Correlation of Terrestrial gamma flashes, Electric fields, and Lightning strikes (COTEL) in thunderstorms using balloon payloads

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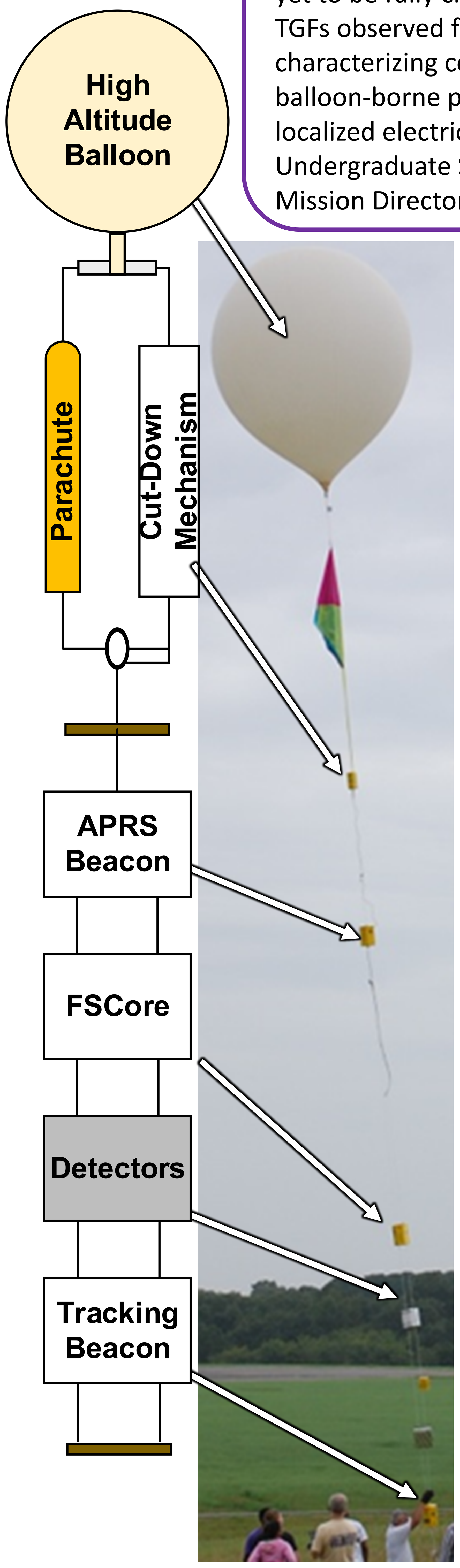


Abstract

High energy gamma ray flashes from terrestrial sources have been observed by satellites in orbit for decades. The actual Terrestrial Gamma ray Flash (TGF) production mechanism, assumed to be thunderstorm lightning, has yet to be fully characterized. Recently, a scientific group at LSU (TETRA/TETRA-II) produced the first catalog of TGFs observed from the ground. The goal of COTEL is to complement the TETRA ground measurements by characterizing conditions within thunderstorms that might lead to TGF emission. This will be accomplished using balloon-borne payloads suspended in and around thunderstorms to detect and timestamp the intensity of localized electric fields, gamma radiation bursts, and lightning strikes. This project is funded via an Undergraduate Scientific Instrumentation Project (USIP) award from NASA Office of Education and Science Mission Directorate (#NNX16AI73A).

Scientific Background

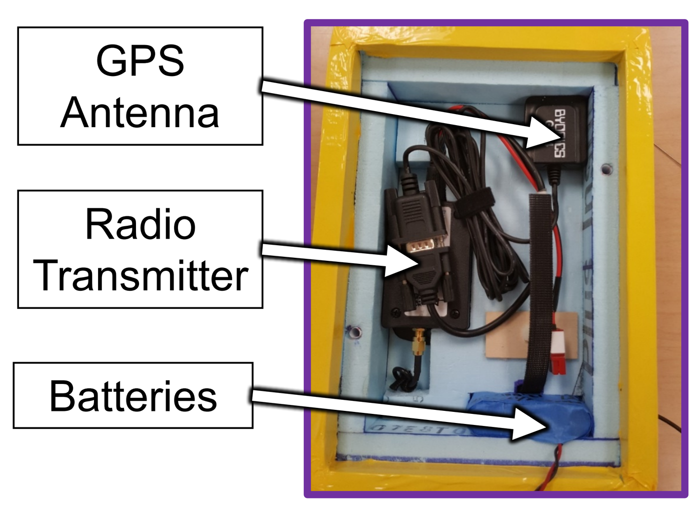
Terrestrial Gamma Flashes (TGFs) are anomalous, rapid bursts of gamma radiation that are associated with thunderstorms. The current model of TGF production associates intense electric fields with high-energy electrons, resulting from lightning strikes. Gamma rays are produced when these electrons are deflected by air atoms. TGFs are short lived (<1ms) and vary in energy (keV to MeV). Investigating the process that creates TGFs and identifying their correlation with lightning strikes and their induced electric fields will help to advance the knowledge of thunderstorm dynamics. This will lead to a better understanding of how TGFs may effect humans traveling aboard planes and spacecraft.

Project Design

Beginning in 2015, the COTEL team drafted and submitted the project proposal document, formed the student team, and began work on the Flight System Core (FSCore) as part of a senior design project within the College of Engineering at LSU. Over the last year, the team has focused on the development of three major components of the COTEL system: the common payloads, the electric field mill, and the ground station. The design and principles of operation of each component is detailed below.

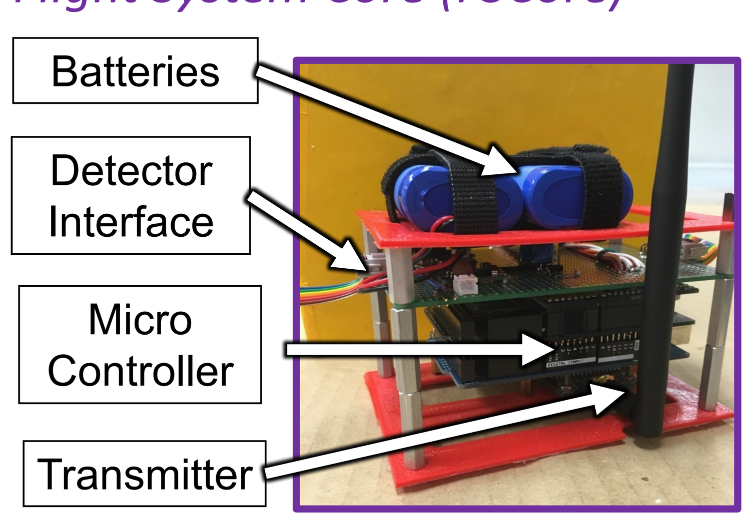
Common Payloads

APRS Radio Tracking Beacon



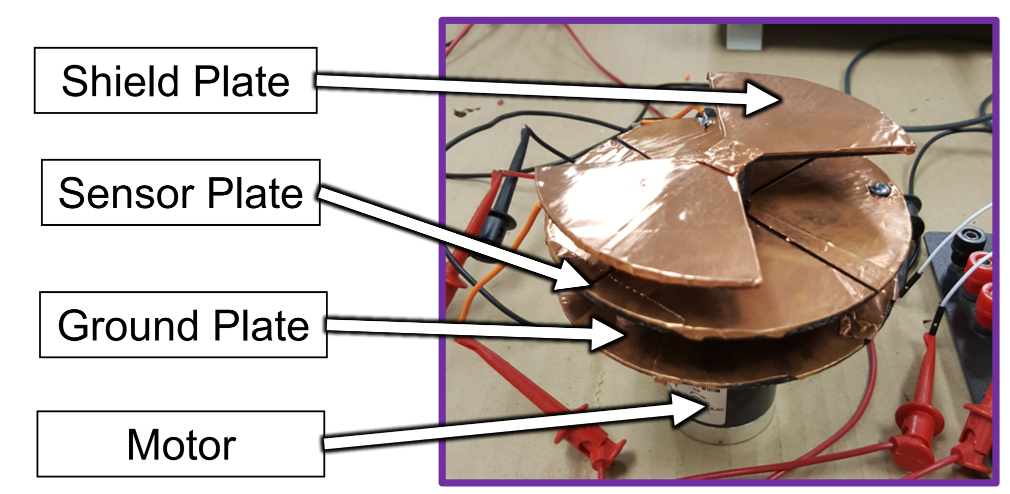
The APRS Radio tracking beacon consists of an onboard GPS system and a radio transmitter. The transmitter broadcasts the flight string's position, allowing the ground station and the chase team to track the payloads while in flight.

Flight System Core (FSCore)



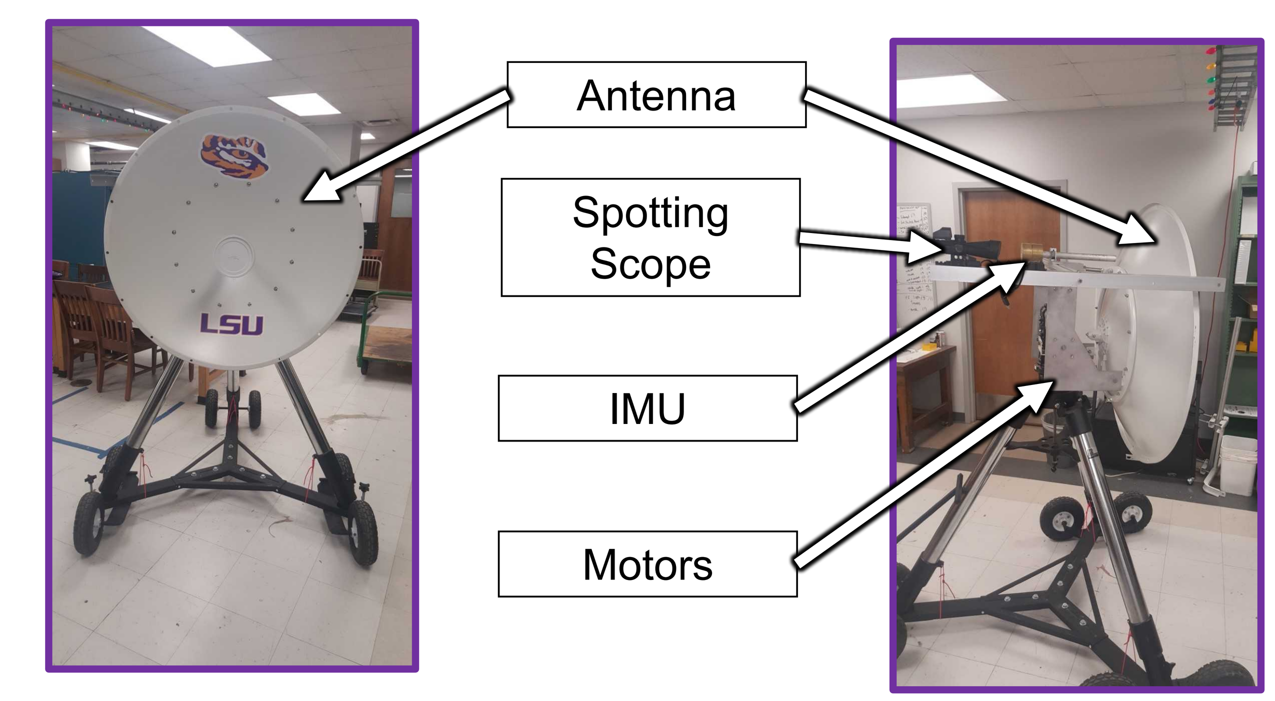
The Flight System Core (FSCore) is the main flight computer of COTEL. The FSCore will store all data collected during the flight, as well as transmit the collected data to the ground station for redundancy.

Electric Field Mill Prototype



The Electric Field Mill (EFM) will be used to measure the magnitude of localized electric fields in the thunderstorm environment. As the motor rotates the shield plate, the sensor plate is continuously exposed and then shielded from local electric fields. This allows the sensor plate to charge and then discharge repeatedly. Measuring the voltage on the sensor plate in reference to the ground plate shows the magnitude of electric fields.

Ground Station



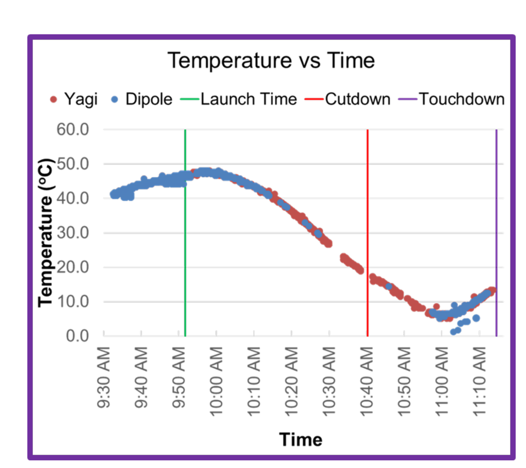
The Ground Station will be used to receive data transmitted from the FSCore during flight. Based on location data received from the Tracking Beacon and readings from the on-board Inertial Measurement Unit (IMU), the ground station will point its antenna at the FSCore throughout the flight to ensure maximum bandwidth of data can be received.

Preliminary Testing

Flight Testing

Ten test balloon flights have been conducted in order to train student team members and to test the functionality of the FSCore and ground station. The ground station has successfully tracked throughout several balloon flights, and the FSCore has had one successful flight test in which it transmitted temperature data throughout the duration of a flight.

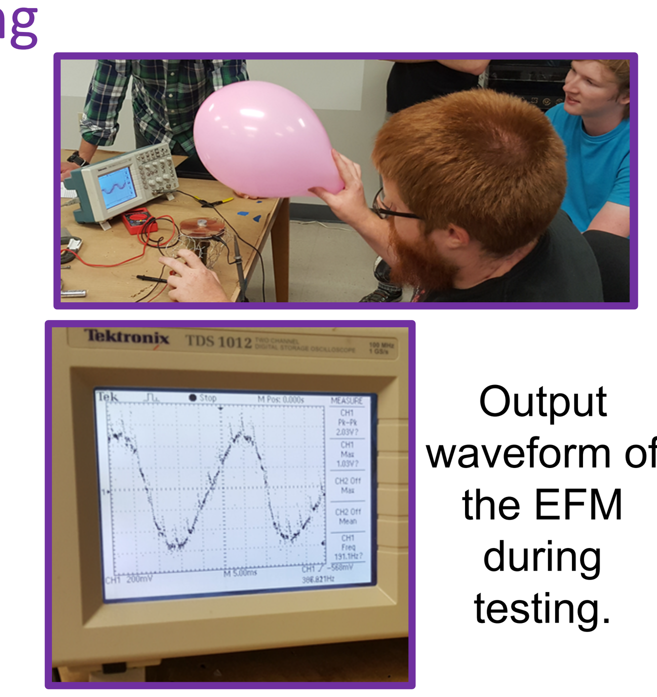
Team members inflating a balloon as part of a training test flight



Temperature data from test flight of FSCore

Electric Field Mill Testing

Bench testing of prototype EFMs have been successful. When E-field sources are introduced to the detector, the magnitude of the output waveform changes based on the source's distance from the sensor plate.



Output waveform of the EFM during testing.

Future Plans

Development and testing of the electric field, gamma radiation, and lightning strike detectors will continue into 2018. Full flight operations will take place during the Spring 2018 Louisiana thunderstorm season.