Overview of the GeoXO Lightning Mapper (LMX)

Peter Armstrong*, Monica Todirita, Tina Gentry, Joanna Joiner, Candace Carlisle, Alexander Krimchansky, Monica Coakley, Steve Goodman, Scott Rudlosky, Dan Lindsey, Brian Gockel, Andy Heidinger, Pam Sullivan

AMS Meteorological Uses of Lightning Data
12 – 16 January 2025

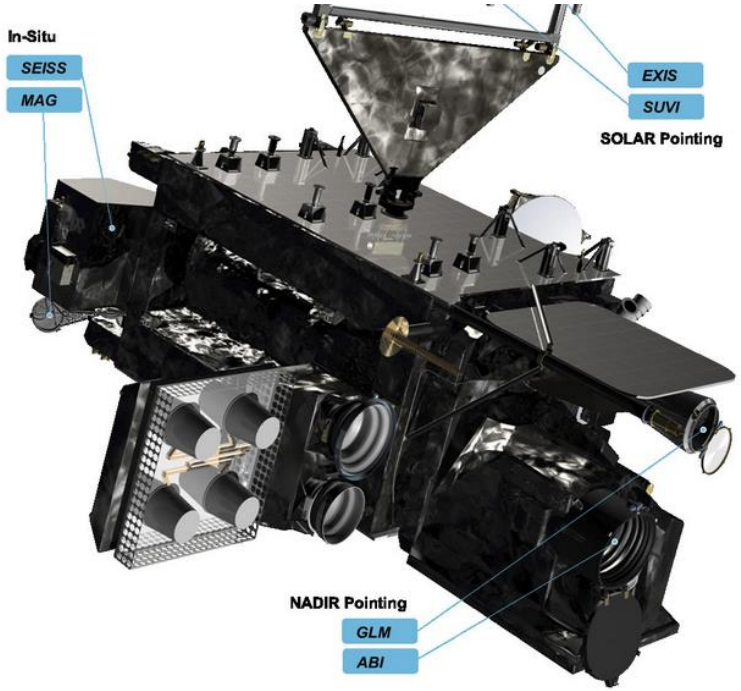
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***GeoXO LMX Instrument Scientist**

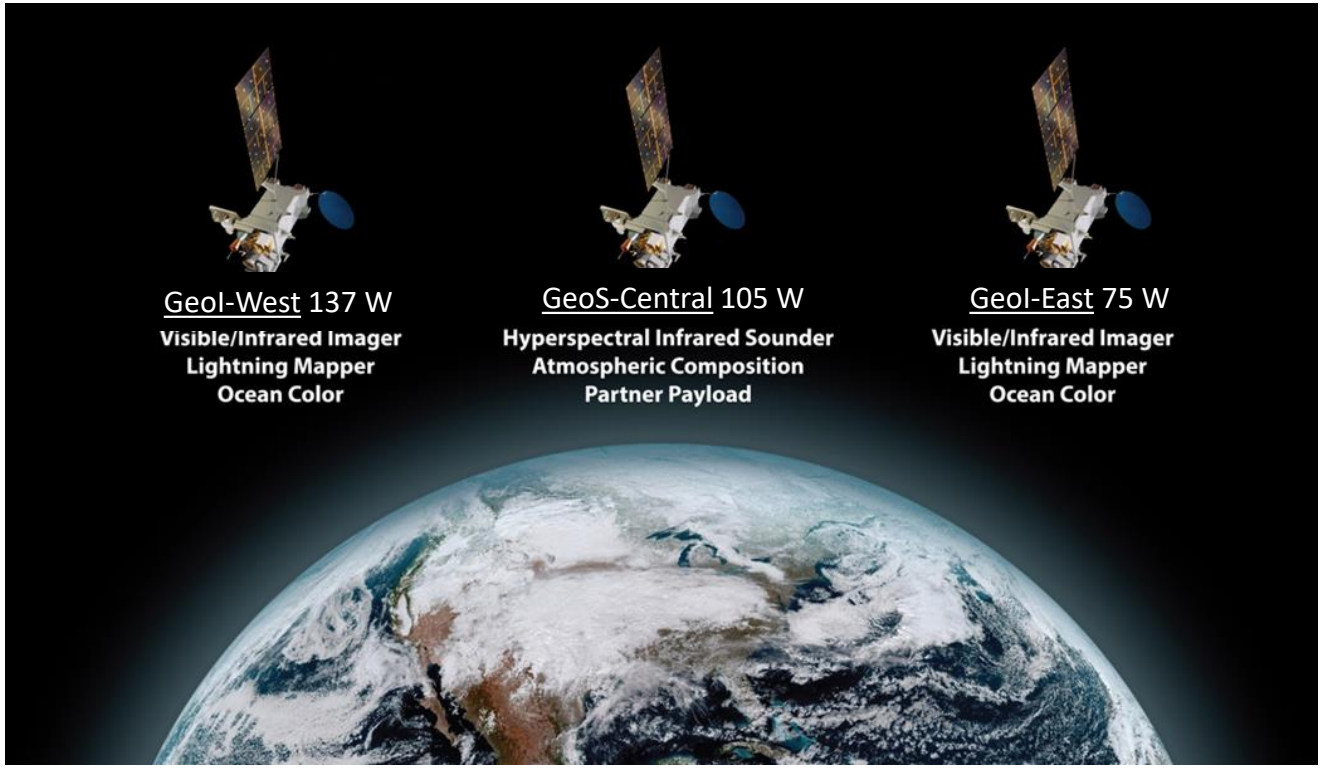
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Geostationary Operational Environmental Satellites
From GOES-R GLM to GeoXO Series LMX

GOES-R System



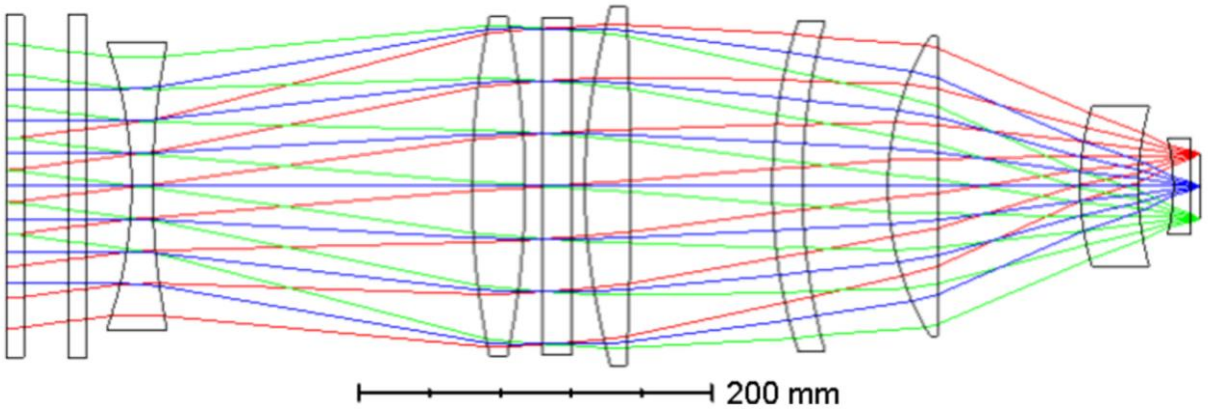
GeoXO System



- **First Geostationary Lightning Mapper (GLM) launched in 2016**
  - **Fourth unit launched on 2024-06-25**
  - **Detects near-IR optical transients against nighttime and bright daytime backgrounds**
- **Geostationary Lightning Mapper Value Assessment (2020)**
  - **Valued for severe weather assessments**
- **GeoXO LMX scheduled to launch in 2032**

GLM: The Heritage System for LMX

- GOES-R series Geostationary Lightning Mapper (GLM)
  - Single telescope design
  - Instrument updates
    - CMOS FPA replacing CCD
      - Simpler electronics
      - Faster framerate
    - Modified spectral filters
      - Capture more lightning signal at larger angles-of-incidence

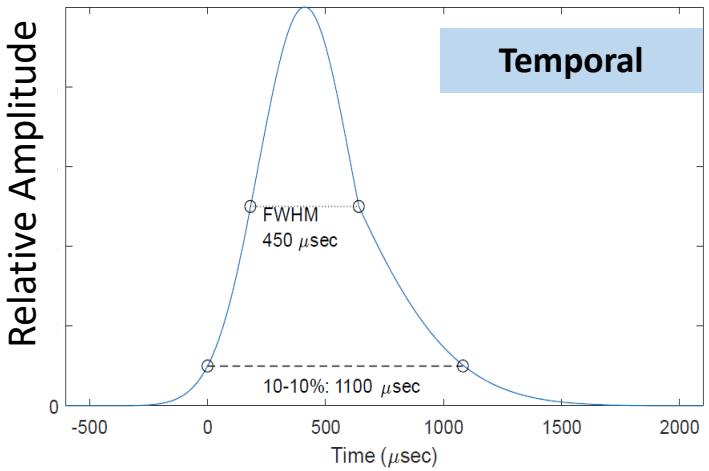


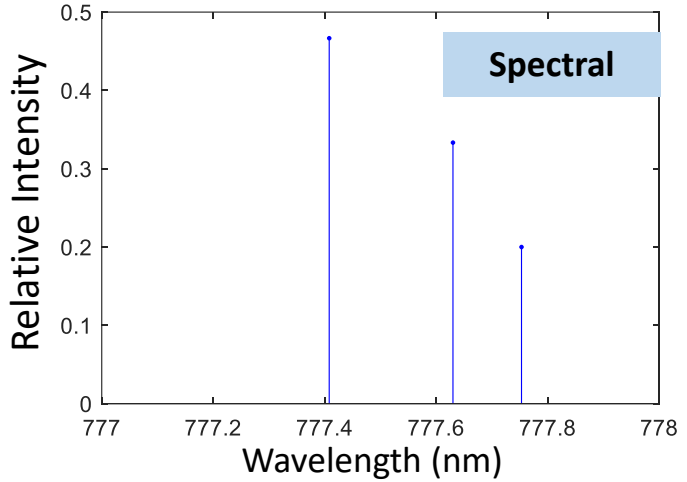
Filter	FWHM (nm)
Solar Rejection Filter	~ 70
Solar Blocking Filter	~ 3
Narrow Band Filter	~ 1

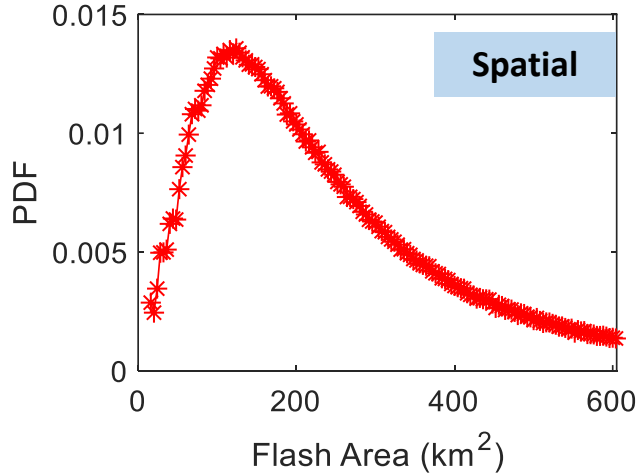
S. Edgington et al. “Design, calibration, and on-orbit testing of the geostationary lightning mapper on the GOES-R series weather satellite”, ICSO 2018, International Conference on Space Optics (2018) SPIE 11180, 1118040, 1-15

Requirements Comparison GLM to LMX

Requirement	GOES-R GLM	MTG-LI	GeoXO LMX
Coverage (GEO-view)	>78% of Earth Disk	84% of Earth Disk	86% of Earth Disk
Detection Efficiency	70% Lightning Flashes [a]	70% Lightning Flashes	70% Lightning Event Detection [a]
False Alarm Ratio	5% False Lightning Flashes [a]	2/s False Lightning Flashes	5% False L1b Data Products [a]
Signal-to-Noise Ratio	None	None	> 4.0 (6.4 & 8.8 µJ/m²/sr for nighttime & daytime, respectively)
Navigation Accuracy	140 µrad [b]	112 µrad [b]	98 µrad [b]







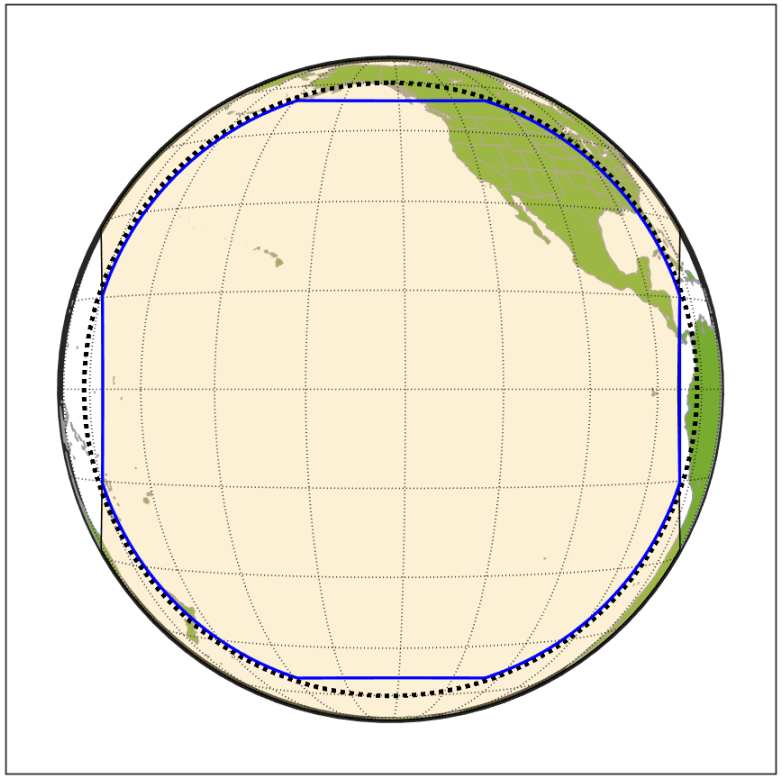
- Minimum detectable at maximum background level: ~8 µJ/m²/sr (1/200 of background)
- Lower-level requirements are documented

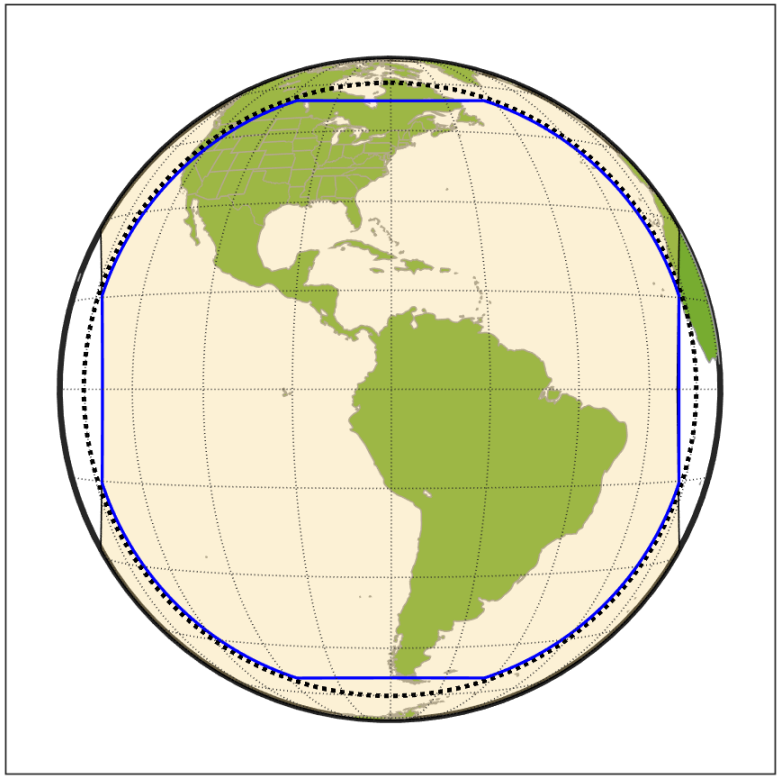
[a] Averaged over 24-hour period
[b] At sub-satellite point (SSP)

Coverage of GLM & LMX Instruments
GOES Operational Slots

GLM
LMX
Constant LZA (0.86 FD)

Required coverage (LMXPORD109) of 0.86 of the full disk (dashed black oval)



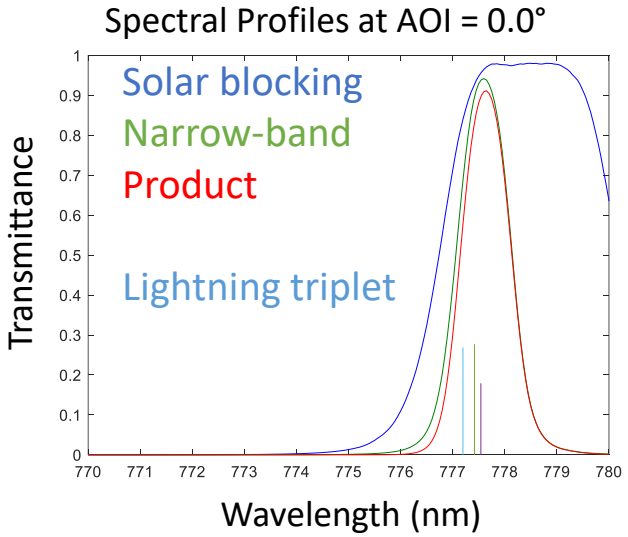


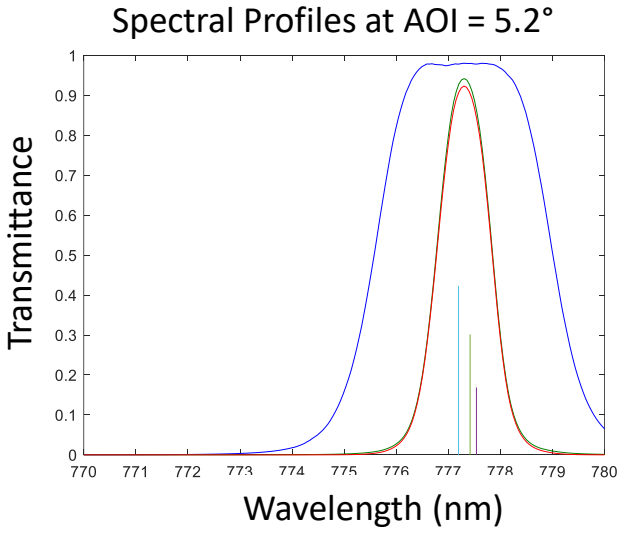
Coverage drives telescope design and filter angle-of-incidence

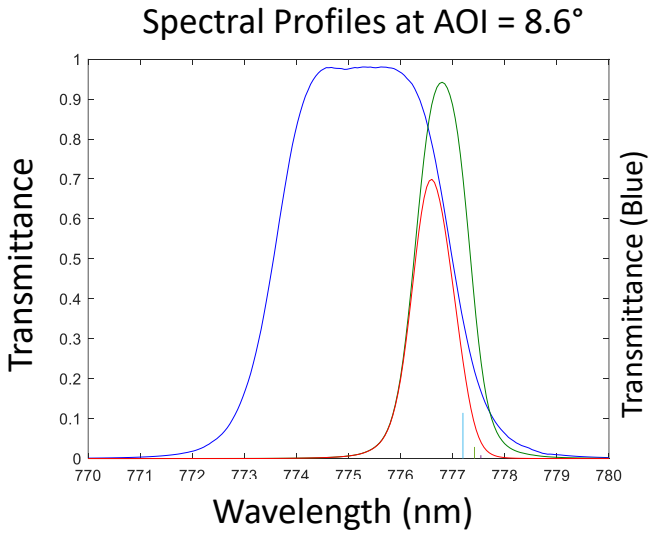
Spectral Filters: Impact of Angle of Incidence

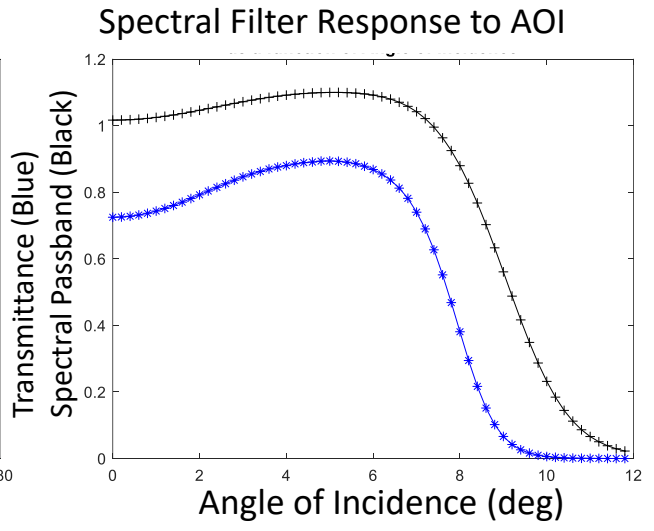
- Spectral filter design affects detection efficiency across FOV
  - Maximum AOI (edge of FOV) is approx. 8.7° for full disk
  - Both heritage designs limit AOI at narrow-band filter (NBF) to 5° - 6°
- Lightning transmission impacted by AOI
  - Pictures use spectral widths of filters from heritage GLM listed on slide 3
- System responds differently for background versus narrow-band lightning as a function of AOI

LMX must maximize lightning signal in the presence of varying background









Detection Efficiency (LMXPORD120)

The lightning event detection probability over the coverage area specified in LMXPORD109 shall be greater than 70% after Level 1b processing including

- integrating over space (imaged area) and time (lightning pulse duration),
- averaging minimum detectable event energy density over 24 hours,
- using the Lightning Distribution Spectrum Table (right), and
- averaging the percent lightning detected over any contiguous regions of 910 microradians x 910 microradians.

Minimum Detectable Event Energy Density ($\mu J/m_2/sr$)	Percent Lightning Detected
3.8	95
4.5	90
5.1	85
5.9	80
6.7	75
7.6	70
8.7	65
9.9	60
>9.9	0

False Event Probability (LMXPORD121)

- The percentage of false events computed over all temporal samples during any contiguous 24-hours shall be less than 5% after Level 1b processing.
- Confusion matrix for classification algorithm shows relationship of analyzed results to the known input dataset
  - LMX L1b data product contains true and false positives (first column)
  - False positive event sources include radiation-induced events, surface glints, detector read noise, shot noise due to bright backgrounds, and S/C jitter

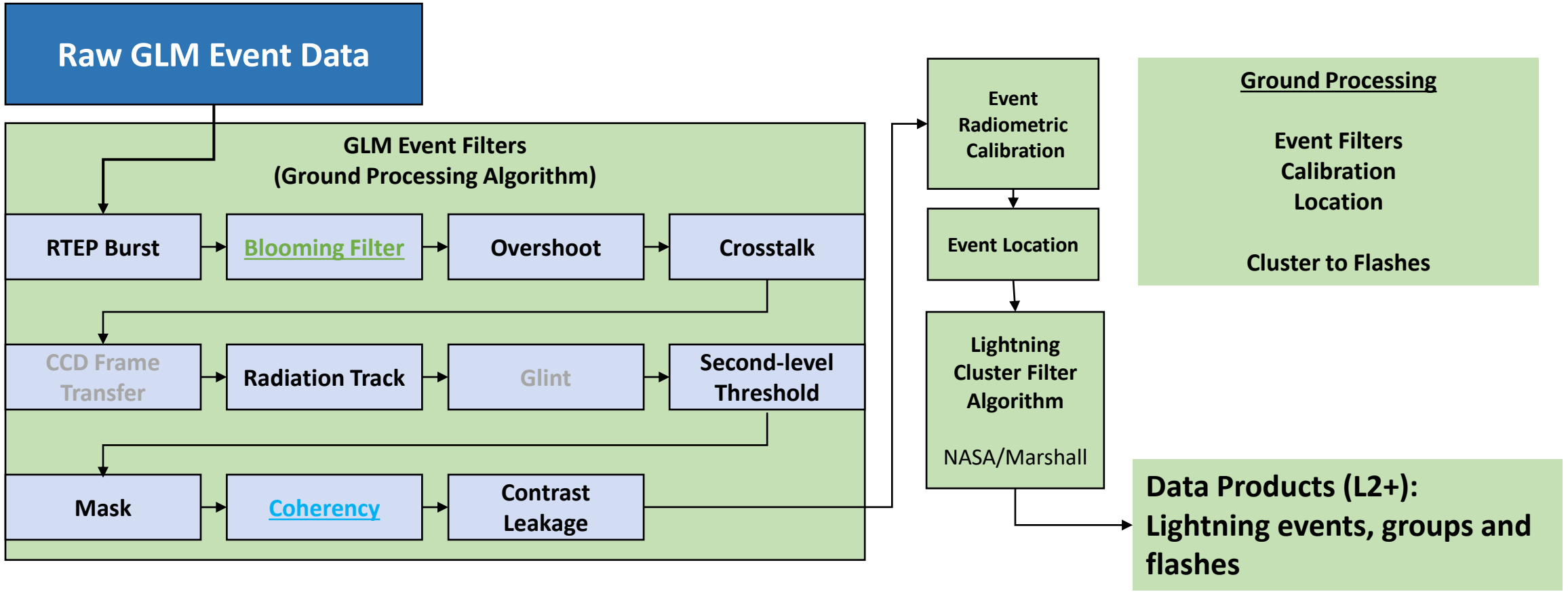
		Analysis Results	
		True (1)	False (0)
Truth Dataset	True (1)	True Positives (TP)	False Negatives (FN)
	False (0)	False Positives (FP)	True Negatives

$$FEP = (100\%)\frac{FP}{FP + TP}$$

$$DE = (100\%)\frac{TP}{FN + TP}$$

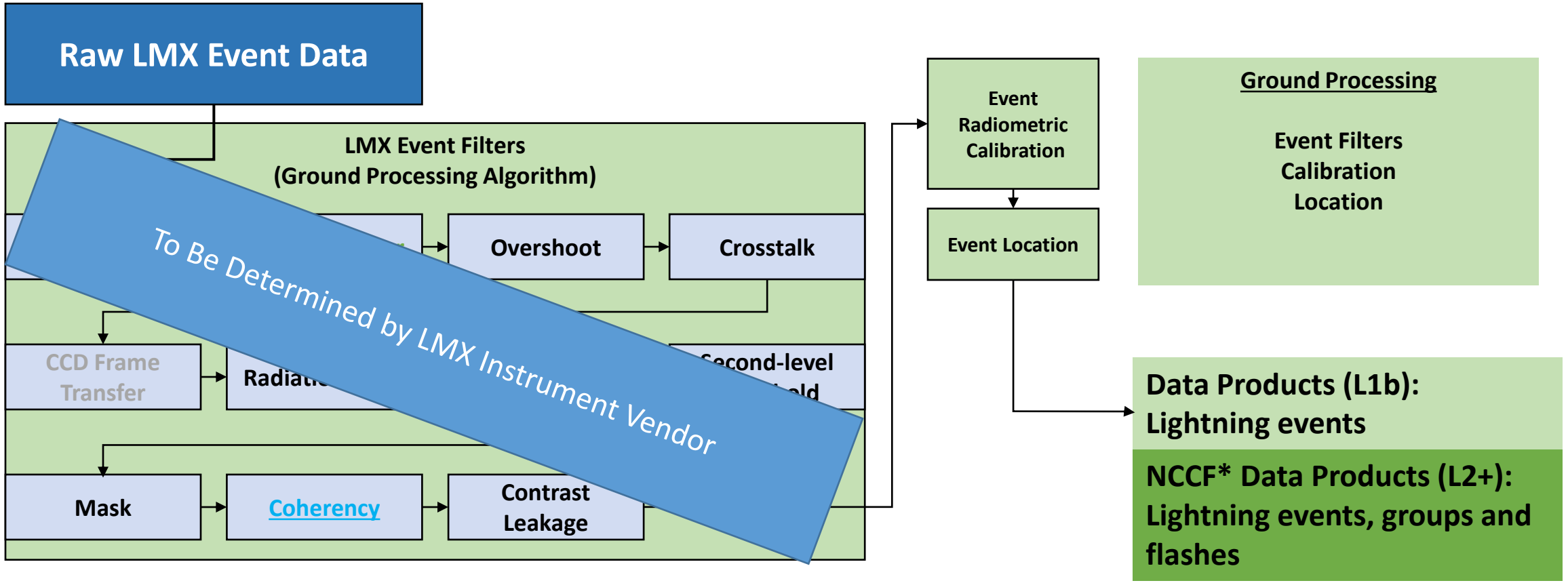
GOES-R Lightning Ground Processing

- Process raw instrument data to remove false events, leaving lightning events
- Lightning events combined to groups and flashes by Lightning Cluster Filter Algorithm



GeoGround Lightning Processing

- Process raw instrument data to remove false events, leaving lightning events
- LMX L1b data products are radiometrically calibrated, navigated lightning events



*NCCF = NESDIS Common Cloud Framework

Summary for GeoXO Lightning Mapper

- NOAA's Geostationary eXtended Observations (GeoXO) series satellites will follow the GOES-R series satellites in 2032, providing continuity of environmental imagery over the western hemisphere
- GeoXO Lightning Mapper will be manifested on GeoI-East and GeoI-West platforms at the current operational slots at 75° W and 137° W
- From these locations, LMX will detect optical transients at 777 nm generated by lightning over a minimum coverage area of 86% of the full disk visible from geostationary orbit.
- Combination of Coverage, Detection Efficiency and False Event Percentage requirements drive the design of spectral filters and processing algorithms
  - Within the minimum coverage area, the LMX system will have a minimum detection efficiency of 70% and a false alarm probability of 5% over any 24-hour period
  - Removal of false lightning events relies on the ground processing algorithm
- Lockheed Martin, the instrument vendor of GLM, received authority to proceed on 2024-10-10 as LMX vendor