



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

Presented by

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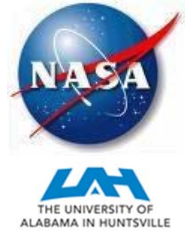
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Acknowledgements



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¹NASA Marshall Space Flight Center, ²University of Alabama in Huntsville (UAH), and ³University Space Research Association

- The many scientist and engineers at NASA, UAH and Space Test Program (STP) involved in preparing the Lightning Imaging Sensor for flight to the International Space Station.
- The ISS Program Office at NASA Johnson Space Center and the Science Mission Directorate at NASA Headquarters for project sponsorship.

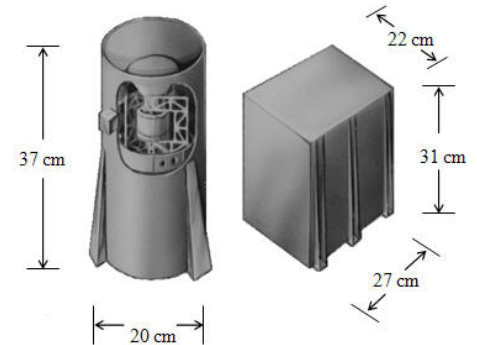


Lightning Imaging Sensor (LIS) on ISS



Mission Overview

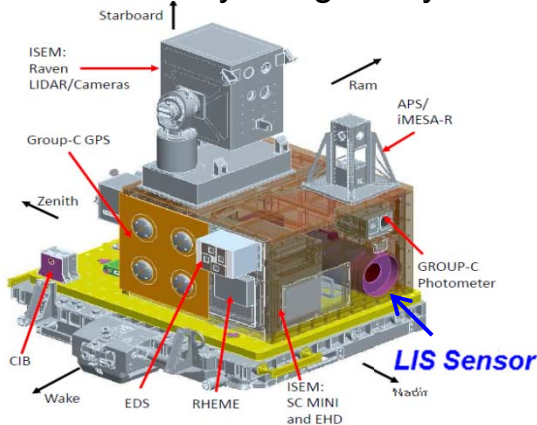
- NASA and UAH developed space-based lightning observation as a remote sensing tool under the Earth Observing System (EOS) and Tropical Rainfall Measuring Mission (TRMM) (*LIS still operational on TRMM*).
- LIS on the ISS will extend TRMM time series observations, expand latitudinal coverage, and provide real time observations in support of important and pressing science and applications objectives.
- Integrate as hosted payload on DoD Space Test Program (STP-H5) and launch on SpaceX Dragon in February 2016 for 2 year mission.



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

Measurement

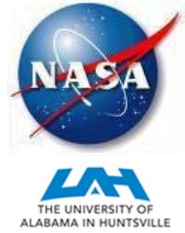
- LIS measures global lightning (*amount, rate, radiant energy*) during both day and night, with storm scale resolution, millisecond timing, and high, uniform detection efficiency.
 - LIS daytime detection is both unique and scientifically important (>70% occurs during day).
 - Only LIS globally detects TOTAL (*both cloud and ground*) lightning with no land-ocean bias.



Need and Benefit

- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes.
- Therefore lightning observations provide important gap-filling inputs to pressing Earth system sciences issues in a wide range of disciplines (e.g., *weather, climate, atmospheric chemistry, lightning physics*).
- Real time observations will be provided to operational users.
- LIS data is the “Gold Standard” for global lightning climatology.

STP-H5 (preliminary design)

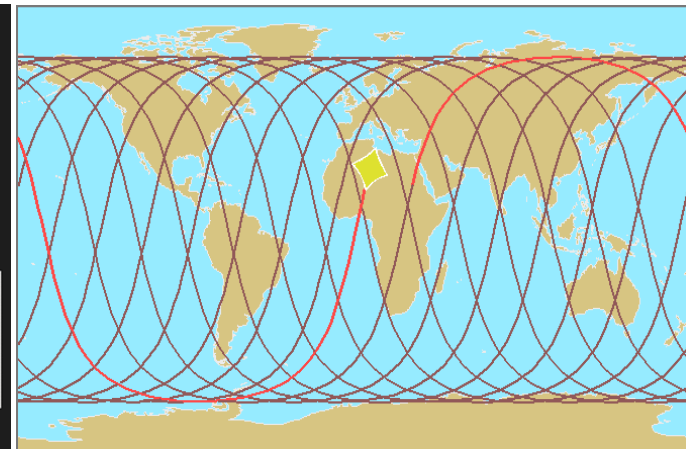


LIS Flight Heritage

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

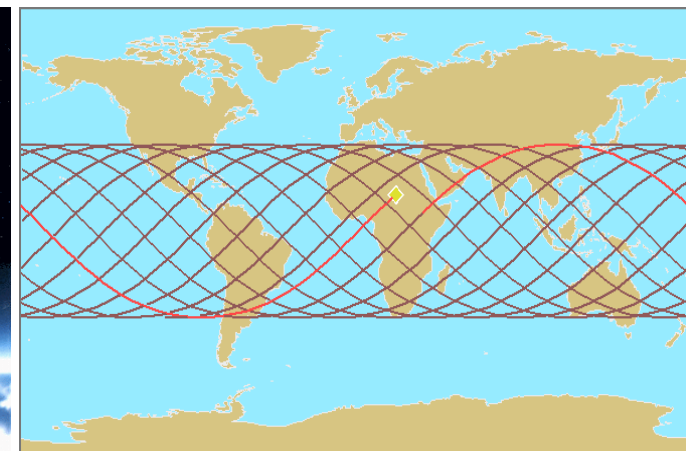
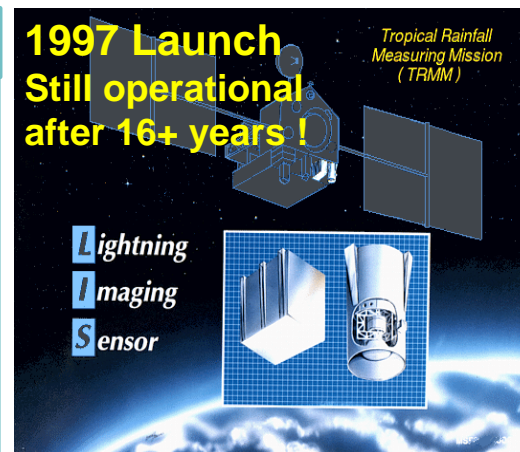
Optical Transient Detector

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



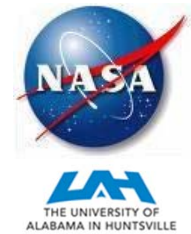
Lightning Imaging Sensor

Launched: November 1997
Data: Jan. 1998 - present
Orbit: 35° inclin., 350 km
(boosted to 400 km in 2001)
(detects to ~38°)
Field of view: 600 x 600 km
Diurnal cycle: sampled in 49 days





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.



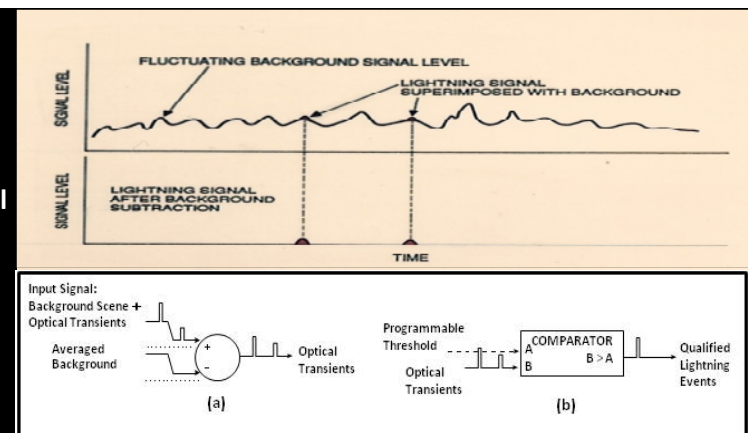
<p>Spatial</p> <p>Optimal sampling of lightning scene relative to background scene.</p> <p>Pixel field-of-view 4-10 km.</p>		<p>Spectral</p> <p>Optimal sampling of lightning signal relative to background signal.</p> <p>LIS uses 1nm filter at 777.4 nm.</p>		<p>Temporal</p> <p>Optimal sampling of lightning pulse relative to background signal .</p> <p>LIS uses 2 ms frame rate.</p>	
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- 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

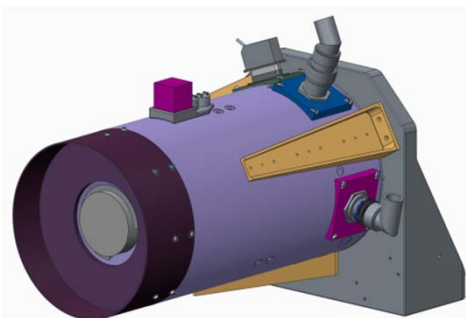
Optimal subtraction of background signal levels at each pixel.

Transient events selected for processing.

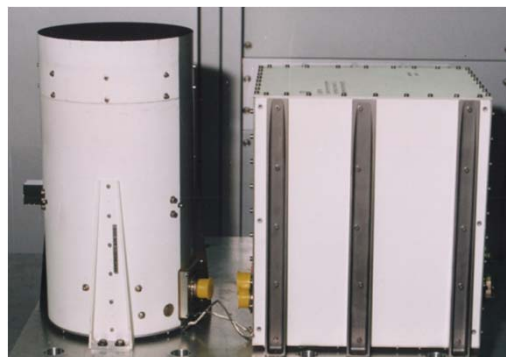




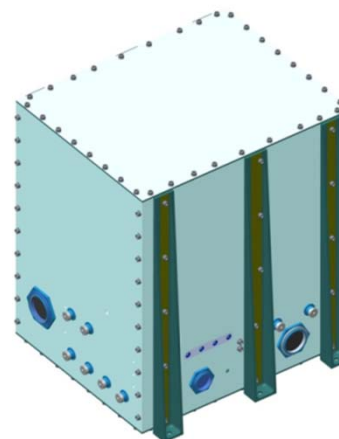
LIS Hardware



LIS Sensor Unit
Optical Assembly
128x128 CCD Focal Plane



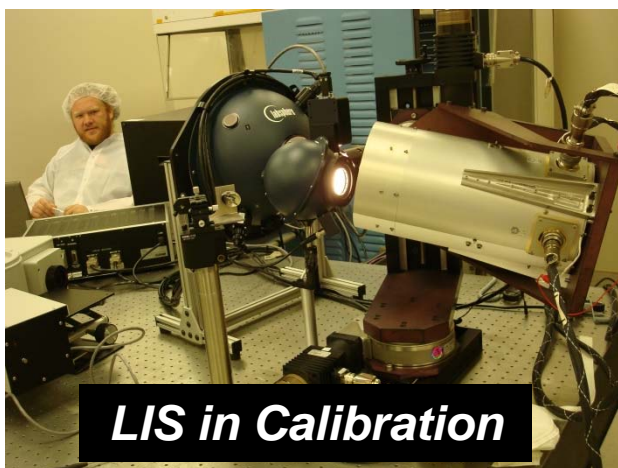
Flight Spare LIS



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



Interface Unit (*new*)
Power conversion
1 PPS Time Signal Generation
C&DH Formatting
ISS Interface

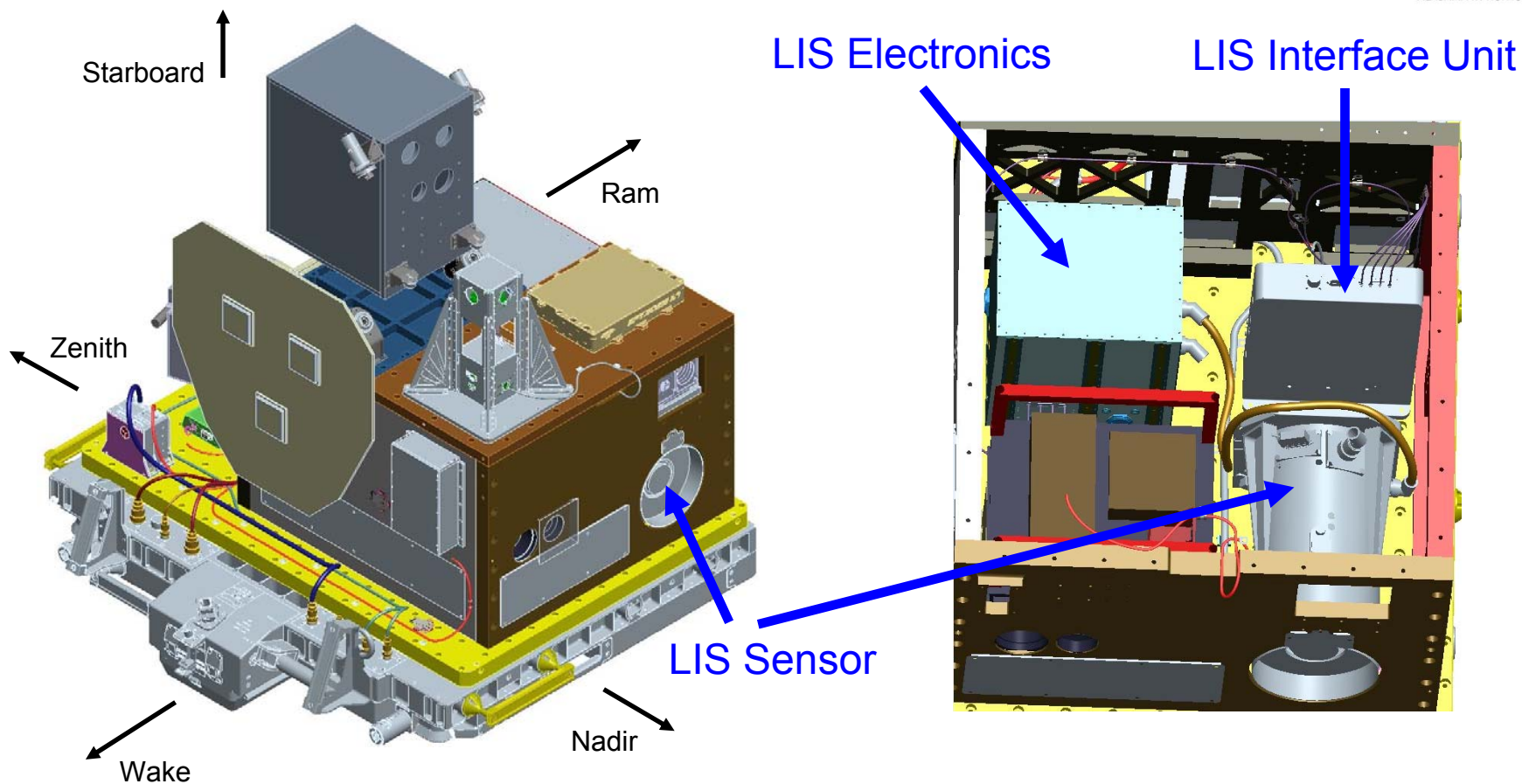


LIS Performance Parameters

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



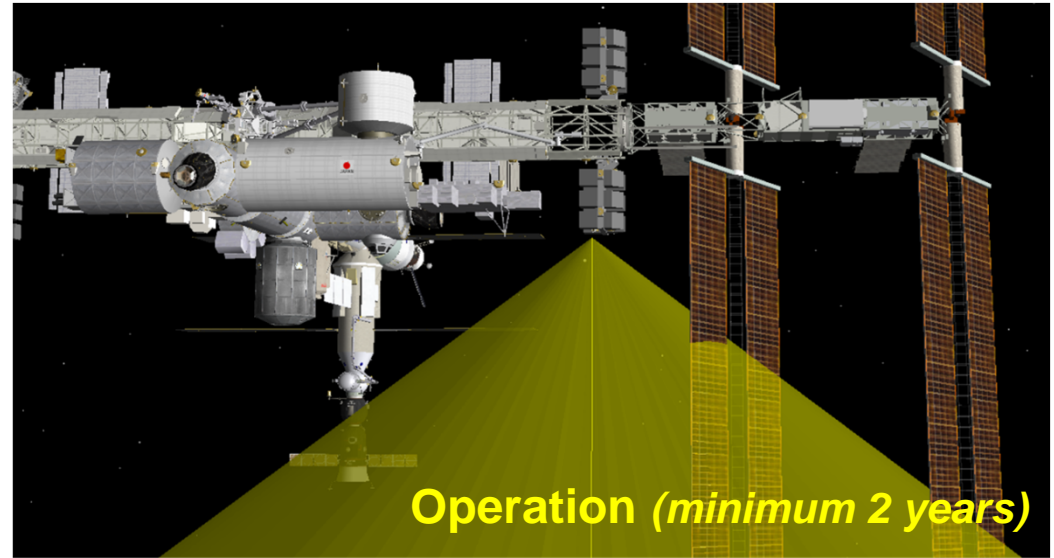
LIS Integration on STP-H5 as Hosted Payload



- LIS is one of thirteen instruments on the STP-H5 payload manifest.
- LIS will be installed on ISS in a Earth (nadir) viewing position.



LIS Launch, Installation and Operation on ISS



- 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



Science and 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.

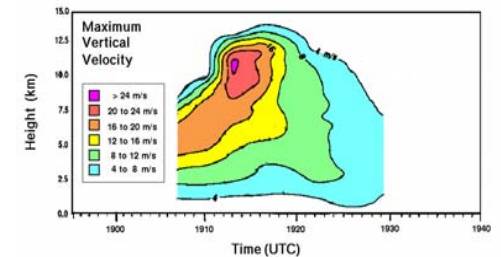
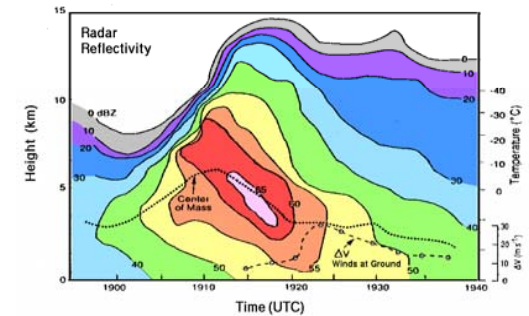
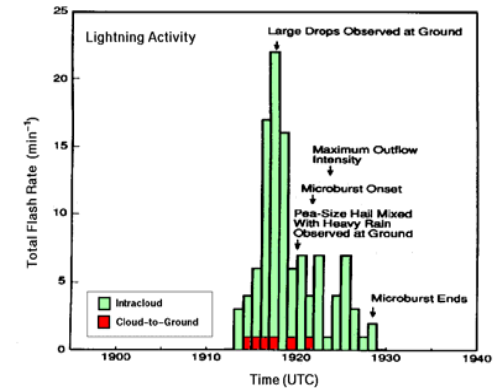
Climate: Lightning is an excellent variable for climate monitoring because it is sensitive to small changes in temperature and atmospheric forcing. ISS LIS will:

- 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

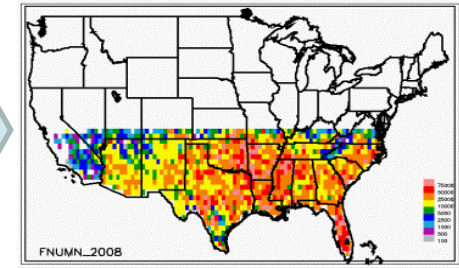


Unique Science Contributions from ISS Platform

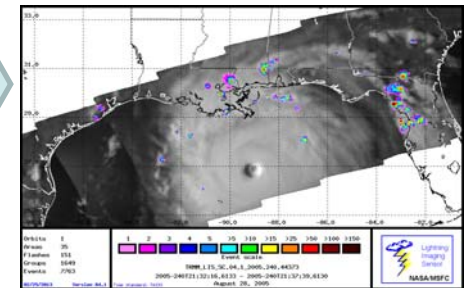
“New and Improved” Science



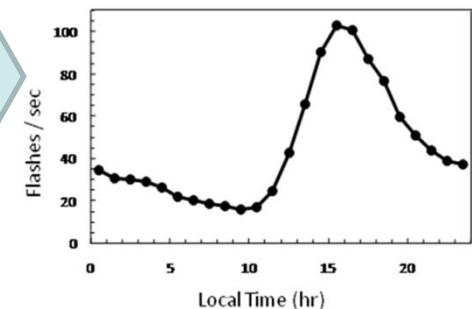
- Higher latitude lightning coverage
 - TRMM LIS misses up to 30% lightning in N. Hemisphere summer
 - Enhance regional and global weather, climate, and chemistry studies
 - Provide CONUS coverage (needed for National Climate Assessment)
- Real time lightning using ISS Low Rate Telemetry (LRT)
 - Desired by SMD 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)
 - Provide real time lightning for data sparse regions, especially oceans (storm warnings, nowcasts, oceanic aviation and international SIGMETs, long-range lightning system validation, hurricane rapid intensification evaluations)
- Simultaneous / complementary LIS observations
 - Provide critical daytime lightning to better understand mechanisms leading to TGFs and TLEs (strongly endorsed by ESA ASIM and JAXA GLIMS)
- Cross-sensor calibration
 - 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)



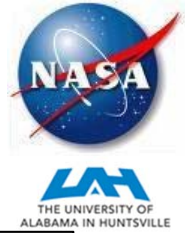
LIS detects lightning during the day when most lightning occurs

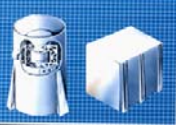
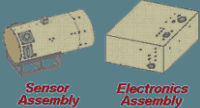


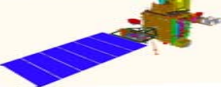
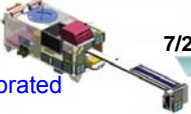
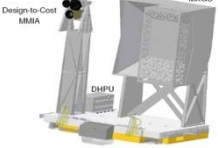


Timeline of ISS LIS and Related Space Missions

Blue: LIS observations or LIS science enabling contributions

Red: related mission observations



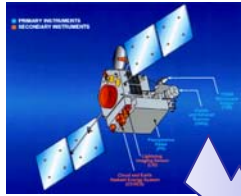
	1995-1999					2000-2029																														
	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	
OTD	4/1995 → 5/2000										Cross calibration obtained between OTD and TRMM LIS																									
TRMM LIS	11/1997 →					Estimated end of operations 2/2015 through 2018																							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	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	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	GLIMS: VHF, optical photometers					ISS LIS: coincident <u>daytime</u> lightning location, calibrated radiance																							7/2012 → Mission end ?							
ESA ASIM	ASIM: TGF, video cameras, optical photometers					ISS LIS: coincident <u>daytime</u> lightning location, calibrated radiance																							Launch Date 2016 (mission duration ?)							



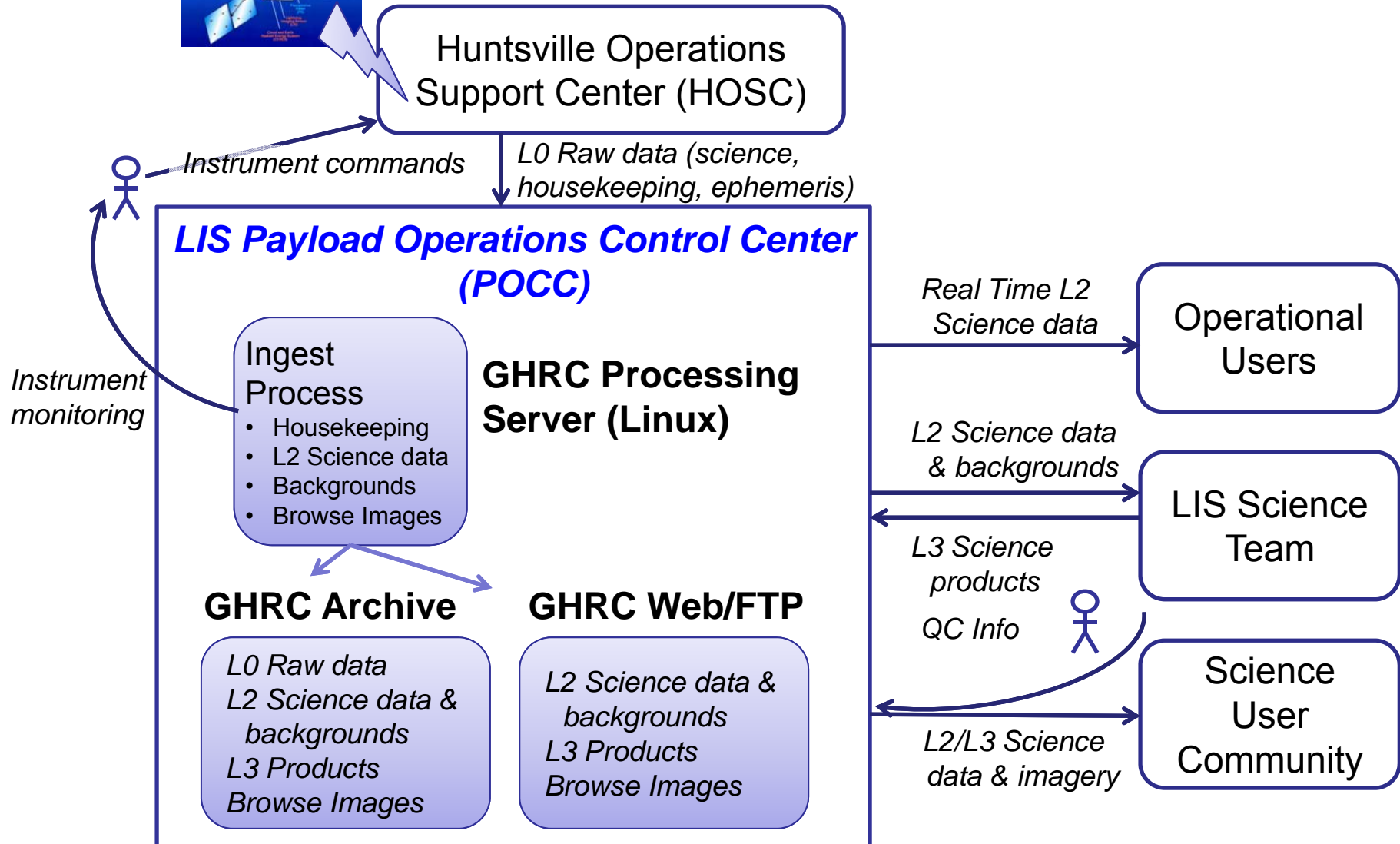
Established User Community and Infrastructure



- Large and established LIS science users community
 - 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
- Established processing, archival, and distribution system
 - Leverage TRMM LIS infrastructure to quickly get ISS LIS data into the hands of science and application users (fully ready prior to 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
 - Data used across multiple disciplines including weather/precipitation, climate, chemistry, and thunderstorm/space connections.
 - 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 the “Gold Standard” for global lightning climatology



LIS Data Flow & Processing Overview





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.





Back-up Slides



ISS LIS Scientific Justification Summary

Strong scientific rationale exists for ISS accommodation



- **ISS LIS well aligned with multiple NASA themes.**
 - NASA Earth Science Focus Areas (4 of 6), National Research Council Decadal Survey Climate Studies, Space Science (Earth/Space connection).
 - Supports TRMM LIS and the Global Precipitation Mission (GPM).
- **Supports multiple high value science activities and objectives.**
 - 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 due to large, established LIS science users community and data processing/distribution infrastructure.
- **Supports 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
 - Significantly enhances science return of ESA's **A**tmosphere-**S**pace Interaction **M**onitor (ASIM) and JAXA's **G**lobal **L**ightning and sprite **M**easurements (GLIMS) experiments. Also cross validation of ESA's geostationary **L**ightning **I**mager (LI)