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Small Satellites for Low-Cost Space Access: Launch, Deployment, Integration, and In-Space Logistics

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Abstract

Satellite launches have skyrocketed in recent years, as they become more affordable to smaller businesses in a variety of sectors. They no longer need as much space to construct it after using digital technology to considerably lower the size of its typical satellite communications payload. As a result, they relocated to a smaller space. A downsized payload may now fit on smaller satellites, providing them with more versatile and powerful communications capabilities that they may not have had before. Small satellites and CubeSats have transformed the space industry by providing an efficient alternative for cost-effective space launches as well as undertaking numerous technological demos, scientific research, Earth exploration, and other missions. Furthermore, since they are easier to design, construct, and launch than conventional satellites, these satellites are widely employed by commercial firms, government, military, and non-profit groups. In this article, we look at how the space industry has grown significantly over the years, resulting in a greater number of startups entering the market. Case studies on tiny satellite and CubeSat manufacturers as well as mission integrator firms are covered. This study also discusses how entrepreneurs may construct the CubeSat ecosystem by developing new methodologies and improved subsystems for the efficient operation of CubeSats. Finally, the article explores current trends as well as potential difficulties and advancements in tiny satellite and CubeSat technologies. This study makes it very evident that having private space enterprises is the only way for a nation to become a member of the global space economy. As a result, one of the country's most significant responsibilities is to encourage private firms to participate in space operations.

Keywords

Small Satellites, CubeSats, Space, Low Earth Orbit, Startups, Trends

1. Introduction

Following the growth in popularity of tiny satellites, particularly in the last decade, there has been an increasing interest in the usage of distributed systems or constellations of small satellites. This increase in the usage of tiny satellites has been driven mostly by the shrinking of electronics and sensors, as well as the availability of commercial-off-the-shelf components with growing capabilities, which has considerably reduced the cost of hardware development. The availability of secondary payload launch options improves access to orbit and economics for these spacecraft, particularly for tiny satellites that adhere to defined form factors such as CubeSat. A number of microsatellite-class missions have also successfully proved the usage of tiny satellites in constellations. CubeSats are a kind of satellite that was developed in 1999 with the goal of making space science more accessible to students. Unlike previously notable satellites, which were enormous and costly, CubeSats are compact and inexpensive. CubeSats are the boxy little relatives of the Hubble and Landsat, having a standardized size scheme of a 10 square centimeter unit. Their design has made them especially influential in terms of increasing engagement in space, giving hands-on teaching possibilities, and allowing new, exploratory space research (Selva et al., 2017), (Novak et al., 2022).

While the transition from huge satellites in geostationary orbit to low Earth orbit constellations had many experts predicting a future in which GEO systems would be less important, that hasn't happened. Instead, it seems that diversity is the trend in both commercial and government sectors. The future isn't a GEO thing or a non-GEO thing; it's really this sort of hybrid, multi-orbit solution that really relies on what types of missions and customer bases our operators and customers are essentially trying to reach. On the government side, the desire for hybrid systems is primarily motivated by the assumption that having many satellites in multiple orbits makes it more difficult for adversaries to knock down huge swathes of capability all at once. The satellite service is transitioning to more robust architectures with various capability combinations across several orbits. If the industry wants to transition from huge, monolithic systems to hybrid, diverse space architectures, it cannot continue to develop costly satellites with exceptional mission assurance. They must prioritize cost reduction as the primary motivator for developing very dispersed systems that are durable in battle. Unless industry develops in tandem with the government, the government will be unable to fund a dispersed, resilient force architecture (Ruiz-de-Azua et al., 2021; Kodheli et al., 2020).

Small satellites are more accessible to users outside of government organizations and commercial businesses, which has traditionally led to satellite development and launch. Universities, small country space agencies, citizen scientific organizations, start-ups, amateurs, and even artists are among the new users. The significance of small satellites in increasing involvement in, and hence expanding access to, space research has a number of advantages for science and society (Novak et al., 2022), including:

- Improved science, technology, engineering, and math (STEM) education for university and high school students: CubeSats allow students to get hands-on experience in aeronautical engineering (Heidt et al., 2000).
- New sorts of research: Standard satellites are costly and time-consuming to develop. As a result, they are mainly utilized on low-risk missions. CubeSats, on the other hand, are ideal for exploratory, high-risk research because of their low cost and rapid construction.
- Faster innovation: Small satellites and CubeSats allow new users from all fields to contribute their ideas and unique skill sets to small satellite design. Solutions to difficulties in space and on Earth may be quicker and more creative with more and more varied contributors.
- Public engagement: The accessibility of small satellites and CubeSats gives members of the public greater control over the scientific problems they address. Citizen scientists, for example, employ CubeSats to undertake space experiments of interest, such as those that expand our knowledge of Earth. The ability for the public to participate in and define research agendas helps improve the bond between science and society.

The CubeSat standard was developed in 1999 by California Polytechnic State University (Cal Poly), San Luis Obispo, and Stanford University's Space Systems Development Lab to simplify university students' access to space (Cal Poly CubeSat Laboratory, 2022). Since then, hundreds of organizations throughout the globe have implemented the standard. CubeSat standards primarily aid in the promotion and development of skills required for the design, construction, and testing of tiny satellites designed for low Earth orbit (LEO) that conduct a variety of scientific research roles and explore new space technologies (Puig-suari, 2001). Until 2013, more than half of CubeSat launches were for non-academic objectives, and by 2014, the bulk of newly deployed CubeSats were for commercial or amateur projects. Some CubeSats have been a country's first satellites, having been launched by universities, state-owned enterprises, or private firms. The searchable Nanosatellite and CubeSat Database contains information on over 3200 CubeSats that have been flown or are scheduled to be launched since 1998 (Kulu, 2020).

Today, the number of new space firms that specialize in novel turn-key small satellite missions, including launch and operations for in-orbit delivery, is developing at an exponential rate. These tiny satellite systems have been utilized for a broad range of missions, from student teaching to testing new space technology, from atmospheric and climatic research to maritime traffic monitoring. Government organizations, research institutions, universities, and commercial businesses are among its satellite mission clients (Sweeting, 2018). The tiny satellite and CubeSat platform is a low-cost, quick-delivery technology that fits the performance requirements of a broad variety of applications. Because each mission is unique, these small space firms have concentrated on a design that allows for the correct blend of flexibility, compatibility, and dependability, while concentrating on the mission and payload and minimizing time-to-orbit. The platform is also accessible as an engineering model, which may be used for teaching or interface development (Poghosyan & Golkar, 2017).

Owning and running space infrastructure requires specialist expertise, committed teams, and significant capital investments before real returns can be obtained. Even though tiny satellite advancements have dramatically reduced time-to-market and total cost of ownership, this gap often poses a barrier to the deployment of novel space systems in day-to-day operations (Sweeting, 2018). As seen in **Figure 1**, the satellite-as-a-service model gives all of the advantages of a dedicated space infrastructure without the inconvenience.

Next, this paper is structured as follows: Section 2 reviews the evolutionary development of small satellites. Section 3 discusses case studies on small satellite manufacturers and mission integrators. The discussion shows that the ease and lower cost of access to space and the growing use of small satellites and space activities have attracted new entrepreneurs. Section 4 describes how small satellites and CubeSat drive the space industry in the present and the future. Section 5 provides recommendations. Finally, Section 6 is the conclusion.

2. Review of the Evolutionary Development of Small Satellite

Undoubtedly the most important of these new initiatives was the Motorola-led Iridium Satellite network. The concept that was advanced called for a 66 satellite LEO constellation with spares and included beamforming antennas on the satellites, inter-satellite links, and novel ground antennas that could be made smaller and more effective using digital processing and integrated circuit firmware. This

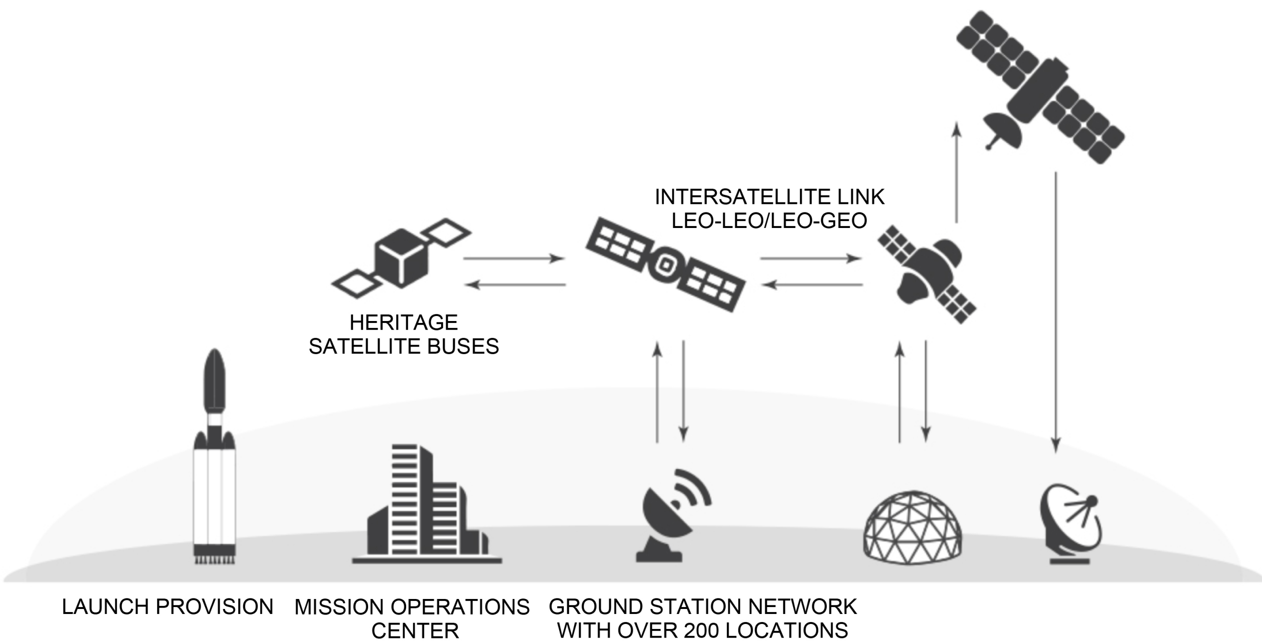


Figure 1. The Satellite-as-a-service concept for space infrastructure (Sweeting, 2018).

ground-breaking LEO small satellite system aimed to break the trend of advancing technology by putting ever-larger satellites into GEO orbits. Motorola and a global network of partners were the driving force behind this project to develop a system using more compact satellites in low Earth orbit. Motorola already had a lot of expertise in manufacturing high-quality, mass-produced consumer goods and handheld radios for cellular communications services, but not much with satellites. In order to develop, produce, and deploy this LEO constellation, it established a global partnership. Along the way, it sought out a number of commercial Intelsat network participants to join the alliance and hired knowledgeable individuals from the global Intelsat community (Dimov Stojce Ilcev, 2022).

The Globalstar was the mobile satellite communications system project that immediately succeeded Iridium. Since they believed there was little demand from seals and polar bears, the goal in this scenario was to launch 50 tiny satellites into a LEO constellation. Additionally, Globalstar planned to use tiny satellites in LEO orbit for voice and data satellites services to portable devices. The INMARSAT network, which ran a number of GEO-based satellites for marine and aviation mobile communications, also decided to spin off a new business. The planning and launch of a constellation of 15 - 18 satellites in MEO orbits got under way with this new project. Finally, the Orbital Sciences Corporation proposed a constellation of relatively small satellites for machine-to-machine communications and store and forward data links (Dimov Stojce Ilcev, 2005).

When handheld units were intended to work from inside a car or another vehicle, the technology for LEO constellations had some link margin difficulties. Nevertheless, despite some initial issues, all three systems (namely, Iridium, Globalstar, and Orbcom) technically functioned and gradually improved in performance. Small satellite constellations, ever-improving ground systems, user handsets, and user terminals have all shown that such systems are capable of directly delivering satellite services to end users. There were undoubtedly issues in high-rise cities, in woods, and inside of vehicles, but these issues may be resolved by second-generation systems with more power (Curzi et al., 2020).

The concept of LEO constellations persisted even if new entrants' ability to offer LEO-based services from "smallsats" in a LEO constellation effectively came to a halt. The environment was altered by a variety of factors. The restructured companies managed to turn a profit after buying the Iridium, Globalstar, and Orbcom satellites out of bankruptcy. The low cost of purchasing the satellites from the insolvent companies contributed to this success in part, and market growth also played a role. All of these systems have now been equipped with second-generation satellites, and it has been determined that each network is financially viable. Systems for ground users have substantially advanced. The market need has grown and new solutions for usage on marine and aircraft systems have improved. Twenty years gives plenty of time for advancements (Lal et al., 2017).

Numerous experimenters have developed innovative and tiny CubeSat designs that are extremely functional, and they have also discovered that they can build these satellites using far more affordable off-the-shelf parts. The eventual result was that these tiny satellites, which measured only 10 × 10 × 10 cm, could be fitted with an incredible capability. They still have a relatively low mass even when expanded up to a three-unit CubeSat (10 × 10 × 30 cm), and their capability is getting more and more incredible. Of course, using less-expensive off-the-shelf components and using smaller satellites in savings. The launch costs have been reduced the most (Millan et al., 2019).

Small satellites developed with an altogether different attitude have begun to replace satellites designed by space agency designers, major aerospace companies, and military organizations. These young inventors' and entrepreneurs' CubeSats served as the foundation for challenging traditional wisdom regarding how huge a satellite needed to be in order to carry out its varied missions. There are already numerous businesses that have grown out of efforts to develop new, more affordable launch vehicles, small satellite businesses for remote sensing, or businesses for satellite networking and communications services, especially in underserved regions of the world (Lappas & Kostopoulos, 2020).

3. Case Studies on Small Satellite Manufacturers and Mission Integrators: ISISpace and NanaAvionisa Corp

NanoAvionics Corp is a high-tech tiny satellite bus manufacturer and mission integrator that was created in 2014 as a spin-off from Vilnius University in Lithuania. The company specializes in the development of commercial and scientific satellite missions, as well as the production of small satellite buses: mission design, hardware assembly, integration and verification, testing campaigns, standardized products (highly integrated communication, on-board computer, attitude determination and control systems, solar panels, structural elements), and modular chemical propulsion systems. It sells four multifunctional satellite buses: M16P, M12P, M6P, and M3P, which are designed to meet 16U, 12U, 6U, and 3U Cubesat requirements, respectively. It also provides modular microsatellite bus MP42 (up to 115 kg) that have fulfilled a broad variety of missions since the company's founding, including remote sensing, enhanced communications, and basic research (California Polytechnic State University, 2020; Mehrparvar, 2014). To assure the practical dependability of its spacecraft, the business employs the most recent technical breakthroughs. As an alternative, critical satellite systems such as the Flight Computer, Payload Controller, Electric Power System, and all others. The company provides a full launch package that includes finding and procuring a suitable launch slot, technical interface control, providing a deployment mechanism, frequency allocation and satellite registration, documentation and logistics, and integration into deployer and launcher; final satellite checkout (Martin et al., 2018).

ISISPACE (Innovative Solutions in Space) is a Delft-based Dutch New Space firm focused on the design, construction, and operation of CubeSats. ISISpace was created in January 2006 as a spin-off from Delft University of Technology's Delfi-C3 nanosatellite project (ISISpace, 2021c).

ISISpace was working on the Brik-II satellite for the Royal Netherlands Air Force in 2017. In Europe, the firm is a market leader in the nano-satellite area. As of October 2019, ISISpace has sponsored the launch of 367 satellites on various launch vehicles. The PSLV, Vega, and Electron rockets are among the launch vehicles that have already launched or are expected to carry payloads for ISISpace. ISISpace also supports small satellite launches via Innovative Space Logistics (ISL), its launch services company, by negotiating piggyback launch chances to low Earth orbit on a range of different launch vehicles. The business specializes on CubeSat bus designs weighing 1 to 30 kg. The business specializes in executing unique turn-key small satellite missions, including launch and in-orbit operations (Andreia, 2021a).

Both firms' products have been utilized for a broad range of missions, from student instruction to testing new technologies in space, from atmospheric and climatic research to maritime traffic monitoring. Government organizations, research institutions, universities, and commercial businesses are among the customers for satellite missions. They offer turnkey small satellite and CubeSat solutions to both government and commercial clients worldwide. To better comprehend CubeSat platforms, this work refers to the ISISPACE CubeSat platform, which includes 16U, 12U, 6U, 3U, and 1U CubeSat specifications, as shown in **Figure 2** (ISISpace, 2021a). These CubeSat platforms are flight-proven, low-cost systems with quick delivery that fulfill the performance requirements of a broad variety of applications.

Your team can concentrate on payload development and operation since the 1-Unit platform provides power, structures, antennae, communications, and an on-board computer. It helps academic studies and experiments, in-orbit demonstration flights, and radio communications operations by providing excellent performance and dependability at a cheap cost. The 3U CubeSat Bus incorporates flight-proven components and provides extensive capabilities in a compact package. The 3-Unit is the CubeSat platform of choice for more complex missions such as maritime safety and vessel tracking (AIS), air traffic monitoring (ADS-B), Signals Intelligence (SIGINT), Internet-of-Things services (IoT), Earth Observation (EO), and Science Experiments, thanks to its precise Attitude Determination and Control, high-end communications architecture, increased electrical power, and a robust Command & Data Handling System. The 6-Unit platform allows challenging military, commercial, and scientific operations in areas like as Signals Intelligence (SIGINT), Geospatial Intelligence (GEOINT), Internet-of-Things (IoT), air traffic surveillance (ADS-B), Earth Observation (EO), and Space Science. The 6-Unit CubeSat platform is the appropriate choice for tactical, communications, and dispersed scientific constellations, and it meets the requirement for a dependable, high-capability, full-featured CubeSat platform. The 12U and 16U Cubesat Buses are outfitted with cutting-edge subsystems

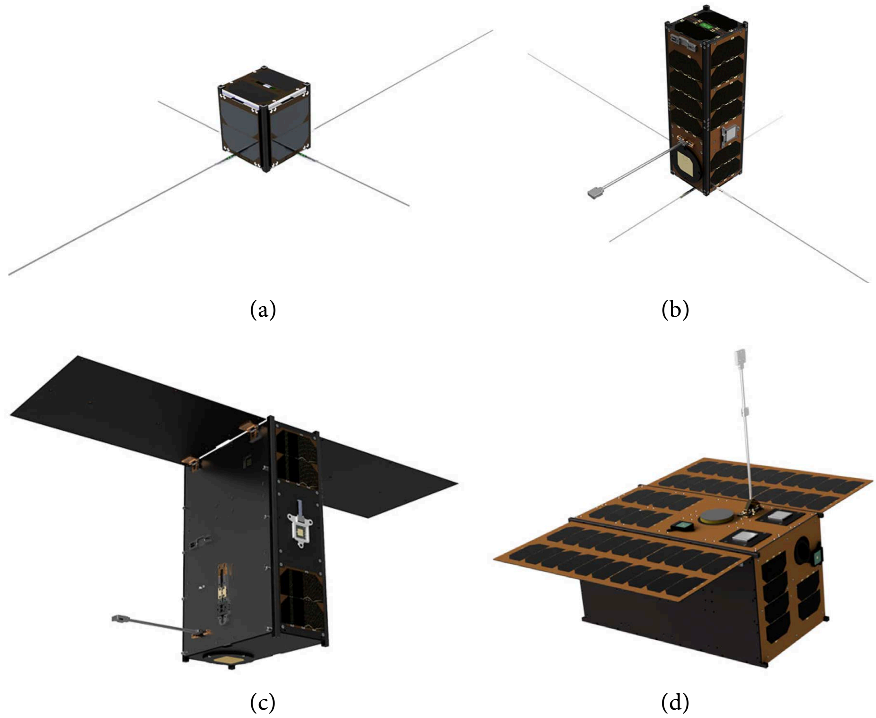


Figure 2. CubeSat platforms (ISISpace, 2021a). (a) 1U CubeSat platform. (b) 3U CubeSat platform. (c) 6U CubeSat platform. (d) 12U/16U CubeSat platform.

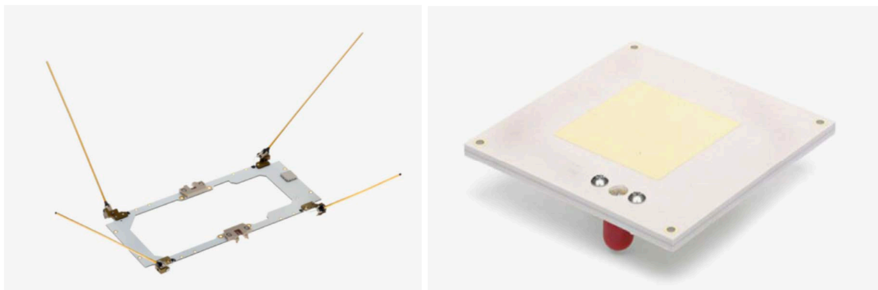
and equipment designed specifically for challenging missions. Allow for 8 - 12 payload units, significant power, a sophisticated attitude/trajectory control suite, and a high-speed payload data connection. These systems are ideal for payload In-orbit Demonstration (IoD), high precision Earth Observation (EO), high throughput communications (RF), or Deep Space missions. The 12- and 16-unit systems provide the capabilities required for moonshot missions (ISISpace, 2021a; Andreia, 2021b).

Both firms may create the desired payload for the spacecraft using their own payload development team or by collaborating with specialist partners. Their diverse teams can accommodate most payload accommodation needs, and they have various collaboration relationships with specialist companies that can create smaller optical payloads if needed. They have successfully produced a variety of RF payloads for missions in the development and accommodation of technological demonstration payloads aboard CubeSats in recent years. **Figure 3** illustrates an example of a CubeSat subsystem (ISISpace, 2021a).

CubeSat satellite subsystems are highly standardized and often available off-the-shelf at set costs and lead times. Antenna systems, attitude control systems, command data processing systems, communication systems, Cubesat structures, launch equipment, ground support equipment, ground stations, power systems, and solar panels are among the subsystems.

As illustrated in **Figure 4**, the Antenna Systems accommodate a broad variety of frequencies in the VHF, UHF, L, and S bands by employing deployable

Figure 3. A CubeSat subsystem (ISISpace, 2021a).



(a) (b)

Figure 4. CubeSat antenna (ISISpace, 2021a). (a) CubeSat UHF Antenna. (b) CubeSat S-band Patch Antenna.

components or patch antennas. These systems offer excellent transmission and reception quality, as well as system dependability, at a low volume. Antenna systems are basically compatible with a broad variety of standardized CubeSat designs as well as custom-made structures that comply to the CubeSat standard. CubeSat communication systems are compatible with a broad variety of frequencies in the VHF, UHF, and S bands (ISISpace, 2021b). These systems are critical components of the communications chain, allowing your satellite to perform both Uplink and Downlink functions.

Both firms provide a low-cost, turnkey solution for tiny satellite ground stations that are intended to connect with satellites in low earth orbit (LEO) that operate in either amateur or commercial frequency bands. S-band, UHF, and VHF frequency bands are all covered. The ground station comprises of an antenna that contains the transceiver, rotor control, and computer, resulting in a highly compact device.

In general, CubeSat Power Electrical System (EPS), as seen in **Figure 5** (Sat-Search, 2022), includes ready-to-use on-board Lithium-Ion batteries with an integrated Battery Management System (BMS), which helps to extend mission lifespan and guarantee proper operating conditions. Because of external battery pack compatibility, the EPS may also be configured with sufficient battery capacity for power-hungry systems. On-board monitoring and logging capabilities enable the user to readily monitor EPS activities in all input and output circuits. In the case of an unforeseen malfunction, the EPS watchdog mechanism

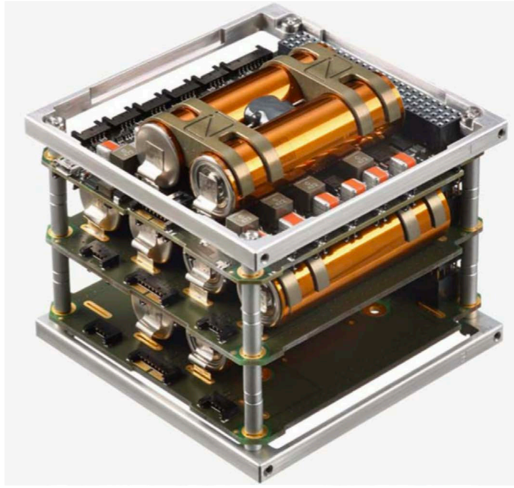


Figure 5. CubeSat power electrical system (SatSearch, 2022).

guarantees that the satellite and EPS are restarted and returned to a reliable, operational state. Additional support gear included with the EPS, such as an external battery charger, enables the user to rapidly and easily set up the system for immediate usage.

The small satellite propulsion system, seen in **Figure 6** (NanoAvionics, 2022c), is modular in design, allowing integration with a variety of current and future small satellite platforms on the market. By altering the capacity of the tank to handle varying propellant quantity demands, the system is intended to be readily scaled to optimize for the client mission. For example, the NanoAvionics CubeSat propulsion system has the potential to save satellite owners up to 80% on restart costs. Furthermore, the system provides for a high thrust-to-volume-to-weight ratio while requiring a very low power budget, making it a highly competitive and proven option.

Essentially, manufacturers of tiny satellites and Cubesats, as well as mission integrators, will provide fully serviced launch options. They understand how difficult it may be to identify the optimal launch for a launch mission. They have created standard launch hardware interfaces and procedures, as well as a network of critical partners and suppliers, in order to maximize launch services. Rideshare launches for microsatellites, nanosatellites, and CubeSats are offered on a variety of launch vehicles on a regular basis. ISISPACE, for example, has completed or sponsored many launch campaigns using different launch vehicles, successfully launching 467 CubeSats and 1 spacecraft into orbit. Last year, SpaceX's Falcon 9 rocket successfully deployed dozens of small satellites into Sun-Synchronous Orbit for ISISPACE's commercial and government customers from Space Launch Complex 40 (SLC-40) at Cape Canaveral Space Force Station as part of the SpaceX SmallSat Rideshare Program mission, setting a new world record (Swartwout, 2013).

In general, GaAs (Triple junction GaInP/GaInAs/Ge epitaxial structure) solar

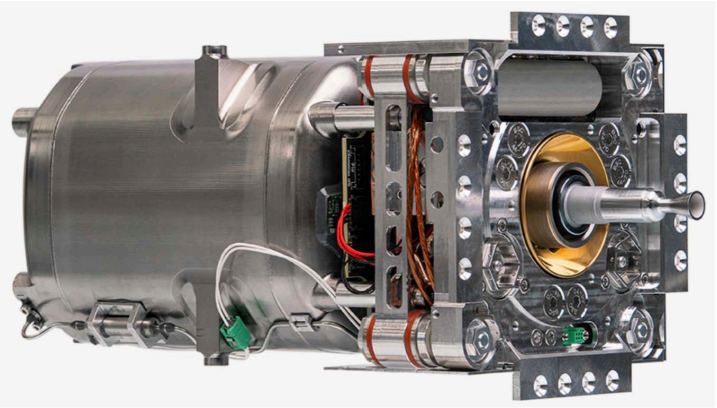


Figure 6. A small satellite propulsion system (NanoAvionics, 2022c).

arrays for CubeSat solar panels are composed of high-performance triple junction space grade solar cells that allow missions with high power needs. These solar cells feature a maximum efficiency of 29.5 percent with an inbuilt by-pass diode to prevent series-connected solar cell strings from shadowing effects. Solar cells are constructed in a clean room environment utilizing NASA designated low outgassing adhesive adhesives to ensure acceptable quality. The panel is constructed with internal copper ground planes for increased EMI compatibility and circuit design without current loops to avoid spontaneous satellite spin up to prevent interference. **Figure 7** depicts a solar panel structure (NanoAvionics, 2022a).

The SpaceX Transporter-4 mission contained three satellites constructed for several clients by small satellite mission integrator NanoAvionics. MP42 is NanoAvionics' biggest satellite to date, designed and launched using one of the industry's first commercially available modular microsatellite buses. The MP42 mission is a rideshare mission that is part of the company's continuing program. It will house a variety of payloads, including OQ Technology's "Tiger-3", which will add another satellite to their 5G IoT/M2M (machine-to-machine) communication constellation, and VeoWare's RW500 fully integrated reaction wheel (NanoAvionics, 2022b).

The two additional satellites, launched atop NanoAvionics' flagship M12P and M6P nanosatellite buses with SpaceX's Falcon-9 launch vehicle, are specialized telecommunications and Earth Observation missions. Another of Lacuna Space's IoT (Internet of Things) gateways was also sent into space. The British-Dutch firm, based in Harwell, UK, is building a worldwide network to link low-cost and low-power IoT devices. The Lacuna Network uses LoRaWAN to link even the most distant places of the globe where traditional connection is not financially feasible. NanoAvionics has taken a step closer to capturing a sizable piece of the lucrative microsatellite market with the debut of the MP42. It is an expansion of the company's end-to-end small satellite mission infrastructure, which includes mission design, manufacturing, launch brokering, ground segment, and satellite operations.

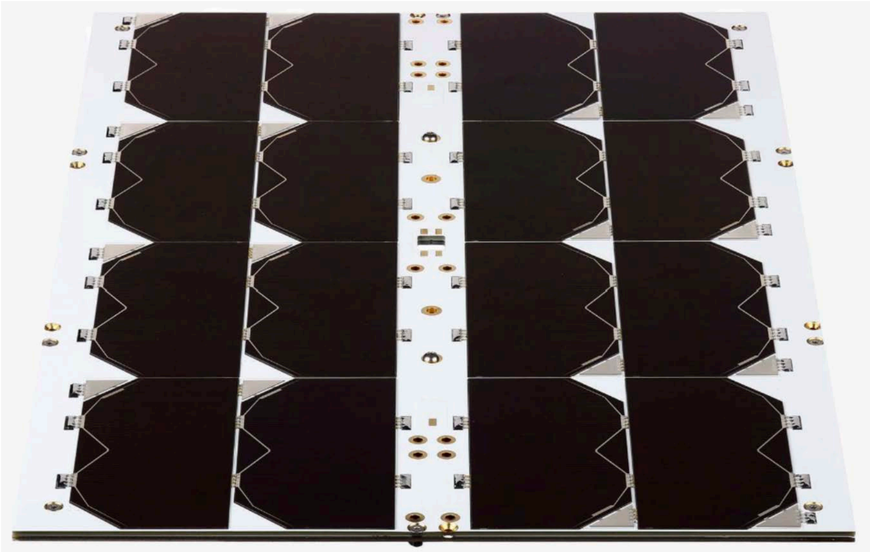


Figure 7. A solar panel structure (NanoAvionics, 2022a).

The MP42's basic architecture and modular design enable considerably faster integration and deployment of spacecraft than other available options, greatly lowering time-to-market. The MP42 mission also marks the conclusion of NanoAvionics' GIoT (Global Internet of Things) R&D project, which aims to deliver constellation-as-a-service to current and developing IoT/M2M operators in a business-to-business configuration. After receiving specialized financing from the European Commission's Horizon 2020, ESA's ARTES, and private investments, the business created the project alongside consortium partners KSAT and Antwerp Space. The satellite houses various essential enabling technologies developed during the course of the GIoT project, such as an inter-satellite connection and a next-generation payload controller.

ISISPACE designed, manufactured, and tested the satellite platform and ground segment for the Royal Thai Air Force's first Earth Observation CubeSat, NAPA-1 6U CubeSat, as depicted in **Figure 8** (Krebs). The primary cargo is a Gecko Imager from the South African firm SCS, capable of imaging in the RGB-band with a ground sampling distance of roughly 39 m from the normal Low Earth Orbit. The fulfillment of this milestone comes much later than expected owing to a launch delay caused by the failure of an earlier flight, followed by the global pandemic scenario, pushing the launch of Napa-1 all the way to September 3, 2020. There is also a secondary payload, which is a demonstration model of Simera Sense's TriScape 100 Imager, with a target ground sampling distance of 5 m from the normal Low Earth Orbit. ISISPACE is still under contract to maintain the RTAF ground station in Thailand and to provide satellite operations assistance as needed. In the meanwhile, they are working on the second RTAF satellite, Napa-2.

4. Small Satellites and New Space Exploration

Every year in the New Space Age, new developments and discoveries are made

Figure 8. NAPA-1 6U CubeSat of RTAF, Thailand (Krebs).

that provide new possibilities for governments and businesses of all sizes and industries. In 2018, 253 satellites weighing between 1 and 50 kg were launched around the world, a figure that is expected to rise significantly in the coming years. More and more entrepreneurs, businesses, and governments are able to launch their own satellites. In fact, SpaceWorks anticipates 513 to 745 launches in 2023. If such projections come true, the number of tiny satellites launched into orbit would more than double in the next five years. In the best-case scenario, it would almost treble (Disruptive Investing, 2021).

Some of the advancements we will witness in the future of tiny satellites (more data processing and transmission capacity, artificial intelligence, propulsion systems, and so on) are strongly tied to the rising trend of using bigger CubeSats. In order to meet these increased demands, the 6U and 12U platforms are gaining traction in the industry.

The space industry is heading toward a future with vast constellations of tiny satellites capable of offering all sorts of services over large geographical regions or throughout the world. As a result of this shift, satellite coordination and administration face new problems. Some solutions, such as ISL (Inter-Satellite Link) communication technology, will aid in the optimization of coordination amongst CubeSats in the same constellation, allowing satellites to interact with each other for a variety of reasons. CubeSats, for example, will be able to send data in space without the need of middlemen, thus the satellite with direct eyesight of the ground station will be responsible for collecting and downloading all of this information through a high-speed connection. These advancements will also enable highly accurate formation flights, which will aid in the coordination of CubeSats working together on applications like SAR (Synthetic Aperture Radar), which demand a high degree of precision and are otherwise only attainable with huge satellites (ALEN Space, 2019).

This dedication to improved CubeSat cooperation has also resulted in the development of satellite docking projects, which will be implemented in the next years. This method provides the capacity to deliver on-orbit services such as refueling or even to "piece-build" a bigger satellite in space, allowing various CubeSats to operate as building pieces of a larger structure. The utilization of sensors and thrusters would allow for the accuracy necessary to link two or more tiny spacecraft in orbit. Artificial intelligence (AI) is also making its appearance in space. If we concentrate on the future of tiny satellites, we will see significant gains. To begin, consider autonomous diagnostics based on telemetry, which will be available owing to artificial intelligence systems that will predict future issues based on current telemetry data from satellites.

Another intriguing feature is the use of AI for on-board information processing and download data reduction. This pre-processing of information, for example, would allow Earth observation or Signals Intelligence (SIGINT) programs to carry out the analysis in orbit and download just the exact data or pictures required for the operation. Another prospective use of artificial intelligence is autonomous learning systems for satellite constellation management (Disruptive Investing, 2021). The control of large CubeSat constellations will be optimized by intelligent ground station networks and autonomous learning algorithms. Artificial intelligence will aid in the simplification of all duties related with satellite operation and the services they supply.

Some of the most common Cubesat applications need substantial data processing and transmission capacity. This is one of the most significant technological hurdles that tiny spacecraft will face in the New Space Age. Some CubeSats have already begun to contain Ku-Band and Ka-Band transmitters with data speeds of hundreds of megabits (Mb) per second, if not gigabits (Gb). These technologies need increased power consumption in order to enhance data transmission capacity, implying the necessity for bigger satellites. Another path that the industry may take in the next years is to use laser communication technologies to attain extremely high data transfer speeds. This approach requires tremendous accuracy in order for the satellite's laser beam to be properly aligned with the receiver on Earth while in LEO orbit at a speed of roughly 7.8 kilometers per second.

Many CubeSat projects do not need satellite propulsion systems to perform the goal for which they were created, yet this is a solution that may be effective in some sorts of missions. In the next years, the future of tiny satellites indicates to a growth in the employment of electric, chemical, or water propellants that enable CubeSats to move in a controlled and purposeful manner without relying on passive techniques. These propulsion technologies, for example, enable tiny satellite orbits to be modified or adjusted (Lappas & Kostopoulos, 2020).

One of the sector's key worries is the existence of space trash in Earth's orbit, which presents a danger to operational satellites. Today's CubeSats are meant to hit the Earth's atmosphere at the end of their useful life and dissolve without leaving a trace, however this process may take years in certain situations, and if anything goes wrong, they may wind up as space trash. The de-orbiting systems are in charge of directing the process of orbital detachment and controlled destruction. The industry is moving toward bettering these methods, which are in part tied to the propulsion systems we've just examined. These active de-orbiting systems use electric, chemical, and aqueous propellants to guide the CubeSat back into the Earth's atmosphere after its mission is over. Work is also being done to improve the efficiency of passive de-orbiting devices, such as braking employing Air Drag Augmentation Devices (DADs) and magnetic torques or inertia wheels. Of both situations, these are significant steps toward the goal of reducing the amount of danger connected with the growth in space trash in Earth's orbit in the future years.

The small size of CubeSats necessitates creative solutions for equipment that goes on board satellites in order to take up as little space as feasible. Antennas are one of the areas where the greatest development has been achieved and where significant improvements are predicted in the next years. There are existing projects that use the Japanese art of origami in this arena, such as NASA's RainCube project. The parabolic antennas are folded to take up as little space as possible before being unfurled in orbit. These folding techniques enable larger and better antennas in space, with all the implications for enhancing communications and the future of tiny spacecraft (Millan et al., 2019).

The rising frequency of CubeSat launches and tiny satellite constellations will result in the introduction of new laws that will enable all new projects to be accommodated safely and without hindrance. These rules might apply to frequencies, orbits, quality standards, cyber security, or de-orbiting systems, among other things. Fresh Space is an endless supply of new business prospects. New and potential technological developments in tiny satellites are developing in the future, which will assist enhance the practical uses of CubeSats (Novak et al., 2022).

5. Recommendation

Some common issues come up in the global context of developing space nations, not the least of which is the requirement for a strategic vision and the urgency with which the necessary framework must be put in place to support the growth of the space industry, be it from a legal standpoint, the requirement for a strategic roadmap, or the requirement to increase knowledge and expertise. There is a need to create and establish a long-term strategy for space activities that will outline the direction for sustainable activities and capacity within the sector, address which industries should be prioritized, maintain workforce skills, and make the most of already existing resources. In order to create a more integrated economy, it is necessary to design a plan for maximizing the advantages of space operations and utilizing space to support other industrial sectors and socio-economic development programs.

For many developing space nations, teamwork and international cooperation are crucial, particularly when it comes to facilitating access to space, developing infrastructure, and guaranteeing workforce training. Complementarity is made possible by being a member of an international system, which also enables more developed space nations to assist developing ones. Emerging space states can foster cooperation by utilizing each nation's national resources and competitive advantages. Emerging space states must address how to incorporate space into many market sectors and develop broad public acceptance. Space operations must include education of the public about the advantages and necessity of funding space exploration.

6. Conclusion

Tiny satellite data service providers, small satellite service providers, remote sensing service providers, technical service providers, and investors all have a lot of promise with small satellite systems. The market is one of the most profitable segments of the space business. Small satellite investments have been driven by factors such as flexibility, cheap cost, sophisticated mechanics, simplicity of assembly and launch, mass manufacturing, and short life cycles. As new technologies emerge and more satellites come up, the volume of satellite data and the variety of uses for that data will continue to rise in the future. The accessibility of small satellites, or Cubesats, has permitted their expansion and benefitted many diverse groups and use cases. They have paved the way for fresh research and faster innovation.

Interestingly, earth observation businesses or satellite imaging startups are redefining the market by employing tiny satellites rather than the massive and hefty satellites that national space agencies deploy every year. CubeSats have rendered satellite hardware less important than previously thought. The earth observation business is experiencing a paradigm change in terms of manufacturing cycle time, or the time it takes from idea to satellite launch. CubeSats have forced companies to think outside the box in order to fit as much hardware and sensor capability as possible into a small box, which has resulted in some interesting innovations where companies use rather interesting pieces of commercial off-the-shelf equipment that would never have been the case with conventional satellites. The cost of failure for traditional satellites was much too high to enable corporations to experiment in the way that CubeSats allow them to.

The rising commercialization of space operations has resulted in the emergence of a new generation of space firms. The most successful of these private enterprises have resulted from persistent collaboration and assistance from government authorities. To present, the New Space industry has garnered several billion USD in investment, with this figure projected to expand in the next years as more government and private sector assistance is provided. Finally, open cooperation is the greatest method for the New Space economy to thrive, not just between nations but also between private firms and governments, research institutions and for-profit organizations. The prospects for commercialization of space are limitless, and only increasing cooperation will allow us to capitalize on this most promising of marketplaces. The space industry has shown to be a major socioeconomic development engine, thus nations must embrace space activity.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

ALEN Space (2019). *10 Predictions about the Future of Small Satellites and New Space*.

Andreia (2021a). *The Netherlands Launches Its First Military Nanosatellite*. ISISpace. https://www.isispace.nl/news/the-netherlands-launches-its-first-military-nanosatellite

Andreia (2021b). *Time to Make a Difference—Rebranded ISISPACE Celebrates Its 15th Anniversary*. ISISpace. https://www.isispace.nl/news/time-to-make-a-difference-rebranded-isispace-celebrates-its-15th-anniversary

Cal Poly CubeSat Laboratory (2022). *The CubeSat Standard*. Cal Poly CubeSat Laboratory at California Polytechnic State University. https://www.cubesat.org

California Polytechnic State University (2020). *Cubesat Design Specification* (p. 12). Cal Poly SLO.

Curzi, G., Modenini, D., & Tortora, P. (2020). Large Constellations of Small Satellites: A Survey of Near Future Challenges and Missions. *Aerospace, 7,* 133. https://doi.org/10.3390/aerospace7090133

Dimov Stojce Ilcev (2005). *Globle Mobile Satellite Communications*.

Dimov Stojce Ilcev (2022). *The Iridium LEO Satellite System for Global Mobile Communications*.

Disruptive Investing (2021). *The Future of Space, What's in Store for the Coming Years*.

Heidt, P.-S. et al. (2000). *CubeSat: A New Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation*.

ISISpace (2021a). *CubeSat Subsystems*.

ISISpace (2021b). *CubeSat UHF Antenna System*.

ISISpace (2021c). *Disruptive Space Solutions for a Better Tomorrow. Turn-Key Mission/Launch Services/Components*.

Kodheli, O., Lagunas, E., Maturo, N. et al. (2020). Satellite Communications in the New Space Era: A Survey and Future Challenges. *IEEE Communications Surveys & Tutorials, 23,* 70-109. https://doi.org/10.1109/COMST.2020.3028247

Krebs, G. D. "NAPA 1, 2 (RTAF-SAT 1, 2)". Gunter's Space Page. https://space.skyrocket.de/doc_sdat/napa-1.htm

Kulu, E. (2020). *Nanosatellite & CubeSat Database*.

Lal, B., de la Rosa Blanco, E., Behrens, J. R., Corbin, B. A., Green, E. K., Picard, A. J., & Balakrishnan, A. (2017). Small Satellite Scenarios and Drivers. In B. Lal, *et al.* (Eds.), *Global Trends in Small Satellites* (pp. 2-1-2-20). Institute for Defense Analyses. http://www.jstor.org/stable/resrep22890.5

Lappas, V., & Kostopoulos, V. (2020). A Survey on Small Satellite Technologies and Space Missions for Geodetic Applications. In V. Demyanov, & J. Becedas (Eds.), *Satellites Missions and Technologies for Geosciences* (pp. 1-9). IntechOpen. https://doi.org/10.5772/intechopen.92625

Martin, H. B., Brown, C. G. L., Prejean, T. A., & Daniels, N. D. (2018). Bolstering Mission Success: Lessons Learned for Small Satellite Developers Adhering to Manned Spaceflight Requirements. In *32nd Annual AIAA/USU Conference on Small Satellites* (pp. 2-11). NanoRacks LLC.

Mehrparvar, A. (2014). *CubeSat Design Specification*. The CubeSat Program, CalPoly SLO.

Millan, R. M. et al. (2019). Small Satellites for Space Science: A COSPAR Scientific Roadmap. *Advances in Space Research, 64,* 1466-1517. https://doi.org/10.1016/j.asr.2019.07.035

NanoAvionics (2022a). *CubeSat GaAs Solar Panel.* https://nanoavionics.com/cubesat-components/cubesat-gaas-solar-panel

NanoAvionics (2022b). *First NanoAvionics Modular Microsatellite "MP42" and Two Other NanoAvionics-Built Satellites Were Launched with Falcon 9.*

NanoAvionics (2022c). *SmallSat Propulsion System EPSS.* https://nanoavionics.com/cubesat-components/cubesat-propulsion-system-epss

Novak, A., Schuett, A., Parker, A., Bowser, A., Newbury, E. M. H., & Goguichvili, S. (2022). *The Rise of Cubesats: Opportunities and Challenges*. Wilson Center.

Poghosyan, A., & Golkar, A. (2017). CubeSat Evolution: Analyzing CubeSat Capabilities for Conducting Science Missions. *Progress in Aerospace Sciences, 88,* 59-83. https://doi.org/10.1016/j.paerosci.2016.11.002

Puig-suari (2001). *Development of the Standard CubeSat Deployer and a CubeSat Class PicoSatellite.*

Ruiz-de-Azua, J. A., Calveras, A., & Camps, A. (2021). From Monolithic Satellites to the Internet of Satellites Paradigm: When Space, Air, and Ground Networks Become Interconnected. In *Computer-Mediated Communication* (pp. 3-5). IntechOpen. https://doi.org/10.5772/intechopen.97200

SatSearch (2022). *An Overview of Satellite Electrical Power Systems (EPS) on the Global Marketplace for Space.*

Selva, D., Golkar, A., Korobova, O., Cruz, I., Collopy, P., & de Weck, O. (2017). Distributed Earth Satellite Systems: What Is Needed to Move Forward? J*ournal of Aerospace Information Systems, 14,* 1-26. https://doi.org/10.2514/1.I010497

Swartwout, M. (2013). The First One Hundred CubeSats: A Statistical Look. *JoSS, 2,* 213-233. https://www.jossonline.com

Sweeting, M. (2018). Modern Small Satellites-Changing the Economics of Space. *Proceedings of the IEEE, 106,* 343-361. https://doi.org/10.1109/JPROC.2018.2806218