ISS Utilization: LIS (Lightning Imaging Sensor)

ISS Utilization: LIS (Lightning Imaging Sensor) on STP-H5's investigations of DoD

Launch Instrument Description Ground Segment References

Note: LIS is one of thirteen instruments on the DoD STP-H5 payload manifest. See also ISS: STP-H5 / ISEM and ISS: SAGE-III on the eoPortal.

LIS (Lightning Imager Sensor)

LIS, flown on the TRMM (Tropical Rainfall Measuring Mission) of NASA (launch Nov. 27, 1997), was designed and developed at NASA/MSFC, the UAH (University of Alabama in Huntsville), and their partners. Hugh Christian of UAH is the PI (Principal Investigator) of LIS. After more than 17 years on orbit, the instrument has demonstrated successfully space-based lightning observations as an effective remote sensing tool for Earth science research and applications.

In April 2013, a space-qualified LIS built as the flight spare for TRMM, was selected for flight as a science mission on the International Space Station. The ISS-LIS will be flown as a hosted payload on the DoD STP-H5's investigationsmission, which is scheduled for launch in 2017 aboard a SpaceX launch vehicle for a 2-4 year or longer mission. [1)]

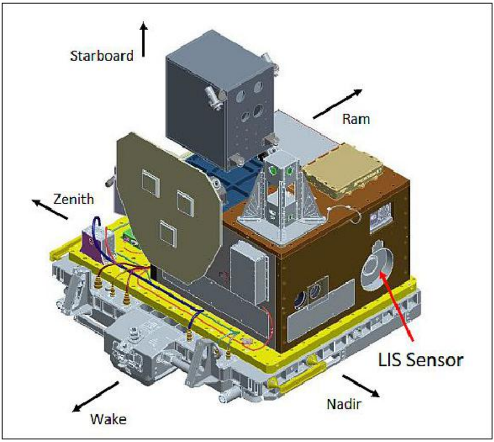

Figure 1: ISS-LIS accommodation, one of 13 instruments on the STP-H5 mission payload (image credit: DoD, NASA/MSFC)

The LIS measures the amount, rate, and radiant energy of total lightning over the Earth. More specifically, it measures lightning during both day and night, with storm scale resolution (~4 km), millisecond timing, and high, uniform detection efficiency, without any land-ocean bias. Lightning is a direct and most impressive response to intense atmospheric convection. It has been found that lightning measured by LIS can be quantitatively related to thunderstorm and other geophysical processes. Therefore, the ISS -LIS lightning observations will continue to provide important gap-filling inputs to pressing Earth system science issues across a broad range of disciplines, including weather, climate, atmospheric chemistry, and lightning physics. [2)]

Background:

Directory
Directory Home
Satellite Missions
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V, W, X, Y, Z
Airborne Sensors
Observation of the Earth

NASA's first spaceborne lightning sensor, called OTD (Optical Transient Detector), was launched aboard the MicroLab-1 satellite in 1995 from Vandenberg Air Force Base. The primary mission of the OTD instrument was to improve the understanding of thunderstorm distributions, cloud processes, and storm variability by detecting lightning activity over large areas of the Earth's surface. The concept for this instrument was developed at MSFC in the 1980s, and was selected for development as part of NASA's Earth Observing System (EOS). [3]

Prior to 1995, spaceborne lightning observations had been severely limited by one or more problems, including low or unknown detection efficiency, poor spatial and temporal resolution, a limited number or brief periods of observations, and an inability to measure lightning during the daytime, leading to incomplete sampling over the diurnal cycle. The launch of OTD ushered in a new era of spaceborne lightning detection, being specifically designed to address the deficiencies of available ground-based, in situ, and space-based lightning measurements. In particular, it provided—for the first time—highly detailed and accurate statistics of the geographical distribution of lightning frequency, worldwide.

The OTD was positioned in a near-circular orbit at an altitude of 740 km , at a 70° inclination. This orbit provided observations of lightning activity over most regions of the world where lightning is generated (coverage between 75° N and S latitude). During OTD's five-year mission, the instrument optically detected lightning — both intracloud and cloud-to-ground discharges — that occurred within its 1300 x 1300 km footprint during both day and night. The instrument also had storm-scale (~10 km) spatial resolution, two-millisecond time resolution, and high, uniform detection efficiency (~50%).

With the launch of TRMM, LIS joined OTD at an altitude of 350 km and 35° inclination orbit. LIS on TRMM represented a significant advance upon OTD with its sensitivity improved by a factor of three. The increased sensitivity of LIS resulted in a detection efficiency approaching 90%, while its lower orbit altitude improved its spatial resolution to 4 km , but at the cost of a decreased surface footprint of 600 x 600 km (Figure 2).

Although LIS provided smaller global coverage than OTD, it still is thought to have detected 90% of of the world's lightning on an annual basis. An important science benefit of flying on TRMM was the acquisition of LIS lightning measurements simultaneous with TRMM visible, infrared, microwave, and radar observations, which provided the capability to directly test a number of hypotheses on the interrelationships between updrafts, ice formation, and lightning over a large number of global tropical cloud regimes from a spaceborne platform. LIS on TRMM operated for an impressive 17 years.

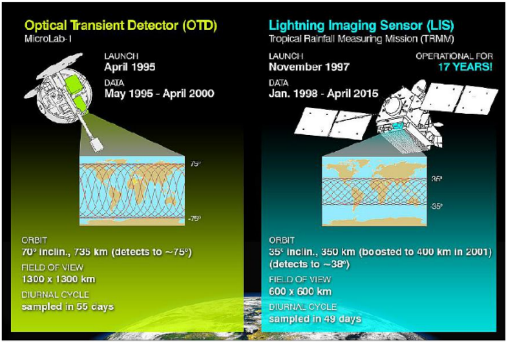

Figure 2: Since 1995, OTD and LIS on TRMM have provided 20 years of continuous combined lightning observations to create a robust global lightning climatology throughout the diurnal cycle (image credit: NASA and the University of Alabama in Huntsville (UAH))

Optical Transient Detector *
April 1995 - May 2000
Tool for the Analysis of RAdiation from lightNing and Sprites *
Planned Launch Date 2016
(2-4 Year Mission)
GOES-R Series Geostationary Lightning Mapper (Four GLMs) ‡
Planned Launch Dates R-October 2016, S-May 2018, T-2021, U-2024
(20 year Mission)

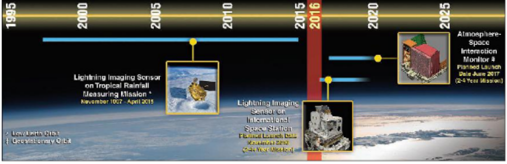
1995
2000
2005
2010
2015
2016
2020
2025
Lightning Imaging Sensor on Tropical Rainfall Measuring Mission *
November 1997 - April 2015
Lightning Imaging Sensor on International Space Station
Planned Launch Date November 2016
(2-4 Year Mission)
Atmosphere-Space Interaction Monitor #
Planned Launch Date June 2017
(2-4 Year Mission)
* Low Earth Orbit
‡ Geostationary Orbit

Figure 3: A timeline showing LIS on ISS, along with several closely-related space missions (image credit: NASA, Ref. 3)

A unique contribution from the ISS platform will be the availability of realtime lightning, especially valuable for operational applications over data sparse regions such as the oceans. The ISS platform will also uniquely enable LIS to provide simultaneous and complementary observations with other payloads such as **ASIM** (Atmosphere-Space Interaction Monitor) of ESA (European Space Agency) that will be exploring the connection between thunderstorms and lightning with terrestrial gamma-ray flashes (TGFs). - Another important function of the ISS-LIS will be to provide cross-sensor calibration/validation with a number of other payloads, including the next generation geostationary lightning mappers, e.g., **GLM** (Geostationary Lightning Mapper) on GOES-R of NOAA and **LI** (Lightning Imager) on MTG (Meteosat Third Generation) of EUMETSAT. This inter-calibration will improve the long term climate monitoring provided by all these systems. Finally, the ISS-LIS will extend the time-series climate record of LIS lightning observations and expand the latitudinal coverage of LIS lightning to the climate significant upper middle-latitudes.

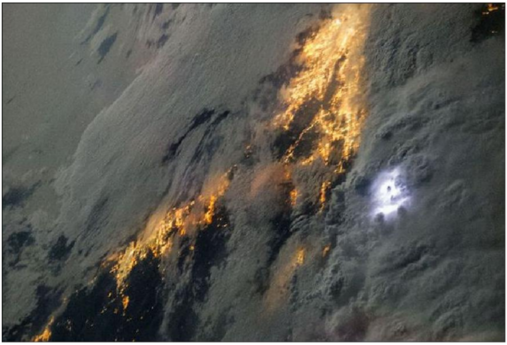

Figure 4: This ISS (International Space Station) crew Earth image of storm clouds over California shows lightning as a white glow to the right of center. The yellow lit areas beneath the clouds are the night lights from the highly populated areas of Los Angeles and San Diego (image credit: NASA,ISS036-E-022863, 21 July 2013) [4]

LIS instrument preparation:

The legacy LIS instrument selected for this mission has been carefully maintained in environmentally controlled storage since 1998, effectively providing an available off-the-shelf instrument for this ISS opportunity. Although this instrument is nearly 20 years old, its controlled storage and solid TRMM operating heritage — e.g., as of early 2015, LIS still performing well after 17 years in space — give a high degree of confidence that this flight spare will perform without problems when it is launched in 2016 (Ref. 1).

Immediately after selection, an "aliveness" test verified that the hardware still functioned. Much more extensive functional tests and a full radiometric calibration will be completed prior to delivering the LIS in December 2014 for integration into STP-H5. The integrated package will then undergo additional testing in 2015 prior to its launch. Fortunately, many of the original scientists, engineers, and infrastructure involved with LIS development, calibration, operations and data handling, and science analysis are either still in place or still available to support pre-mission preparations and the post-launch mission and science operations. The primary mission risks faced by the project are obsolescent electronic components in the legacy LIS should a failure occur during its preparation, and the fast-track schedule that must be met.

LIS science goals and objectives:

Lightning can be quantitatively related to both thunderstorm and other geophysical processes across a broad range of disciplines, making it an effective and valuable remote sensing tool to address a variety of science and application problems facing the nation and the world. The core science goals and objectives for LIS were first defined in NASA

Technical Memorandum-4350. [5] These research objectives have continued with various refinements and augmentations since the launch of OTD (Optical Transient Detector) in April 1995 and TRMM LIS in November 1997, and they remain fully applicable for the ISS-LIS mission. At the broadest level, the LIS science goals and objectives are to acquire and investigate the global distribution and variability of total lightning and to advance the understanding of underlying and interrelated processes.

Specific research topics of scientific importance identified in NASA TM-4350 include:

1) Provide information on the total rain volume and degree of convective activity in the core regions of tropical and extra-tropical storms and storm systems, particularly as relevant to severe weather occurrence.

2) Study the global distribution of lightning and its relationship to storm microphysics and dynamics, its dependence on regional climatic environments and their changes, its relationship to precipitation and cloud type, and the incorporation of these relationships into diagnostic and predictive models of global precipitation, the general circulation and the hydrological cycle.

3) Develop global lightning climatology in order to study the distribution and variability in lightning frequency as an indicator of the intensity of the Walker and Hadley circulations and assess the impact of sea surface and land surface temperature changes on the distribution and intensity of thunderstorms, including extreme weather events.

4) Study the production, distribution, and transport of trace gases attributed to lightning and determine the contribution (and the sources of variability) to the global amount of trace gases.

5) Conduct observational and modeling studies of the global electric circuit and the factors that cause it to change. This last topic also includes investigating the relationship of lightning with ionospheric/magnetospheric processes, as well as basic lightning physics.

Lightning measurements serve to increase knowledge of the amount, distribution, and variability of deep convection and natural sources and sinks of key trace gases on a global scale. The high temperatures attained within lightning channels provide the mechanism for the production of nitrous oxides and other trace gases. Lightning relationships are also being sought with atmospheric electrical processes such as the global electric circuit. The more recent discoveries of TLEs (Transient Luminous Events, - e.g., sprites, jets, elves) and TGFs (Terrestrial Gamma-ray Flashes) further motivates the desire for space-borne lightning measurements.

Unique science contributions for the ISS platform: Even though TRMM LIS has acquired a lightning climatology that now spans 17 years, there are several unique and highly valuable science benefits to be gained by also taking LIS to the International Space Station, and these represent key reasons why the LIS was selected to fly on ISS. These benefits trace to the ISS orbital characteristics – especially its higher 51.6° orbit inclination for greater global latitudinal coverage, the ISS communication advantages, and the opportunity to engage in important complementary science observations.

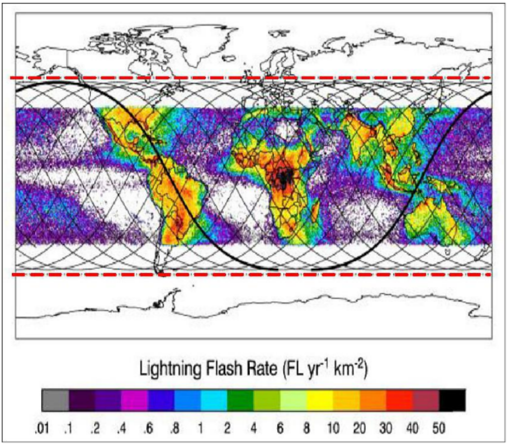

Figure 5: The maximum ISS latitude coverage of ±54.33° represents 81% of the Earth's surface, but includes 98% of the global lightning on an annual basis (image credit: NASA/MSFC)

The first benefit is the higher latitude coverage that will be gained from the ISS as depicted in Figure 5. The TRMM LIS misses up to 30% of the lightning in the northern hemisphere in the warm season months. The ISS-LIS will detect nearly all of that lightning to enhance regional and global weather, climate, and chemistry models, studies and assessments. Also, the ISS-LIS will provide CONUS (CONtinental US) observations needed for the NASA sponsored National Climate Assessment program.

Another unique important benefit gained from the ISS platform will be the availability of real time lightning brought down via the station's low rate telemetry channel which LIS will use. This will provide realtime lightning for operational applications in data sparse regions, especial over the oceans. It would be used to support storm forecasts and warnings, nowcasts, and oceanic aviation warnings and SIGMETs (Significant Meteorological Information). The ISS-LIS mission has been strongly endorsed by several operational partners, including the NOAA Ocean Prediction Center, Aviation Weather Center, Joint Typhoon Warning Center, and the NWS (National Weather Service) Pacific Region. The best latency that TRMM provided was on the order of 90 minutes from its quick look orbit files – the project hopes to reduce this to a few minutes or better with ISS.

Next, the ISS platform will uniquely enable ISS-LIS to provide simultaneous and complementary observations with other ISS payloads such as the ESA sponsored ASIM (Atmosphere-Space Interaction Monitor) or the JAXA (Japan Aerospace Exploration Agency) sponsored GLIMS (Global Lightning and sprIte MeasurementS) missions. The combination of LIS, ASIM, and GLIMS will enable simultaneous acquisition of optical (NASA), X-ray, gamma-ray (ESA), and very high frequency or VHF (JAXA) lightning measurements that represent a unique measurement capability providing great science value, heretofore not achieved before on a single satellite platform.

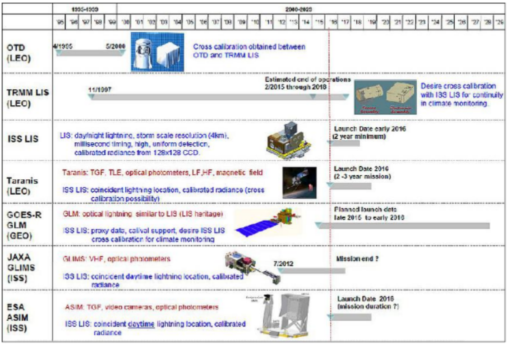

Figure 6: Timeline of ISS-LIS and related space missions (image credit: NASA)

Gaining a better understanding of TGFs (Terrestrial Gamma-ray Flashes) represents a prime focus of ASIM. Although a connection between TGFs and lightning/thunderstorms is apparent, a detailed understanding of the relationships remains elusive, primarily because of the lack of simultaneous TGF and lightning measurements. The LIS on ISS would be capable for the first time of observing the individual lightning strokes associated with TGF events and record this information on a millisecond time scale. The type of thunderstorm, the altitude of origin and the beaming angle of the hypothesized electron beam could then be determined, leading to a greatly improved understanding of the TGF process. The present ASIM instrument suite is incapable of detecting optical lightning events on the millisecond time scale that is required for one–to-one comparisons with TGFs. Furthermore, the conventional ASIM video cameras can only detect lightning at night, while as LIS detects lightning during both day and night. This capability alone results in an 80% increase in the probability of simultaneous observations. TGFs may pose at times significant radiation hazard to aircraft pilots and passengers. This joint LIS-ASIM observation capability will advance our understanding of this threat, and, if necessary, guide mitigation strategies.

Finally, a very important function of the ISS-LIS will be to provide cross-sensor calibration/validation observations with other satellites, including the low Earth orbit TRMM LIS (if it is still in orbit in early 2016, and the prospects for this remain promising) and TARANIS (Tool for the Analysis of Radiations for lightNings and Sprites) of CNES, the next generation geostationary lightning mappers (e.g., GOES-R Geostationary Lightning Mapper and Meteosat Third Generation Lightning Imager), and even with ground-based lightning detection systems. These inter-calibrations will improve the long term climate monitoring record provided by all these systems. The ISS-LIS will extend the time-series climate record of LIS observations and expand the latitudinal coverage of LIS lightning to the climate significant upper middle-latitudes.

Launch: The DoD STP-H5 payload package along with LIS was launched on February 19, 2017 on the SpaceX CRS-10 (Commercial Resupply Service-10) Dragon cargo flight to the ISS from Launch Complex 39 Pad A of Kennedy Space Center, Cape Canaveral, FL. 6) 7) 8)

The resupply mission to the International Space Station carries hardware and supplies to support dozens of the of approximately 250 science and research investigations that will occur during Expeditions 50 and 51. The Expedition crew members Thomas Pesquet and Shane Kimbrough will use the station's robotic arm to capture Dragon when it arrives on station. The spacecraft will be berthed to the Earth-facing port on the Harmony module.

The Dragon resupply vehicle is carrying a total cargo of 2490 kg, of which 1530 kg are in the pressurized cargo bay (732 kg science investigations, 296 kg crew supplies, 382 kg vehicle hardware, 10 kg of spacewalk equipment, 11, kg of computer resources, and 22 kg of Russian hardware).

The unpressurized trunk of the spacecraft (960 kg) holds the SAGE-III (Stratospheric Aerosol and Gas Experiment-III) , which will provide continuity for key climate observations and data records, and the STP-H5 payload package, including LIS (Lighting Imaging Sensor). -There are separate files for SAGE-III, LIS and STP-H5 instrumentation on the eoPortal.

Table 1: CRS-10 mission overview 9)

Orbit: Near-circular orbit, altitude of ~ 400 km, inclination = 51.6°.

LIS instrument description:

The legacy LIS instrument selected for this mission has been carefully maintained in environmentally controlled storage since 1998, effectively providing an available off-the-shelf instrument for this ISS opportunity. Although this instrument is nearly 20 years old, its controlled storage and solid TRMM operating heritage give a high degree of confidence that this flight spare will perform without problems once launched. A recalibration of the flight-spare LIS performed in preparation for this ISS mission showed its performance and calibration has remained unchanged. It is also worth noting that by monitoring the reflected sunlight from deep convective clouds, LIS on TRMM showed no degradation in its sensitivity during its many years in orbit.

The legacy LIS is a small, solid state optical imager that detects lightning from LEO (Low Earth Orbit) with high detection efficiency and location accuracy, marks the time of occurrence, and measures the radiant energy. An imaging system, a focal plane assembly, a realtime signal processor and background remover, an event processor and formatter, power supply and interface electronics comprise the major elements of the sensor.

The optical and electrical elements are combined into a cylindrical sensor assembly (20 x 37 cm) and an electronics assembly (31 x 22 x 27 cm), with a total mass of approximately 20 kg, less than 30 W of power, and a telemetry data rate of only 8 kbit/s. Table 2 summarizes the overall instrument parameters and performance criteria, while Figure 7a shows the legacy LIS hardware.

Parameter	Value	Parameter	Value
FOV (Field of View) Pixel IFOV (Instantaneous FOV)	80° x 80° 4 km	Measurement accuracy: - Location - Intensity - Time	1 pixel 10% Tag at frame rate
Interference filter - Wavelength - Bandwidth	777.4 nm 1 nm	Dimensions - Sensor head assembly - Electronics box	20 x 37 cm 31 x 22 x 27 cm
Detection threshold	$4.7\ \mu J\ m^{-2}\ sr^{-1}$	Instrument mass	25 kg
CCD array size	128 x 128 pixels	Instrument power	35 W
Dynamic range	>100	SNR (Signal to Noise Ratio)	6
Detection efficiency	~90%	Telemetry data rate	8 kbit/s
False event rate	<5%	Telemetry format	PCM (Pulse Code Modulation)

Table 2: LIS parameters and performance criteria

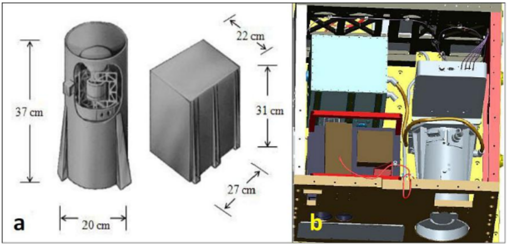

Figure 7: a) Legacy flight spare LIS the sensor assembly (left) and the electronics box (right). b)This is an advanced concept drawing showing how the Legacy LIS hardware will be mounted on the STP-H5 payload. The grey box behind the sensor assembly is the new interface unit (IFU) that will enable the legacy hardware to receive power and communications from the ISS (image credit: NASA/MSFC)

LIS operations: The LIS primarily operates as a transient event detector, although it also provides periodic background images that help with long-term navigation and calibration monitoring. The sensor design was driven by the requirement to detect weak lightning signals during the day when the sunlight reflecting from the tops of clouds is much brighter than the illumination produced by lightning. This requirement was met by implementing special filtering techniques in the instrument hardware to take advantage of the significant differences in the temporal, spatial, and spectral characteristics between the lightning signal and the background noise.

The design employs an expanded optics wide field-of-view lens, combined with a narrow-band interference filter, centered on the strong oxygen emission line [i.e., the oxygen multiplet at OI (Oxygen Iodine) line at 777.4 nm] in the lightning spectrum, that focuses the image on a small, high-speed 128 x 128 CCD focal plane. The final step in this process is to apply a frame-to-frame background subtraction to remove the slowly varying background signal from the raw data coming off the LIS focal plane. The signal is read out from the focal plane at 500 images per second into a real-time event processor for event detection and data compression. The resulting "lightning data only" signal is formatted, queued, and sent to the spacecraft for transmission to ground stations.

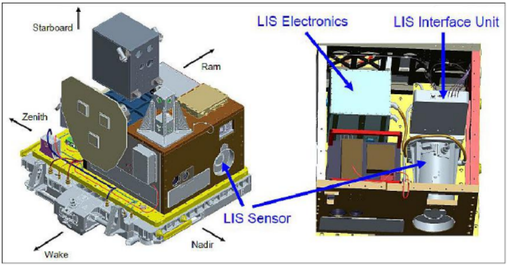

Figure 8: LIS integration as hosted payload on STP-H5 (image credit: NASA/MSFC)

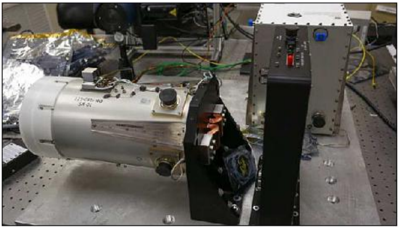

Figure 9: Photo of the completed ISS-LIS instrument (image credit: UAH)

In February 2015, UAH (University of Alabama in Huntsville) researchers have passed the NASA qualifying inspections and shipped out a LIS (Lightning Imaging Sensor) in preparation for its planned March 2016 flight to the International Space Station (ISS). 10)

Funded by NASA, ISS-LIS is being shipped to JSC (Johnson Space Center) in Houston, Texas, where it will be integrated onto the Space Test Program H5 spacecraft as one of 10 instruments. The integrated H5 spacecraft will then undergo environmental testing at JSC through August of 2015. The H5 will then be shipped to NASA/KSC (Kennedy Space Center) for integration onto the EXPRESS (EXpedite the PRocessing of Experiments to Space Station) Pallet Adapter (ExPA). The ExPA will in turn be attached to a SpaceX Dragon Capsule for the 2016 launch.

ISS accommodation of LIS:

There are no significant differences in how the legacy LIS hardware is used and operates on ISS versus how it is used and operates on the TRMM platform with the minor exception of the availability of realtime data delivery. However, it is necessary to provide an additional interface unit for the ISS implementation to translate the ISS power and communications into a form that makes the ISS platform appear like the TRMM satellite to the heritage LIS electronics assembly.

Functional testing early in the ISS-LIS mission development will establish that this interface unit performs properly to pass LIS commands and science data between the LIS instrument and the ground-based operations center. Figure 7 b shows the new interface unit and the mounting configuration expected on the STP-H5 payload.

The ISS-LIS will be located in a nadir viewing position. The ISS platform is presently operated at an altitude of about 425 km, which is close to that of the current TRMM mission. As such, the pixel resolution and FOV footprint on the Earth will be almost identical to that of TRMM – on the order of 4 km at nadir. On ISS, a small portion of the LIS FOV will experience obstruction as a solar panel and radiator translate through the instrument's FOV on a predictable time schedule. An analysis has shown that the maximum mean (peak) percent obscuration that would be experienced by LIS on an orbit would be 3.6% (12.3%). This will have no impact on meeting the LIS science objectives. The OTD (Optical Transient Detector) on OrbView-1 (launch on April 3, 1995) had a permanent obstruction of similar magnitude to this peak amplitude in its FOV from its gravity gradient boom with no detrimental impact on science.

A LIS pixel, obtained from laboratory measurement, is approximately 38.94 arcmin in one dimension. It was required by the LIS science team that accuracy in pointing be within one pixel and the uncertainty in pointing, sometimes called knowledge (about the nominal pointing direction), be within one half of a pixel, or about 19.47 arcmin. Similar requirements will be imposed for the ISS-LIS instrument on the STP-H5 payload. Fortunately, the STP-H5 payload will include a star tracker that will provide much better pointing knowledge than the minimum LIS requirement (the star tracker itself will be 0.66 arcmin at 3σ). If the star tracker should have problems, another instrument on the ISS has demonstrated that pointing close to the science team requirement is possible using ISS navigation data.

Another area of concern for the ISS-LIS is solar glare/glint. This concern traces to the fact that glint, the direct specular reflectance of sunlight into the instrument, could possibly produce an excessive amount of false detections that temporarily fill the FIFO (First-In First-Out) data buffer of LIS. Only if the real event rate plus the false event rate (from glint in this case) exceeds the maximum LIS sustained event rate of about 300 events/s would real science data be lost. Ground-based algorithms in the LIS processing software easily identify and remove glint signals in the case where data has not been lost due to a FIFO overflow. A detailed analysis was conducted that evaluated glare from the solar panels and radiator by simulating lighting for a complete range of ISS solar beta angles from ±75º increments with images generated at one minute intervals. This analysis, for nadir or 5º off-nadir viewing, found no glare areas or fast changing illumination for either the solar panels or the radiator. This model result is consistent with an examination of a series of photos from a current ISS instrument with a similar nadir position as planned for LIS. This result, along with other photographic and video examples from ISS, provide strong evidence that glint reflecting off the solar panels or the radiator will not impact ISS-LIS.

LIS on STP-H5 will be accommodated on ELC-1 (External Logistics Carrier-1) as shown in Figure 10, provided by the CBPSS (Committee on Biological and Physical Sciences in Space). [11)]

The overarching purpose of the US committee is to support scientific progress in space research in the biological, medical, and physical sciences and assist the federal government in integrating and planning programs in these fields. The scope for CBPSS spans plant and microbial biology, animal and human physiology, and basic and applied physical sciences, in the context of understanding the role of gravity in living and physical systems in order to develop capabilities required for space exploration, and using the space environment as a tool of science to advance knowledge. The CBPSS provides an independent, authoritative forum for identifying and discussing issues in space life and physical sciences between the research community, the federal government, and the interested public. The CBPSS will also monitor the progress in implementation of the recommendations of the RFSE (Recapturing a Future for Space Exploration): Life and Physical Sciences Research For a New Era decadal survey — building on the survey that was tasked with establishing priorities for an integrated portfolio of biological and physical sciences research in the decade of 2010-2020.

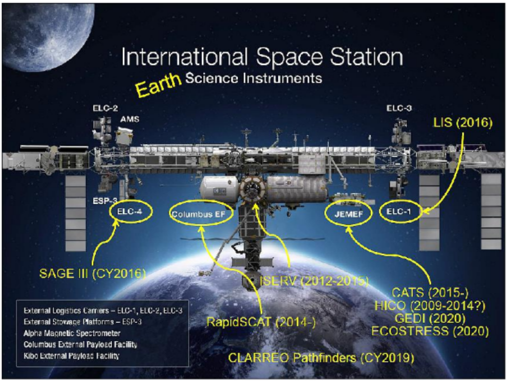
International Space Station
Earth Science Instruments
ELC-2
AMS
ELC-3
LIS (2016)
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
SAGE III (CY2016)
ISERV (2012-2015)
CATS (2015-)
HICO (2009-2014?)
GEDI (2020)
ECOSTRESS (2020)
RapidSCAT (2014-)
CLARREO Pathfinders (CY2019)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

Figure 10: Accommodation of ISS science instruments (image credit: NASA, CBPSS)

Ground segment:

Orbital science operations will be managed from the newly established LIS POCC (Payload Operations Control Center), located at theNSSTC (National Space Science and Technology Center) in Huntsville, AL. Activities from the LIS POCC will be conducted during the work week at regular business hours, and will include monitoring the operation of the LIS and its science and housekeeping data, and commanding the instrument as necessary. More extensive 24/7 monitoring of the LIS will be provided by the POIC (Payload Operations Integration Center) at MSFC (Ref. 3).

The LIS data handling involves a close partnership between the LIS Science Team and the Global Hydrology Resource Center (GHRC), one of NASA's Distributed Active Archive Centers (DAACs) that extends to the earlier OTD and LIS on TRMM missions. The well-established and robust processing, archival, and distribution infrastructure used for TRMM was easily adapted to the ISS mission. This assures that lightning data observations from LIS on ISS can be quickly delivered to science and application users soon after routine operations are established and underway.

Real-time data, available for the first time with this mission, will be provided to interested users in partnership with NASA's SPoRT (Short Term Prediction Research and Transition) Center, also located at the NSSTC. A full suite of space-based lightning observations is available from the GHRC DAAC (https://ghrc.nsstc.nasa.gov/home/). The LIS data products consist of geolocated and time-tagged lightning events, background images ("snapshots" of the LIS CCD acquired about every 30 seconds, depending on the flash rate), and orbit statistics and metadata. Visit the

GHRC's lightning data portal (http://lightning.nsstc.nasa.gov/data/data_lis.html) to access these and other lightning datasets, related tools, and documentation.

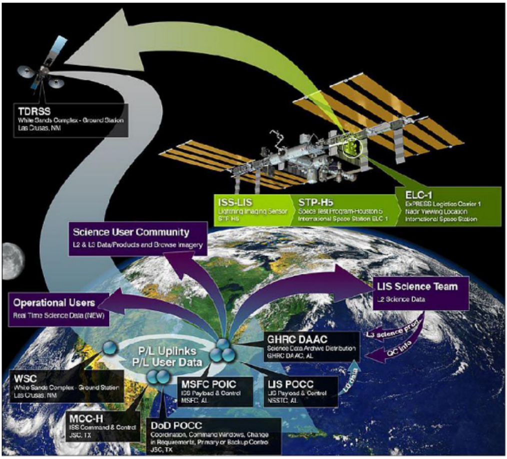

Figure 11: This graphic shows the data flow from the LIS instrument to the LIS POCC and GHRC DAAC, where the data will be processed, archived, and distributed to the science community and operational users (image credit: NASA and UAH)

Research Areas and Applications:

Data from the LIS on ISS mission will be applied to several scientific studies including examining the relationship between lightning and severe weather; extending the global lightning climatology; estimating lightning nitrogen oxides (LNOx) for lightning chemistry applications; determining the interrelationships between lightning, cloud properties, and precipitation; and examining the detailed physics of lightning. All of these elements of investigation are intertwined to varying extents. For example, a better understanding of the interrelationships between lightning, precipitation, and severe weather, coupled with an extended lightning climatology record, provides a better understanding of extreme storm statistics and how hurricane intensity and lightning flash rate are related. Coincident observations of atmospheric aerosol content with lightning and precipitation structure will also provide information for examining the complex interplay between the background aerosol environment, cloud physics, and lightning. Similarly, an extended lightning climatology record, coupled with improved LNOx estimation (from an improved understanding of lightning channel physics), provide improved understanding of lightning/climate relationships. Many other examples can be obtained by combining the various science goals in different ways.

• **Severe 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.

Weather data from OTD, LIS on TRMM, and ground-based regional lightning detection systems have been employed to better understand the relationship between variations in the total (i.e., intracloud plus cloud-to-ground) flash rate in a thunderstorm, and the thunderstorm's tendency to produce severe weather (e.g., high winds, damaging hail, tornadoes). Sudden increases in the total lightning flash rate, referred to as lightning jumps, are considered to be precursors to a severe weather outbreak, and these jumps provide improved severe-weather warning lead-time (i.e., between 10 and 20 minutes before the event). Consequently, it has been possible to build a baseline lightning jump severe weather warning algorithm for the GOES-R GLM. However, the interrelationships between lightning jumps and severe weather outbreaks are by no means clean cut, and additional studies are needed to take full advantage of the information content of lightning phenomenology. For example, not all flashes are equal in terms of energetics, and hence the lightning jump algorithm might be further improved by taking into consideration the energy of each lightning flash, as opposed to just counting flashes in a particular time interval to obtain flash rate. Hence, there is a desire to use ancillary LIS on ISS data (e.g., flash brightness, areal extent, duration) that help define overall flash energy, in order to further examine and optimize the baseline lightning jump algorithm.

In addition, LIS on ISS data will be used for air-traffic advisories, similar to how LIS data was used during the TRMM mission. The LIS data will be provided to national forecast offices and the NOAA/AWA (National Oceanic and Atmospheric Administration/ Aviation Weather Center) to identify convective weather hazards, particularly over the ocean where ground-radar coverage is limited. Forecasters will be able to overlay the LIS data with conventional visible and infrared satellite imagery to understand which convective cells have an increased chance of turbulence.

• **Lightning Climatology:** 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.

The OTD and TRMM LIS data have been applied to obtain robust maps of the worldwide geographical distribution of lightning frequency; it is very important that LIS on ISS continue this essential climatological data record. For example, the global diurnal variability of lightning flash rate is intimately connected to the climatological variation of many atmospheric processes including global temperature; storm frequency, intensity, and distribution; and the global electric circuit. An extended lightning climatology record also provides improved statistical information that allows for creating several useful products for the research community, such as higher spatial resolution lightning climatologies and new thunderstorm-scale databases that combine lightning information with other products (e.g., hydrometeor content, radar reflectivity information, and brightness temperature).

• **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.

Since LIS observes the diffuse cloud-top optical emissions from lightning discharges, it will provide important information about the energetics of each flash, which in turn can be related to the thermochemical yield of LNOx. The LNOx are important trace gases that impact the concentration of tropospheric ozone (O3; a greenhouse gas), and hydroxyl (OH) radicals that are highly reactive and affect the concentration of all other greenhouse gases. Therefore, LIS on ISS data will play a significant role in improving both coupled global climate–chemistry models and regional air quality models. First-time comparisons between LIS-inferred LNOx, and the O3 and nitrogen dioxide (NO2) observations that will be provided by SAGE-III/ISS, which will launch concurrently with LIS, will provide new insights to lightning and atmospheric chemistry. The SAGE-III/ISS O_3 profile measurements penetrate deeper into the atmosphere reaching down into the troposphere and can be compared with LIS lightning chemistry results. Since climate is most sensitive to O_3 in the upper troposphere and since LNOx is the most important source of NOx in the upper troposphere at tropical and subtropical latitudes, lightning is a particularly good parameter to monitor for climate assessments.

• **Precipitation:** Lightning is primarily linked to ice-phase precipitation processes produced by strong updrafts in individual thunderstorm cells that have a mixed-phase distribution of hydrometeors (i.e., presence of supercooled water droplets, ice crystals, and graupel particles, important for cloud electrification). Hence, it is no surprise that the characteristics of lightning are coupled to the characteristics of cold-cloud precipitation, and vice versa. Cold precipitating clouds are usually associated with intense storms, which are predominantly found over continental landmasses during the summer (in both hemispheres), when they intrude deep into the middle and high latitudes of Earth's continents. Precipitating clouds of this type also occur over isolated ocean regions during winter, where the mid- and high-latitude storm tracks are most active.

Similar to LIS on TRMM, LIS on ISS will fly within the view of the GPM satellite constellation, enabling frequent coincident sampling between GPM precipitation remote sensing platforms and LIS on ISS across the Earth's tropical and higher latitudes. This will enable measurements from GPM — which is rapidly assembling one of the most complete collections of active and passive precipitation measurements ever assembled — to be combined with total lightning information over a large fraction of the globe.

Evolving from the TRMM era, it will also be important to use data from LIS on ISS to continue building and extending cloud and precipitation feature (CPF) databases that focus on thunderstorm-scale events, pairing individual convective cells with associated microphysical properties, brightness temperatures, and lightning-flash characteristics. From this perspective, the lightning information may well be useful for improving the algorithms developed to characterize and estimate precipitation from GPM. At a minimum, the CPF databases can be used to help evaluate and possibly improve passive microwave precipitation retrievals. Multiple CPF databases have now been used to analyze the regional, seasonal, and diurnal variations of precipitation and to document deep convection in the tropics. Because of the higher latitudinal coverage, the ISS data will also allow for new investigations on the effects of topography, more extreme changes of season, forcing by large mid-latitude cyclones, and even investigating lightning response to the transition of warm-core hurricanes to cold-core mid-latitude cyclones on both precipitation and lightning.

• **Discharge Physics:** LIS on ISS will continue to offer detailed insight into the physics of lightning discharges. For example, each LIS-detected lightning flash is composed of one or more diffuse cloud-top emissions called optical groups. The MGA (Maximum Group Area) in a flash (i.e., the area of the largest optical emission in a flash) is a useful probabilistic indicator of whether or not the flash strikes the ground. Particularly good physical insight is obtained when the LIS optical products are compared with observations from VLF/LF (Very Low Frequency/Low Frequency) or VHF (Very High Frequency) ground-based lightning-detection system. Since the systems observe in different parts of the electromagnetic spectrum, they all see different physical processes — and it is usually through intercomparing these datasets that the most is learned about discharge physics. Also, as noted earlier, LIS — in conjunction with other observations — will be used to better understand the mechanisms leading to TGFs (Terrestrial Gamma-ray Flashes) and TLEs (Transient Luminous Events) associated with lightning and thunderstorms.

In summary, LIS on ISS will continue its cross-disciplinary support of the high-value science and applications established by the heritage OTD and LIS on TRMM missions. The project has leveraged the data-handling infrastructure (i.e., processing, archival, and distribution) from TRMM to quickly deliver high-quality LIS data to users once operations begin.

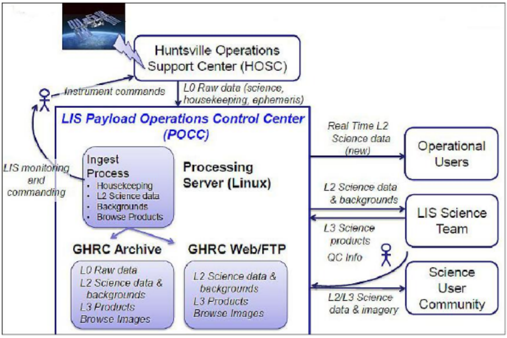
Huntsville Operations Support Center (HOSC)
Instrument commands
L0 Raw data (science, housekeeping, ephemeris)
LIS Payload Operations Control Center (POCC)
Real Time L2 Science data (new)
Operational Users
LIS monitoring and commanding
Ingest Process
Housekeeping
L2 Science data
Backgrounds
Browse Products
Processing Server (Linux)
L2 Science data & backgrounds
LIS Science Team
L3 Science products
QC Info
GHRC Archive
GHRC Web/FTP
L0 Raw data
L2 Science data & backgrounds
L3 Products
Browse Images
L2 Science data & backgrounds
L3 Products
Browse Images
Science User Community
L2/L3 Science data & imagery

Figure 12: LIS data flow & processing overview (image credit: NASA/MSFC)

1) R. J. Blakeslee, H. J. Christian, M.F. Stewart, D.M. Mach, M. Bateman, T.D. Walker, D. Buechler, W.J. Koshak, S. O'Brien, T. Wilson, E.C. Colley, T. Abbott, J. Carter S. Pavelitz, C. Coker, "Lightning Imaging Sensor (LIS) for the International Space Station (ISS): Mission Description and Science Goals," XV International Conference on Atmospheric Electricity (ICAE 2014), Norman, Oklahoma, USA, June 15-20, 2014, URL: http://www.nssl.noaa.gov/users/mansell/icae2014/preprints/Blakeslee_39.pdf , URL of Resentation: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011791.pdf

2) Richard J. Blakeslee, H. J. Christian Jr., D. Mach, D. E. Buechler, W. J. Koshak, T. D. Walker, M. Bateman, M. F. Stewart, S. O'Brien, T. Wilson, S. Pavelitz, C. Coker , "Lightning Imaging Sensor (LIS) for the International Space Station (ISS): Mission Desciption and Science Goals," Seventh Conference on the Meteorological Applications of Lightning Data, Phoenix, AZ, USA, Jan. 4-8, 12015, URL of abstract: https://ams.confex.com/ams/95Annual/webprogram/Paper266774.html

3) Richard Blakeslee, William Koshak, "LIS on ISS: Expanded Global Coverage and Enhanced Applications," The Earth Observer, Volume 28, Issue 3, May-June 2016, pp: 4-14, URL: http://eospso.nasa.gov/sites/default/files/eo_pdfs/May_June_2016_color%20508.pdf

4) Janet Anderson, Jessica Eagan, "Space Station Sensor To Capture 'Striking' Lightning Data," NASA/MSFC, Sept. 9, 2014, URL: http://www.redorbit.com/news/space/1113229345/lightning-imaging-sensor-iss-nasa-090914/

5) H. J. Christian, R. J. Blakeslee, S. J. Goodman, "Lightning Imaging Sensor (LIS) for the Earth Observing System," NASA Technical Memorandum 4350, 1992, URL: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19920010794_1992010794.pdf

6) Tabatha Thompson, Dan Huot, Stephanie Martin, "NASA Cargo Headed to Space Station Includes Important Experiments, Equipment," NASA, Feb. 19, 2017, Release 17-021 , URL: https://www.nasa.gov/press-release/nasa-cargo-headed-to-space-station-includes-important-experiments-equipment

7) "SpaceX CRS-10 Mission Overview," NASA, URL: https://www.nasa.gov/sites/default/files/atoms/files/spacex_crs-10_mission_overview.pdf

8) Ken Kremer, "NASA's Historic Pad 39A Back in Business with Maiden SpaceX Falcon 9 Blastoff to ISS and Booster Landing," Universe Today, Feb. 19, 2017, URL: http://www.universetoday.com/133508/nasas-historic-pad-39a-back-business-maiden-spacex-falcon-9-blastoff-iss-booster-landing/

9) "SpaceX CRS-10 Mission Overview," NASA, URL: https://www.nasa.gov/sites/default/files/atoms/files/spacex_crs-10_mission_overview.pdf

10) "UAH scientists ship instrument that will expand view of global lightning," UAH, Feb. 15, 2015, URL: http://www.uah.edu/news/research/uah-scientists-ship-instrument-that-will-expand-view-of-global-lightning

11) "International Space Station Research Integration and Capabilities," Committee on Biological and Physical Sciences in Space, Rod Jones Research Integration Office, October 2014, URL: http://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_152362.pdf

---

The information compiled and edited in this article was provided by Herbert J. Kramer from his documentation of: "Observation of the Earth and Its Environment: Survey of Missions and Sensors" (Springer Verlag) as well as many other sources after the publication of the 4th edition in 2002. - Comments and corrections to this article are always welcome for further updates (herb.kramer@gmx.net).

Launch Instrument Description Ground Segment References Back to top

© ESA 2000 - 2017