WIRELESS CUBESAT: ARDUINO FEMTOSAT SOLUTION

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Abstract:

As advances in technology have made satellite systems and their applications more reliable, militaries around the world increasingly rely on satellite systems in their operations. Among the most common applications are communications, remote sensing, and weather forecasting. Nevertheless, satellite systems have some drawbacks. For example, they are expensive and subject to failure. In addition, they are vulnerable to the dangers inherent to the space environment, such as collisions with comets. Most critical, satellites are vulnerable to adversaries who target them to prevent friendly military forces from using space-based systems (Commission to Assess United States National Security Space Management and Organization, 2004). These drawbacks raise the need for approaches that could support the military in cases where the current space systems shut down. One potential solution is the quick deployment of Femtosatellites.This project focuses on the design, development, and analysis of a femto satellite, a miniature satellite with a mass ranging from a few hundred grams to a kilogram. The objective of this project is to demonstrate the feasibility of utilizing femto satellites for various space-based applications, including communication, Earth observation, and scientific research. The project involves designing the satellite's structure, subsystems, and mission payload, followed by simulation, testing, and analysis of its performance.

KeyWords:
Femto Satellite, CubeS ats,NPS, Femto satellites, Simulation

I. INTRODUCTION

In the last few decades, a new generation of space mission architecture design is emerging in USS. It will collectively perform missions; both earth-orbiting and intersatellite communication, in a distributed fashion. Solutions are proposed for optimization of critical distributed system for space mission architectures. To usethis kind of architectures, a more creative and involves coming up with new ways of tackling the issue, with a high volume production of Femto-Satellite less than 100g satellites-on-achip or satellite on board at low cost, is required.

The need to communicate with remote units or people who lack the means of communication and terrestrial infrastructure raises the demand for satellite communication. Three major elements comprise a satellite communication system: the payload, which is the communication system itself; the vehicle carrying that system, which is limited by orbital mechanics; and the network that extends the accessibility and utilities of the communication system.

Femto satellites, also known as picosatellites, nanosatellites, or CubeSats, have gained significant attention due to their compact size and low cost of development and launch. This report outlines the process of creating a femto satellite and evaluates its potential applications.

II.RESEARCH AND LITRATURE REVIEW

Space technology accessible for all over the world, the fact that proves m any countries as Spain which studied WIKISAT in 2011 and Tunisia which studied l'EREPSAT1 in 2009.

This orientation offers many countries, societies and even individuals to build their personal satellites. Chile makes an example of constellation study with FemtoSatellite for controlling the climatic change from the space in order to guess the security. The countries that are situated on the cyclone trajectory or that have nuclear constructions are the focus of observers in order to reform dynamic database on climate, atmospheric temperature and gaze concentration. The FemtoSatelitte is the future solution if it guards the following principles.

- Simpler and more functional : KISS (keep it Simple and Safe)
- Low and reliable costs:
- Miniature autonomous power
- Feasibility study gives the opportunity to valorize and to prove the FemtoSatellite efficacy in order to be the first generation of personal satellite.

Indeed, low cost by prototype and launching encourages countries and researchers to study and to design prototypes until their use in the following services:

- Observation system
- Help decision system
- Security and military control system
- Didactic research system
- Commercial imagery system

Literature survey

Different papers are many requirements uses to minimumthe development cost and time push researches towards satellite generations. To offer more chance to the world to implement their own satellites responding to a requirements, these generations are developed to be cheaper, more rapid to be on service, simpler to function and with a commercialized technology [1]. Figure 2 displays a comparison according to five parameters including Pico Sats and FemtoSats. These parameters offer the advantage of m igration from the Pico Sats generation to the FemtoSats. We can note that this position of FemtoSats focus on its architecture and its power in terms of services and lifetime.

Migration Toward The Ultra-Small Satellite Generation

Classification of satellites frequently depends on its masses. Actually, we talk about satellites which are inferior to 1 kg and sometimes to some grams, as shown on table 1. PicoSat is, eventually, larger than Fem toSatellite, AttoSatellite and ZeptoSatellite. This passage i s justified with the technological evolution i n terms of integration density. In the last decades , the world of technology manifested mixing between the conception of micro-electromechanic MEMS approach and the conception of electronic CMOS approach, which allows the development of captors, processors and systems that are completed on a miniature surface even granular. These systems have thefollowing advantage –

1. Reduction of the cost of production 2.Reduction of the cost by prototype.

Table 1: Ultra-Small Satellite

Name	Weight	Price
PicoSatellite	1 kg	10000 $
FemtoSatellite	0.1Kg	100 $

AttoSatellite	0.01Kg	Few $
ZeptoSatellite	0.001 Kg	Few $

Table 2: Historic of 10 years FemtoSat generation

Reference	Author	Year
Femto Sat-On Ship	A. Brett et al	2002
WISNET	D. Barnhart et al	2007
FemtoSatOn Board	D. Barnhart	2009
WIKISat	J.Tristancho et al	2011

High level Comparison : functional, structural- In general Satellite and Femto Satellite in particular,it is composed into six bigsubsystems.andthat subsystems can also be subdivided elementarily. These subsystems assure the navigation, the communication, the management, and the captures by using a de dicated structure and one or more sources of energy. Often, we find other classifications of subsystems such as the navigation which is responsible for the control and the determination of the attitude as well as the position.

Low level Comparison Subsystems This part highlights the different architectural parameters of two FemtoSatellites. Table No.3 contains the summarizes the comparison. This comparison displays the possibility of to design or construct in small size the satellite. Thereby, this trend encapsulated multitasking and multi-discipline systems that still suffer from energetic limitation which influences the service quality and the lifetime of satellite.

Fields of Actual Resources On Femto Stats On Board

All the modules directly influence the lifetime in space which has been already limited by the resource insufficiency. Actually, researches are around some minutes. These limitations are, nowadays, the large perspectives of research. Works are distributed between the updates of commercialized components, the study of certain modules such as communication and the exploration of FemtoSat services. Modeling, first of all, builds a mathematic model of the phenomena, which is called the digital modeling. Then, this model will be transformed in an observable system where we can change the parameters. There by, these digital and analogical modelings are treated in several works such as:

In 2011, Chang-Chan designed the power system of USS by specifying the solar cells and the battery. In fact, he calculated the provided solar power, masses, and the lifetime of the satellite functioning by his battery. - In 2012, author studied and analyzed the architecture of the new adaptive to design or construct in small sizesatellite generation. He oriented the power efforts of spatial system toward the conception of system on board with com mercialized modules keeping a service quality and a masse/power compromise. He designed the weight, the used power and the lifetime. These modelings, later on, facilitate the conception and even the research of optimist components. However, they are not followed by concrete realizations, the fact that raises the question of their feasibility. Despite this, certain works, that we will detail later on, have responded at this question as well as finishing the prototypes.

In other research related to NPS Femto satellites, Lieutenant David Justamante wrote a master's thesis for NPS, "Randomness from Space," documenting the nextgeneration NPS Femto satellite capabilities that provide a true random number generation. Author utilizes the different systems some of the system is onboard BMC 150 6-axis eCompass in the Intel Quark D2000system . He concluded that the next-generation NPSFS is a good source for entropy (Justamante, 2017). Although such valuable literature pertaining to the NPSFS exists, to the author's best knowledge, there is no paper or study pertaining to the NPS Femto Satellites communication network.

III. DESIGN AND DEVELOPMENT

The femto satellite is designed based on a CubeSat form factor, specifically a 1U configuration (10 cm x 10 cm x 10 cm). The design process involves selecting suitable materials, subsystems, and components. The satellite subsystems include:

i. Structure: The satellite's framework is constructed using lightweight and robust materials to withstand the rigors of space environment.
ii. Power: Solar panels and rechargeable batteries provide power to the satellite's systems.
iii. Communication: A communication module facilitates data transmission between the satellite and ground stations.
iv. On-board Computer: A microcontroller manages satellite operations, data handling, and communication protocols.
v. Payload: The mission payload, which varies based on application, is integrated into the satellite's design.

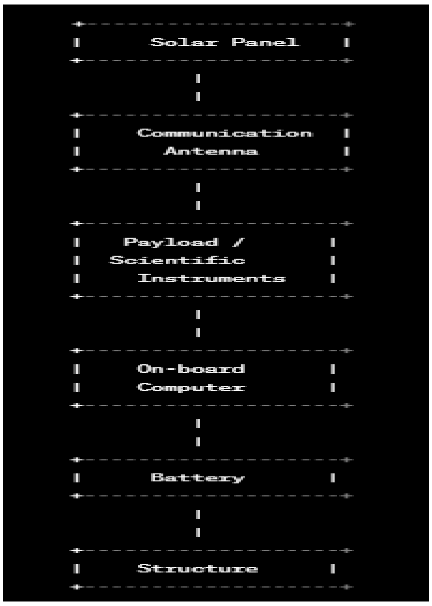


Fig.1 Design and development Hierarchy

IV.BENEFITS

“Large Benefits of Small Satellite Missions,” is a paper written by researchers from NASA, Stanford University, and Colorado University, and addresses some advantages of small satellites. The most important benefit is the cost and convenience of the inexpensive commercial-off-the shelf satellite. For example, the KickSat costs about $35. Another cost-related advantage is its inexpensive launch. These two benefits lead to even more benefits. By having small satellites, scientists and researchers can gain frequent access to space, which accelerates space development programs (Baker & Worden, 2008). From a military perspective, small satellites provide a rapid launch capability that can provide a quick space-based service. Besides that, small satellites are difficult to track, so the adversary is less likely to detect them and shut them down.

1. **Mission Payload:**The specific mission payload for the femtosatellite is chosen based on its intended application. Examples include:
2. **Earth Observation:** A miniaturized camera captures images of Earth's surface for environmental monitoring.
3. **Communication:** A low-power communication system enables short-range data transfer between satellites or to ground stations.
4. **Scientific Research:** Sensors collect data on space radiation, magnetic fields, or other phenomena.

5. **Simulation and Testing:**Various simulation tools are employed to model the satellite's behavior in the space environment, including thermal simulations, radiation analysis, and power consumption modeling. Hardware-in-the-loop (HIL) testing and ground-based experiments validate the satellite's subsystems and overall functionality.
6. **Launch and Deployment:**Thefemto satellite is launched into space as part of a rideshare mission, piggybacking on a larger launch vehicle. Upon reaching its designated orbit, the satellite is deployed into space.
7. **Performance Analysis:**The satellite's performance is analyzed based on several criteria, including:
8. **Communication Range:** The range over which the satellite can successfully transmit and receive data.
9. **Data Quality:** The accuracy and reliability of data collected by the mission payload.
10. **Power Efficiency:** Evaluation of power consumption and the ability to sustain operations.
11. **Durability:** Assessment of the satellite's ability to endure space conditions over time.

V. COMPONENTS USED:

Structure: The physical frame of the CubeSat, typically made of aluminum or other lightweight materials. It provides support for all other components and protects them during launch and deployment.

Power System:

- **Solar Panels:** Convert sunlight into electrical power to charge the batteries.
- **Batteries:** Store electrical energy generated by solar panels for use when the satellite is not in direct sunlight.

Communication System:

- **Antennas:** Transmit and receive radio signals for communication with ground stations or other satellites.
- **Transceiver:** Radio communication device that sends and receives signals.

Onboard Computer (OBC):

- **Processor:** Controls the satellite's functions and executes commands.
- **Memory:** Stores software programs and data.
- **Interfaces:** Connects to various subsystems like sensors, actuators, and the communication system.

Attitude Determination and Control System (ADCS):

- **Magnetorquers:** Use Earth's magnetic field to adjust the satellite's orientation.
- **Reaction Wheels:** Spin to control the satellite's attitude (orientation) in space.
- **Gyroscope:** Measures and maintains the satellite's orientation.
- **GPS**: The core component that captures and processes signals from GPS satellites. It determines the satellite's position, velocity, and time by analyzing the signals received from multiple GPS satellites shown in Fig.6.

Payload:

- **Sensors:** Collect data relevant to the satellite's mission (e.g., cameras, spectrometers, magnetometers).
- **Actuators:** Perform actions based on commands (e.g., deploying a mini-satellite, adjusting solar panels).

Thermal Control System:

- **Heaters:** Maintain optimal temperature inside the satellite.
- **Radiators:** Dissipate excess heat into space to prevent overheating.

Deployment Mechanisms:

- **Antenna Deployers:** Release antennas after reaching orbit.
- **Solar Panel Hinges:** Allow solar panels to unfold after deployment.

- **Payload Release Mechanisms:** Release secondary payloads or experiments

Fig.2 BMS (Battery Management System)

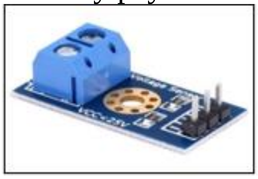


Fig.3 VSU(Voltage Sensing

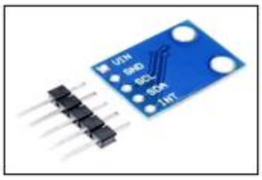


Fig.4 NAV (Navigation)

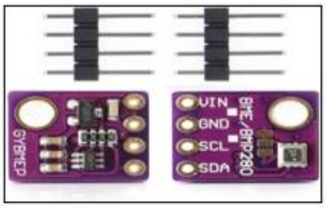


Fig. 5 BME (Barometric Pressure Sensor)

Fig.6 GPS

VI.WORKING OF FEMTO SATELLITE

The actual working of a femto satellite, also known as a CubeSat or nanosatellite, involves a series of coordinated processes and systems working together to achieve its mission objectives. Here's an overview of the working principlesforfemto satellite:

Launch and Deployment:

Femto satellites are typically launched into space as secondary payloads aboard larger rockets. They are stored in a deployer, which releases them into orbit once the primary payload reaches its designated orbit.

Deployment mechanisms ensure that the femto satellite safely separates from the deployer and is oriented correctly in space.

Orbit and Attitude Control: Once in orbit, the femto satellite's attitude control system ensures that it maintains the correct orientation for its mission. This involves:

Magnetorquers: These use Earth's magnetic field to adjust the satellite's orientation.

Reaction Wheels: Spin to control the satellite's attitude in space.

Gyroscopes: Measure and maintain the satellite's orientation.

Power Generation and Management: Femto satellites are equipped with solar panels that convert sunlight into electrical power. This power is used to operate the satellite's systems and charge onboard batteries.Batteries store excess power generated by the solar panels for use when the satellite is in the Earth's shadow or during peak power demands.

Communication: Femto satellites communicate with Earth-based ground stations or other satellites via radio signals.The communication system includes:

-Antennas: Transmit and receive signals.

-Transceiver: Radio device for sending and receiving data.

-Onboard Computer: Controls communication functions and data processing.The satellite establishes a link with ground stations to receive commands, transmit data, and receive software updates.

Onboard Computer (OBC): The OBC serves as the "brain" of the femto satellite, executing commands, processing data, and managing subsystems.

It runs software algorithms for:

-Navigation: Determining the satellite's position using GPS shown in Fig. or other navigation systems.

-Payload Operations: Controlling the different scientific instruments, cameras, sensors, or other payloads.

-Communication: Handling data transmission to and from the ground.

Payload Operation:Femto satellites often carry payloads such as cameras, sensors, or scientific instruments.The OBC controls the operation of these payloads, collecting data according to the mission objectives.

Examples of payloads include:

Imaging Systems: Capture images of Earth's surface for remote sensing applications.

Sensors: Measure environmental parameters such as temperature, pressure, or radiation.

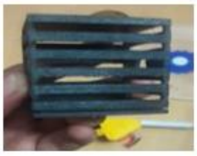
Data Handling and Storage: The satellite's onboard computer processes and stores data collected by the payloads.Data is compressed and formatted before transmission to optimize bandwidth.Storage devices such as memory modules or solid-state drives store data for later download to ground stations.

Mission Execution: Thefemto satellite executes its mission tasks based on pre-programmed commands and instructions from ground control.It autonomously performs its functions, such as imaging specific areas, monitoring environmental changes, or conducting scientific experiments.

End of Mission: Eventually, the femto satellite's mission may conclude due to factors such as fuel depletion, battery degradation, or completion of objectives.

Some femto satellites are designed for de-orbiting, using propulsion systems or drag-inducing devices to re-enter Earth's atmosphere and burn up safely.

Others remain in orbit as inactive space debris some working is shown in below images:



This project report highlights the key stages involved in the design, development, and analysis of a femto satellite. The project contributes to the growing field of small satellite technology and underscores the value of compact, cost-effective solutions for space-based endeavors.

The field of femto satellites, also known as CubeSats or nanosatellites, continues to evolve with ongoing advancements in technology. Here are some potential future directions and applications for femto satellites:

Advanced Sensing and Imaging:

- **HyperspectralImaging**:Femto satellites equipped with hyperspectral sensors can provide detailed information about Earth's surface, vegetation health, mineral composition, and more.
- **High-Resolution Cameras:** Improvements in camera technology can enhance the imaging capabilities of femto satellites, allowing for sharper images and better monitoring of Earth's surface.

Climate Monitoring and Environmental Research:

- **Weather Forecasting:**Femto satellites can contribute to weather monitoring and forecasting by providing real-time data on atmospheric conditions.
- **Oceanography:** Monitoring ocean temperature, currents, and pollution levels from space can aid in understanding and protecting marine ecosystems.

Communication Networks:

- **Internet of Things (IoT) Connectivity:**Femto satellites can be part of IoT networks, providing connectivity to remote areas and enabling data transmission from sensors and devices worldwide.
- **Global Broadband Access:** In collaboration with larger satellites, constellations of femto satellites could help provide global broadband coverage, especially to underserved regions.

Space Debris Mitigation:

- Femto satellites equipped with sensors can contribute to tracking and monitoring space debris, helping to prevent collisions with active satellites and spacecraft.
- **De-orbiting Technology:** Future femto satellites may integrate propulsion systems or deployable structures to assist in de-orbiting at the end of their missions, reducing space debris.

Autonomous Navigation and Formation Flying:

- Advancements in autonomous navigation algorithms will enable femto satellites to navigate independently and maintain precise formations in space.
- **Formation Flying Missions:** Groups of femto satellites working together can achieve complex missions, such as distributed sensing or multi-point observations.

Scientific Research:

- **Astrophysics:**Femto satellites can contribute to astrophysical studies by observing cosmic phenomena, such as gamma-ray bursts, from unique vantage points.
- **Space Biology:** Studying the effects of microgravity on biological systems with femto satellites can provide insights into long-duration space travel and potential life on other planets.

Interplanetary Exploration Support:

- As technology advances, femto satellites could serve as scouts or communication relays for larger interplanetary missions, reducing the need for dedicated spacecraft in orbit around other planets.
- **Proximity Operations:**Femto satellites with advanced guidance and control systems could assist in orbital maneuvers or lander operations during missions to other celestial bodies.

Education and Outreach:

- Femto satellites offer an accessible platform for educational institutions and students to learn about space technology, engineering, and science.
- **Citizen Science Projects:** Engaging the public in femto satellite missions can promote scientific literacy and involve amateur astronomers and enthusiasts in space research.

VII. CONCLUSION

The development and analysis of the femto satellite demonstrate its potential for various space-based applications. The project successfully showcases the feasibility of utilizing miniature satellites for specific missions, paving the way for further research and innovation in the field of femtosatellites.Throughout this report, we have explored the fundamental components of femto satellites, from their basic structures to their intricate systems such as power, communication, and navigation. We have also delved into the diverse array of potential applications for femto satellites, ranging from Earth observation and climate monitoring to scientific research and interplanetary exploration support.As we look ahead, the continued development of femto satellites holds immense potential for addressing pressing challenges on Earth, expanding our understanding of the universe, and inspiring the next generation of space explorers. It is clear that femto satellites will play a vital role in the future of space exploration and scientific discovery.In conclusion, the compact size, versatility, and affordability of femto satellites make them a powerful asset for a wide range of missions and applications, marking a significant advancement in the field of space technology.

VIII.FUTURE WORK

Future work could involve enhancing the satellite's capabilities, exploring new mission profiles, and optimizing subsystems for improved performance. Additionally, investigating collaborative swarm-based operations and advanced communication protocols could expand the potential applications of femto satellites.

The future of femto satellites is promising, with ongoing advancements in technology paving the way for even greater capabilities. Advanced sensing and imaging technologies will allow femto satellites to provide high-resolution data for environmental monitoring and scientific research. Additionally, the potential for femto satellites to contribute to global communication networks, space debris mitigation efforts, and autonomous navigation systems is significant.Furthermore, the accessibility and affordability of femto satellites make them an invaluable tool for educational institutions and students, fostering interest and engagement in space science and engineering.

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