

EDGE FLYTE CubeSat Kit

Instructional Materials

Kit Description

Introducing the Educational CubeSat Kit, an all-in-one educational package designed to demystify satellite technology and space science. This 1U CubeSat Kit replicates the real deal, with onboard electronics, solar panels, atmospheric sensors, and a transceiver for wireless communication. The kit provides comprehensive resources for hands-on learning, fostering STEM education, problem-solving, and project-based learning. It's perfect for schools, hobbyists, STEM clubs, and anyone passionate about exploring space. Embark on your space journey with this inspiring educational tool!

Kit Outcomes

This miniature satellite kit provides students with a unique opportunity to gain practical insights into satellite design, construction, and deployment. One of the key outcomes of working with this kit is the development of critical problem-solving skills as students tackle real-world engineering challenges. Additionally, this kit can spark a lifelong passion for space exploration and technology, inspiring the next generation of scientists and engineers.

Furthermore, CubeSat projects often result in tangible accomplishments, such as successful launches and data collection, reinforcing the value of teamwork and persistence in achieving scientific goals. This CubeSat Kits offers a dynamic and engaging platform for students to learn, explore, and engage in the exciting field of space exploration.

This document grants permission for replication, provided it is for internal, educational, or non-commercial use, with proper attribution. Redistribution to external parties for any purpose is strictly prohibited without prior written consent. Unauthorized redistribution may result in legal action. This license remains in effect beyond any agreement termination or expiration.

Thank you for using our CubeSat Instructional Material! If you have any questions, feedback, or need assistance, please don't hesitate to get in touch with us. We are here to help you make the most of your learning experience.

Contact Information:

Technical Support Email: cs@edgeflyte.com

Phone Support: +1 (307) 202-8309

Website: www.edgeflyte.com/contact

Hours: Monday to Friday, 9:00 AM -5:00PM (MST)

Feedback and Suggestions

We value your feedback and suggestions for improving our instructional materials. Please feel free to share your thoughts with us at feedback@edgeflyte.com.

Stay Connected

Stay updated with our latest instructional materials, updates, and educational content by following us on social media:

Twitter: <https://x.com/edgeflyte>

Instagram: <https://www.instagram.com/edgeflyte/>

We're committed to providing you with high-quality educational resources and excellent customer support. Your success is our top priority, and we look forward to assisting you in your learning journey.

Thank you for choosing our CubeSat Instructional Material!

Table of Contents

1.0 | CubeSats5

 1.1 | What are CubeSats?6

 1.2 | What’s Inside CubeSats?.....9

 1.3 | How CubeSats Operate12

2.0 | Electronics.....15

 2.1 | Basics of Electricity16

 2.2 | Basics of Embedded Systems18

 2.3 | Basics of Radio Communications20

 2.4 | Basics of Communications Protocols.....23

 2.5 | How CubeSats Communicate25

 2.6 | Information and Data28

3.0 | Environmental Relations31

 3.1 | The Atmosphere32

 3.2 | Orbital Physics34

 3.3 | Interference35

 3.4 | Legal and Regulatory Landscape38

4.0 | EdgeFlyte CubeSat Kit41



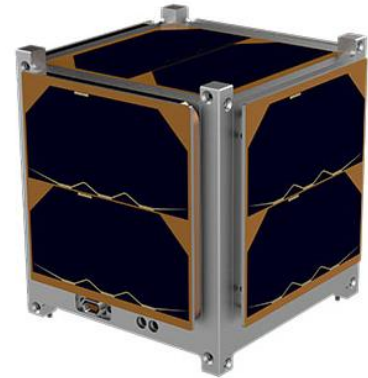
1.0 | CubeSats

1.1 What are CubeSats?	6
1.2 What's Inside CubeSats?.....	9
1.3 How CubeSats Operate	12

1.1

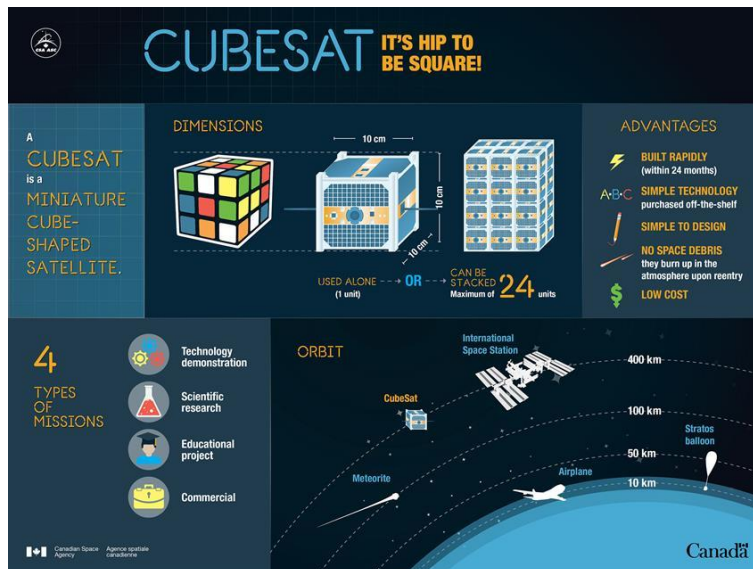
What Are CubeSats?

In the world of space exploration, CubeSats are making waves. These miniature satellites, slightly larger than a Rubik's Cube, have ushered in a new era of accessibility and cost-effectiveness. This section takes you on a journey through CubeSats, uncovering their origins, structure, components, missions, deployment, communication systems, advantages, limitations, and their promising future.



The story of CubeSats began at Stanford University in 1999 when professors Bob Twiggs and Jordi Puig-Suari conceived a visionary idea. Their goal was to create a standardized, affordable platform for educational and scientific purposes. Over the years, CubeSats have gained popularity, expanding their roles and democratizing access to space for a diverse array of organizations, from universities to private companies.

CubeSats are built on a modular structure, using standardized CubeSat Units, each measuring 10 cm x 10 cm x 10 cm. These units house essential components, including power systems, sensors, communication equipment, and often deployable solar panels. This modular design simplifies the building process and reduces costs.



CUBESAT IT'S HIP TO BE SQUARE!

A CUBESAT is a MINIATURE CUBE-SHAPED SATELLITE.

DIMENSIONS
10 cm x 10 cm x 10 cm
USED ALONE (1 unit) OR CAN BE STACKED Maximum of 24 units

ADVANTAGES
BUILT RAPIDLY (within 24 months)
SIMPLE TECHNOLOGY purchased off-the-shelf
SIMPLE TO DESIGN
NO SPACE DEBRIS they burn up in the atmosphere upon reentry
LOW COST

4 TYPES OF MISSIONS
Technology demonstration
Scientific research
Educational project
Commercial

ORBIT
International Space Station (400 km)
CubeSat (100 km)
Stratos balloons (50 km)
Airplane (10 km)
Meteorite

Canadian Space Agency / Agence spatiale canadienne

One of the most remarkable aspects of CubeSats is their versatility. They can be deployed for a multitude of missions, from Earth observation to scientific research, technology demonstration, and educational projects. Their small size allows them to perform tasks as diverse as imaging Earth's surface and studying celestial bodies.

CubeSats are typically launched as secondary payloads alongside larger satellites. This ride-sharing approach significantly reduces launch costs, making space more accessible to a broader spectrum of organizations and institutions. They can be deployed into orbit from deployers attached to the rocket or released directly from the International Space Station (ISS).

Communication is key to the success of CubeSats. These tiny satellites communicate with Earth through radio signals. They collect data, capture images, conduct experiments, and transmit this information back to ground stations for analysis. This real-time data acquisition capability has expanded the scope of scientific research and enabled numerous breakthroughs.



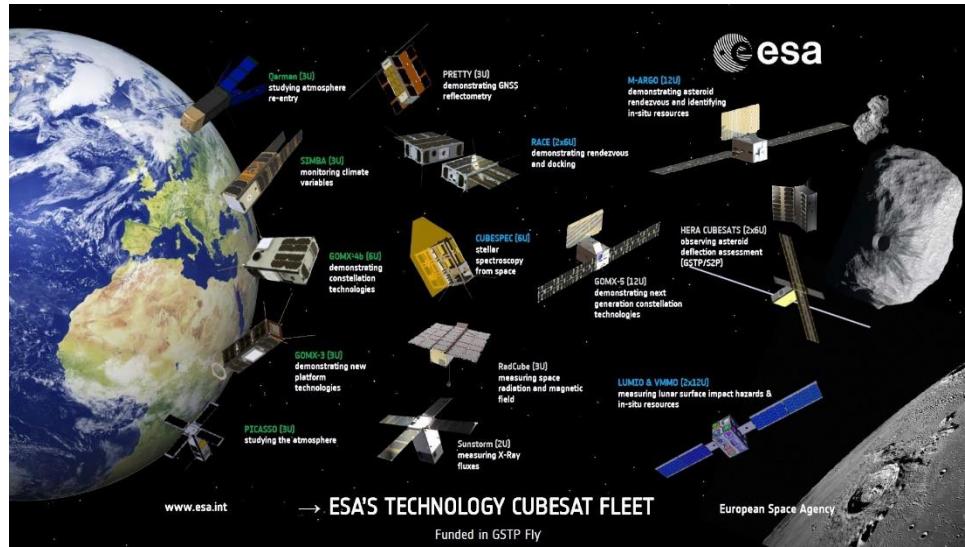
The rise of CubeSats offers several advantages. They provide a cost-effective means of conducting space research, enabling rapid development cycles, and allowing students and smaller organizations to participate in space exploration. This democratization of space access has ignited innovation and inclusivity within the field.

However, CubeSats are not without their challenges. These include limited power generation, relatively short lifespans, and size constraints that may not suit all mission objectives. Despite these challenges, ongoing developments continue to expand their capabilities.

Looking to the future, CubeSats continue to evolve, with ongoing technological advancements and expanding mission capabilities. They are expected to play an even more substantial role in future space exploration endeavors, including lunar and planetary missions. CubeSats are poised to become integral to the space research landscape, making it more inclusive, accessible, and impactful.

CubeSats have disrupted the traditional space exploration landscape, offering opportunities for a wider range of participants to engage in space research. Their compact size, affordability, and versatility have paved the way for innovative missions and diverse applications

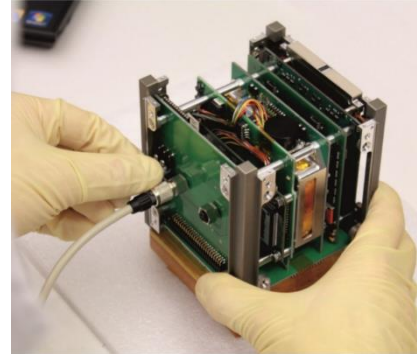
in space science and technology. As technology continues to improve, CubeSats are poised to shape the future of space exploration, making it more inclusive, accessible, and impactful.



1.2

What's Inside CubeSats?

CubeSats, those diminutive but powerful wonders of modern space technology, have revolutionized the way we explore space and conduct scientific experiments in the cosmos. These miniature spacecrafts are standardized in size, but what's inside a CubeSat can be a marvel of innovation, featuring an array of components and instruments packed into a tiny, cube-shaped package. In this exploration, we'll take a closer look at what typically resides within the confines of a CubeSat.



The CubeSat Structure

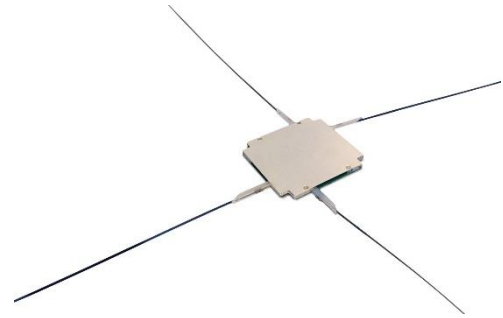
The CubeSat structure, in compliance with the CubeSat standard, is the outermost layer of the satellite. It serves as the protective shell and provides the platform for all the other components. The typical CubeSat has a 10x10x10-centimeter form factor and is composed of aluminum or other lightweight materials, ensuring it's both robust and compact. The CubeSat's sturdy structure is designed to withstand the harsh environment of space, including extreme temperatures, radiation, and micro-meteoroid impacts.

Power Generation and Storage

Within a CubeSat, there are various systems for power generation and storage. Solar panels are a common feature on external surfaces, capturing energy from the sun to power the satellite's components. These solar panels are strategically placed to maximize exposure to sunlight. The generated electricity is then stored in onboard batteries, typically lithium-ion, ensuring that the CubeSat remains operational during eclipses when it's not exposed to sunlight.

Communication Systems

CubeSats need a way to communicate with Earth and other satellites in orbit. They are equipped with compact radio transceivers that enable data transmission to and from mission control centers. These communication systems operate in different frequency bands, depending on the mission's requirements. CubeSats can use various antennas, such as dipole, patch, or deployable antennas, to establish reliable links with ground stations.



Onboard Computers

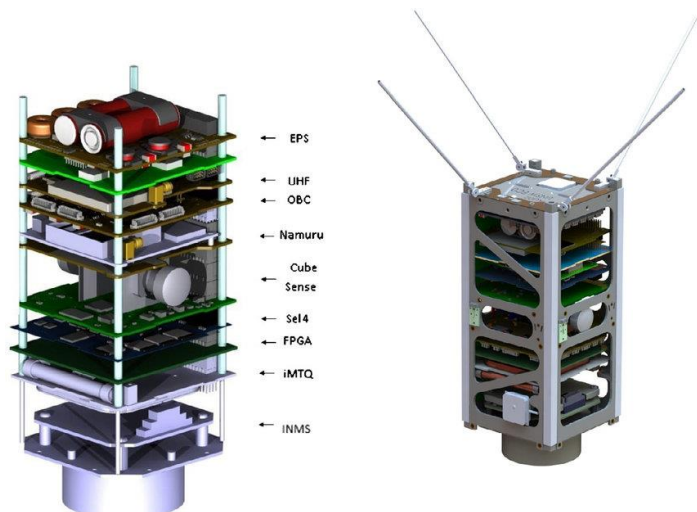
The heart and brain of a CubeSat is its onboard computers. These computers manage the satellite's systems, process data from onboard sensors, and execute mission-specific commands. CubeSat computers are designed to be power-efficient and radiation-tolerant, as they must operate reliably in the harsh space environment. They typically run on radiation-hardened microcontrollers or microprocessors and are programmed to carry out the satellite's mission objectives.

Attitude Control and Stabilization

To function effectively in orbit, CubeSats must maintain the correct attitude, or orientation. Typically, they use reaction wheels, magnetic torquers, or cold gas thrusters for attitude control. Gyroscopes and accelerometers provide the necessary data for the control system to adjust the satellite's orientation and ensure it points in the right direction for observations and communication.

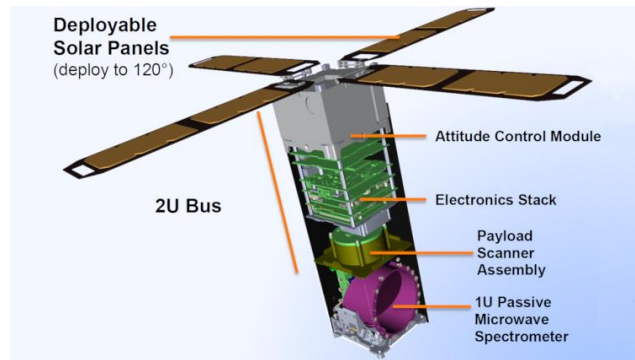
Sensors and Payloads

CubeSats are versatile platforms used for a wide range of scientific missions. The onboard sensors and payloads can vary greatly depending on the mission's goals. They may include cameras, spectrometers, magnetometers, radiation detectors, or other specialized instruments. These sensors gather data that is then transmitted back to Earth for analysis.



Thermal Control and Insulation

The temperature in space can vary dramatically between the sunlit and shaded sides of a CubeSat, making thermal control essential. CubeSats are equipped with thermal insulation to protect their sensitive electronics from extreme temperature fluctuations. Some CubeSats may also use active thermal control systems, such as heaters or radiators, to maintain a stable temperature range.



Deployment Mechanisms

In some cases, CubeSats are carried as secondary payloads on larger launch vehicles and deployed into orbit. CubeSats have various deployment mechanisms, such as spring-loaded pushers or electromagnetic railguns, which help them exit the launch vehicle and start their missions.

In summary, what's inside a CubeSat is a sophisticated combination of systems and components engineered to fulfill a wide range of scientific, technological, and exploratory missions. From power generation to communication, attitude control to data collection, these small but mighty spacecraft have expanded our capabilities for space exploration and research, demonstrating that size is no barrier to making significant contributions to our understanding of the cosmos. CubeSats have democratized access to space, enabling academic institutions, small companies, and even amateur astronomers to participate in space missions and advance our knowledge of the universe.

1.3

How CubeSats Operate

CubeSats are not only remarkable for their diminutive size but also for their incredible versatility. In this exploration, we'll delve into how CubeSats operate, detailing their internal workings, communication frequencies, the harsh environments they endure, and the networks they utilize for successful missions.

Internal Components and Systems

The internal workings of a CubeSat are a carefully choreographed symphony of systems, each playing a crucial role in ensuring the success of the mission. Here's an overview of some of the most common components:

Power Generation and Storage: CubeSats typically employ solar panels to generate electricity from the sun's energy. This power is stored in space grade batteries to keep the satellite operational during orbital eclipses and when it's in the Earth's shadow.

Onboard Computers: CubeSats are equipped with onboard computers, usually featuring radiation-hardened microcontrollers. These computers manage various functions, including data collection, communication, and attitude control.

Communication Systems: Communication is vital for CubeSats to relay data to Earth and other satellites. Common communication frequencies include UHF (Ultra High Frequency), VHF (Very High Frequency), and S-band. CubeSats use omnidirectional and directional antennas to establish reliable links with ground stations and other spacecraft.

Attitude Control and Stabilization: CubeSats require precise control over their orientation in space to perform observations and align communication antennas. Attitude control mechanisms often include reaction wheels, magnetic torquers, or cold gas thrusters.

Sensors and Payloads: CubeSats carry a variety of sensors and payloads tailored to their mission objectives. These instruments can include cameras, spectrometers, magnetometers, radiation detectors, and more. They collect data that is subsequently transmitted back to Earth for analysis.

Thermal Control and Insulation: CubeSats need to maintain stable temperatures in the extreme environment of space. They use thermal insulation and may employ active thermal control systems, such as heaters or radiators, to regulate temperature.

Harsh Environments

CubeSats must endure the unforgiving conditions of space, including extreme temperatures, radiation, and micro-meteoroid impacts. While their small size and low cost can make them more susceptible to these environmental challenges, CubeSat designers work to mitigate these risks through careful engineering.

Radiation-resistant components are used to shield onboard electronics from the harmful effects of cosmic radiation. Additionally, CubeSats may be designed to enter a lower Earth orbit, reducing their exposure to the most intense radiation at higher altitudes.

Communication Frequencies

CubeSats employ a range of frequencies for communication, with UHF, VHF, and S-band being the most common choices:

UHF (Ultra High Frequency): UHF is often used for downlink communications from CubeSats to ground stations. It provides relatively high data rates and can penetrate the Earth's atmosphere effectively.

VHF (Very High Frequency): VHF frequencies are suitable for uplink communications from ground stations to CubeSats. These frequencies are also used for beacon transmissions and command reception.

S-band: S-band is employed for higher data-rate applications and is especially useful for missions with larger data requirements.

CubeSat Networks

CubeSats often operate as part of networks or constellations, working together to achieve common mission goals. These networks can include:

Global Navigation Satellite Systems (GNSS) Constellations: CubeSats are sometimes deployed to enhance GNSS signals and provide more accurate positioning data.

Earth Observation Constellations: CubeSats equipped with imaging payloads are used in constellations to monitor the Earth's surface, providing frequent and high-resolution imagery for a range of applications.

Scientific Research Networks: CubeSats are deployed in networks to study the Earth's atmosphere, space weather, and cosmic phenomena. These networks enable collaborative research efforts.

In conclusion, CubeSats are remarkable for their compact size and ability to achieve scientific, technological, and exploratory goals. Their internal systems, communication frequencies, ability to withstand harsh environments, and participation in networks make them a cost-effective and accessible means of space exploration, ushering in a new era of space research and innovation. As technology continues to advance, CubeSats will undoubtedly play an increasingly pivotal role in our understanding of space and our planet.



2.0 | Electronics

2.1 Basics of Electricity	16
2.2 Basics of Embedded Systems	18
2.3 Basics of Radio Communications	20
2.4 Basics of Communications Protocols	23
2.5 How CubeSats Communicate	25
2.6 Information and Data	28

2.1

Basics of Electricity

Introduction

Before delving into the intricate workings of CubeSat systems, it is essential to establish a strong foundation in basic electronics and electricity. This chapter will provide an overview of the fundamental principles of electronics and electricity and how they are applied in CubeSat technology. A solid grasp of these concepts is critical for designing, building, and operating CubeSats effectively.

Electric Charge and Current

Electric charge is a fundamental property of matter that gives rise to electric forces. Current, on the other hand, is the flow of electric charge through a conductor. It is the rate of flow of electric charge, and the unit of current is the ampere (A).

Voltage, Resistance, and Ohm's Law

Voltage, also known as electric potential difference, is the force or energy per unit charge that drives the flow of electric current in a circuit. It is typically measured in volts (V). Voltage can be thought of as the "push" that drives electric charge through a conductor.

Resistance is the opposition that a material offers to the flow of electric current. It is typically measured in ohms (Ω). The resistance of a material depends on its type, length, cross-sectional area, and temperature. Conductors have low resistance, while insulators have high resistance.

Ohm's Law is essential for understanding and analyzing electrical circuits. It provides a simple mathematical relationship between voltage, current, and resistance, allowing for the prediction and control of these parameters in various electrical systems.

Electronic Components

CubeSats contain a range of electronic components, including resistors, capacitors, inductors, diodes, and transistors. Understanding how these components work and interact with each other is essential for designing circuits and systems within the satellite.

Power Generation and Management in CubeSats

Solar Panels

Many CubeSats rely on solar panels to convert sunlight into electrical power. Understanding the principles of photovoltaic cells, solar irradiance, and power generation is essential for designing effective solar arrays.

Batteries and Energy Storage

CubeSats use rechargeable batteries to store electrical energy. Knowledge of battery technology, capacity, and charge/discharge cycles is vital for managing the power requirements of CubeSat missions.

Electronics in CubeSats

Onboard Computers and Microcontrollers

CubeSats are equipped with onboard computers or microcontrollers responsible for controlling the satellite's operations, managing sensors and instruments, and processing data. Understanding programming, microcontroller architecture, and software development is crucial for CubeSat mission success.

Sensors and Data Acquisition

Various sensors and instruments in CubeSats collect data about the satellite's environment, position, and mission objectives. These sensors often require signal conditioning and data processing circuits for accurate measurement and data transmission.

Communication Systems

Communication systems in CubeSats facilitate data exchange with ground stations. Knowledge of radio frequency (RF) communication, antennas, and modulation techniques is essential for designing effective CubeSat communication systems.

In summary, mastering the basics of electronics and electricity is a foundational step in the design and operation of CubeSat systems. This knowledge is indispensable for building reliable and functional CubeSats that can carry out their missions effectively in space.

2.2

Basics of Embedded Systems

Introduction

Embedded systems play a pivotal role in the design and operation of CubeSats. This chapter will introduce you to the fundamental components of embedded systems, including Printed Circuit Boards (PCBs), microcontrollers/processors, and board-level communication protocols. Understanding these building blocks is crucial for designing CubeSat systems that can efficiently execute their missions in the space environment.

Printed Circuit Boards (PCBs)

Printed Circuit Boards (PCBs) are fundamental components in modern electronics that provide a platform for connecting and supporting electronic components. A PCB is a flat board made of non-conductive material (usually fiberglass or composite epoxy) with thin conductive pathways or traces etched or printed onto its surface. These conductive pathways serve to connect and provide electrical communication between various electronic components on the board.

PCB Fundamentals

Printed Circuit Boards (PCBs) are at the heart of CubeSat electronic systems. They provide the physical platform for mounting electronic components, interconnecting them, and ensuring the necessary electrical connections. Key topics in PCB design include:

PCB Materials: Materials used in CubeSat PCBs, such as FR-4, polyimide, and ceramics, are chosen for their performance in space conditions.

Layer Stacks: Understanding the layer stack of a PCB is crucial for routing traces, managing signal integrity, and minimizing electromagnetic interference (EMI).

Soldering and Assembly

Soldering is a process used to join two or more metal components by melting and flowing a filler metal into the joint. The filler metal, known as solder, has a lower melting point than the workpieces, and it solidifies to create a strong and conductive bond. Soldering is widely used in the assembly of electronic components on printed circuit boards (PCBs) and in various other applications.

With the CubeSat Soldering Kit, students will learn the principles of THT soldering through assembling their own satellite. With these kits, attention to detail is critical! After all, it is a miniature satellite!

Microcontrollers/Processors

A microcontroller is a compact integrated circuit that contains a processor core, memory, and programmable input/output peripherals. It is designed to execute specific tasks and control various applications in embedded systems. Microcontrollers find applications in a wide range of devices, from simple household appliances to complex industrial systems.

Software development refers to the process of creating, designing, programming, testing, and maintaining software and applications. It encompasses a set of activities and tasks that lead to the creation of a functional and reliable software product. Software development involves both the creation of new software and the modification of existing software to meet specific needs or address issues.

Board-Level Communication Protocols

CubeSats rely on various communication protocols to exchange data and commands with ground stations, other CubeSats, or even other spacecraft. Key communication concepts include:

Serial Communication: Understanding serial protocols like UART, SPI, and I2C, which are commonly used in CubeSat systems. Serial communication is a method of transferring data between digital devices by sending it sequentially, one bit at a time, over a communication channel or a physical wire. In serial communication, data is transmitted in a series, and each bit is sent sequentially, one after another. This is in contrast to parallel communication, where multiple bits are sent simultaneously over separate channels.

RF Communication: Knowledge of radio frequency communication, including modulation schemes (e.g., BPSK, GMSK) and protocols for data transmission. RF (Radio Frequency) communication refers to the wireless transmission of data using radio frequency signals. It is a method of communication that relies on the modulation and demodulation of radio waves to transmit information between devices. RF communication is widely used in various applications, including wireless networking, mobile communication, remote control systems, RFID (Radio-Frequency Identification), and more.

In summary, embedded systems are the backbone of CubeSat technology. Mastering PCB design, microcontroller programming, and board-level communication protocols is essential for creating CubeSats capable of executing complex missions, collecting data, and communicating with ground stations.

2.3

Basics of Radio Communication

Introduction

Radio communications form the backbone of CubeSat operations, enabling data exchange with ground stations and other spacecraft. This chapter will delve deeper into the advanced aspects of radio communications, including HAM radio, encoding, frequency formulas, modulation types, antennas, and antenna theory. A comprehensive understanding of these concepts is paramount for the success of CubeSat missions.

Radio Communications Fundamentals

The electromagnetic spectrum encompasses a broad range of frequencies, from radio waves to gamma rays. CubeSats operate primarily within the radio frequency (RF) portion of the spectrum. Understanding the various frequency bands and their applications is essential for selecting the appropriate communication frequencies for CubeSat missions.

Frequency and wavelength are inversely related, following the formula:

$$C = f \cdot \lambda$$

Where:

c is the speed of light (approximately 3×10^8 meters per second),

f is the frequency (in Hertz), and

λ is the wavelength (in meters).

This relationship is fundamental for CubeSat operators when choosing the appropriate communication frequency for their mission and designing antennas optimized for specific wavelengths.

Antennas and Radiation Patterns

Antennas are crucial components in radio communications. Knowledge of antenna theory, radiation patterns, and gain is critical for optimizing CubeSat communication systems.

Understanding the directivity of different antenna types, such as dipoles, patch antennas, and helical antennas, allows for efficient signal transmission and reception.

An antenna is a device designed to transmit or receive electromagnetic waves. It is a crucial component in various communication systems, including radio, television, mobile phones, radar, and satellite communication. Antennas can be categorized into two main types:

Transmitting Antennas: These antennas are used to convert electrical signals into electromagnetic waves for transmission.

Receiving Antennas: These antennas capture incoming electromagnetic waves and convert them into electrical signals for reception.

Modulation and Encoding

Modulation is the process of varying a carrier signal's properties, such as amplitude, frequency, or phase, in accordance with the information signal being transmitted. The purpose of modulation is to enable the transmission of information over a communication channel. The carrier signal, which is typically a high-frequency waveform, is modified by the characteristics of the information signal, allowing it to carry the information over a distance.

Encoding is the process of converting digital data into a format that can be transmitted efficiently and decoded accurately at the receiver. Error correction techniques, such as Forward Error Correction (FEC) codes, are employed to enhance the reliability of data transmission. CubeSat operators must select appropriate encoding and error correction schemes based on their specific mission requirements.

Encoding involves converting information from one form to another, often to facilitate its storage, transmission, or processing. In the context of communication systems, encoding is used to represent information in a way that is suitable for transmission over a particular channel.

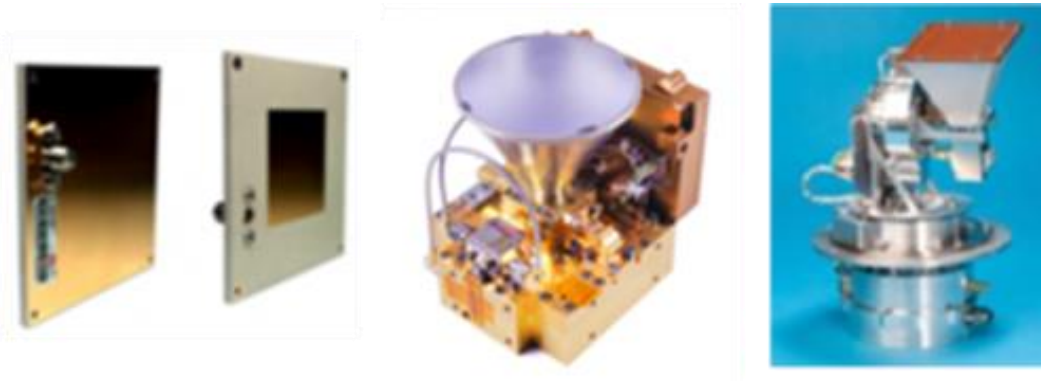
The combination of modulation and encoding allows for the efficient and reliable transmission of information over communication channels, whether they are wired or wireless. Modulation modifies the carrier signal, while encoding prepares the information for transmission in a way that suits the characteristics of the channel and the requirements of the communication system.

HAM Radio and CubeSats

HAM radio, also known as amateur radio, is a valuable communication option for CubeSats. It provides a direct and reliable means of communication with amateur radio operators (Hams) worldwide. CubeSats equipped with HAM radio transceivers can transmit telemetry data and receive commands from ground stations operated by Hams.

Operating HAM radio equipment on CubeSats requires compliance with licensing and regulatory requirements established by national and international authorities, such as the International Telecommunication Union (ITU). CubeSat operators must be familiar with these regulations to ensure legal and proper use of HAM radio frequencies.

In summary, advanced radio communications are integral to CubeSat technology. A comprehensive understanding of HAM radio, encoding, frequency formulas, modulation types, antennas, and antenna theory is crucial for designing and operating CubeSats with highly effective and reliable communication systems.



(from left to right) CubeSat-compatible S-band patch antenna (IQ spacecom), X-band high-gain antenna and pointing mechanism (Surrey Satellite Technology, Ltd.), and Ka-band transmitter with a horn antenna (Astro Digital).

2.4

Basics of Communication Protocols

Introduction

Communication protocols are the foundation of data exchange in CubeSat missions, enabling the transfer of information between the satellite and ground stations. This chapter will provide a comprehensive exploration of advanced communication protocols and their significance in CubeSat operations. Additionally, we will discuss encrypted data transmission and the standardization of space communications, focusing on specific protocols and standards that enhance CubeSat communication.

Communication Protocol Fundamentals

Understanding communication protocols within the context of the OSI model is vital for CubeSat communication systems. The OSI model consists of seven layers, each with distinct responsibilities, such as the physical layer for transmitting signals and the transport layer for end-to-end communication. CubeSat operators need to comprehend how these layers function together to ensure efficient data exchange.

Encrypted Data Transmission

Ensuring data security in CubeSat missions involves more than just encryption. CubeSat operators should understand data security strategies, including access control, data integrity checks, and secure key management.

Advanced cryptographic protocols are abstract or concrete protocols that perform a security-related function. The Secure Sockets Layer (SSL) and Transport Layer Security (TLS) are used for securing data in transit. These protocols facilitate secure data transmission between CubeSats and ground stations.

Standardization of Space Communications

Standardization in space communications simplifies interoperability, streamlines mission operations, and enhances data reliability. CubeSat operators benefit from adhering to established standards and practices.

The Consultative Committee for Space Data Systems (CCSDS) provides a wide range of communication protocols and standards tailored to space missions. CubeSat operators can

leverage CCSDS protocols like the Space Data Link Protocol (CCSDS 133.0-B-1) and the Telemetry Channel Coding and Synchronization Sublayer (CCSDS 131.0-B-1) for reliable and standardized communication.

In summary, advanced communication protocols are the lifeblood of CubeSat technology. A comprehensive understanding of protocol layers, TCP/IP, encrypted data transmission, and space communication standards is essential for designing and operating CubeSats with secure, reliable, and compatible communication systems.

2.5

How CubeSats Communicate

Introduction

Communication is the lifeline of CubeSat missions, enabling data transfer between satellites and ground stations or another spacecraft. In this chapter, we will delve into the fundamentals of CubeSat communication, exploring the impact of the ionosphere, interference, the role of amateur ground stations, and the complexities of inter-orbit communication.

CubeSat Communication Fundamentals

Telemetry refers to the collection of data from the CubeSat and its sensors, while telecommand involves sending instructions and commands to the satellite. Understanding these basic communication functions is vital for operating CubeSats effectively.

Frequency Bands

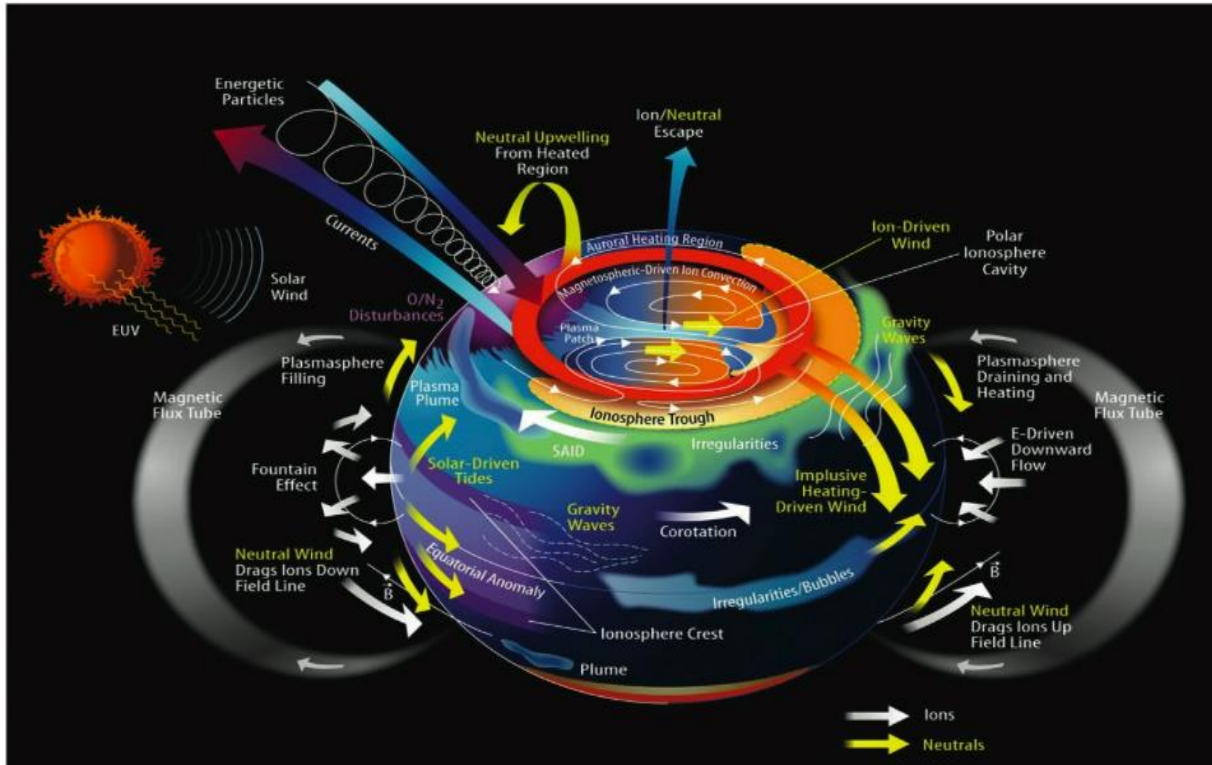
CubeSats communicate using a variety of frequency bands. Depending on the mission, CubeSats may use UHF, VHF, S-band, or other frequencies. Selecting the appropriate frequency band depends on the satellite's mission requirements and regulatory approvals.

One of a succession of acoustic, radio, or spectral frequency ranges each beginning where the preceding one leaves off.

Band	Frequency
VHF	30 to 300 MHz
UHF	300 to 1000 MHz
L	1 to 2 GHz
S	2 to 4 GHz
C	4 to 8 GHz
X	8 to 12 GHz
Ku	12 to 18 GHz
K	18 to 27 GHz
Ka	27 to 40 GHz
V	40 to 75 GHz

Challenges in CubeSat Communication

The ionosphere, the ionized part of the upper part of the atmosphere of Earth. It consists of charged particles in Earth's upper atmosphere, can influence radio signals by reflecting, refracting, or absorbing them. CubeSat operators must consider ionospheric conditions when planning communication windows and data collection.



Interference and Radio Noise

Interference from other electromagnetic sources and radio noise can disrupt CubeSat communication. Understanding how to mitigate interference and filter out unwanted signals is essential for maintaining a reliable link with the satellite.

Amateur Ground Stations and HAM Radio

Amateur radio operators (Hams) around the world often establish ground stations to communicate with CubeSats equipped with HAM radio transceivers. CubeSat missions frequently leverage amateur ground stations for data exchange, as they provide a widespread means of communication.

To work with amateur ground stations and HAM radio frequencies, CubeSat operators must adhere to licensing and regulatory requirements. Being aware of these rules and regulations ensures that communication complies with legal and technical standards.

Inter-Orbit Communication

CubeSats may require inter-orbit communication to exchange data with other spacecraft, including CubeSats in different orbits or larger satellites. Understanding the complexities of

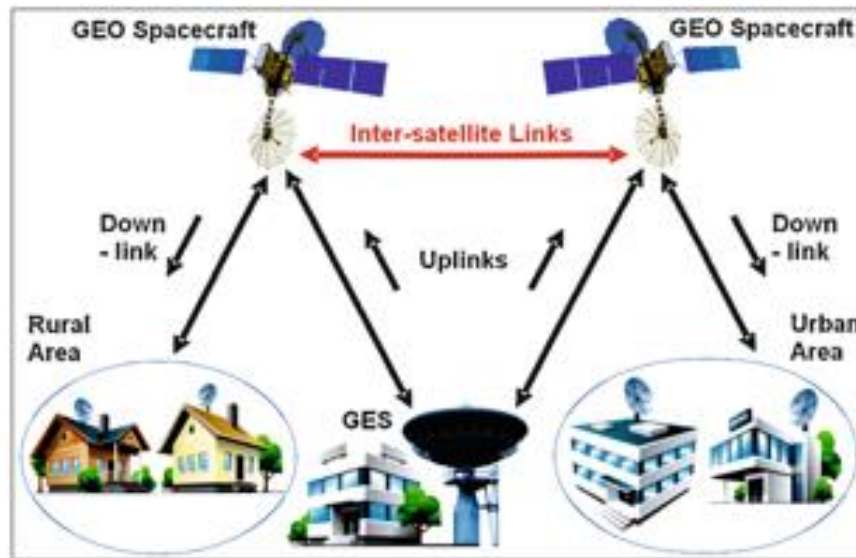
cross-link communication and inter-orbit networking is crucial for CubeSat missions that involve formation flying or collaborative data collection.

Relay Satellites

In some cases, CubeSats use relay satellites to facilitate inter-orbit communication. These relay satellites serve as communication hubs, forwarding data between CubeSats and ground stations. Knowledge of relay satellite systems is essential for planning such missions.

Inter-satellite links allow satellites to act as relays, using lasers or radiofrequency transponders to beam data across to each other and down to ground station antennas, shortening the time between data collection and delivery to customers.

In summary, CubeSat communication is a complex and multifaceted field. An in-depth understanding of the fundamentals, challenges, and unique aspects of CubeSat communication is crucial for ensuring successful missions and reliable data exchange with the satellite.



Satellite uplink, downlink, and crosslink.

D. Stojce (2019)

2.6

Information and Data

Introduction

Satellites orbiting Earth capture a treasure trove of data that fuels scientific research.. In this chapter, we'll explore the diverse categories of satellite-generated information, from weather monitoring and satellite internet to telescopes, amateur satellites, and the global positioning system (GPS).

Weather Monitoring with GOES Satellites

The GOES is operated by the United States by National Oceanic and Atmosphere Administration, (NOAA). Spacecraft and ground-based elements of the system provide a stream of data. They play a vital role in weather forecasting, severe storm tracking, and environmental monitoring, helping us prepare.

GOES satellites are equipped with various remote sensing instruments, including advanced weather radars and imaging devices. These instruments capture essential meteorological data used for climate research, hurricane prediction, and day-to-day weather monitoring.

Satellite Internet

Satellite internet providers deploy communication satellites in low Earth orbit (LEO) or medium Earth orbit (MEO). These ground stations are known as gateways that relay internet data to and from the satellite via radio waves. enable global broadband internet access, bridging the digital divide and connecting remote regions to the online world.

Satellite internet satellites use radio frequencies to deliver internet services to users worldwide. Understanding the components of satellite internet systems, including ground stations, is essential for comprehending this technology's role in modern connectivity.

Scientific Discoveries

Space telescopes have been instrumental in making groundbreaking discoveries, from identifying exoplanets to uncovering the origins of galaxies.

Amateur Satellites and Satellite Constellations

Amateur radio operators, or Hams, have launched their satellites, enabling direct communication with other enthusiasts worldwide. These amateur satellites serve educational and communication purposes, fostering scientific experimentation.

Satellite Constellations

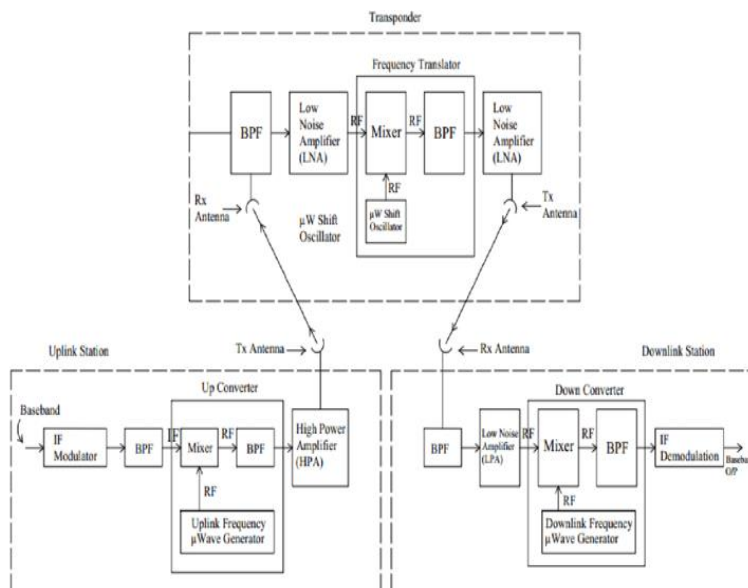
Commercial satellite operators deploy constellations of spacecraft, such as Starlink and OneWeb, to deliver high-speed internet access. These constellations rely on coordinated communication between multiple satellites.

The Global Positioning System (GPS)

The Global Positioning System is a satellite-based radio navigation system that provides precise location and timing information to GPS receivers on Earth. This system consists of 3 segments: the space segment, the control segment and the user segment.



GPS consists of a global network of satellites orbiting Earth, and each satellite continuously broadcasts its position and time information. An understanding of satellite constellations and their interaction with GPS receivers is crucial for efficient and accurate navigation.



Transmit and receive block diagram.

Karim et al. (2018).



3.0 | Environmental Relations

3.1 The Atmosphere	32
3.2 Orbital Physics	34
3.3 Interference	35
3.4 Legal and Regulatory Landscape.....	38

3.1

The Atmosphere

Introduction

In the previous chapters, we explored the basics of CubeSats, their components, and their applications. CubeSats are small and cost-effective spacecrafts that have gained popularity in various fields, including Earth observation, scientific research, and technology demonstration. To effectively design and operate CubeSats, it is crucial to understand their interaction with the Earth's atmosphere. In this chapter, we will delve into the dynamics of CubeSat interactions with the atmosphere and the key factors that affect their mission success.

CubeSats in Low Earth Orbit (LEO)

CubeSats are primarily deployed into Low Earth Orbit (LEO), which is an orbit around the earth with a period of 128 minutes or less and an eccentricity less than 0.25. It is located between approximately 160 kilometers (100 miles) and 2,000 kilometers (1,240 miles) above the Earth's surface. CubeSats orbiting in LEO experience several important characteristics:

Microgravity: CubeSats in LEO are in a state of continuous free fall, experiencing microgravity conditions. These conditions are falling faster and faster with acceleration due to gravity. This microgravity environment allows them to orbit the Earth while maintaining relatively constant altitude.

Atmospheric Drag: Despite being in the vacuum of space, CubeSats in LEO experience a minimal but significant amount of atmospheric drag. This drag can cause a gradual reduction in orbital altitude, which impacts the satellite's longevity and mission duration.

Atmospheric Density & Drag

The density of the Earth's atmosphere decreases with altitude, and this variation significantly affects CubeSat operations. At lower altitudes, the atmosphere is denser, resulting in greater atmospheric drag. CubeSats in LEO encounter varying atmospheric conditions depending on their altitude, latitude, and time of year. This atmospheric variability



must be considered when planning CubeSat missions, as it influences the satellite's orbital decay rate and power requirements.

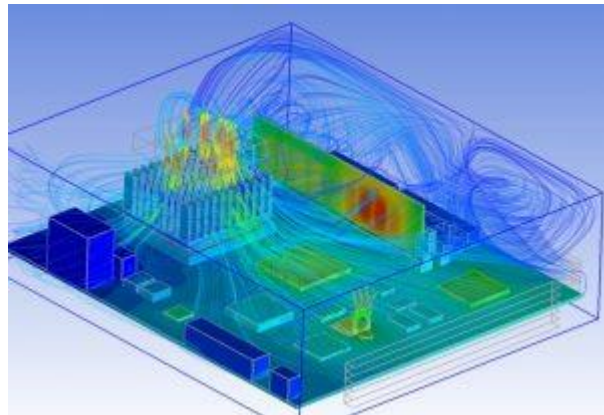
To counteract atmospheric drag, CubeSat operators may employ various strategies, such as deploying drag sails, implementing passive magnetic stabilization, or using propulsion systems for periodic altitude maintenance. These measures can extend the satellite's operational lifespan.

Orbital Decay and Reboost

Orbital decay is a gradual decrease of the distance between two orbiting bodies. One of the critical factors CubeSat operators must manage is orbital decay. Atmospheric drag at lower altitudes can cause CubeSats to gradually lose altitude and, if left unaddressed, re-enter Earth's atmosphere. To counteract this, operators may need to perform periodic reboost maneuvers using onboard propulsion systems to maintain the desired orbital altitude.

Thermal Management

The Earth's atmosphere also plays a crucial role in CubeSat thermal management. Thermal management refers to the tools and technologies used to maintain a system within its operating temperature range. The differences in temperature at different altitudes can affect the satellite's heat dissipation, potentially causing overheating or temperature extremes.



Operational Constraints

The variations in atmospheric conditions can impose operational constraints on CubeSats, affecting their communication capabilities and the timing of data collection. Operators must plan missions, communication windows, and data acquisition accordingly to optimize CubeSat performance.

3.2

Orbital Physics

Orbital physics is a complex field that underpins the motion of objects in space. This chapter delves deeper into the advanced principles of orbital mechanics and their direct applications to CubeSats. A comprehensive understanding of these concepts is essential for precise mission planning, orbit management, and effective navigation in the realm of space.

Polar Orbits and Sun-Synchronous Orbits

Polar Orbits: These orbits pass over the Earth's poles and are ideal for CubeSats conducting Earth observation missions, as they provide global coverage.

Sun-Synchronous Orbits (SSO): SSOs maintain a consistent local solar time, which is crucial for imaging and scientific missions.

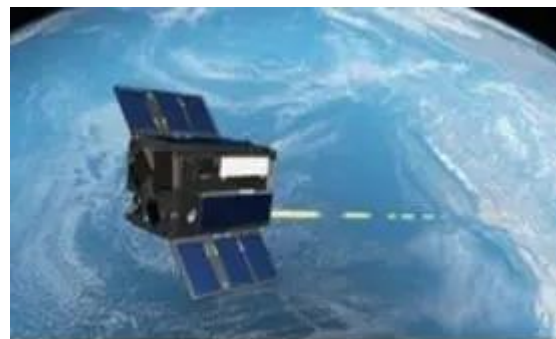
Section 4: CubeSat Navigation and Control

CubeSats must maintain specific attitudes to achieve their mission objectives. Understanding attitude control systems, such as reaction wheels and thrusters, is vital for ensuring proper orientation.

CubeSats rely on ground stations for tracking, telemetry, and command. Familiarity with ground station networks, antenna pointing, and the Deep Space Network is vital for continuous communication and data exchange.

Advanced knowledge of orbital mechanics, orbit dynamics, and mission design is essential for precise mission planning and execution. CubeSat operators must select orbits, altitudes, and trajectories that align with mission objectives.

CubeSats operating in real-world environments encounter complex perturbation effects.



CubeSats must maintain specific attitudes and communicate with ground stations for successful mission operations. In-depth knowledge of attitude control systems, ground station networks, and communication protocols is vital for mission success.

3.3

Interference

Interference in satellite communication, whether from radio frequency (RF), light, or other electromagnetic sources, is a formidable challenge. The following delves into advanced strategies for designing, accommodating, and dealing with interference, ensuring resilient and reliable satellite communication.

Radio Frequency (RF) Interference

Radio frequency interference is the conduction or radiation of radio frequency energy that causes an electronic or electrical device to produce noise that typically interferes with the function of an adjacent device. RF interference is a pervasive challenge, arising from various sources, such as competing RF signals, electromagnetic radiation, and co-frequency interference. Dealing with RF interference requires in-depth knowledge of frequency bands and advanced RF engineering.

Optical Interference

Optical interference is the effect of two or more light waves interacting with each other¹². It occurs when the light waves have spatial and temporal overlap.

Frequency and Spectrum Management

Spectrum management is the process of regulating the use of radio frequency.

Effective interference mitigation begins with strategic frequency and spectrum management. Satellite operators must meticulously allocate frequency bands and optimize spectrum usage to minimize interference, ensuring spectrum efficiency and reducing potential sources of conflict.

Redundancy and Error Correction

Incorporating redundancy and advanced error correction mechanisms is a fundamental approach to interference mitigation. CubeSat operators need to master error correction algorithms like Reed-Solomon codes, which enable data recovery and resilience to interference.

Spatial Diversity

Spatial diversity techniques, such as multiple antennas or beamforming, counteract signal fading and interference effects. CubeSat missions can leverage spatial diversity strategies to enhance link reliability and communication robustness.

Interference Monitoring and Spectrum Analysis

Real-time interference monitoring and spectrum analysis are crucial for identifying and mitigating interference promptly. Satellite operators must be proficient in using specialized equipment to diagnose interference sources, characterize interference patterns, and take corrective actions.

Interference Mitigation Strategies

Advanced interference mitigation strategies involve a multidimensional approach. CubeSat operators employ techniques like interference cancellation, adaptive filtering, and power control to mitigate the effects of interference in real-time. These strategies demand expertise and an adaptive response to dynamic interference scenarios.

Relating Advanced Interference Management to CubeSats

Interference Identification: CubeSat operators must be adept at identifying interference sources and patterns, whether they originate from RF or optical sources, to respond promptly and ensure uninterrupted communication.

Frequency and Spectrum Management: Proper frequency allocation, coordination, and effective spectrum management allow CubeSats to navigate complex RF environments and maintain spectrum efficiency.

Error Correction and Redundancy: Mastery of error correction codes, redundancy mechanisms, and forward error correction is indispensable for CubeSats to recover data accurately in the presence of interference.

Advanced Modulation Techniques: CubeSat operators must harness advanced modulation techniques to maximize data throughput and maintain communication reliability in the face of interference.

Interference Monitoring and Mitigation: Proficiency in monitoring tools and real-time interference mitigation strategies is vital for CubeSat operators to maintain robust communication links.

In summary, managing interference in satellite communication is a critical facet of CubeSat technology. A profound understanding of interference types, frequency and spectrum management, advanced modulation techniques, error correction, spatial diversity, interference monitoring, and mitigation strategies is imperative for designing and operating CubeSat systems that can consistently communicate in the presence of interference, securing mission success.

3.4

Legal and Regulatory Landscape

Launching a satellite into Low Earth Orbit (LEO) involves complying with a multitude of governmental requirements, legal obligations, and certification processes. This chapter will provide comprehensive insights into the intricacies of LEO satellite operations, including laws, regulations, international treaties, and the certification procedures that satellite operators must navigate for a successful mission.

Outer Space Treaty

The Outer Space Treaty is a foundational document governing space activity, emphasizing the peaceful use of outer space, international cooperation, and non-appropriation of celestial bodies.

Various international agreements, such as the Rescue Agreement, Liability Convention, and Registration Convention, provide additional guidance on satellite operations and responsibilities.

Regulatory Bodies

In the United States, the FAA's Office of Commercial Space Transportation (AST) regulates commercial space launches, ensuring safety and compliance.

Other countries have their regulatory authorities, each with its own set of rules and requirements for launching satellites into space. CubeSat operators must navigate these regulations to secure necessary approvals.

Licensing and Authorization

Satellite operators must obtain launch licenses to launch their payloads into space. These licenses are issued by the relevant national authority and include detailed safety and environmental assessments.

To communicate with satellites, CubeSat operators need to secure radio frequency spectrum licenses to ensure that their transmissions do not interfere with other systems.

Ensuring the safety of satellite launches and operations is paramount. Operators must adhere to strict safety guidelines, conducting hazard analyses and demonstrating compliance.

Satellite technologies are subject to export control regulations to protect national security interests. Understanding these regulations is essential, especially for international missions.

Liability and Insurance for Space Activities

International agreements and national laws establish liability regimes for space activities, defining responsibilities and compensation in case of accidents or damages.

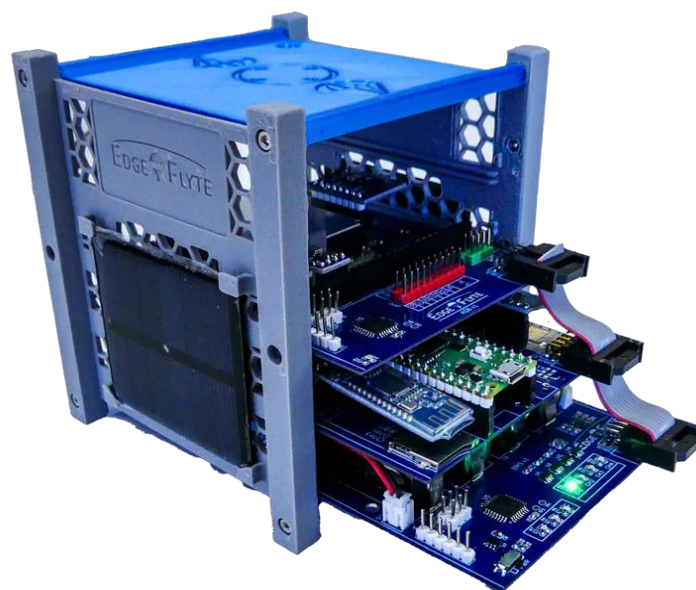
Satellite operators must secure insurance coverage to protect against potential liabilities, failures, or damages arising from their missions.

In summary, launching a satellite into Low Earth Orbit is a complex process that requires thorough knowledge of international treaties, national regulations, licensing, safety certification, and insurance. CubeSat operators must meticulously navigate these legal and regulatory landscapes to ensure a successful and legally compliant LEO satellite mission.



4.0 | EdgeFlyte CubeSat Kit

A unique and engaging platform to explore principles of science, technology, engineering, and mathematics. This CubeSat Kit provides an accessible entry point for students to delve into the complexities of space technology. Assembling and customizing a CubeSat kit involves practical applications of physics, electronics, and programming, fostering an understanding of STEM concepts. Students can gain insights into satellite design, communication systems, and embedded systems, enhancing their problem-solving skills and creativity.



Elevate Learning

Designed for STEM educators and hobbyists, our 1U CubeSat Kit is a hands-on educational tool that empowers you to build and experiment your very own mini satellite. It's an engaging way to explore STEM, delving into atmospheric sensors, microcontrollers, communications, and much more!

Realistic Design

The kit is crafted to mimic the design and functionality of a real CubeSat satellite. It's not just a toy; it's a genuine learning experience that provides insights into satellite technology, space communication, and more.

Suitable for All Ages

Our 1U CubeSat Kit is designed to be versatile and fun. Whether you're an educator looking to enhance your curriculum or a hobbyist looking to expand your horizons, this kit is suitable for all ages and experience levels. It's a fantastic tool for family projects, science clubs, and STEM programs.

The EdgeFlyte CubeSat v1 is designed to be customized, expanded, and integrated with. From embedded GPIO ports, communication ports, and debugging ports, the possibilities are endless!



Inside the box, you'll find everything you need to get started on your space exploration journey. From the CubeSat frame and structure to the solar panels, sensors, and communication system, we've got you covered. The included educational materials provide step-by-step instructions for a seamless learning experience.

IMU: The onboard 9-axis Motion Processing Unit provides real time information about the CubeSats' orientation, acceleration, compass direction, and gyroscopic movements.

GPS: Provides up to 3m accuracy on the CubeSats position on the earth. Additionally supports positioning up to 18,000m (for edge-of-space experiments).

Telemetry Link: Enables the CubeSat to transmit real-time data to a compatible ground station (included). Data can be viewed in countless formats and stored for later processing.

Onboard SD Card: Logs all data collected by the onboard sensors in an easily accessible format for post-mission analysis.

Temperature, Pressure, and Relative Humidity: Track the fundamental conditions of the atmosphere in high resolution with sensors equipped onboard the Atmospheric Sensing Board.

Particulate Matter: Track and analyze particulate matter mass concentration and number of particles of $1 \mu\text{g}/\text{m}^3$, $2.5 \mu\text{g}/\text{m}^3$, $4 \mu\text{g}/\text{m}^3$, and $10 \mu\text{g}/\text{m}^3$.