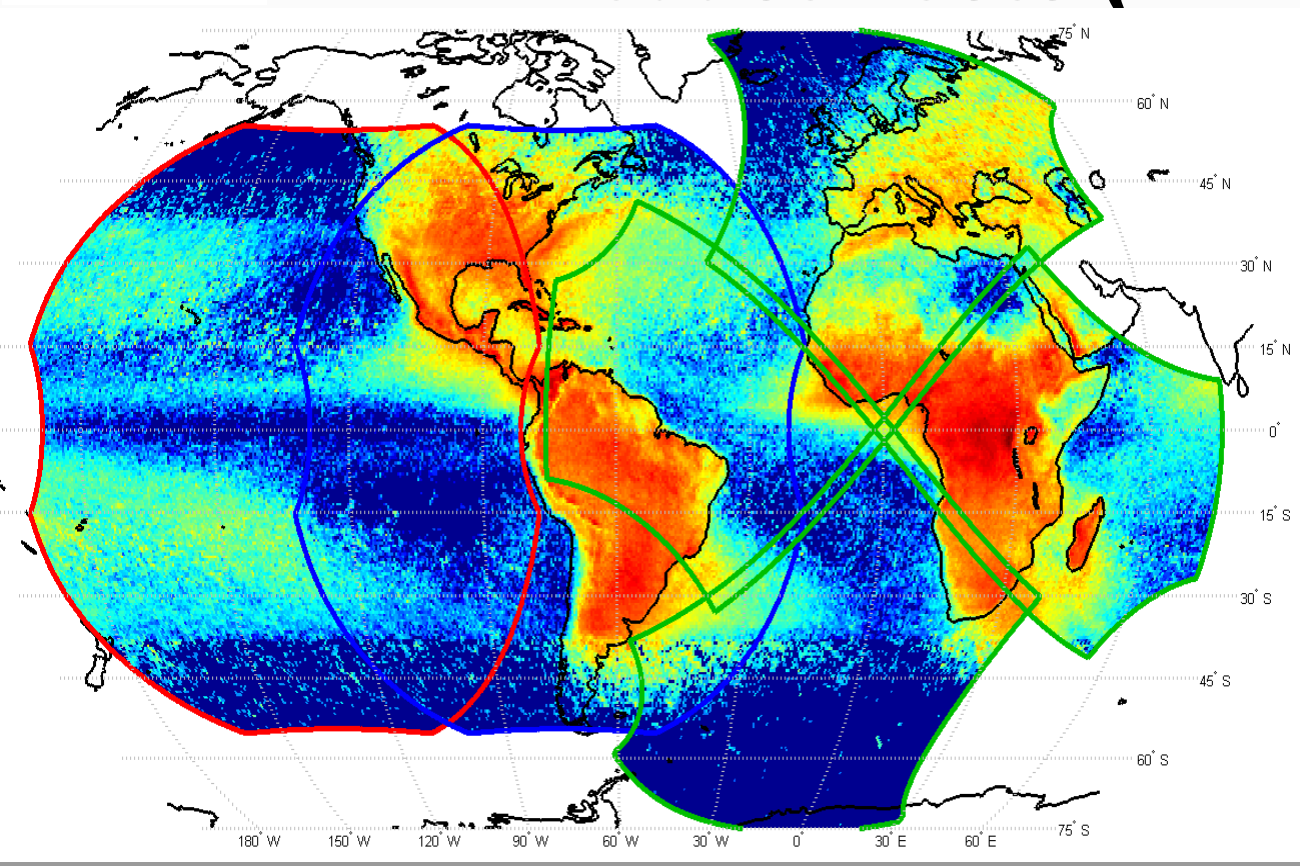
GOES-R GLM Post Launch Product Tests (PLPTs)



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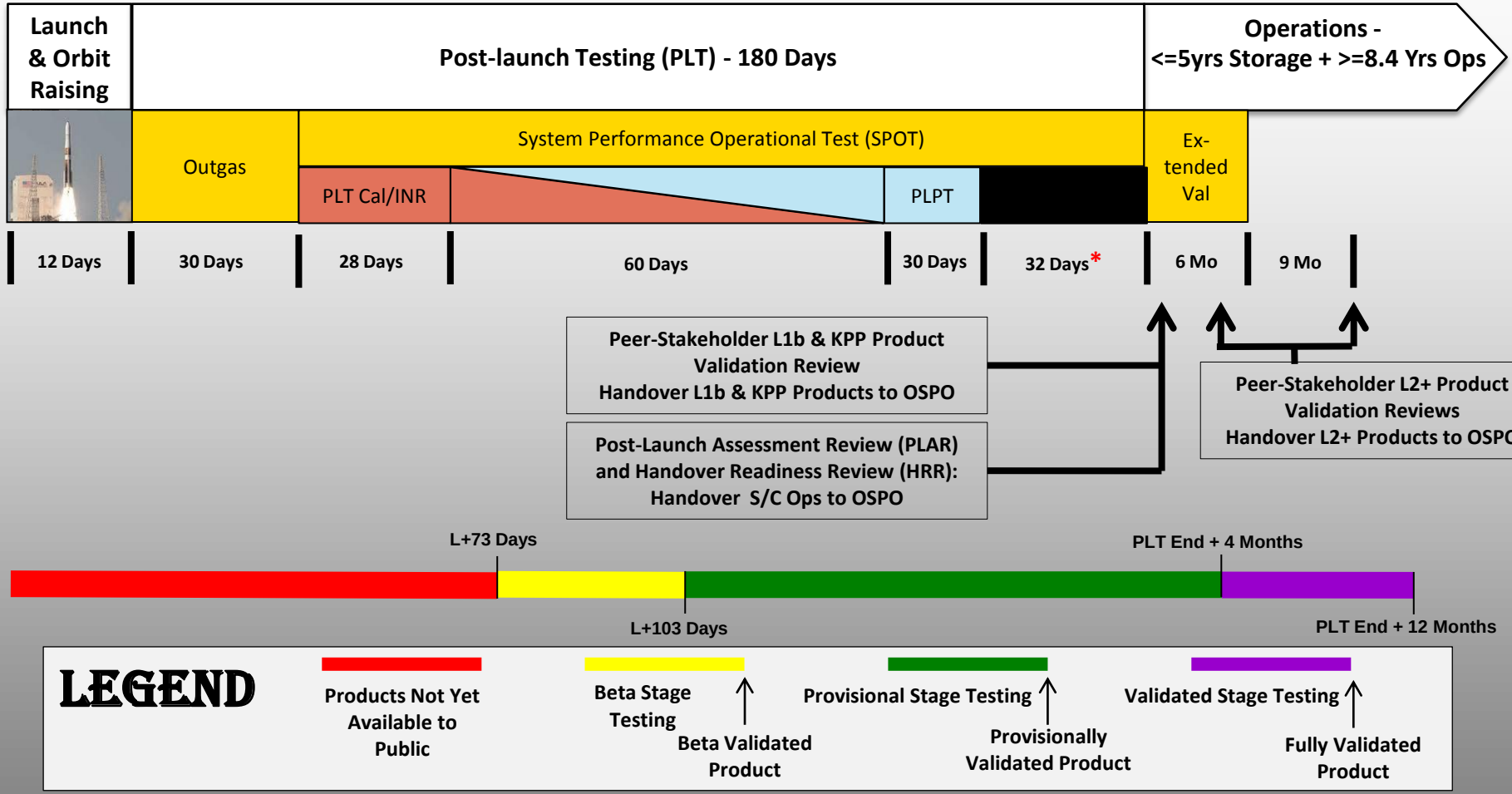
STI is an institute of the Universities Space Research Association www.usra.edu

Joint MTG LI Mission Advisory Group & GOES-R GLM Science Team workshop
27-29 May, 2015

GLM L2+ Product Science Validation Baseline Schedule



* Data blackout due to COOP test and Station Change to 105W.

GLM PLPT Types

- The MSFC GLM L2+ team has 4 major categories of PLPTs
  - **Validate GLM Product with Reference Data Set Comparisons** (is the GLM actually meeting specifications for detecting lightning (DE), rejecting false alarms (FAR), and locating the lightning in time and space?)
  - **Algorithm Testing** (is the GLM algorithm correctly filtering, geolocating, and clustering the raw Level 0 (L0) data, both backgrounds and lightning, so that GLM is meeting specifications?)
  - **Instrument Navigation and Registration (INR) Testing** (is the GLM navigation correct so that GLM is meeting specifications?)
  - **Long Term Baseline Testing** (what is the current sensitivity of GLM, how does it compare to the Lightning Imaging Sensor (LIS) and the Optical Transient Detector (OTD), and how does it change over the years?)

Purpose GLM Validation PLPT

- Recertification of GLM Pre-Launch Predicted Performance
- GLM has a single product: Lightning Detection (with three components)
  - Events (L1b)
  - Groups (L2+)
  - Flashes (L2+)
- GLM Lightning Detection Requirements (the Five W's)
  - Where? (location) – Geolocation error over the FOV is less that that created by a 112 μrad instrument pointing error (5 km at the sub-satellite point)
  - When? (time) – within 1 ms
  - Wow! (energy) – within 10% (waived due to schedule & cost constraints)
  - Right? (DE) – >70% over 24 hours
  - Wrong? (FAR) – <5% over 24 hours
- All tests contribute to Beta, Provisional, and Validated levels
  - Just more data, better statistics, more locations, more seasons

Validate GLM Product with Reference Data Sets (PLPT Format)

- Objective: Compare the GLM product (events, groups, & flashes) with those detected by well characterized networks and systems. Determine if GLM meets specified product values.
- Description: There are a number of systems (ground, airborne, and space based) that detect lightning at various locations, rates, and types. Each PLPT of this type uses one of these systems/networks to determine if the GLM detects the lightning. The detection of a “flash” by any of these systems is taken as "truth", and the percent detection of these “flashes”, locations, amplitudes, and times are used to determine the validity of the GLM product (does it meet specifications).
- Success Criteria: If analysis of the “ground truth” data shows the GLM detects at least 70% of the flashes, with a FAR of less than 5%, a location closer than 5 km, and a time within 1 ms, the GLM will have met success criteria for these tests.
- Data Analysis Roles/Responsibilities: Douglas Mach (or delegate), using internal VaLiD and other tools to access the “ground truth” datasets and GLM L1b-L2 data

GLM PLPT Reference Datasets

- To validate the GLM data (PLPT), must compare to well characterized lightning Reference Datasets
- Most Datasets are already at the National Space Science Technology Center (NSSTC), Global Hydrology Resource Center (GHRC)
- Others are readily or will/should be available
  - NOAA MOUs exists with cooperative institutes and international partners
- No one system can duplicate GLM (that's why we need GLM and multiple other sources)

GLM PLPT Reference Data Sources

ACTUAL DATA			Minimum Needs*		Maximum Needs*	
Data Type	**Data Avail**	**Data From**	**Data Quantity**	**Duration**	**Data Quantity**	**Data Duration**
NLDN	In house	Vaisala	100 flashes in GLM FOV	1 day	None	1 active lightning month
GLD360	In house	Vaisala	100 flashes in GLM FOV	1 day	None	1 active lightning month
WWLLN	In house	Univ. of Washington	100 flashes in GLM FOV	1 day	None	1 active lightning month
ENTLN	In house	Earth Networks	100 flashes in GLM FOV	1 day	None	1 active lightning month
BrazilDAT	MOU	INPE	100 flashes in GLM FOV	1 day	None	1 active lightning month
RinDAT	MOU	INPE	100 flashes in GLM FOV	1 day	None	1 active lightning month
STARnet	MOU	Univ. Sao Paulo	100 flashes in GLM FOV	1 day	None	1 active lightning month
ATDnet	MOU	UK Met Office	100 flashes in GLM FOV	1 day	None	1 active lightning month
NALMA	In house	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
DCLMA	In house	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
OKLMA	MOU	OU-CIMMS	100 flashes in GLM FOV	1 day	None	1 active lightning month
WTLMA	MOU	Texas Tech	100 flashes in GLM FOV	1 day	None	1 active lightning month
KSCLMA	MOU	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
NMLMA	MOU	New Mexico Tech	100 flashes in GLM FOV	1 day	None	1 active lightning month
HLMA	MOU	Houston Texas	100 flashes in GLM FOV	1 day	None	1 active lightning month
FCLMA	MOU	Colorado State Univ.	100 flashes in GLM FOV	1 day	None	1 active lightning month
WILMA	In house	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
NGLMA	MOU	Georgia Tech	100 flashes in GLM FOV	1 day	None	1 active lightning month
TLMA	MOU	Environment Canada	100 flashes in GLM FOV	1 day	None	1 active lightning month
KSC FM	MOU	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
HAMMA	In house	Univ. AL Huntsville	100 flashes in GLM FOV	1 day	None	1 active lightning month
AGS	In house	Univ. AL Huntsville	100 flashes in GLM FOV	1 day	None	1 active lightning month
ISS-LIS	In house	NASA Server	100 flashes in GLM FOV	1 day	None	1 active lightning month
TARANIS	MOU	CNES	Across 5% of GLM FOV	30 min	Max overlap w/ GLM FOV	10 hours
MSG SEVERI	MOU	EUMETSAT	Across 5% of GLM FOV	30 min day	Max overlap w/ GLM FOV	10 hours in daytime
NEXRAD Radar	MOU	NOAA-NWS	Across 5% of GLM FOV	30 min	Max overlap w/ GLM FOV	10 hours

*** GLM is not an imager, data quantities are not fixed and depend on lightning quantities**

Validate GLM Product DE and FAR with Reference Data Sets (PLPTs)

Test ID	Class
GLM-L0-2+_EGF_FOV_Detection_Efficiency_NLDN-001n	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_ENTLN-001e	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_BrazilDAT-001b	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_RinDAT-001r	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_STARNet-001s	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_ATDNet-001a	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_NALMA-002a	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_DCLMA-002d	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_FCLMA-002f	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_NGLMA-002g	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_HLMA-002h	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_KSCLMA-002k	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_NMLMA-002n	PLPT

Validate GLM Product DE and FAR with Reference Data Sets (PLPTs) (cont)

Test ID	Class
GLM-L0-2+_EGF_FOV_Detection_Efficiency_OKLMA-002o	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_WTLMA-002t	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_WILMA-002w	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_TLMA-002y	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_GLD360-003g	PLPT
GLM-L0-2+_EGF_FOV_Storm_Detection_NEXRAD-003n	PLPT
GLM-L0-2+_EGF_FOV_Storm_Detection_WWLLN-003w	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_AGS_Obs-004	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_TARANIS-005e	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_ISS_LIS-005i	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_MSG_SEVERI-005m	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_HAMMA-006h	PLPT
GLM-L0-2+_EGF_FOV_Detection_Efficiency_KSC_FM-006k	PLPT
GLM-L2_Detection_DE_FER_Location_Accuracy-007	PLPT

Validation of GLM Product General Concepts

- Not all PLPTs may be activated
  - Weather at the time of the PLPT period will determine which ones will be utilized
- If multiple, possibly conflicting PLPTs can be activated, priority will be given to PLPTs in this general order:
  - Ground truth systems that are optical based (Airborne GLM Simulator (AGS), ISS-LIS)
  - Regions with no prior PLPT lightning (both temporal and spatial)
  - Ground truth systems with the highest DE, lowest FAR for total lightning
  - Note, these priorities are “flexible”
    - Field program based PLPTs (e.g., using AGS) would take priority over all others due to limited time/location of field program data

Other GLM PLPT Types

- **Algorithm Testing** (is the GLM algorithm correctly filtering, geolocating, and clustering the raw Level 0 (L0) data, both backgrounds and lightning, so that GLM is meeting specifications?)
- **Instrument Navigation and Registration (INR) Testing** (is the GLM navigation correct so that GLM is meeting specifications?)
- **Long Term Baseline Testing** (what is the current sensitivity of GLM, how does it compare to the Lightning Imaging Sensor (LIS) and the Optical Transient Detector (OTD), and how does it change over the years?)

Validate GLM Ground Processing Algorithm

- Objective: Determine if the GLM L0-L2 Ground Processing Algorithm (GPA) is working as specified by comparing the event/group/flash clustering/filtering to the results from the spec code created by MSFC.
- Description: The GLM L1b-L2 spec code and ATBD were written by the GLM-MSFC-AWG team. In addition we have an equivalent L0-L1b code. This series of PLPTs will:
  - take the L0 output of GLM, which is stored at our GHRC local Level Zero Storage System (LZSS)
  - remove sections of the GPA code
  - replacing them with the spec code that the GLM-AWG team produced
  - compare the output of the spec code with the output of the operational code to verify that the operational code is reproducing the spec code results.
- Success Criteria: If the GLM operational code is able to produce the same results as the AWG spec code, then the GLM L0-L2 code will have met success criteria for this test.
- Data Analysis Roles/Responsibilities: Douglas Mach, using VaLiD and other tools to display and compare GLM L2 data determined with the on-board code and with the independent MSFC code.

GLM Instrument Navigation and Registration

- Objective: To assess Instrument Navigation and Registration (INR) accuracy of GLM L0-L2 products.
- Description:
  - Assess geolocation of GLM L1-L2 products by comparing with lightning positions of coincidently observed lightning locations observed by ground networks (NLDN, WWLLN, ENTLN, NALMA, WTLMA, OKLMA, NMLMA, KLMA, HLMA, DCLMA, etc.).
  - Evaluate GLM INR relative to ABI. The relative offset of bright cloud target locations of the GLM background location of bright cloud targets are compared to those observed by the ABI visible channel and relative offsets computed.
- Success Criteria:
  - GLM L1-L2 products occur within 5 km of network lightning locations.
  - Bright cloud targets observed are observed by GLM and ABI and the relative INR offset is within 112 µrad.
- Data Analysis Roles/Responsibilities: Dennis Buechler, using VaLiD and other tools to display and compare GLM L0 background data ABI visible images.

GLM Baseline Radiances for Long Term Trending

- Objective: To obtain baseline radiance values of GLM L0-L2 data for long term trending to assess instrument degradation (DE and FER).
- Description:
  - Generate GLM L1-L2 radiance distributions, compare to LIS and AGS to obtain baseline L1-L2 product radiance distributions.
  - Determine the GLM background radiance (L0) distribution of Deep Convective Clouds (DCCs), identified using ABI IR channel. This will establish a GLM DCC radiance distribution baseline for monitoring long term trending of GLM instrument performance.
- Success Criteria:
  - GLM L1-L2 radiance distributions are similar to those of LIS
  - The GLM DCC background (L0) distribution is similar to LIS
  - The GLM DCC background (L0) is determined for use during instrument lifetime
- Data Analysis Roles/Responsibilities: Dennis Buechler, using VaLiD and other tools to display and compare GLM L0-L2 data, ABI IR images, and LIS data.

GLM L2+ PLPT Summary

- GLM L2+ PLPTs consist of 4 types
  - **Validate GLM Product**
  - Algorithm Testing
  - Instrument Navigation and Registration (INR) Testing
  - Long Term Baseline Testing
- Goal of GLM L2+ PLPTs is to help validate the GLM data for operational use
  - Reach Beta Validation (minimally validated, and may still contain significant errors) within 1 month of start of PLPT period
  - Reach Provisional Validation (analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose) within 4 months of the end of the PLPT period
  - Reach Full Validation (analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose) within 1 year of end of the PLPT period

Questions?

Acronyms

- ABI = Advanced Baseline Imager
- ADTNet = Arrival Time Difference NETwork
- AGS = Airborne GLM Simulator
- ATBD = Algorithm Theoretical Basis Document
- AWG = Algorithm Working Group
- BrazilDAT = Sistema Brasileiro de Detecção de Descargas Atmosféricas
- CWG = Calibration Working Group
- DCC = Deep Convective Cloud
- DCLMA = District of Columbia Lightning Mapper Network
- DE = Detection Efficiency
- ENTLN = Earth Networks Total Lightning Network
- FAR = False Alarm Rate
- FCLMA = Fort Collins Lightning Mapper Network
- FM = Field Mill
- GHRC = Global Hydrology Resource Center
- GLD360 = Vaisala Global Lightning Dataset
- GLM = Geostationary Lightning Mapper
- GOES-R = Geostationary Operational Environmental Satellite R-Series
- GPA = Ground Processing Algorithm
- HAMMA = Huntsville Area Marx Meter Array
- HLMA = Houston Lightning Mapper Network
- INR = Image Navigation and Registration
- IR = Infrared
- ISS = International Space Station
- IV&V = Independent Verification and Validation
- KSC = Kennedy Space Center
- KSCLMA = Kennedy Space Center Lightning Mapper Network
- LIS = Lightning Imaging Sensor
- LM = Lockheed Martin
- LZSS = Level Zero Storage System
- MOU = Memorandum Of Understanding
- MSFC = Marshal Space Flight Center
- MSG = Meteosat Second Generation
- NALMA = North Alabama Lightning Mapper Network
- NEXRAD = NEXt-generation RADar
- NGLMA = North Georgia Lightning Mapper Network
- NLDN = National Lightning Detection Network
- NMLMA = New Mexico Lightning Mapper Network
- NOAA = National Oceanic and Atmospheric Administration
- NSSTC = National Space Science and Technology Center
- OKLMA = OKlahoma Lightning Mapper Network
- OTD = Optical Transient Detector
- PLPT = Post Launch Product Test
- RINDAT = Rede Integrada Nacional de Detecção de Descargas Atmosféricas
- SEVERI = Spinning Enhanced Visible and Infrared Imager
- STARNet = Sferics Timing And Ranging NETwork
- TARANIS = Tool for the Analysis of RAdiations from lightNIngs and Sprites
- TBD = To Be Determined
- TLMA = Toronto Lightning Mapper Network
- TRMM = Tropical Rainfall Measuring Mission
- VaLiD = Validate Lightning Data
- WILMA = Wallops Island Lightning Mapper Network
- WTLMA = West Texas Lightning Mapper Network
- WWLLN = World Wide Lightning Locating Network

Backup Slides

Validate GLM GPA (PLPTs)

Test ID	Class
GLM-L1b-L2_Clustering_Verification-009	PLPT
GLM-L0-L1b_Coherency_Filter_Check-010c	PLPT
GLM-L0-L1b_Contrast_Leakage_Filter_Check-010cl	PLPT
GLM-L0-L1b_Crosstalk_Filter_Check-010ct	PLPT
GLM-L0-L1b_Second_Level_Threshold_Filter_Check-010lt	PLPT
GLM-L0-L1b_Radiation Filter_Check-010r	PLPT
GLM-L0-L1b_Solar_Glint_Filter_Check-010sg	PLPT
GLM-L0-L1b_Transfer_Noise_Filter_Check-010tn	PLPT

GLM Instrument Navigation and Registration Tests

Test ID	Class
GLM-ABI_INR-015	PLPT
GLM-EvGRFL_INR-016	PLPT
(reuse PLPTs 001-007 for INR)	PLPT

GLM Baseline Radiances for Long Term Trending Tests

Test ID	Class
GLM-L0_BG_DCC_RadCal-012	PLPT
GLM-L0_BG_DCC_RadCal_coincident-013	PLPT
GLM-L0_BG_DCC_EvGrFl_Rad-014	PLPT