LEISA: LOW-EARTH ORBIT SPECTRUM ANALYZER

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ABSTRACT

The Configurable Space Microsystems Innovations and Applications Center (COSMIAC) at the University of New Mexico (UNM) has been awarded the Research Experience for Undergraduates (REU) grant by the National Science Foundation (NSF) to design, prototype, and launch a space borne ionospheric spectrum analyzer 1-U (1000cm3) CubeSat. The LEISA (Low Earth Orbit Ionospheric Spectrum Analyzer) satellite constellation will measure intracloud lightning via the production of radio wave distortions as a means to measure total electron content (TEC) in the ionosphere. The satellite constellation and various ground stations will digitize, record, and timestamp RF signals emitted by lightning. This allows for clientele to download data easily and rapidly for use in ionospheric modeling and real time GPS correction. The LEISA constellation is currently being developed by various graduate and undergraduate students at UNM and has introduced students to orbital mechanics, plasma physics, and signal propagation. In addition, lightning interactions with the atmosphere provide students with a solid foundation in research, integration, and design techniques.

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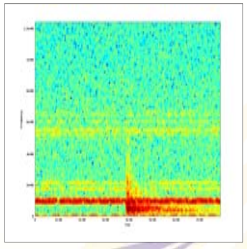
INTRODUCTION

•The effects of the ionosphere on radio wave propagation have been known since the early days of wireless radio transmission.
•The same mechanisms that assist radio wave propagation affect GPS systems causing inaccuracies.
•One way to correct GPS systems is to use the total electron content (TEC) of the ionosphere.
•Lightning is a natural source of RF signals and can be used to create a spectrometer.
•LEISA will be a low-earth orbit satellite that will record, process, and send ionospheric data to clients.

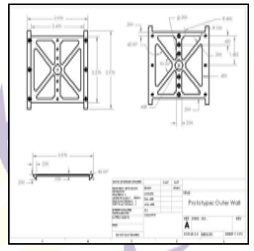
MISSION OBJECTIVES

•LEISA will provide scientists and engineers with an inexpensive and easy to use ionospheric data measurement platform.
•LEISA will detect RF emissions created by intracloud lightning at the 20-200 MHz range and allow for the triangulation of lightning events.
•LEISA, as a CubeSat, will provide 50 days of data collection.
•The simplicity, affordability, and ease of use of LEISA will allow for the production of additional CubeSats to continue the mission.

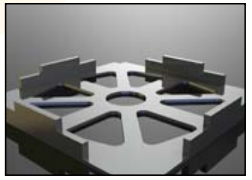


SATELLITE DESIGN

•CubeSat encloses only 1000 cm^3 requiring compact component design and antenna deployment.
•CubeSat physical prototype is a novel design based on industry standard Pumpkin designs.
•Prototype made from Aluminum 6061 T6.
•Design is light weight, easy to assemble, and easily customizable for use with personalized chipsets.

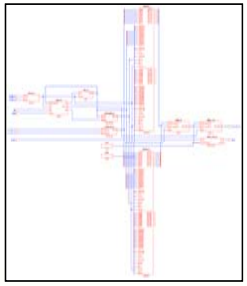


•Small satellite volume forces antenna systems to fit within satellite and open once satellite is in orbit.
•Antenna deployment system dependent on launch restrictions and space environment.
•Antenna design dependent on system mission. Current antenna design proposals include spiral conical antennas.



UNDERGRADUATE RESEARCH CONTRIBUTIONS

•Various engineering and science undergraduate and graduate students have been responsible for the design, development, and prototyping of the LEISA satellite.
•The LEISA satellite project has incorporated various electrical engineering, mechanical engineering, nuclear engineering, and physics students from universities throughout the western United States.
•Students have learned digital logic, VHDL design, numerical methods, and other engineering skills while forming part of an actual engineering project.



THEORY

• Ionosphere is a highly ionized region of atmosphere located from 60 to over 500 km above the Earth's surface.
•Ionization of layers characterized by four parameters: electron density, electron temperature, ion temperature, and ionic composition.
•Electron density affects radio wave propagation causing refraction or reflection.
•How much a radio wave is refracted is a function of its frequency, the ionosphere's plasma frequency (1), and the layers' indices of refraction (2).

$$\omega_p^2 = \frac{n_e e^2}{\varepsilon_0 m_e} \quad (1)$$

$$n_p = \sqrt{1 - \frac{\omega_p^2}{\omega^2}} \quad (2)$$

DESIGN REQUIREMENTS

LEISA's specialized mission forces certain requirements on its design. Components necessary for LEISA are not standard on basic CubeSats and must be designed according to mission parameters and limitations.

•LEISA's dependence on intracloud lightning as an RF source makes a 350 km, 60 degree inclination orbit necessary due to lack of atmospheric drag and inability to detect lightning at different altitudes and inclinations.
•LEISA's small volume and surface area makes it necessary for internal components to be compact and energy efficient.
•Communication and data collection antennas must be able to fit inside CubeSat during launch and be deployable once in orbit according to launch limitations and standards.

CONCLUSIONS

•Tentative launch date is summer 2013, subject to CubeSat launch providers' launch dates and requirements.
•The LEISA satellite will provide invaluable ionospheric total electron content measurements to interested clients in an inexpensive and simple to use fashion.
•LEISA, if successful, will be the first of many CubeSat satellites forming a constellation dedicated to the accurate and timely measurement of ionospheric data.
•The LEISA satellite will demonstrate the value of small space projects in today's political climate.

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