Lightning Imaging Sensor (LIS) on ISS and Plans for Sustained Ground Measurements in Support of GLM Cal/Val

Presented by

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Joint MTG LI Mission Advisory Group & GOES-R GLM Science Team Workshop, Rome Italy

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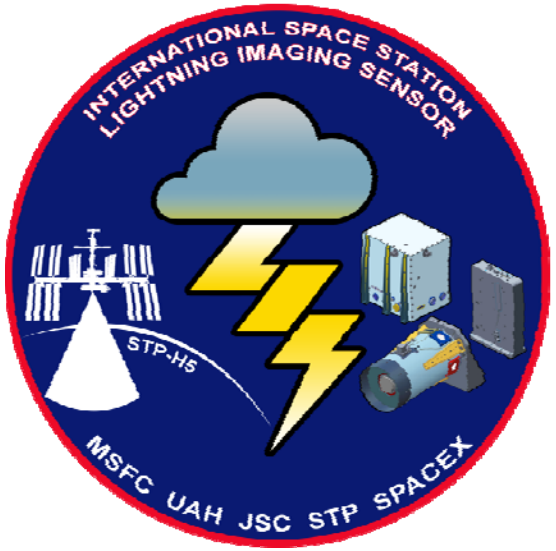
LIS on ISS

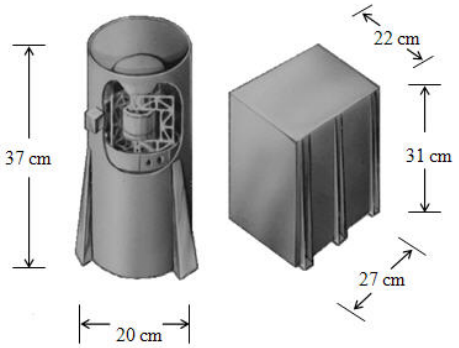

DoD SPACE TEST PROGRAM
STP-H5
5
AFRL USAFA NRL GSFC MSFC JSC SPACEX


INTERNATIONAL SPACE STATION
LIGHTNING IMAGING SENSOR
STP-H5
MSFC UAH JSC STP SPACEX

ISS Lightning Imaging Sensor (LIS) Overview

Mission

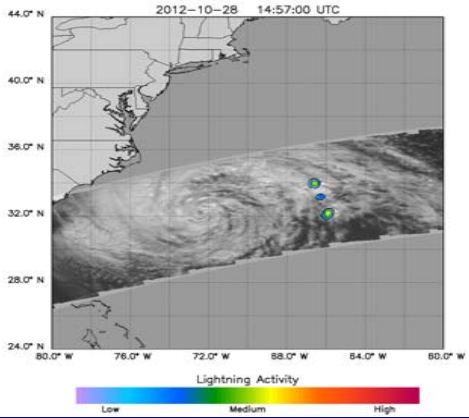
- Fly a space-qualified, flight-spare LIS on ISS to take advantage of unique capabilities provided by the ISS *(e.g., high inclination, real time data)*.
- Integrate LIS as hosted payload on DoD Space Test Program (STP-H5) and launch on SpaceX rocket in January 2016 for 2 year mission.



LIS Sensor Head and Electronics Unit (20 kg, 30W, 128 x 128 CCD, 1kB/s)

Measurement

- NASA, the University of Alabama in Huntsville (UAH) and their partners developed and demonstrated effectiveness and value of space-based lightning observations as a remote sensing tool.
- LIS measures total lightning (*amount, rate, radiant energy*) during both day and night, with storm scale resolution, millisecond timing, and high, uniform detection efficiency.
  - LIS daytime detection is especially unique and scientifically important (~60% occurs during day).
  - Also LIS globally detects TOTAL (*both cloud and ground*) lightning with no land-ocean bias.



LIS Lightning and Background Images (Super Storm Sandy October 28, 2012)

Need and Benefit

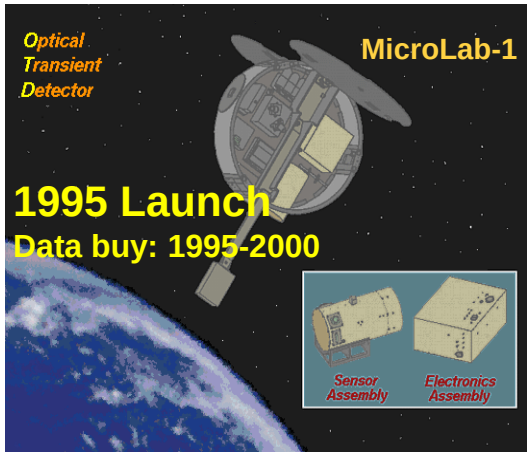
- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes, and therefore provides important science inputs across a wide range of disciplines (e.g., *weather, climate, atmospheric chemistry, lightning physics*).
- ISS LIS (or i LIS as Hugh Christian prefers) will extend TRMM time series observations, expand latitudinal coverage, provide real time data to operational users, and enable cross-sensor calibration.

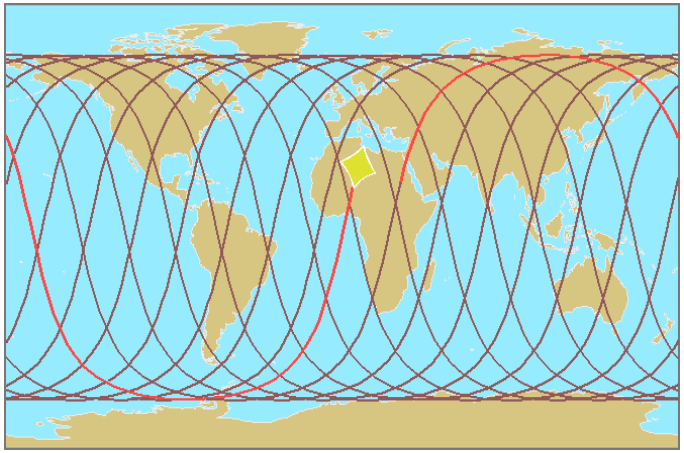
LIS Flight Heritage

- ISS LIS builds upon a solid foundation of 20 years on-orbit observations.
- Key LIS scientists, engineers, and facilities still in place.

Optical Transient Detector

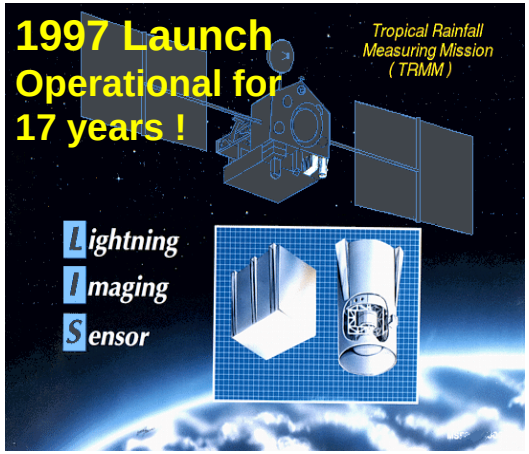
Launched: April 1995
Data: May 1995 - April 2000
Orbit: 70º inclin., 735 km
(detects to ~75º)
Field of view:1250x1250 km
Diurnal cycle: sampled in 55 days

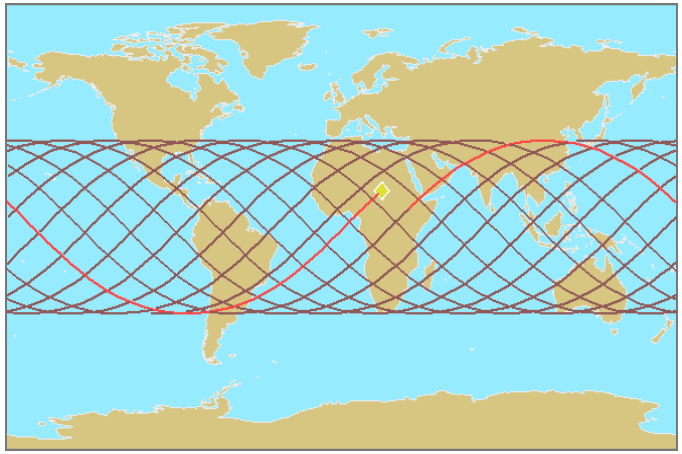




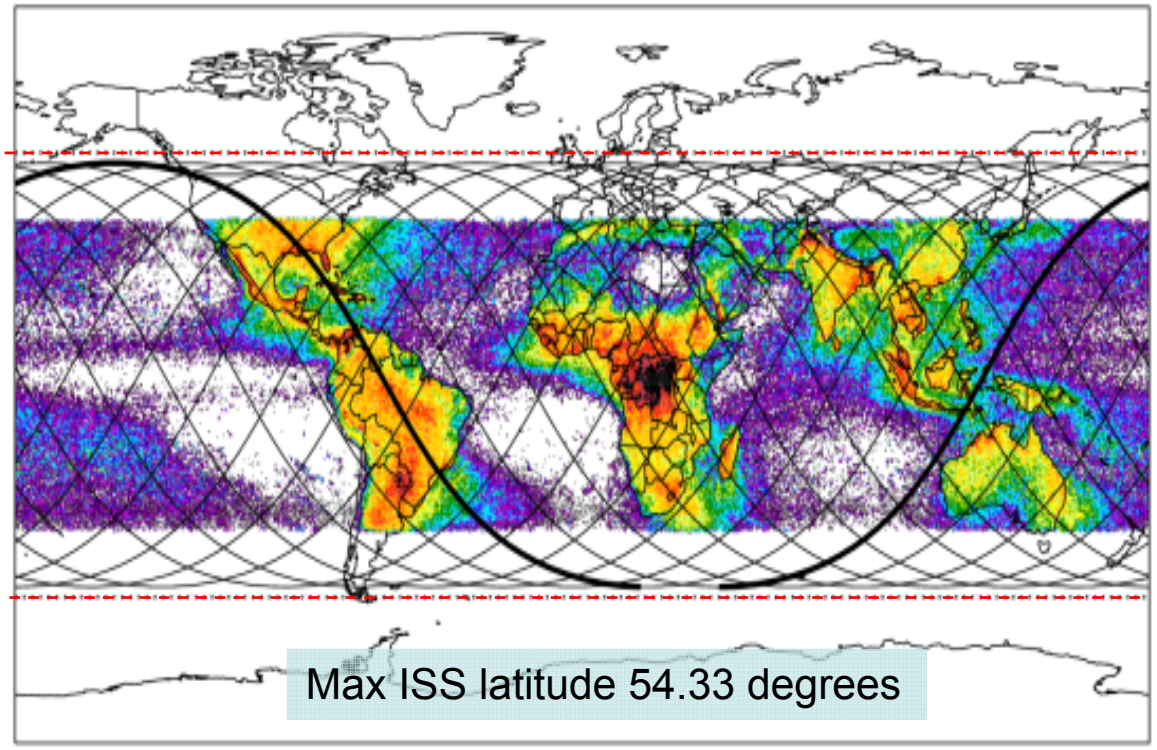
Lightning Imaging Sensor

Launched: November1997
Data: Jan.1998 – April 2015
Orbit: 35º inclin., 350 km
(boosted to 400 km in 2001)
(detects to ~38º)
Field of view:600 x 600 km
Diurnal cycle: sampled in 49 days





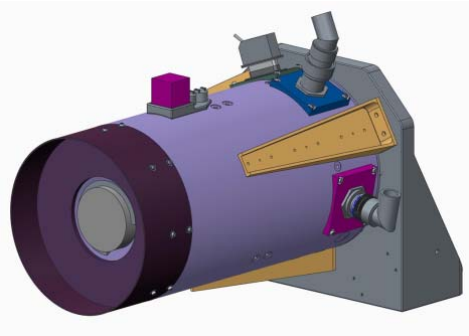
ISS LIS Global Coverage

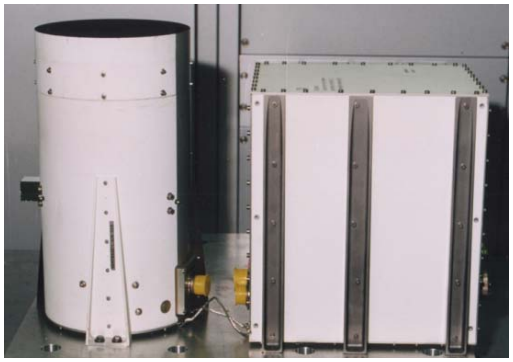


	% globe	% lightning
• *Global Coverage of LIS/ISS (between red dashed lines)* =	*81%*	*98%*
• *Global Coverage of LIS/TRMM (data shown above)* =	*62%*	*90%*

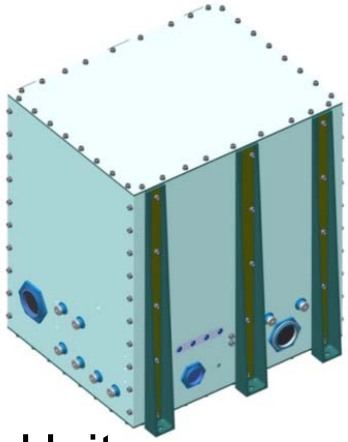
- *Expanded Areal Coverage gains important mid-latitude storms, CONUS, and Middle and Southern Europe*

LIS Hardware





Flight Spare LIS



LIS Sensor Unit

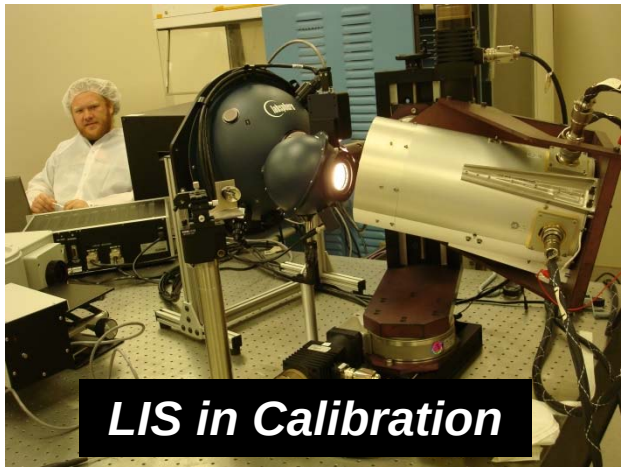
Optical Assembly
128x128 CCD Focal Plane

Electronics Unit

Real Time Event Processor and
Background removal
Control & Data Handling (C&DH)
Power conversion and control

Interface Unit (*new*)

Power conversion
1 PPS Time Signal Generation
C&DH Formatting
ISS Interface

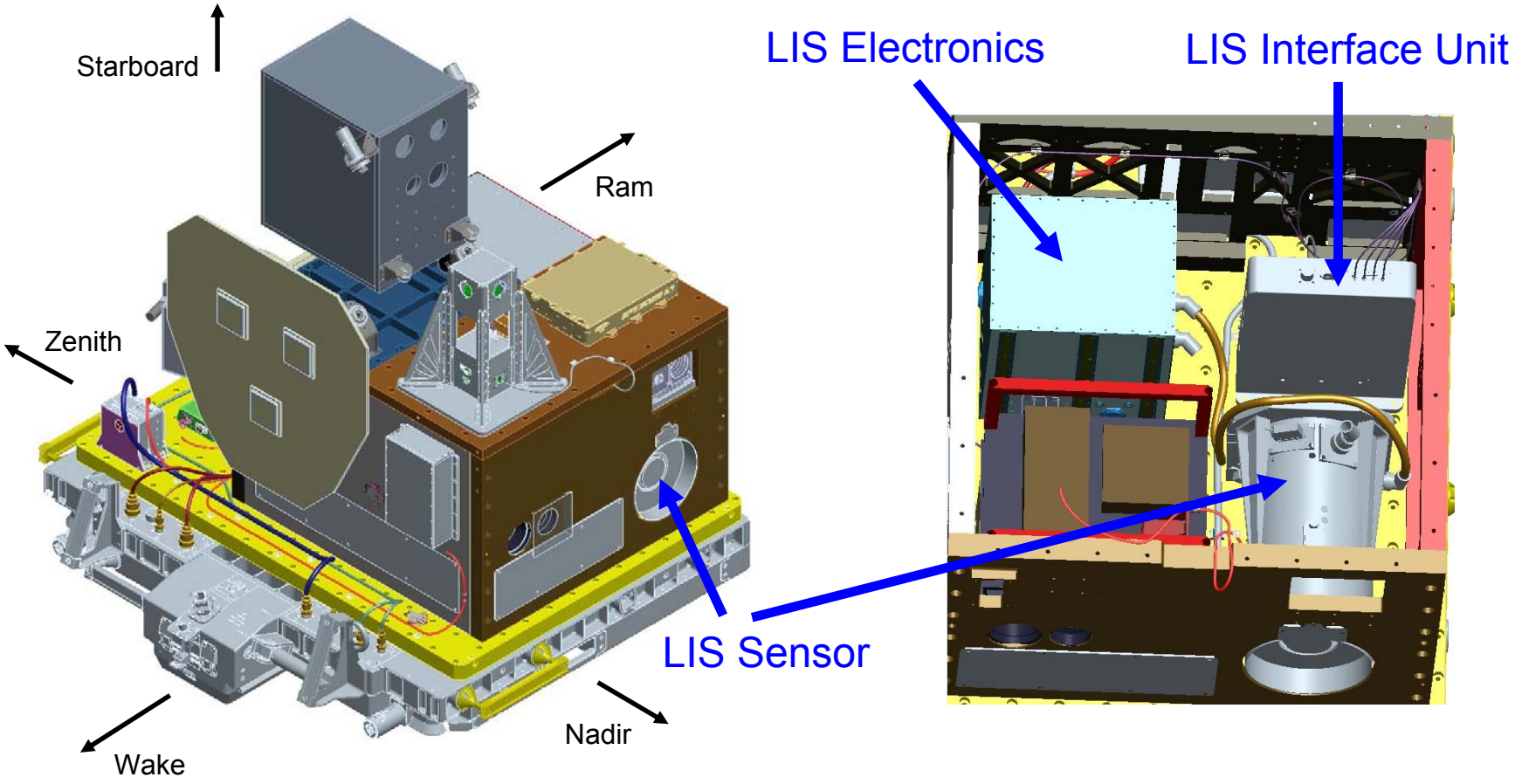


LIS in Calibration

LIS Performance Parameters

Field-of-View (FOV)	80° × 80°	Measurement Accuracy	
Pixel IFOV (nadir)	4 km	location	1 pixel
Interference Filter		intensity	10 %
wavelength	777.4 nm	time	tag at frame rate
bandwidth	1 nm	Dimensions	
Detection Threshold	4.7 μJ m^{-2} sr^{-1}	sensor assembly	20 × 37 cm
Signal to Noise Ratio	6	electronics assembly	31 × 22 × 27 cm
CCD Array Size	128 × 128 pixels	Weight	20 kg
Dynamic Range	> 100	Power	30 Watts
Detection Efficiency	~ 70 - 90 %	Telemetry	
False Event Rate	< 5 %	data rate, format	8 kb/s, PCM

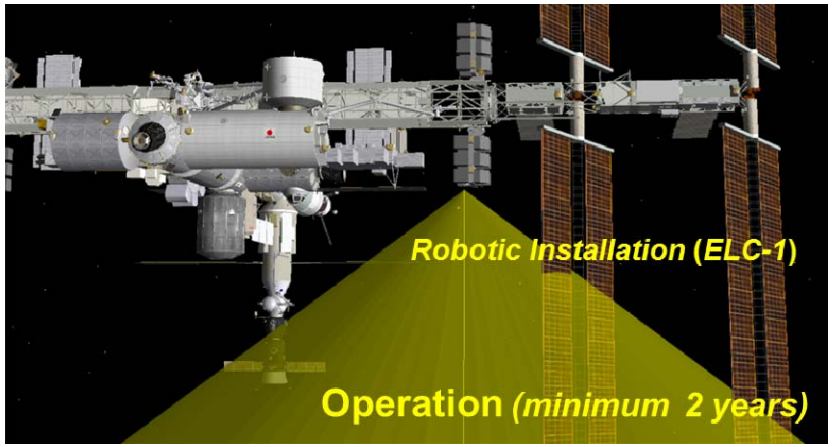
LIS Integration as Hosted Payload on STP-H5

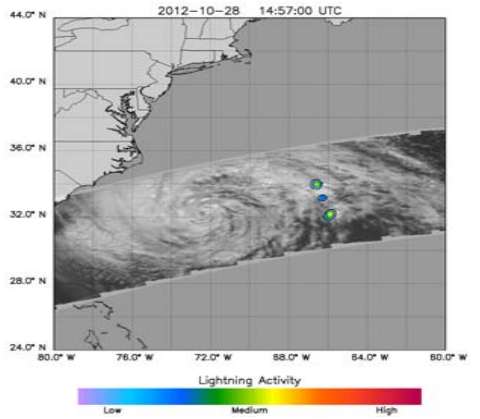


- LIS is one of thirteen instruments on the STP-H5 payload manifest.
- LIS will be installed on ISS in an Earth viewing (nadir) position.
- Payload built on special structure to allow robotic installation on ISS.

LIS Launch, Installation and Operation on ISS

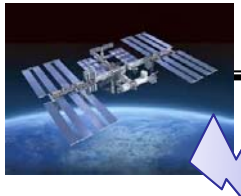
- Ship to NASA Kennedy Space Center in October 2015.
- Launch to ISS on a Space X rocket with Dragon cargo vehicle in January 2016.
- Payload will be robotically installed on ISS.
  - Installed on Express Logistics Carrier-1 (ELC-1)
- LIS will be operated for a minimum of 2 years.
  - Mission extension will be sought from NASA





LIS Lightning and Background Images
(Super Storm Sandy October 28, 2012)

LIS Data Flow & Processing Overview



Huntsville Operations Support Center (HOSC)

Instrument commands

L0 Raw data (science, housekeeping, ephemeris)

LIS Payload Operations Control Center (LIS POCC)

LIS monitoring and commanding

Commanding, Ingest, and Processing
- Housekeeping
- L2 Science data
- Backgrounds
- Browse Products

Processing Server (Linux)

GHRC Archive

L0 Raw data
L2 Science data & backgrounds
L3 Products
Browse Images

GHRC Web/FTP

L2 Science data & backgrounds
L3 Products
Browse Images

Real Time L2 Science data (new)

Operational Users

L2 Science data & backgrounds

L3 Science products

LIS Science Team

QC Info

L2/L3 Science data & imagery

Science User Community

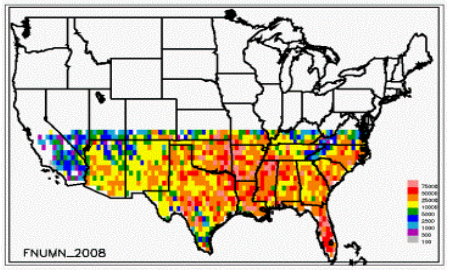
Mission Operations, Data Handling, and Products

- The mission will leverage existing TRMM LIS infrastructure to quickly get ISS LIS data into the hands of users.
  - Key scientists, engineers, and facilities remain in place from recently ended TRMM mission.
  - TRMM LIS mission operations and data handling (processing, archival, and distribution) is robust and easily adapted to the Payload Operations Control Center (POCC) model used by ISS.
  - Hence, LIS data users should see no change from TRMM LIS (i.e., LIS data products and formats, analysis software, documentation and access will remain unchanged)
  - LIS science and data teams have experience delivering real time data to NOAA and other users.
- The LIS instrument and its observations are well characterized.
  - All indications suggest that the flight spare ISS LIS will perform exactly like TRMM LIS on orbit.
  - LIS observations will be excellent for GLM Cal/Val both because LIS data is well characterized and because GLM's lightning detection approach traces to LIS heritage.
  - LIS data remains an accepted "benchmark" for global lightning climatology intercomparisons.

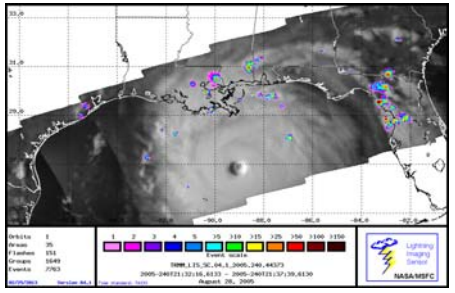
Unique Science Contributions from ISS Platform

"New and Improved" Science

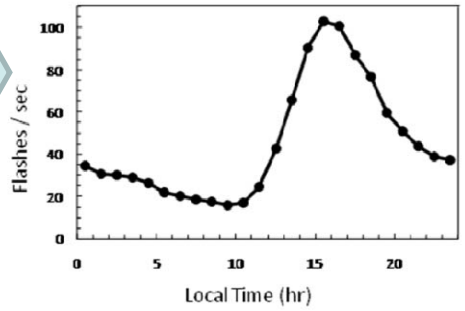
- Higher latitude lightning coverage missed by TRMM
  - TRMM LIS misses up to 30% lightning in N. Hemisphere summer
  - Enhance regional and global weather, climate, and chemistry studies
  - Provide CONUS coverage (needed for National Climate Assessment)
- Real time lightning using ISS for operational applications
  - Provide real time lightning in data sparse regions, especially oceans (storm warnings, nowcasts, oceanic aviation and international SIGMETs, long-range lightning system validation, hurricane rapid intensification evaluations)
  - Desired by NASA and strongly endorsed by NOAA partners (partners include: NWS Pacific Region, Joint Typhoon Warning Center, Ocean Prediction Center, Aviation Weather Center, and National Hurricane Center)
- Enable simultaneous / complementary observations
  - Provide critical daytime lightning to better understand mechanisms leading to TGFs and TLEs (strongly endorsed by ESA ASIM and JAXA GLIMS)
- Support cross-sensor calibration and validation activities
  - Inter-calibrate ISS LIS, TRMM LIS, GOES-R GLM and MTG LI for improved science and applications (strongly endorsed by NOAA and ESA)



TRMM LIS does NOT cover CONUS for climate and chemistry assessments



Real time LIS lightning useful for a host of operations (LIS in Hurricane Katrina)



LIS detects lightning during the day when most lightning occurs

Timeline of ISS LIS and Related Space Missions

Blue: LIS observations or LIS science enabling contributions

Red: related mission observations

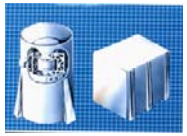
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

1995-1999 | **2000-2029**

'95 '96 '97 '98 '99 '00 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17 '18 '19 '20 '21 '22 '23 '24 '25 '26 '27 '28 '29

OTD (LEO)

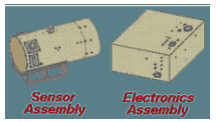
4/1995 – **5/2000**



Cross calibration obtained between OTD and TRMM LIS

TRMM LIS (LEO)

11/1997 – **Operations ended 4/2015**



ISS LIS

LIS: day/night lightning, storm scale resolution (4km), millisecond timing, high, uniform detection, calibrated radiance from 128x128 CCD.

Launch Date January 2016 (2 year minimum)

Mission extension will be sought via NASA Senior Review process.

Taranis (LEO)

Taranis: TGF, TLE, optical photometers, LF,HF, magnetic field

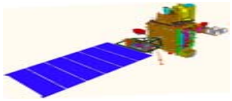
ISS LIS: coincident lightning location, calibrated radiance (cross calibration possibility)

Launch Date 2016 (2 -3 year mission)

GOES-R GLM (GEO)

GLM: optical lightning similar to LIS (LIS heritage)

ISS LIS: proxy data, cal/val support, desire ISS LIS cross calibration for climate monitoring



Planned launch date March 2016

MTG LI launch in 2019 (LIS mission extension desirable for Cal/Val).

JAXA GLIMS (ISS)

GLIMS: VHF, optical photometers

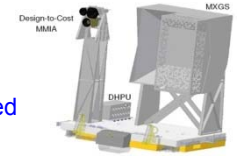
ISS LIS: coincident **daytime** lightning location, calibrated radiance

7/2012 – **mission duration ?**

ESA ASIM (ISS)

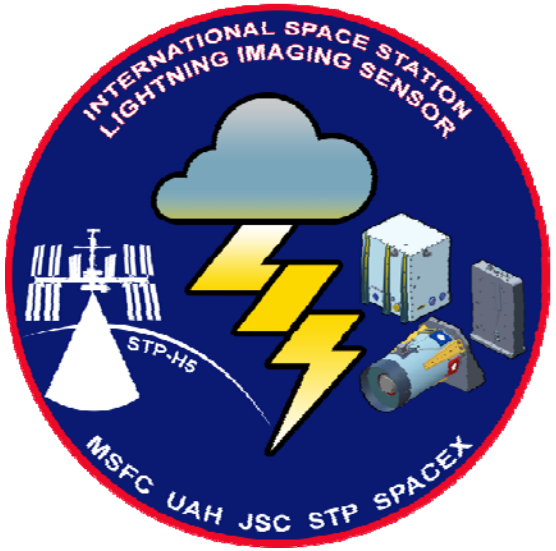
ASIM: TGF, video cameras, optical photometers

ISS LIS: coincident **daytime** lightning location, calibrated radiance



Launch Date 2016 (mission duration ?)

Questions on ISS LIS portion?



Plans for Sustained Ground Measurement in Support of GLM Cal/Val

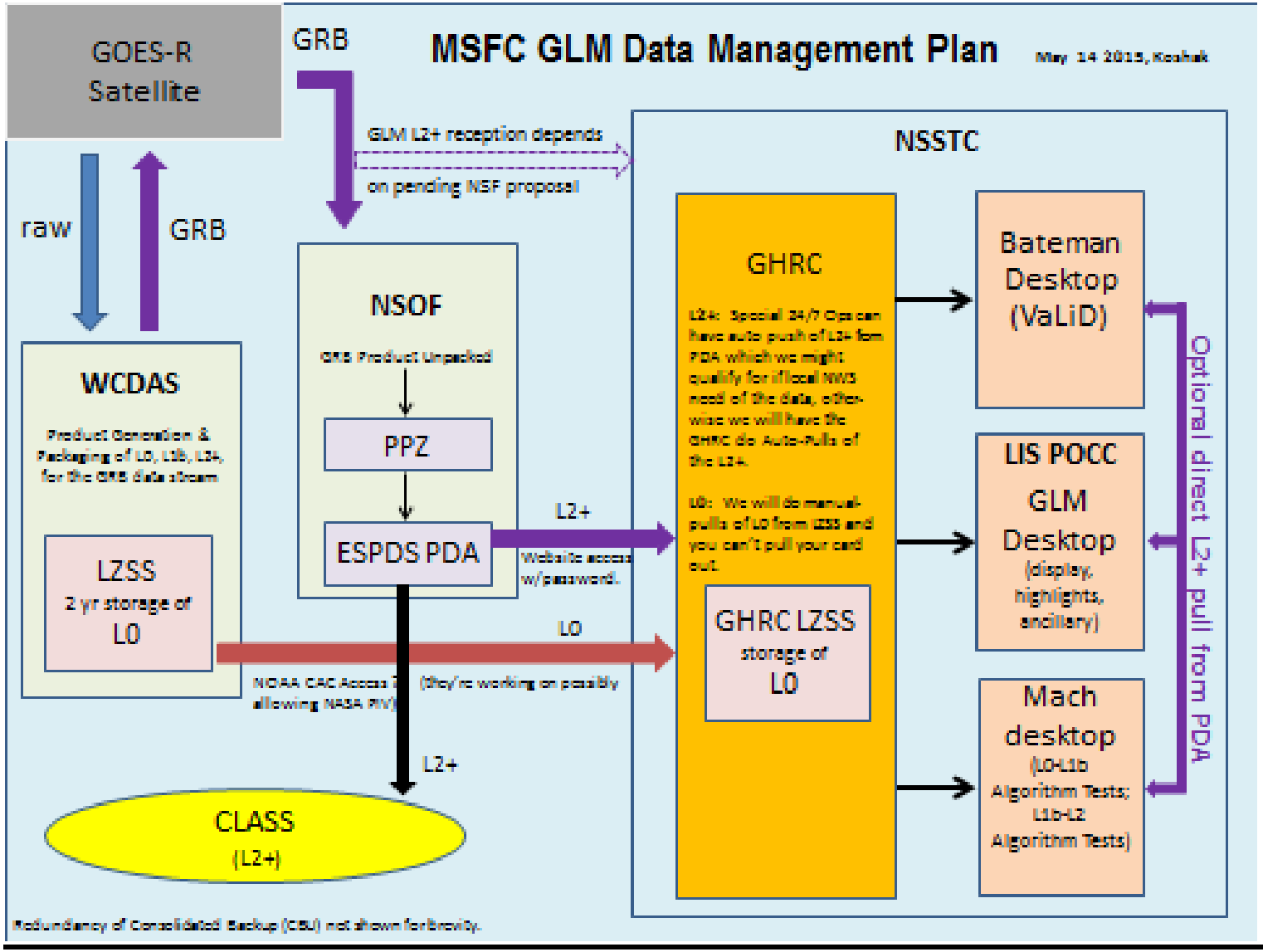
GOES-R GLM Validation

- Goal of GLM validation is to verify GLM products (events, groups, flashes) and to ensure that they meet requirements.
- Various Val tools have been developed to accomplish this goal (e.g., the VaLiD application, as well as the deep dive analysis suite developed by Ken Cummins) .
- In supporting GLM validation, these tools require many truth datasets, which include ground, airborne and satellite observations.
- These data, in turn, are collected in field campaigns (e.g., CHUVA, ER-2 field campaigns), sustained ground measurements, and directed observations (e.g., laser beacon) .

GLM Validation Truth Datasets

- GLM truth data sets include research and commercial lightning detection systems, both short-medium range and long range.
  - LMA (various locations across US)
  - HAMMA (North Alabama)
  - Vaisala NLDN and GLD360
  - Earth Networks TLN
  - WWLLN
- Airborne and satellite systems include:
  - Fly's Eye GLM Simulator (FEGS)
  - ISS LIS
- Other GLM truth data sets made available via collaboration.
  - LINET
  - ATDnet
  - STARNET

GLM Data Flow in Support of Validation



Propose GLM Validation Data Portal

- We would like to propose creating a GLM validation data portal (similar to what is created to support field campaigns)
  - Serve as “one stop shopping” to access both GLM data (L2+), various truth datasets, and validation tools – to make this data more easily available to the validation community.
  - Log on credentials required to control access to the data.
  - European collaborators will be invited to contribute data or links to the portal.
  - Clearly, data sharing policies will have to be established, especially with the restricted data from commercial vendors.

Discussions/Questions on GLM Data Portal?

Back-up Slides

Project Status and Milestones

- ☑ April 2013: LIS selected as ISS payload.
- ☑ December 2013: System Requirements Review/Preliminary Design Review successfully completed.
- ☑ April 2014: Critical Design Review successfully completed.
- ☑ January 2015: Deliver LIS to Space Test Program (STP) for integration on STP-H5.
- ☐ October 2015: STP-H5 environmental testing completed
- ☐ October 2015: Deliver STP-H5 to Kennedy Space Center for launch vehicle integration and test.
- ☐ January 2016: Launch to ISS on SpaceX 10 using Dragon Cargo vehicle.
- ☐ January 2016: Mission operations begin after short checkout.

Core Science Applications from Lightning

Why Lightning Matters

Weather: Total lightning is strongly coupled in a quantitative way to thunderstorm processes and responds to updraft velocity and cloud particles (concentration, phase, type, and flux).

- LIS acts like a radar in space: it reveals the heart of the cloud.
- Lightning can improve convective precipitation estimates.
- Lightning is strongly coupled to severe weather hazards (winds, floods, tornadoes, hail, wild fires) and can improve forecast models.

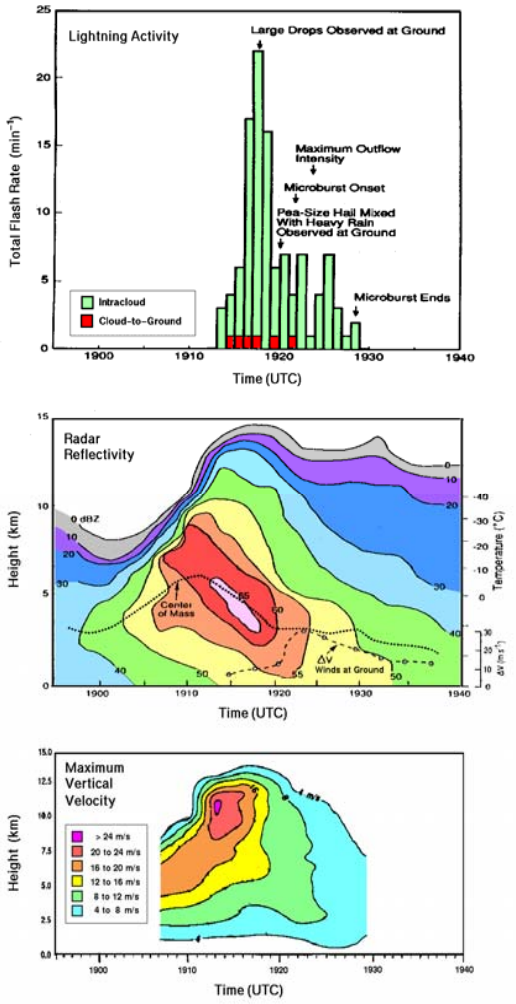
Climate: Lightning is an excellent variable for climate monitoring because it is sensitive to small changes in temperature and atmospheric forcing. ISS LIS will:

- Extend 16 year time series of TRMM LIS, expand to higher latitudes.
- Monitor the occurrence and changes in extreme storms.
- Provide much desired cross-sensor calibrations between platforms.

Chemistry: ISS LIS will help improve estimates of lightning produced NO_x for climate and air quality studies.

- Lightning NO_x also impacts ozone, an important green house gas.
- Climate most sensitive to ozone in upper troposphere, exactly where lightning is the most important source of No_x.

Other: Complementary ISS LIS observations will help unravel the mechanisms leading to terrestrial gamma-ray flashes (TGFs) and Transient Luminous Events (TLEs).



Lightning (top), radar (middle), and vertical velocity (bottom) illustrate strong lightning-storm coupling

Summary of Important Science Value of ISS LIS

- Supports multiple high value science activities and objectives.
  - Data used across multiple disciplines including weather/precipitation, climate, chemistry, and thunderstorm/space connections.
  - LIS data is an accepted “benchmark” for global lightning climatology.
  - ISS LIS supports on-going and future research missions both as a stand alone mission and through key complementary observations.
- Immediate science and applications returns anticipated.
  - Large, established LIS science community will be eager to obtain data
  - TRMM data processing/distribution infrastructure remains in place for ISS LIS
- Supports important interagency and international collaborations.
  - NOAA for cross sensor validation for the Geostationary Lightning Mapper (GLM) launched aboard the GOES-R in 2015 and real time operational users
  - Mutually enhances science return of ESA’s **A**tmosphere-**S**pace **I**nteraction **M**onitor (ASIM) and JAXA’s **G**lobal **L**ightning and spr**I**te **M**easurement**S** (GLIMS) experiments. Also cross validation of ESA’s geostationary **L**ightning **I**mager (LI)

LIS Lightning Detection: How it works

Lightning from Space: Lightning appears like a pool of light on the top of the cloud as the discharge lights up the cloud like a light bulb.

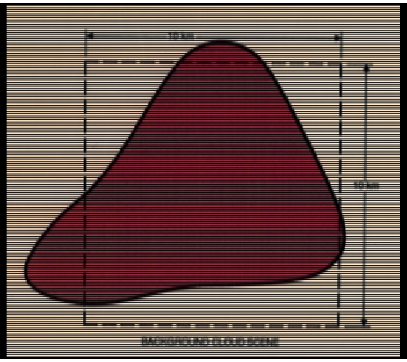
Daytime Challenge: During day, sunlight reflected from cloud top totally "swamps out" and masks the lightning signal. Daytime lightning detection drove the design.

Solution: Special techniques must be applied to extract the weak, transient lightning signal from the bright, background noise.

Spatial

Optimal sampling of lightning scene relative to back-ground scene.

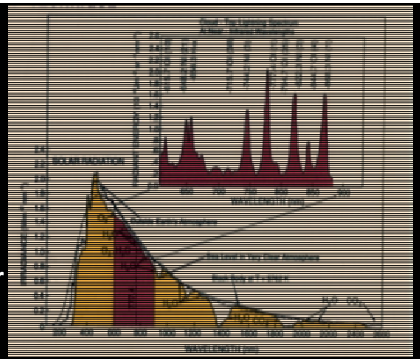
Pixel field-of-view 4-10 km.



Spectral

Optimal sampling of lightning signal relative to back-ground signal.

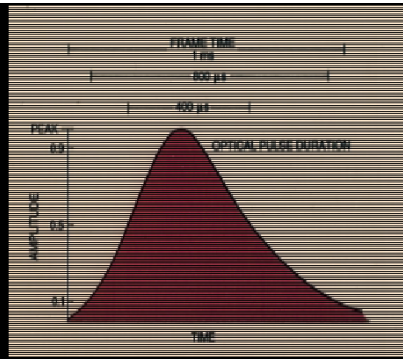
LIS uses 1nm filter at 777.4 nm.



Temporal

Optimal sampling of lightning pulse relative to back-ground signal .

LIS uses 2 ms frame rate.



- *Even with spatial, spectral and temporal filters, background can exceed lightning signal by 100 to 1 at the focal plane.*
- *The final step is a frame-by-frame background subtraction to produce a lightning only signal*
- *Filtering results in 10^5 reduction in data rate requirements while maintaining high detection efficiency for lightning .*

Background Subtraction

Optimal subtraction of background signal levels at each pixel.

Transient events selected for processing.