THINK TANK
BY LAB45

Accessing the final frontier: Evolution of space tech. A Primer

Reusable rockets & satellite miniaturization collaboratively are democratizing access to space. Fuelling innovation across multiple domains and fostering a future where space is accessible to enterprises, individuals, and nations alike.

WHAT'S INSIDE!

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Space race

2nd August 1955, a date that plays a significant role in the history of humankind, marks the start of the space race between the USA and USSR. What started as the pursuit to dominate the space flight technology for national security and political superiority resulted in a remarkable scientific and technological improvement without which the world may not have turned out to be the way it is.

> **Eighty-two percent of senior executives in Deloitte's 2023 space survey said that innovation in the space market is a priority for their organization"**

Source: Future of the space economy | Deloitte Insights

In 1991, the collapse of the USSR officially ended the space race, but it created the technological infrastructure, starting a chain reaction of technological innovation leading to the present day.

The cluster of satellites provides communication capabilities, High-Definition television, weather reporting, GPS (Global positioning system) providing positional and navigational capabilities, CAT scans, portable computer peripherals, and wireless headphones. All of the above technologies originated as part of the space race.

The last few years have witnessed exponential growth in space technology sectors fueled by innovation in operating space-based (e.g., satellites) with reduced manufacturing costs and, last but not least, the cost of launching a payload using reusable rockets.

Source: Space race timeline | Royal Museums Greenwich (rmg.co.uk)

The economies of reusable rockets

A major significant stride in space technology has been the development of cost-effective launch systems and the introduction of reusable rockets. Traditionally, all the payload launches from NASA, the Indian Space Research Organization (ISRO), and the European Space Agency (ESA) have been done primarily with rockets designed for single launch. Companies like SpaceX have pioneered the concept

> **The Aerospace Security Project (ASP) in Sept '22 conducted an analysis of the cost of payload launches throughout history. The cost of heavy launches in LEO have been reduced by almost 95% from $65,000 to $1,500.**

LEO (Low Earth Orbit i.e., <2000km altitude)

of reusable rockets, drastically reducing the price of accessing space.

By landing and reusing rocket boosters, these companies have significantly decreased the expense associated with each launch, making it more economically viable for various stakeholders.

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Space X Falcon 9 Launch

Source: Space X

Launch

Ascent

Stage separation

First stage has left Earth's atmosphere

Flip maneuver

Cold gas thrusters flip first stage

Fairing separation

Payload separation

Grid fins deploy

Entry burn

Engines light again to slow down first stage

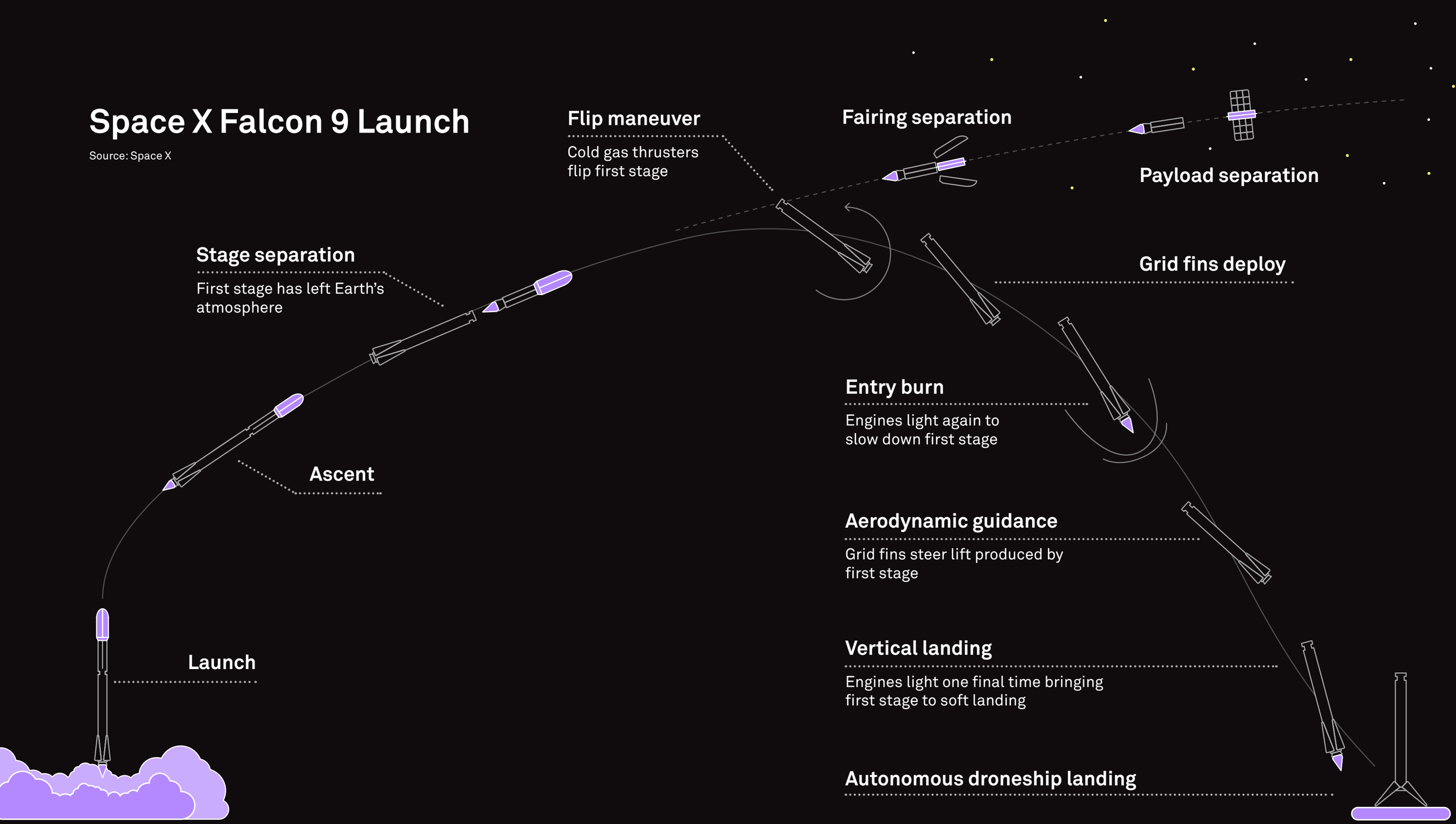
Aerodynamic guidance

Grid fins steer lift produced by first stage

Vertical landing

Engines light one final time bringing first stage to soft landing

Autonomous droneship landing



The reduction has brought space exploration within reach of not only governments and large corporations but also private entities, research institutions, and even educational organizations.

Source: Space launch: An oversupply or a shortfall? | McKinsey

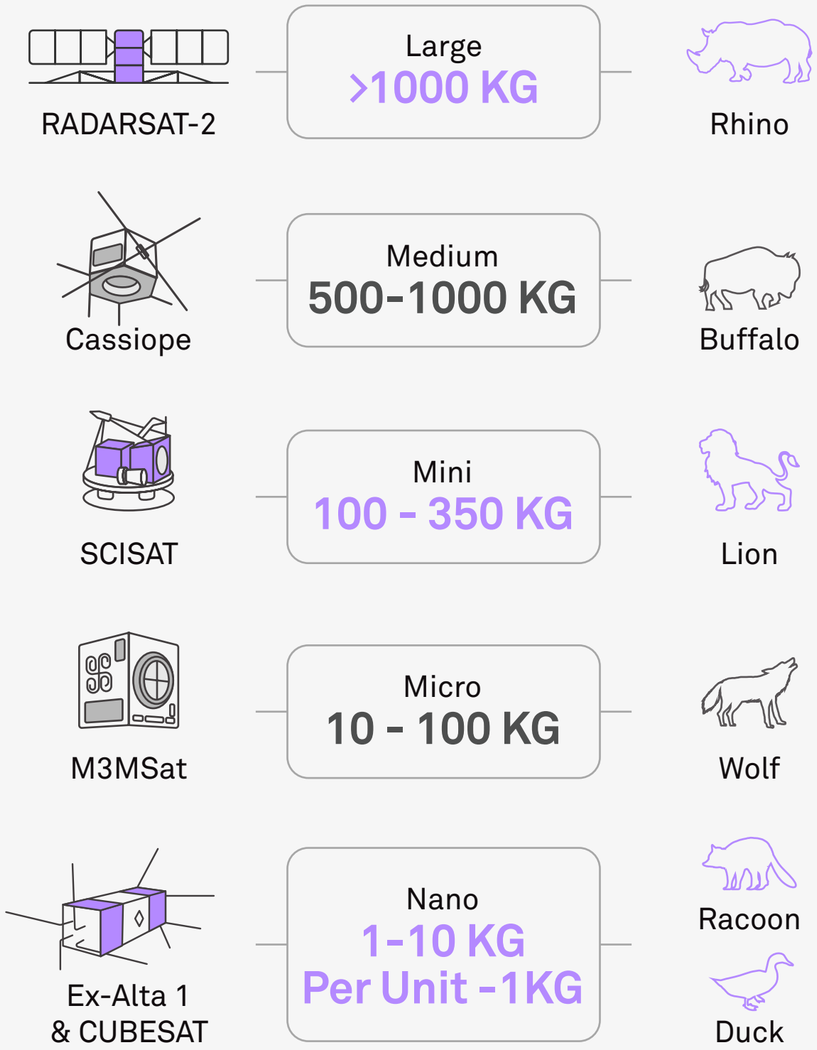
Miniaturization and cubesats

The other variable of the space tech affordability equation is the cost of Satellites. Satellites, just like consumer electronics, are on the trend of miniaturization, reducing the size and weight while trying to maintain the functionalities of traditional satellites, leading to the development of CubeSats.

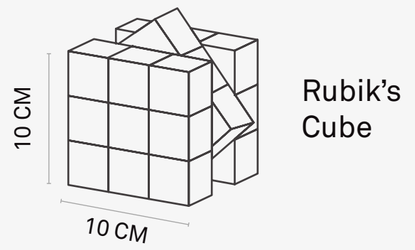
CubeSat, in a nutshell, is a modular platform where a satellite can be configured in multiple formats of standard modules measuring 10cmx10cmx10cm, approximately the size of a Rubik's cube weighing about 1kg. The module is an independent functioning satellite on its own but can also be grouped together with up to 24 modules.

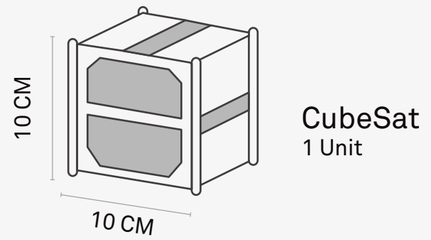
Two major financial factors associated with the payload (Satellite) launch are the cost of satellite assembly and the cost of launching a satellite.

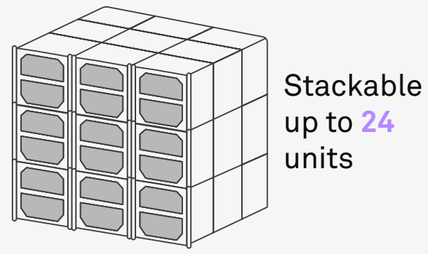
How heavy is a satellite



CubeSat
Dimensions & modularity







Source: Canadian Space Agency

Beyond the economies of scale realized by reusable rockets, CubeSats, with their limited size, do not require a dedicated launch vehicle for their launch and can hitch a ride in the extra capacity of a scheduled payload launch.

With reduced costs and simplified deployment processes, CubeSats have empowered a new generation of space enthusiasts to participate actively in scientific experiments, Earth observation, communications, and more.

Transforming agriculture with CubeSat

CubeSats are transforming the way we monitor farms and agricultural operations. By equipping these satellites with high-resolution multispectral and hyperspectral sensors, they can capture detailed imagery of farmland.

An example of this is services provided by one of the most prominent players in the CubeSat market, Planet. Planet manufactures and operates one of the largest fleets of earth observation satellites, making the highest near-daily frequency of earth observation data commercially available.

The use of satellite imagery for Earth observation and farm monitoring is not new and has been done by traditional satellites before, but what makes Planet's satellites (CubeSats) unique are:

1. Higher frequency of image capturing with a near-daily data scan of all of Earth's landmass.
2. Ability to monitor smaller farms with approximately 3-meter resolution.
3. Cost-efficient and accessible in comparison to traditional satellites.

Precision farming

One of the primary applications of CubeSats in agriculture is precision farming. By equipping these satellites with high-resolution multispectral and hyperspectral sensors, they can capture detailed imagery of farmland.

This imagery aids in identifying variations across the following parameters.

Crop health

Throughout the various growth stages of crops, plants emit distinct spectral patterns, forming a reference for their health status and revealing irregularities in their development. When plants are damaged, or experience decreased vitality, the reflected light quantity changes. Decreased vitality can be due to multitudes of reasons, including pest and disease outbreaks.

Identifying and mapping these changes in vigor aids farmers as they direct their scouting efforts, pinpointing necessary interventions, and enhancing resource allocation in those specific regions.

Resource planning (workforce, seed, irrigations, fertilizers, and pesticides)

The data provided by CubeSats can play an integral part in managing all resources in order to practice precision farming practices. If agronomists or farmers are monitoring the vegetative health of each sector of the farm, with CubeSats, they can experience the following benefits:

1. A reduced manual effort to pinpoint the areas that need attention (directed scouting).
2. Optimized use of the resources: Instead of using pesticides throughout the field, farmers can now target specific areas of interest (AOIs), reducing resource costs and air pollution caused by pesticide drifts.

3. Access to archival images can help agronomists (experts in the science of soil management and crop production) in helping farmers with seeding strategies focusing on historical high-yield areas and stable soil zones.

4. Early indicators of any pest or disease can be treated with a precise solution that reduces the onset of symptoms and lessens the impact to adjacent fields.

Farming subsidies verification

An example of this is CAP (Common Agricultural Policy) of the EU, under which farmers following the sustainable land use guidelines are eligible for green direct payments. Farmers receive the green direct payment if they comply with three mandatory practices that benefit the environment (soil and biodiversity in particular).

1. **Crop diversification**
   A greater variety of crops makes soil and ecosystems more resilient.

2. **Maintaining permanent grassland**
   Grassland supports carbon sequestration and protects biodiversity (habitats).

3. **Dedicate 5% of arable land to areas beneficial for biodiversity**
   Ecological focus areas (EFA), for example, trees, hedges or land left fallow that improves biodiversity and habitats.

Ensuring accurate assessment and payouts for each farmer under the policy requires a team of on-ground auditors to visit and verify the farmers' eligibility.

The application of CubeSats is already assisting in the tedious auditing process for subsidies. The geospatial data currently being captured by CubeSats, deployed by organizations like Planet, is helping to reduce the manual effort for auditing agricultural land. This assists the paying agencies as they produce accurate subsidy payments to each farmer.[1]

Corporate farming contract management

Farming contract management is an important activity that several organizations have to manage, especially food, beverages, textiles and alcohol companies.

These contracts hold a crucial value for the organizations as they directly contribute to the inventory, production risk, supply chain risk, and sustainability. Managing these risks requires a certain investment and effort to ensure that risk is measured and mitigated with minimum disruption to business.

CubeSats provide a new-age solution to monitor the risks involved by providing organizations with measurements of crop health, yield and sustainability aspects. The data can reduce the cost and effort for auditing the growth, planting timelines and possible yield with a much higher frequency than manual field visit monitoring.

Once they have this level of information at hand, managing supply chains and mitigating any risk – which may or may not be due to farming operations – becomes easier, e.g., in the case of low yield situation, procurements teams will have longer lead time to contract and procure the expected raw material shortfall, giving the organization a competitive advantage over others.

Further innovations brought in by CubeSats.

Scientific & technological research

CubeSats have opened up unprecedented opportunities for scientific research in space with applications across the gamut of spectrum, like

studying phenomena such as Earth's atmosphere, climate change, space weather, and celestial bodies.

CubeSats are also serving as testbeds for new technologies and innovations. Their small form factor and lower risk profile make them ideal for demonstrating novel instruments, propulsion systems, communication technologies, and advanced materials.

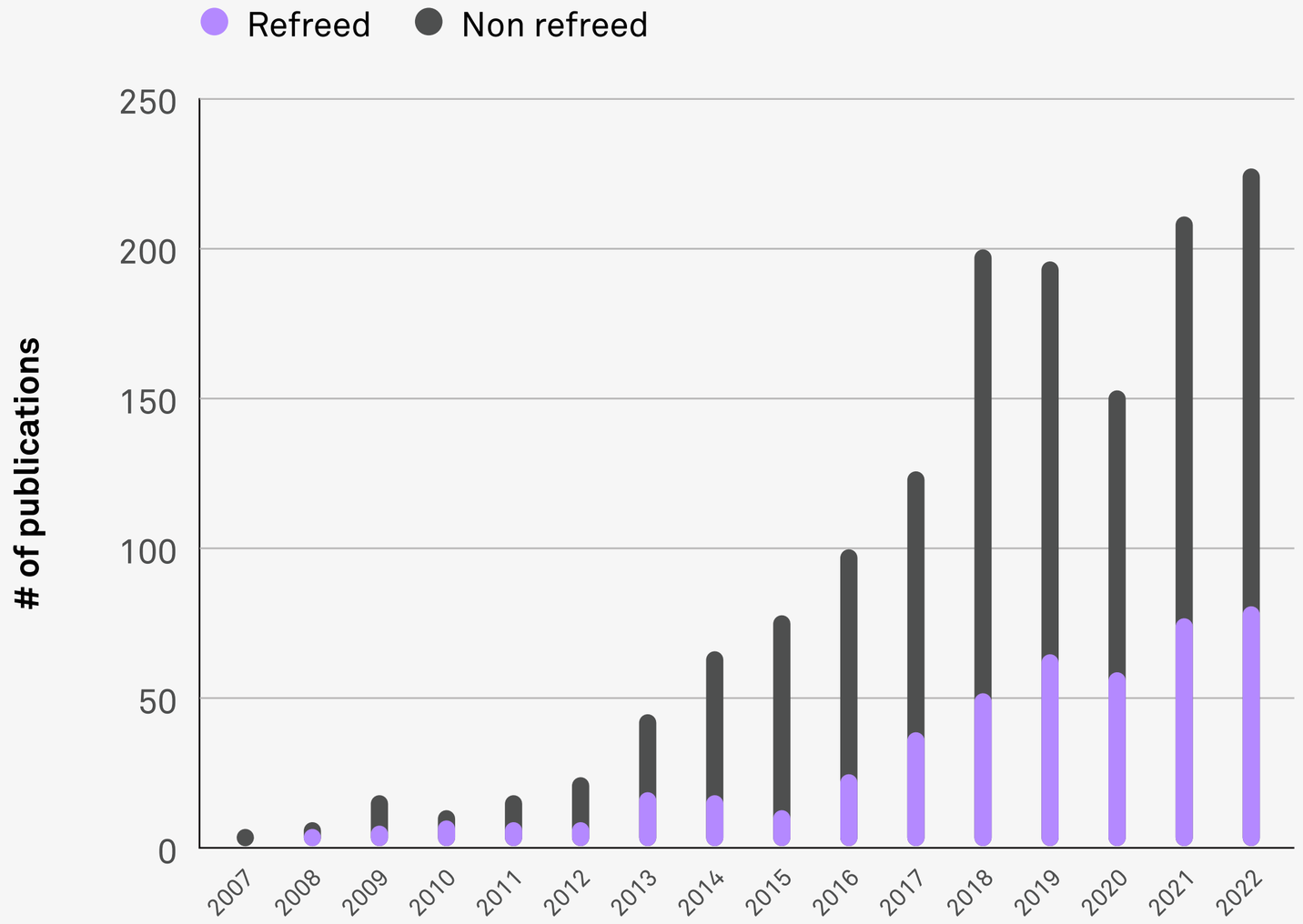
CubeSats have been utilized to validate concepts that could eventually be scaled up for larger missions, paving the way for future advancements in space technology.

An interesting metric that can provide the kind of impact CubeSats have had on research can be seen in the graph on the right. Showcasing the rise of research papers referencing CubeSats in their research papers.

Education and capacity building

Interdependent subsystems remain one of the most challenging concepts to grasp in aerospace engineering, but at the same time, it is a crucial concept that determines the success of space missions. While theory around the subject has been available for a few decades, a hands-on approach and active engagement are proving to be essential for budding scientists and engineers. Traditional satellites have been an expensive affair that limits the

No. of publications as a function of year with terms "CubeSat" or "CubeSats" in the NASA/ADS abstract service



opportunity for students to have an active involvement in the development of a space system and with limited experience through internships in industry.

CubeSats offer a feasible alternative with the advantage of generally shorter development timelines, fewer requirements due to a less complex system, a briefer mission duration, and typically a greater tolerance for mission-related risks.

Business models in the next generation of space services

Since its introduction to software in 1960, the As-a-Service model has permeated most, if not all, sectors in one way or another. The model has historically proven to increase the affordability factor from software services to infrastructure accessibility like cloud platforms, rocketing the rate of innovation as well. Space technology industry now adds to that list with the as-a-service model being adopted across the industry in multiple ways. The following models have the potential to increase affordability and flexibility for organizations to tailor their space technology strategy.

1 Data-as-a-Service

The first and the most obvious one is Data as a service. To put the model into perspective, consider organizations providing CubeSats services like Planet. Let us take an example of collecting and delivering geospatial imagery data for Agriculture. The customer with the need for geospatial imagery data for a specific piece of agricultural farm/land will pay a subscription fee to obtain imagery of specified AOI (Areas of Interest).

Additionally, organizations can also offer customer archival data to carry out analysis on any historical data, providing them with trends and insights over a longer period of time.

2 Satellite-as-a-Service

A host/multi-tenant satellite can reduce costs and speed up space technology development, especially in software. This approach is akin to cloud computing's IaaS or PaaS, enabling customers to perform missions and experiments as needed. The platform is designed as a development and qualification service with the potential to host customer applications based on its capabilities.

3 Ground-as-a-Service

Ground as a Service is a service-based model for satellite operations' ground segment, where a provider manages the physical infrastructure and provides software tools and systems for operating the ground segment and delivering data to the customer. Customers can book time on the ground station on a pay-per-use basis, providing flexibility in managing their data transmission needs without the responsibility of owning and operating their own ground infrastructure.

4 Mission-as-a-Service

The primary distinction between the two service types, i.e., Satellite as a Service and Mission as a service, are in a "satellite-as-a-service" platform; customers are responsible for developing the entire suite of mission software. In contrast, the "mission-as-a-service" platform already has multiple pre-existing software packages available to run and operate, depending on the selected mission type.

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[1] Citation: CAP and the environment (europa.eu) Planet Fusion Offers Solutions For The EU's Common Agricultural Policy (CAP)

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