Next Generation Space Based Optical Lightning Sensors and the Upcoming ALOFT Program

2021 GLM Science Meeting

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21 September 2021

What are the Essential Characteristics/ Tradeoffs for the Next Generation Space-Based Optical Lightning Instruments

The first generation high performance instruments, starting with OTS/LIS and GLM were significantly compromised by existing technology and knowledge of lightning characteristics

- Focal Planes - Charge Coupled Device (CCD) technology was in maturing stage during OTD/LIS development.
  - Limited well depth meant limited dynamic range (we had to bin 4 x4 to met minimum requirements)
  - Limited readout speeds limited the frame rates and thus the integration times.
  - Backside thinning to achieve higher quantum efficiencies was available, with risk, too high a QE on OTD/LIS would have caused background saturation of the CCD
    - Both these issues limited the achievable sensitivity
- Narrow-band Filter - hard oxide filters were just developing as we were developing OTD/LIS. We choose the new technology despite the risk. A fortunate decision, otherwise the life on orbit would have been very short.
  - Development was very challenging. Never got a filter that full met specs, but got close enough

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- GLM- filter technology had undergone significant advancements; filters were not an important issue for GLM performance. They met specifications
- Focal planes- were the primary challenge. There were significant CCD advancements since LIS, but GLM stretched the technology.
  - Size- well depth bettered LIS even with pixels a quarter the size, but the total number of pixels made rapid readout difficult.
    - Large pixels with long readout chains produced very high CCD capacitance. This required very, high current drivers which challenged the readout electronics, resulting in the well known overshoots, etc.
    - The high currents also cause high heat dissipation which required heat pipes.
  - CCD technology, limited the number of pixels that and thus limited the IFOV to 8km.
    - CMOS would have circumvented many of these limitations but it was too immature to implement.
      - If a CMOS focal plane had been attempted, GLM would not have met delivery schedule.

How can one minimize these limitations on the Next Generation Mapper

First it is imperative to understand the primary objectives of the Mapper

- No optical sensor can do everything, all are compromised.
  - The eye is as close as optimized as any due to its incredible real-time processor: the brain
  - All optical instruments are limited in sensitivity, dynamic range, spatial resolution, temporal resolution, spectral resolution and so on.
- In order to optimize the Mapper, it is important to identify the primary objective.
  - Is it to detect the onset of severe weather or to monitor global lightning change?
    - i.e. severe weather detection might be best served by high sensitivity and a small footprint. However this might compromise performance on large extended sources.

Next Generation

- Safe to assume that it will use a CMOS focal plane. This enables the implementation of more pixels, but too many pixels can reduce performance.
  - The Mapper is not an imager, it is an event detector and must be optimized for the size and characteristics of the event.
    - Imagers always strive for better spatial resolution, too high a resolution on a Mapper could severely reduce performance.
      - Too high equals spatial splitting of the lighting event, slower readout rates and lower signal to noise ratios.
      - Smaller footprint, means smaller pixels which reduces area for on die processing electronics and possibly less well depth.
    - Reduced frame times can improve performance up to a point. Too fast will cause more events to be split between frames thus reducing the signal to noise.
- Much of the other technology, including the filter can be carried over from the GLM

What is required for better detection of the onset severe weather?

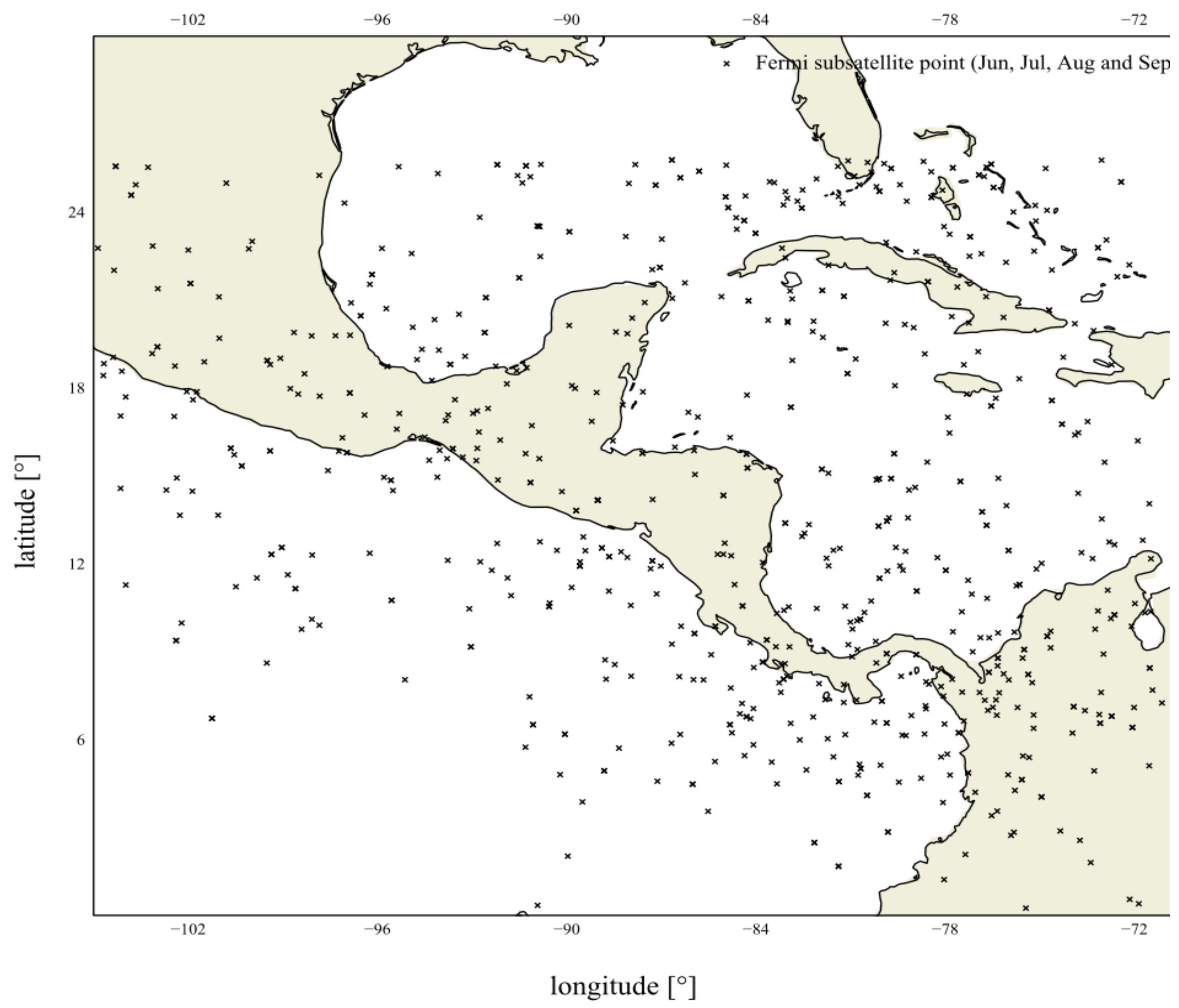
- Assumptions: severe weather is characterized by high, increasing lightning rates
  - These lightning events tend to be dimmer and spatially smaller than “normal” lightning. Best detected by a Mapper with a smaller footprint and lower sensitivity threshold.
  - So, relative to GLM, desire smaller footprint and faster frame times (easiest changed parameters. (parameters QE, throughput, etc. are already near optimum)
  - How small a footprint, how short an integration time?
    - Optical pulse widths are well know: optimal frame rates are easily determined, but not necessarily easy to implement super high rates do to limited readout rates.
    - Optimum footprint is dictated by size of the lightning event and the tradeoff of the lightning signal verses the square root of the noise - too small means too few lightning photons and loses relative to the background.
      - The size of lightning events, especially for severe weather is not accurately known, but is certainly smaller than the GLM footprint.
    - The ALOFT program should help improve this deficiency.
- However, what are the consequences of these tradeoffs for the detection of large, spatially extended events and very bright events?

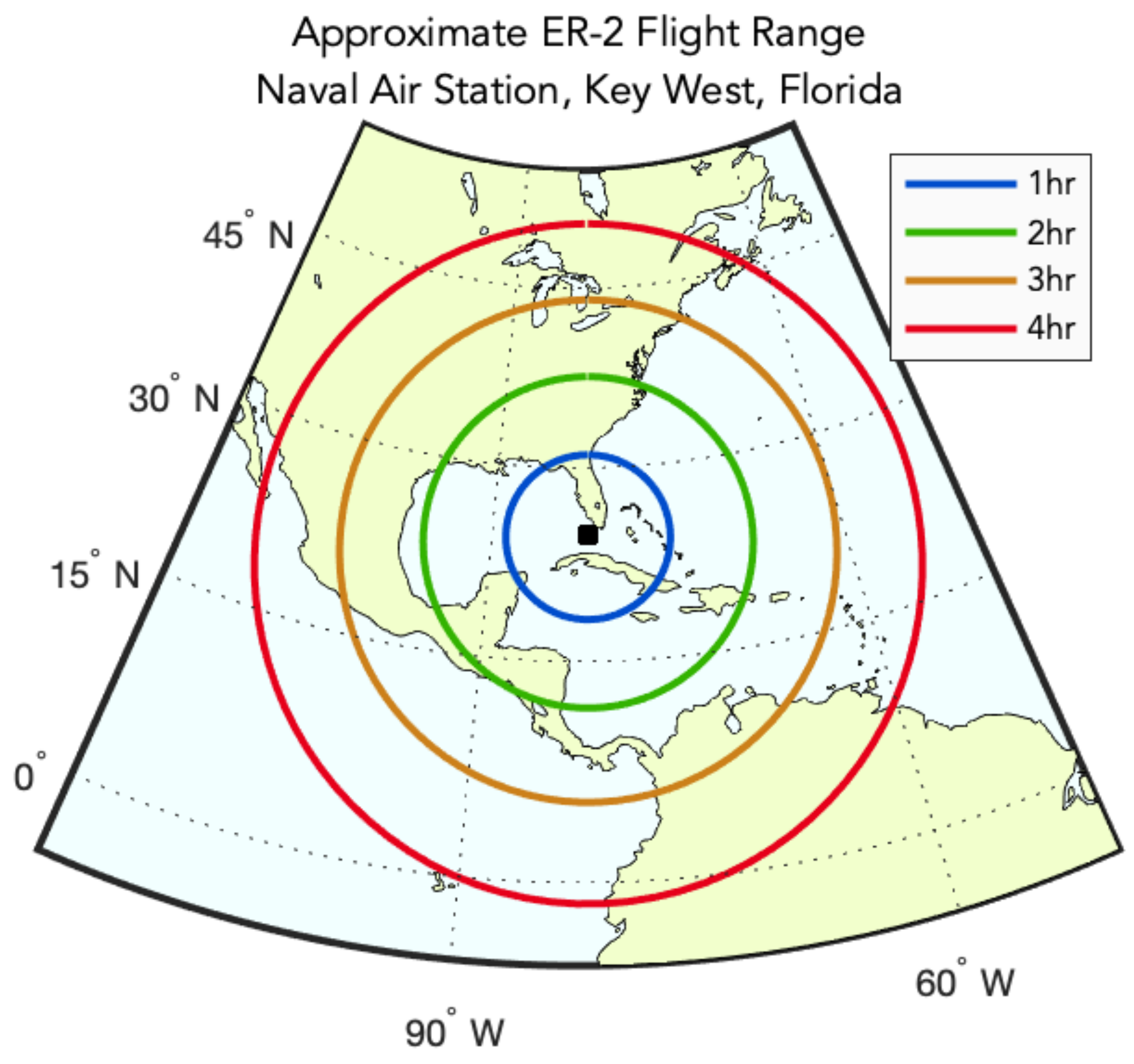
Airborne Lighting Observatory for FEGS and TGFs (ALOFT)

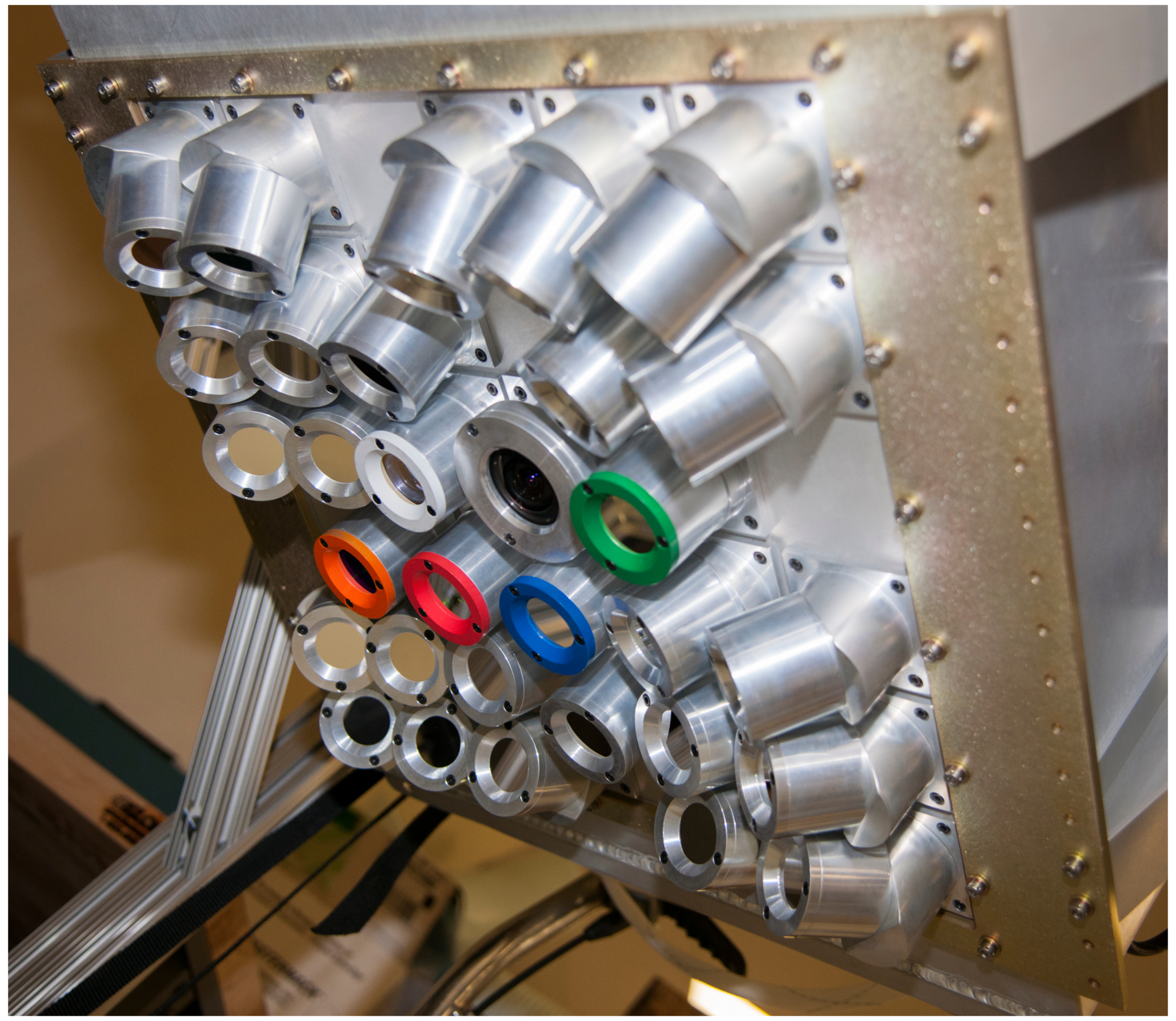
<u>What is ALOFT?</u>

- ALOFT is an ER-2 field campaign focused on Terrestrial Gamma-ray Flashes (TGFs)
- Scheduled for July 2023, 40-50 flight hours based out of Key West, FL
- Payload includes Fly's Eye GLM Simulator (FEGS), Lightning Instrument Package (LIP), and Scintillators (TGF detectors)

TGF Climatology







- ALOFT payload will make detailed, high-resolution measurements of lightning in convection clouds

- The ALOFT payload will take up roughly half a superpod (FEGS + Scintillators; LIP fits around other instrumentation – e.g., IPHEx, IMPACTS, etc.); i.e., core payload leaves the plane almost empty

- The ER-2 deployment + 40-50 h flight time are going to be paid for by University of Bergen (this process will be facilitated by MSFC/UAH)

- Core flight profiles will involve repeated overflights of convective cells

ALOFT

- How can AlOFT help the design of the Next Generation Lightning Mapper?
  - Will provide basically the same information as FEGS from the verifications flights.
    - However FEGS will be modified:
      - Improved calibration and excellent performance during the nighttime
      - Modifications to some photometer wavelengths.
        - Adding adding UV filter for steamers and 868.3 nm filter
      - Adding UV and near IR spectrometers to extend and improve mid 1980s measurements
  - The FEGS footprint is approximately 2.5 km at cloud top. This will provide significant event footprint data
  - The gain settings of the fast and slow electric field change will be improved. This will make it easier to determine the various lightning stages such as streamer, PB, leader, stroke.
  - Will provide additional tropical, validation data for the GLMs on the current GOES satellites.

Thank you