One of the crucial measurements for characterizing any space weather event is absolute plasma density and plasma density fluctuations, both spatially and temporally. Among the various methods to perform in-situ plasma density measurements is a simple Langmuir probe. This poster discusses the various implementations of a Langmuir probe and why a Planar Ion Probe (PIP) is the easiest and best method to measure high cadence absolute ion density. We then present the design and performance of a PIP for the NASA LLITED dual Cubesat mission which is expected to be manifested for flight in late 2019. Performance data for the constructed PIP instruments is also presented. This includes noise analysis and calibration data, as well as refined instrument requirements. Due to its intended Cubesat platform, the designed instrument has extremely low size, weight, and power requirements. Thus, if needed, it can be deployed as a patch on multiple faces of a Cubesat, thereby reducing the satellite requirements as well as enabling the study of the wake structure around the spacecraft.

**Introduction**

Coupling between Earth’s Ionosphere-Thermosphere (IT) regions has recently been observed to be more complex than previously expected. IT interactions in the low-latitude dusk-side manifest through two dominant phenomena: the Equatorial Ionization Anomaly (EIA) and the Equatorial Temperature and Wind Anomaly (ETWA), shown in figure 1 and 2 below. The EIA has been extensively observed and modeled, while the ETWA is relatively unknown.

**LLITED Mission**

LLITED is a twin 1U CubeSat mission and is expected to be launched in a polar 550 - 450 km orbit in 2019-2020. This will provide global coverage of low-latitude ETWA regions. Observations of the low-latitude regions necessary instruments only operate 25 - 45% of the orbital period. The dual satellites travel with 1/4 - 1/2 orbital separation, allowing for temporal observations of ETWA. LLITED satellite configurations after launch separation (solar panels stowed) and during nominal science mission activities (solar panels deployed) depicted in figure 3.

LLITED directly addresses a key science goal from the Heliophysics Decadal Survey: “Determine the dynamics and coupling of Earth’s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.” LLITED will characterize and improve our understanding of the ETWA, provide insight into the coupling physics between the ETWA and the EIA, and increase our knowledge of the ionosphere region’s flat current region’s flat current density, ion density, and total electron content profiles of the low-latitude IT region.

**Langmuir Probe Background**

Traditionally, in-situ plasma density is determined through the use of sweeping Langmuir probes. Sweeping a voltage bias on an electrode immersed in plasma and measuring the resultant current yields an IV curve from which one can determine electron and ion density, and electron temperature. The IV curve characteristics are dependent on probe geometry, wherein collected current by cylindrical and spherical probes increases with applied potential (Fig 4a), and the current collected by planar probes remains essentially flat (Fig 4b).

Sweeping Langmuir probes require a ratio of vehicle surface area to probe area of greater than 10,000 to avoid charging the spacecraft with every sweep. Thus, fixed bias probes are much preferred for small spacecraft such as a Cubesat. While probes fixed biased in electron saturated region are thus charged, they do not result in negatively charging the spacecraft.

Thus, for a Cubesat form-factor Langmuir probe, a fixed-bias probe in ion saturation region is a more efficient arrangement. Using a flat plate probe has an additional benefit of being immune to variation in spacecraft charging potential, given the ion saturation region the planar probe’s current response, as well as the benefit of not being a deployable.

**Planar Ion Probe (PIP)**

PIP is a flat-plate, fixed-bias Langmuir probe designed to remain in the ion saturation region, where negative voltage repels electrons, and current collected is effectively due to ions only. Typically, Langmuir probes biased in ion saturation region measure thermal ion current, but at orbital velocities ion ram current is an order or magnitude larger than thermal current for planar geometry. Ion ram current is given by the expression $I_{probes} = (n_i q_i) (V) (A_{probe})$.

where $n_i$ is ion density, $q_i$ is ion charge, $V$ is spacecraft velocity, and $A_{probe}$ is the ram cross section area. With the above, as the signal to noise ratio, they do result in negatively charging the spacecraft.

Thus, for a Cubesat form-factor Langmuir probe, a fixed-bias probe in ion saturation region is a more efficient arrangement. Using a flat plate probe has an additional benefit of being immune to variation in spacecraft charging potential, given the ion saturation region the planar probe’s current response, as well as the benefit of not being a deployable.

**Miniature Planar Ion Probe for CubeSat Missions**

**PIP's Salient Features**

- Total 17cm3 electronics board
- 1.5 cm square with 1 cm wide guard electrode
- Low mass components: instrument 9 g, sensor 10 g, envelope 27 g
- Power draw of 125 mW at nominal ion density (2 x 10$^3$ m$^{-3}$)
- Power draw of 250 mW at maximum ion density (2 x 10$^4$ m$^{-3}$)
- Instrument boot-up time ≤ 350 ms
- Current measurement range from 2.05 x 10$^{-3}$ to 20.5 μA corresponding to density measurement range of 2 x 10$^3$ m$^{-3}$ to 2 x 10$^4$ m$^{-3}$
- Current resolution, while high gain noise averages 19.8 nA, the low gain signal noise is discussed below. This validates that the channels properly amplify the input currents and provide coverage of the intended 4-10$^4$ dynamic range in a linear fashion.

**PIP Software Design**

A digital connection connects PIP to the command and data handling board. A trigger signal initiates a 16x oversampling science measurement. Flight data packages include 32 bits for the two channels of science data and 16 bits for instrument state and cycling the device. Figure 7 shows this PIP state machine algorithm.

**PIP Analysis**

Calibration and testing setup is shown in Fig 8. Testing is conducted using a specialized resistor array block which houses 0.1%, precision resistors housed in a large aluminum mass for temperature stability. Connecting the probe input and instrument ground across a resistor with an ultra low noise cable supplies the instrument with a known current that is then used to check instrument performance and calibration.

**Summary and future work:**

PIP is an ultra low SWaP and low noise instrument to measure in-situ absolute ion density. This poster presents an introduction to LLITED mission and details the PIP mechanical and electrical design. The results presented here enumerate flight board characterization data. The flight electronics have completed design performance validation, as well as vibrational, electrical design. The results presented here enumerate flight board characterization data. The flight electronics have completed design performance validation, as well as vibrational, electrical design. The results presented here enumerate flight board characterization data. The flight electronics have completed design performance validation, as well as vibrational, electrical design. The results presented here enumerate flight board characterization data. The flight electronics have completed design performance validation, as well as vibrational, electrical design.