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

Presented by

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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.

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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.

**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.

**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: 70° inclin., 735 km (detects to ~75°)
- Field of view: 1250x1250 km
- Diurnal cycle: sampled in 55 days
- Provided proof-of-concept for this approach

**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 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 Time Signal Generation
ISS Interface

LIS Performance Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field-of-View (FOV)</td>
<td>80° × 80°</td>
</tr>
<tr>
<td>PixelIFOV (nadir)</td>
<td>4 km</td>
</tr>
<tr>
<td>Interference Filter</td>
<td></td>
</tr>
<tr>
<td>wavelength</td>
<td>777.4 nm</td>
</tr>
<tr>
<td>bandwidth</td>
<td>1 nm</td>
</tr>
<tr>
<td>Detection Threshold</td>
<td>4.7 μJ m⁻² sr⁻¹</td>
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<tr>
<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>
</tr>
<tr>
<td>False Event Rate</td>
<td>&lt; 5 %</td>
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</tbody>
</table>

| Measurement Accuracy       |                     |
| location                   | 1 pixel             |
| intensity                  | 10 %                |
| time                       | tag at frame rate   |

| Dimensions                 |                     |
| sensor assembly            | 20 × 37 cm          |
| electronics assembly       | 31 × 22 × 27 cm     |

| Weight                     | 20 kg               |
| Power                      | 30 Watts            |
| Telemetry                  |                     |
| 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.
• 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

Huntsville Operations Support Center (HOSC)

L0 Raw data (science, housekeeping, ephemeris)

Instrument commands

LIS Payload Operations Control Center (POCC)

Ingest Process
- 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

LIS Science Team

L3 Science products
QC Info

Science User Community

L2/L3 Science data & imagery
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).
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)

- 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)
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 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)
Thank You!

Hugh C, Steve G, and me examine early results from OTD in 1995
Back-up Slides
**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.
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

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<th>Date</th>
<th>Mission Details</th>
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<td>OTD (LEO) Cross calibration obtained between OTD and TRMM LIS</td>
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<td>5/2000</td>
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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.