

# Charge Analyzer Responsive Local Oscillations

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## Sponsoring Program(s)

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Marshall Space Flight Center/Center Management  
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## Project Description

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The first transatlantic radio transmission, demonstrated by Marconi in December of 1901, revealed the essential role of the ionosphere for radio communications. This ionized layer of the upper atmosphere controls the amount of radio power transmitted through, reflected off of, and absorbed by the atmospheric medium. Low-frequency radio signals can propagate long distances around the globe via repeated reflections off of the ionosphere and the Earth's surface. Higher frequency radio signals can punch through the ionosphere to be received at orbiting satellites. However, any turbulence in the ionosphere can distort these signals, compromising the performance or even availability of space-based communication and navigation systems.

The physics associated with this distortion effect is analogous to the situation when underwater images are distorted by convecting air bubbles. In fact, these ionospheric features are often called 'plasma bubbles' since they exhibit some of the similar behavior as underwater air bubbles. These events, instigated by solar and geomagnetic storms, can cause communication and navigation outages that last for hours. To help understand and predict these outages, a world-wide community of space scientists and technologists are devoted to researching this topic. One aspect of this research is to develop instruments capable of measuring the ionospheric plasma bubbles.

Figure 1 shows a photo of the Charge Analyzer Responsive to Local Oscillations (CARLO), a new instrument under development at NASA Marshall Space Flight Center (MSFC). It is a frequency-domain ion spectrum analyzer designed to measure the distributions of ionospheric turbulence from 1 Hz to 10 kHz (i.e., spatial scales from a few kilometers down to a few centimeters). This frequency range is important since it focuses on turbulence scales that affect VHF/UHF satellite communications, GPS systems, and over-the-horizon radar systems. CARLO is based on the flight-proven Plasma Local Anomalous Noise Environment (PLANE) instrument, previously flown on a U.S. Air Force low-Earth orbiting satellite, which successfully measured ion turbulence in five frequency decades from 0.1 Hz to 10 kHz (fig 2).

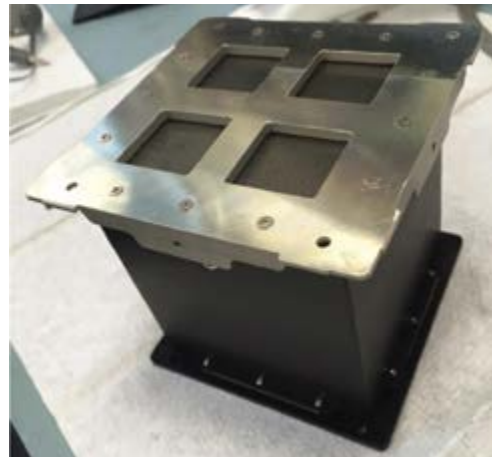
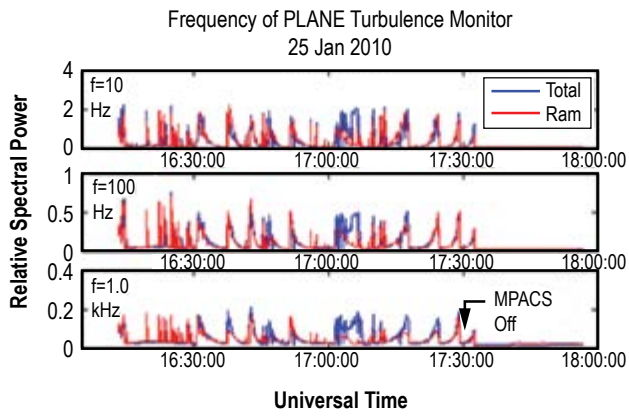


Figure 1: CARLO engineering unit.

## Anticipated Benefits

CARLO was designed to foster the plug-n-play development approach for rapid/modular spacecraft development. An overview of the CARLO assembly appears in figure 3. CARLO's new features include an additional capability to measure turbulence in temperature, an increase in frequency resolution to 20 passbands, its own microprocessor for onboard spectral analysis, and standard mechanical, electrical, and telemetry interfaces to the CubeSat platform.



**Figure 2: Data from CARLO’s predecessor. Ionospheric density fluctuations in three bands were observed during operation of an onboard pulsed plasma thruster.**

**Potential Applications**

With its modular design, CARLO can be operated as a conventional retarding potential analyzer, an ion drift meter, or a planar Langmuir probe. For terrestrial missions, appropriate platforms include sounding rocket, International Space Station external, CubeSats, sub-orbital reusable launch vehicle external flight, and other spacecraft that sample the Earth’s ionosphere from 50 km through 1,000 km in altitude.

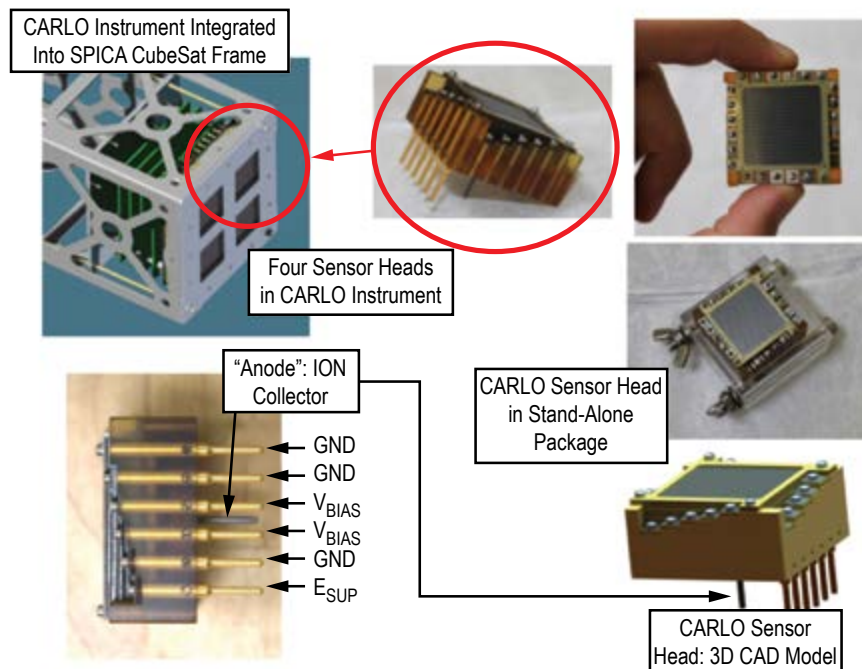
**Notable Accomplishments**

In 2014, the CARLO sensor heads passed their functional testing when exposed to a wide range of ion densities and drift energies in two separate MSFC plasma chambers. Since the CARLO instrument was selected by the InterAmerican University (IAU) in Puerto Rico as the primary science payload for the IAU’s 3U CubeSat, it is anticipated this mission will serve as the heritage flight for this instrument. The IAU CubeSat is being developed for a low-Earth orbit mission, which will allow the CARLO to be used (with other data and models) to investigate ionospheric-magnetospheric coupling mechanisms.

**References**

Habash Krause, L.; Enloe, C.L.; and McHarg, M.G.: “In situ measurements of ionospheric plasma turbulence over five frequency decades: Heritage flight of the Plasma Local Anomalous Noise Experiment (PLANE),” *Adv. Space Res.*, Vol. 52, No. 11, pp. 2006–2014, 1 December 2013.

TIP



**Figure 3: Overview of CARLO sensor heads assembled into the CARLO instrument, which is then integrated into the SPICA CubeSat. The CARLO takes up <1U of CubeSat volume.**