VALUEQUEST

JUNE 2026

VQ DEEP DIVE

The New Space Race

From Exploration To Infrastructure

SEBI Registration: INP000003724

By:

Arvind Ananthanarayanan & Aniket Dharamshi

Contents

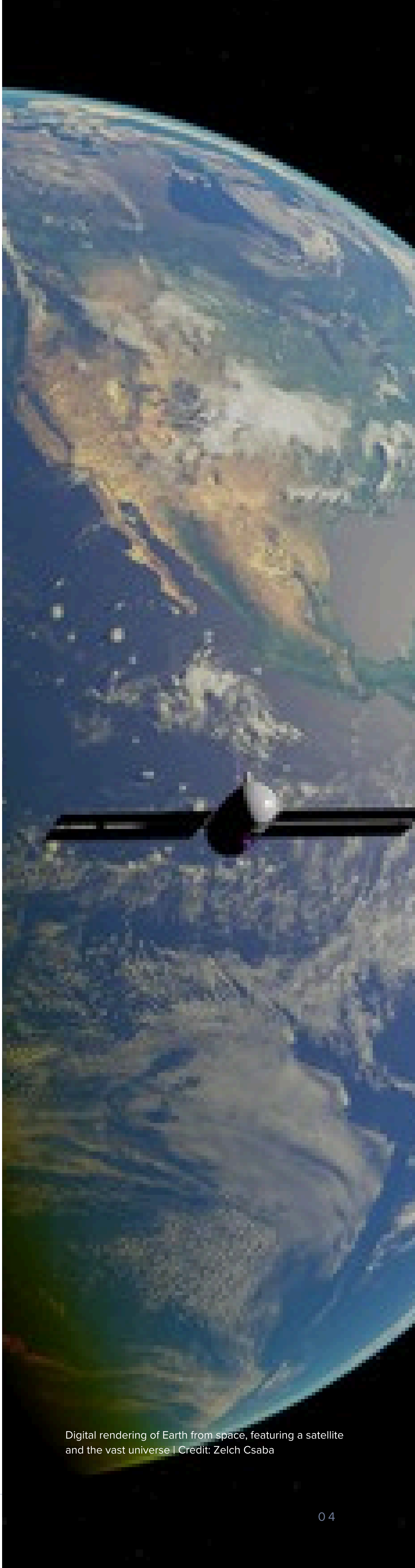
The report traces space's shift from a government-led prestige domain into a commercial infrastructure layer, mapping where investable value is likely to accumulate. It closes by assessing India's cost-efficient engineering edge and what's needed to fully catalyse its space ecosystem.

Executive Summary

Space is undergoing its most fundamental transformation since the Cold War. The $613 billion global space economy is transitioning from a domain of scientific exploration and national prestige into a persistent, commercial infrastructure layer, as essential to the modern economy as undersea cables, cloud datacentres, and financial networks. As the ecosystem develops, value is migrating up the stack with economic rents likely to accumulate in data, intelligence, software and mission-critical systems whether for enterprise or defence/nation sovereignty applications.

This deep dive traces the physics, history, and economics of that transformation, explains why the commercialisation of space is now structurally irreversible, and maps India's emerging role as a cost-efficient engineering hub and strategic node in the new space supply chain.

For investors, the opportunity is not symmetric. Value accrues where data, software, and recurring revenues dominate, not where capital intensity and government procurement define the economics. India's window is real, its structural advantages are durable, but it requires the demand anchor of a large-scale constellation operator to catalyse the full ecosystem.



Digital rendering of Earth from space, featuring a satellite and the vast universe | Credit: Zelch Csaba

Introduction

In recent years, space and the commercial applications of space technology have captured investor interest, with space playing an increasingly important role in defence, communications, geo-location, and other sovereignty missions. Unlike many other sectors where private involvement catalysed strategic interest, such as aviation (refer to the previous deep dive), space has been a domain dominated by geopolitics and strategic interest, often paid for by national balance sheets. The private sector functioned as a systems provider within this ecosystem, with the large infrastructure owned nationally and key pick-and-shovels such as launch vehicle assemblies, rockets, satellites, and key communication infrastructure sourced from the private sector.

This model was invigorated in the US where aeronautics companies in the post-World War II environment also began providing systems for space exploration and exploitation, making the leap to become aerospace companies. From then to the present, where private entities such as SpaceX and Blue Origin are presenting new business models for the commercialisation of space activities, the sector has evolved through the interplay of four overlapping stories, which we will present in this article.

With the global space economy exceeding $600 billion in 2024 and growing at ~7.8% CAGR, to reach a projected $1 trillion by 2032, commercial activities will represent nearly 80% of all activity in this sector. The sector has therefore evolved into a discussion about capital, competition and returns.

Hence, we explore the role of private investments, present unit economics arguments for large-scale space activities such as reusable rockets and satellite constellations, assess the global commercial opportunity in its updated 2025–2026 context, and suggest avenues where Indian investors can benefit from the rise of the Indian space sector, while highlighting areas where deeper investigation is required.

$600bn ➔ $1T

7.8% CAGR to 2032, with commercial activity making up nearly 80% of the space economy

Why Now? The First Steps Toward Infrastructure

Space is undergoing a categorical shift (Exhibit - 1), one that most market participants have yet to fully price. For the first six decades of the space age, it was principally a domain of exploration, national prestige, and strategic deterrence. The assets were expensive, few-of-a-kind and owned by governments or large telecommunications companies with balance sheets to match. However, in the last few years, commercial forces, technology and use cases have converged to create a self-reinforcing flywheel (Exhibit 1).

Indeed, the emergence of SpaceX and Starlink as a vertically integrated model has parallels with the early aviation industry where wall street financiers, formed integrated companies encompassing airframe, engine and airlines in single vertically integrated entities (which were then unravelled post the depression of 1929).

The ability to pack high capability into smaller satellites, reusable first stage boosters (and plans for second stage re-use by Space X with Starship), possibly backed by the promise of use cases underpinning high launch cadence allow the re-alignment of space into a form of persistent infrastructure. The eco-system of asset owners/operators supported by enablers and key participants is taking shape leading to investible opportunities across the value chain and creating a distribution of potential economic return.

It may be noted that the development of a megatrend is not an assurance of shareholder returns. While booming access to space is creating burgeoning demand, this itself does not create investment opportunity. Those are in turn generated by the industry structure allowing economic rents to concentrate and companies developing to capture this value.

Just as aircraft evolved first as reconnaissance machines in the crucible of World War I, satellites performed the same task five decades later as a method to survey the opponent from the highest of the high grounds (space). Then as with aviation, commercial and military applications evolved driven by a confluence of technology and emerging use cases. While airlines have shown massive growth but delivered poor returns to shareholders, several companies supplying to the airlines (aircraft, engines, systems and sub-system manufacturers) have formed a close-knit ecosystem with excellent moats, resistant to disruption for the past six decades and high quality of earnings. In the same light, while the developers of the internet infrastructure have been capital intensive businesses with poor returns, the internet platforms built on this infrastructure have captured substantial value with growing penetration. It is still early to tell where value will be captured in the space theme.

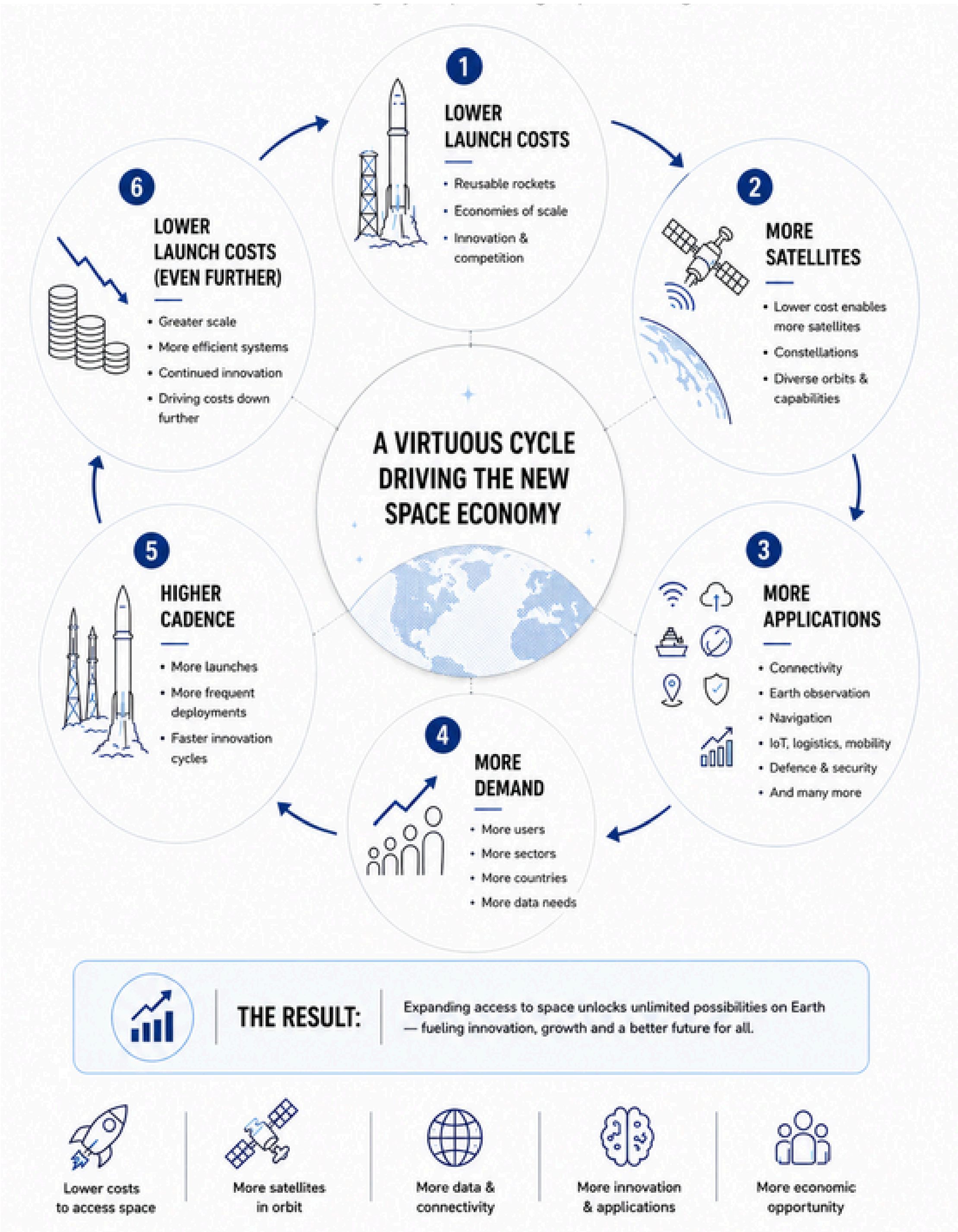
However, it is important to note that the present push to space is anchored equally in national as in corporate balance sheets. The former aim to secure sovereignty by securing the high ground of information with round-the-clock coverage; the latter aim to secure an edge in markets and services: resilient global connectivity, low-latency communications, earth-observation data monetisation, and new revenue streams from launches, in-orbit services, and space-based infrastructure. Together these drivers blur the line between public security and private profit, making space both a strategic common and a commercial battleground.

To understand the origin of this sector and where and how business might evolve, it is useful to revisit the history of space exploration.

> A categorical shift, one that most market participants have yet to fully price.

Why Now? The First Steps Toward Infrastructure - Continued

Exhibit 1: The space economy flywheel, a self-reinforcing cycle of falling launch costs, more satellites, demand and applications.



Source: VQ Research

ACT I

Early Thoughts and Premonitions

A satellite in orbit captured from space | www.pexel.com | SpaceX

Early Thoughts and Premonitions

The theme of Act I is the development of rocketry in warfare, which began with the use of gun powder to propel arrows and ever more elaborate projectiles well into the early twentieth century[1]. By this time the idea of interplanetary travel using rockets had also gained ground, fuelled by science-fiction writers such as Jules Verne and H. G. Wells and by philosophical movements such as “Cosmism” in Russia[2].

In 1903, a high school mathematics teacher and early cosmist, Konstantin Tsiolkovsky published “The Exploration of Cosmic Space by Means of Reaction Devices”, which is widely regarded as the first serious scientific work exploring whether rockets could achieve the speeds required for space travel. The Tsiolkovsky rocket equation, named in his honour, forms a corner stone of rocket propulsion. He advocated for liquid hydrogen and oxygen, arguing this combination would yield the highest exhaust gas velocity and therefore the highest propulsive efficiency. He was also the first to suggest the multi-staging of rockets in his publication "Space Rocket Trains."

1903

Tsiolkovsky publishes the first serious scientific work exploring whether rockets could reach the speeds needed for space travel.

Another pioneer and a founding father of modern rocketry was Robert Goddard. Inspired by H. G. Wells, the young American was a firm believer in solid fuelled rockets and pioneered the use of a combustion chamber and a convergent-divergent (De Laval nozzle) to augment propulsive efficiency, while strongly advocating multi-staging. He also worked on liquid fuelled rockets and in 1920 published “The Exploration of Cosmic Space by Means of Reaction Devices” which also contained remarks about sending a solid fuelled rocket to the moon. The work – now widely regarded as the genesis of practical interplanetary travel – was met in equal measures with praise and misguided criticism[3].

In Germany, the foundations of rocketry were laid by Hermann Julius Oberth who pioneered the concept of interplanetary travel in his book “Die Rakete zu den Planetenräumen ("The Rocket to Interplanetary Space") in 1923. Oberth’s students included various early luminaries in the field such as Max Valier, who would join forces with Max Von Opel to create the world’s first large scale experimental rocket programme, the Opel RAK 1 (Exhibit 2) and Wernher von Braun, a core member of the V2 rocket programme, which was the first artificial object to travel into space.

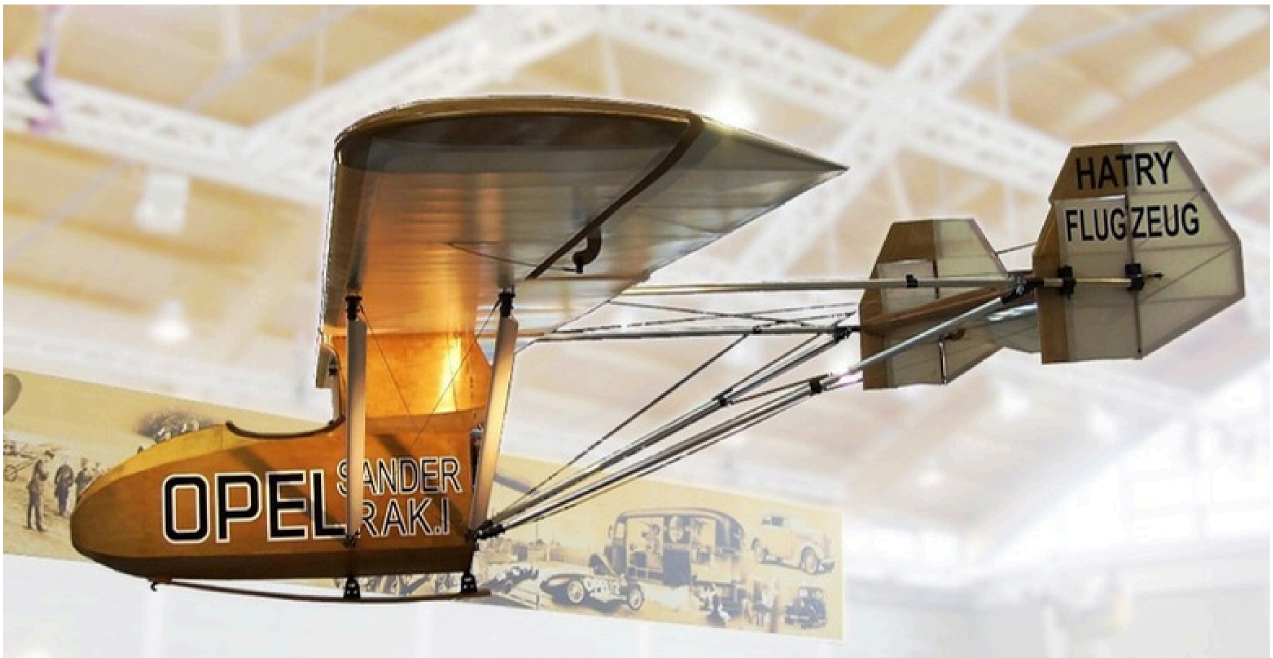
[1]The first rockets were used as propulsion systems for arrows, and may have appeared as early as the 10th century in Song dynasty China. However, more solid documentary evidence does not appear until the 13th century. The technology probably spread across Eurasia in the wake of the Mongol invasions of the mid-13th century. Usage of rockets as weapons before modern rocketry is attested to in China, Korea, India, and Europe. One of the first recorded rocket launchers is the "wasp nest" fire arrow launcher produced by the Ming dynasty in 1380. In Europe, rockets were also used in the same year at the Battle of Chioggia. The Joseon kingdom of Korea used a type of mobile multiple rocket launcher known as the "Munjong Hwacha" by 1451. Iron-cased rockets were used by Kingdom of Mysore (Mysorean rockets) and by Marathas during the mid-18th century and were later modified and used by the British. The later models and improvements were known as the Congreve rocket and used in the Napoleonic Wars.

[2]Russian cosmism, also known as cosmism, is a philosophical and cultural movement that emerged in late 19th- and early 20th-century Russia. It is characterised by the belief in humanity's cosmic destiny, the potential for immortality, and the use of scientific and technological advancements to achieve control over nature and explore space.

[3]A New York Times editorial on the 13th of January 1920 suggested, referring to Newton's third law: “That Professor Goddard, with his 'chair' in Clark College and the countenancing of the Smithsonian Institution, does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react – to say that would be absurd. Of course, he only seems to lack the knowledge ladled out daily in high schools." - **In reality, in terms of Newton's third law, a rocket "pushes against" its exhaust gases, so the lack of surrounding air is not relevant (Emphasis added by authors)**

Early Thoughts and Premonitions - Continued

Exhibit 2: Replica of the Opel RAK.1, the world's first purpose-built rocket plane, at the Technoseum in Mannheim.



ACT I

Four Propositions, 1925

In the second edition of his book, published in 1925, Oberth set out four propositions that remain remarkable in their prescience. Each would be met in the 20th and early 21st century.

PREMISE 1

With the current level of science and technology, the construction of machines that can fly higher than the Earth's atmosphere is likely.

PREMISE 2

With further refinement, these machines can reach such speeds that they do not have to fall back to Earth, and are even able to leave its sphere of attraction.

PREMISE 3

Such machines can be built so that people (probably without health problems) can ride up with them.

PREMISE 4

Under certain economic conditions, the construction of such machines can be worthwhile. Such conditions may arise within a few decades.

FROM PREMISE TO PROOF

1944

PREMISE I

V-2 crosses 100 km altitude - the edge of space

1957

PREMISE II

Sputnik 1 reaches orbit aboard the R-7

1961

PREMISE III

Yuri Gagarin's crewed spaceflight

2024

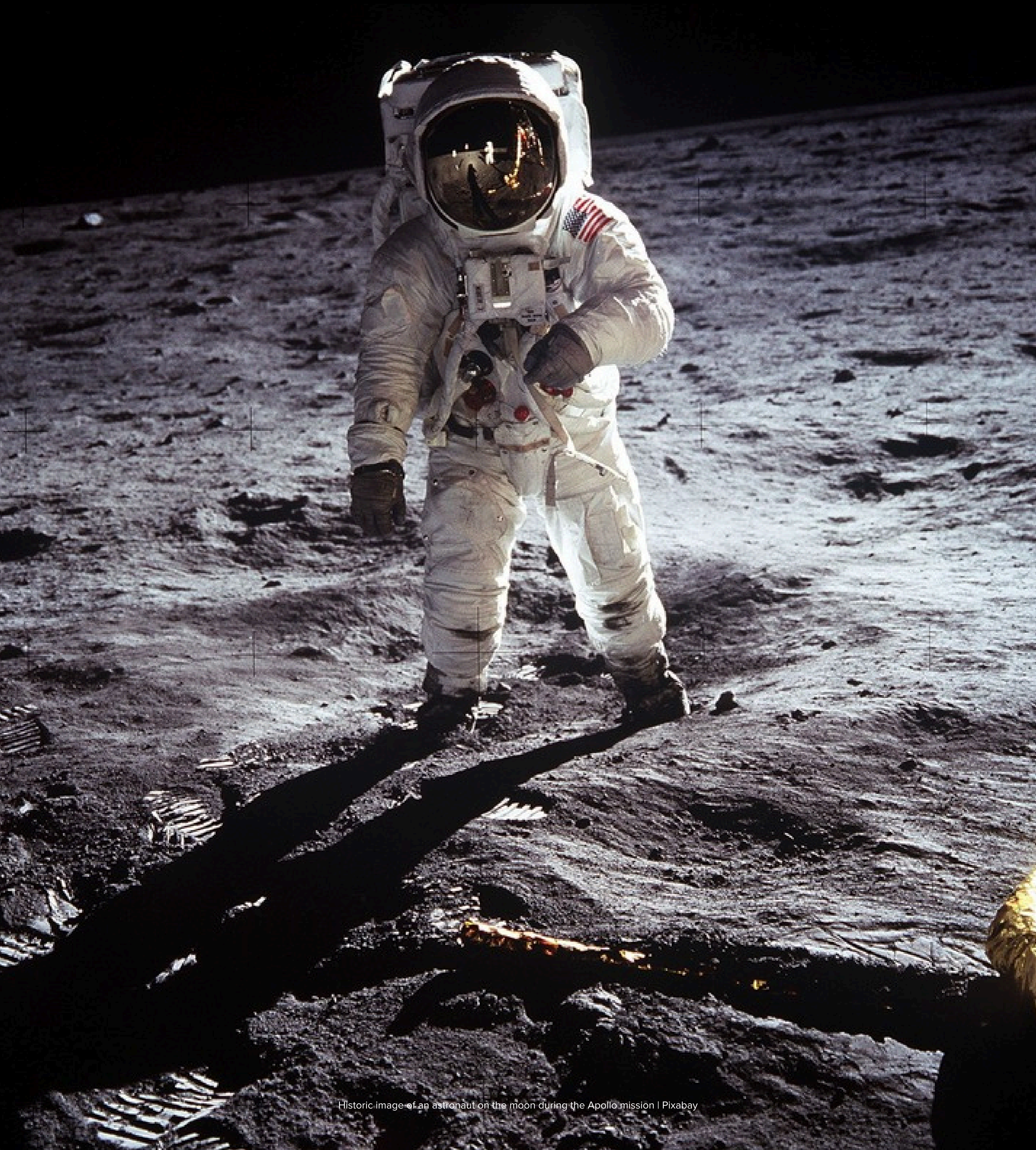
PREMISE IV

$600 bn space economy takes shape

By 1944 the V-2, *Vergeltungswaffe 2* (Vengeance Weapon 2) with the development code Aggregat-4 (A4), had fulfilled the first premise, crossing an altitude of 100 km (the edge of space) and reaching an apogee of 176 km. On 4 October 1957, Sputnik 1 was inserted into an elliptical, low-Earth orbit by an R-7 "Semyorka" rocket, fulfilling the second premise and underscoring the growing interplay between scientific and military access to space. By 1961, with the space flight of Yuri Gagarin, the third premise was met and the conditions for the commercial exploitation of space were set in motion. In 2024, with the space economy worth over $600 billion and an ecosystem of asset owners, operators, enablers and key participants taking shape, Oberth's fourth premise has been increasingly met.

ACT II

The Space Race



Historic image of an astronaut on the moon during the Apollo mission | Pixabay

The Space Race

In the aftermath of the Second World War, the United States, the Soviets and the British scrambled to capture technology and personnel from the German rocket programme. Of these, the US was the most successful, under the auspices of "Operation Paperclip"[4].

Rapidly, the V-2 was repurposed into the Redstone rocket which was originally a medium-range ballistic missile (MRBM). Soviet development began with direct copies of the V-2 but diverged quickly with the pioneering work of Glushko and Isaev producing the R-7. Designed as a carrier for a nuclear payload, the R-7 became the first intercontinental ballistic missile (ICBM). However, it is best remembered as the vehicle that put Sputnik into orbit in 1957 and carried Yuri Gagarin into space in 1961. A testament to its design, a derivative remains in service as the Soyuz-2.

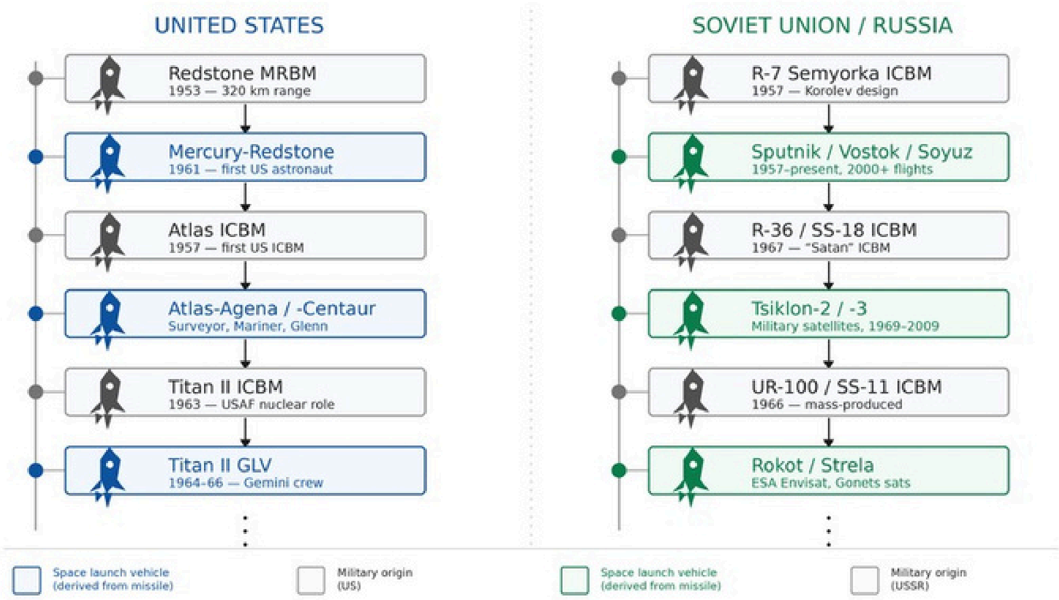
Many US and Soviet systems developed during the competition from the late 1950s to the 1990s were created to demonstrate superior capabilities in space from a strategic perspective of nuclear deterrence and satellite reconnaissance capability. An ICBM is already a precision rocket capable of propelling a nuclear warhead thousands of kilometres; raising it another hundred kilometres and adjusting the trajectory slightly allows orbital insertion. Both superpowers exploited this from the very beginning, and the lineage runs astonishingly deep (Exhibit 3).

China would follow a similar path, repurposing its Dong Feng (DF) family of ballistic missiles into the Long March family of launch vehicles in the late 1980s. India, in contrast, went the other way in the 1990s, using dual-use technology developed for the SLV-3 family of rockets in ballistic missiles such as the Agni.

STRATEGIC OBSERVATION

For most of the space race, national security, prestige, technology nucleation and pure science drove national programmes. Each was bespoke, state-owned, without a pure commercial motive and often one-of-a-kind. Systems and sub-system providers were either government entities or, in the US, private defence companies, working in a margin-accretive environment.

Exhibit 3: Both the US and the Soviet/Russian space efforts were often based on repurposed ballistic missiles. Early space launch vehicles were developed by adapting existing ballistic missile systems, laying the foundation for the modern space age.



[4]Operation Paperclip was a secret United States intelligence program in which more than 1,600 German scientists, engineers, and technicians were taken from former Nazi Germany to the US for government employment after the end of World War II in Europe, between 1945 and 1959.

ACT II

The First Commercial Signals

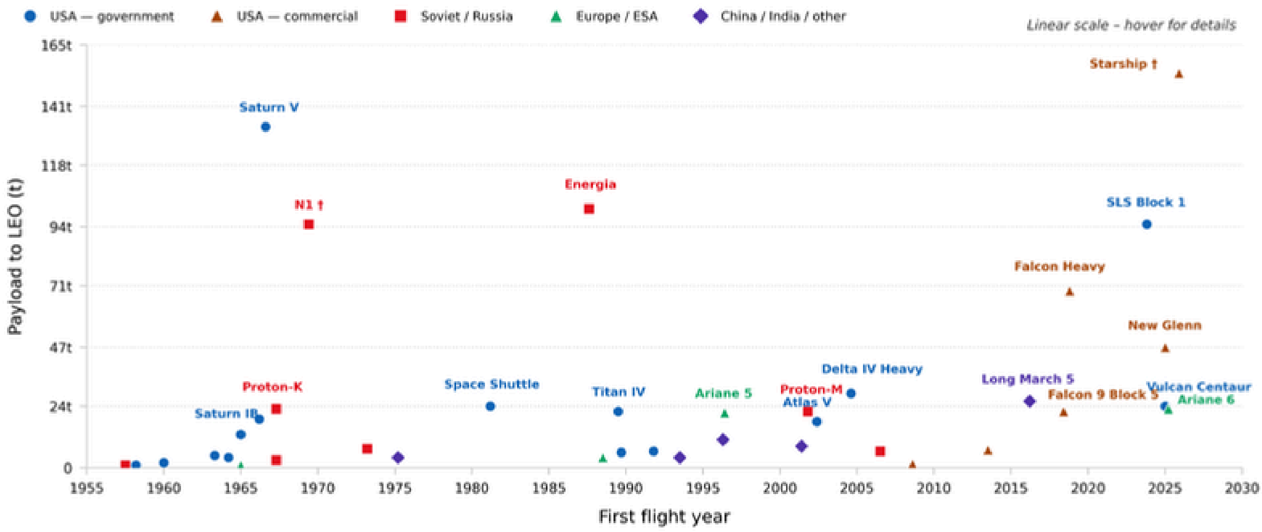
By the early 1960s, space had also become attractive for commercial communications satellites. Telstar, a flagship satellite launched as part of a multinational collaboration between AT&T, Bell Telephone Laboratories, NASA, Britain's GPO and France's Direction générale des Télécommunications, pioneered experimental satellite links across the Atlantic. Bell Labs held a contract with NASA, paying the agency for each launch independent of success: a prototype for a launch contract. Six ground stations were built to communicate with Telstar, one each in the US, France, the UK, Canada, West Germany and Italy and this satellite could broadcast a single television channel or multiplexed telephone circuits. By 1972, the first Landsat was launched in a programme that has provided the longest running satellite imagery of the Earth for application in agriculture, cartography, geology etc. as part of the US Geological Survey (USGS).

Bigger launch vehicles and heavier satellites

During the early, Cold-War-fuelled space race, launch vehicles developed ostensibly as nuclear-delivery systems grew ever more powerful. The development of multiple warheads (MIRV: Multiple Independently Targeted Re-entry Vehicle) based deterrence and the bulk of early nuclear weapons caused a rapid increase in the throw weight of rockets as shown in Exhibit4. In 1957, the R7, which carried Sputnik could place 500 kg in a low earth orbit (LEO). However, by the mid-1960s, both Soviet and US rockets could place ~ 20 metric tonne into LEO.

The Saturn V and the N1 were US and Soviet contenders for reaching the moon and were consequently more powerful. They were also substantially more massive. However, after the initial increase in payload, it is only in the late 2010s that an increase is again visible. Once again, SLS – 1 is a part of a manned moon flight mission and therefore is an anomaly. Therefore, putting more mass into orbit needs a more massive launch vehicle which cost more. (Exhibit 5) shows the evolution of gross lift off mass over the same period.

Exhibit 4: Launch vehicle throw weight expanded rapidly in the 1960s but has remained constant since then with few exceptions.

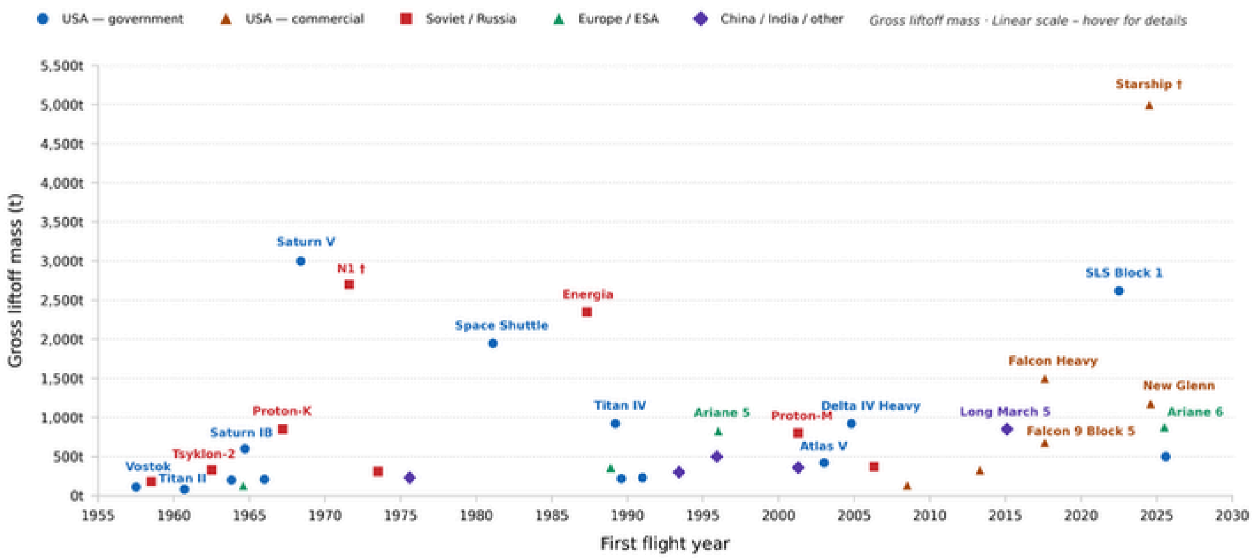


Notes: Labels shown only for vehicles above 18t. † N1 never achieved orbit. Starship figure is SpaceX's stated reusable target.
Source: VQ Research

The Tyranny of Mass

Exhibit 5 shows starkly payload to LEO has increased primarily by increasing the gross lift off mass of the launch vehicles. The following points emerge.

Exhibit 5: Gross lift off mass of various launch vehicles over the years



Notes: Labels shown for vehicles above 550t. † N1 never achieved orbit. Starship gross mass is approximate; varies by configuration. All masses are fully-fuelled liftoff mass.
Source: VQ Research

By using large quantities of methane as a propellant, the SpaceX's Starship loses out on lean mass fraction as evident in the payload fraction chart presented in (Exhibit 6)

Human rated systems (Space Shuttle, SLS, Saturn V) carry a large mass penalty for life-support and re-entry systems which then drive-up cost and complexity.

Payload Fraction and the Case for Reuse

Exhibit 6 brings into sharp relief that the larger the payload, the larger the launch vehicle needed. Once launch vehicle technology reached maturity in the 1960s, payload fraction to LEO plateaued between 1% and 6%, depending on design optimisation[5].

It is also important to note that the payload fraction of a Falcon 9, Block 5 operating in expendable configuration is 4.1% versus 2.5% in reusable configuration due to reserve propellant needed for booster recovery. Seen in this light, the ~3% mass fraction of Starship suggests an asymmetric reliance on reusability for economics, else the 5000-tonne rocket will be uncompetitive in terms of structural costs.

Exhibit 6: Mass fraction to LEO for various launch vehicles

Notes: Indian vehicles (PSLV, GSLV Mk III) and European vehicles (Ariane 4, 5, 6) now labelled.
Points at the 7% ceiling show true fraction in brackets.
Source: VQ Research

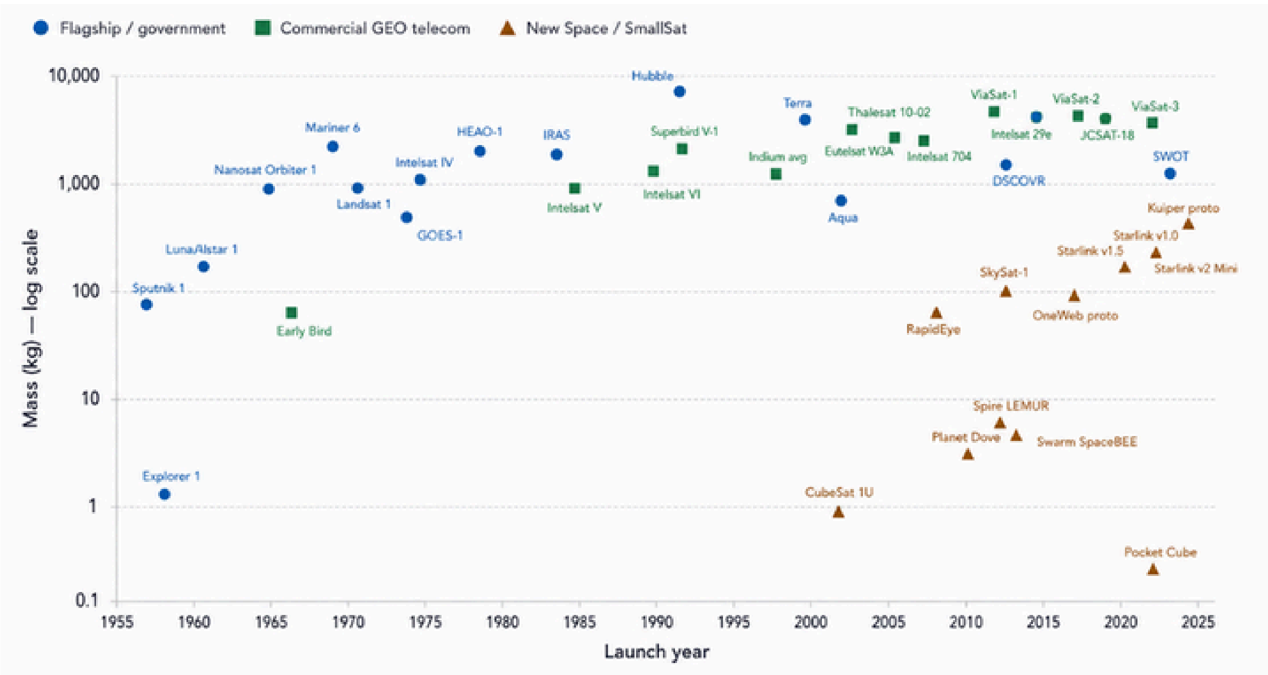
[5] Mass fraction is a useful but incomplete metric. The more important questions are cost per kilogram, reliability, and availability — and on those dimensions, dedicated launchers like Ariane 5 built a strong commercial case for two decades despite their modest mass fractions, because they offered predictable pricing, neutral geopolitics (no US ITAR restrictions on payloads, no dependence on Russian launch sites), and dual-manifest capability that let two GEO satellites share a single launch. PSLV similarly built its reputation on near-perfect reliability and low cost, not raw efficiency numbers. ICBMs were optimised for one thing above all else: throwing a given mass as far and as fast as possible with the minimum vehicle mass. The repurposed ICBM advantage was real in the 1960s but has largely dissolved.

The Plateauing of Satellite Mass

As launch vehicles became more massive, they carried larger payloads and satellites consequently grew larger (Exhibit 7). From the 1950s to the 1970s, electronics meant vacuum tubes and discrete transistors; power systems were heavy and structures over-engineered because failure modes were poorly understood. Mass became a by-word for capability and the higher liftoff mass was used to win capability through size and complexity. By the 1980s, commercial geostationary satellites converged on a characteristic mass band of 3,000–6,500 kg, driven by a simple commercial logic: a larger satellite carries more transponders, hence more revenue per launch.

The cost of a launch was largely fixed regardless of payload mass up to the vehicle's limit, so operators kept growing their spacecraft until they bumped against structural or thermal limits. This produced the "GEO bus" form factor — a standardised platform (Boeing 601, SSL 1300, Airbus Eurostar) that could be ordered like a product and scaled. ViaSat-2 (6,440 kg) and ViaSat-3 (7,000 kg) mark the practical ceiling of this philosophy on a conventional launch vehicle.

Exhibit 7: Satellite mass over time plotted on a log-scale to show that the mass ranges across five orders of magnitude.



Notes: Indian vehicles (PSLV, GSLV Mk III) and European vehicles (Ariane 4, 5, 6) now labelled.
Source: VQ Research

The Plateauing of Satellite Mass

ACT II — RECAP

- Launch-vehicle technology developed rapidly in the 1950s; throw-weights reached the limits of chemical propulsion.
- Mass was a measure of capability. Early electronics were bulky and satellite masses grew in concert with available launch weight.
- By the 1970s, satellites reached the the structural and thermal limits of launch vehicles; further capability came from developments in electronics and miniaturisation (increasing number of sensors/transponders per satellite).
- For most military, government, scientific or commercial missions, cost of launch was small relative to the payload, and each payload was one-of-a-kind or few-of-a-kind.
- Large balance sheets such as nations, militaries or large telecom companies owned space assets.
- Suppliers of systems, and launch services prioritised reliability and tailored flexibility in a high margin environment.
- No significant opportunity for learning rates

500kg ➔ 20t

Growth in LEO payload capability from Sputnik's 1957 launch to the mid-1960s, as throw-weight became the sector's main measure of capability.

1–5%

Payload fraction ceiling chemical rockets plateaued at, with no significant opportunity for learning rates despite the mass increase.

Where Aircraft and Rockets Differ and why the rocket equation is implacable

To fully appreciate why the privatisation of space follows a different trajectory to aviation, where larger aircraft capable of carrying more people rapidly drove down costs, we must examine the fundamentals of efficiency in aircraft and rockets. While this digression might appear technical, it is important to the development of ride shares and reusable boosters which makes the modern space sector more attractive, in addition to expanding use cases. While both aircraft and rockets are reaction propelled (they move forward by exhausting hot gases rearward), aircraft fly in the atmosphere and generate lift using their wings, carrying only fuel and use oxygen from the air for combustion. While the derivation is beyond the scope of this article, the efficiency of a commercial jet aircraft is expressed by the Breguet range equation (Equation 1).

The aircraft — Breguet range

EQUATION 1

$$Range\,(R) = V.\,(\frac{L}{D}).\,\frac{1}{SFC}.\,ln(\frac{W_i}{W_f})$$

V - Velocity of flight
$\frac{L}{D}$ - Lift to drag ratio: Dependent on aircraft and wing design
SFC - Specific fuel consumption or mass of fuel consumed per unit thrust
W_i - Initial weight
W_f - Final weight

(Equation 1) then influences cost per available seat kilometre (CASK) as follows:

EQUATION 2

$$CASK = \frac{Fuel\ cost + Other\ cost}{R \times Number\ of\ seats}$$

Since there are many variables to maximise range, including improved engines to reduce specific fuel consumption (high bypass turbofans); or aerodynamic optimisations to enable high lift to drag ratio at a given cruising speed, aircraft with more seats are generally more efficient in reducing cost (assuming that the seats are filled). Due to this, CASK has reduced substantially driven by an increase in Breguet range, making air travel commercially viable and accessible. Finally, aircraft can and do operate with lower than maximum fuel on many profiles to reduce weight, which is not possible for a rocket.

Unlike aircraft, rockets carry their own fuel and oxidiser and rely purely on thrust to fly and insert their payload into a particular orbit, necessitating that some velocity be imparted to the payload to allow it to stay in that orbit. The change in velocity, delta v is expressed as follows:

The rocket - Tsiolkovsky Equation

EQUATION 3

$$\triangle v = v_e ln\left(\frac{m_0}{m_f}\right)$$

$\triangle v$ - Total change in velocity, typically 28,000 kph for LEO
v_e - Effective exhaust gas velocity of the rocket
m_0 - Total initial mass of the mission including structure, fuel and payload
m_f - Final mass inserted into orbit

In (equation 3), total change in velocity is constrained by orbital physics and engineers optimised engine design to maximise the exhaust gas velocity v_e. As a result, the payload fraction grew rapidly in the late 1950s and early 1960s as seen in (Exhibit 6). However, with fewer avenues to optimise, space launches soon came to reflect the tyranny of the Tsiolkovsky equation. Payload fractions plateaued in the 1 – 5% range as rockets had to carry oxidiser and fuel to lift more fuel. Unlike aircraft where the Breguet equation offered paths to operating leverage and commercial viability, the Tsiolkovsky equation suggested that the only path to increasing payload fraction is an increase in exhaust velocity, which in turn would lead to an exponentially increasing mass of fuel.

THE FUNDAMENTAL INSIGHT

Building bigger rockets to lift bigger payloads is not a path to operating leverage — and space remained a niche for governments and large telecom operators willing to pay for capability, ensuring suppliers were rewarded with high margins commensurate with the technical risk and first-of-a-kind nature of each mission. The only possibility for a breakthrough is then through a high launch cadence made possible by constellation economics of small, mass-produced satellites which then become enablers for global infrastructure. In such a scenario, the economic benefits of reusability also become relevant.

ACT III

The First Wave of Commercialisation

Artisitc representation of a GPS constellation | www.gettyimages.in

Electronics, Miniaturisation and Commercial Uses

Even as the use of satellites for government/military purposes dominated the headlines, the wave of miniaturisation and solid-state electronics was leading to a rapid increase in the capabilities of satellites which were otherwise constrained in mass by the Tsiolkovsky equation. By the 1970s, satellite use for weather mapping, land use and meteorology were well developed. By the 1980s, telecommunication satellite signals were being received in most households via satellite dish antennae. However, the single most important area of civilian use was the Global Positioning System (GPS) which has since expanded into the Global Navigation Satellite System (GNSS) which encompasses not only the US GPS constellation but also Russia's GLONASS, the EU's Galileo, China's BeiDou, India's IRNSS, and Japan's QZSS. Therefore, it is only fair to regard the development and adoption of GPS as the rise of the second space age in the 1990s. (Exhibit 8) shows the various global and regional navigation systems used currently.

All GNSS systems owe their origin to efforts by US scientist at the Applied Physics Laboratory (APL) affiliated to the John Hopkins University to track the soviet satellite Sputnik. They observed that the frequency of radio signals transmitted by Sputnik increased as the satellite approached, and the signal frequency decreased as it moved away, the Doppler shift[6].

Utilising the Sputnik's Doppler Effect allowed the scientists to use radio signals to track the movement of the satellite from the ground. They later expanded the idea: If a satellite location could be determined from the ground via the frequency shift of its radio signal, then the location of a receiver on the ground could be determined by its distance from a satellite. In 1958, the Advanced Research Projects Agency (ARPA) used this principle to develop Transit, the world's first global satellite navigation system.

The first satellite for Transit launched in 1960 and the concept, developed by John Hopkins University APL, could provide navigation to military and commercial users, including the Navy's missile submarines. The program was transitioned to the Navy in the mid-1960s and by 1968 a constellation of 36 satellites was fully operational. Transit would remain in service till 1996 when it was replaced with GPS. During this time, improvements in bandwidth utilisation and the decision to move the timing clock into the satellite allowed ground receivers to become more compact.

In 1983, Ronald Reagan authorised the use of Navstar (or GPS as it became known) by civilian commercial airlines to improve navigation and safety for air travel[7]. The authorisation to provide free access to GPS data to industries outside the U.S. military became the first step towards authorised civilian usage. By 1989, commercially available hand-held GPS units hit the market, including the Magellan Corporation's Magellan NAV 1000, which weighed 1.5 pounds, offered only a few hours of battery life, and cost $3,000.

By the 1990s, the US ended the "selective availability" which limited the accuracy of civilian GPS and the market exploded. The price of GPS receivers dropped from over $3000 to less than $15 allowing the use of GPS for in-car navigation, location-based services, personal technology and usage in shipping, sailing and other industries. Reports estimate that since the 1980s, GPS satellites have helped generate nearly $1.4 trillion in economic benefits. PNT timing is crucial for running our data networks and financial systems. We use it for the scientific study of earthquakes, volcanos, and the movement of the tectonic plates. Space-based navigation is used to aid construction and optimise farming, including the application of water and pesticides. A 2019 study estimated that between 2007 and 2017, GPS-enabled location-based services such as guidance apps helped American consumers save 52 billion gallons of fuel and drive over one trillion fewer vehicle-miles.

[6] This is like the pitch of a train's horn apparently increase as it enters the station you are standing at and then reduces as it pulls away.
[7] While it is commonly reported that the accidental shoot down of Korean Airlines 007 after it violated Soviet Kamchatka airspace motivated this decision, the original Navstar (later GPS) global positioning plan of 1974 already had civilian applications planned.

ACT III

From Sputnik's Echo to a Trillion-Dollar Utility – Continued

The commercialisation of GNSS created several private companies and represents Act 3's key transition: a predominantly government-driven system gave way to vibrant private players across systems integration, mapping, timing, and location-based services. More than the vibrant private sector created, it is important to note that these companies were generally providers of key services or systems, while the assets (GPS, GLONASS, etc.) remained government owned. However, the large civilian market allowed the stratification of space into launch facilities, ground stations, satellite buses, and services/data management, differentiated infrastructure instrumental in enabling the final act. The civilian market allows the stratification of space into the following areas:

1 Launch facilities

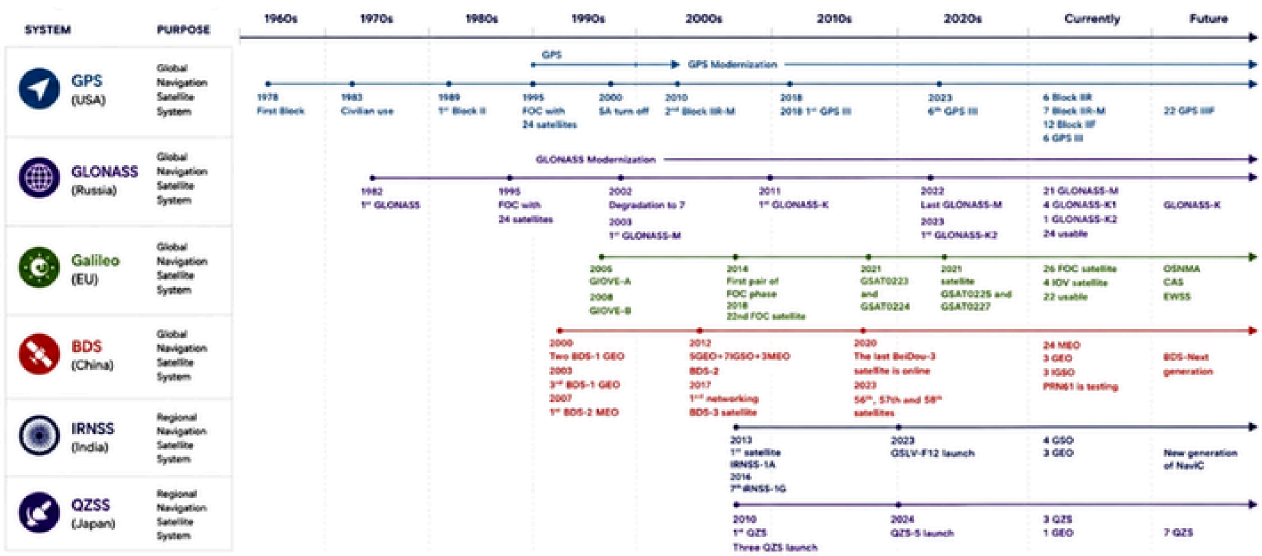
2 Ground stations

3 Satellite buses and common systems

4 Services and data management

This differentiated infrastructure is instrumental in the final act of the space sector, a rise in both civilian and military uses driven by constellations of small satellites in low earth orbit allowing near real time communication, positioning, surveillance and reconnaissance in GNSS denied environments, expanding the knowledge gained from about a hundred GNSS satellites to potentially several thousand small satellites, owned and operated privately.

Exhibit 8: An overview of the various global and regional navigation satellite systems.



Note: FOC - Full Operational Capability; SA - Selective Availability; IIR - Block IIR; IIF - Block IIF; IIIF - GPS IIIF; GEO - Geostationary Earth Orbit; MEO - Medium Earth Orbit; IGSO - Inclined Geosynchronous Orbit; GSO - Geosynchronous Orbit Source: VQ Analysis, Zhang et al. Satellite Navigation, 2025, 6:17

ACT IV

CubeSats, Constellations, Dual Use and Reusable Launchers

New Glenn on the launch pad at LC-36 ahead of the NG-3 mission. (April 12, 2026) | Blue Origin

ACT IV

The Small, Modular Satellite

The pivotal moment which allowed a confluence of off the shelf components, shared launch cost and a true opening of scale leading to the new age space bifurcation was the definition of the CubeSat specification at CalPoly and Stanford in 1999 and first launched in 2003. This specified a 10 x 10 x 10 cm^3 1.33 kg unit (1U) as a standardised unit form factor. By standardising the form factor, it allowed universities to build satellites using commercial-off-the-shelf components and share launch costs as secondary payloads. The consequences cascaded: component suppliers scaled up, costs fell, lead times shrank, and suddenly a university or startup could put hardware in orbit for tens of thousands rather than tens of millions of dollars.

The modularisation of the satellite bus has created two diverging streams since 2013. At the small end, constellation operators like Planet Labs (Dove CubeSats at 4 kg), Spire Global (LEMUR at 4-5 kg), and Swarm Technologies (SpaceBEE at 0.3 kg) operate hundreds of identical, cheap, rapidly replaceable satellites.

> The business model depends on volume and cadence, not individual capability.

At the medium end, Starlink and OneWeb have converged on a "flat-panel" form factor of 250–800 kg — heavier than traditional SmallSats but far lighter than GEO buses, optimised for mass production and ridesharing on large rockets. A single Falcon 9 can carry 60 Starlink v1.0 satellites; a Falcon Heavy can carry even more of the newer, heavier v2 Mini variants.

The five orders of magnitude mass range of today's operational fleet, from sub-kilogram Pocket Cubes to multi-tonne GEO platforms, is historically unprecedented and reflects the fact that "a satellite" is no longer a single engineering archetype but a spectrum of very different objects, built for very different economics, coexisting in the same orbital environment.

THE MILITARISED FRONTIER

Capability, Competition and Consequence

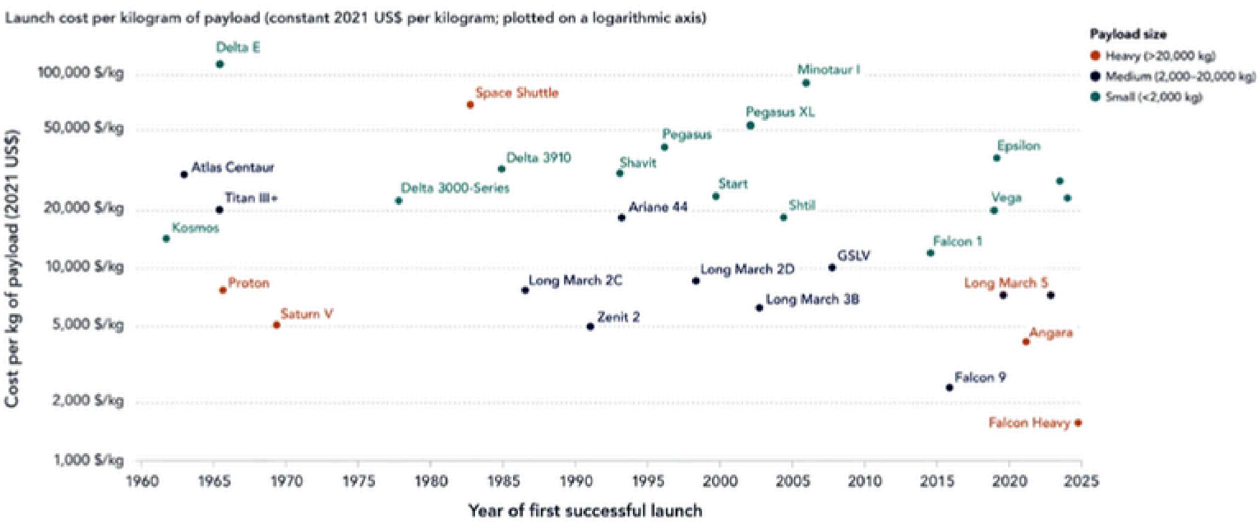
AI generated image of space debris

A New Space Race: Capability and Dual Use

Reflecting on (Exhibit 5), as miniaturisation takes place and the cost of each small satellite becomes progressively smaller, LEO activity becomes dominated by launch cost, which then places a requirement for spreading booster cost over many missions assuming high launch cadence can be maintained. Indeed, the ability to place hundreds of satellites in orbit and keep replenishing small satellite constellations is what drives down launch cost and gives an impetus to reusable launchers (Exhibit 9).

Of course, LEO is not new. Military satellites have been in low Earth orbit since the very beginning, the first US reconnaissance satellite (Corona) flew in 1960, the same year Sputnik was three years old. Today, rough estimates suggest around 60–70% of all operational satellites serve defence or dual-use purposes when you include intelligence, surveillance, reconnaissance (ISR), communications, navigation, and early warning functions. The US Space Force alone operates or contracts for several hundred satellites; Russia and China each field substantial constellations, and middle powers including France, Japan, India, Israel, and the UAE have dedicated military space programmes.

Exhibit 9: Cost curves are bending down especially for heavy launch vehicles and reusability can be a gamechanger at high cadence and low failure rates.



Note: Costs are inflation-adjusted to 2021 US dollars using the US CPI. Reusable launch vehicles shown reflect marginal cost estimates.
Source: VQ Research

Where Low-Earth Orbit is Attractive

The LEO environment is attractive for military purposes through proximity, closer orbits mean finer resolution and lower latency. This makes it the natural domain for four mission classes.

Reconnaissance & ISR

Corona's film-return satellites gave way to electro-optical and radar imagers resolving objects tens of centimetres across. Planet, Maxar and BlackSky have privatised much of this; Ukraine has used their imagery extensively since 2022, and any planner must now assume adversaries hold near-real-time commercial imagery.

Communications

LEO offers far lower latency than GEO (~20–40 ms vs ~600 ms) and resilience through redundancy. Starlink's role in Ukraine since 2022 is the most visible demonstration of LEO comms in active conflict; the US military now contracts Starlink capacity directly.

Missile Warning & Tracking

Next-Gen OPIR and its LEO component, HBTSS, aim to track hypersonic glide vehicles that evade ground-based radar for much of their flight — driving a new class of LEO tracking satellites.

Navigation

GPS sits in medium-Earth orbit, not LEO — but LEO augmentation layers are now being developed to improve accuracy and resilience.

$10–15k → **$2–3k**

DELTA II, EARLY 2000S → FALCON 9, TODAY

Cost per kilogram to LEO has fallen roughly an order of magnitude in fifteen years — driven almost entirely by Falcon 9 reusability and constellation economics spreading fixed costs across thousands of launches.

The driver for increased military activity in LEO is mainly the cost versus capability trade-off. The cost to orbit has dropped roughly an order of magnitude over the past 15 years, driven almost entirely by Falcon 9 reusability and the secondary effects of constellation economics spreading fixed costs across thousands of launches. A kilogram to LEO that cost $10,000–$15,000 on a Delta II in the early 2000s costs $2,000–$3,000 on a Falcon 9 today.

The Commercial Frontier: Starlink's Ascent

The reduced launch cost and the increased cadence enabled by entities such as Starlink to allow increased capabilities. Latency has fallen from 44ms (2022) to ~24ms today; speeds have risen from 23 Mbps to 170+ Mbps. V3 satellites launching in 2026 via Starship (if the vehicle is adequately matured; which is why the future of SpaceX and Starlink is inextricably linked to this vehicle) offer 10x current downlink capacity, targeting ~1 Tbps per satellite. This creates a tiered use case progression:

CAPTURED	Rural broadband · maritime (10,000+ vessels) · disaster and backup connectivity
MATURING	Aviation (100+ Mbps at altitude, multiple airline deals signed) · direct-to-cell (650+ D2C satellites launched; texts operational, voice and data in progress)
EMERGING	Clinical-grade telemedicine · industrial IoT control in remote extractive operations · edge AI inference · NTN participation in 6G architecture

> **THE STRUCTURAL UNLOCK**
>
> The non-linear jump to 1 Gbps+ does not merely serve more users, it structurally unlocks enterprise categories that previously required terrestrial infrastructure. SpaceX's internal launch cost is ~$15–28M per Falcon 9 mission against a ~$67M market price; Starlink benefits from below-market launch pricing with no regulatory obligation to disclose the internal allocation.

The Challengers: Kuiper and China

As asset owners scale and capabilities mature, Starlink will face competition, but on two very different axes. One challenger fights on the cloud ecosystem; the other on sovereign strategy.

Amazon — Project Kuiper

UNITED STATES

The play

Make satellite connectivity a native AWS feature — bundling SLAs, AI analytics and cloud lock-in. This shifts the battle from connectivity price to ecosystem lock-in.

Traction

Has won government BEAD contracts on price and secured Delta, JetBlue, AT&T and Vodafone.

Weakness

No proprietary launch until Blue Origin's New Glenn scales (2027+, possibly later), limiting deployment speed and embedding a cost disadvantage versus Starlink.

China — Guowang & Qianfan

SOVEREIGN

Commercial

Lags the US private sector — ~300 satellites in orbit versus 10,000+, with higher failure rates and slower cadence.

Strategic

Guowang carries broadband, SAR, optical sensors and laser comms on one bus — a sensor-fused architecture with no Western equivalent, aimed (with the Digital Silk Road) at influence in the Global South.

Cadence

ITU deadlines (10% of planned satellites by 2026) accelerate launches; projected cadence reaches 1,800+ satellites per year by 2030.

WHY STARLINK'S ECONOMICS ARE HARD TO MATCH

Cost per bit is structurally lower than any competitor procuring launches at market rates. And low-orbit deployment, which improves latency but demands faster replenishment, is only economically rational if you own your launch stack. Starlink operates at these altitudes precisely because it does.

Where Military and Commercial Become Inseparable

Perhaps the most consequential development is that military and commercial capabilities in LEO are now almost inseparable. Starlink is a commercial network that has shown decisive military utility; Planet's imaging constellation, built for commercial customers, is now routinely used for arms monitoring, sanctions verification and battlefield intelligence. This creates three problems.

For deterrence	Striking Starlink infrastructure means striking an American commercial company with civilian customers in 100 countries, not merely a military asset. Targeting decisions become fraught.
For arms control	It is nearly impossible to negotiate meaningful limits on military space capability when the very same satellites serve both purposes.
For market structure	Defence agencies increasingly depend on commercial providers they do not control and those providers have shown willingness to make unilateral service decisions (Musk reportedly restricted Starlink coverage near Crimea in 2022 to prevent a Ukrainian drone attack on Russian vessels).

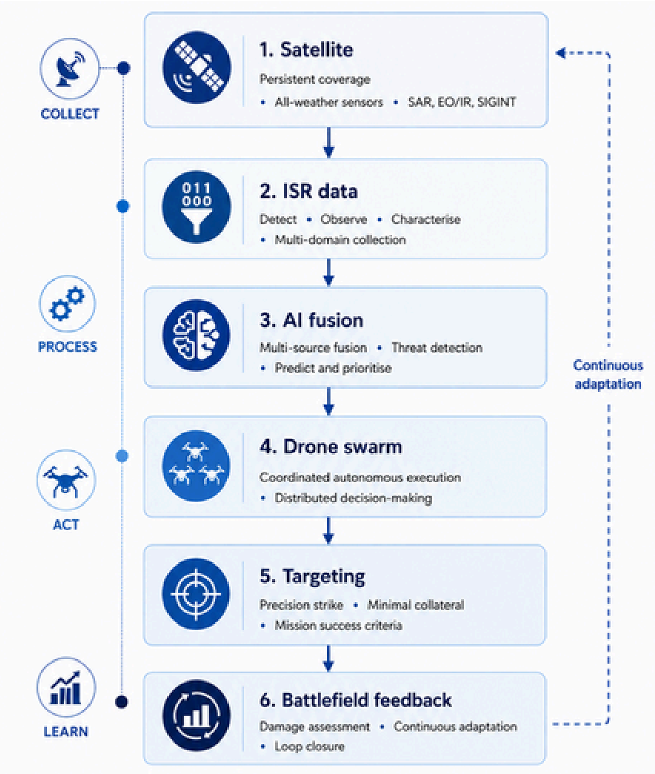
The dependency runs both ways: military contracts provide a significant revenue base for commercial operators, while commercial scale drives down the per-unit cost of capabilities that militaries then enjoy. It is a tighter civil–military entanglement than any before it, and its full strategic implications are still being worked out.

The new space race, therefore, is not only about rockets and satellites. It is increasingly about machine vision, autonomous targeting, predictive intelligence, geospatial AI, automated change detection and drone-warfare coordination, the "proliferated LEO" strategy of replacing a few expensive, one-of-a-kind satellites with many cheaper ones. The US Space Development Agency's Proliferated Warfighter Space Architecture is its clearest expression.

The OODA Loop and the Cost-Exchange

A typical satellite-enabled military AI stack (Exhibit 10) maps onto the classic Observe → Orient → Decide → Act loop: satellites and distributed sensors provide high-quality, round-the-clock observation while AI compresses the Orient and Decide phases to milliseconds. Legacy space surveillance offered persistence at a high price.

Exhibit 10: A typical space based OODA loop in defence applications.



Note: ISR - Intelligence, Surveillance & Reconnaissance
SAR - Synthetic Aperture Radar; EO/IR - Electro-Optical / Infrared
SIGINT - Signals Intelligence; AI - Artificial Intelligence
Source: VQ Analysis

The arithmetic reverses

The reduced cost of persistence changes the cost-exchange ratio between attacking and defending a space asset. Under the old paradigm, a single reconnaissance satellite might cost $1–3 billion to design, build, launch and operate; a direct-ascent ASAT interceptor perhaps $50–100 million. The attacker held a massive economic advantage.

When satellites cost $0.5–5 million and fly in constellations of hundreds or thousands, the arithmetic reverses. Destroying ten satellites in a constellation of five hundred achieves little militarily, while the attacker has expended ten interceptors. The defender wins the cost-exchange.

The critical investment implication is that value is migrating up the stack. Raw imagery is commoditising — Planet Labs and dozens of competitors have driven down the cost of earth observation dramatically. Insights are monetising, companies that can process multi-source data streams in real time, detect change automatically, and surface actionable intelligence are at the frontier of the highest-value layer of the space economy.

THE IMPLICATION

Therefore, space is moving from transportation to intelligence. The satellite itself is becoming a sensor node. The data layer above it is where economic power concentrates. Invest where the data, software, and mission-critical enablers create durable economic moats.

Unusable Orbits, and the Global Value Chain

As satellites crowd into LEO, orbital debris and collision risk move to centre stage. China's 2007 ASAT test against its own Fengyun-1C at 865 km created over 3,500 trackable fragments, most still in orbit; Russia's 2021 test against Cosmos 1408 added 1,500+. Kinetic ASAT weapons are self-defeating at scale — the debris they generate threatens the attacker's own constellation as much as the adversary's, an orbital re-run of mutually assured destruction (MAD).

This has pushed military space competition increasingly toward non-kinetic means, electronic warfare (jamming GPS and communications signals), laser dazzling of optical sensors, cyber intrusion into satellite command systems, and proximity operations (manoeuvrable satellites that can inspect, interfere with, or threaten adversary spacecraft). These approaches deny or degrade capability without generating debris.

The economics of debris are also creating a commons problem. As commercial LEO becomes more congested, the risk of the Kessler cascade (a chain reaction of collisions generating debris faster than it decays) at certain altitude bands becomes a genuine long-term threat to the entire orbital economy. No binding international framework currently governs debris generation or remediation, and military programmes are largely exempt from the voluntary guidelines that commercial operators nominally follow.

Exhibit 11: Highest value accrues at the data and applications layers.

GLOBAL SPACE VALUE CHAIN - REVENUE AND MARGIN PROFILE

Five Distinct Profit Pools with Different Margin Profiles and Capital Intensity

VALUE CHAIN LAYER	CURRENT REVENUE SCALE (ANNUAL)	DOMINANT PLAYERS	MARGIN CHARACTER (ESTIMATED EBITDA MARGIN)	CAPITAL INTENSITY (RELATIVE)
1 LAUNCH SERVICES Putting payloads into space	~$10–12B	SPACEX, ROCKET LAB, arianespace arianegroup	10–20% High capex, winner-take-most	VERY HIGH ■■■■□ Heavy infrastructure, R&D and scale critical
2 SATELLITE MANUFACTURING Building the space assets	~$18–22B	AIRBUS, BOEING, MAXAR TECHNOLOGIES, + STARTUPS	8–15% Volume-driven, component intensity	HIGH ■■■□□ High manufacturing capex, scale benefits
3 SATELLITE SERVICES (COMMS, BROADBAND) Connectivity from space	~$140B+	STARLINK, Viasat, SES, INTELSAT	25–40%+ Recurring, high ARPU at scale	MEDIUM ■■□□□ Moderate capex, driven by constellation scale
4 EARTH OBSERVATION & DATA Turning raw data into insights	~$5–8B FAST GROWING	planet, MAXAR TECHNOLOGIES, PIXXEL, AIRBUS	30–50%+ High margin, analytics upside	LOW-MEDIUM ■■□□□ Lower hardware needs, software & data driven
5 GROUND EQUIPMENT & SATCOM Connecting space to Earth	~$150B+	Diverse ecosystem: many global & regional players	10–20% High volume, lower margin	LOW-MEDIUM ■■□□□ Mass market, price competition

KEY TAKEAWAY
The highest economic value accrues to recurring services and data intelligence, while launch and manufacturing remain capital-intensive and structurally lower margin.

VALUE CONCENTRATION
~70%+ of total revenue sits in Services (Satcom & Ground), with higher durability.

(Sources: Euroconsult 2023 & 2024, Company Reports, Morgan Stanley, McKinsey, Allied Market Research, VQ Analysis)

INDIA'S SPACE MOMENT

Reform, Ambition and the Investment Case

LVM3 M3/OneWeb India-2 Mission lift-off at Sriharikota | www.isro.gov.in

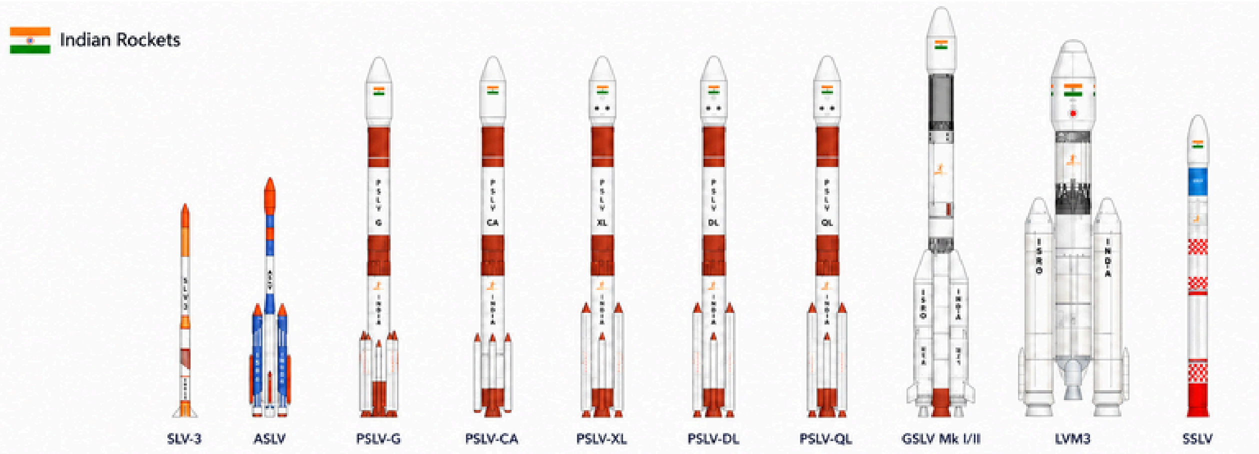
From Fringe Participant to Strategic Node

Indian ambitions in space began post-independence in the 1950s when the Department of Atomic Energy (DAE) began conducting research into aspects of metrology and the Earth's magnetic field. Motivated by the success of the Soviet Sputnik, the Indian National Committee for Space Research (INCOSPAR) was established in 1962 at the behest of Dr. Vikram Sarabhai with the goal of fostering space science and technology development in India.

H.G.S. Murthy, an Indian Ordnance Factory Services officer holding a PhD in aerospace engineering from the University of Minnesota, was appointed as the first director of the Thumba Equatorial Rocket Launching Station (now the Vikram Sarabhai Space Centre) in Thiruvananthapuram. In this role, he recruited Dr. A.P.J. Abdul Kalam into INCOSPAR, a recruitment that would shape both India's civilian and military applications of rocketry for decades.[8]

By 1969, INCOSPAR was consolidated as the Indian Space Research Organisation (ISRO). Unlike the Soviet, US or Chinese programmes, the Indian space programme was created for space science and exploration rather than being a sandbox for military development. This is the reason why Indian launch vehicles were developed from the Satellite Launch Vehicle (SLV) which in 1980 made India the sixth country in the world with orbital launch capability. A snapshot of Indian launch vehicles is presented in (Exhibit 12), and many of these developments would be militarised in the creation of the Agni family of Intercontinental Ballistic Missiles (ICBMs).

Exhibit 12: A view of the different launch vehicles from ISRO



	SLV-3	ASLV	PSLV-G	PSLV-CA	PSLV-XL	PSLV-DL	PSLV-QL	GSLV Mk I/II	LVM3	SSLV
First Launch	1979	1987	1993	1994	1997	2001	2010	2001/2006	2014	2022
Payload to LEO (kg)	40	150	1,750	1,750	1,850	2,950	3,850	5,000/6,250	8,000	500
Stages	4	5	4	4	4	4	4	3	3	3
Height (m)	22.7	23.5	44.4	44.4	44.4	44.4	44.4	49.0	43.5	34.0

Note: Payloads to LEO are approximate and may vary with mission configuration.
Source: HistoricSpacecraft.com

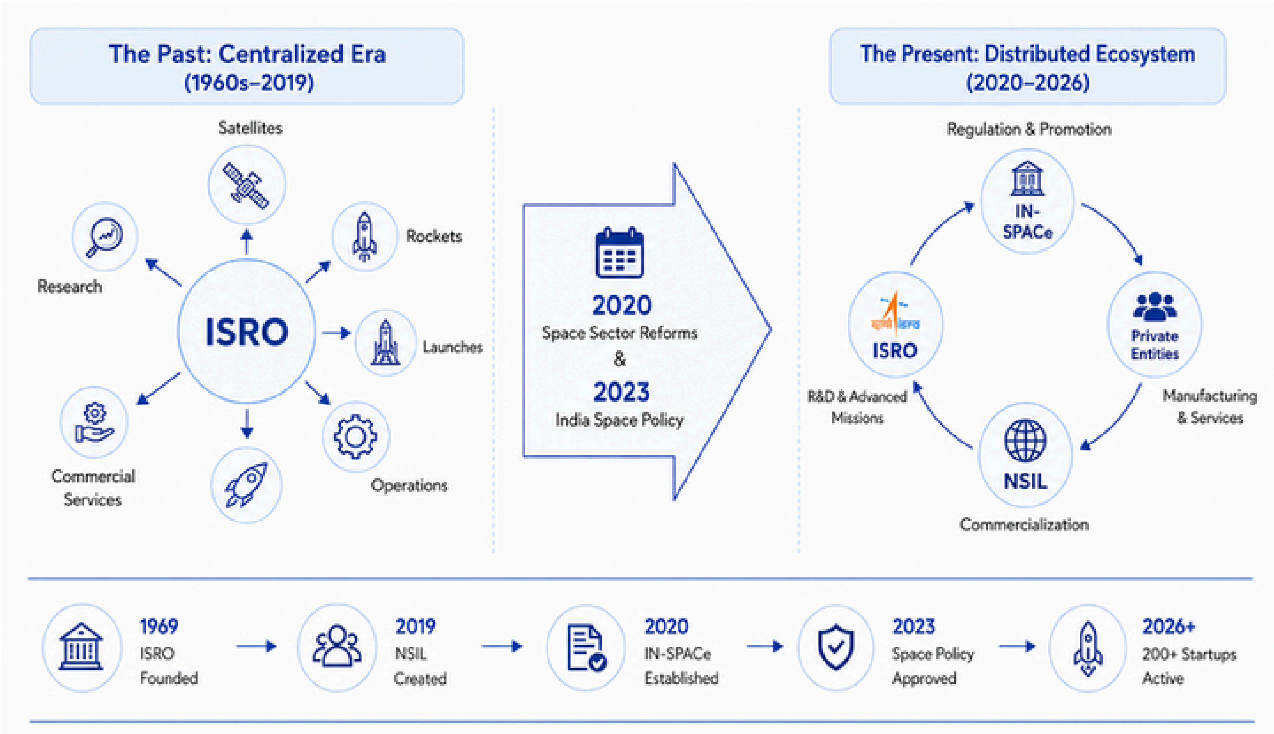
[8]Dr. H.G.S. Murthy (PhD, University of Minnesota, Aerospace Engineering) set up the Thumba sounding rocket facility and recruited Dr. A.P.J. Abdul Kalam into INCOSPAR. Along with Drs. Bhabha, Sarabhai, Kalam, Patwardhan, Aravamudan, and Ramachandran, he is considered one of the seven pioneers of the Indian space programme.

Reform and the Opening of the Sector

By the early 2000s, ISRO was the nerve centre of all commercial space activity in India including development, exploration and science. Its commercial reputation was built on near-perfect reliability and cost-effectiveness - Chandrayaan-3's 2023 soft landing at the lunar South Pole at approximately $75 million, and the Mars Orbiter Mission at $74 million, are the most cited evidence of ISRO's engineering philosophy.

However, as the new space race described in Act -4 began gathering pace, the Government of India perceived that ISRO's size was becoming detrimental to its fundamental goals and brought about the space sector reform in 2020 and the India space policy in 2023. A pictorial snapshot is presented in (Exhibit 13).

Exhibit 13: The impact of the Indian space sector reform and space policy of 2020 and 2023 respectively



Source: ValueQuest

2020 — Space Sector Reform

Private access to India's space activities, including ISRO's facilities. Its centrepiece, IN-SPACe, was created as an autonomous single-window agency to promote private participation across the entire spectrum — opening centres at Bangalore, Sriharikota and Thiruvananthapuram and signing an MoU with NewSpace India Limited to transfer commercial technologies.

2023 — Indian Space Policy

Policy clarity through a norms-, procedures- and guidelines-based approach. ISP-23 set out a vision in which ISRO eventually focuses entirely on R&D of advanced technologies and transitions out of manufacturing and operating spacecraft, giving non-government entities a level playing field across the full value chain.

The Results and the Defence Convergence

The results have been dramatic. In 2019, India had merely 11 private space companies; today the number is estimated to be over 400, with private players heavily involved across the value chain. Since 2020, ISRO, IN-SPACe, and NSIL have signed 75 technology transfer agreements to empower the private sector, and the government has launched a $120 million venture capital fund to support space startups. India is now targeting growth of its space economy from $8.4 billion in 2022 (about 2% of global share) to $44 billion by 2033 (approximately 4% of global share). Further liberalisation followed in 2024, when FDI restrictions were relaxed, allowing up to 74% automatic foreign ownership for satellite manufacturing and related systems, and up to 49% for launch vehicle development, with higher stakes permitted case by case.

The defence dimension is handled separately: IN-SPACe and ISRO sit under the Department of Space, while the DRDO develops defence systems and the Defence Space Agency (2019) integrates space-security operations across the services. The clearest convergence is in surveillance, the Space-Based Surveillance Phase III (SBS-III) programme, ~₹27,000 crore, will deploy 52 military satellites by 2027–28 through an unprecedented public–private partnership, with three South Indian firms building 31 of the 52. Mission DefSpace (2022) adds 75 “Defence Space Challenges” under the iDEX framework.

Exhibit 14: Evolution of the Indian private sector in Space since reforms.

YEAR	MILESTONE	SIGNIFICANCE
2019	11 private space companies	Pre-reform baseline
2020	Space Sector Reform + IN-SPACe	ISRO facilities opened to private sector; technology transfer MoUs signed
2022	Defence Space Agency active; Mission DefSpace launched	iDEX framework; 75 defence space challenges; SBS-III PPP announced
2023	Indian Space Policy 2023 enacted; Chandrayaan-3 soft landing	ISRO to pivot to R&D; end-to-end private participation enabled
2024	400+ private space companies; FDI released	Up to 74% auto FDI for satellite manufacturing; $120M VC fund announced
2025	658+ IN-SPACe applications; 1,200+ registered startups; $147M+ startup funding in FY2025–26	Pixxel leads India's first private EO constellation (₹1,200 Cr PPP); SSLV technology transferred to HAL; Skyroot–Axiom Space partnership; Agnikul 3D-printed engine world-first

Source: ValueQuest

Space Privatisation, Dual Use and Defence

With the changes in the space sector, the Government of India aims to benefit from the dual use of commercial space technology described in Act 4. IN-SPACe and ISRO are both overseen by India's Department of Space, while the defence dimension is handled separately, the DRDO develops India's defence technologies and systems, including in space, through collaborations with ISRO and the Department of Space. Additionally, the Defence Space Agency (DSA), established in 2019, promotes integration on space-security policy and operations between the Army, Navy and Air Force.

> While IN-SPACe is primarily a civilian and commercial body, its role has clear defence implications. The transition from a government-led programme to the private sector will bring an expansion of both capabilities and capacities — in areas like small-satellite development, launch services and downstream applications that serve military needs.
>
> AIR VICE MARSHAL DV KHOT (RETD.) · PRINCIPAL CONSULTANT, IN-SPACE · FORMER DG, DEFENCE SPACE AGENCY

The most concrete convergence is in surveillance.

₹27,000cr
SBS-III PROGRAMME

Space-Based Surveillance Phase III will deploy **52 military satellites by 2027–28** through an unprecedented public–private partnership — three South Indian firms building 31 of the 52, the rest by ISRO.

For the first time, private companies will play a significant role in developing satellites for strategic defence purposes. Mission DefSpace, launched in October 2022 under the iDEX framework, further promotes indigenous development of dual-use technologies, introducing 75 “Defence Space Challenges” covering launch systems, satellite systems and communications.

India is integrating space capabilities to service its military needs, though this has been slow, a lack of capacity and resource infusion has held back a dedicated military space architecture able to meet the needs of the Armed Forces. The broader strategic driver is China: in 2019 India established the Defence Space Research Organisation to advance space-warfare technologies and launched Project NETRA, a space-situational-awareness system designed to monitor and protect Indian space assets.

Structural Limits, Structural Advantages

The integration of defence needs into the private eco-system then provides investment opportunities as private sector entities scale rapidly requiring capital for CAPEX, working capital and sometimes R&D. However, having the Indian defence complex as the end customer creates structural limitations that investors must price such as:

- Vague or highly ambitious programme specifications, leading to protracted negotiations.
- Aggressive price bids to meet L1, compressing margins.
- Volumes too low for the high cadence small-satellite economics demand, compromising unit economics and learning rates.
- Elongated gestation cycles and procurement frictions: pre-dispatch clauses, liquidated damages, earnest-money deposits and performance bank guarantees.

While the global industry has moved away from high-margin contracts for few-of-a-kind assets, India still leans on the ambitions of its defence forces, so margins will matter, especially with Indian interest rates above those of the US. Yet India holds advantages that transcend cost (Table 2)

Table 2: Some structural advantages of the Indian space ecosystem which can allow expanded use cases beyond defense procurement dynamics

STRUCTURAL ADVANTAGE	IMPLICATION FOR GLOBAL SPACE ECONOMY
Cost Structure	ISRO missions at **10–20%** of Western costs (Chandrayaan-3: ~$75M; Mars Orbiter: $74M). Private companies inherit this philosophy. Indian space startups target **$200–300/kg to LEO** — within striking distance of global competitiveness.
Engineering Talent	**~1.5 million** STEM graduates annually, Top IIT/IISc talent migrating from software services to space startups. **2.5× productivity premium** vs. broader Indian industry (Novaspace study, 2024).
Geographic Position	**Sriharikota** at 13.7°N offers excellent orbital coverage. New **Kulasekarapattinam** spaceport optimised for SSO — the preferred orbit for Earth observation constellations.
Geopolitical Neutrality	India is not aligned with either the US-led or China-led blocks in space. This enables India to serve as a **trusted manufacturing and service node** for middle powers seeking supply chain diversification.
Defence Urgency	China's 2019 ASAT test and growing PLA space programme creates **structural demand** for India's own sovereign space stack, driving funded government procurement across surveillance, communications, and ISR.
Software Stack	India's established software engineering base creates competitive advantage in ground control systems, geospatial analytics, **AI-enabled change detection** — the highest-value layers of the space economy.

Source: ValueQuest

A Critical Node in the Global Supply Chain

India has the potential to become to space what it became in pharmaceuticals and IT services: a trusted, cost-efficient, engineering-intensive global partner. It may lack China's geopolitical ambitions, SpaceX's vertical integration or Amazon's platform advantage, but by sitting at the intersection of low-cost engineering, software capability, electronics, geopolitical neutrality, manufacturing scale-up, defence urgency and sovereign demand, India is likely to emerge as a critical node in the global space economy.

It can be a trusted allied manufacturing node, supplying satellite subsystems, ground systems, software and control stacks, analytics and geospatial AI, and a launch alternative for middle powers seeking supply-chain diversification, playing strongly into the China+1 theme. This is already visible.

Skyroot Aerospace

LAUNCH

Partnered with Axiom Space (June 2025) to expand access to LEO — the first such tie-up between an Indian private launch company and a US commercial space-station operator.

Pixxel

EARTH OBSERVATION

Awarded India's first commercial EO constellation (₹1,200 crore PPP with PierSight, SatSure and Dhruva Space), positioning Indian hyperspectral imaging for global clients.

Bellatrix Aerospace

PROPULSION

Establishing manufacturing facilities in the United States — demonstrating that Indian propulsion technology is globally competitive.

US Subsidiaries

CHINA+1

Multiple Indian startups are setting up US subsidiaries to compete directly with domestic providers in launch services, satellite components and analytics.

> A real step-change will come when an Indian satellite-solutions player integrates with a high-volume supplier such as SpaceX, accessing its production cadence as a learning-rate lever, rather than competing against it directly.

A fork in the road: The Jio variable

The single most important near-term catalyst for India's space economy is not a government programme but a commercial decision: whether Reliance Jio builds a LEO broadband constellation at scale.

Jio's ambition to build a LEO broadband constellation would do for India what Starlink did for SpaceX's broader launch economics: create the volume and cadence that makes the entire upstream ecosystem, launch vehicles, satellite buses, components, ground stations, signal processing, commercially viable rather than government-dependent.
A notional constellation of 500–1,000 LEO satellites would require:

01

Launch cadence

100–200 satellites a year for deployment and replacement, a multi-year anchor for Skyroot, Agnikul and the HAL–L&T PSLV consortium.

02

Satellite buses at scale

Potentially India's first bus-manufacturing programme at genuine volume, finally enabling the learning-rate curve that has been absent.

03

Ground network

A nationwide ground-station network, creating sustained demand for SATCOM infrastructure, terminals and signal processing.

04

Software stack

Constellation management, terminal optimisation and network control among the highest-value and most defensible parts of the stack.

PATH A — JIO-OWNED CONSTELLATION

Creates genuine Indian upstream demand, catalysing launch, buses, components and ground systems across the domestic ecosystem.

PATH B — JIO–STARLINK DISTRIBUTION

Brings foreign broadband infrastructure to India quickly, but risks pre-empting the domestic ecosystem before it can form. Jio already holds a D2C partnership modelled on T-Mobile–Starlink.

The investing lens: India and the world

Space is a genuinely heterogeneous investment universe, home to both the highest-margin recurring-revenue software businesses in the global economy and some of the most capital-intensive, policy-dependent, low-margin hardware businesses. Treating it as a single thematic allocation is a mistake.

Table 3: Potential areas of value creation and areas requiring caution in the space sector.

LIKELY VALUE CREATORS	AREAS REQUIRING CAUTION
Sensors & Payloads High IP intensity, small mass, high value-density; strong dual-use demand; mission-critical with barriers to entry	**Launch Economics** High CAPEX; intense competition; scale asymmetry (SpaceX); airline-like margin risk
SATCOM & Secure Comms Recurring, annuity-like revenues; high switching costs; sovereignty premium; expanding across defence, maritime, aviation	**Constellation Replacement** LEO satellites replaced every 3–7 years; continuous CAPEX cycle; rapid obsolescence
Encryption & Cybersecurity Indispensable for secure space networks; software-like economics; scalable; high IP content	**CAPEX Intensity** Long gestation before monetisation; negative cash flows; dilution risk
Ground Infrastructure Picks-and-shovels exposure; lower obsolescence risk; network effects and recurring usage	**Policy Dependence** Spectrum rights, orbital slots, export controls; regulatory uncertainty; geopolitical restrictions
Geospatial Analytics & AI Highest potential value layer; data→insight monetisation; massive horizontal applicability; software margins	**Orbital Debris Regulation** Rising collision risk; stricter deorbit rules; compliance and insurance costs
Dual-Use Software Asset-light; continuous upgrades; high margins; mission-critical integration platforms	**Defence Procurement Cycles** Long timelines; limited volumes; L1 pricing pressure; cash flow lumpiness

Source: ValueQuest

The core insight is structural: infrastructure gets built, platforms get used, and intelligence gets monetised. History suggests that in every infrastructure build cycle — internet, cloud, telecom, the greatest compounders were not the infrastructure builders (telcos, cable operators, tower companies) but the platform and application layer businesses (Google, Amazon, Salesforce) that benefited from the infrastructure without owning it. The space economy is likely to follow the same pattern, and the following levels reflect potential value capture in descending order:

Level 1 HIGHEST CAPTURE	Data acquisition, processing and management — geospatial intelligence, defence AI, ISR analytics, LEO-based internet and mission software. Monetises the data space generates, with SaaS-like economics.
Level 2 ENDURING	SATCOM, critical sensor packages, managed services, ground stations and mission-critical hardware (thermal, power). Failure-critical hardware with few high-quality suppliers — capital-goods economics and margins.
Level 3 OPPORTUNISTIC	Commoditised but high-volume manufacture — satellite buses, space-rated solar, booster structures, propellant tanks, cryogenic handling. Strong demand tailwinds for precision manufacturing.
Level 4 ASSET OWNERS	Launch providers, pad owners and constellation owners. High capex, predictable returns only at high cadence with recurring replacement capex — investable mainly when packaged with Level 1 or 2 assets.

The Near-Term Opportunity for India

History suggests the greatest compounders in every infrastructure cycle — internet, cloud, telecom — were not the infrastructure builders but the platform and application businesses built upon them. For India specifically, the near-term investable opportunity concentrates in four areas:

System suppliers to payloads

Communications, sensors, radar packages, signal processing, encryption — high IP intensity, mission-critical relationships and sovereign-backed dual-use demand.

Ground tracking & SATCOM

Significant demand from military and civilian operators; the push toward drones in agriculture, defence and logistics is a sustained tailwind.

Signal encryption & cybersecurity

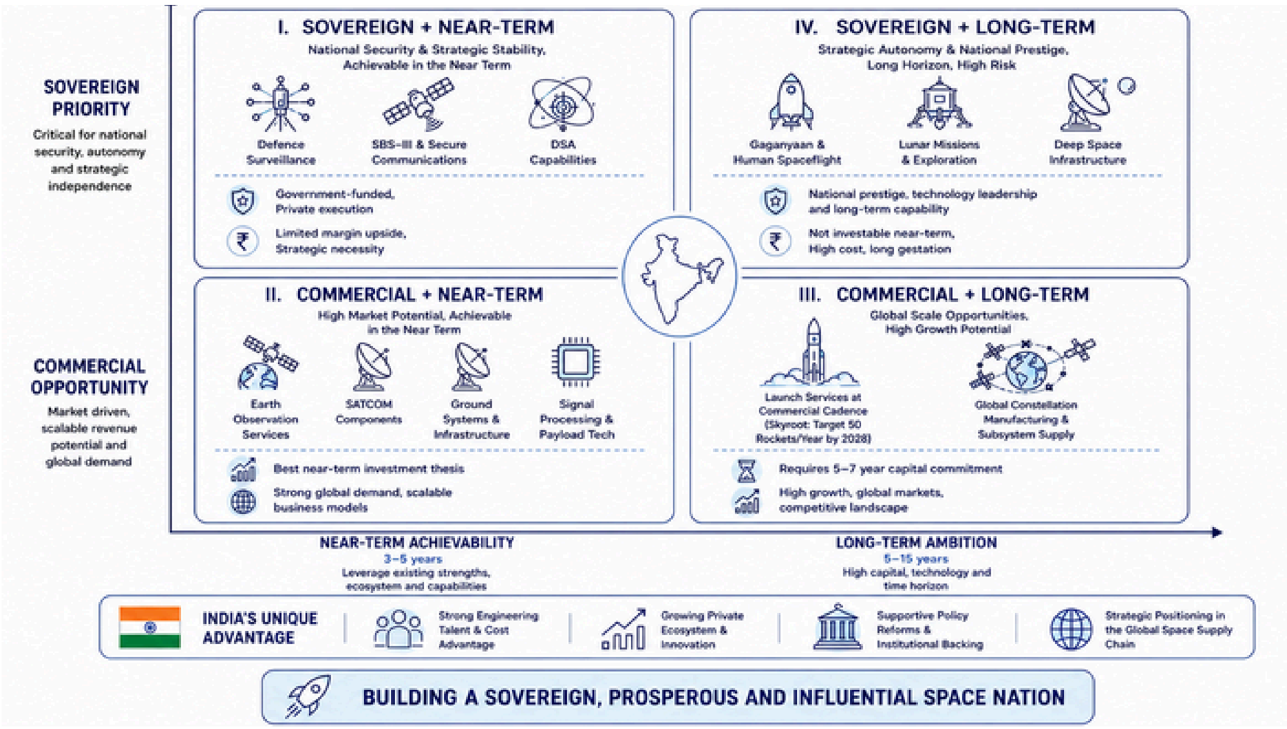
Satellite-to-satellite and satellite-to-ground links are often unencrypted; improving data security will be a critical, recurring need.

Geospatial analytics & AI

The highest-margin segment; Indian software-engineering talent is directly applicable, and the global market is accessible from day one.

INDIA'S ROLE IN THE NEW SPACE - A FRAMEWORK

Positioning Indian Space Activities Across Sovereign Priority, Commercial Opportunity, Near-Term Achievability and Long-Term Ambition



Source: VQ data

> Indian companies will likely establish an initial foothold with second-tier space nations, the UAE, Indonesia and Southeast Asia, before the real step-change: integrating with high-volume suppliers like SpaceX as a component or sub-system supplier, using their production cadence as a learning-rate lever rather than competing head-on.

BEFORE THE HYPE

Structural Risks and The SpaceX Inflection

SpaceX Falcon 9 | www.pexels.com | Daniel Ponomarev

Structural Risks the Models Must Price

While the sector is seeing substantial traction and growing investor interest, discipline demands that we reflect on the risks. (Exhibit 15) maps them by probability and severity. The top-left quadrant (high probability, high severity) are the risks are baked into the physics and economics of the sector and show up in every model. Launch costs can be mitigated by vertical integration, which is the SpaceX bet. However, constellation economics are an important variable with deployment timelines routinely running ahead of demand, and ARPU pressure from terrestrial alternatives worsening even as other use cases develop beyond satellite internet leading to higher cash burn. Also, capital intensity amplifies every other vector in (Exhibit 15) because a thinly capitalised operator has no buffer when a secondary risk materialises.

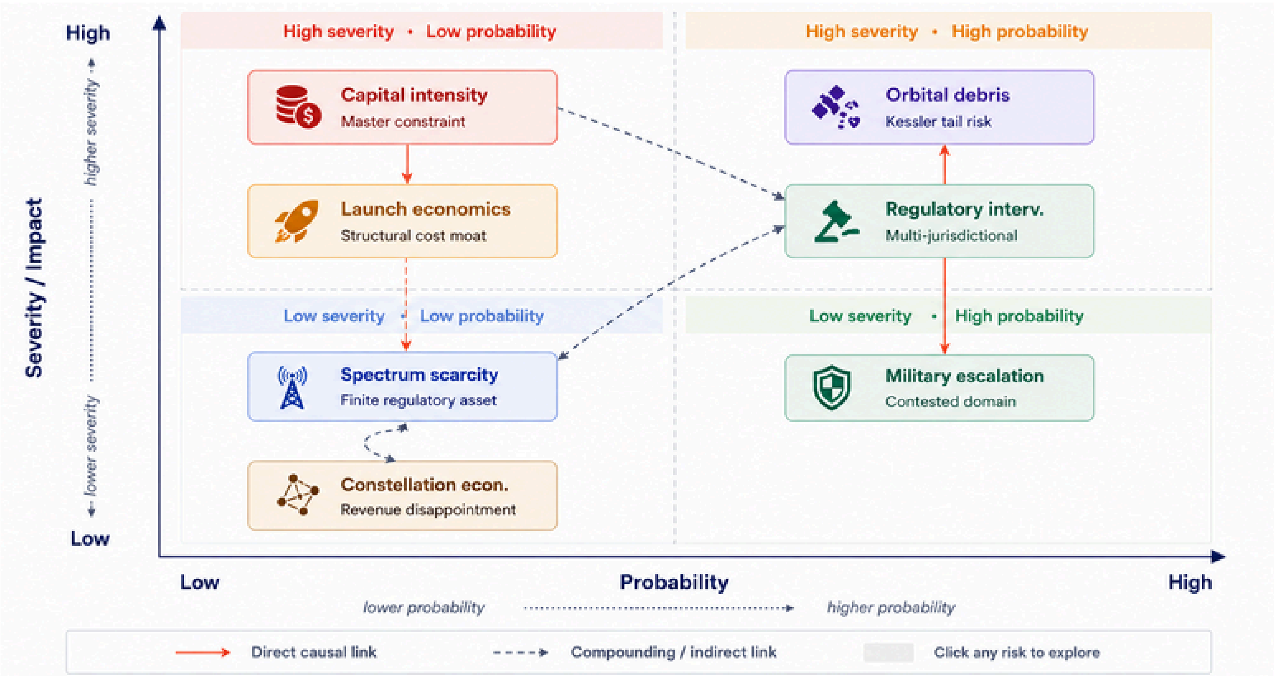
Market friction works in concert with capital intensity feeding into the risks of spectrum allocation and orbital slot availability as more satellites enter LEO.

It is also important to note that spectrum is a regulatory asset and can be granted or clawed back adding a geopolitical dimension that goes beyond the commercial.

Debris risk is the long-duration tail: a Kessler cascade wouldn't just impair one company's assets; it could impair the orbital shell itself with military action in a great power conflict could view dual use assets in LEO as legitimate targets.

Finally, it is important to note that the current push to LEO is driving an increase in the number of rockets launches which inject propellant residues and aerosols into the Earth's upper atmosphere at unprecedented concentrations. There are no reliable environmental models for the climate impacts this might create including any effects on weather patterns or the ozone layer. Other effects including noise, and debris risk in the vicinity of launch and recovery sites also remain concerns and may invite regulatory action which will then disproportionately affect thinly capitalised operators.

Exhibit 15: Risk matrix for space investing.



Source: ValueQuest

The SpaceX Inflection: Projects to Platforms

SpaceX's recently filed IPO marks a seminal moment for the space sector from a markets perspective. Its vertical integration of launch and Starlink satellite-based connectivity, alongside promises for space-based AI, has created substantial interest, reflected in a $1.7 trillion+ valuation. Valuation discussions aside, SpaceX’s IPO documents highlight some interesting points about an industry that is changing, while also highlighting areas where financial investors must exercise discretion before being swept up by the narrative.

The first point is that SpaceX has a more robust business model than OneWeb, which was also an LEO broadband constellation targeting global coverage with sub-100ms latency. Through Starlink, SpaceX operates a consumer-first mega constellation with direct-to-consumer sales, owning customer relations end-to-end. This anchors increasing satellite demand, permitting a high cadence of launches from in-house facilities and obviating dependence on commercial providers, a flywheel enabling lower costs (improved by reusable boosters) that further increases adoption.

This flywheel demonstrates an industry moving from projects to platforms, SpaceX's entire economic premise is embedded in transitioning from single-satellite, single-mission government contracts to a platform underpinned by constellations generating recurring revenues with robust network effects, turning space from bespoke engineering into a scalable infrastructure platform and a saleable business idea. SpaceX's IPO material suggests that, as with all infrastructure, the value delivered is the use case, connectivity, intelligence, communication, navigation, and security — with space, its satellites, and the launch services that get them there forming the underlying infrastructure. While it is tempting to compare launches to cloud computing infrastructure, rockets are powerful, potentially hazardous, and explosive vehicles, so substantially greater engineering redundancy and safeguards will always be imposed.

A CRUCIAL DISTINCTION

LEO viability should not be confused with LEO profitability. At sufficient scale, most infrastructure models can show operating leverage — but the investor question is whether that scale is reached before replacement capex, spectrum constraints, pricing pressure, regulatory friction and dilution overwhelm the economics. Many infrastructure businesses create enormous societal value while generating only modest shareholder returns.

Scale Is Not Profitability

Scale should not be confused with profitability. At a sufficiently large scale, most infrastructure businesses can generate meaningful operating leverage. The critical investment question, however, is whether that scale can be reached before replacement capex, spectrum constraints, pricing pressure, regulatory friction and shareholder dilution overwhelm the economics. The distinction between technological viability and economic viability is subtle but crucial and history suggests that many infrastructure businesses create enormous societal value while generating only modest shareholder returns.

The challenge for investors is therefore not to identify whether space will succeed as a technology, but to identify where along the value chain the economic rents will ultimately accumulate.

An important point that also emerges is that SpaceX is building its constellation and space-infrastructure narrative on vertical integration, which in turn relies on the emergence of scale at which point it becomes an unassailable moat against competition. Given the tyranny of the rocket equation and the limitations of present technology with chemically-fuelled rockets, growing scale and vertical integration may be the only viable route for future champions in this sector.

Therefore, even India must move strategically in the direction of high cadence and vertical integration, which must be underpinned by a strategic anchor of demand, such as an Indian constellation, as discussed previously.

Two Exponentials, and a Cross-Subsidy

SpaceX recognises that rockets have a structural cost floor imposed by physics. Rather than make rockets dramatically cheaper, it aims to generate enough high-margin downstream revenue, Starlink broadband, AI compute in orbit, launch services for others that launch economics become almost irrelevant to entity value. It is betting on two revenue exponentials.

1 Starlink as subscriber infrastructure

COMPOUNDING, THEN LOGISTIC

Each satellite adds capacity serving more subscribers at near-zero marginal cost once built. But satellite broadband is ultimately constrained by spectrum, gateway capacity and the finite number of underserved locations — so the exponential becomes a logistic curve and hits a ceiling. The more durable value sits in maritime, aviation, government/defence and IoT: stickier, higher-ARPU, slower to compound.

2 AI-enabled launch services

THE SPECULATIVE LEG

This is the more speculative leg. The argument runs thus: AI requires massive compute, compute requires energy, energy is constrained on Earth (land, heat, regulation), therefore space-based compute or energy beaming becomes a real market, and SpaceX has the only cost-competitive access to orbit. It's a very long option which maybe feasible (if at all) in 20 years while remaining economically unproven at present.

SpaceX is betting on a combination of vertical integration and cross-subsidy to allow launch of Starlink satellites at transfer prices no competitor can match, thereby subsidising constellation build-out while starving rivals of cost parity. At the same time, launch revenue from external customers (NASA, commercial) funds Starlink capex; Starlink revenue justifies continued Starship development, which in turn makes the vertical integration more powerful. SpaceX is therefore aware of the rocket equation and its limitations but is attempting to make those economics irrelevant to the investment thesis by ensuring the entity's value accrues in downstream services rather than launch margins. This then implies that the downstream businesses (Starlink, future AI/compute services) must compound fast enough and long enough to justify the capital destruction that building Starship, constellation replenishment and infrastructure costs represents. SpaceX's real achievement has been to absorb the rocket equation within a vertically integrated balance sheet, while shifting the profit pool toward downstream services.

> Despite these observations, SpaceX represents the first attempt to have a large space infrastructure company and its successes, failures and how the market perceives it will all be interesting to investors tracking this sector.

For the Investment Practitioner

The space industry launch solutions, data management, ground stations and satellite assembly, has seen a renaissance in the 2010s, driven by the high-cadence launch of small, modular satellites forming large constellations in LEO. Six conclusions follow for the practitioner.

01 The dual use of space technologies, with blurred civil–military lines is driving the weaponisation of LEO and creating durable sovereign demand for the underlying capabilities.

02 Reusable boosters are only financially viable at the high cadence that constellation economics enable. The two are inseparable.

03 Launch and infrastructure remain capital-intensive, but value is likely to accrue to the users of the data and networks and to key systems providers, rather than the asset owners.

04 For India, the revolution opens ISRO mission areas to the private sector, but military interest drives demand. Sensors, IR, radar, data processing, signal uplink, SATCOM, geospatial analytics and encryption are the preferred entry points.

05 Greater policy clarity is needed on IP transfer, IP pricing and incentives for the private sector to grow beyond military use defence volumes alone cannot sustain new-age space economics.

06 The major near-term variable is the Jio decision: a Jio-owned constellation catalyses the upstream ecosystem; a Jio–Starlink distribution model pre-empts it. This is the single most important watch item for Indian space investors.

CONCLUSION

A New Layer of Sovereignty

This is the beginning of a new and exciting era in the commercialisation of space. The first space race was about proving technological superiority; the second may be about embedding space into everyday economic, military and digital infrastructure at a cost structure accessible not just to superpowers but to companies, startups and middle-income nations.

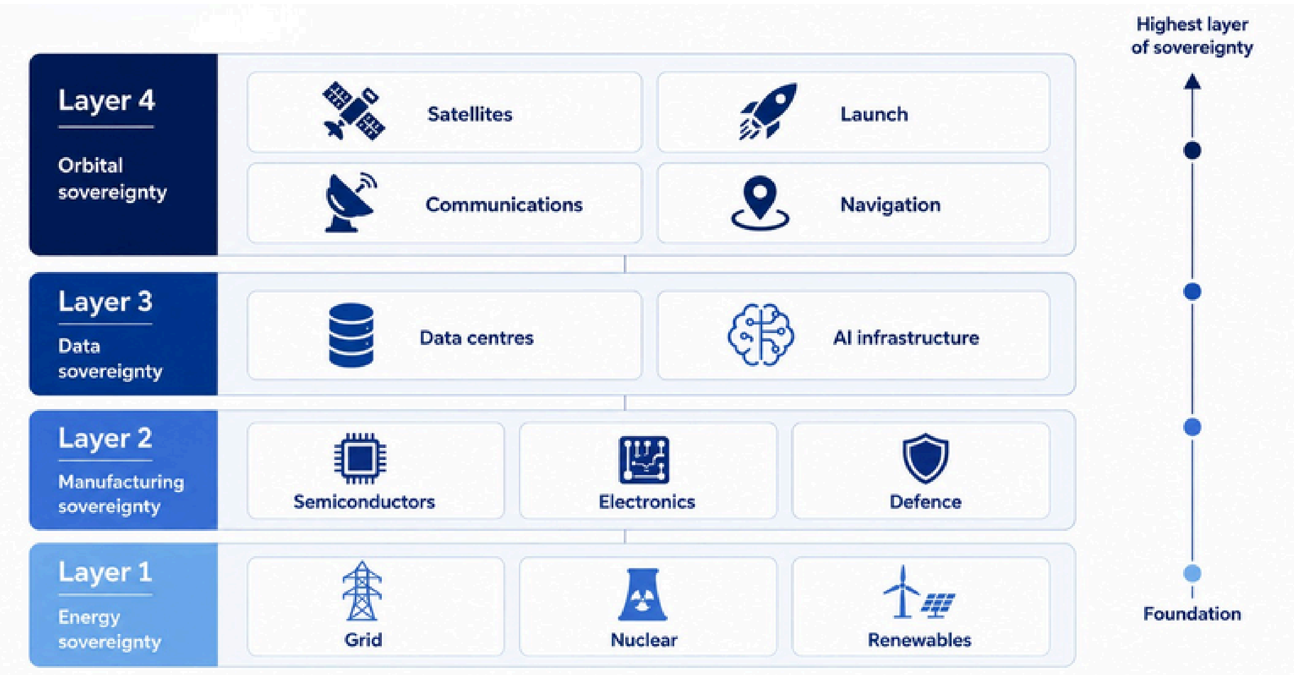
Space is evolving from a prestige industry into a compounding infrastructure industry, and the future belongs to those who can innovate. Nations that fail to participate risk strategic dependence; those that succeed may shape the next layer of the global economy. India's opportunity is structural, its advantages durable and the window, while open, will not remain so indefinitely. Early in any megatrend, investors must remain disciplined about where value truly accumulates.

In an emerging multipolar world, space will form a new layer of sovereignty **"Orbital Sovereignty"** which, alongside data, manufacturing and energy, will be a central consideration for every nation.

(Exhibit 16) presents the ValueQuest framework on the layers of sovereignty, with orbital sovereignty resting atop the foundations of energy, manufacturing and data.

> What you see is important. What you cannot see is even more important.

Exhibit 16: Layers of sovereignty with orbital sovereignty forming the highest layer



Source: ValueQuest

Disclaimer

ValueQuest Investment Advisors Pvt Ltd.
Kohinoor Square Business Park, B – 4101, 41st
Floor, NC Kelkar Marg, Shivaji Park, Dadar West,
Mumbai 400028, India

info@valuequest.in
022 69394444
www.valuequest.in

VALUEQUEST