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

Presented by
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Acknowledgements

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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.

**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.
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.

**Spatial**
- Optimal sampling of lightning scene relative to background scene.
- Pixel field-of-view 4-10 km.

**Spectral**
- Optimal sampling of lightning signal relative to background signal.
- LIS uses 1nm filter at 777.4 nm.

**Temporal**
- Optimal sampling of lightning pulse relative to background 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.
LIS Hardware

LIS Sensor Unit
Optical Assembly
128x128 CCD Focal Plane

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Field-of-View (FOV)</td>
<td>80° × 80°</td>
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<tr>
<td>PixelIFOV (nadir)</td>
<td>4 km</td>
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<tr>
<td>Interference Filter</td>
<td></td>
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<tr>
<td>wavelength</td>
<td>777.4 nm</td>
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<tr>
<td>bandwidth</td>
<td>1 nm</td>
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<tr>
<td>Detection Threshold</td>
<td>4.7 μJ m⁻² sr⁻¹</td>
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<td>Signal to Noise Ratio</td>
<td>6</td>
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<tr>
<td>CCD Array Size</td>
<td>128 × 128 pixels</td>
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<tr>
<td>Dynamic Range</td>
<td>&gt; 100</td>
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<tr>
<td>Detection Efficiency</td>
<td>~ 70 - 90 %</td>
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<tr>
<td>False Event Rate</td>
<td>&lt; 5 %</td>
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<td>Measurement Accuracy</td>
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<td>time</td>
<td>tag at frame rate</td>
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<tr>
<td>Dimensions</td>
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<td>sensor assembly</td>
<td>20 × 37 cm</td>
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<tr>
<td>electronics assembly</td>
<td>31 × 22 × 27 cm</td>
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<td>Weight</td>
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<td>Power</td>
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<td>Telemetry</td>
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<td>data rate, format</td>
<td>8 kb/s, PCM</td>
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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

Launch (February 2016)

Operation (minimum 2 years)

ISE2.0 Camera 3
STP-H4 on ELC 1
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\textsubscript{x} for climate and air quality studies.

- Lightning NO\textsubscript{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\textsubscript{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)
### Timeline of ISS LIS and Related Space Missions

**Blue:** LIS observations or LIS science enabling contributions  
**Red:** related mission observations

<table>
<thead>
<tr>
<th>Year</th>
<th>OTD</th>
<th>TRMM LIS</th>
<th>ISS LIS</th>
<th>Taranis</th>
<th>GOES-R GLM</th>
<th>JAXA GLIMS</th>
<th>ESA ASIM</th>
</tr>
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<tbody>
<tr>
<td>1995</td>
<td>4/95</td>
<td>11/97</td>
<td>LIS: day/night lightning, storm scale resolution (4km), millisecond timing, high, uniform detection, calibrated radiance from 128x128 CCD.</td>
<td>Taranis: TGF, TLE, optical photometers, LF, HF, magnetic field</td>
<td>GLM: optical lightning similar to LIS (LIS heritage)</td>
<td>GLIMS: VHF, optical photometers</td>
<td>ASIM: TGF, video cameras, optical photometers</td>
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<td>1997</td>
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<td>Estimated end of operations 2/2015 through 2018</td>
<td>ISS LIS: coincident lightning location, calibrated radiance (cross calibration possibility)</td>
<td>ISS LIS: proxy data, cal/val support, desire ISS LIS cross calibration for climate monitoring</td>
<td>ISS LIS: coincident <strong>daytime</strong> lightning location, calibrated radiance</td>
<td>ISS LIS: coincident <strong>daytime</strong> lightning location, calibrated radiance</td>
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<td>Launch Date early 2016 (2 year minimum)</td>
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- **Cross calibration obtained between OTD and TRMM LIS**
- **Estimated end of operations 2/2015 through 2018**
- **Desire cross calibration with ISS LIS for continuity in climate monitoring.**
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

Huntsville Operations Support Center (HOSC)

**Ingest Process**
- Housekeeping
- L2 Science data
- Backgrounds
- Browse Images

**GHRC Processing Server (Linux)**
- Real Time L2 Science data
- L2 Science data & backgrounds
- L3 Science products
- QC Info

**GHRC Archive**
- L0 Raw data
- L2 Science data & backgrounds
- L3 Products
- Browse Images

**GHRC Web/FTP**
- L2 Science data & backgrounds
- L3 Products
- Browse Images

**LIS Payload Operations Control Center (POCC)**

Instrument commands

**Instruments monitoring**

**Operational Users**

**LIS Science Team**

**Science User Community**
Project Status and Milestones

- April 2013: LIS selected as ISS payload.
- December 2013: System Requirements Review/Preliminary 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.
Thank You!
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 Atmosphere-Space Interaction Monitor (ASIM) and JAXA’s Global Lightning and sprite MeasurementS (GLIMS) experiments. Also cross validation of ESA’s geostationary Lightning Imager (LI)