Title: *Development of a Ionospheric Electron Content and Weather Measurement System in a CubeSat nanosatellite mission.*
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(X) We apply for Student Prize.

Need

Current telecommunication systems require accurate and up-to-date ionospheric information, conditions and data found on Total Electron Content Maps (TEC-Maps). Those maps are generated by multiple emission-reception of probe signals sent from earth, but rarely from *in situ* measurements into the Low Earth Orbit through small satellite missions.

Mission Objectives

- Design of a CubeSat nanosatellite-based mission for the measurement and quantification of the Total Electron Content in a determined location of the ionosphere.
- Design of a proper array of ground stations enabled to receive and process the data obtained from the CubeSat measurements in order to generate regional TEC-Maps over Mexican territory.

Concept of Operations

Space Segment

Consists in three different modules, each of them referred to a standard CubeSat Unit (1U). In that case, the proposed satellite will be a 3U CubeSat. The three units will be determined as The Main Unit, The Power Unit and The Payload. This will be described with more detail in the **Space Segment Description** section.

Ground Segment

It will consist of multiple ground stations, each one placed in specific locations through the Mexican territory. This will provide a full ground-coverage of the trajectory and measurement locations, making it possible to receive in real-time through different places the data transmitted from the CubeSat.

Launch Segment

Because of its ease of implementation, the idea is to use the ISS P-POD, which will be able to deploy a fully functional 3U CubeSat, according to the Cal Poly Specifications, saving a lot of resources by launching the satellite through an ISS Cargo, reducing significantly the vibrations during the deployment and ensuring the proper execution of the mission.

Key Performance Parameters

1) In order to get successful measurements of the electron density and temperature from the ionosphere, the selected Langmuir probes must operate within space implementation ranges[1].
2) For a complete and optimal data acquisition, the selected orbit for the CubeSat must be able to cover at least once a day a full sweep over the territory of Mexico.
3) According to the last key parameter, a series of multiple ground stations must be carefully placed in strategic areas, in order to have a full data reception during each of CubeSat's orbit over Mexico.

Space Segment Description

The proposed 3U device is divided in three different sections, according to each unit:

- The Main Unit (top): Contains the UHF-Transceiver with it's antennas at the top of the CubeSat, the GPS module and the On-Board Computer (OBC) module, all connected to a I^2C node, following the standard CubeSat BUS pinout.
- The Power Unit (central): Is where the heaviest modules are attached. These modules are the Electrical Power Supply (EPS) with three output regulated voltages (3.3V, 5V & 12V) and an un-regulated battery voltage (2 Cell Li-Ion Batteries 8.2V-30Whr) and the Attitude Control and Determination System (ADCS), operating with reaction wheels, and a 9-degrees-of-freedom (DOF) Inertial Movement Unit (IMU) to determine the accurate pitch, roll and yaw angles of the CubeSat.
- The Payload Unit (bottom): It will contain the Mission's Measurement Instruments, made of four Langmuir Probes and one magnetometer and its own data processing subsystem, which will deliver the measurements through the I^2C node to the OBC.

Figure 1 shows the conceptual CAD design for the mission through an outside general viewing of the proposed 3U CubeSat. Figure 2 shows the exploded version of the whole system.

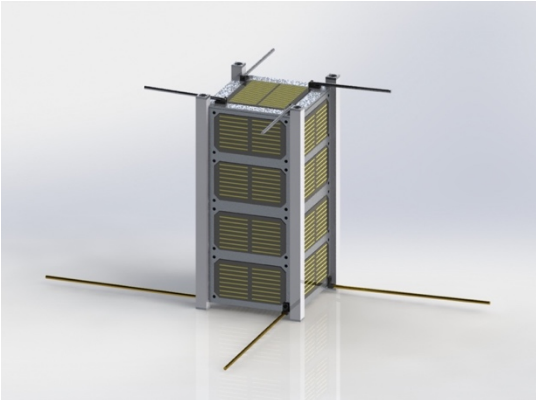

Figure 1. 3U CubeSat General View CAD.

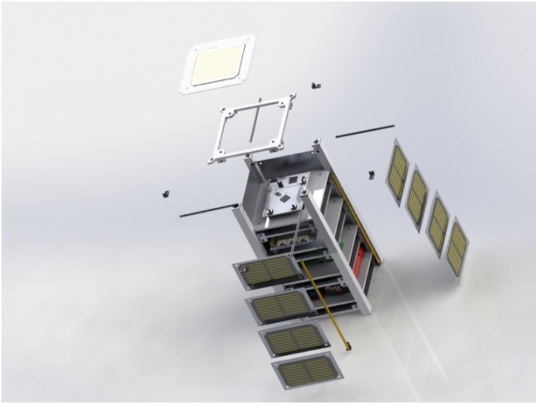

Figure 2. Exploded View of the CubeSat.

[1] Langmuir Spatial Probe Measuring Parameters form *Impedans® Ltd.* [9]

Orbit/Constellation Description

We proceeded with the selection the orbit by approaching to the ISS orbit, because of the selected CubeSat's deployment method. The criteria for the ground stations placement was to get the maximum possible reach of the ionosphere over Mexican territory and according whit convenient locations of some universities for ground stations facilities. A series of Technological Universities were selected in order to create a network of Ground Stations, which will enable to cover the entire Mexican territory. Table 2 shows the Latitude and Longitude of every University.

Table 2. Universities' Coordinates for the Ground Stations

Ground Station	Latitude N	Longitude W
CICESE (Ensenada, Baja California Norte)	31°48'21.6"	116°35'24.4"
Instituto Tecnológico de Sinaloa (Culiacán, Sinaloa).	24°47'19.0"	107°23'48.3"
Universidad Autónoma de Nuevo León (Monterrey, Nuevo León).	25°39'52.7"	100°14'40.1"
Universidad Autónoma de Chihuahua (Chihuahua, Chihuahua).	28°39'18.8"	106°05'25.0"
Universidad Autónoma de Zacatecas (Zacatecas, Zacatecas).	22°46'29.2"	102°37'33.7"
INAOE (Cholula, Puebla)	19°02'53.3"	98°13'07.6"
Instituto Tecnológico de Tuxla Gutiérrez. (Tuxtla Gutiérrez, Chiapas)	16°45'25.4"	93°10'20.7"
Instituto Tecnológico de Mérida (Mérida, Yucatán).	21°00'43.6"	89°37'24.0"

Due to coordinates of maximum and minimum latitude and longitude shown previously, the CubeSat orbit was described in order to cover the most effective area over Mexican terrain. Orbital simulations are shown in figures 3, 4 and 5, using the AGI® System Toolkit Simulation Software, within a time interval of one week.

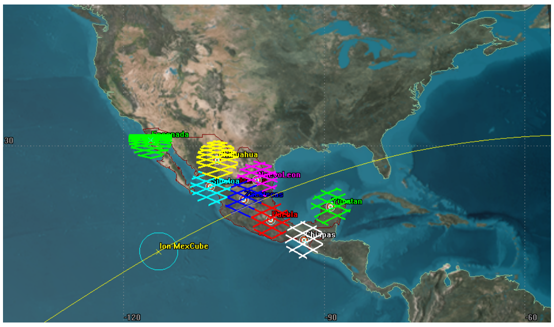

Figure 3. Approaches of Mexican territory.

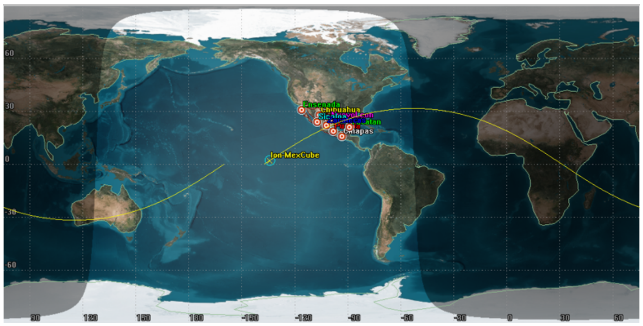

Figure 4. 2D view of satellite path.

Figure 5. 3D view of satellite path.

Implementation Plan

Primary key players

- **Association with University Authorities:** For the CubeSat development and data usage from the mission.
- **Ministry of Communications and Transportations of Mexico (Secretaría de Comunicaciones y Transportes, SCT):** Mexican entity that regulates the frequency bands. Coordination is necessary because it is the Mexican representative with ITU.
- **Mexican Space Agency (AEM):** Mexican entity that regulates national space activities and acts as important consultant for the development of this project.
- **Federal Telecommunications Institute (IFT):** It's the first player in the regulatory side of the project, due to the newest Telecommunications General Law in Mexico.

Costs

Phase	Cost (USD)
Design, development and assembly.	$80,000.00
Integration and testing.	$40,000.00
Launching.	$120,000.00
Operations.	$60,000.00
TOTAL COST	**$300,000.00**

The disposal of the 3U CubeSat is expected to occur in about 14 months after launching into orbit due to atmospheric drag. This first analysis was made taking into account an initial altitude of the orbit of 400 km, considering deploying from the ISS, a ballistic coefficient of 65 kg/m^2 for a 3U CubeSat and an initial in-orbit operation during solar minimum.[2]

Infrastructure

- **Design, development and assembly:** University facilities consisting on electronic laboratories and clean rooms.
- **Integration and testing:** For the environmental and flight acceptance tests, vehicle assembly, integration and test services. As in Mexico there are no complete facilities that let a CubeSat system to be tested, foreign organizations and companies will be needed.
- **Launching:** Launching services like Tyvak, Cal-Poly, Innovative Solutions in Space (ISIS), NanoRacks and Spaceflight Industries Inc., will be used to access the International Space Station through cargo vehicles. Another options of space access through NASA, ESA or JAXA will be considered too.

Project Organization

1) **Mission planners, control and developers:** The team proposing this project.
2) **University authorities and researchers:** They will provide the facilities for the design and development of the engineering and fly model.

[2] This estimation was made according to [3] p.210.

3) **Users of TEC maps and ionospheric measurements parameters:** the users and people interested in the payload information of the mission (national or international).

Schedule

Phase	2017	2018	2019	2020	2021	2022
Funding						
Design, development, integration and testing						
Launching						
Operations of the mission, scientific data analysis and modeling						
Disposal.						

Project risks

1) **Funding,** being unable to reach the amount of money needed to fully execute the mission.
2) **Delay of delivery parts from vendors,** because the complete project could be shifted and important milestones have the high risk of being lost, for example, the case of launching opportunities.
3) **Unsuccessful operation in space** because of the low expertise of the team involved in the development of the mission, being this a firs-time space project development.
4) **Regulations of small satellites,** like frequency coordination with the ITU, export regulations, testing and disposal among others. In this case time management will be important.
5) **Launching opportunity lost** depending mainly on launchers availability and possible failures on the launch vehicle or deployment device.

References

[1] *Real-Time Ionospheric Maps.* Jet Propulsion Laboratory. California Institute of Technology.

[2] Langmuir Spatial Probe Measuring Parameters. *Impedans Plasma Measurement.*

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[4] EEPFLx: EE585x *Space Missions Design an Operations*, EDX.

[5] Megan R. Brewer, *CubeSat Attitude Determination And Helmoholtz Cage Design.* USAF.

[6] Evaluation-of-a-Commercial-Off-the-Shelf-Fluxgate-Magnetometer-for-CubeSat-Space-Magnetometr, Elecdom Matandirotya, Cape Peninsula University of Technology, 2013.

[7] J. Martin-Hidalgo; C. M. Swenson; D. Farr. *Radio Science Meeting (USNC-URSI NRSM)*, 2014. United States National Committee of URSI National.

[8] Z. Chacon; W. Deraad; A. Lerides; M. Mccullough; M. Ortega; S. Suddarth. *Antennas and Propagation (APSURSI)*, 2011 IEEE International Symposium.

[9] https://www.impedans.com/langmuir-spatial-probe [2016-04-03]