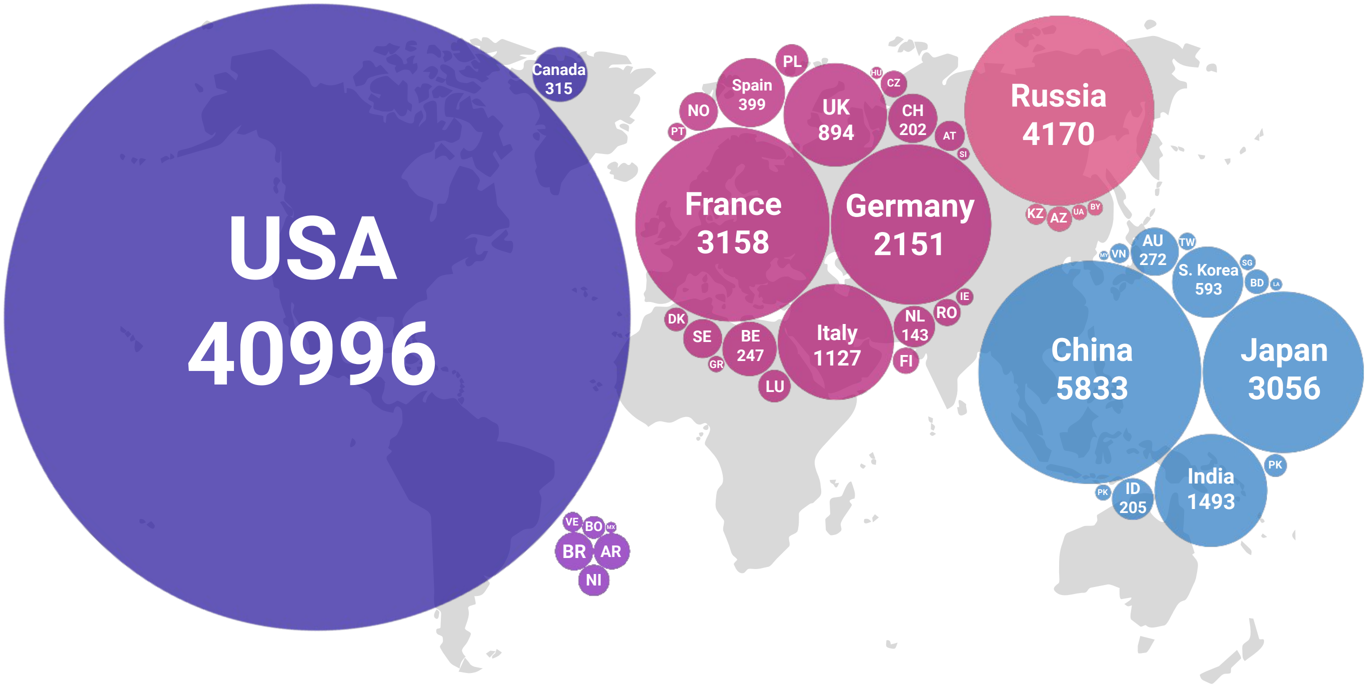
Government Space Budgets in Billions of USD

	Government space budgets	Number of space companies	Presence of missions to Mars	Number of missions to Mars	Space national programme	Participation in the international programmes of European Space Agency	Number of government space agencies
USA	40,996	1741	+	15	+	-	22
China	5,833	147	+	2	+	-	3
France	3,158	170	-	-	+	+	2
Russia	4,170	8	+	3	+	-	2
Japan	3,056	72	+	1	+	-	1
Europe	2,115	1768	+	4	+	-	-
Germany	2,151	158	-	-	+	+	2
India	1,493	110	+	1	+	-	10
Italy	1,127	56	-	-	+	+	1
UK	894	99	+	1	+/-	+	9
South Korea	593	17	-	-	+	0	-
Spain	399	103	-	-	-	+	1
Canada	315	125	-	-	+	-	2
UAE	383	28	+	1	+	-	2
Australia	272	66	-	-	+	-	2

+ - Yes; **-** - No; **+/-** - Partial

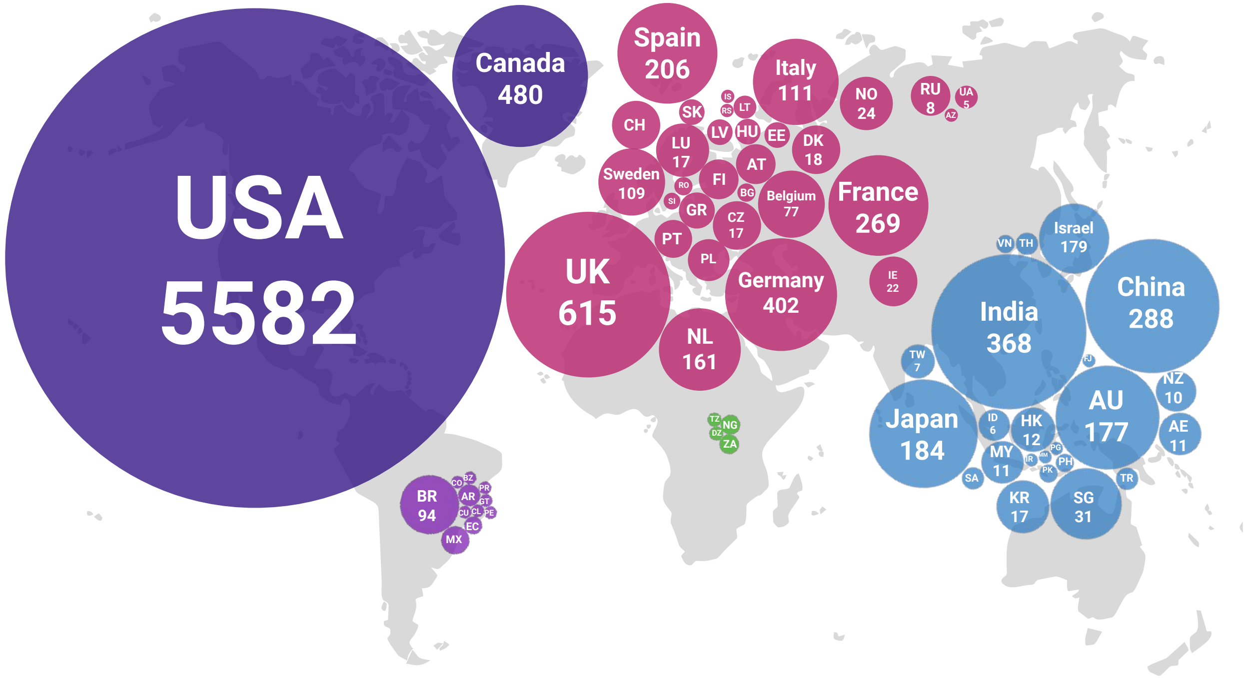
Government Space Budgets in $, Millions



The United States spends more on space than all other countries combined. Its space exploration budget exceeds those of China, Russia, France, Japan, and Germany by wide margin. In 2018, of $70.9 billion government space investments, 63% were spent on civil programs, as military budgets tend to fluctuate on lengthier budget cycles. World space budgets are projected to continue their growth trend in the medium term, peaking at an estimated $84.6B by 2025, before downcycling.

Sources: Euroconsult

Number of SpaceTech Companies by Country



More than half of the companies analyzed in the report are US-based. However, the geographical distribution of SpaceTech companies is wider and more diverse than that of government-funded space exploration programmes. Interestingly, even countries whose space exploration budgets are relatively small have SpaceTech companies.

The USA

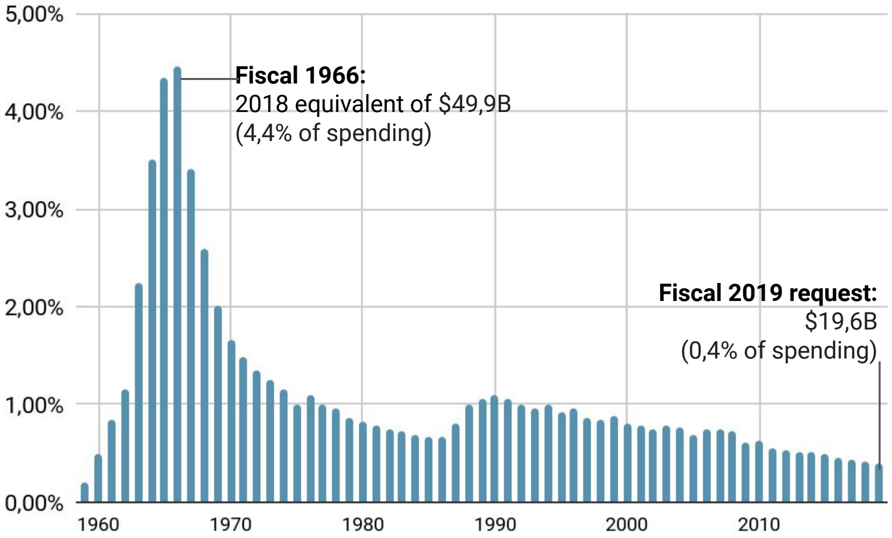
Since the retirement of its space shuttle program in 2011, the United States had depended on Russia's Soyuz spacecraft to get its astronauts to the International Space Station. That changed on May 30, 2020, with the launch of SpaceX Crew Dragon spacecraft. This is a clear demonstration of NASA's plans to cooperate with viable commercial alternatives; however, it doesn't mean that further cooperation with other countries, including Russia, will no longer be an option.

Relationships with China

Complicated as they are, they tend to be particularly tricky when it comes to cooperation in space. American legislation, namely the Wolf Amendment of 2011, prevents the White House and NASA from engaging in space-related cooperation with China without prior sign-off from the FBI. Though it does not stop the two countries from having strategic space dialogue, it still is a major obstacle to US-China cooperation in space. In June 2020, the Defense Department released its **four-pillar strategy** outlining work to be done in space in the next decade and beyond. According to it, the country's main efforts will be invested in:

- Building a comprehensive military advantage in space;
- Integrating space in the joint force together with allies and partners;
- Shaping a strategic environment;
- Working with allies, partners, industry partners, and other U.S. agencies.

NASA's Share of Federal Spending



Sources: *World Politics Review, U.S. Dept of Defence*

The Juno Mission

Launched in 2011, the Juno mission is expected to continue until September 2025 or the end of its life, whichever comes first. The Juno spacecraft has already made discoveries about:

- Jupiter's interior structure,
- magnetic field, and magnetosphere
- have found its atmospheric dynamics to be far more complex than scientists previously thought.

Juno will further continue to observe both the gas giant and the planet's rings and its moons, including "close flybys" of Ganymede, Europa, and Io.

The InSight Mission

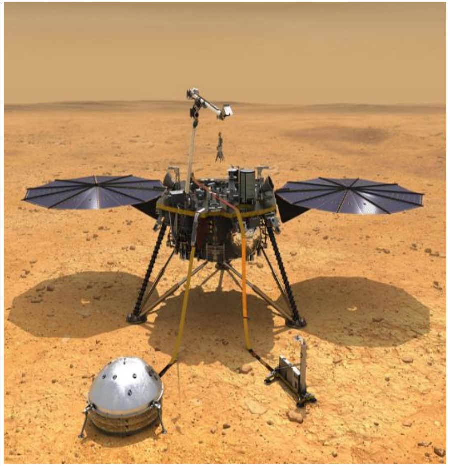
It is extended for two years, running through December 2022. InSight's spacecraft deployed its highly sensitive seismometer to expand the understanding of Mars' crust and mantle. The mission team collected data demonstrating the robust tectonic activity of Mars.

- In April 2019, the InSight lander recorded the first-ever "Mars quake."
- In September 2019, the InSight lander detected bizarre bursts of magnetic pulses on Mars.

Two main NASA missions: Mars and Jupiter exploration

Citing discoveries that have "produced exceptional science," NASA has decided to add several years to two of its planetary science missions: the Jupiter Juno mission and the Mars InSight lander.

"The Senior Review has validated that these two planetary science missions are likely to continue to bring new discoveries, and produce new questions about our solar system," said Lori Glaze, director of the planetary science division at NASA Headquarters in Washington.



Sources: JPL, Fox News

China

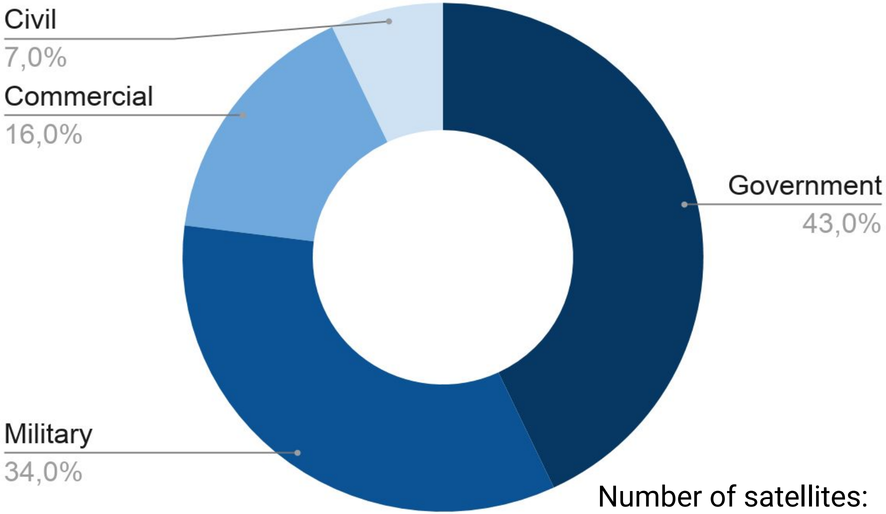
After becoming the third country to launch a human into space in 2003, China has been steadily expanding its space program. One of its major accomplishment was when Chang'e 5 lunar probe successfully landed on the Moon on December 1, 2020. The landing brought Beijing a step closer to becoming the third country in the world to retrieve geological samples from the Moon. While reaching the Moon remains a significant accomplishment for any space program, Beijing's space program is still in its early stages.

"They're catching up to where the United States was in the 1960s,"

said Todd Harrison, director of defense budget analysis and space security at the Center for Strategic and International Studies, a Washington think tank. "The United States has already sent not just probes to the moon but humans and returned to the Earth and brought back samples of lunar rocks. So China is catching up in that respect, but they're still not where the United States is in terms of space technology. But it is nevertheless a competition for science."

Xi Jinping aspires to achieve an authoritarian-led space order with economic generosity and a carefully constructed narrative of "benefiting humankind." Lurking behind that feel-good narrative, however, is a highly nationalistic and ambitious space program that aspires to establish China as the leading nation in space innovation by 2049.

Total Satellite Launches in China
till 31.03.19



Number of satellites:
Launches in 2020: **39**

Sources: *VOA*, *The Diplomat*

Tiangong Space Station

One the most ambitious China's projects is Tiangong Space Station. Tiangong is the successor to China's Tiangong-1 and Tiangong-2 space laboratories, which were deorbited in 2016 and 2019 respectively. Station shall be completed until the end of 2022 and will consist of a core module Tianhe and two laboratory modules Wentian and Mengtian. It will be capable of docking two more spacecrafts: one manned and another cargo. It will be able to accommodate three astronauts in normal circumstances.

Tianhe core module will be used as a command center and living space, while lab modules will be equipped with special facilities for conducting scientific and technological experiments. One of them is also equipped with a special airlock chamber to support extravehicular activities and a small mechanical arm, while the other one is equipped with a special airlock chamber to support the entry and exit of cargo.

On 29 April 2021 Tianhe Core Module was launched into orbit with The Long March-5B rocket. It was successfully brought to orbit at an altitude from 340 km to 450 and in an hour and 13 minutes after launch, its solar panels started operating and the module powered up. However, the launch vehicle started tumbling during deorbiting and entered a temporary, uncontrolled failing orbit. The main concern was that the trajectory of the vehicle was unpredictable, so it could cause serious damage during re-entry, but eventually it ended up falling onto the Indian ocean

Countries with the Most Advanced Space Programmes: Russia

The Russian Federation

Russia is renowned for having sent the first man into space and launching the first satellite as a part of USSR. However, it has recently experienced a series of major setbacks, resulting in the loss of expensive spacecraft and satellites. Only a decade ago Russia was the world's leader in terms of the number of space launches; however, that is no longer the case today. Due to competition from China and SpaceX, Russia has lost its long-held monopoly as the only country capable of ferrying astronauts to the International Space Station.

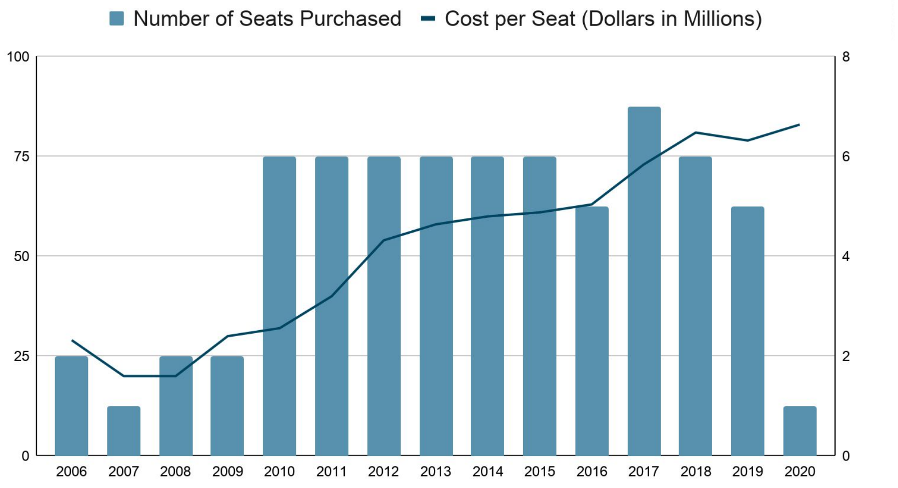
Today, Russia's priorities in space are far more 'down to earth' than those of the USSR.

Starting from 2014, Russia has focused its efforts on massive reorganization and consolidation of its space industry under Roscosmos, a state-owned corporation since 2015.

In September 2020, Roscosmos declared Venus a "Russian planet" and announced its intention to send a mission to the Moon, which will be independent from the one planned with the US.

Roscosmos also plans to send tourists to the ISS by 2023. In addition to the Luna 27 project, Dmitry Rogozin, the Space Agency's Director General, announced Russia's lunar programme. According to it, Russia plans to send its first astronaut to the Moon in 2030.

NASA's Payments to Russia for Sending Their Astronauts into Space, per seat



Sources: *The Moscow Times, Space News, Global Risk Insights*

Japan

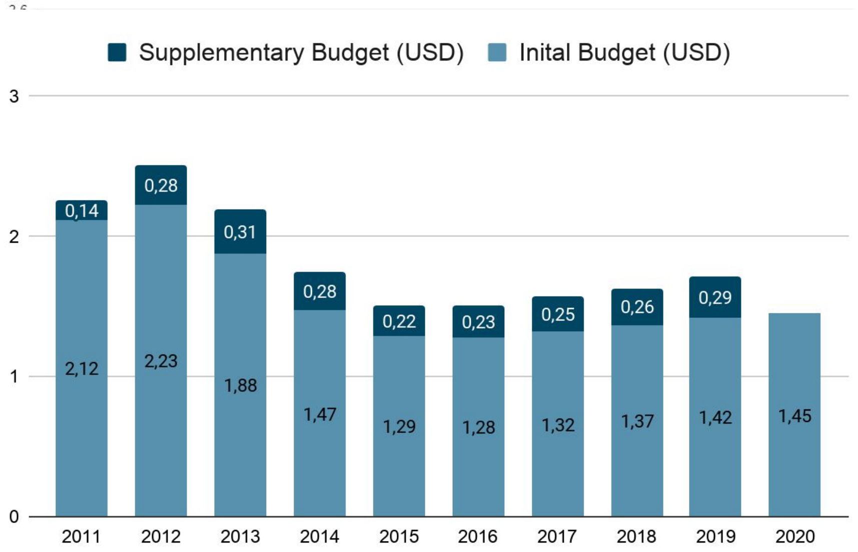
Over the past several decades, Japan has emerged as a leading space-faring nation. Unlike other major players, such as the United States, China, and Russia, Japan has achieved its status while remaining committed to “peaceful uses of outer space” as per the Outer Space Treaty (OST) of 1967. To emerge as a key space-faring nation, Japan relied heavily on its niche strength in robotics. In 2013, Japan became the first country to launch a robotic astronaut, Kirobo, to the International Space Station (ISS).

Japan is focused on finding innovative solutions to tackle the threat of space debris.

The use of robotics in space missions has extended to the arena of deep space exploration, as well through the much-acclaimed Hayabusa missions. In 2003, they have launched the Hayabusa spacecraft, which entered the history books as the first mission to return asteroid dust to Earth. Later on, JAXA has tested the concept of an electrodynamic tether that would catch space debris and float it down to the Low Earth Orbit (LEO). They would work on developing wooden materials highly resistant to temperature changes and sunlight. By 2023, Japan plans to launch the world's first satellite made out of wood.

Wooden satellites would burn up without releasing harmful substances into the atmosphere or raining debris on the ground when they plunge back to Earth.

Annual Budget of the Japan Aerospace Exploration Agency (JAXA), from Fiscal Year 2011 to 2020 (in billion USD)



Sources: *The Diplomat*, *BBC News*

Countries with the Most Advanced Space Programmes: United Arab Emirates

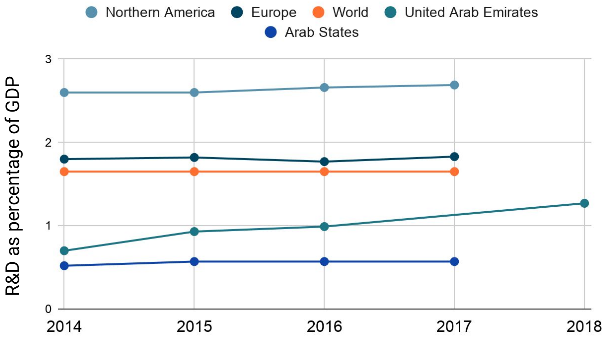
The UAE

The UAE's Space Agency doesn't have a long history; however, it isn't exactly its history that makes it an interesting case study. Established in 2014, it has already scored some major successes, with the most notable one being a mission to Mars. After a seven-month and 494 million kilometre journey, the Agency's spacecraft entered the red planet's orbit in February 2021 and began sending data about the **Martian atmosphere** and **climate**. It made the UAE the fifth space agency to reach the planet. According to the Agency, it has plans for establishing a **Mars settlement by 2117.**

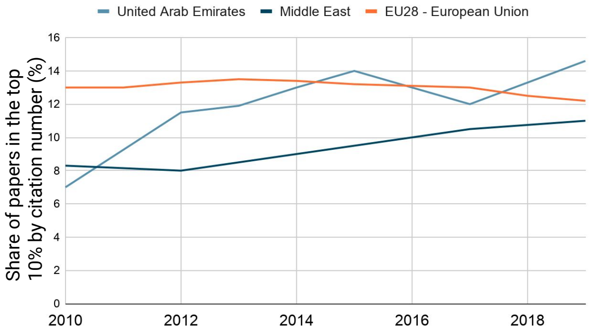
The Mars Programme

The programme is part of the UAE's ongoing effort to develop its scientific and technological capabilities and reduce its reliance on oil. Hence, for Emiratis, space-science goals come second. Faced with economic and environmental challenges, the small, oil-rich Gulf state hopes the Mars project can accelerate its transformation into a knowledge economy — by encouraging research, degree programmes in basic sciences and inspiring the youth across the Arab states. Like major port and road ventures before it, the Mars mission is a mega-project designed to cause "a big shift in the mindset".

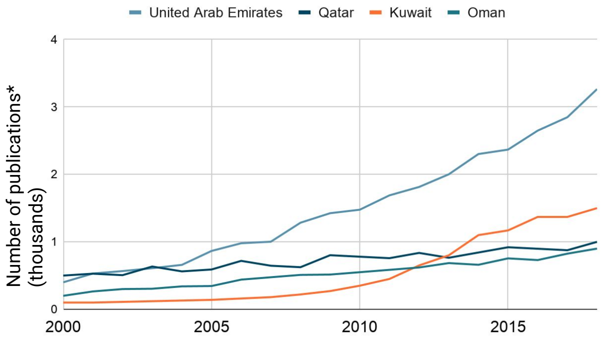
Spending



Publication Impact



Research Output



* For co-authorized publications, a fraction of each paper is assigned to a country depending on its share of authors

Sources: Aljazeera, Nature

India

India's space program has grown and evolved significantly in the past five decades. Originally developing space assets that provided direct developmental benefits, India has shifted its focus toward space exploration and other high-profile missions that do not have as clear a developmental purpose as earlier. This includes, for example, India's Mars and Moon exploratory missions.

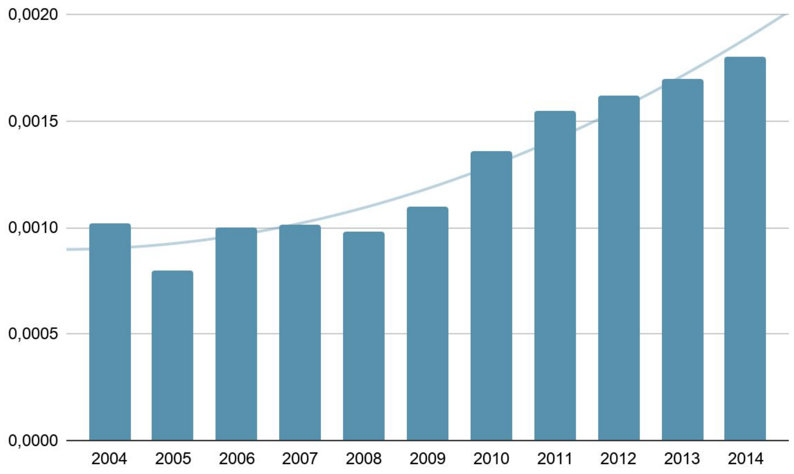
The next major step for India is a first crewed space mission, Gaganyaan, to be undertaken by 2022.

India's already robust program has also acquired national security overtones over the last decade. This is partly driven by India's growing technological capacity. But an important part of the reason for this change is the evolving security threats that India has faced, especially in relation with Pakistan and China.

This decade ISRO (Indian Space Research Organisation) has made public its intention to develop reusable rocket-launch technology and start building reusable rockets in the following decade. Meanwhile, in a "New Year Message for 2021," ISRO Chairman K. Sivan highlighted that "space sector is facing disruption due to the entry of many private players".

18 ISRO centers aim to scale up capabilities related to ground stations, human spaceflight, satellite platforms and more. The Vikram Sarabhai Space Center, in particular, was directed to continue its "competence in launch-vehicle development toward heavy-lift capabilities, achieving partial and full reusability" and scramjet engine (supersonic-combustion ramjet, a type of supersonic engine) research.

Space Expenditure as Percentage of Indian GDP



Sources: ORF, SPACE

The European Space Agency (ESA)

The European Space Agency is the coordinating entity for European civilian space activities. Having 22 member states, it's headquartered in Paris and has several centers in other European countries. It mainly focuses on:

Combating El Nino (a weather phenomenon responsible for some of the world's most drastic and devastating disasters) and monitoring particular aspects of the environment;

Observing environmentally unfriendly factors (air pollution from transportation, power stations and industrial processes) on a daily basis, using ERS satellites, and building up a database from which one can learn and act upon;

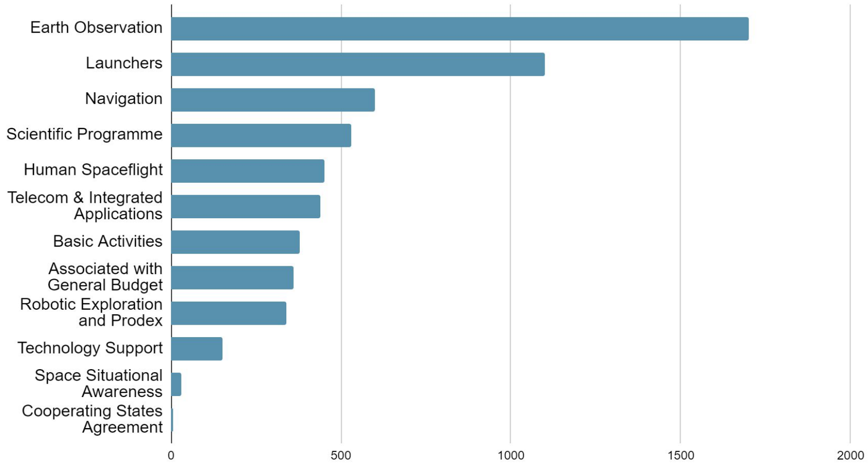
Monitoring ozone levels;

Observing polar ice caps;

Preventing the devastation that oil pollution can bring to coastal, sea and marine environments;

Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. The ESA's purpose shall be to promote exclusively peaceful space exploration, cooperation among European States in space research and technology, as well as their space applications, with a view of using them for scientific purposes and operational space applications systems.

Distribution of the ESA's budget (In Millions of Euro)



Countries with the Most Advanced Space Programmes: European Space Agency (ESA)

By 2030 ESA is going to implement the following visions:

ESA's space weather vision

- Development a European space weather monitoring system;
- Enhancing Coordination Centre's ability to provide warnings and tailored space-weather information;
- Continuing analysing the sensitivity of European infrastructure to space-weather effects;
- Increasing space weather hazard awareness in Europe;
- Developing and testing emergency protocols with European civil authorities to improve resiliency to space weather events.

ESA's vision of planetary defence

- Rendezvous with a binary asteroid system – a little-understood class making up around 15% of all known asteroids;
- Scanning the skies for rogue rocks with Flyeye telescopes, automatically flagging any that could pose an impact risk and bringing them to the attention of human researchers;
- Deploying a new in-space satellite to detect asteroids coming from the direction of the Sun;
- ESA's Near-Earth Object Coordination Centre will continue to be the central access point to a network of European asteroid data sources and information providers.

ESA's response to space debris

- Enabling the safe operation of individual satellites and large constellations by developing and demonstrating an Automated Collision Avoidance System, free from causing damage;
- Supporting the monitoring and safe management of space traffic and the application and verification of the necessary debris mitigation measures according to internationally agreed guidelines, standards and best practices;
- Assessing, modeling and mitigating the risks associated with space debris and reentries.

Source: ESA

International Space Station

The International Space Station (ISS) is a modular space station (habitable artificial satellite) in low Earth orbit. It is a multinational collaborative project involving five participating space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada). The ownership and use of the space station is established by intergovernmental treaties and agreements.

Orbit altitude: 408 km
Orbital speed: 7.66 km / s
Launch date: 20 Nov 1998
Launch weight: 419 700 kg
Cost: $150 billion

Purpose

The ISS was originally intended to be a laboratory, observatory, and factory while providing transportation, maintenance, and a low Earth orbit staging base for possible future missions to the Moon, Mars, and asteroids. However, not all of the uses envisioned in the initial memorandum of understanding between NASA and Roscosmos have been realised, In the 2010 United States National Space Policy, the ISS was given additional roles of serving commercial, diplomatic, and educational purposes.

Scientific research

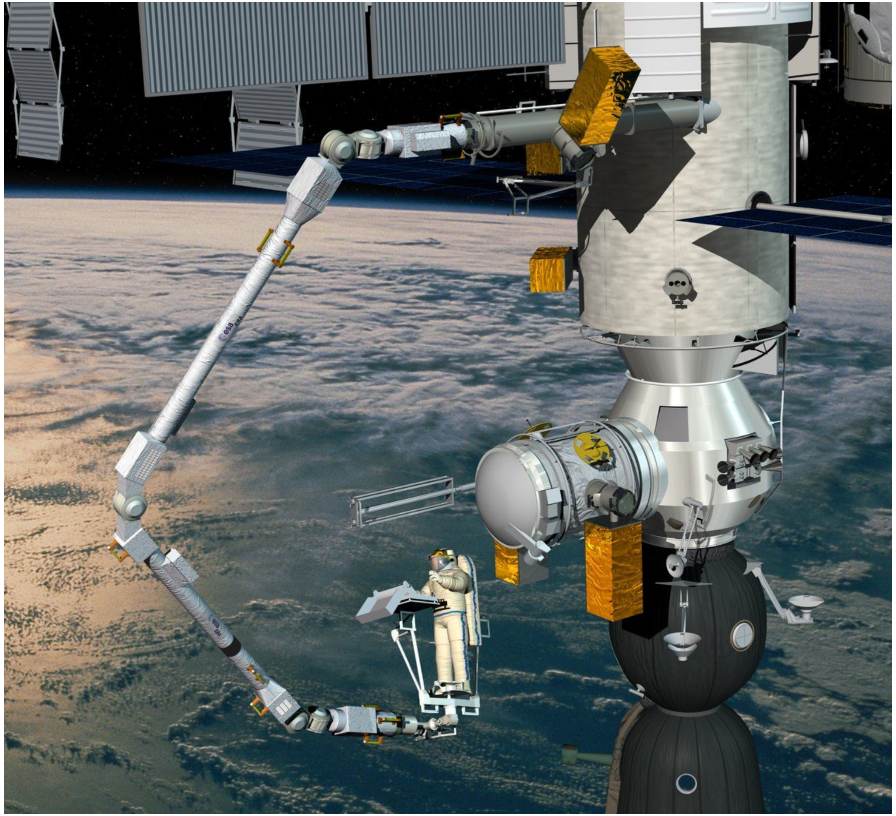
The ISS provides a platform to conduct scientific research, with power, data, cooling, and crew available to support experiments.

European Robotic Arm

The **European Robotic Arm** (**ERA**) is a robotic servicing system, which will be used to assemble and service the Russian segment of the International Space Station.

The ERA has several interesting features. Most prominent are its ability to 'walk' around the exterior of the Russian segments of the station under its own control, moving hand-over-hand between pre-fixed base points, and its ability to perform many tasks automatically or semi-automatically, thereby freeing its operators to do other work. Specific tasks of ERA include:

- **Installation and deployment of solar arrays**
- **Replacement of solar arrays**
- **Inspection of the station**
- **Handling of (external) payloads**
- **Support of astronauts during space walks**



NASA Space Apps Challenge 2020

NASA Space Apps Challenge is a world's largest global hackathon that, created in 2012, that engages thousands of people across the planet to use NASA's open data to build innovative solutions to challenges humanity faces on Earth and in space. Teams of technologists, scientists, designers and others are welcome to collaborate and to figure out the best solutions of challenges on Earth and in space with NASA's open source data in a 48-hour sprint. Last year's hackathon had over 26000 participants in 2303 teams from 150 countries. Here are the winners:

DATA
Team: Monsoon Overflow
Challenge: *A Flood of Ideas*
Location: Vallabh Vidyanagar, India

MISSION
Team: Loud and Clear
Challenge: *Can You Hear Me Now?*
Location: Perth, Australia

IMPACT
Team: Project L.L.O.C.U.S.T.
Challenge: *Automated Hazards Detection*
Location: Universal Event

SCIENCE
Team: ASPIRE
Challenge: *Scanning for Lifeforms*
Location: Tilangana, India

TECHNOLOGY
Team: FireWay
Challenge: *Let's Connect*
Location: Dnipro, Ukraine

INSPIRATIONAL
Team: A.I. Itruistics
Challenge: *Create a Mascot*
Location: Universal Event

INSPIRATIONAL
Team: Team Twilight
Challenge: *Scanning for Lifeforms*
Location: New York, USA

Launches and Landings Scheduled by NASA in 2021

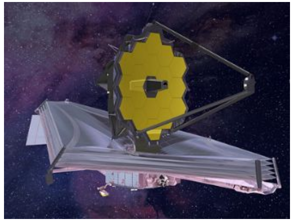
Date: No Earlier Than April
Mission: NASA, SpaceX Crew-1 Mission Splashdown
Description: Return of Crew-1 with NASA astronauts Michael Hopkins, Victor Glover and Shannon Walker, along with JAXA astronaut Soichi Noguchi

Date: No Earlier Than September
Mission: Boeing Crew Flight Test
Description: NASA astronauts Mike Fincke, Nicole Mann, and Barry "Butch" Wilmore are slated to launch aboard Boeing's CST-100 Starliner atop a United Launch Alliance Atlas V rocket.

Date: No Earlier Than April 2, 2021
Mission: Boeing Orbital Flight Test 2 (Uncrewed)
Description: For this second uncrewed flight test, Boeing's CST-100 Starliner will launch atop a United Launch Alliance Atlas V rocket.

Date: October 31, 2021
Mission: Lucy Mission
Description: Launching from Kennedy Space Center in Florida, Lucy will be the first space mission to study the Trojan asteroids associated with the planet Jupiter.

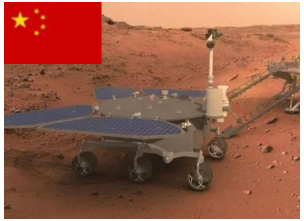
Date: No Earlier Than April 20, 2021
Mission: JNASA, SpaceX Crew-2 Mission to the International Space Station
Description: NASA's SpaceX Crew-2 mission will launch four astronauts aboard a Crew Dragon spacecraft on a Falcon 9 rocket to the space station.



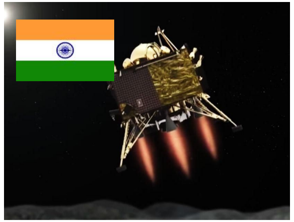
Date: No Earlier Than October 16, 2021
Mission: James Webb Space Telescope
Description: The James Webb Space Telescope will find the first galaxies that formed in the early universe and peer through dusty clouds to see stars forming planetary systems.

Source: NASA

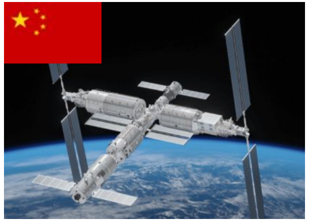
Launches and Landings Scheduled by Other Space Agencies in 2021-2022



Date: No Earlier Than May 2021
Mission: CNSA, Tianwen-1, Zhurong Rover Landing
Description: China's first Mars rover Zhurong will land on Red Planet's surface in order to study geology and look for water.



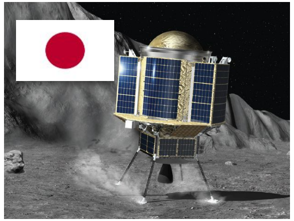
Date: 1st half of 2022
Mission: ISRO, Chandrayaan-3
Description: Chandrayaan-3 consists of a lunar lander and a rover and is a successor of Chandrayaan-2 that failed to soft land previously.



Date: 2021-2022
Mission: CNSA, Tiangong Space Station
Description: In April 2021 China launched the core module of its stationary space station to Earth orbit. The carrier rocket then went to an uncontrolled fall. The other modules will be launched in the following year.

Date: No Earlier Than May 2021
Mission: ESA, European Robotic Arm
Description: The Robotic Arm is going to be launched to the ISS and attached to the Russian Segment. The purpose of it is assembly work and maintenance

Date: No Earlier Than December 2021
Mission: ISRO, Gaganyaan
Description: Gaganyaan is a first indian vehicle capable of containing three crew members. ISRO will launch Vyomitra, humanoid robot inside in order to conduct some tests.



Date: No Earlier Than January 2022
Mission: JAXA, SLIM Lunar Lander
Description: Smart Lander for Investigating Moon is designed to demonstrate innovative landing techniques, that will highly improve the accuracy of landing.

International Collaborations in Space Exploration

May 2021

www.spacetech.global

SpaceTech Analytics

International Organisations Involved in Space Activities

Since the beginning of time, exploring the universe has been a dream of humankind. Human curiosity has fuelled interest in exploring and discovering new worlds, pushing the boundaries of the known and expanding scientific and technical knowledge.

States and space agencies have been engaged in space exploration since the first launch of a spacecraft. The first space launch led to the first **human space flight**, which, in turn, led to the first **moonwalk**. Nowadays, focus has shifted to joint human and robotic missions, near-Earth asteroids, Mars and destinations beyond our own solar system.

The current **trends** suggest that significant progress can be made in the following areas:

New Materials	Health and Medicine	Transportation	Computer Technology

Space exploration and the innovation it entails are essential drivers for opening up new domains in space science and technology. They promote new partnerships and create new opportunities for addressing global challenges. Space exploration also motivates young people to pursue careers in science, technology, engineering and mathematics **(STEM disciplines).**

Many international organisations are deeply involved in **space activities**. Some of the most prominent ones include:

1959 - The United Nations General Assembly established a **Committee on the Peaceful Uses of Outer Space** (95 countries were members of the committee in 2020).
In 1967, the committee came up with the Outer Space Treaty, which sets forth the general legal principles governing the uses of space.

1964 - At the initiative of the United States, an **International Telecommunications Satellite Consortium** (Intelsat) was founded to develop and operate a global system of communications satellites.
By 1969 the organization had established a system of satellites with global coverage.
In 1999, the decision was made to change the ownership of the organization from national governments to the private sector (membership grew to 144 countries).

1979 - **International Maritime Satellite Organization** (Inmarsat), was established as an intergovernmental organization to supply maritime and other mobile communications services via satellite; it was later transformed into a privately-owned entity.

Sources: UNOOSA, Britannica

Artemis Program: National Partners

USA

Japan

Italy

Australia

The Artemis program involves several national space agencies, including space agencies from the US, Japan, Italy, Australia, UK, Canada, Luxembourg, UAE

UK

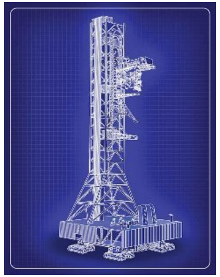
Canada

Luxembourg

UAE

Sources: NASA, SpaceNews

Artemis Program

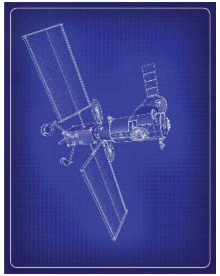


Exploration Ground System
All the Structures on the Ground Required to Support Launch

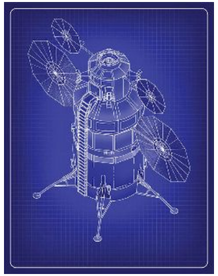
Space Launch System
All the Structures on the Ground Required to Support Launch

Orion
Spacecraft for Lunar Missions

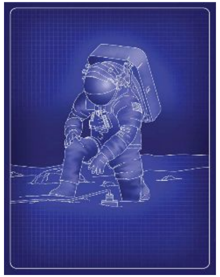
Artemis is a NASA program designed to land the first woman and the next man on the Moon by 2024. To achieve this, NASA uses innovative technologies for more in-depth exploration of the lunar surface than ever before. The program also envisages collaboration of national and private partners



Gateway
Lunar Outpost Around the Moon



Lunar Landers
Modern Human Landing Systems



Artemis Generation Spacesuits
Modern Spacesuits for Deep Space

Source: NASA

Moon Village

European Space Agency
Paris, France

Skidmore, Owings & Merrill (SOM)
Chicago, IL, USA

MIT Department of Aeronautics and Astronautics
Cambridge, MA, USA

Moon Village is a Moon exploration strategy proposed by the European Space Agency (ESA) and aimed at establishing lunar habitation systems. It is rather a vision than a solid plan which encourages participation of private and national partners. However, the project is still in the early stages of development.

MIT Media Lab
Cambridge, MA, USA

Sources: ESA, MIT Media Lab

The Global Exploration Roadmap (GER)

- Brazil
- Australia
- Thailand
- Luxembourg
- Norway
- Poland
- Switzerland
- Vietnam

The GER is a non-binding document that space agencies co-author to foster coordination and partnership opportunities. The iterative development process of the GER demonstrates the growing interest in space exploration across the globe and emphasizes the importance of coopera tion to realize individual and common goals and objectives for ISECG (International Space Exploration Coordination Group) members.

Source: GER 2020 supplement

The Global Exploration Roadmap (GER)

Romania	India
China	Japan
Canada	Korea
Europe (HQ: France)	USA

ISECG
International Space Exploration Coordination Group

The GER reflects an exploration strategy that begins with the International Space Station (ISS) and extends to the Moon, asteroids, Mars and other destinations. This strategy builds on a shared set of exploration goals and objectives and reflects missions that will provide substantial benefits to the citizens of Earth.

Source: GER 2020 supplement

The Global Exploration Roadmap (GER)

Russia

ROSCOSMOS

Germany

DLR

UK

UK SPACE AGENCY

Ukraine

ISECG

International Space Exploration Coordination Group

The steadily increasing number of ISECG agencies underscores the growing global interest and momentum for going forward to the Moon and Mars. Since the 2018 GER release, the number of ISECG agencies has increased from 15 to 24.

France

cnes

Italy

ASI Agenzia Spaziale Italiana

New Zealand

CSIRO

UAE

وكالة الإمارات للفضاء
UAE SPACE AGENCY

Source: GER 2020 supplement

Conclusions

USA with its NASA is leading the SpaceTech industry by margin, especially making use of the cooperation with SpaceX. They have groundbreaking projects on the subject of Mars and Jupiter exploration and also the launching of an innovative telescope. There are at least six significant launches planned for 2021, part of which has already been executed. Russia and China are fiercely competing with US, but that doesn't rule out the possibility of cooperations between those three.

Such agencies as japanese JAXA and european ESA are on the way of "peaceful use of outer space", which means that those strive not for the superiority, but for the progress in technology and science and so the cooperation is made easy and advantageous. Both agencies are focusing on the ecologically positive ways to conduct space missions, meaning reducing the amount of space debris and acquiring info about different factors of pollution and ways to fix them.

Arab and Indian programmes are continuously developing their way to becoming the strong players in the space tech industry. These programmes are showing the fastest results among the newly established space agencies.

The bullet-point conclusions are:

- The number of governmental space agencies is increasing. There are 11 new agencies that are expected to emerge in the following years.
- The development of the governmental agencies has accelerated during last 10 years.
- The analysis revealed a trend of cooperation between various agencies, including private companies (NASA and SpaceX; Artemis and Boeing).
- Overall output of the space programmes is expected to be increasing.
- Some of the agencies are now able to have a number of significant launches on their own in a single year, compared to a relatively low efficiency in the past.
- Russian space programme slowly loses momentum of development.
- China is developing its programme with a huge effort, however there are some major failures in its recent past.
- UAE and India are developing space technologies rapidly.
- ESA and JAXA are working their "green" way to science.

Space Law & Economics

May 2021

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Space Law: Main Principles

The legal framework for space activities is based on the 1967 Outer Space Treaty (OST) and four subsequent United Nations treaties implementing its provisions.

The main principles of the treaty are summarized below.

With the latest trends in the space industry as the growing importance of **private initiatives** in the exploration of space, the main principles of the Space Law may be challenged as most of those principles were designed when space exploration was only the business of the states.

- The exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind
- Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.
- States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner.
- States shall be liable for damage caused by their space objects; States shall avoid harmful contamination of space and celestial bodies.
- Outer space shall be free for exploration and use by all States.
- The Moon and other celestial bodies shall be used exclusively for peaceful purposes.
- States shall be responsible for national space activities whether carried out by governmental or non-governmental entities.
- Astronauts shall be regarded as the envoys of mankind.

Source: UNOOSA,

Space Law: Crimes in Space

Sometimes compared to the **high seas, space** belongs to everyone and to no one; hence, no country may lay claim to it. In legal terms, it is called **Res Communis.**

International law allows countries to assert jurisdiction outside their territory in several ways, including via the nationality principle, which covers crimes committed by a country's citizens outside its borders, and the universality principle, which allows countries to prosecute anyone for serious crimes against international law, such as piracy.

As for the question of who prosecutes space crimes, the short answer is that a spacefaring criminal would generally be subject to the law of the country of which they are a citizen, or the country aboard whose registered spacecraft the crime was committed, because the treaty grants that country authority "over any personnel thereof".

However, the term "personnel" is not defined, and this raises questions as to what the case might be for private citizens, such as, for example, an Australian space tourist flying aboard a US-registered spacecraft. The visualization on the right highlights several issues related to space industries and space exploration which may cause legal debates in the near future.

Potential Issues with Legal Jurisdiction in Space

Crimes involving citizens of different countries	If space crime involves citizens of different countries, it makes the question of jurisdiction more complicated.
Dual Citizenship	The treaty framework on criminal law in space relies heavily on nationality. This makes the situation more complicated if an alleged criminal is a dual citizen
Personnel vs Travellers	OST grants country upon which spacecraft is registered has the authority "over any personnel thereof". This raises questions about private tourists from other countries
Limits of Space	It is not determined from which altitude does space begin, which makes it hard to determine whether air law or space law should apply at a given altitude
Universal Crimes	For serious crimes such as genocide, crimes against humanity, or war crimes, the jurisdiction of the International Criminal Court may also extend into space

Source: The Conversation

Space Law: Crimes in Space and Space-Related Crimes

In 2019, **Anne McClain**, a NASA astronaut, was accused of committing a **crime** in outer space. She was charged with accessing the bank accounts of her former spouse without her authorization.

An investigation subsequently cleared the astronaut Anne McClain of wrongdoing. Her former spouse, Summer Worden, was charged with lying to federal investigators.

Due to the **unprecedented nature** of the case, it raised a number questions, one of them being whether records of Ms. McClain's Internet usage in space could be presented in court to help aid in Ms. Worden's defense. With space becoming more accessible, cases like this can become more commonplace in the future.

Space-Related Legal Cases

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020

2011: NASA detained a space engineer's widow attempting to sell a Moon rock

NASA claims it is illegal for private individuals to own lunar material

2013: A Russian satellite hit by debris from a Chinese anti-satellite test

The case highlights the growing problem of space debris

2017: An Austrian citizen sued Space Adventures, a space tourism agency, to retrieve his deposit for a trip that never took place.

Rising interest to private space tourism may lead to similar cases

2019: Anne McClain accused of committing a crime while being aboard the International Space Station

First accusation of crime committed in outer space by a human being.

Sources: The New York Times, Space Legal Issues, SpaceNews, The Conversation

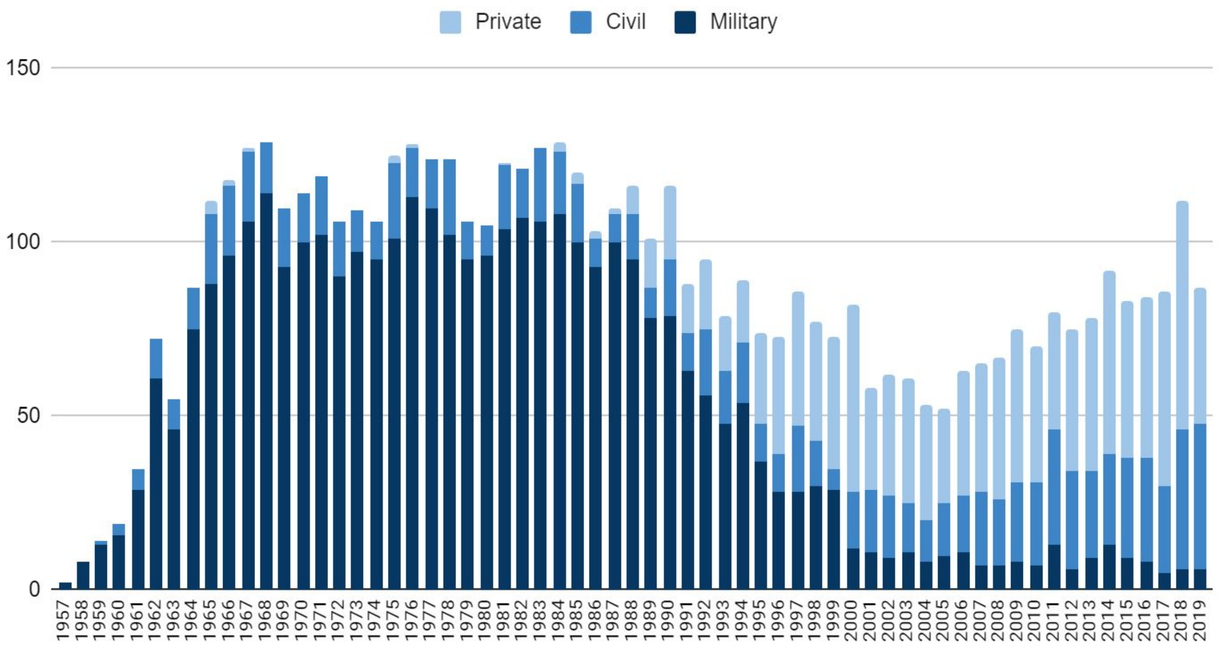
Number of Launches

Every Rocket Launch that Successfully Carried a Payload into Orbit (Categorized by Owner)

“**New Space**” is a concept describing the current trends in the space industry when the field, once dominated by the public and military agents, opens up for private initiatives.

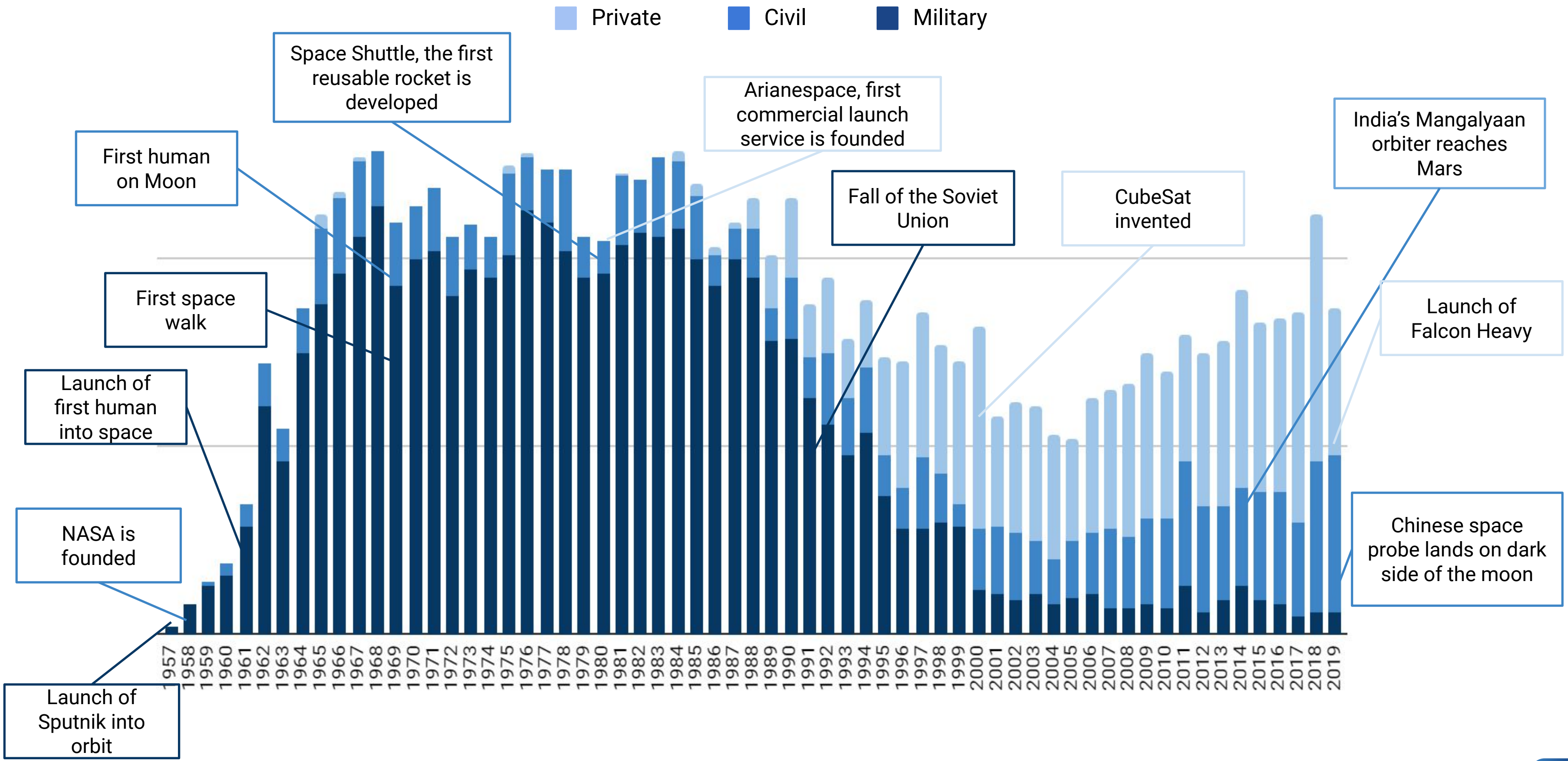
Technology improvements reduced the cost of producing rockets, making it possible for startups to enter the space industry.

That makes private companies the driver of the space race, contrary to the “old space” when space exploration was lead by military and civil organizations.



Source: Reuters

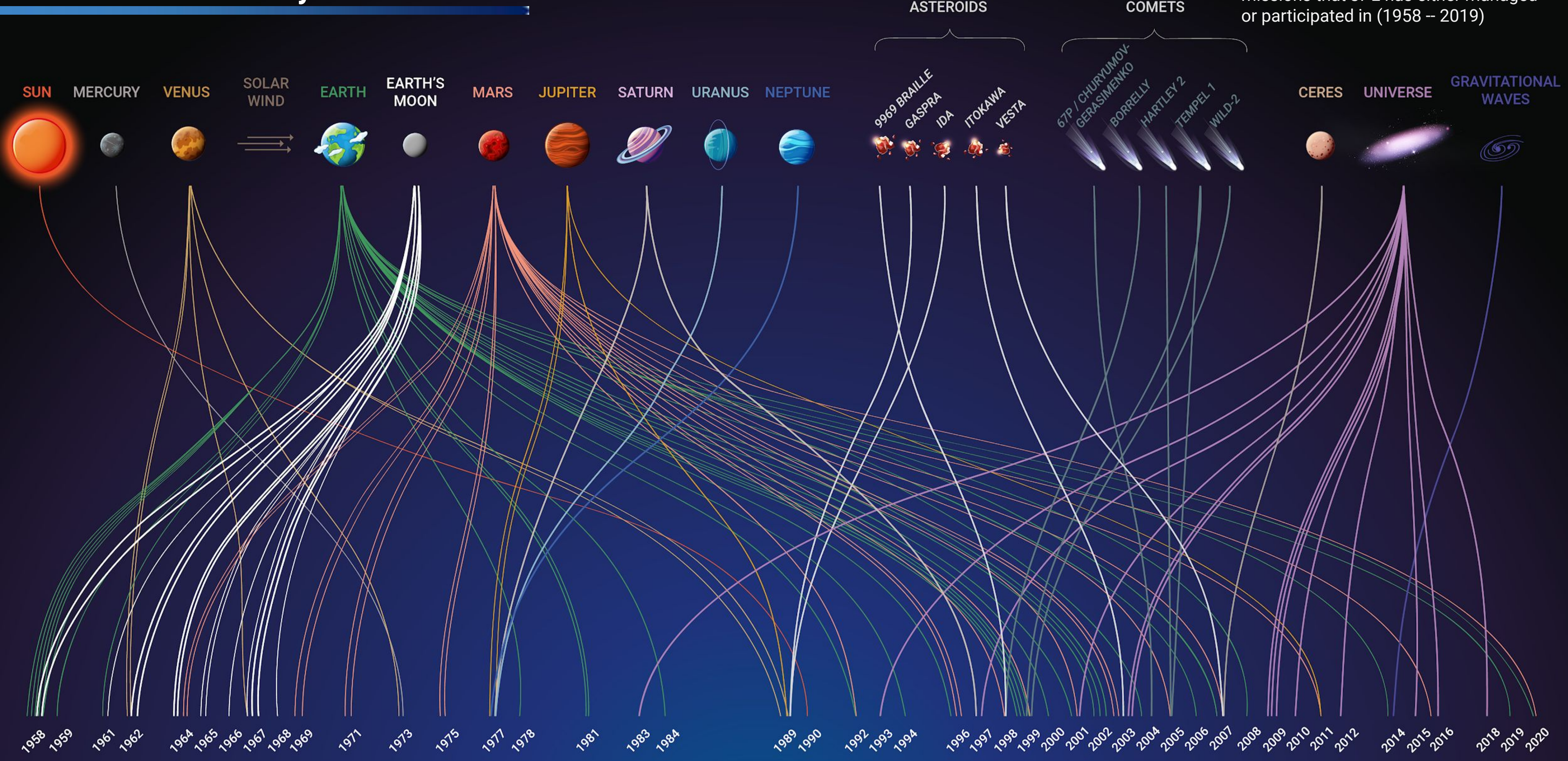
Government/Private Space Exploration Timeline



Source: *Reuters*

JPL Mission History

Launch dates of the more than 100 missions that JPL has either managed or participated in (1958 -- 2019)



Source: jpl.nasa.gov

Sharing and Regulating Space Orbit

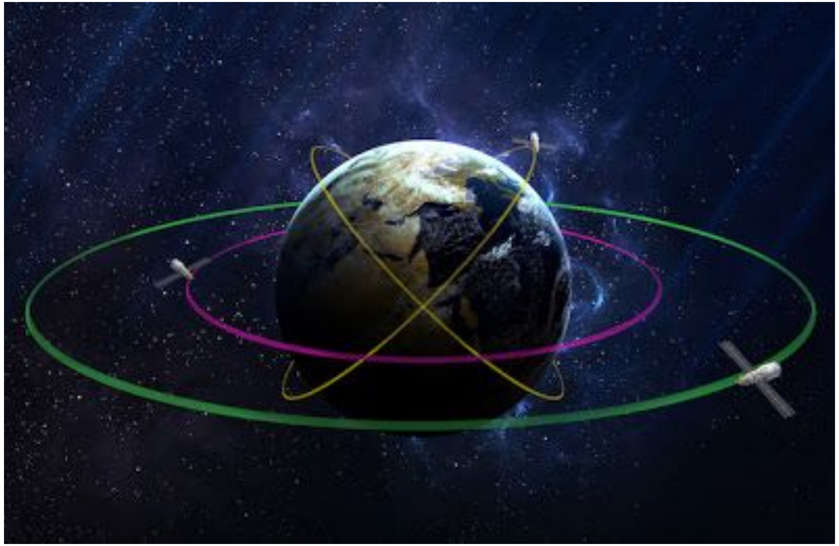
The increased and more diversified space traffic caused **cheaper and simpler satellite technologies** to lead to more crowded traffic in the Earth's orbit. If unregulated, it may lead to a situation where the strongest can take an unfair advantage, **monopolizing** the use of the orbit.

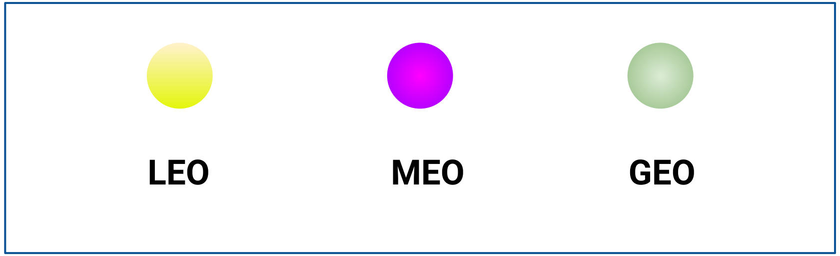
Those regulations should apply to **Low Earth Orbit (LEO)**, to develop and enforce current regulatory framework to manage the increasing "space traffic" to prevent interferences or collisions between assets of different operators, as well as to **Medium (MEO)** or Geosynchronous **Earth Orbit (GEO)** and interplanetary exploration and exploitation.

New regulations should be implemented in respect to established treaties and principles as the "Outer Space Treaty" or the "Convention on International Liability for Damage Caused by Space Objects".

In the areas with already developed and followed regulatory framework, like the satellite telecommunication sector, it is important to stay **abreast of technology progress and market evolution**.

At the same time, the development of rules and regulations must be mitigated to avoid unnecessary red tape stifling new enterprises, and space law should preserve the freedom to generate new ideas and implement new applications.





Source: *Frontiers In Space Technologies*

Outer Space: Regulation

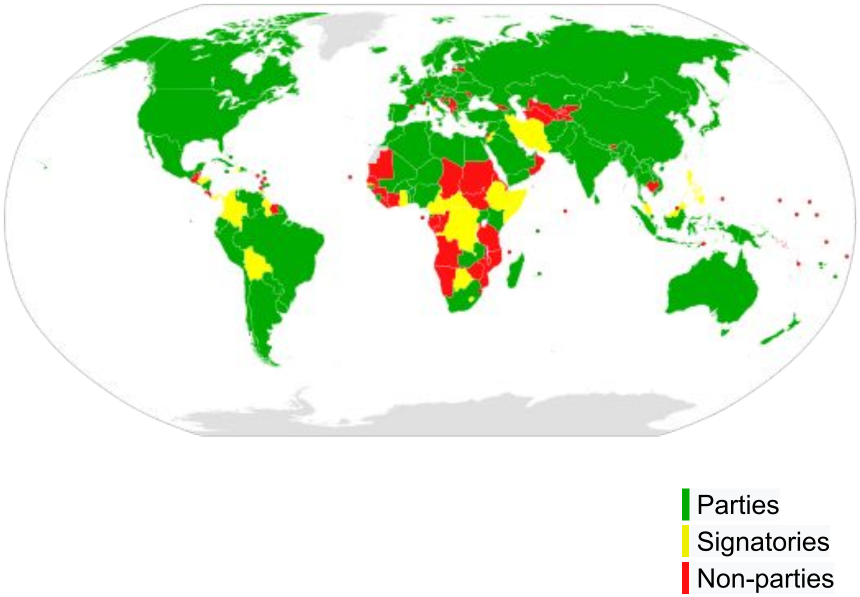
According to the 1967 Outer Space Treaty (OST), outer space, including the Moon and other celestial bodies, **“is not subject to national appropriation by claim of sovereignty”**. However, the OST could be the biggest obstacle to one of the most promising new frontiers of space exploration: asteroid mining.

In 2015, the US government made an attempt to **update the law on space mining**, producing a bill that allows companies to “possess, own, transport, use, and sell” extra-terrestrial resources without violating US law. That move boosted the space mining industry in the US. However, steps like that may fuel international conflicts if the rules are not be discussed between different stakeholders represented by states and companies.

It also calls into question the principle of the OST which states that “the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall **be the province of all mankind”.**

These issues can become even more pronounced once the space economy becomes more self-dependent. At the moment, the vast majority of space enterprises aim to satisfy the needs of humans on Earth. However, once the share of the space economy aimed at **satisfying the needs in space** (e.g. extracting water and resources on the Moon for the needs of lunar settlements) grows, new regulations will be required.

Outer Space Treaty Members



Sources: The Guardian, Mining, Business Wire

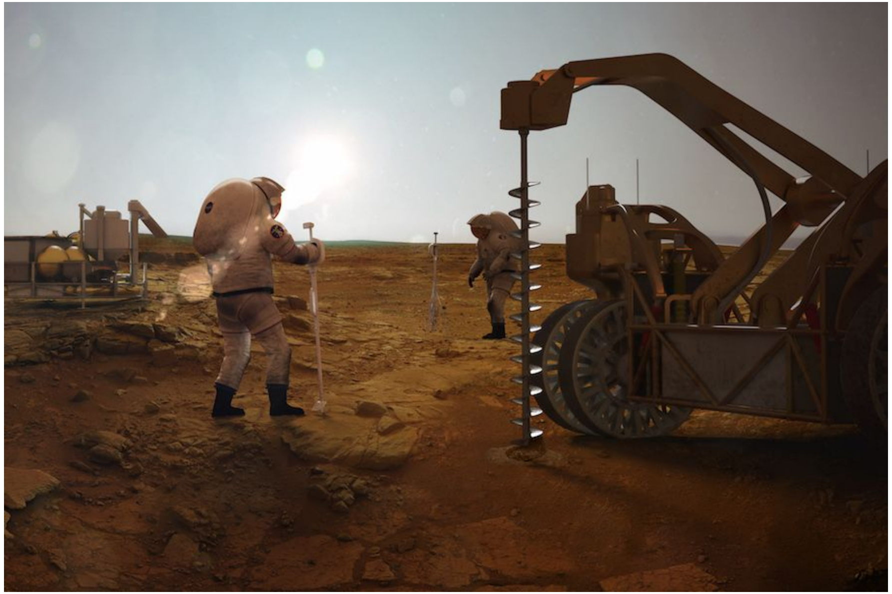
The Luxembourg Case

The tiny European country of Luxembourg has set itself an ambitious goal of becoming a **Europe's hub for space mining**. Being one of the EU's wealthiest nations, it has a well-developed space industry, which plays a significant role in the development of satellite communications.

The Luxembourg government has put in place a legal framework necessary for exploiting space resources. Passed in 2017, it says that private companies **can be entitled to the resources they mine in outer space**, but they can't own celestial bodies. In addition, the country's government announced its plans to create the European Space Resources Innovation Centre **(ESRIC)** and open a $225 million line of credit for space companies intending to set up their European HQs in the country. As of now, Luxembourg has invested in **Planetary Resources,** collaborated with Deep Space Industries, Ispace and other companies. The country's Space Agency actively participates in international space programs, such as Artemis, International Space Exploration Coordination Group and others.

What makes the Luxembourg case unique is that it has set a **precedent** of a government creating incentives for private space companies, including those of them that specialize in space mining. In addition to its space program,

The global space mining market is expected to grow at a **CAGR of 23.7%** over the forecast period **2020 to 2026.**



Sources: *The Guardian*, *Mining*, *Business Wire*

Outer Space Mining

Experiencing a rapid growth and decline in the 2010s, the space mining industry was dominated by **Planetary Resources** and **Deep Space Industries**, two competing startups founded in 2012.

PLANETARY RESOURCES	Raised **$50 million** by 2016. Acquired in October 2018.
DSi DEEP SPACE INDUSTRIES	Raised **$3.5M** in funding over 2 rounds. Acquired in January 2019.

NASA-funded research into asteroid-mining; the Colorado School of Mines offered an **asteroid-mining degree program**; Senator Ted Cruz predicted that Earth's first trillionaire would be made in space.

By the end of the decade, both companies struggled to secure funding. In 2018, **Planetary Resources was acquired by ConsenSys,** a blockchain software company.

Companies like **OffWorld, Moon Express** and **ispace** continue developing mining and robotics technologies, thus laying a foundation for space mining in the long term.

Space Mining: Moon vs Asteroids

There are two major targets for mining in space: the Moon (and planets closest to the Earth, i.e Mars) and asteroids. In terms of the technologies used and goals set, they have their advantages and disadvantages. For example, asteroids may be more difficult to access; however, their low gravity and unique resources outweigh the disadvantages related to accessibility.

Moon Mining	Asteroid Mining
The main goal is to supply lunar bases with resources (e.g. fuel and water) instead of sending them from Earth.	The main goal is to extract materials which are rare on Earth or whose mining is harmful for the environment or humans.
Mining is to happen directly on the surface of the Moon.	To make mining operations easier, asteroids could be brought closer Earth.
The Moon is closer to Earth; however, landing and taking off from it require more energy because of the gravity.	Asteroids are further away; however, energy-related requirements could be less stringent.

Sources: The Guardian, MIT Technology Review,

Space Mining: Leaders

ispace	Tokyo, Japan, 2010	Founded in 2013, Ispace Technologies is a space resource exploration company specializing in developing micro-robots capable of locating resources necessary to extend human life into outer space. Their main focus is to locate, extract, and deliver lunar ice to customers in cis-lunar space. Ispace was awarded with two out of four contracts by NASA to collect lunar resources for NASA's Artemis program.
MOON EXPRESS	Cape Canaveral, Florida, US, 2010	Moon Express develops a robotic spacecraft for low cost missions beyond the Earth, including the Moon, asteroids, and Mars. The company has signed a contract with NASA for lunar cargo delivery; NASA has also selected Moon Express as a partner in developing lunar landers to put the U.S. back on the surface of the Moon.
OFFWORLD	Pasadena, California, US, 2016	OffWorld is developing a learning robotic workforce for heavy industrial jobs on Earth, Moon, asteroids and Mars. The company's vision is to develop and test robotic workforce for difficult Earth environments so it could be used in the outer space.
PLANETARY RESOURCES	Redmond, Washington, US, 2010	After raising $50 million in 2016, Planetary Resources became one of the most promising space mining startups. In 2018, it was acquired by ConsenSys, a blockchain technology company.
DSI DEEP SPACE INDUSTRIES	San Jose, California, US, 2012	Originally founded to pursue asteroid mining, DSI has shifted its focus lately toward small-sized satellites. It was acquired by Bradford Space in 2019.

Sources: Space News, NASA,

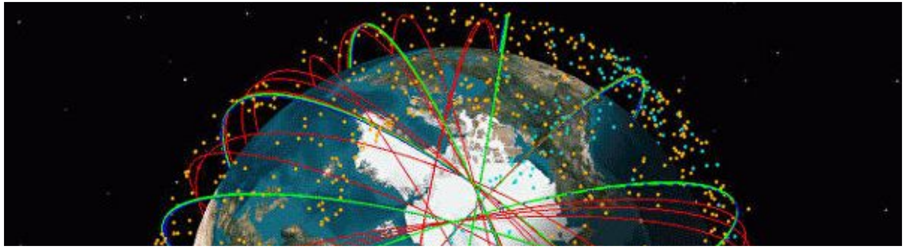
Space Debris on the Orbit and Emerging Anti-satellite Weapons Threat

The **US Space Surveillance Network** has eyes on:

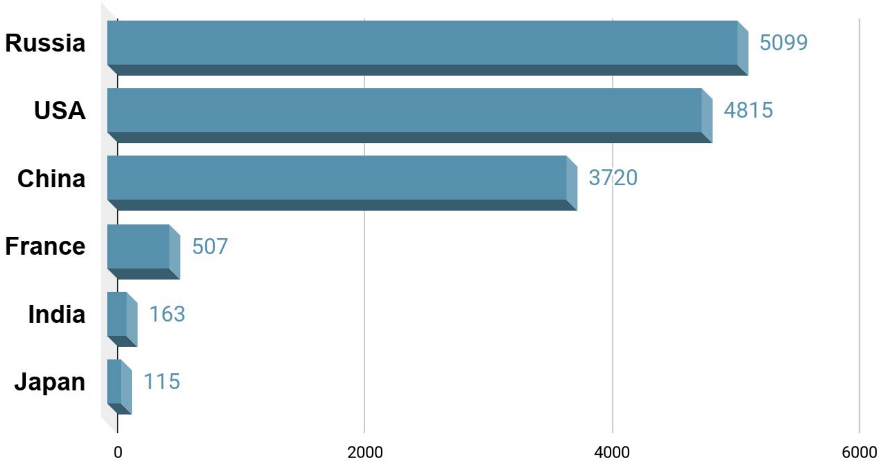
17,000 objects at the size of softball	**500,000** objects under 10 centimeters.

Earth's orbit already contains approximately **4,000** of Whipple shields, what makes flights more challenging. Mission control avoids dangerous paths; however its tracking systems aren't that perfect.

All this traffic can potentially lead to a disaster. In 2009, **Iridium,** a US commercial satellite crashed into **Cosmos-2251,** an active Russian communications satellite. As a result, thousands of new pieces of space debris were created which are now threatening other satellites in low Earth orbit - an area stretching up to 2,000 kilometres in altitude. Altogether, there are roughly **20,000 human-made objects in orbit**, from working satellites to small shards of solar panels and rocket pieces.



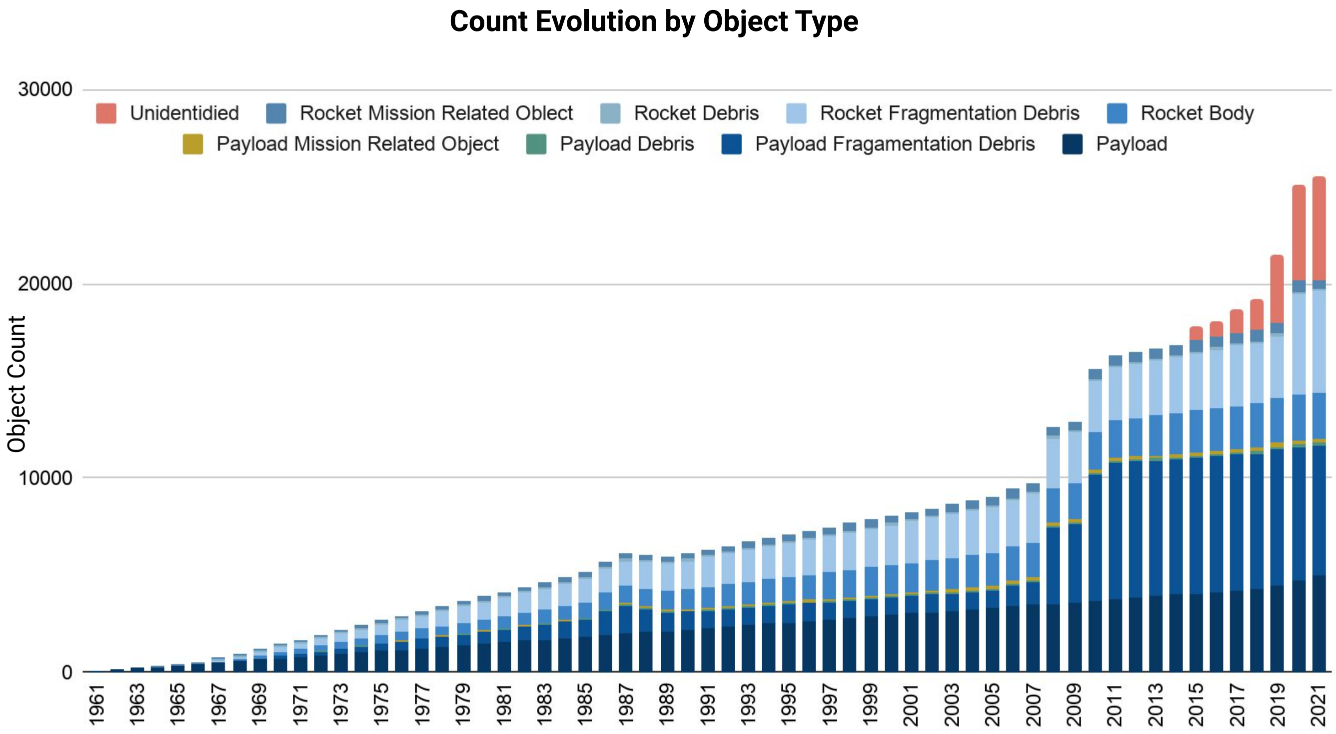
Number of Rocket Bodies and Pieces of Space Debris as of October 2019



"Putting decommissioning programs in **90 percent of new launches will prevent the Kessler syndrome**, when one collision leads to more collisions until there's so much crap up there, no one can fly at all. That might be a century hence—or a lot sooner if space war breaks out. If any country starts blowing up enemy satellites, "**it would be a disaster,**" says Holger Krag, Head of the Space Debris Office at the European Space Agency.

Sources: NASA, Wired, BBC News

Space Debris on the Orbit and Emerging Anti-satellite Weapons Threat



Due to the 2009 satellite collision and China's destruction of its Fengyun-1C weather satellite during an anti-satellite missile test in 2007, the amount of **space debris has increased sharply** in recent decades. On March 27, 2019, India announced a successful completion of an anti-satellite missile test. That resulted in the creation of a new cloud of space debris consisting of at least 400 pieces, which increased the risk of impacts to the ISS by an estimated 44 percent over a 10-day period.

Source: National Geographic

Planetary Defense

Near Earth Objects, such as asteroids or comets, can pose a significant threat to Earth and earthlings. Although smaller objects, such as meteors, hit our planet daily and mostly burn up whilst traveling through its atmosphere, some larger objects can survive and hit the Earth's surface with significant energy. Fortunately, the probability of these events is very low; however, their consequences can be disastrous and, therefore, **require development of mitigation strategies.** All major space organizations, such as NASA and ESA, pay a lot of attention to this issue; the UN has also taken steps in this regard by establishing the International Asteroid Warning Network and the Space Mission Planning Advisory Group **(SMPAG)**.

However, because this is a global threat, **a greater level of international coordination and integration is necessary** to produce an effective response. The world cannot afford a **disorderly and fragmented response**, such as the one we have seen during the previous and current global crises (e.g. the COVID-19 pandemic). Apart from improving detection capabilities and increasing accuracy of impact predictions, the development and testing of methodologies and technologies for deflecting a large object (the most realistic and effective method of intervention to date) have to progress to a point when they can be confidently deployed and ensure a high success rate.

Asteroid size	Bigger than 3 meters	Bigger than 30 meters	Bigger than 140 meters	Bigger than 1,000 meters
How often do they hit Earth?	About once a year	About 1 time in every 100 years	1 in 100 chance in every 100 years	1 in 50,000 chance in every 100 years
What happens if they hit the Earth?	A bright flash in the sky; no ground effects	A big air burst or a kilometer-wide crater; devastation of a relatively big area (a size of a city)	A crater several kilometers in diameter; devastation of a huge area (a size of a small country); mass casualties - worse than after any natural disaster in recorded history	A crater over 10 kilometers in diameter; global devastation and possible collapse of civilization
How many of them are tracked?	0% for a 3-meter asteroid; 0.02% of a 10-meter asteroid	1.4% for a 30-meter asteroid; 25% for a 100-meter asteroid;	40% for a 140-meter asteroid; 77% for a 500-meter asteroid;	81% for a 100-meter asteroid; 100% for objects with a diameter of 6.5 km and more

Source: The Planetary Society

Space Exploration and Space Travel: Pros and Cons

Pros: The benefits of space exploration can be **direct** or **indirect**. **Direct benefits** include the generation of scientific knowledge, diffusion of innovation and creation of markets, inspiration of people around the world, and agreements concluded between countries engaged in space exploration. **Indirect benefits** include tangible enhancements to the quality of life over time, such as improved economic prosperity, health, environmental quality, safety, and security. They also include intangible (philosophical) benefits, such as a more in-depth understanding and new perspectives on humankind's place in the Universe. Possibilities for benefit creation multiply rapidly when the products of space exploration interact with the imagination and creativity present in other fields of endeavour.

- Generation of Scientific Knowledge
- Creation of Markets
- Diffusion of Innovation
- Inspiration of People Around the World
- Cooperation Between Countries
- Ability to Prevent Threats from Space (Space Objects)
- Improved Quality of Life in Different Spheres
- General Understanding of the Universe

Cons: Space exploration programs require large financial resources. Hence, the question that arises here is: Which is more rational: to allocate those resources to the space industry or use them to solve problems on Earth? Opponents of space exploration claim that exploring space is a luxury humanity can ill afford. Therefore, instead of wasting time and effort on 'prestige-only' space exploration projects, humanity should focus on solving problems on Earth.

SpaceTech can greatly **improve lives of people** on Earth (e.g. cheap satellites can provide Internet to people in rural areas or prevent the spread of agricultural diseases). However, more demanding programs, such as missions to other planets, may be seen as unreasonable, especially when they are part of public programs.

- Requires Extensive Resources
- Unsolved issues on Earth
- Disruption of Natural Environment in Space
- Production of Space Debris
- Projects That Do Not Bring Tangible Results

Sources: Wired, ISECG

Technological Issues and Solutions

May 2021

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SpaceTech Analytics

Propulsion Systems

One of the major limitations preventing humans from venturing farther into the solar system is the length of travel in space. And this, in turn, is directly related to the performance of the existing propulsion systems. It also places major limitations on the mass of payload that can be carried by a rocket into space

Propulsion technologies can be grouped into three categories: **"escape propulsion"** (from Earth to orbit), **"in-space propulsion"** (in orbit), and **"deep space propulsion"** (from orbit to outer space). The launch vehicles currently used for "escape propulsion" rely on very mature technologies; however, there are prospects of significant technological advances for **"in-space"** and "deep space" vehicles, too.

Until now, propulsion used to operate the **"escape propulsion"** region in launch vehicles included variations of chemical propulsion. Satellite launch vehicles or spacecrafts operating "in-space" mainly rely on chemical propulsion (i.e. in-space propulsion); however, other propulsion types are also being increasingly researched and used now. The types of propulsion used to operate the **"deep-space propulsion"** region represent variations of chemical (i.e. escape and in-space) and non-chemical, (i.e. in-space and advanced) propulsion.

Deep Space propulsion	**Everything beyond Geostationary Earth Orbit (GEO), including the Moon and other planets**
In-Space Propulsion	**The region between Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO)**
Escape Propulsion	**Same as a launch vehicle. Distance between Earth's surface and Earth's orbit**

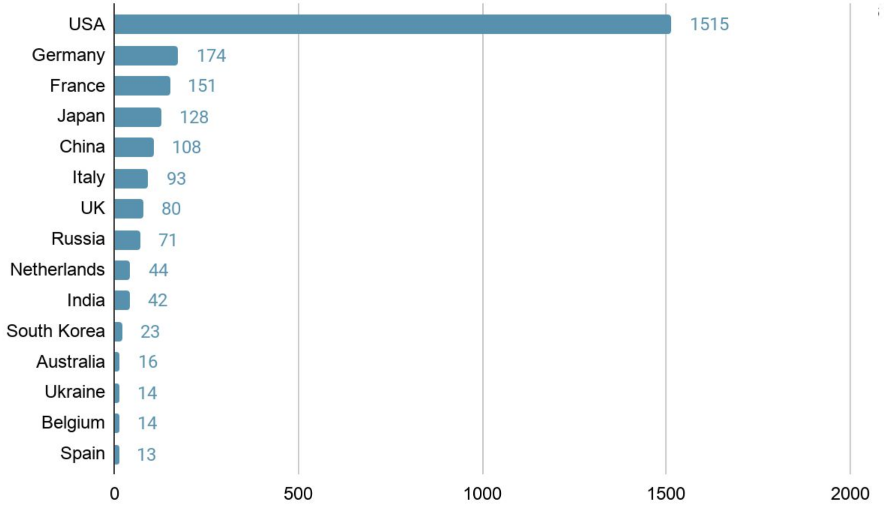
Sources: Frontiers in Space Technologies, SciElo

Propulsion Systems

Improving and developing propulsion systems is key for future space exploration. As available data demonstrate, propulsion system malfunctions account for 58% of all launch failures. What this demonstrates is that a seemingly mature technology like this will require further improvements to become safer and more reliable. The scientific community's interest in the field also confirms the need to develop more advanced propulsion systems.

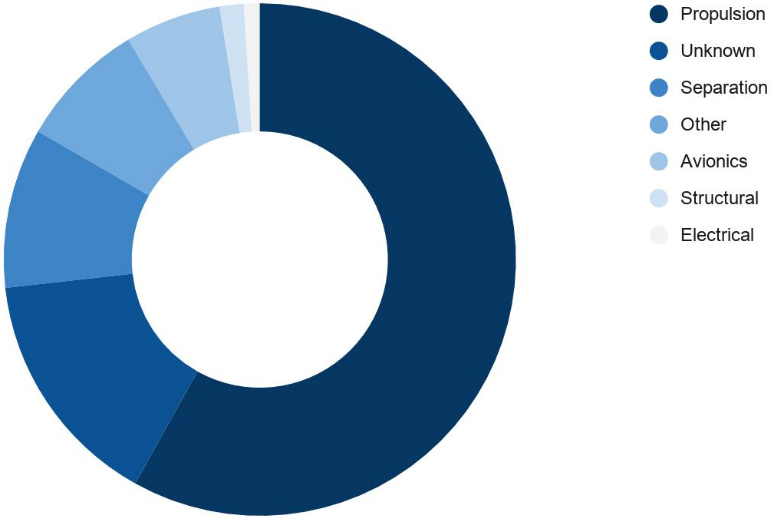
Number of Publications on Space Vehicles Propulsion Systems

Top 15 from 1959 to 2015, as indexed by Scopus.



Causes of Launch Vehicle Failures

1980-2016



Sources: Frontiers in Space Technologies, SciElo

Propulsion Systems: Propulsion Technologies

Chemical Propulsion
- Solid
- Liquid
- Hybrid
- Green Propellants

Non-Chemical Propulsion
- Plasma (Electric or Ionic Propulsion)
- Solar Sail Propulsion
- Tether Propulsion

Advanced Propulsion Technology (Initial Stages)
- Nuclear Propulsion
- Laser Propulsion
- Fusion Propulsion

Supporting Technologies
- Propellant Storable
- In-space Platform to Transfer Propellant

Escape Propulsion

In-Space Propulsion

Propellantless
- Aerocapture
- Solar Electric Propulsion

Deep Space Propulsion

Source: SciElo

Propulsion Systems: Leaders and Innovators

Company	Location, Founded	Description
Momentus Space	Santa Clara, California, US, 2017	Momentus is developing an innovative water-based propulsion system for moving satellites and cargo in space. The system will enable companies to launch satellites into low orbit and “navigate” them to their precise position.
Accion Systems	Boston, Massachusetts, US, 2014	Being one of the fourteen US companies selected by NASA for its Tipping Point partnership in 2019, Accion Systems specializes in developing technologies for Moon and Mars exploration. Accion will work with NASA’s Jet Propulsion Laboratory (JPL) to replace the cold gas propulsion system used for interplanetary CubeSats with a more efficient ion electrospray propulsion system.
ThrustMe	Paris, Ile-de-France, France, 2017	ThrustMe, a French startup, has recently demonstrated its electric space propulsion system that uses iodine as a propellant. Iodine’s low price point solves the problem of unnecessary expenditure in creating a propulsion system for bigger satellites. That is precisely why ThrustMe’s technology is applied in next-generation satellites, as well as in products designed to solve problems associated with the increasing number of satellite constellations.
Dawn Aerospace	Christchurch, Canterbury, New Zealand, 2017	Dawn Aerospace builds same-day reusable launch vehicles and high-performance, non-toxic propulsion systems for satellites of all sizes. For their product SmallSat, the startup simplifies systems and replaces poisonous hydrazine with nitrous oxide and propene. For CubeSats, it increases capabilities by supplying 1.000x higher performance than electric-based propulsion systems with the same propellants.
Northrop Grumman	Falls Church, Virginia, US, 1939	Northrop Grumman is a global security company providing solutions for sectors such as aerospace, electronics and technical services. Northrop Grumman is providing the five segment boosters for NASA's Space Launch System (SLS) and the main launch-abort motor and the attitude control motor for the Orion Crew Vehicle’s Launch Abort System (LAS).

Sources: Start Us Insights, Northrop Grumman, Fast Company,

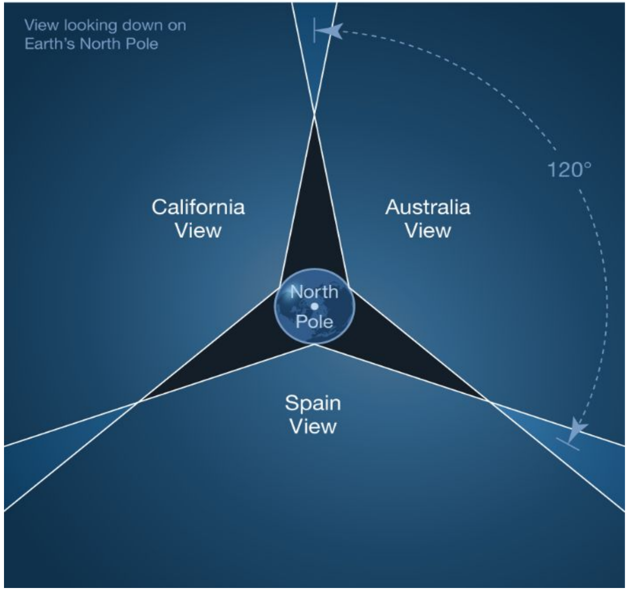
Comparison of 22 Companies in Space Propulsion by Development Stage and Type

Space Propulsion researches and develops new technologies for more advanced in-space propulsion

Propulsion Type

Navigation in Space

Being a collection of antenna arrays in California, Australia, and Spain, the **Deep Space Network** is the only tool for navigation in space. Everything from student-project satellites to the New Horizons probe meandering through the Kuiper Belt depends on it to stay oriented. An ultra precise atomic clock on Earth times how long it takes for a signal to get from the network to a spacecraft and back, and navigators use that to determine the craft's position.



Problem

As more and more missions are sent into space, the network gets increasingly congested, causing the switchboard to be frequently busy. To address the problem, NASA is currently working on installing atomic clocks in spacecraft. They will enable to cut transmission time in half, allowing distance calculations with a single downlink. NASA is also developing higher-bandwidth lasers capable of transmitting big data packages, such as photos or video messages, much faster.

Plans

For future missions, Joseph Guinn, a deep-space navigation expert, wants to design an autonomous system that would collect images of targets and nearby objects and use their relative location to triangulate a spaceship's coordinates without requiring any ground control. "It'll be like GPS on Earth," Guinn says.

Sources: Wired, NASA Science

Navigation in Space

Besides the difficulty of signal transferring, space navigation covers the following problems:

Communication

Deep space missions have limited amount of power available for radio communication to and from Earth. Being at substantial distance from the Sun, they cannot generate enough energy all the time. The radio signals they transmit are very weak and have to be picked out of background noise. Furthermore, they take hours to reach the Earth.

Distances

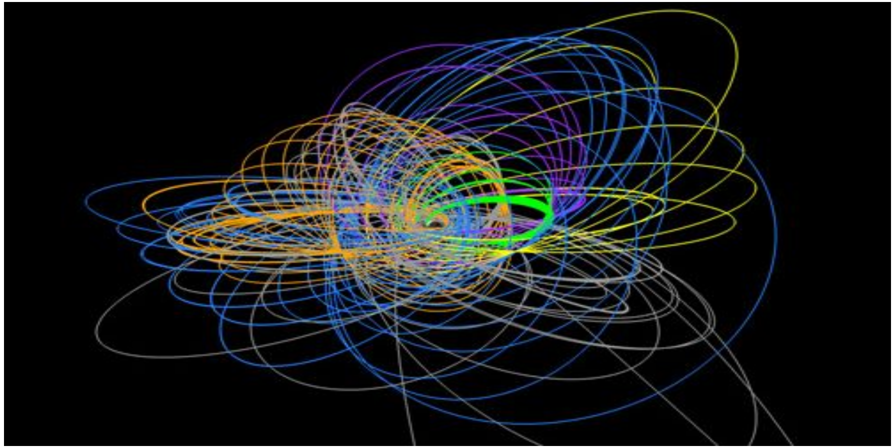
Distances between destinations are significant, and the targets are too small and moving. If Earth were the size of a softball, the International Space Station would be orbiting just above the seams, the Moon would be a marble about 2 meters away, and Mars would be 1.2 to 2.4 kilometers away.

Gravity

The Sun's gravity determines the basic trajectory of an interplanetary spacecraft. But for deep space missions, a navigator also has to take into account gravitational forces from planets and moons and other forces that might affect the trajectory.

Motion

Navigators have to keep in mind that everything is moving and take into account not only speed of the spacecraft, but also the destination planet or moon.



A computer-generated representation of all Cassini's Saturn orbits. The time frame spans Saturn Orbit Insertion on July 1, 2014 to the end of mission on Sept. 15, 2015.

Sources: Smithsonian, NASA Science

Low Cost Space Technologies (SWOT Analysis)

Strengths	Weaknesses
• Mass Earth coverage • Relatively fast manufacturing • Reduced vehicle mass budget for propellant	• Limited amount of power collected. • Limited optical resolution • Low platform stability

Opportunities	Threats
• Many developing start-ups • Increased rate of researches • Great numbers of satellites allow new studies to be held	• Relatively high probability of malfunction • Possible technology peak in given size and cost

This **democratization** and **marketization** of space is evident in the growth of the cubesat market. Small mass satellites are available at prices so low that it has attracted a growing number of customers (from Space Agencies to institutions like universities and schools), which in turn have enabled the creation of start-ups and spinoffs. This has led to the development of deployable structures to package relevant elements into small (cubesat compatible) volumes and then deploy them in space to achieve the required level of performance. Sometime these act as demonstrations for applications aimed at larger satellites, like **drag sails**.

There are other **technical issues** that affect all smaller mass satellites, not just cubesats, and present significant challenges, like the need to achieve high platform stability. This is crucial for all missions supporting highly accurately targeted optical payloads (e.g., high-resolution cameras/telescopes or laser communication systems)

Small Satellites

May 2021

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Satellites Companies Landscape 2021

SpaceTech Analytics

USA

UK

Canada

Germany

China

Spain

Other Countries

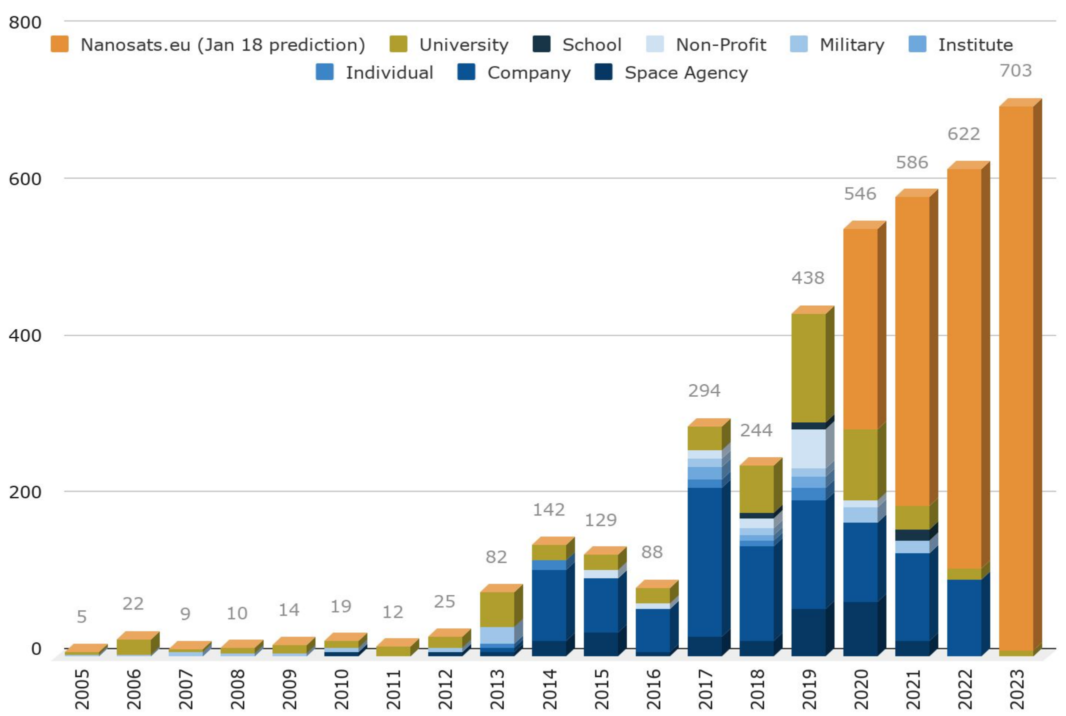
The Beginning of the Small Satellite Era

After the USSR's Sputnik, the world's **first artificial satellite,** was sent into the Earth's orbit in **1957**, the world's superpowers have launched **hundreds of satellites**, competing for supremacy in space exploration in a series of increasingly ambitious and complex projects.

Since then, the mass of satellites/spacecraft have increased dramatically. **The first and second Sputniks weighed 80 kg and 500 kg respectively,** while the today's **International Space Station has a mass of 420,000 kg**. However, it seems like the era of big and heavy satellites is over, the only exception being satellites used for military, astronomy, and specific communication purposes.

New Space is built around the concept of building **less expensive** satellites in shorter periods of time. Thanks to this, satellite manufacturers can decrease costs and achieve miniaturisation of electronic parts. As a result, satellite launches are now accessible even for companies, universities, schools and private individuals.

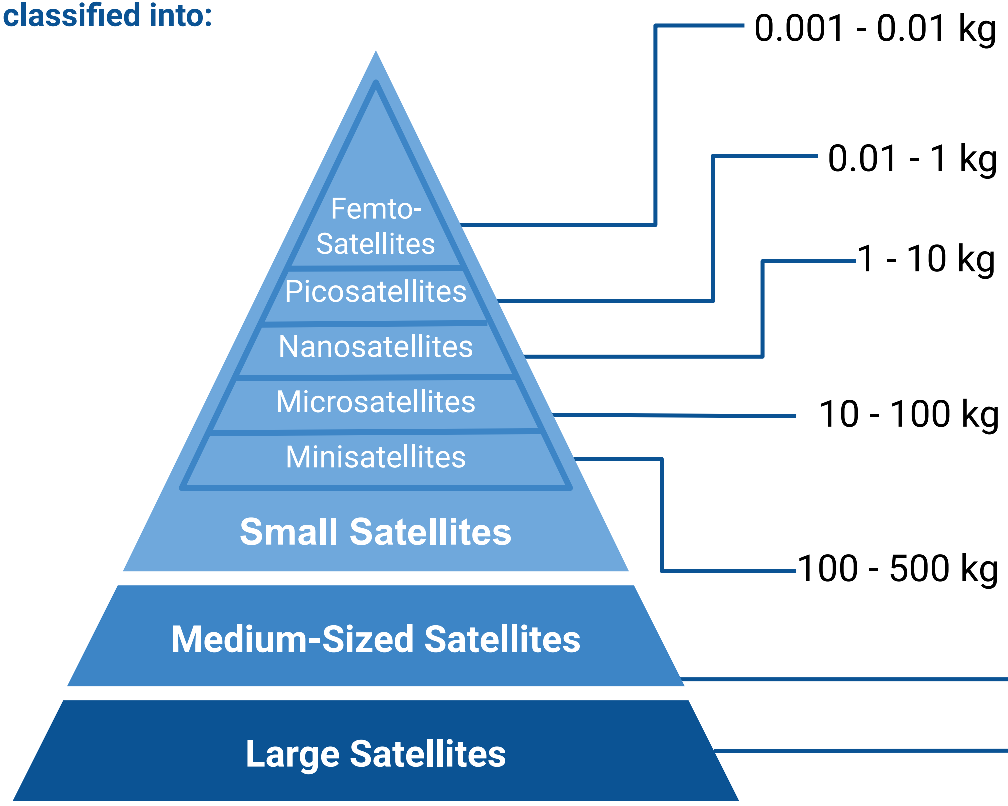
Nanosatellite Launches by Organisations

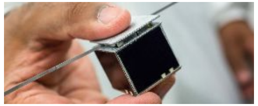


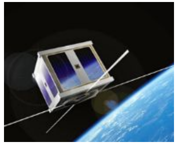
Sources: *IntechOpen*, *Alén Space*

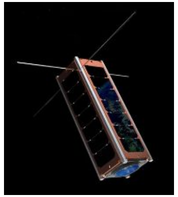
Small Satellites

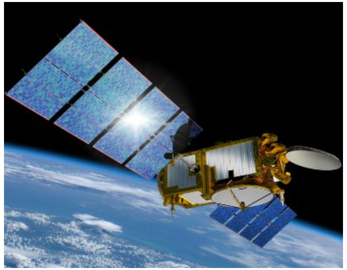
According to their mass, satellites are classified into:











Sources: [Alén Space](), [NASA]()

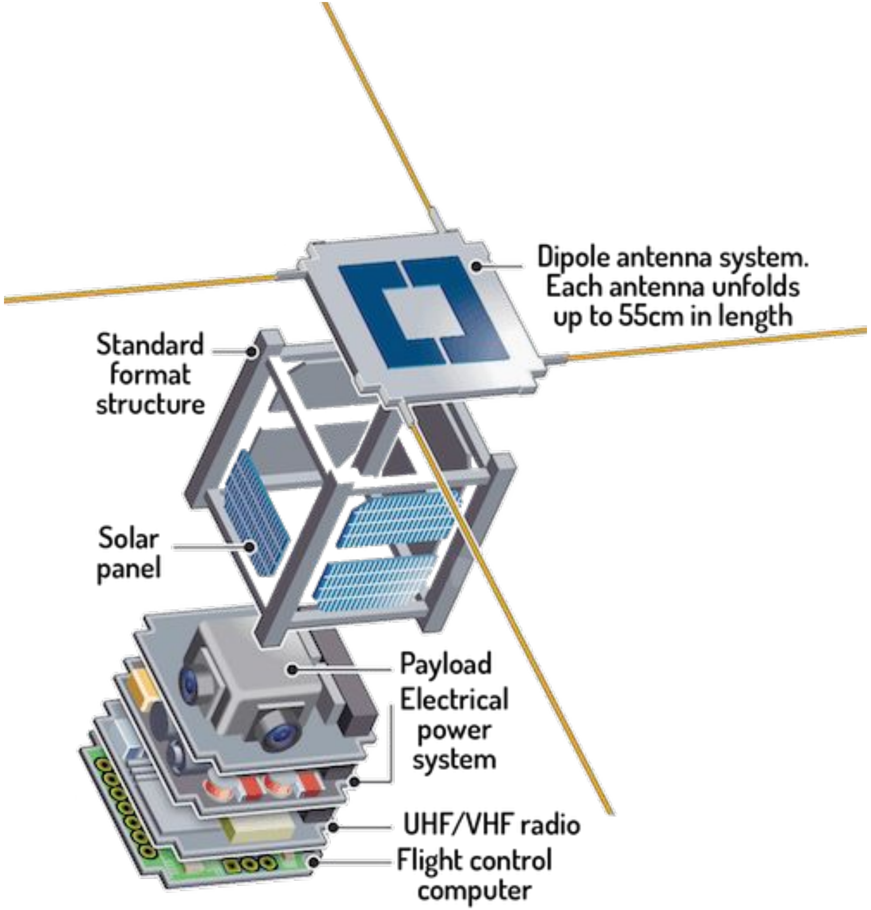
Why Nanosatellites?

Apart from their size and cost, the biggest advantage of nanosatellites is a **shorter time period required for their development**. A medium- or large-sized satellite requires its designers to spend from 5 to 15 years on its development and placement in the right orbit.

There may be changes during a satellite's operational lifetime, which means that its initially planned uses will no longer be commercially viable. What's more, telecommunications technologies are constantly changing, causing conventional satellites to cease to use those of them that have been around for more than 15 years. **It is impossible to constantly upgrade large-sized satellites**; therefore, they cannot be modified even when a market or technological opportunity presents itself.

Depending on its specifications, a nanosatellite can be built and placed in orbit for **500,000 euros.** In contrast, the cost of a conventional satellite can be as high as **500 million euros.**

Launching a nanosatellite as part of a constellation enables to distribute mission-related risks amongst smaller segments; however, the failure of a large-sized satellite may jeopardise an entire mission.



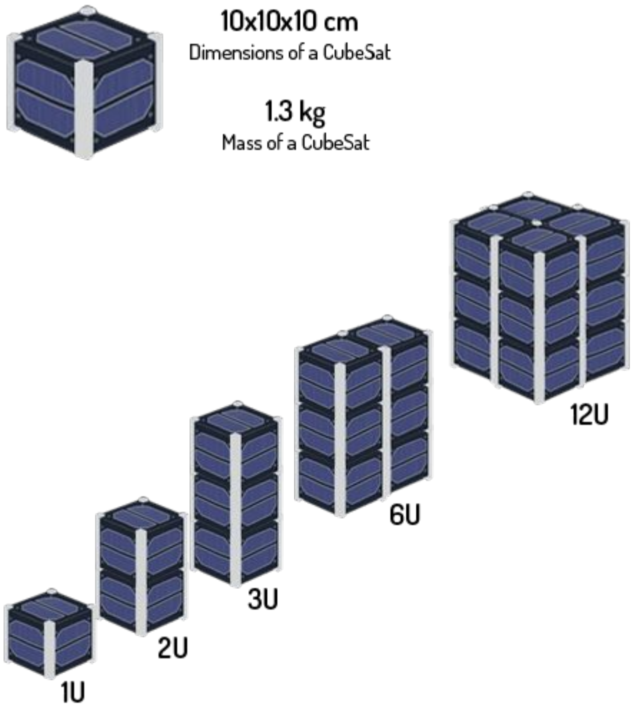
Source: Alén Space

As a general rule, **nanosatellites** are launched in low circular or elliptical orbits (altitudes of between 400 and 650 km) and travel at around 8 km per second. At this altitude and height, it takes them around 90 minutes to orbit the Earth, completing between 14 and 16 orbits a day. By orbiting closer to the Earth, they not only guarantee optimum conditions for land observation or communications, but are also better protected from solar and cosmic radiation.

The CubeSat Standard

CubeSats are a class of nanosatellites that use a standard size and form factor. The standard **CubeSat size** uses a "**one unit**" or "1U" measuring 10x10x10 cms and is extendable to larger sizes; 1.5, 2, 3, 6, and even 12U. Some companies have produced standards up to 27U. At the same time, smaller picosatellites, the so-called PocketQubes, about 1/8 the size of a CubeSat, have also been standardized.

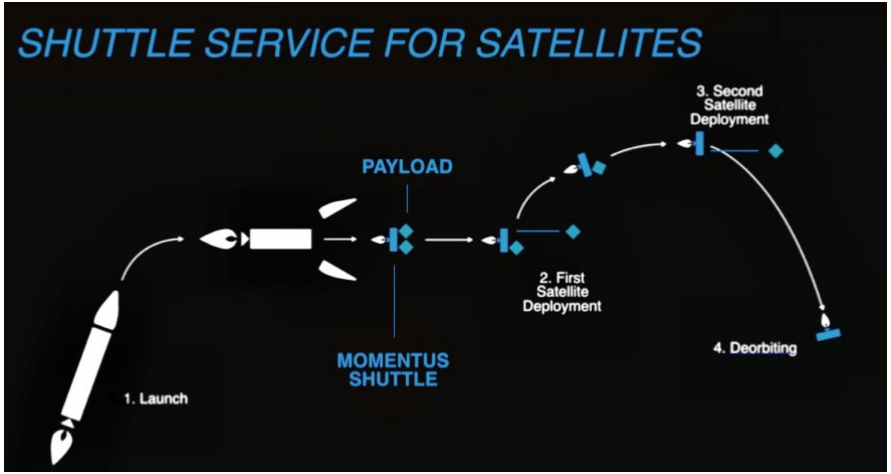
Originally, they were developed in 1999 by California Polytechnic State University at San Luis Obispo (Cal Poly) and Stanford University to provide a platform for education and space exploration. The development of CubeSats has advanced into its own industry with government, industry and academia collaborating for ever-increasing capabilities. CubeSats now provide a cost-effective platform for science investigations, new technology demonstrations and advanced mission concepts using constellations, swarms disaggregated systems.



Sources: Alén Space, NASA, IntechOpen

Small Satellites in Use

On January 24, 2021, **SpaceX successfully launched** a rideshare mission as one of its veteran boosters hoisted 143 small satellites — **a new record for a single rocket** — into space before nailing a landing at sea. Acting as a cosmic carpool, Elon Musk's company launched **10 own Starlink satellites and 133 satellites** for a broad variety of government and private customers, including 48 Earth imaging satellites dubbed SuperDoves from Planet, 17 tiny communications satellites for Toronto-based Kepler, and 30 small satellites for the US and Europe packaged by Berlin, Germany-based Exolaunch. Technology demonstrations and payloads, including satellite components, in-space laser communications and remote sensing of interest to the U.S. military in particular.



The **mission** is expected to deposit the flat-paneled **Starlink satellites in a unique polar orbit** — a first for its broadband fleet that will help provide coverage to customers in Alaska and other polar regions. Following a successful liftoff, the Falcon 9's first stage landed on SpaceX's drone ship "Of Course I Still Love You" in the Atlantic Ocean. The catch marked the 73rd recovery of a first-stage booster for SpaceX and the first catch **of the 2021** year for the company's main drone ship, after receiving some needed refurbishments.

Sources: Space.com, The Verge, SpaceNews

Space Travel

May 2021

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Space Tourism

The main goal of space tourism companies is to fly paying customers to space. Despite having a slightly futuristic ring to it, space travel is not such a far-fetched possibility. From 2001 to 2009, private individuals were **successfully sent into space** aboard a Russian Soyuz spacecraft. Space Adventures, a US-based company, arranged eight space trips to the ISS for seven private individuals, too. However, those space flights were made possible thanks to Russia's Space Agency, which means that Space Adventure only arranged, but did not operate them.

The current challenge is to **make space trips cheaper and thus more accessible to public.** To achieve that, private companies develop their own spacecraft to become independent from state-owned companies. Some of the major private companies developing spacecraft for space travels include **Virgin Galactic, SpaceX, Blue Origin, and Boeing**.

Dennis Tito visits the ISS. The trip is conducted by the Russian Space Agency and arranged by Space Adventures

Blue Origin, Virgin Galactic, and SpaceX Rocket Lab are founded

VSS Unity, a spacecraft designed by Virgin Galactic, enters outer space during test flight

Space Adventures announces an agreement with SpaceX to fly four space tourists in 2021-2022

A private tour with a spacewalk is planned by the Russian Space Agency and Space Adventures (2023)

2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023

Space Adventures arranges flights for seven tourists to the ISS (2001-2009)

Private companies aim to make space travels cheaper and more accessible

No space tours in the 2010s; however, private companies develop vehicles for space tourism

It may become the first private space tour not only arranged, but also conducted by a private company

If successful, that would be the first ever spacewalk by private tourists

Sources: Space, RevFine, Space Tourism Guide, Space News, NBC News,

Pioneers in Space Tourism

Dennis Tito was the first space tourist to pay his own way**.** Despite strong objections from NASA leadership and astronauts, he flew to the ISS aboard Russia's Soyuz spaceship in 2001.

Quote

“In 2021 a private company may charter a private spaceship, fill it up with private passengers, and fly it to orbit in the hands of a private astronaut. The expedition is poised to be the first of its kind, and the gravity of that responsibility is not lost upon its commander.” *Michael López-Alegría, a retired NASA astronaut.*

Setting the Bar High for Commercial Human Spaceflight

In 2019, NASA announced that **private individuals could stay in US modules of the ISS at $35,000 per night**. A year later, NASA began funding efforts to help build private replacements for the space station, which will be deorbited around 2030.

Challenges and Opportunities

López-Alegría believes that space travel is possible for a **vast majority of the population**. People just have to be open-minded and willing to learn. At the same time, they need to be well-prepared, organized and punctual. They must, therefore, undergo a 4-month training course before going to space.

USD 250K

The price of a seat on a suborbital spaceplane designed and developed by **Virgin Galactic**

USD 55M

The price of a seat on a spacecraft designed and developed by **CrewDragon**

USD 90M

The price of a seat on a spacecraft designed and developed by **Boeing Starliner**

Source: [Business Insider]

Space Tourism: Leaders

BOEING	Seattle, Washington, US, 1916	Boeing is a well-known corporation that designs, manufactures and sells airplanes, rotorcraft and other flying vehicles worldwide. Its recent contract with NASA whereby it will be responsible for the development of a crew capsule provides Boeing with an opportunity to sell seats to space tourists. The idea is that at least one space tourist will be participating in each future space mission.
SPACE adventures	Vienna, Virginia, US, 1998	Space Adventures has arranged a total of eight spaceflights for private individuals so far. There have been no space tours since 2009; however, the company is currently offering its clients spacewalks and circumlunar missions.
BLUE ORIGIN	Kent, Washington, US, 2000	Blue Origin's rocket is is more traditional than the one developed by Virgin Galactic. Known as the New Shepard, it takes off and lands vertically. The company's main goal is to achieve orbital spaceflight' hence. It has already performed several test flights. However, it hasn't flown any customers to space yet.
SPACEX	Hawthorne, California, US, 2002	Apart from launching advanced rockets and spacecraft, SpaceX also plans to fly space tourists. Unlike other space tourism companies, it mostly focuses on space tourism extending beyond Earth orbit (e.g. lunar tourism).
Virgin GALACTIC	Mojave, California, US, 2004	Virgin Galactic aims to provide suborbital space flights to space tourists, do suborbital launches for space science missions, and launch orbital human spaceflights. The company already has an extensive waiting list of people wishing to become space tourists; however its spacecraft will still have to be tested by professional pilots.
Zero 2 Infinity	Barbará, Catalonia, Spain, 2009	The company offers a trip to the stratosphere in a helium-filled balloon capable of carrying four passengers and two crew members. Technically speaking, the height of the flight (36 km) is not enough to consider it a space flight.

Sources: RevFine, Space Tourism Guide, CNBC

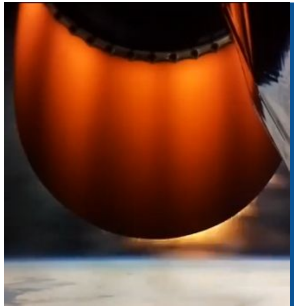
Comparison of 12 Space Tourism Companies by Development Stage and Destination

Nearly half of all known Space Tourism companies have failed, with another half being less than successful.

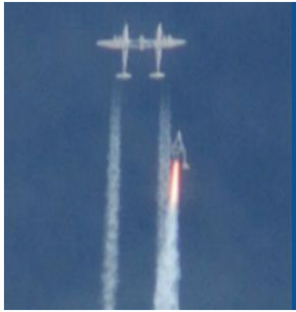
The Biggest Failures in Space Industry

Space exploration is associated with risks and unexpected problems (both technical and commercial ones). However, a recent trend suggests that private companies are becoming increasingly important in the space industry. This is explained by the fact that they are making space travel more popular and affordable. However Space Industry is a pretty complicated thing to develop, so the failures are imminent.

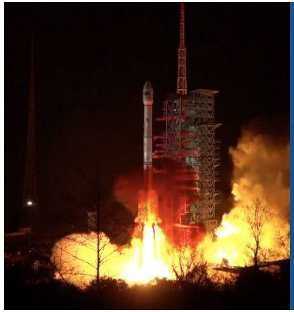
The explosion of **SpaceX Crew Dragon** on a launchpad in 2019 proves that even leading players are not immune from failure. The company later found out a leaky propellant valve was a core of problem.



Based in New Zealand, **Rocket Lab** company lost **seven small satellites** due to an electrical connection failure in the second stage of their Electron Rocket. However, they were able to fix the problem and did four more successful launches in 2020.



Sometimes, space exploration results in the loss of human lives. This was the case during the **crash of Virgin Galactic's SpaceShipTwo** in **2014** during which a pilot was killed. The company then stated: "vehicle suffered a serious anomaly resulting in the loss of SpaceShipTwo".



Two of **China's Long March** rockets. one of them being Long March 7A, crashed in 2020. 2020 also saw another **Long March** rocket fail to deliver an Indonesian satellite into orbit. Despite these incidents, China went on with launching for most of 2020.

Sources: Mit Technology Review, BBC, space.com

Unidentified Aerial Phenomena and Artefacts (Reports by Governmental Organizations)

May 2021

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Unidentified Aerial Phenomena and Artefacts

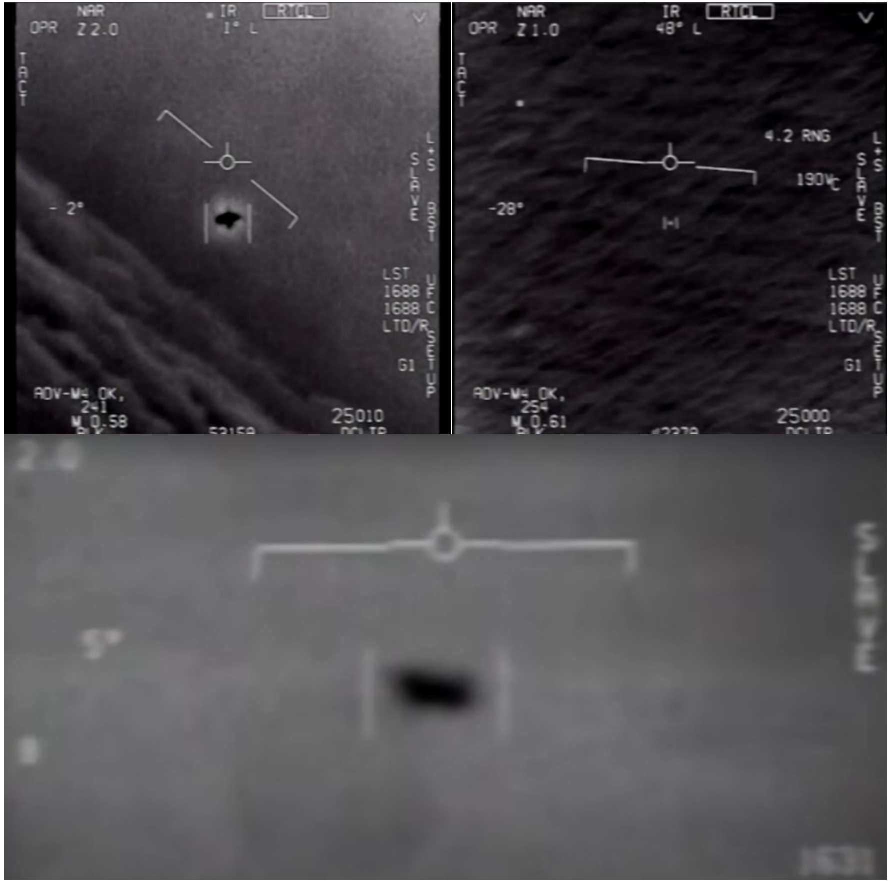
Type: Sighting
Authority: US Government

These still shots are from the video that leaked out in 2017 and **was confirmed** to show **unidentified aerial phenomena** by **Pentagon** in 2020.

"The Department of Defence is releasing the videos in order to clear up any misconceptions by the public on whether or not the footage that has been circulating was real, or whether or not there was more to the videos. The aerial phenomena observed in the video remain characterized as 'unidentified'"
U.S. Department of Defence.

"*These aircraft are displaying characteristics that are not currently within the US inventory nor in any foreign inventory that we are aware of,*" said Luis Elizondo, the former head of a government-funded UFO program.

In some of the videos, the pilots filming them are heard saying: "*Not behaving by the normal laws of physics*"



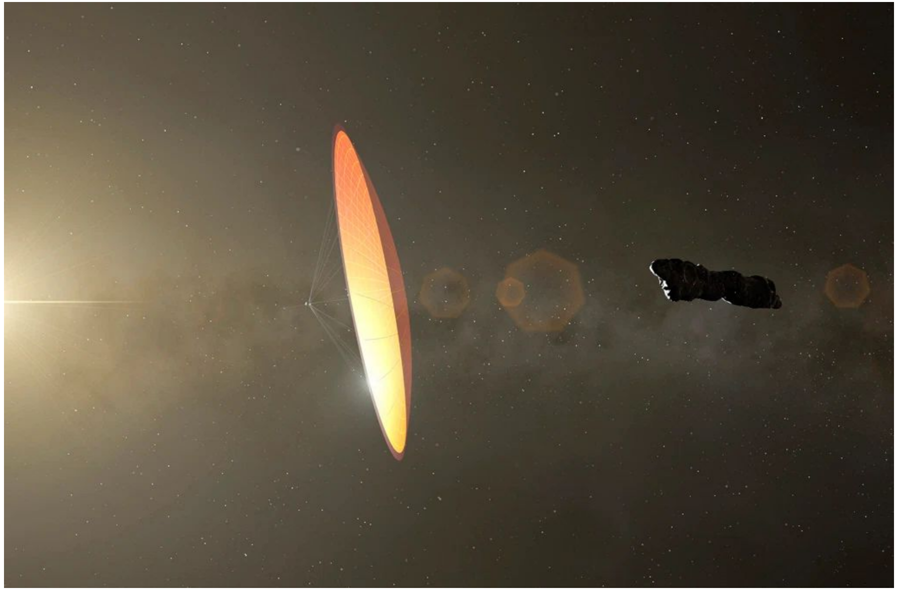
Source: Insider

Type: Data
Authority: Chair of Harvard's Department of Astronomy

On **September 6, 2017,** an extraterrestrial object flew past Earth. Initially identified as an asteroid and called **"Oumuamua",** it could have passed for one if it hadn't been for two things: **Shape**. According to scientists, it was either a very long cigar-shaped object or one that was really flat. No such asteroids had been sighted before.

Acceleration. Asteroids and comets can sometimes accelerate due to the evaporating water; however, that was not the case with this object.

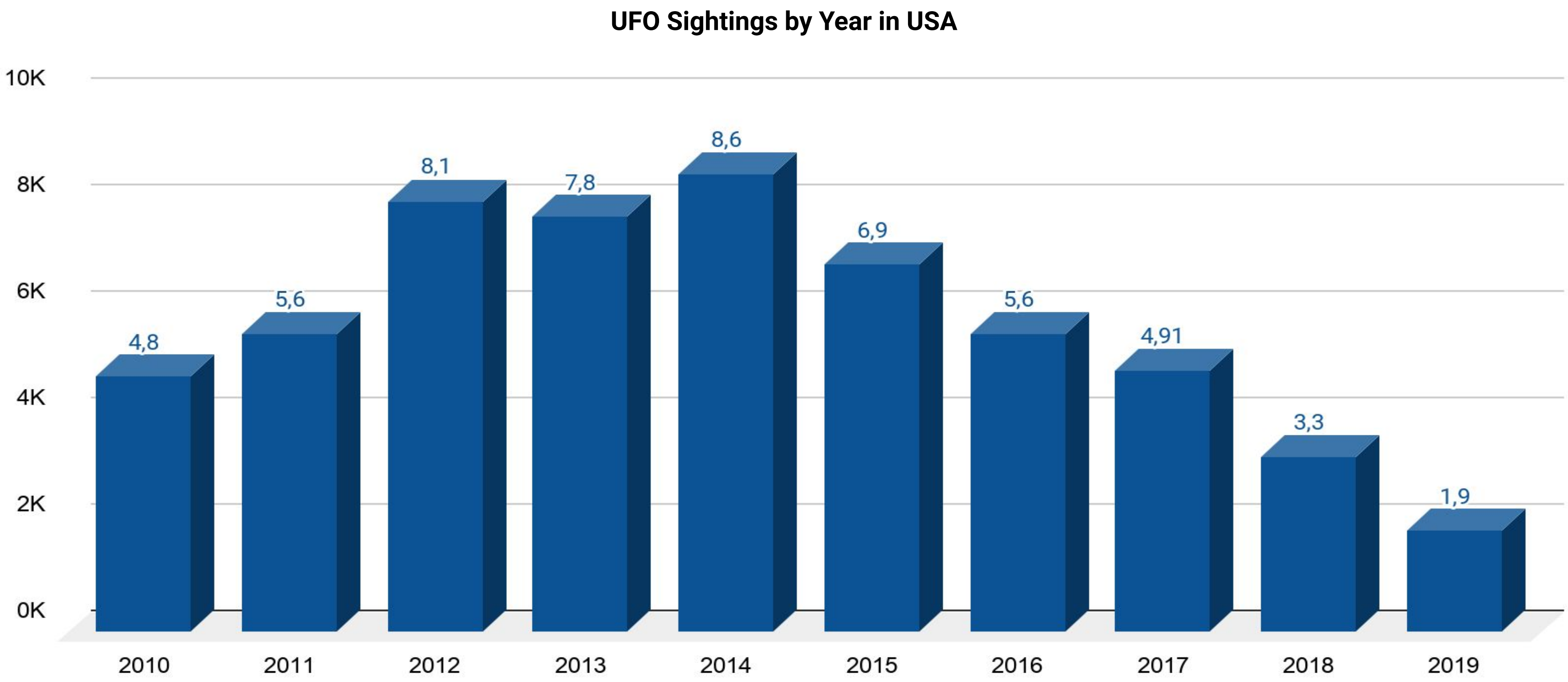
Artist's impression of possible shapes for `Oumuamua.



Avi Loeb, Chair of Harvard's Department of Astronomy, believes that the object is in fact an alien vehicle with a sun sail. Theoretically, it is possible to develop such technology if proper materials are available. "I don't see any other compelling possibility", said Loeb explaining Oumuamua's lack of acceleration.

Source: NYpost

UFO Sightings



There is a clear downward trend on UFO sightings in United States, which may be caused by the development of entertainment technologies, making people spend less time outside.

Sources: [Insider]

Unidentified Aerial Phenomena and Artefacts

Type: Sighting
Authority: Russian astronaut

On August 20, 2020, Russian astronaut Ivan Vagner posted a timelapse video of five unidentified objects in his Twitter account. The video features five spherical objects that appear and disappear in rapid succession. According to the astronaut, the objects travelled at the same speed and were equidistant from one another.

"The information was brought to the attention of Roscosmos management. The video footage was sent to TsNIIMash and the Space Research Institute of the Russian Academy of Sciences for further analysis," the astronaut was reported as saying.

Source: Twitter

Type: Statement
Authority: Former Israeli Space Security Chief

According to Haim Eshed, former Israeli Space Security Chief, humanity has been in contact with extraterrestrials from a so-called "**galactic federation**".

"They have been waiting until today for humanity to develop and reach a stage where we understand, in general, what space and spaceships are" Eshed said. He goes on to say that the United States and Israel have long been in contact with an alien race called "galactic federation".

He claims that former US President Donald Trump knew about that and was deeply concerned about the fact. Eshed insists that Trump was going to reveal this information but was kindly asked not to do so by the aliens, because that could lead to "mass hysteria".

Source: NBC News

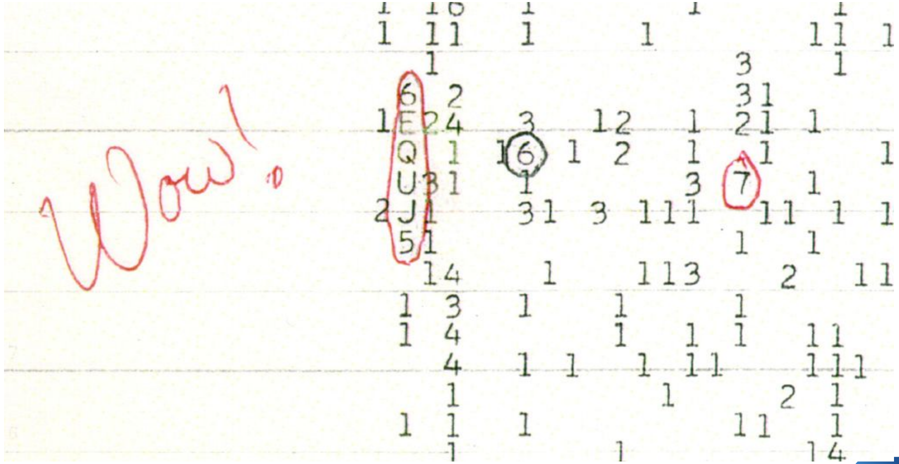
Unidentified Aerial Phenomena and Artefacts

Type: Signal
Authority: Parkes Observatory

In April, 2019 the Parkes radio telescope caught a strange narrowband radio signal from the closest star system Proxima Centauri. It was later called **BLC-1**. Scientists believe it could be a technosignature of a civilisation that lives on one of the two planets orbiting Proxima, but the are also theories that are more likely. Experts say, this may be a radio interference, since we use the same radio band for satellites, or a natural process that is not well-known to the scientists.

Type: Signal
Authority: Ohio State University

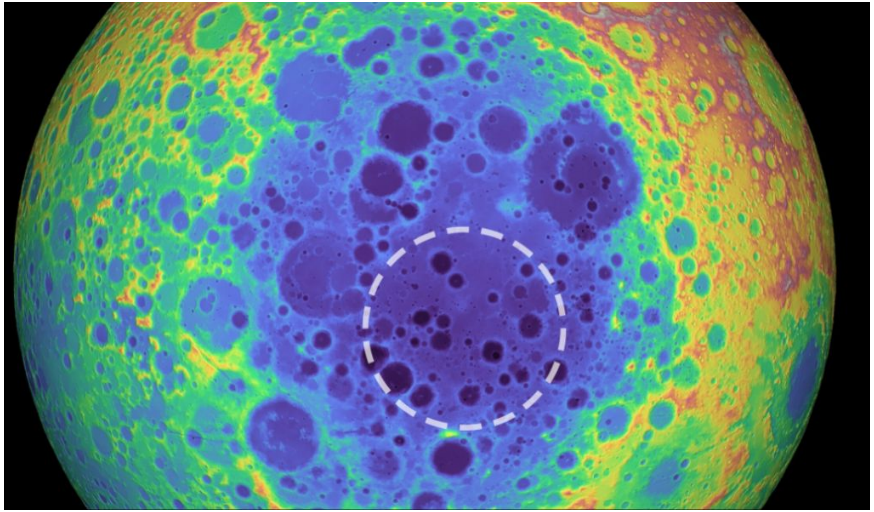
WOW! Signal was also a strong narrowband signal back in the 1977, that lasted for only 72 seconds. The signal was not modulated, which means, that there are no known ways to convey any information with such transmission. There were suggestions, that it had been an Earth-sourced signal that simply got reflected off a piece of space debris, but those were rejected in some time. Scientific community sticks to the theory, that the signal was an artifact, because it never repeated.



Source: *[Forbes]*

Type: Data
Authority: Astronomers from Baylor University

A team of researchers from Baylor University in Texas have found a large cluster of mass under the Moon's largest crater. Perhaps, it is a core of a metal asteroid that struck the Moon a millenia ago or a magma solidification. Some scientists even go so far as to assume that there can be a metal structure under the Moon's mantle. There are different hypotheses; however, none of them can be confirmed yet.



Type: Data
Authority: International team of astrobiologists

Data sent to Earth by NASA's Curiosity rover indicates that Mars could have has the environment factors to support life. Thiophene, a chemical substance found in coal and crude oil, could be a sign of life on the Red Planet. "There are several biological pathways for thiophenes that are more likely than chemical ones," says Dirk Schulze-Makuch, Washington State University astrobiologist.

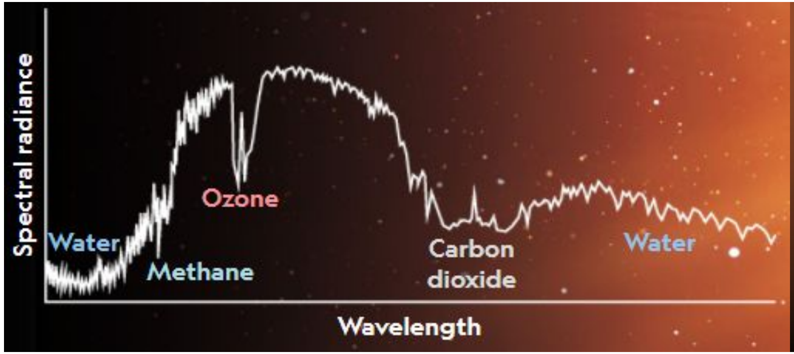
Source: Futurism

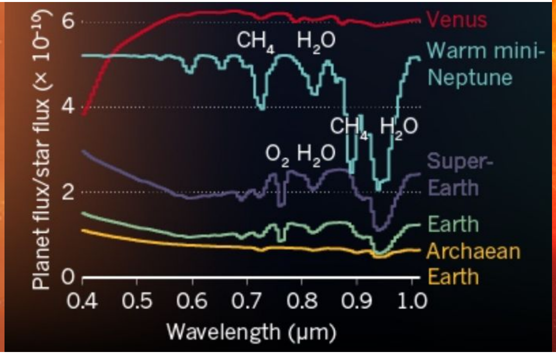

Radio telescope Robert C. Byrd

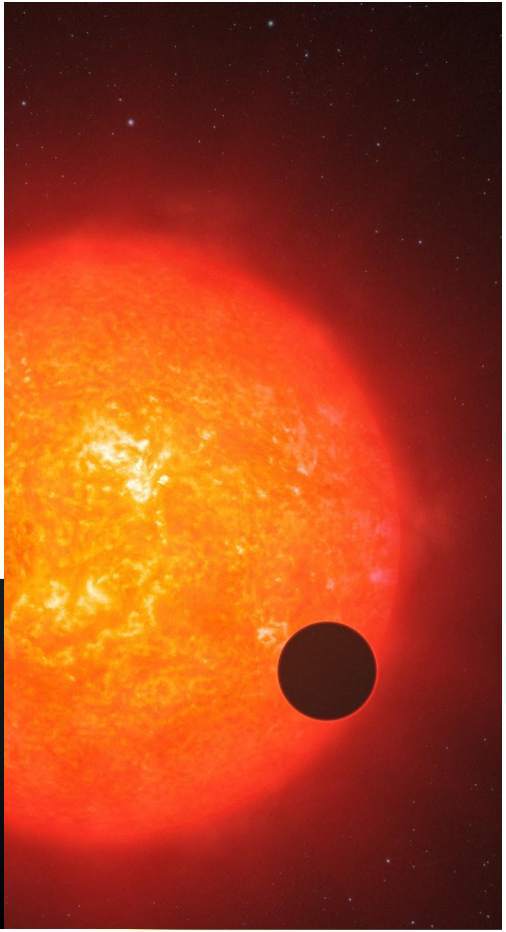
Search for Extraterrestrial Intelligence (or **SETI**) is a collective term for a scientific search for intelligent extraterrestrial life, involving monitoring electromagnetic radiation for signs of transmissions from civilizations on other planets.
Most of the work is done with the help of radio telescopes looking for radio or laser transmissions. It is a pretty rare occasion that such telescope stumbles upon a signal that is not considered to be normal or known, but even if it does, there is a long procedure before it can become a candidate for extraterrestrial transmission. First, the telescope is moved away from the signal and returned back. The signal must disappear and reappear again to prove that the signal is coming from the telescope's field of view. Then known Earth or near-Earth sources, such as satellites, must be ruled out as originators of the signal. Same goes for known natural extraterrestrial sources, such as pulsars. Afterwards the signal must be confirmed by another radio telescope.

The project called **Breakthrough Listen** is made to search for intelligent extraterrestrial communications in the Universe. It operates $100 million in funding and thousands of hours of dedicated telescope time involving a set of reliable modern telescopes. The project uses radio wave observations from the Green Bank Observatory and the Parkes Observatory, and visible light observations from the Automated Planet Finder. All data generated from the project are available to the public. The first results were published in April 2017, and the further updates are expected every 6 months.

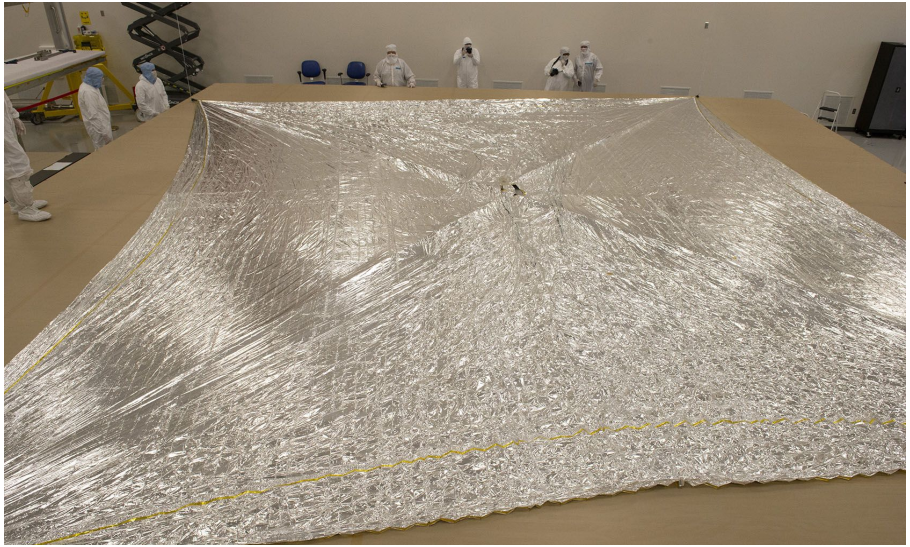
There is a crucial thing in SETI. In order to find life, you first have to find planets that are habitable. In order to be considered habitable the planet should remain its orbit not too close and not too far from its star, because the equilibrium temperature influences the possibility of liquid water being present on the planet's surface. The star shouldn't have frequent and powerful solar flares, because otherwise any life form would be wiped out by a deadly dose of radiation. Humanity knows about **47** potentially habitable planets, and **11** of them are quite likely to have water on their surfaces. Moreover there are theoretically at least **25 millions** of Earth-sized planets in Milky Way that lay in the habitable zone of their stars, but it is not clear if there is any life there. That is why such thing as **biosignatures** exists. Those are mostly gases, such as **Ozone**, **Methane**, **Carbon Dioxide** or **Water,** that carbon-based lifeforms need or produce. Spectral characteristics of the starlight transmitted through the planet's atmosphere reveal the gases within. So seeing such gases in the atmosphere leads us to a conclusion, that life is really possible on that planet.

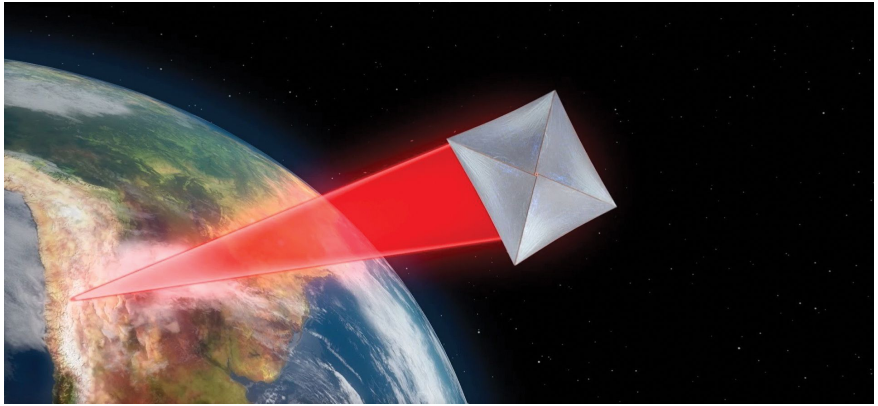




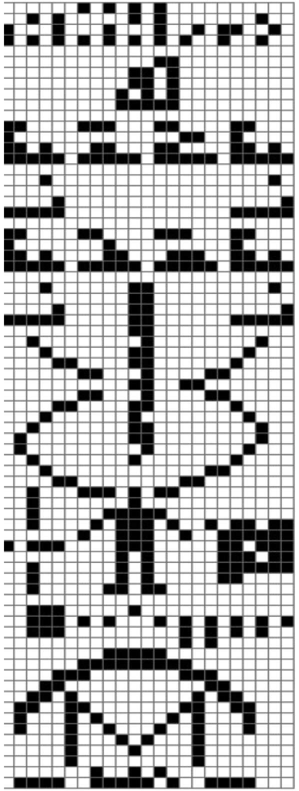


Starshot Breakthrough is a project that aims to launch a tiny vehicle with a speed of one fifth of the speed of light to the closest star system Proxima Centauri, that is situated only in 4,2 light years from Solar System. The idea is to survey the planet called **Proxima b**, because it lays in the habitable zone of its planet and spectral analysis shows that it is likely to have fluid water on it surface. Moreover, the latest signal **BLC-1**, that is considered to be a possible technosignature, was received from the same star system.





The technology is that a set of lightweight probes are launched from the low Earth orbit and propelled by nearly a billion laser beams, creating a pulse with the power of 100 gigawatts for several minutes. The probes have a quarter inch chip each, that weighs five grams and fulfills the function of a camera, laser transmitter, computer and a navigation system. The crucial point of the technology is a giant featherweight foil sail that will be pushed by the laser beam. The information received by the probes in approximately 20 years after the launch will be transmitted back to Earth via laser, that will travel home for another 4 years. The scientists expect to prove the existence of liquid water on the planet.

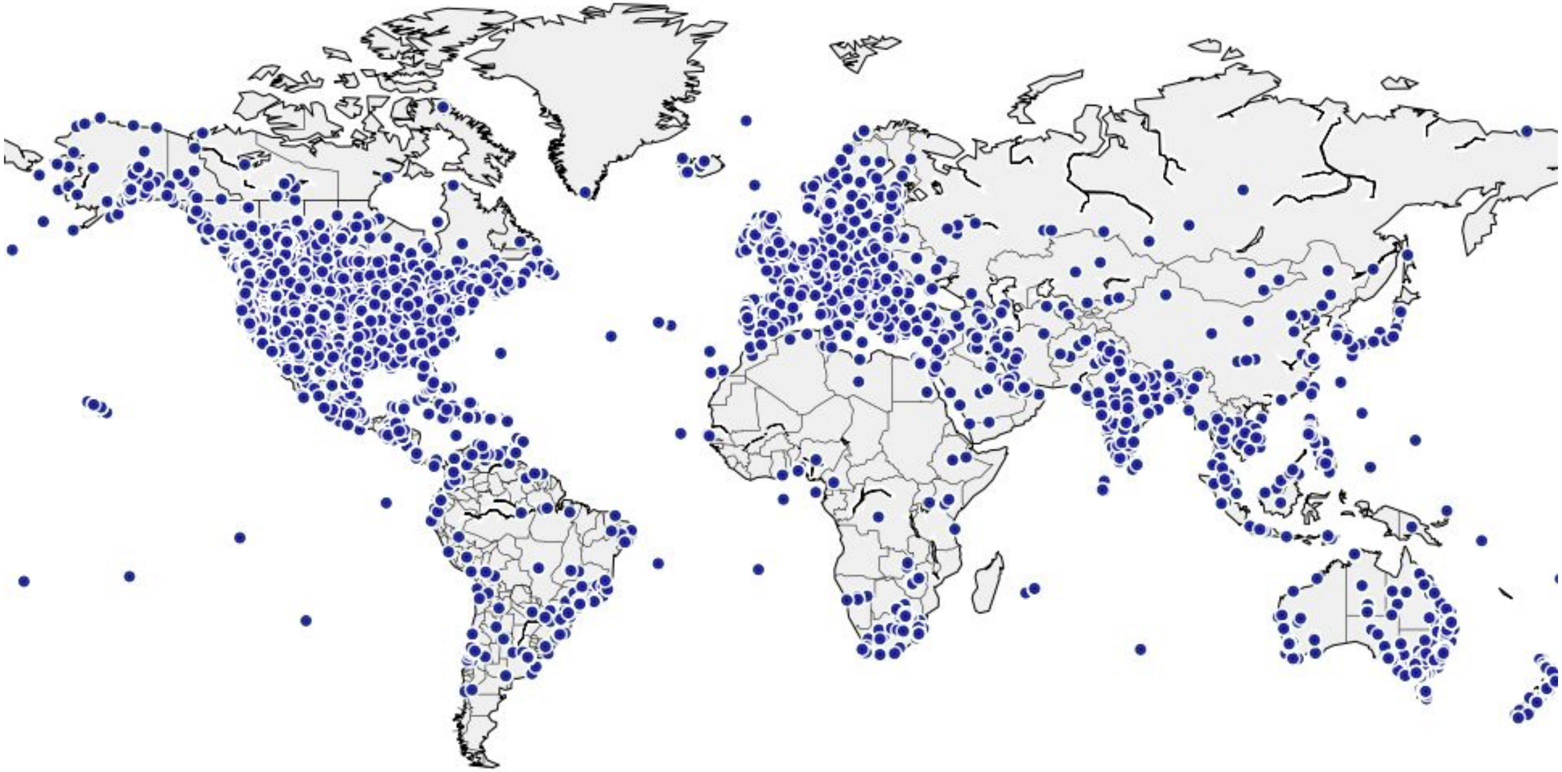


A representation of the 1679-bit Arecibo message.

Messaging to Extra-Terrestrial Intelligence (METI) also known as Active SETI is an initiative by a group of astronomists and astrobiologists made to contact the extraterrestrial intelligence with mostly radio messages. In 2010, **Douglas A. Vakoch** of the SETI Institute proposed to integrate the Active SETI and Passive SETI programs to engage in an articulated, ongoing, and developing set of experiments to contact another civilisation, considering all the problems like the Fermi Paradox. Articulated in this case means a well-designed message that could be interpreted by any sapient organism, that doesn't know anything about human alphabet or culture. For example Arecibo message has an encoded information about our numerical system, the chemical composition of DNA, a representation of a human and the population, Solar System and an image of a telescope that sent the message in binary code There were other messages like **Cosmic Call** or **Teenage Message** that mostly represented such encoded messages or musical compositions. Physical messages like Pioneer Plaque, that was attached to Pioneer 10 and 11, also count as METI. It had a picture of naked humans, the telescope and some graphical syphers telling about Solar System and how to find it.

UFO Sightings

World Map of Single or Group Sightings



Source: [Medium]

Space Medicine

May 2021

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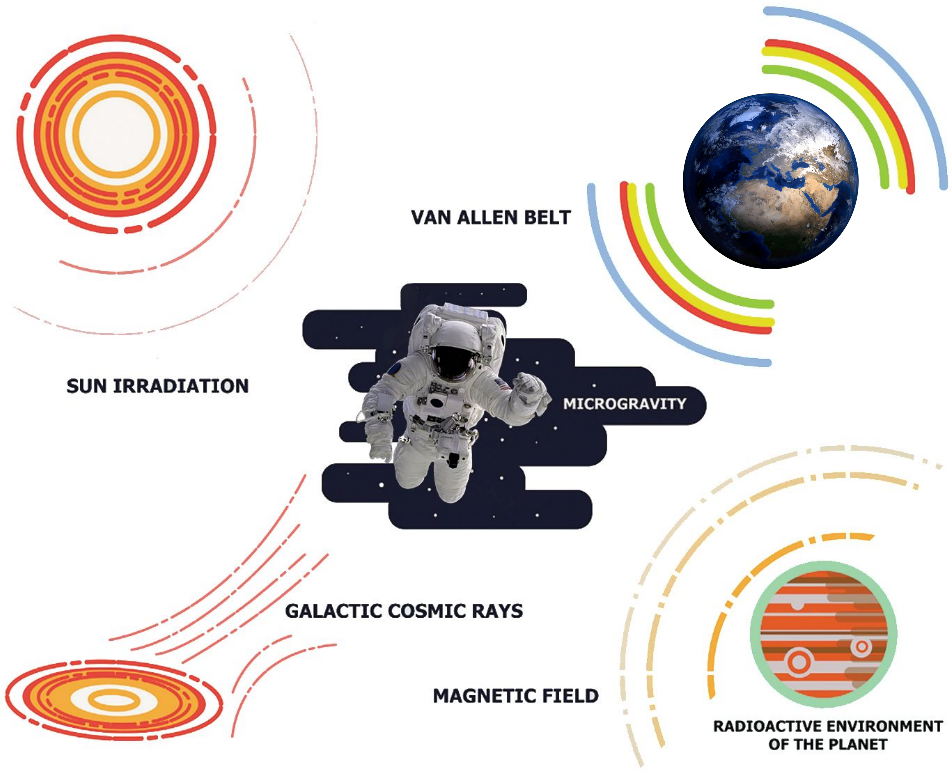
SpaceTech
Analytics

The Core of the Problem

Advancements in longevity are crucial to the future of the space economy. People should be able to not only live and work in space for weeks or months, but also perform amazing feats of engineering for years and, eventually, decades. In **ideal conditions** on Earth, the human body can live up to **90 years** until aging-associated diseases lead to its decay and death. Surviving the harsh conditions of space travel, especially multi-month or multi-year missions, will lead to enormous physical losses for astronauts.

With current technology, it would take a crewed mission roughly **6 months** to reach Mars, **18 months** the Asteroid Belt, and up to **7 years** Titan. Given the current state of medical technologies, a multi-year journey to the nearest star system (let alone a multi-decade one) would probably **not be survivable**.

The interplanetary environment presents immensely difficult challenges: zero gravity weakens and wreaks havoc on all bodily systems; cosmic radiation damages cellular DNA; traveling any appreciable distance will result in decades of aging.



Space Medicine Framework

SELECTING FITTEST INDIVIDUALS

Conducting genetic, biochemical, physiological psychological, and physical tests to select the fittest individuals capable of surviving extreme space flight conditions.

HIBERNATION

Lowering the body's temperature with the help of chemicals or neural stimulations to reduce the need for food in humans.

GENE THERAPY

Biotechnologically enhancing radioresistance, microgravity tolerance and DNA repairing mechanisms of the human body.

PROTECTION DRUGS

Researching and producing drugs capable of reducing damage caused by radiation, microgravity and general stress (e.g. radioprotectors, geroprotectors and redox scavengers).

P4 MEDICINE

P4 (Precision Preventive Personalized Participatory) diagnostic, prognostic and therapeutic technologies to maintain an optimal state of astronauts' health for as long as possible.

CELL THERAPY

Cell therapies, bioengineered organs, tissue engineering and xenotransplantation targeting damage caused by space flight conditions.

BIOMARKERS

Discovering and developing biomarkers of damage and resistance, as well as the core infrastructure required for testing the safety and efficacy of therapies and effectiveness of interventions

LONGEVITY NEUROTECH

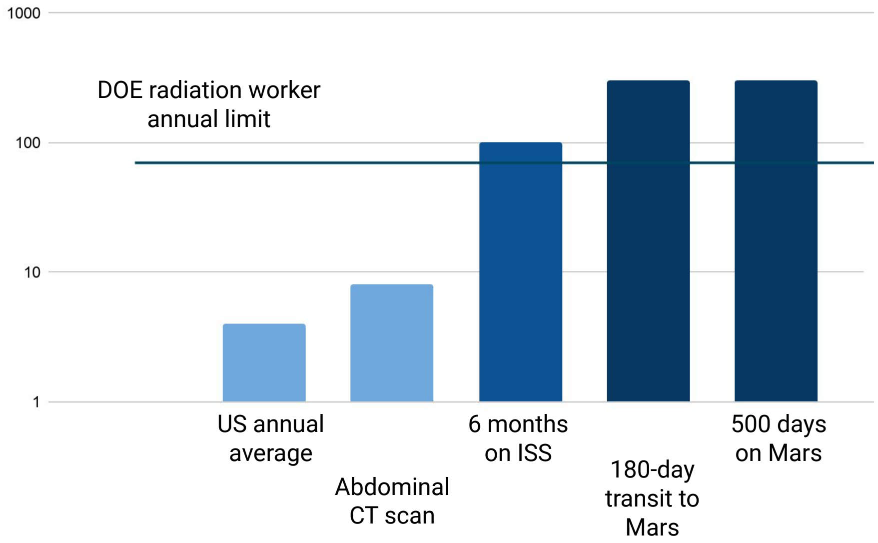
NeuroTechnologies to improve and maintain cognitive abilities, neurological plasticity, sleep quality (SleepTech) and psychological well-being of astronauts

Radioprotectors

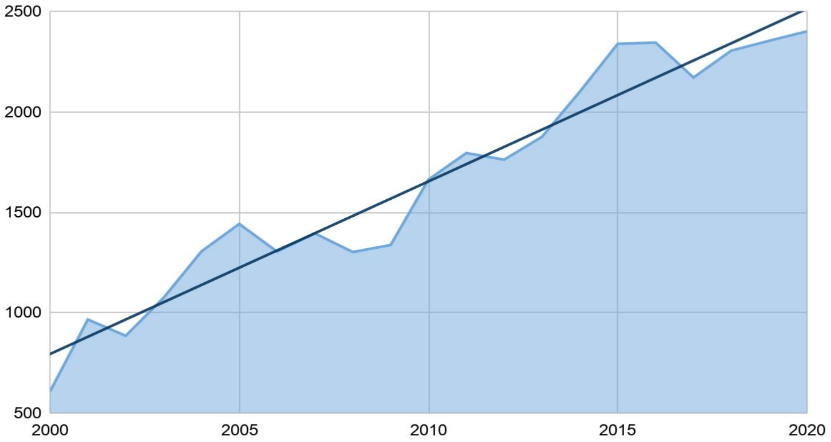
Outside the safe cocoon of Earth's atmosphere and magnetic field, subatomic particles zip around at close to the speed of light. **Space radiation** can penetrate habitats, spacecraft, equipment, spacesuits, and even astronauts themselves. The **interaction of ionizing radiation** with living organisms can lead to harmful health consequences, such as tissue damage, cancer, and cataracts in space and on Earth. The underlying cause of many of these effects is damage to deoxyribonucleic acid (DNA).

Drugs called **Radioprotectors** are capable of reducing damage caused by space radiation and increasing astronauts' resistance to radiation exposure. Having a formidable potential, they are extremely important in the Space Exploration Era.

Radiation Dose (Milliseverts)



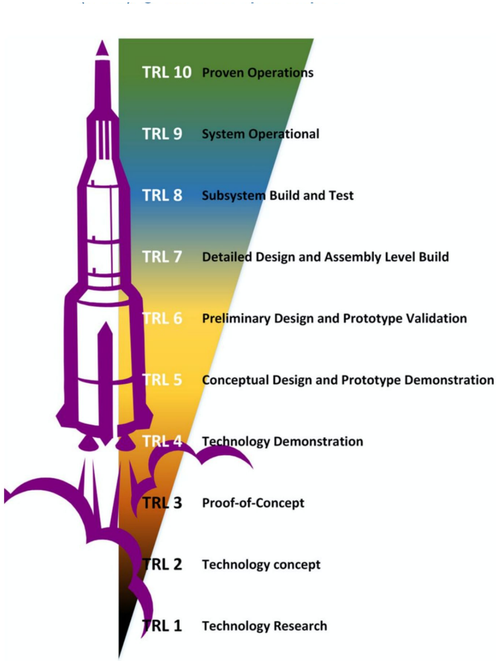
There is an Upward Trend in Research Into Radioprotectors:



Source: PubMed

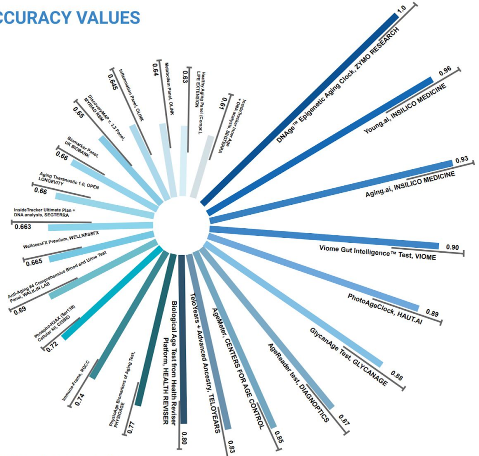
A **biomarker** is a measurable indicator of some biological state or condition. Biomarkers are often measured and evaluated using different biological samples to examine normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention. In this case there is a list of biomarkers that indicate the damage caused by space operations in the astronaut's organism. The continuous monitoring of small changes in such biomarkers, and the continuous and commensurate micro-adjustment of treatments in response, allows for lowering the harmful impact on individual's health and elongating the lifespan of a space traveller

The data is partly taken from the "The Rising Wave of Human Biomarkers of Longevity"report by Longevity International and Deep Knowledge Group.



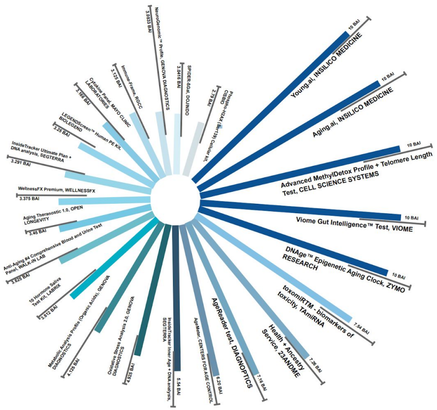
Technology Readiness Level (**TRL**) is a method of estimation of the maturity of technologies. Today, the most promising technologies, i.e. the ones that have the highest growth potential, have from 4 to 8 TRL.

ACCURACY VALUES



Illustrative only; non-real values.

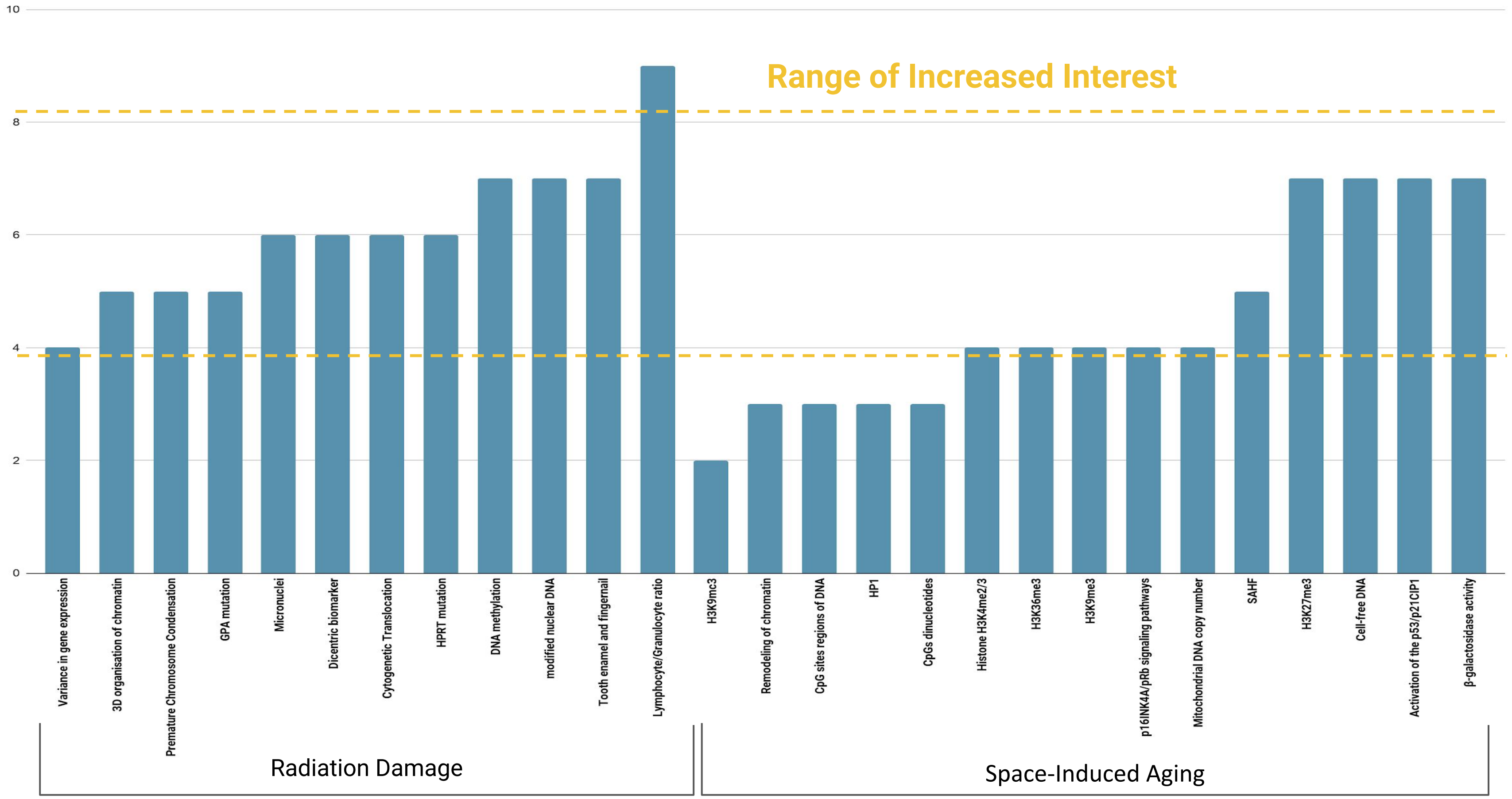
AVAILABILITY VALUES



Illustrative only; non-real values.

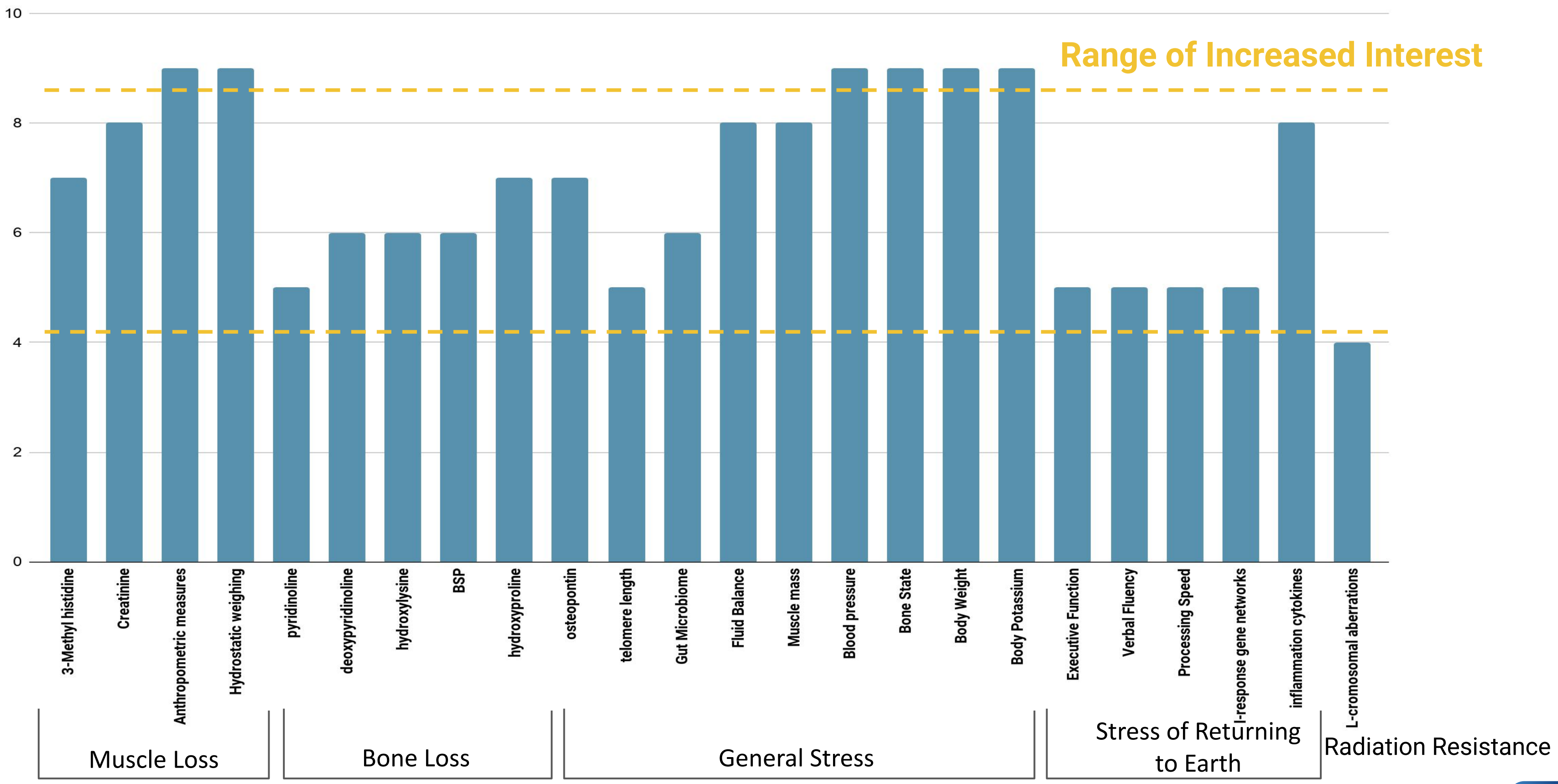
Source: Longevity International

TRL of Space Travel-Related Biomarkers

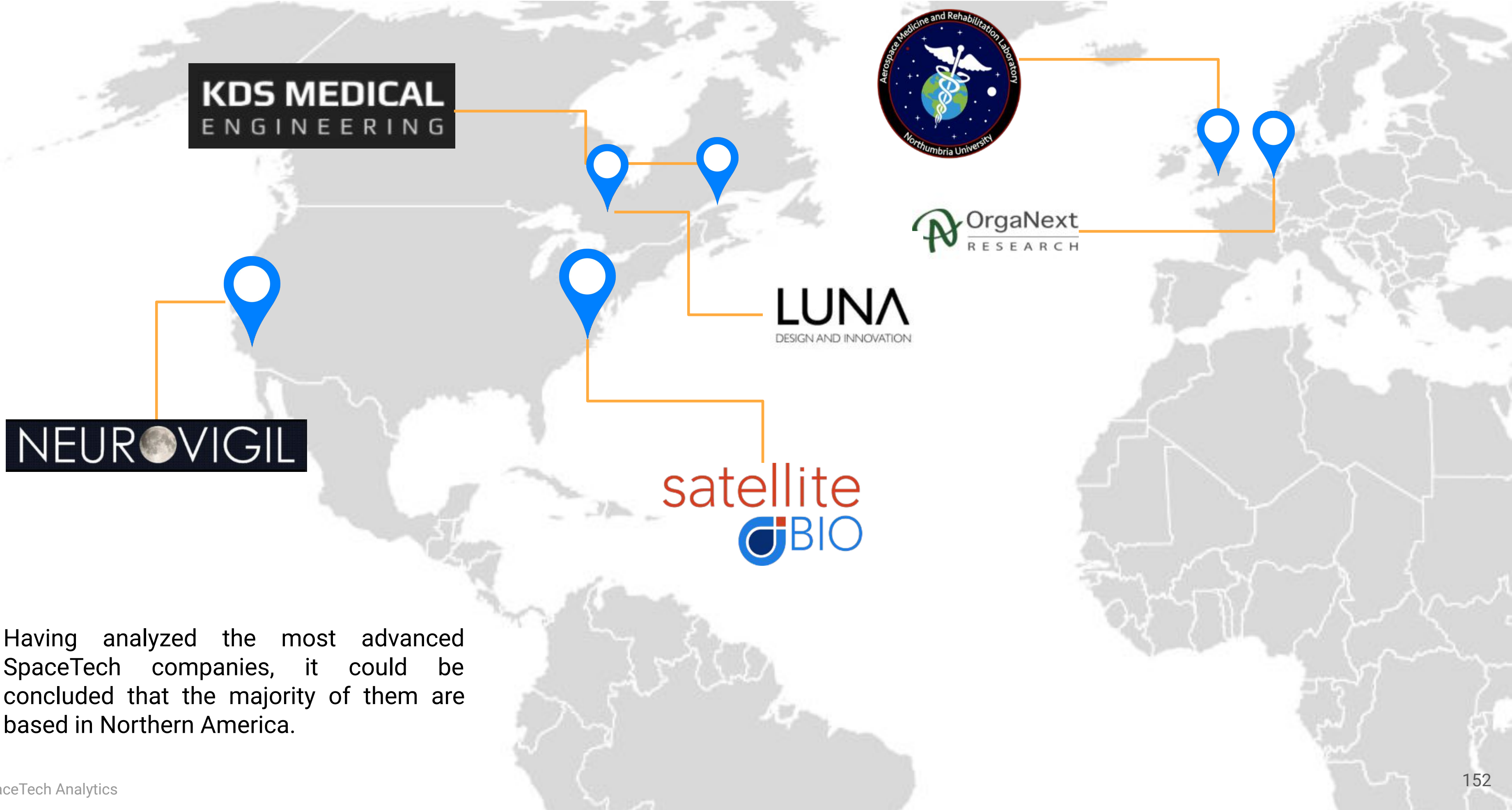


Source: PubMed

TRL of Space Travel-Related Biomarkers



Most Advanced Space Medicine Companies



Having analyzed the most advanced SpaceTech companies, it could be concluded that the majority of them are based in Northern America.

Universities and Organisations that Make Studies in the Following Directions

Biomarkers

- University of Alabama at Birmingham (USA)
- University of Michigan (USA)
- University of Washington (USA)
- Max Planck Institute for Biology of Ageing (Germany)
- University of Vienna (Austria)
- UCL (UK)
- Leiden University Medical Center (The Netherlands)
- Tsinghua University (People's Republic of China)
- University of Auckland (New Zealand)
  Institute of Nuclear Medicine & Allied Sciences (India)

Radioprotector

- University of Notre Dame (Australia)
- University of Sydney (Australia)
- Université de Lyon (France)
- Harwell (England)
- Philipps-University Marburg (Germany)
- Mittelhessen University of Applied Sciences (Germany)
- Belgian Nuclear Research Centre (Belgium)
- National Council on Radiation Protection and Measurements (USA)
- Southern Illinois University Carbondale (USA)
- University of New Mexico School of Medicine (USA)
- Memorial Sloan Kettering Cancer Center (USA)

Hibernation

- University of Tsukuba (Japan)
- RIKEN Center for Biosystems Dynamics Research (Japan)
- Niigata University (Japan)
- University of Bologna (Italy)
- Gifu University (Japan)
- Oregon State University (USA)
- University of British Columbia (Canada)
- Trento Institute for Fundamental Physics and Applications (Italy)
- National Institute of Nuclear Physics (Italy)
- University of New England (USA)

Gene Therapy

- University of London (England)
- GSK (England)
- Herlev Hospital (Denmark)
- University of Copenhagen (Denmark)
- The Icahn School of Medicine at Mount Sinai (USA)
- Universite Sorbonne Paris Cite (France)
- University of Pennsylvania (USA)
- The University of Tasmania (Australia)
- Baylor College of Medicine (USA)
- the University of Massachusetts Medical School (USA)

Source: PubMed

* Selected and categorized by the subject of their recent researches

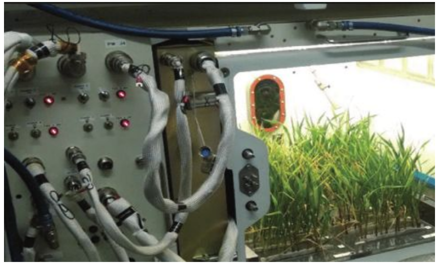
Supporting Human Life in Space: Food, Bone and Muscle Loss

Food

NASA is currently looking for ways to **provide astronauts with long-lasting and easily digestible nutrients**, such as fresh fruit and vegetables. Simply providing astronauts with multivitamins will not be enough. The challenge here is how to do that in a closed environment devoid of sunlight or Earth's gravity.

Advanced Plant Habitat

The Advanced Plant Habitat (APH) is a growth chamber for plant research on a space station. It uses LED lights and a porous clay substrate with controlled release fertilizer to deliver water, nutrients and oxygen to the plant roots.

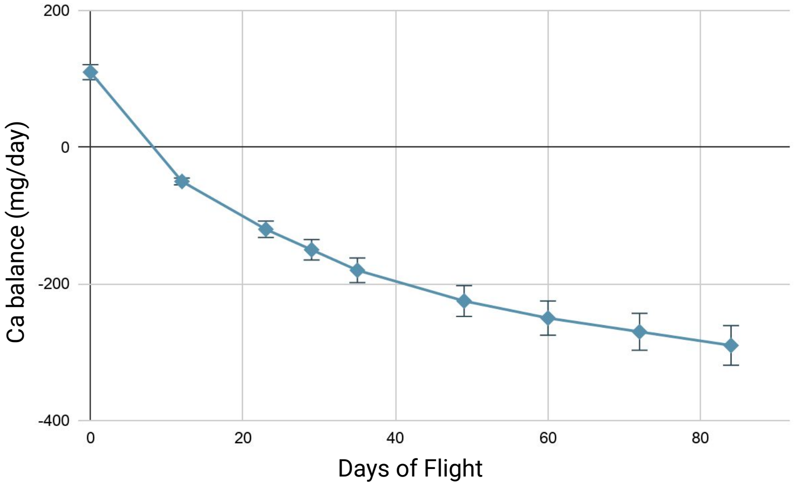


Biological Research in Canisters

The Biological Research in Canisters (BRIC) is a facility used to study the effects of space on organisms small enough to grow in petri dishes (e.g. yeast and microbes).

Bone and Muscle Loss

The human body evolved within the constant pull of the **Earth's gravity**. In the microgravity environment aboard the orbiting International Space Station, bones and muscles don't have to support the body's mass (weight on Earth). Without Earth-like exercise, astronauts would experience **bone and muscle loss** or atrophy during their stay in space. Bone and muscle atrophy also occurs from normal aging, sedentary lifestyles and illnesses. This may cause serious health issues from injuries due to falls or osteoporosis for both astronauts and people on Earth.



Source: NASA, SpringerLink

Bone and Muscle Loss: How Top Space Food Companies Tackle the Challenge

The Vegetable Production System is a deployable plant growth unit capable of producing salad-type crops in space. This technology will provide future space explorers with a sustainable food supplement during their long-duration missions.

Alter-G uses NASA technology to help astronauts preserve their muscle weight. The company also works on improving astronauts' health in future missions.

Developed by NASA's Center of Excellence for Collaborative Innovation, ISS Fit app is designed for use aboard the International Space Station. It provides astronauts with an option to track their food intake by making audio recordings, shooting videos, taking photos or scanning barcodes.

Being a health technology company, Mission: Space Food brings together a team of Michelin star chefs, aerospace engineers, doctors, astronauts and cognitive nutritionists. They are working together to define the future of space nutrition.

A company that develops space food which can also be used for mass consumption on Earth.

The Space Foods Company Ltd. has the knowledge and ingredients to provide its services to the modern space traveller.

Main obstacles of Space Exploration and Colonisation

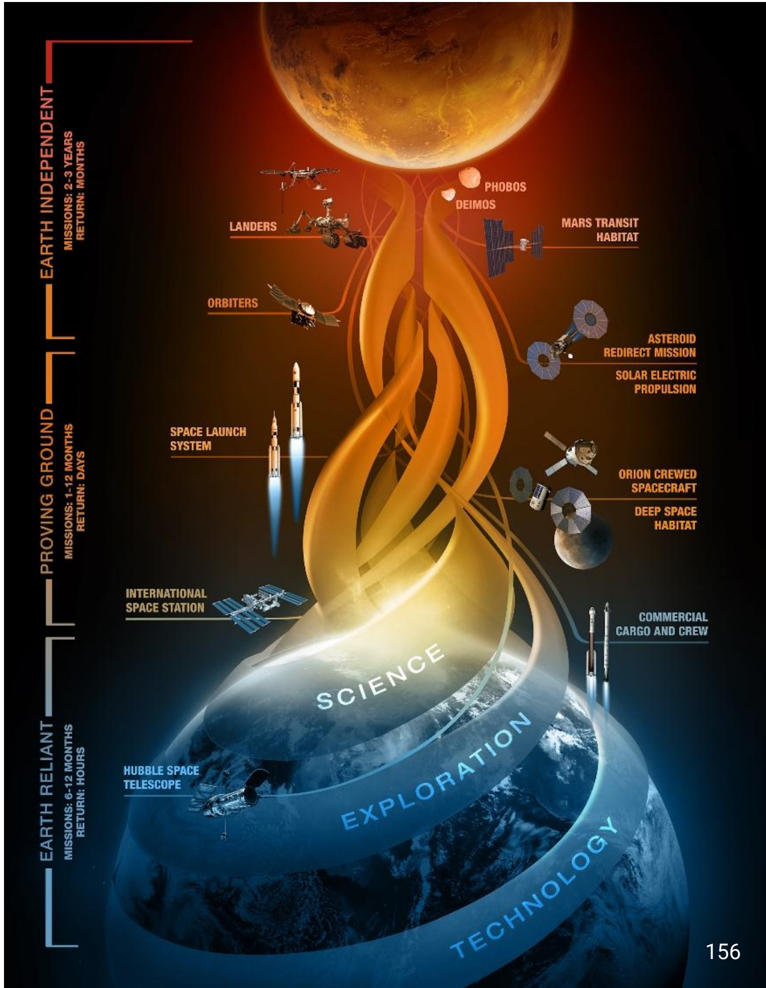
- Slow and expensive spacecrafts
- Mass-inefficient fuels
- Low-speed transmitters
- Calculation-heavy navigation

- Water and air purification,recapturing and generation
- Soil fertilisation for agricultural purposes
- Efficient renewable energy generators
- Resource-efficient architecture of habitats

- Governance of colonies
- Colonisation permit
- Secession and independence
- Population ethics and inequality

- Radiation damage
- Muscle and bone loss
- Harmful long-term flights
- Psychological impact

- Space dust filtering
- Electromagnetic emission shielding
- Compact air-tight habitats
- Biohazard protection



Source: [NASA]

Conclusions

May 2021

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SpaceTech Analytics

Key Takeaways

1. The analysis demonstrated that the richest and most powerful investors of the world expressed their interest in SpaceTech and consider the industry as perspective area of opportunities.
2. The team of analysts identified that there are more than **10 000 SpaceTech** related companies, **5 000 leading investors**, **150 R&D Hubs and Associations and 130 governmental organizations** who operate in the industry.
3. Collaboration between public and private agencies and companies proved its **effectiveness**. A synergy of public and private companies is considered to be the most efficient way to achieve goals and develop technological progress.
4. Manufacture, Satellite communication and Software are the **largest sectors** within SpaceTech.
5. Use of space technologies in medicine, agriculture, navigation and other sectors of global economy allows to increase productivity and become more efficient.
6. The US is a **global leader** in both the private and public SpaceTech.
7. New **space industries** such as, tourism and mining are undoubtedly perspective areas to invest into. The potential size of aforementioned industries is counted in billions of US dollars.
8. **Space industry becomes more profit-oriented**.
9. The **rising role** of private companies.
10. There is a wider access to space and space products for people who are not directly involved in SpaceTech.
11. The rising role of smaller space nations is another positive indicator which reflects the dynamic and promising growth of SpaceTech industry.
12. **Utilization of developments in AI, BioTech, Blockchain technologies** in SpaceTech is significant.
13. There are **11 new governmental agencies** that are expected to emerge in the following years.

Key Financial Takeaways

1. The COVID-19 pandemic had a profound impact on all sectors of the global economy. Some of them, such as **the SpaceTech sector, are currently experiencing rapid growth**. This resulted in multiple medium and large funding rounds for SpaceTech companies in 2020, especially for those of them that focus on space exploration.
2. In 2019-2021, more than 350 **longevity-focused companies closed large-sum late-stage venture capital rounds (B, C, and D)**. Some of them are now working on space exploration technologies. The growing amount of **IPOs** in SpaceTech industry is the evidence of high investors' interest in the sector.
3. 2020 saw **a genuine "SpaceTech IPO boom"**, which was partly caused by the coronavirus pandemic. The latter — directly and indirectly - had a dramatic impact on the SpaceTech industry.
4. The closing of IPOs **will attract a significant number of non-SpaceTech investors looking to enter the sector**. 2020-2020 was marked by **6 IPOs** in the SpaceTech sector.
5. Despite the crisis, publicly traded companies demonstrated rapid growth, having achieved $4,002B of cumulative capitalization or a 100% growth rate.
6. Currently, VC funds categorize SpaceTech companies according to their seed, series A, series B and other parameters. The stage of a company's development will become less important, while **TRL levels and the level of technological development (assessed by other tangible metrics) will be of far greater significance**. They will ensure data-driven analysis and make it possible to perform certain mathematical calculations of the value of a portfolio company.
7. The declining launch cost and advances in technology can potentially make the SpaceTech **$10 trillion industry by 2030**.
8. The rising public sector interest makes the SpaceTech industry extremely perspective sector for investors. The rapid development of **space exploration** technologies attracts millions of investors from the whole World.

9. The effect of massive investment into SpaceTech makes the industry to develop even faster. The growing amount of available funds allows to develop technologies which **reduce the price of reaching outer space**. As the result, it allows to explore outer Space less expensive.
10. While reusable rockets can help to **reduce the cost of launches significantly**, the production of satellites has a potential to grow rapidly, as Space becomes easier and cheaper place to reach and explore.
11. The increasing demand for data, **cloud services** and **navigation technologies** is one of the most important factors that will impact on the further development of the SpaceTech. The technologies of internet of things, autonomous cars, virtual reality, artificial Intelligence, cloud services, high-speed satellite internet and advanced navigation systems are considered to be main drivers of the rise of SpaceTech.
12. The **demand for production and launches of satellites** is expected to grow dynamically in the nearest decade. The development of SpaceTech industry will influence positively on the capitalisation growth of SpaceTech companies.
13. The rapid development of SpaceTech industry will influence positively on the **capitalisation growth** of SpaceTech companies. Strategic plans of public and private companies to explore Moon, Mars and other astronomical objects **increase the demand for services and products** of SpaceTech companies. The ambitious goal to colonize Moon and create there a space station will allow humans to reduce **the price of outer space exploration**, as Moon station can potentially **make launches of spacecrafts more affordable and easier**. The creation of space station on the surface of Moon will allow to make cargo and passenger trips to Mars and other astronomical objects less expensive and much faster.
14. The colonization of Moon and Mars requires large amount of brand new technologies and manufacture capabilities. Consequently, the increasing demand for services and products of SpaceTech companies will influence positively on the growth of the industry's revenue.
15. Investment in the final frontier is **undoubtedly more perspective idea** than it seems to be.

Key Technology Takeaways

1. In 2021 **The James Webb Space Telescope** will be launched from French Guiana. The telescope project is a collaboration between NASA and European Space Agency and is direct successor of **Hubble Space Telescope.** This telescope has a much wider mirror and is capable of receiving clear input of radiation that humanity has never been capable of receiving before.
2. **NASA Artemis program** will land the first woman and the next man to the Moon by 2024 in order to explore the surface and to lay down the cornerstone for the **Moon Station** called **Gateway**. There are already some blueprints of habitats and rovers crucial for the mission.
3. **Ablative arc mining** is the new technology that allows the water, metal and other resources to be pulled out of Moon surface material known as regolith.
4. **SpaceX's Starship** represents a fully reusable super heavy-lift launch vehicle designed to carry both crew and cargo to Earth orbit, the Moon, Mars and beyond. Starship is the world's most potent launch vehicle on Earth, that can carry in excess of 100 metric tonnes to Earth orbit. **NASA** selected a modified crew-rated Starship system as one of three potential lunar landing system design concepts to receive funding for a 10-month-long initial design phase for the Artemis program.
5. In early 2021, **NASA's Perseverance rover landed on Mars**. Equipped with a revolutionary drill capable of collecting samples of Martian rock and soil, the rover can also collect different types of new data about the red planet. The **innovative technologies** developed by NASA proved to be highly effective in helping the rover achieve safe landing.
6. Recent years have seen a veritable boom in **sample-return missions**. In October 2020, NASA's OSIRIS-REx mission to asteroid Bennu retrieved rock samples and successfully brought them back to Earth. On December 7, Hayabusa2, an asteroid sample-return mission operated by the Japanese state space agency JAXA, retrieved rock samples from asteroid Ryugu and delivered them to Earth. China's Chang'e 5 mission successfully retrieved samples of lunar rocks and soil in late 2020.
7. **Asteroid Mining** technologies can help mine platinum from platinum-rich asteroids. One of them that flew past Earth in 2015 is expected to contain $5T worth of platinum.
8. **Artificial Gravity** technology has long been known to humanity. Using them in space stations will help deal with microgravity issues.

Key Business Takeaways

1. **The segment of Space Technology continues consolidation** with the increasing number of developing companies, including those of Propulsion researches, Satellite, Launch vehicles and others.
2. **Reusable Launch vehicle companies compete for reducing the payload launch to orbit cost.** There are a couple of leading companies that run test flights every quarter or more often. That leads to a rapid improvement of the technology and development of a Commercial Space Flight sector.
3. **Small Satellite sector is on the way to becoming the most promising** inside the SpaceTech sphere. The number of planned launches of Nanosats and Microsats steadily increases and the technology available leads to a massive impact on such spheres as Telecommunication, Navigation, Astrophysics and Geology.
4. **Earth Observation sector is "heating up"**, and becomes a lucrative area for specialized SpaceTech investors as well as investor organizations just entering the satellite space with a goal of including high-risk/high-return companies in their investment portfolios. This is backed by several observations, including an overall increasing investment activity in this sector in 2020

Obstacles that Still Remain

1. **Inefficient and expensive propulsion systems** Modern propulsion systems are much more advanced than propulsion systems used in the past. However, they are still too slow and consume too much fuel. The cost of delivering **1 kg** to orbit varies between **2,000 and 20,000 dollars**. This is very expensive, especially when it comes to exploration and colonization
2. **Hazardous space environment** can cause serious damage to the health of astronauts. Attempts are currently being made to solve the problem; however, there is still a lot of ground to cover in this respect.
3. Solving **colonisation problems** means preserving colonists' lives. From air and water purification to building habitats shielded from deadly electromagnetic radiation, everything needs to be taken care of.
4. There are also **Law and Ethical** dilemmas to solve. Because space belongs to all humans, quite a few organisations will want to have a space station or a permanent settlement on the Moon or Mars. They will have to have a government, legal system and a territory. With that said, there is no known way to deal with land tenure rights and competition for resources.

Conclusions and Future Projections

The main trends in the space industry suggest that space exploration is gradually ceasing to be a realm accessible only to a select few. Instead, it is becoming a really diverse system with extensive connections within and without the field.

Some of the major issues in space law include disputes over space resources, rights and duties of private companies and jurisdiction in outer space. A special emphasis should be placed on the hazards related to space debris, as well as the threat posed by comets and asteroids to the Earth and earthlings.

The majority of breakthroughs in space exploration are expected be achieved either by private companies or in collaboration with them. For example, Artemis, the NASA-led program designed to place astronauts on the lunar surface by 2024, relies heavily on the Human Landing System (HLS) developed by Blue Origin, Dynetics, and SpaceX.

2021 is expected to become a year filled with historical milestones for the space industry. Some of the most eagerly anticipated ones include StarLink's launch of a satellite internet constellation and Blue Origin and Virgin Galactic's commercial suborbital flights for private individuals.

DEMOCRATIZATION

Shifting focus toward more feasible and realistic space exploration programs and initiatives.

PRIVATE SECTOR

Private companies will play a more important role in space exploration. That will be primarily connected with the commercialization of space.

SPACE TOURISM

Several space tourism companies are about to start commercial suborbital flights. Space Adventurers and SpaceX also talk about new orbital and beyond orbit space tours.

NANOSATELLITES

The number of nanosatellites in the Earth's orbit will rise dramatically after nanosatellites constellations are launched by Starlink, OneWeb, and other companies.

MOON EXPLORATION

There is growing interest in the colonisation of the Moon. In particular, NASA-led Artemis program plans to put astronauts on the Moon by 2024.

GLOBAL LEADERS

The role played by China, India, Japan, and UAE in global space exploration will grow.

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