How CubeSats Represent a Paradigm Shift in the Space Industry

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The earliest satellites launched into space were small enough to be lifted by hand and placed on top of rockets. As satellite technology evolved, satellites grew in size and power. Today, 65 years after the launch of Sputnik I, thousands of satellites have been launched into orbit and are significantly smaller and more powerful than ever before. The space race was widely followed in the 1960s, but since the moon landing at the end of that decade, spaceflight has receded from the public eye. Over the past 50 years, technological advancements have continued, but have not received much attention from the public, even though satellites have a significant impact on our modern lives. Most people have limited knowledge about modern-day satellite technology and how it directly affects them.

This research paper analyzes the change in satellite technology using the Paradigm Shift STS framework to answer the question: How have CubeSats and microsatellites facilitated a paradigm shift in the aerospace industry?

The CubeSat design is simple, making it easy to build and launch, and its small size also helps to lower production and launch costs. Additionally, the CubeSat's development cycle is much shorter than that of traditional satellites, making it a more cost-effective and efficient option for many missions. These factors have contributed to the increasing popularity and growth of CubeSats in the satellite industry. From an engineering perspective, CubeSats offer a unique solution for space exploration and research, making them an attractive option for governments, research institutions, and private companies.

History of Space Flight

The launch of Sputnik I marked the start of the Space Age and was a turning point in human history. The small beach ball-sized satellite was capable of only sending out beeps on radio waves, but it sparked a new era of exploration and discovery (Rogers, 2019). The USSR soon followed with the launch of Sputnik II, which carried a living creature, a dog named Laika, into space. The US responded with the launches of Explorer I and Vanguard I, which could gather atmospheric data and send it back to Earth. The primary goal of these early satellite launches was to learn more about the upper atmosphere and gather valuable data for scientific study with the eventual goal of sending a human into space. Eventually, NASA landed men on the moon and in doing so built a body of knowledge of space flight and industry to support it. Major American companies today were contractors to NASA back in the '60s and '70s, like Rocketdyne, IBM, Boeing, and General Motors (Kluger, 2019).

The first private satellite, TELSTAR I was launched in 1962 (Smith, 2010) and was the size of a small car and was paid for by AT&T. The cost per pound to put something in orbit in the 1960s was between twenty and fifty thousand dollars (Roberts, 2022). Later, in the '80s and '90s satellites were brought into orbit from the US on the back of the Space Shuttle. This would prove to be the most expensive time to send a satellite into orbit (Roberts, 2022), as the price per pound was about sixty-eight thousand dollars. The space shuttle was an incredibly expensive method of getting into space but due to political pressures and promises that it will get cheaper over time, the United States continued to use the space shuttle as its primary space launch system. Satellites like the Hubble Space Telescope were taken to their orbits this way and many sections of the International Space Station took rides on the Space Shuttle. However, due to the high cost of a launch, mainly large satellites could fly on the shuttle, and small computer components just were not powerful enough yet to be made practical for a space mission.

In 1999 through a joint venture between Cal Poly San Luis Obispo and Stanford, the CubeSat was invented. A CubeSat is a type of miniaturized satellite for space research and exploration. It is a cube-shaped device that is 10 centimeters on each side and has a mass of less than 1 kilogram. CubeSats are designed to be simple and inexpensive, making them accessible to a wide range of organizations, including universities, research institutions, and private companies. Since then, computers have gotten significantly smaller and more powerful. The CubeSat platform coupled with more powerful computational capabilities has revolutionized the field of aerospace research. At the same time, companies like SpaceX are rapidly bringing the cost of launching to space down with technologies like reusable rockets. (Humphreys, 2010)

Paradigm Shift

A paradigm shift is a fundamental change in the basic concepts and experimental practices in a scientific discipline. In other words, it refers to a change in the way people think about and approach a particular field of study. The term "paradigm shift" was popularized by Thomas Kuhn in his 1962 book, "The Structure of Scientific Revolutions". Change can happen due to multiple advancements in technology, discoveries, or a new scientific theory. In engineering, a paradigm shift can occur when a new technology or design concept becomes widely accepted and replaces the previous standard. This effect can be seen with the modern-day shift from the standard Internal combustion engine to electric engines (Zhang, 2022).

One of the ideas that Kuhn (1962) discusses is that scientific progress is not linear but instead undergoes periodic revolutions. During this time practices and long-held beliefs are rewritten or otherwise revised.

Paradigm shift still has its criticisms and detractors. One of the largest criticisms is that of overgeneralization. A paradigm shift can be attributed to almost any significant change or advancement, leading to an overgeneralization of the topic. There is also no clear definition of what a paradigm shift looks like, always requiring justification. This is unlike other STS frameworks, where the framework is used as a tool to get a closer look at a topic, with a paradigm shift, the justification of the paradigm shift is the analysis.

Research Question and Methods

How have CubeSats and microsatellites facilitated a paradigm shift in the aerospace industry?

To contextualize the current space satellite paradigm the history of satellite launches is examined to gain a further understanding of the challenges and obstacles to sending something to space. Looking at modern satellite design helps to characterize the current paradigm, as well as looking at sources that discuss satellites of the 20th century. Looking at the commercial satellite market during the time of the space shuttle, contrasting with the current market with current spaceflight technologies. The sources are news articles, academic studies, and primary sources from engineering firms.

Discussion

The results of this study demonstrate the significant impact that CubeSats have had on the aerospace research industry. Through a comprehensive analysis of current research and industry trends, it is clear that CubeSats have provided researchers with new opportunities to conduct space research and explore new frontiers. In this section, we will discuss the key findings of this study and provide a detailed analysis of the implications of these findings for the future of the aerospace research industry. We will also highlight some of the challenges and limitations that must be addressed to fully realize the potential of CubeSats in space research and exploration.

Modern CubeSat Projects

Previously, lunar missions, that is missions that travel to the moon, were enormous events that required massive missions like Apollo. Developing a lunar probe took decades of planning and design. As a result, only a few dozen satellites are orbiting the moon (Kulu, 2022). In recent years there has been an explosion in lunar satellite projects due to their ability to hitch rides on other planned lunar missions.

One example of a modern lunar CubeSat mission is NASA's Lunar Flashlight mission, which is scheduled to launch in 2024. This mission will use a CubeSat to search for water ice in permanently shadowed regions near the Moon's south pole. The CubeSat will use a laser to create a map of the lunar surface, which will help scientists identify areas where water ice may be present. This information will be valuable for future lunar missions, as water can be used for drinking, growing crops, and even creating rocket fuel (Hayne, 2013).

Another example of a modern lunar CubeSat mission is the Lunar IceCube mission, which is a collaboration between NASA and several universities. This mission uses a CubeSat to study the Moon's water cycle and determine the source of water on the lunar surface. The CubeSat uses a spectrometer to analyze the lunar regolith and search for water molecules. The mission launched in 2022 aboard the Artemis I mission will help scientists better understand the formation and evolution of the Moon (Schauer, 2022).

Overall, modern lunar CubeSat missions are an exciting area of space exploration. These small, low-cost satellites have the potential to gather important data about the Moon and pave the way for future lunar missions. As technology continues to improve, we will likely see even more CubeSat missions to the Moon in the coming years.

University-Based CubeSat Projects

University CubeSat missions are becoming increasingly popular as educational and research institutions look for opportunities to participate in space exploration. CubeSats are small, standardized satellites that can be developed and launched at a relatively low cost. This makes them an ideal platform for universities to conduct research, test new technologies, and train the next generation of space scientists and engineers with real-world experience. Universities like the University of Illinois have had a nanosatellite building class on offer since the year 2000, which has since focused on CubeSat construction (Kroeker, 2016).

One example of a successful university CubeSat mission is the CubeSat for Solar Particles (CuSP) mission developed by the University of California, Berkeley. Launched in 2018, CuSP is a 3U CubeSat that is studying the high-energy particles emitted by the sun, known as solar energetic particles (SEPs). The mission is providing valuable data about the origin and acceleration of SEPs, which can help improve space weather forecasting and protect astronauts in space (Frazier, 2016). An example of an ongoing, in-development mission is XSAS. This is a CubeSat mission from the University of Michigan. It is designed as a 1U CubeSat mission to study advanced solar cell technology and its deployment in space (Senatore, 2010).

University CubeSat missions also provide valuable training opportunities for students. Students involved in CubeSat projects can gain hands-on experience in spacecraft design, development, and operation. They can also learn about project management, teamwork, and communication skills that are essential in the space industry. Many universities have established CubeSat programs that allow students from different disciplines to work together on a common project, providing a unique learning experience. Overall, university CubeSat missions are an exciting and valuable part of the space industry. These small, low-cost satellites are providing important data and testing new technologies, while also training the next generation of space scientists and engineers. As more universities become involved in CubeSat missions, we can expect to see even more innovative research and breakthroughs in space exploration (Alanazi, 2019).

Before the introduction of CubeSat, these kinds of experiments and experiences were simply unattainable for college students. Pursuing innovative ideas like the LightSail 2 in the previous paradigm would cost orders of magnitude more money than it would with CubeSats.

CubeSats In Industry

One example of CubeSats being used in industry is in the field of remote sensing. Companies are using CubeSats to collect data about Earth from space, such as monitoring weather patterns, tracking agriculture, and measuring environmental changes. This data can be used to improve decision-making processes and provide valuable insights for businesses and government agencies.

Another industry application of CubeSats is in the field of communications. Companies are launching CubeSats to provide low-cost, high-speed internet access to remote and underserved areas. These satellites are also being used to test new communication technologies that could be used for space-to-space communication, which could be vital for future space exploration missions. CubeSats are also being used in the field of space-based research and development. Companies are using CubeSats to test new materials, technologies, and designs for use in space. This includes testing the effects of radiation and microgravity on various materials, as well as developing new propulsion systems that could make future space missions more efficient and cost-effective. In addition, CubeSats are being used in the field of defense and national security. Companies are launching CubeSats to monitor the movements of ships and aircraft, detect missile launches, and provide situational awareness to military personnel. These CubeSats can also be used to test new defense technologies and provide valuable data for strategic planning.

Overall, CubeSats are proving to be a valuable tool for the industry. Their small size, low cost, and versatility make them an attractive platform for a variety of applications, from remote sensing to communications, research and development, and even defense and national security. As technology continues to improve, we can expect to see even more innovative uses of CubeSats in the industry in the years to come.

Where Does This Leave the Traditional Satellite Industry?

The traditional satellite industry has been the backbone of modern space technology for decades. However, in recent years, the emergence of CubeSats has disrupted this industry, creating a paradigm shift in the way we approach space research and exploration. While traditional satellites continue to play a vital role in space exploration and communication, the rise of CubeSats has significantly impacted the traditional satellite industry.

One of the biggest changes brought about by CubeSats is their cost-effectiveness. CubeSats are significantly cheaper to manufacture and launch than traditional satellites, making them an attractive option for small companies, startups, and research institutions. This has created a more diverse space industry, allowing more players to enter the market and develop their space technology. Moreover, CubeSats are more accessible to researchers than traditional satellites, allowing for a wider range of scientific investigations. Because of their small size, CubeSats can be used for a variety of applications, including remote sensing, Earth observation, communication, and even interplanetary exploration. In contrast, traditional satellites are large and complex, requiring significant resources for their design, manufacture, and launch. This has made it difficult for small players to enter the market, limiting innovation and scientific advancement in the industry.

However, despite the advantages of CubeSats, traditional satellites continue to be the preferred option for certain applications. Traditional satellites can carry more sophisticated instruments and are capable of covering a wider area, making them more suitable for applications such as weather forecasting, global navigation, and military surveillance (Harris, 2015). Furthermore, traditional satellites have a longer lifespan than CubeSats, which typically have a lifespan of only a few years (Sagnieres, 2017). This makes them more suitable for long-term applications such as satellite-based internet and TV services, which require a stable and long-lasting platform.

In conclusion, while CubeSats have disrupted the traditional satellite industry, traditional satellites continue to play an important role in space exploration and communication. The rise of CubeSats has created a more diverse and accessible space industry, allowing for more innovation and scientific advancement. However, traditional satellites remain the preferred option for certain applications, and their longer lifespan and advanced capabilities make them a crucial component of the modern space technology ecosystem.

The Future of CubeSats and Aerospace Research

The future of CubeSats looks very promising. As technology continues to improve, and more researchers and companies begin to recognize the benefits of CubeSats, we can expect to see even more innovation in this field.

One of the most significant trends in CubeSat technology is the miniaturization of components. As the size of the CubeSat components continues to shrink, we can expect to see even smaller and more efficient CubeSats being developed like the development of computing technology in smartphones. This will enable researchers to design CubeSats that can perform more complex tasks, such as interplanetary exploration or even sample return missions.

Another trend is the increasing use of artificial intelligence and machine learning in CubeSats. As CubeSats become more autonomous, they will be able to collect and analyze data in real time and adjust their mission objectives on the fly. This will enable researchers to perform more sophisticated scientific investigations and make more informed decisions about their CubeSat missions. Additionally, CubeSats are likely to play a significant role in space exploration in the coming years. CubeSats have already been used in missions to explore the Moon and Mars, and we can expect to see more CubeSat missions in the future, exploring other planets and moons in our solar system. Finally, the increasing popularity of CubeSats is likely to drive even more innovation in the field of space technology. As more companies and research institutions invest in CubeSats, we can expect to see new applications and technologies emerge that will push the boundaries of what is possible in space exploration and communication.

The future of CubeSats looks very bright. As technology continues to improve, and more researchers and companies begin to recognize the benefits of CubeSats, we can expect to see even more innovation in this field. With their small size, affordability, and versatility, CubeSats are poised to play a significant role in the future of space exploration and communication.

Conclusion

In the decades since their inception, CubeSats have grown in popularity and adoption in the aerospace research community. Looking back, they represent a paradigm shift in the accessibility of space research, democratizing a formerly inaccessible frontier. As we continue to explore the possibilities of CubeSats, it is clear that they are a powerful tool for advancing our understanding of the universe and for developing new technologies that will benefit humanity. Whether they are used for Earth observation, communication, or interplanetary exploration, CubeSats are a vital component of the modern space technology ecosystem, and their impact on the aerospace research field is likely to be felt for years to come.

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