NASA Supported Undergraduate Student Instrument Project (USIP): Terrestrial Gamma Flash Research

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September 2016

Presented at the Regional Space Grant Directors Meeting, Lexington, KY

Undergraduate Student Instrumentation Project (USIP)

- Joint solicitation from NASA Science Mission Directorate (SMD) and Office of Education (OE)
- Undergraduate students must research, design, develop, and construct a scientific flight payload

Timeline from Solicitation through PIC

- August 27, 2015: Announcement of participation
- **September 28, 2015: Topic selection, preliminary research, and feasibility report**
- October 15, 2015: Notice of Intent submitted
- November 20, 2015: Proposal submitted
- April 6, 2016: Received Accepted Notification Letter
- June 16, 2016: Received funding from NASA Shared Services Center (NSSC)
- September 15, 2016: Project Initiation Conference (PIC)

USIP Project Proposal: COTEL

"**C**orrelation **O**f **T**errestrial gamma flashes, **E**lectric fields, and **L**ightning Strikes (COTEL) in thunderstorms using networked balloon payloads developed by university and college students"

COTEL Mission Objectives:

- Detect, record, and timestamp terrestrial gamma flashes (TGFs), electric fields, lightning strikes
- Utilize a network of hand-launched balloon-borne payloads across a thunderstorm
- Correlate the data recorded with ground arrays and lightning detection networks

Current Project Team

Project Administration

Principal Investigator:

T. Gregory Guzik

Faculty/Staff Advisors:

Michael L. Cherry
Brad Ellison
Colleen H. Fava
Douglas Granger
Michael Stewart

Student Participation

Senior Design Students:

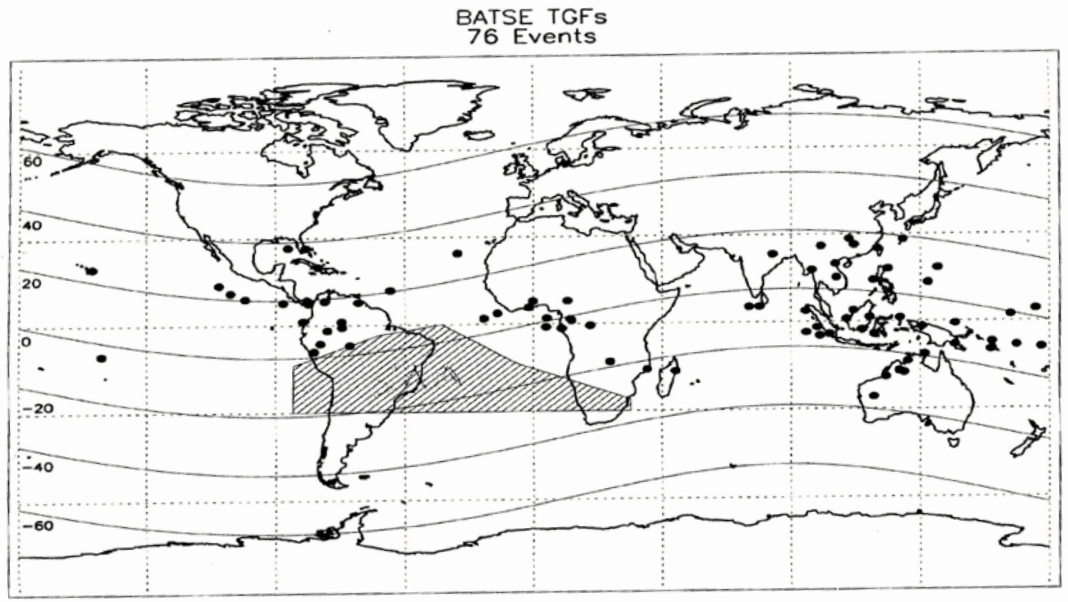
Victor Fernandez-Kim (ME)
Joshua Collins (EE)
Christopher LaForge (ECE)
Elaine Turk (ME)

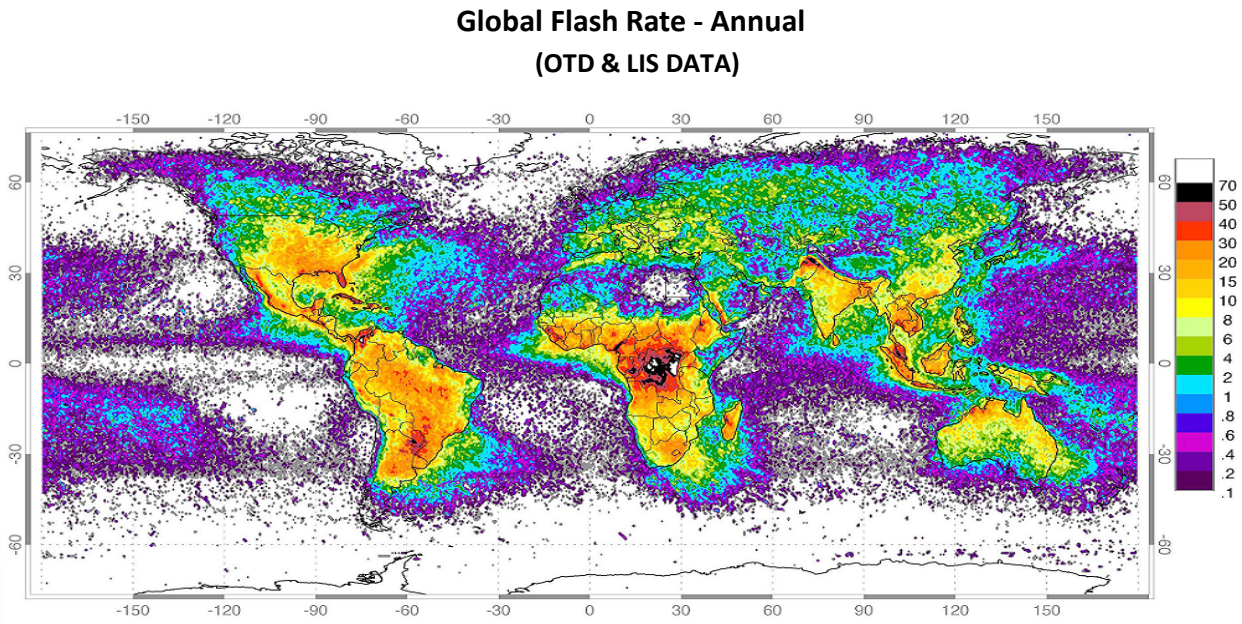
LSU Ballooning Students:

Adam Majoria (PHYS)
Brad Landry (PHYS)
Jordan Causey (ME)
Allen Davis (ME)
Chris Schayer (CS)
Robert Cottingham (PHYS)

Science Background: Terrestrial Gamma Flashes (TGF)

- Anomalous, rapid bursts of energetic gamma radiation (up to ~100 MeV)
- First detected by Burst and Transient Source Experiment (BATSE) on Compton Observatory (CGRO) 1991-2000
- Appears to be associated with terrestrial lightning and thunderstorm activity

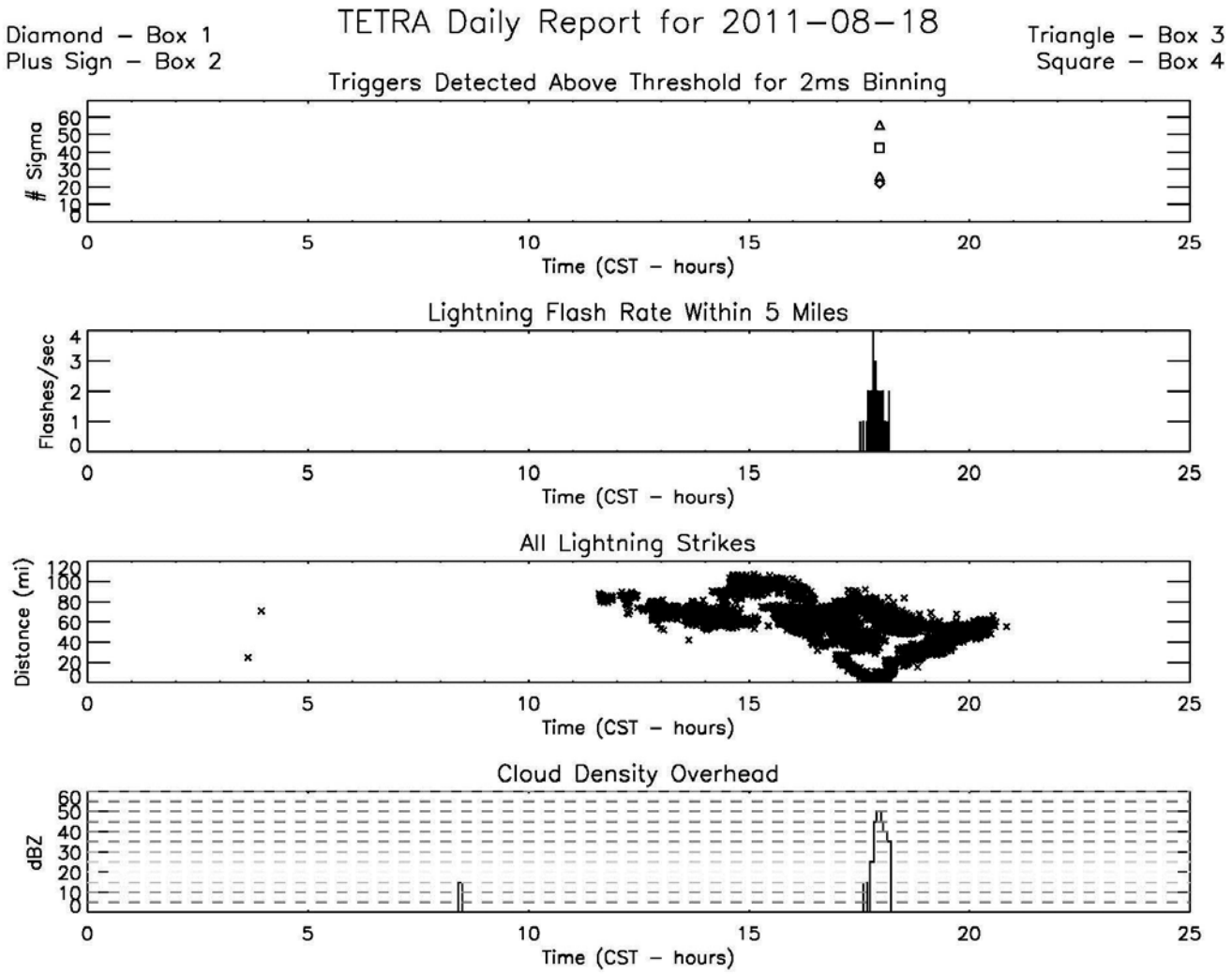




TGF and Energetic Thunderstorm Rooftop Array (TETRA I)

- Array of NaI scintillators on rooftops on LSU campus
- Used to detect TGFs and surrounding lightning strikes from near ground level
- Led by Dr. Michael L. Cherry, LSU

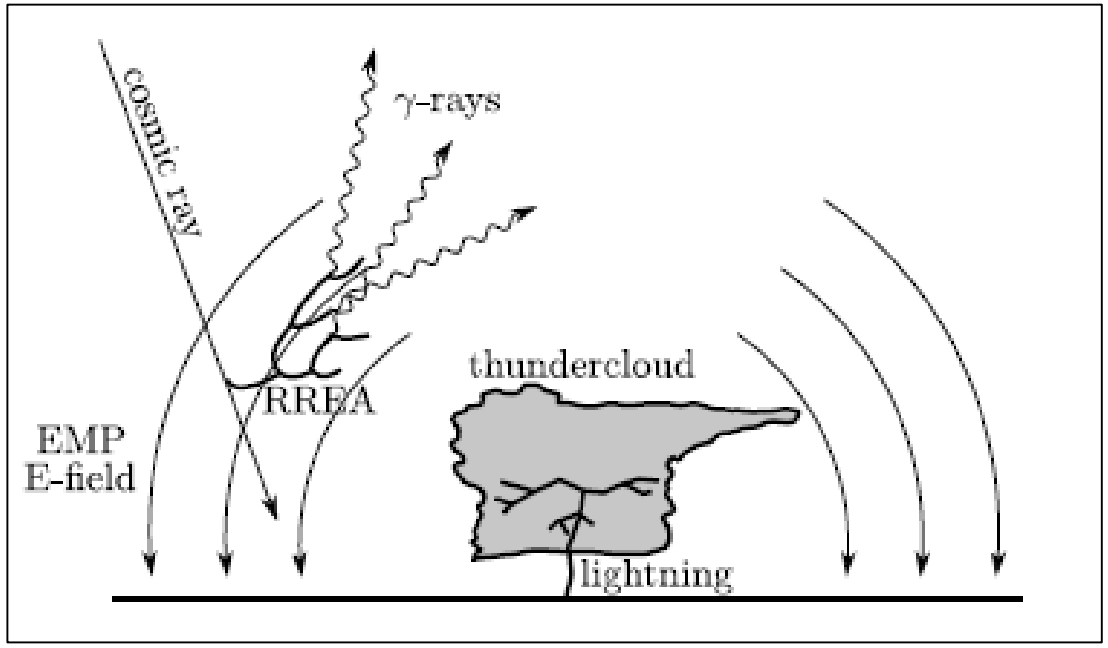
Scintillator and Photomultiplier Tube Assembly Used in TETRA I



Details of TGF production still needs to be understood

- Thunderstorm has an intense electric field
- An initial cosmic ray can start a particle shower or Relativistic Runaway Electron Avalanche (RREA)
- The RREA, driven by the electric field, leads to lightning flashes
- The high energy electrons interact with atmospheric nuclei to produce gamma
- How intense is the electric field in thunderstorms? Is the intensity consistent with the TGF production theory?

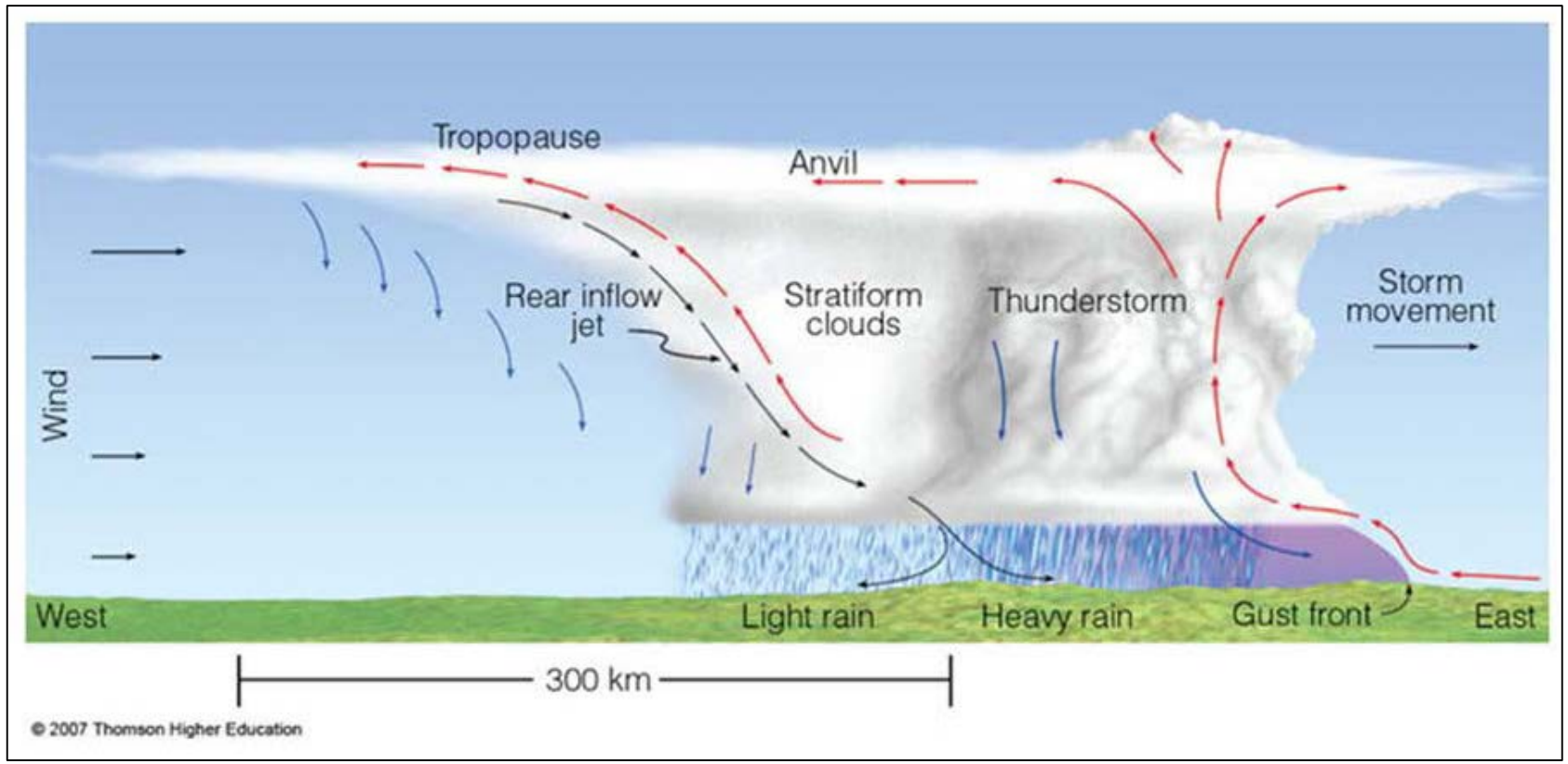
Electromagnetic Pulse TGF Production Mechanism



Most TGF observations have only been made from orbiting satellites or ground arrays

- Understudied region approximately 50,000 ft above the surface
- Necessity to launch detection equipment into or nearby a thunderstorm
- Important to determine the position and orientation of TGF events, lightning strikes, and electric fields
  - Requires multiple payloads to triangulate and correlate detected events

COTEL Weather-Related Mission Challenges



1. Launching into high-speed, turbulent wind conditions
2. Increased risk of lost payload hardware and onboard data
3. Communication interference due to radio wave emissions from nearby lightning strikes

Student Team Partition

Flight Systems Team Objectives:

- Develops the launch system responsible for balloon inflation and payload deployment
- Develops a base payload that interfaces with the launch system, balloon vehicle, detector modules
- Responsible for positioning the payload(s) into a target location within a thunderstorm
- Focus of the 2016-2017 LSU Capstone Senior Design Students

Payload Development Team:

- Develops the ground station that complements the airborne payload
- Develops the payload detector modules for electric fields, lightning strikes, and TGFs
- Responsible for measuring and retrieving data from the payload(s)

USIP is over two years

COTEL Year 1 Goal: Develop and test a flight platform that deploys and supports multiple balloon-borne payloads specialized for testing in thunderstorm environments

COTEL Year 2 Goal: Finalize and integrate detector modules into the flight system, perform full system tests, and reproduce the systems to create a network of balloon-borne payloads

COTEL Project Timeline (1/4)

<u>September-October 2016</u>: Develop project objective statements, qualitative constraints, engineering specifications, functional decompositions, testing and safety plan; perform test launches

- 9/20/16: Objective Statement and Engineering Specifications Report Outline
- 10/3/16: Engineering Specifications Report
  - Functional requirements
  - Qualitative constraints
  - Measurable engineering specifications
  - Preliminary schedule/timeline
  - 10/24/16: Embodiment Proposal Outline (Pre-PDR)

COTEL Project Timeline (2/4)

November 2016: Finalizing design concepts, high-level system design, engineering analysis, budget, and timeline

- 11/04/16: USIP Requirements Review
- 11/11/16: Embodiment Proposal Report (PDR)
  - functional decomposition
  - concept generation
  - evaluation and selection
  - system description
  - engineering analysis and materials selection
  - project management
- 11/21/16: Final Prototype Proposal Outline (Pre-CDR)
- 11/25/16: Project Poster Due

COTEL Project Timeline (3/4)

December 2016: Design review and transition into project embodiment

- 12/7/16: Final Prototype Proposal Report (CDR)
- 12/12/16: Place orders on parts, materials, equipment, components and take inventory
- December 2016: USIP Preliminary Design Review

January – May 2017: Project system construction, testing and troubleshooting

- January 2017: Assembly of base payload and ground station; begin payload and ground station integration and testing
- February 2017: Assembly of launch system and preliminary testing of detector hardware
- February 2017: USIP Critical Design Review
- March 2017: Launch system and payload integration; begin test launches
- April – May 2017: Payload testing, calibration, continue practice launches, solidify mission launch procedures

COTEL Project Timeline (4/4)

June 2017 – May 2018: Finalizing detector module design, integration of systems, system testing, more practice launches

- September 2017: Finalized detector modules and integration with base payload
- September – October 2017: Testing and calibration of single payload; begin construction of duplicate systems; practice launches
- November 2017 – February 2018: Multi-payload launch operations testing and troubleshooting
- February – March 2018: Reserved for delays
- March 2018: USIP Mission Readiness Review
- April 2018: Target Launch Campaign

Conclusions

- A multi-disciplinary, undergraduate, student team from LSU successfully composed a proposal and was awarded funding by NASA to conduct Terrestrial Gamma Flash research at altitude using a network of balloon-borne payloads
- Over the course of 18 months, the student team will develop a system to measure electric field intensity, detect and locate lightning strikes, and measure nearby gamma radiation from within a thunderstorm
- It is expected that analyzing the collected data will provide new information to verify or reject current theories around TGFs to ultimately better our understanding of the mechanisms driving TGF production

References

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