DEVELOPMENT OF LEVEL 1B CALIBRATION AND VALIDATION READINESS, IMPLEMENTATION AND MANAGEMENT PLANS FOR GOES-R

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ABSTRACT

A complement of Readiness, Implementation and Management Plans (RIMPs) to facilitate management of post-launch product test activities for the official Geostationary Operational Environmental Satellite (GOES-R) Level 1b (L1b) products have been developed and documented. Separate plans have been created for each of the GOES-R sensors including: the Advanced Baseline Imager (ABI), the Extreme ultraviolet and X-ray Irradiance Sensors (EXIS), Geostationary Lightning Mapper (GLM), GOES-R Magnetometer (MAG), the Space Environment In-Situ Suite (SEISS), and the Solar Ultraviolet Imager (SUVI). The GOES-R program has implemented these RIMPs in order to address the full scope of Cal/Val activities required for a successful demonstration of GOES-R L1b data product quality throughout the three validation stages: Beta, Provisional and Full Validation. For each product maturity level, the RIMPs include specific performance criteria and required artifacts that provide evidence a given validation stage has been reached, the timing when each stage will be complete, a description of every applicable Post-Launch Product Test (PLPT), roles and responsibilities of personnel, upstream dependencies, and analysis methods and tools to be employed during validation. Instrument level Post-Launch Tests (PLTs) are also referenced and apply primarily to functional check-out of the instruments.

Index Terms— Calibration, Validation, Advanced Baseline Imager, GOES

1. INTRODUCTION

Development of the L1b RIMPs involved a complex process that considered interactions between several different L1b products many times led by different science leads and organizations. Cal/Val activities for each L1b product also had to accommodate a fixed GOES-R Cal/Val schedule and performance requirements set. To accomplish this, the L1b team worked directly with the science leads from NOAA's Satellite Applications and Research (STAR), NOAA's National Centers for Environmental Information (NCEI) in Boulder, Colorado and the GOES-R program to determine the scope of the documents, and then to organize, coordinate, and develop all of the L1b RIMPs. During the RIMP development period, hundreds of pre-existing PLPTs were reviewed and revised before finalizing plans for the baseline post-launch Cal/Val. Although the PLPT format offered a standardized format to describe Validation Events (VE's) during Cal/Val, the complement of PLPTs for each sensor were quite varied in technical content, duration and test output or artifacts.

2. ADVANCED BASELINE IMAGER (ABI)

The baseline Cal/Val plan for ABI includes 21 Post-Launch Tests (PLTs) in order to validate initial on-orbit instrument functional performance. After successful execution of the PLTs, the L1b data is assessed at Beta product maturity. Detailed product testing to advance data product maturity is performed during the subsequent Provisional and Full Validation periods, as described in the corresponding RIMP's and PLPT's, and shown graphically in Figure 1.

Development of the RIMPs involved reviewing existing Cal/Val documents and assisting with development of the requirements verification cross reference matrix. This mapping helped identify risks associated with validation of required performance during low-light operations and the new requirement for GOES-R to operate during orbit adjust maneuvers. These risks were carefully considered by the GOES-R program for mitigation and closure through additional testing and analysis. A top-level Cal/Val schedule for the ABI provisional and full validation activities was also developed to help project managers to categorize, prioritize and schedule tests, analyses, and product tool development. The schedule also helped to identify key performance verification activities and dependencies. A graphical representation of the ABI Cal/Val schedule is shown in Figure 2.

Beta VEs

- G16-C-ABI-001 Detector Select
- G16-C-ABI-002 Initial FTE
- G16-C-ABI-003 Solar Avoidance
- G16-E-ABI-004 VNIR SNR Dyn
- G16-E-ABI-005 FTE Trending
- G16-E-ABI-006 IR Cal Stability
- G16-E-ABI-007 MTF-Spatial
- G16-E-ABI-008 VNIR Initial Cal
- G16-E-ABI-009 Rad.
- G16-E-ABI-010 Coherent Noise
- G16-E-ABI-012 BOL Spatial Unif
- G16-E-ABI-014 Sys Linearity
- G16-E-ABI-015 IR NEDT
- G16-E-ABI-016 Lunar Trending
- G16-E-ABI-018 Spectral Unif.
- G16-R-ABI-021 IR Spatial Unif.
- G16-C-ABI-022 Desert VNIR Mon.
- G16-C-ABIINR-001 LOS Filter Perf
- G16-C-ABIINR-002 LOS Mtn Comp
- G16-C-ABIINR-003 M/LW Co-Reg
- G16-C-ABIINR-004 INR Assessmt
- G16-C-ABIINR-005 Re-Alignment

Provisional VEs

- ABI-L1b-PLPT-01 IR Val. CrIS and IASI
- ABI-L1b-PLPT-02 IR Val. CRTM
- ABI-L1b-PLPT-03 Restricted Zone
- ABI-L1b-PLPT-04 VNIR Val VIIRS
- ABI-L1b-PLPT-05 VNIR Val Sonoran
- ABI-L1b-PLPT-06 VNIR Val RVS
- ABI-L1b-PLPT-07 Instr Perf Mon
- ABI-L1b-PLPT-08 AD Converter
- ABI-L1b-PLPT-09a-f North-South Scan
- ABI-L1b-PLPT-10 Image Nav Assess
- ABI-L1b-PLPT-11 Image CCR Assess
- ABI-L1b-PLPT-12 Image Stitch Assess
- ABI-L1b-PLPT-13 VNIR Val DCC

Full Validation

Continued/Expanded VEs

- ABI-L1b-EV-01 IR Val CrIS and IASI (Continuity of ABI-L1b-PLPT-01)
- ABI-L1b-EV-02 IR Val. CRTM RTM (Continuity of ABI-L1b-PLPT-02)
- ABI-L1b-EV-03 Restricted Zone (Continuity of ABI-L1b-PLPT-03)
- ABI-L1b-EV-04 VNIR Val VIIRS (Continuity of ABI-L1b-PLPT-04)
- ABI-L1b-EV-05 VNIR Val Sonoran (Continuity of ABI-L1b-PLPT-05)
- ABI-L1b-EV-06 VNIR Val RVS (Continuity of ABI-L1b-PLPT-06)
- ABI-L1b-EV-11 Integ Calib Mon (Expanded from ABI-L1b-PLPT-07)
- ABI-L1b-EV-15a-c Underflights/NSS (Expanded from ABI-L1b-PLPT-09a)
- ABI-L1b-EV-16 Image Nav Trend (Continuity of ABI-L1b-PLPT-10)
- ABI-L1b-EV-17 Image CCR Trend (Continuity of ABI-L1b-PLPT-11)
- ABI-L1b-EV-18 Image Stitch Trend (Continuity of ABI-L1b-PLPT-12)
- ABI-L1b-EV-19 VNIR Val DCC (Continuity of ABI-L1b-PLPT-13)

New/Additional VEs

- ABI-L1b-EV-07 Spectral Resp Func
- ABI-L1b-EV-08 Out of Band
- ABI-L1b-EV-09 Solar Cal Rad.
- ABI-L1b-EV-10 Polarization
- ABI-L1b-EV-12 Inter Seas B2B Cal.
- ABI-L1b-EV-13 Monitor Linearity
- ABI-L1b-EV-14 Ghosting

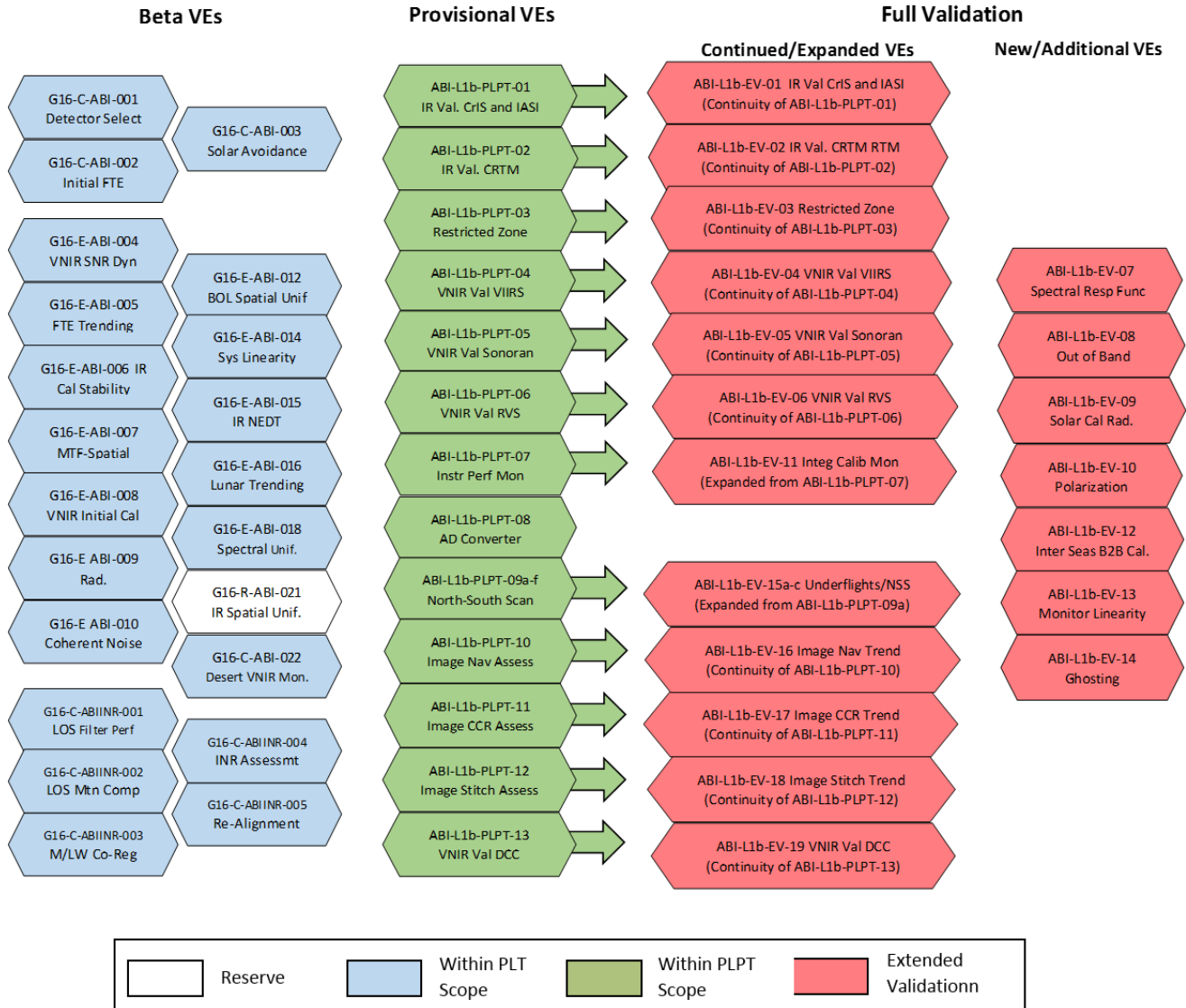Legend: Reserve | Within PLT Scope | Within PLPT Scope | Extended Validationn

Figure 1. Graphical representation of the Advanced Baseline Imager (ABI) Cal/Val Validation Events (VEs). The Post Launch Tests (PLTs) VEs are shown in blue and Post-Launch Product Tests (PLPTs) VEs are shown in Green and Red. Arrows indicate PLPTs that are continued throughout provisional and Full Validation periods.

3. THE GEOSTATIONARY LIGHTNING MAPPER (GLM)

The Level 1b (L1b) and 2 (L2) RIMPs for the PLTs and PLPTs required from the GOES-R Geostationary Lightning Mapper (GLM) [3] were also developed and organized as part of the overall GOES-R Cal/Val effort. PLT and PLPT events and products include Level 1b GLM Events and Level 2 Groups (strokes) and Flashes. The GLM RIMP focuses on those aspects of PLTs and PLPTs (and their preparation activities) that apply or impact the validation of the GLM product science quality. The GLM RIMP differed from other RIMPs by the overall number of the products identified. There are a total of 44 PLPTs in 13 series and each will go to Full data product maturity. Each series refers to a distinct assessment (e.g., Detection Efficiency and False Event Rate) by a specific means (well characterized medium to long range networks with medium to high detection efficiencies and low false alarm rates). In each member of the series a number of PLPTs were possible (e.g., one for each network). The Cal/Val challenge was to develop tools for the multitude of PLPTs, identify sites that provide adequate site diversity, group them appropriately according to specific capabilities, and prepare for the volume of Cal/Val data that the various data sources would generate
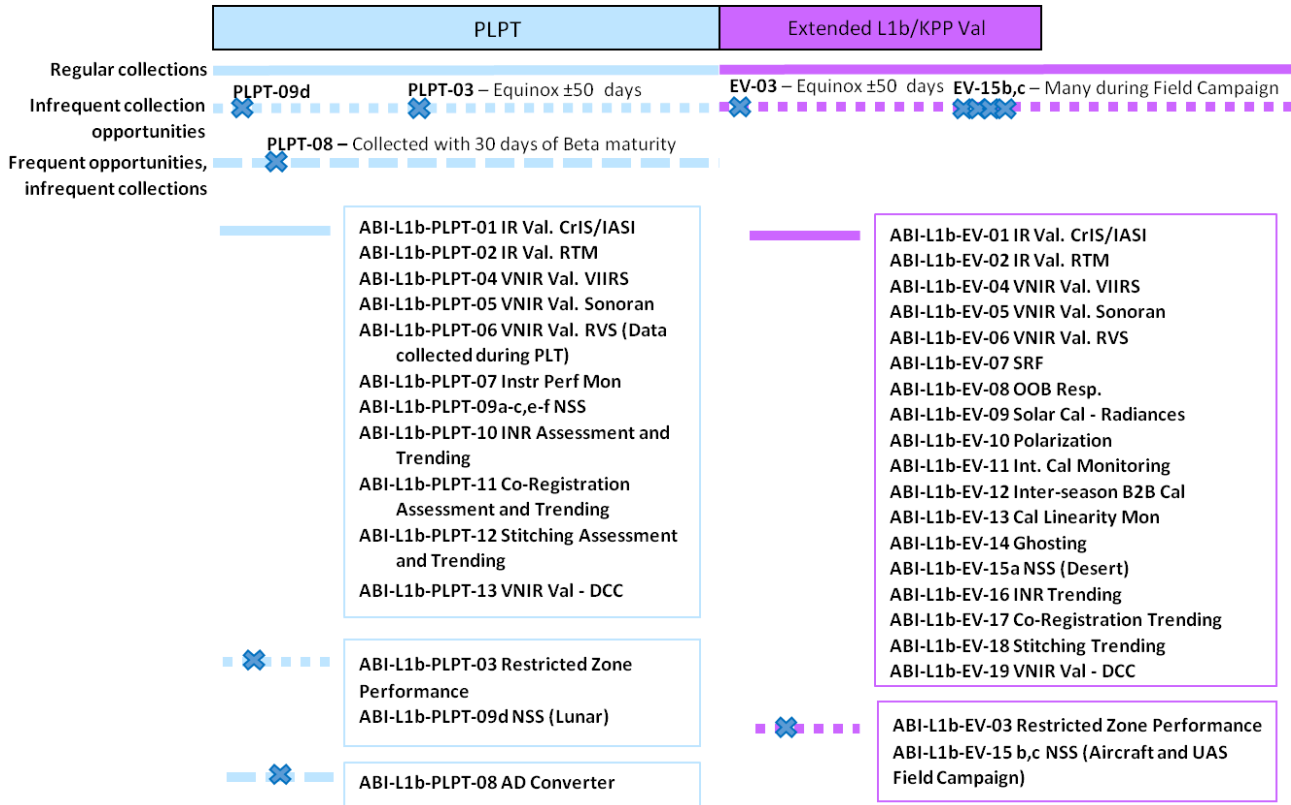
PLPT | Extended L1b/KPP Val

Regular collections

Infrequent collection opportunities

PLPT-09d   **PLPT-03** – Equinox ±50 days   **EV-03** – Equinox ±50 days   **EV-15b,c** – Many during Field Campaign

Frequent opportunities, infrequent collections

PLPT-08 – Collected with 30 days of Beta maturity

ABI-L1b-PLPT-01 IR Val. CrIS/IASI
ABI-L1b-PLPT-02 IR Val. RTM
ABI-L1b-PLPT-04 VNIR Val. VIIRS
ABI-L1b-PLPT-05 VNIR Val. Sonoran
ABI-L1b-PLPT-06 VNIR Val. RVS (Data collected during PLT)
ABI-L1b-PLPT-07 Instr Perf Mon
ABI-L1b-PLPT-09a-c,e-f NSS
ABI-L1b-PLPT-10 INR Assessment and Trending
ABI-L1b-PLPT-11 Co-Registration Assessment and Trending
ABI-L1b-PLPT-12 Stitching Assessment and Trending
ABI-L1b-PLPT-13 VNIR Val - DCC

ABI-L1b-EV-01 IR Val. CrIS/IASI
ABI-L1b-EV-02 IR Val. RTM
ABI-L1b-EV-04 VNIR Val. VIIRS
ABI-L1b-EV-05 VNIR Val. Sonoran
ABI-L1b-EV-06 VNIR Val. RVS
ABI-L1b-EV-07 SRF
ABI-L1b-EV-08 OOB Resp.
ABI-L1b-EV-09 Solar Cal - Radiances
ABI-L1b-EV-10 Polarization
ABI-L1b-EV-11 Int. Cal Monitoring
ABI-L1b-EV-12 Inter-season B2B Cal
ABI-L1b-EV-13 Cal Linearity Mon
ABI-L1b-EV-14 Ghosting
ABI-L1b-EV-15a NSS (Desert)
ABI-L1b-EV-16 INR Trending
ABI-L1b-EV-17 Co-Registration Trending
ABI-L1b-EV-18 Stitching Trending
ABI-L1b-EV-19 VNIR Val - DCC

ABI-L1b-PLPT-03 Restricted Zone Performance
ABI-L1b-PLPT-09d NSS (Lunar)

ABI-L1b-EV-03 Restricted Zone Performance
ABI-L1b-EV-15 b,c NSS (Aircraft and UAS Field Campaign)

ABI-L1b-PLPT-08 AD Converter

Figure 2. Schedule of Cal/Val activities for ABI Provisional and Full Validation.

(including campaign and satellite data). The reviews and discussions necessary to create the RIMP led to extensive consultations with the Cal/Val teams to better organize and improve the GLM Cal/Val mission.

4. GOES-R SPACE WEATHER INSTRUMENTS AND MAGENTOMETER

A summary of the GOES-R space weather instrument complement can be found online [4]. We present the top-level aspects of the RIMP for each of these instruments in this Section.

The Extreme ultraviolet and X-ray Irradiance Sensors (EXIS) includes the X-Ray Sensor (XRS), Extreme Ultra-Violet Sensor (EUVS), and Solar Pointing Sensor (SPS). The XRS and EUVS have heritage sensors on other GOES satellites, although both have been modified for the GOES-R series. The SPS measures the pointing of the EXIS relative to the center of the Sun. For EXIS, a total of 12 PLTs are necessary to establish Beta maturity and 14 PLPTs required to establish provisional maturity. Of these, 7 PLTs will be transitioned to NCEI, and continued for the lifetime of the instrument, however, to establish full validation for the EXIS data products, NCEI requires results from only 2 of the PLPTs.

The Space Environment In-Situ Suite (SEISS) includes the Magnetospheric Particle Sensor - Low energy (MPS-LO), Magnetospheric Particle Sensor - High energy (MPS-HI), Solar and Galactic Proton Sensor (SGPS) and Energetic Heavy Ion Sensor (EHIS). These sensors provide a more comprehensive view of charged particle radiation at geostationary orbit compared with previous GOES satellites. For SEISS, a total of 8 PLTs are defined to support Beta product maturity including 5 PLTs that will be transitioned to NCEI to be carried out over the lifetime of the instrument for trending and continued characterization. A total of 6 PLPTs have been defined to support provisional maturity and 5 there are five of these required for full data product validation over a period of ~1 year from the beginning of Cal/Val.

The Solar Ultraviolet Imager (SUVI) is a normal incidence telescope in the Ritchey-Chrétien configuration with Charge-Coupled Device (CCD) detectors at the Cassegrain focus. Six narrow wavelength bands are utilized to image different

features of the full-disk Sun. Beta product maturity for SUVI is supported by 9 PLTs and all but one of these tests will be transitioned to NCEI and carried out over the lifetime of the instrument. There are six PLPTs that are utilized to validate the instrument calibration. However, they need to be performed at certain intervals over the instrument lifetime in order to maintain the fidelity of the SUVI data.

Provisional data product validation is achieved upon successful completion of the first two PLPTs that will occur ~6 months after launch. Full validation occurs upon completion of the last four PLPTS that will occur ~240 days after launch. The RIMP process allowed the identification of specific criteria, discussed in the Cal/Val plan but not previously identified from the PLPTs alone that must be met for full validation.

The GOES-R Magnetometer (MAG) consists of 2 boom-mounted fluxgate magnetometers capable of providing magnetic field measurements with a temporal resolution 5 times greater (10 Hz) than that of the heritage GOES-N,O, P system. The inboard magnetometer is located at approximately 6.3 m from the baseplate of the boom, and the outboard magnetometer is located at approximately 8.5 m from the baseplate of the boom. For the MAG Cal/Val, 4 PLTs have been defined to support Beta product maturity. Beyond Beta maturity, 5 PLPTs have been defined to support MAG, 2 of which are required for provisional maturity and 4 of the 5 PLPTs are required for full validation. These PLPTs include, for example, comparisons with well-established, empirical magnetic field models of the near-Earth space environment (e.g., Olson-Pfitzer [5], and Tsyganenko [6]).

5. SUMMARY AND STATUS

The GOES-R (now GOES-16) launched on 19 November 2016 from the Kennedy Space Center, FL USA and reached

Geosynchronous Orbit on November 29. Post Launch testing is planned to commence in accordance with the RIMPs developed under the above described effort with public release of the first ABI L1b images scheduled in January 2017. Data products and images from other GOES-R sensors are also scheduled. Accordingly, the earliest data to be made public is planned from the GOES-R MAG in December 2016 and the latest sensor L1b imagery scheduled for public release will be from GLM in April 2017.

This presentation will discuss the formulation of the GOES-R instrument RIMPs highlighting the application of system engineering practices. Examples include mapping program requirements to justify each PLPT, identification of requirements to successfully execute each of the identified PLPTs such as software tools and data access, schedule constraints, and data product interdependencies.

6. REFERENCES

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