Lightning Imaging Sensor (LIS) for the International Space Station (ISS): Mission Description and Science Goals

Presented by

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September 25-26,2014

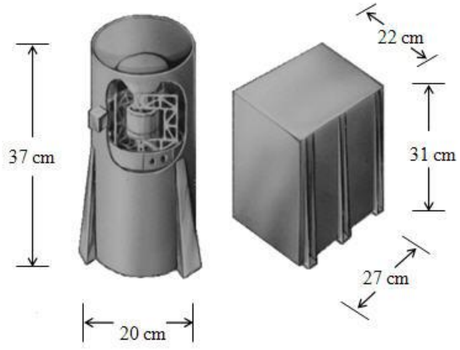
Acknowledgements

- LIS Science and GHRC DAAC team members who have provided and continue to provide great LIS support.
- The many engineers at NASA, UAH and Space Test Program (STP) involved in preparing the Lightning Imaging Sensor for flight to the International Space Station.
- The support and sponsorship of this project from the Science Mission Directorate at NASA Headquarters and the ISS Program Office at NASA Johnson Space Center.

ISS Lightning Imaging Sensor (LIS) Overview

Mission

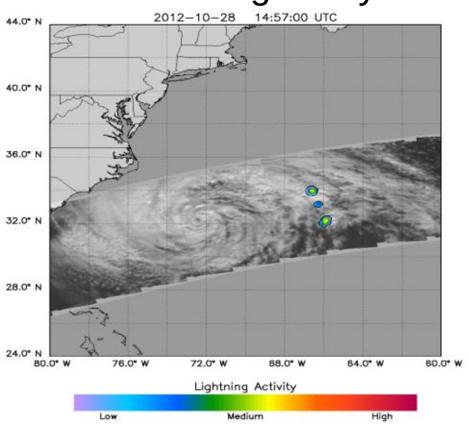
- Fly a space-qualified, flight-spare LIS on ISS to take advantage of unique capabilities provided by the ISS *(e.g., high inclination, real time data)*.
- Integrate LIS as hosted payload on DoD Space Test Program (STP-H5) and launch on SpaceX rocket in February 2016 for 2 year mission.



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 under EOS and TRMM.
- 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

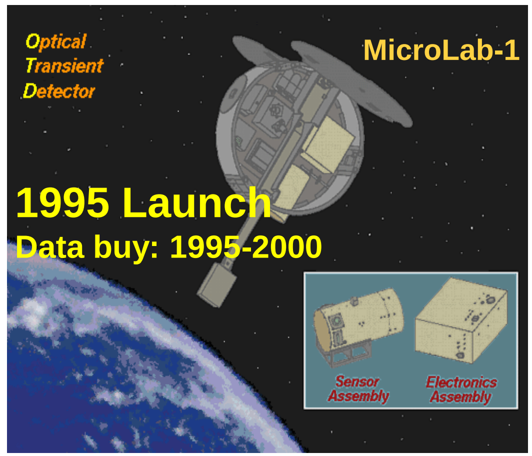
- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes, and therefore provides important science inputs across a wide range of disciplines (e.g., *weather, climate, atmospheric chemistry, lightning physics*).
- ISS LIS (or i LIS as Hugh Christian prefers) will extend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

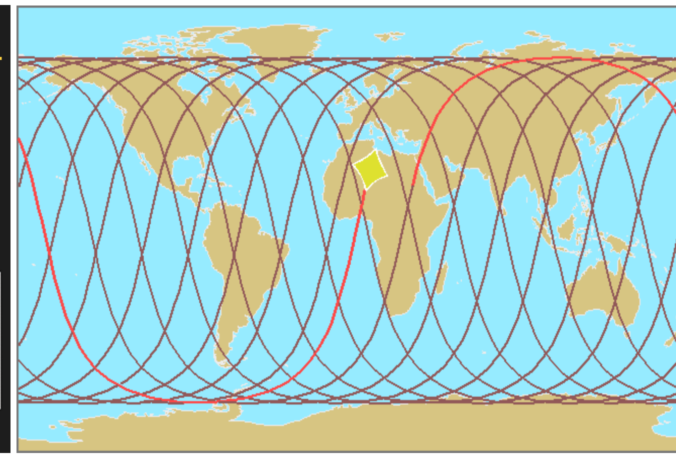
LIS Flight Heritage

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

Optical Transient Detector

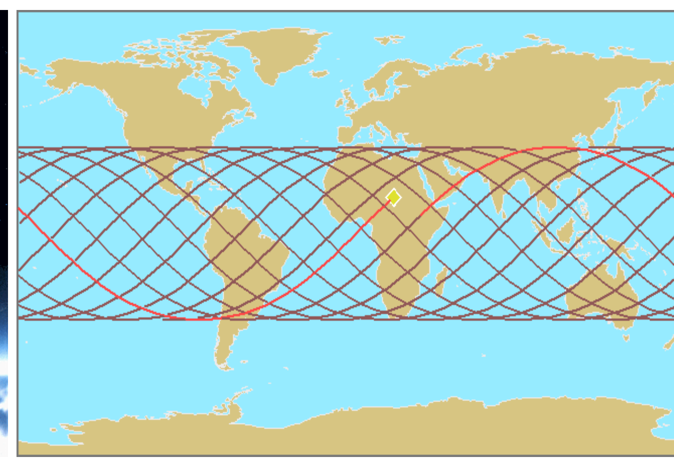
Launched: April 1995
Data: May 1995 - April 2000
Orbit: 70º inclin., 735 km
(detects to ~75º)
Field of view:1250x1250 km
Diurnal cycle: sampled in 55 days
Provided proof-of-concept for this approach



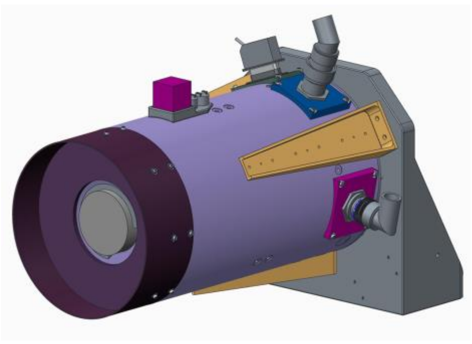


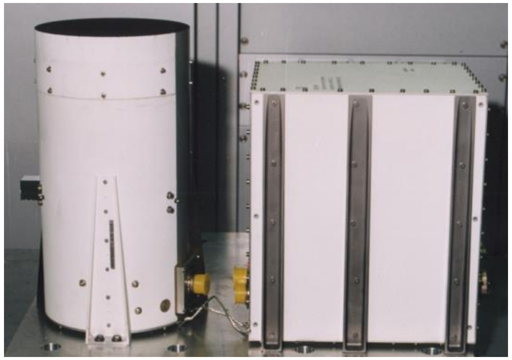
Lightning Imaging Sensor

Launched: November1997
Data: Jan.1998 - present
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

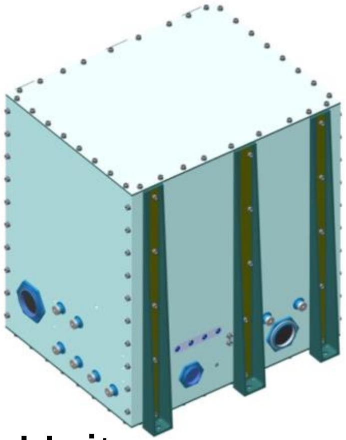


LIS Hardware





Flight Spare LIS



LIS Sensor Unit

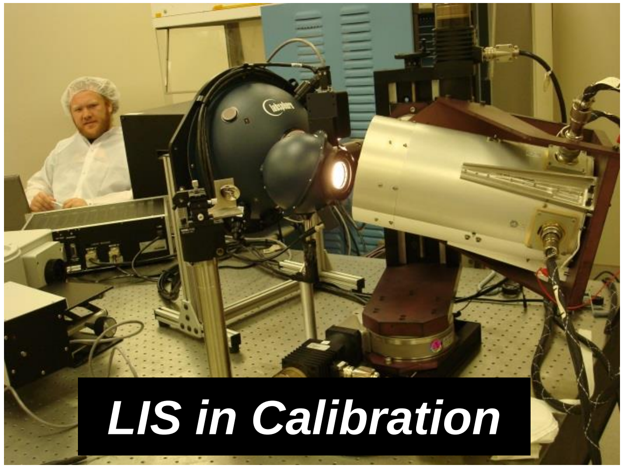
Optical Assembly
128x128 CCD Focal Plane

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



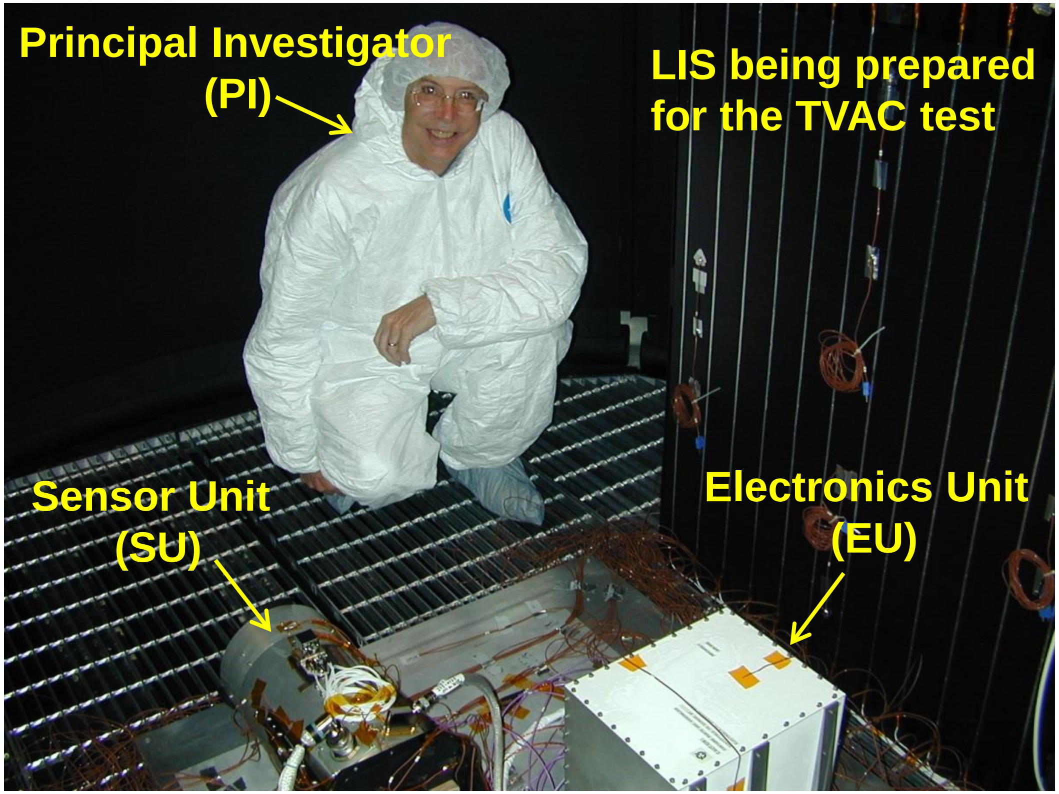
LIS in Calibration

LIS Performance Parameters

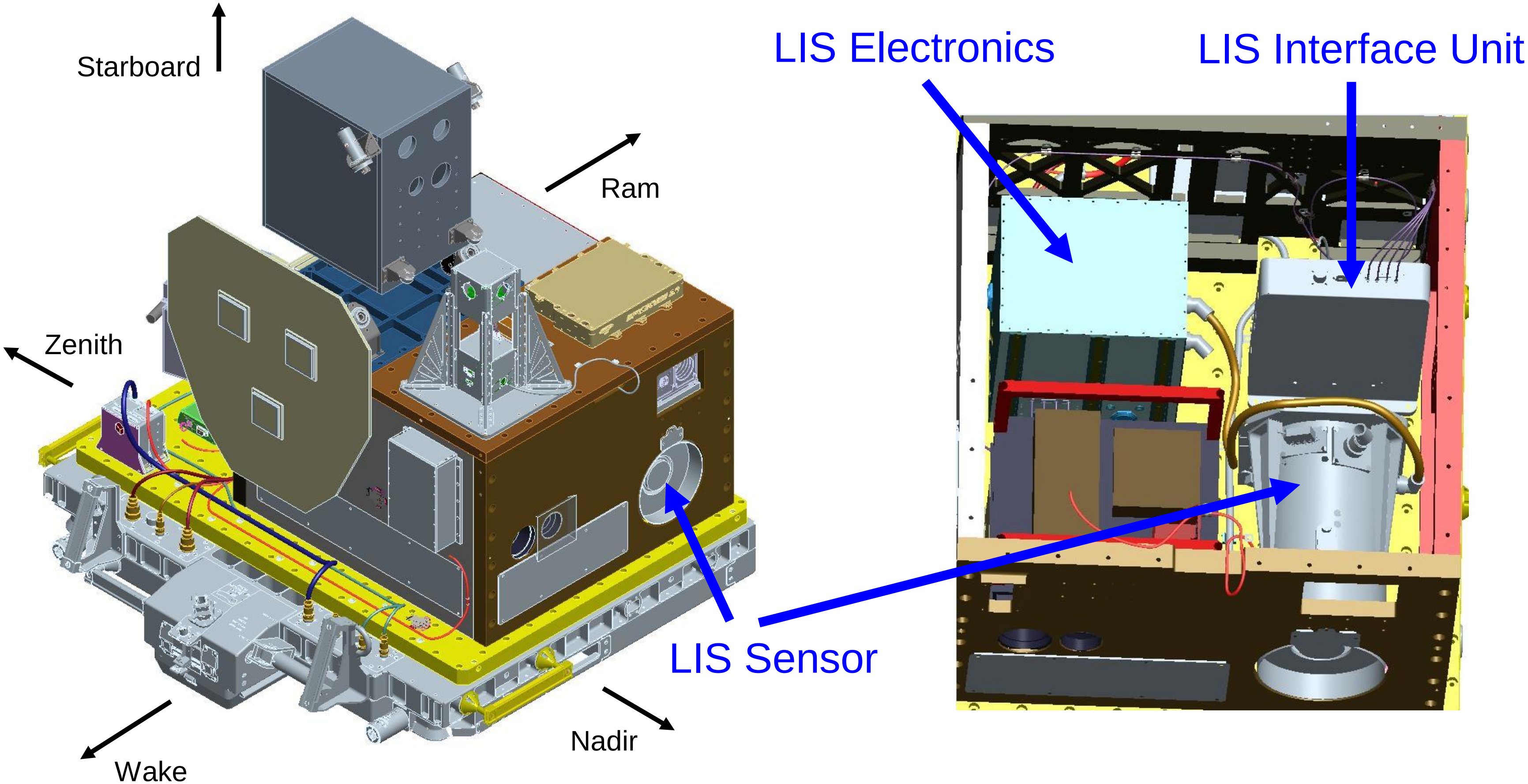
Field-of-View (FOV)	80° × 80°	Measurement Accuracy	
Pixel IFOV (nadir)	4 km	location	1 pixel
Interference Filter		intensity	10 %
wavelength	777.4 nm	time	tag at frame rate
bandwidth	1 nm	Dimensions	
Detection Threshold	4.7 μJ m^{-2} sr^{-1}	sensor assembly	20 × 37 cm
Signal to Noise Ratio	6	electronics 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 Thermal Vacuum (TVAC)

- The legacy LIS hardware also successfully completed thermal vacuum functional testing.
  - LIS operated in its ISS configuration under hot, cold, and ambient environmental conditions it may experience on ISS.
  - LIS performed flawlessly during the test.

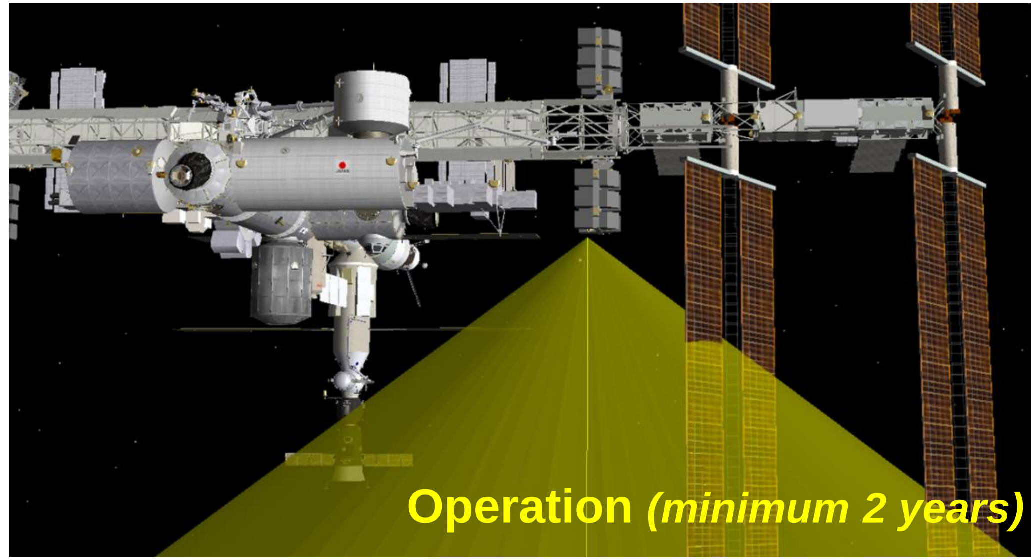


LIS Integration as Hosted Payload on STP-H5



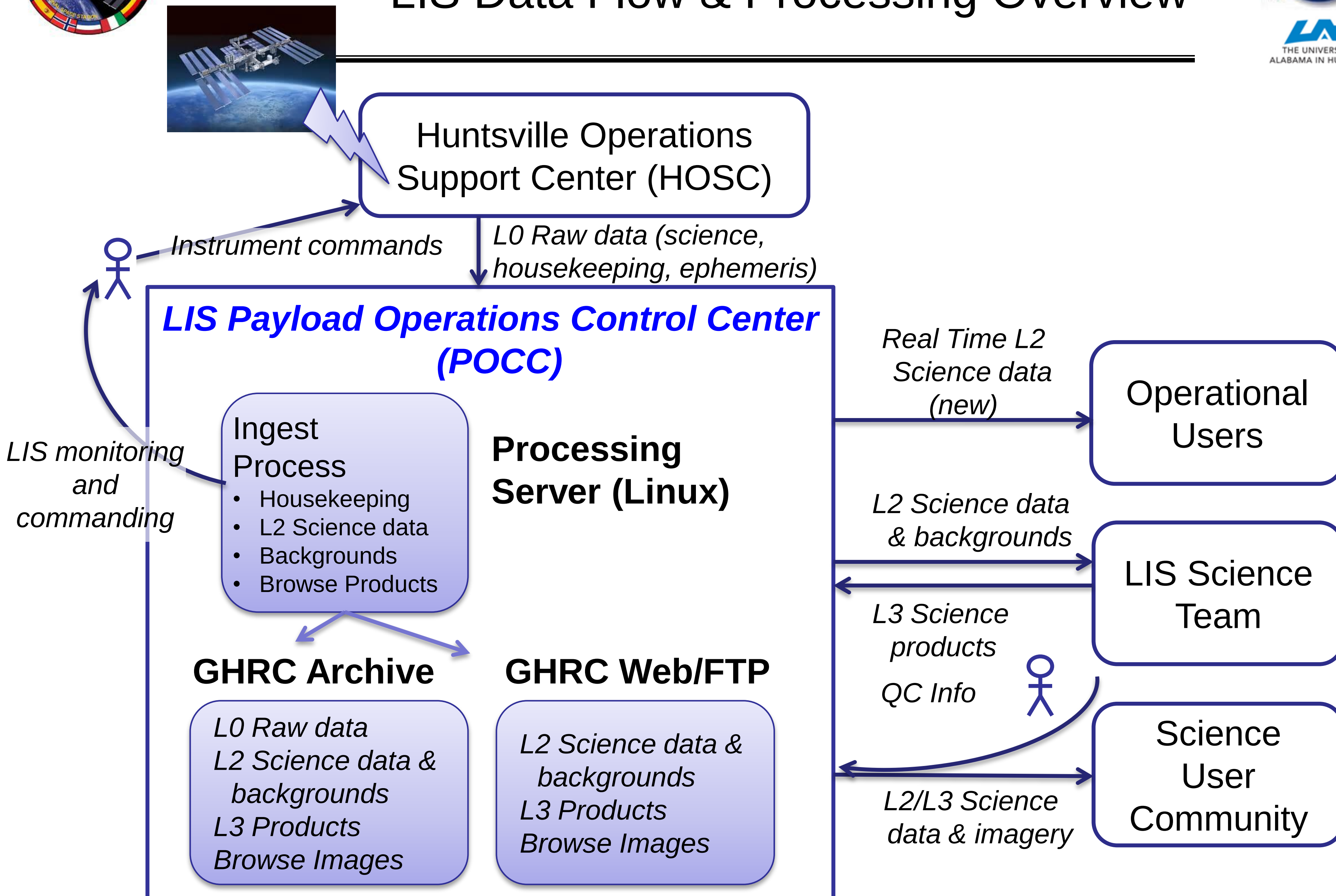
- LIS is one of thirteen instruments on the STP-H5 payload manifest.
- LIS will be installed on ISS in an Earth viewing (nadir) position.
- Payload built on special structure to allow robotic installation on ISS.

LIS Launch, Installation and Operation on ISS



- STP-H5 will be shipped to KSC in August 2015.
- Launched to ISS on a Space X rocket with Dragon cargo vehicle in February 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 Data Flow & Processing Overview



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.

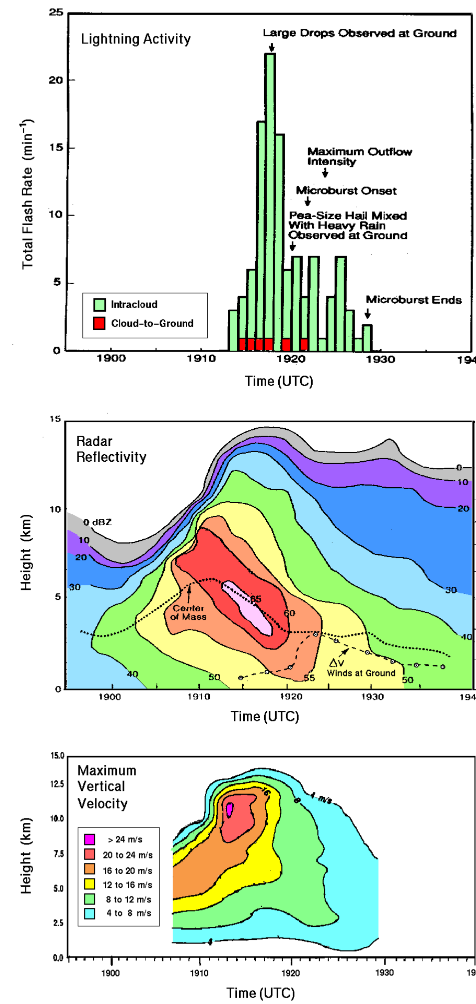
Climate: Lightning is an excellent variable for climate monitoring because it is sensitive to small changes in temperature and atmospheric forcing. ISS LIS will:

– 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).

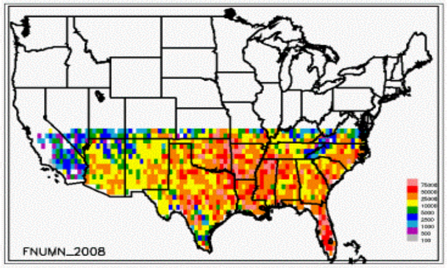


Lightning (top), radar (middle), and vertical velocity (bottom) illustrate strong lightning-storm coupling

Unique Science Contributions from ISS Platform

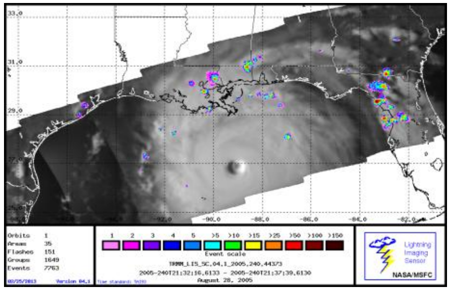
"New and Improved" Science

- Lightning coverage at higher latitudes 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)



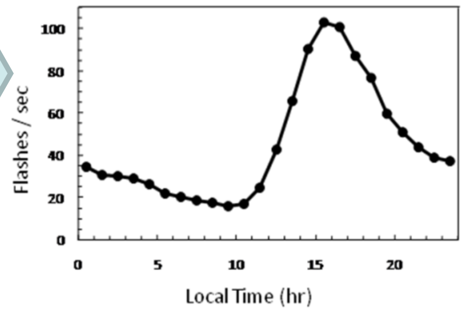
TRMM LIS does NOT cover CONUS for climate and chemistry assessments

- 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)



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

- 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)



LIS detects lightning during the day when most lightning occurs

- 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)

Summary of Important Science Value of ISS LIS

- Supports multitude of 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 that still remains in place.
- 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)

Thank You!

Hugh C, Steve G, and me examine early results from OTD in 1995

Back-up Slides

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.

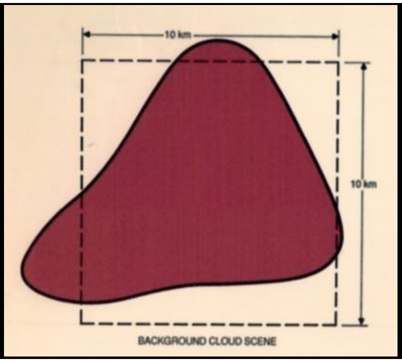
Solution: Special techniques must be applied to extract the weak, transient lightning signal from the bright, background noise.


ISS Image
April 30, 2012

Spatial

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

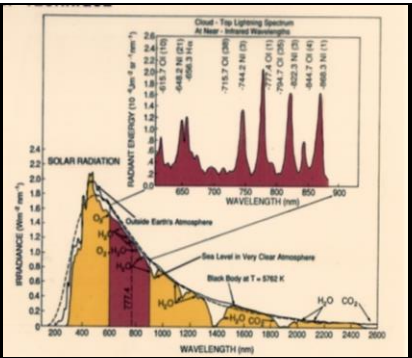
Pixel field-of-view 4-10 km.



Spectral

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

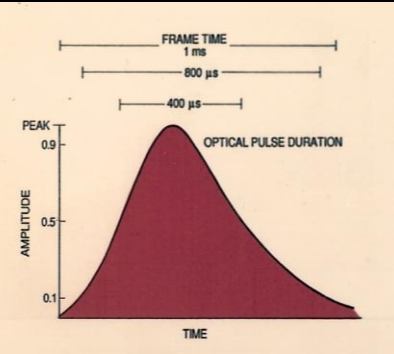
LIS uses 1nm filter at 777.4 nm.



Temporal

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

LIS uses 2 ms frame rate.

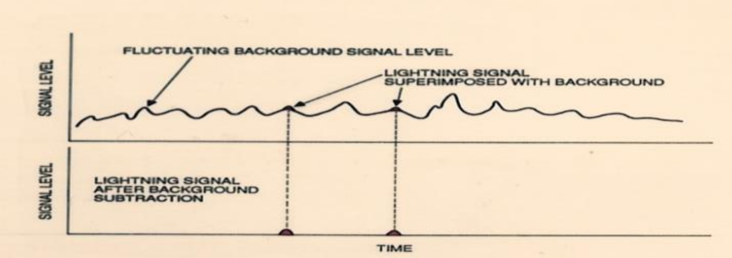


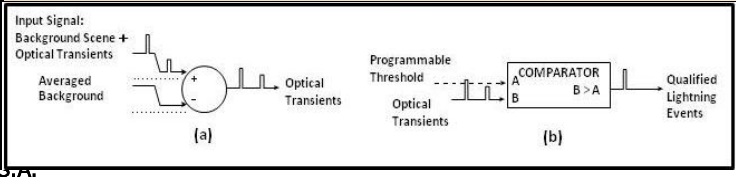
- *Even with spatial, spectral and temporal filters, background can exceed lightning signal by 100 to 1 at the focal plane.*
- *The final step is a frame-by-frame background subtraction to produce a lightning only signal*
- *Filtering results in 10^5 reduction in data rate requirements while maintaining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

Background Subtraction

Optimal subtraction of background signal levels at each pixel.

Transient events selected for processing.





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.
- ☐ August 2015: Deliver STP-H5 to Kennedy Space Center for launch vehicle integration and test.
- ☐ February 2016: Launch to ISS on SpaceX 10 using Dragon Cargo vehicle.
- ☐ February 2016: Mission operations begin after short checkout.

Timeline of ISS LIS and Related Space Missions

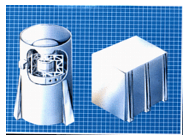
Blue: LIS observations or LIS science enabling contributions

Red: related mission observations

	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

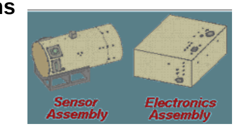


Cross calibration obtained between OTD and TRMM LIS

TRMM LIS (LEO)

11/1997

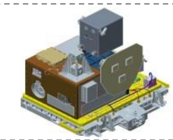
Estimated end of operations 2/2015 through 2016



Desire cross calibration with ISS LIS for continuity in climate monitoring.

ISS LIS

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

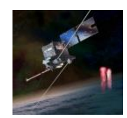


Launch Date early 2016 (2 year minimum)

Taranis (LEO)

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

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

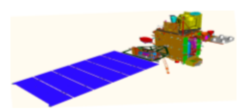


Launch Date 2016 (2 -3 year mission)

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

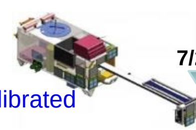


Planned launch date late 2015 to early 2016

JAXA GLIMS (ISS)

GLIMS: VHF, optical photometers

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



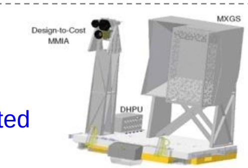
7/2012

Mission end ?

ESA ASIM (ISS)

ASIM: TGF, video cameras, optical photometers

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



Launch Date 2016 (mission duration ?)

Established User Community and Infrastructure

- Large and established LIS science users community will be eager to obtain ISS LIS data
  - Insures the ISS LIS observations will be immediately applied to pressing Earth system science issues through innovative, integrated, hypothesis or science question-driven approaches.
  - The expanded ISS LIS coverage and real time access will lead to new and expanded science and application investigations
  - Data used across multiple disciplines including weather/precipitation, climate, chemistry, and thunderstorm/space connections.
- Well established processing, archival, and distribution system insures data will be quickly placed into the hands of users
  - Leverage existing TRMM LIS infrastructure to quickly get ISS LIS data into the hands of science and application users (fully ready at launch).
  - Ready to provide tracking of data usage for ISS Project reporting.
  - Ready at launch to deliver real time LIS data to NOAA and other users.
- LIS data used extensively by the international science community
  - Since 1997, over 50 peer-reviewed publications and over 40 advanced degrees awarded that used OTD/LIS data. Data used by scientist in more than 40 countries.
  - LIS data is an accepted "benchmark" for global lightning climatology intercomparisons.