Geostationary Operational Environmental Satellite (GOES) – R Series

ABI L2+ Surface Downward Shortwave Radiation and Top-of-Atmosphere Reflected Shortwave Radiation (DSR-RSR) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

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ABI L2+ Surface Downward Shortwave Radiation and Top-of-Atmosphere Reflected Shortwave Radiation (DSR-RSR) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

Submitted by:

Signatures can be viewed in the CMO file 09/26/2016

Matthew Seybold
GOES- R Product Readiness and Operations Manager

Concurred by:

Signatures can be viewed in the CMO file

10/20/2016

Jaime Daniels Date
GOES-R Algorithm Working Group Lead

Signatures can be viewed in the CMO file

11/02/2016

Edward Grigsby Date
GOES-R Program Systems Engineering Lead

Signatures can be viewed in the CMO file

11/15/2016

Raymond Pages Date
GOES-R Ground Chief Project Engineer

Approved by:

Signatures can be viewed in the CMO file

11/29/2016

James Valenti Date
GOES-R Ground Segment Project Manager

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Preface

The evolving calibration and validation (cal/val) maturity of Geostationary Operational Environmental Satellite R-Series (GOES-R) products throughout the beginning of the mission is described by three levels: Beta, Provisional, and Full validation. The Flight Project is responsible for producing the Level 1b (L1b) products according to the Level III requirement documents. Once Beta Maturity of the L1b products is achieved, the Level 2+ (L2+) will begin analysis towards Beta maturity. Further levels of maturity (Provisional and Full validation) require additional and often long-term activities. A detailed description of the three product maturity levels is given in Figure 1, but brief descriptions of the three maturity levels are:

> **Beta:** the product is minimally validated and may still contain significant errors; based on product quick looks using the initial calibration parameters.
> **Provisional:** product performance has been demonstrated through a large, but still (seasonally or otherwise) limited, number of independent measurements. The analysis is sufficient for limited qualitative determinations of product fitness-for-purpose, and the product is potentially ready for testing operational use.
> **Full:** product performance has been demonstrated over a large and wide range of representative conditions, with comprehensive documentation of product performance, including known anomalies and their remediation strategies. Products are ready for operational use.

Assessment and declaration of maturity levels is performed during Peer Stakeholder–Product Validation Reviews (PS-PVRs). At each PS-PVR, the status of products will be presented by members of the cal/val science teams. For L2+ products, Beta maturity PS-PVRs are held in close proximity with and prior to Operations Handover. The review panel at the PS-PVRs will include the GOES-R Operational Readiness Working Group (GORWG), GOES-R Program System Engineering (PSE), NOAA Office of Satellite and Product Operations (OSPO), and GOES-R Product Readiness and Operations (PRO). The Readiness, Implementation, and Management Plans (RIMPs) have been created to document the analysis techniques, methodology, duration, tools, data, resources, staffing, and schedule of the Post-Launch Product Tests (PLPTs) to be used by the cal/val science teams to demonstrate the different levels of product maturity. The primary purpose of the RIMPs is to act as a planning resource for the cal/val teams as they prepare for Launch. Additionally, the RIMPs can be used by other members of the GOES-R Program to prepare for cal/val activities, to assess the suitability of the cal/val test plans, and to understand the data and resource requirements the science teams have. Cal/val testing is likely to reveal necessary algorithm changes to evolve the product quality through the maturity levels. The Algorithm Change Management Plan (ACMP) will be used to track and implement these algorithm changes.

The introspection necessary to create these RIMPs has led to extensive consultations between the cal/val teams and other groups within the GOES-R Program, including the Flight Project, the Ground Segment, and a team of experts from The Aerospace Corporation under contract from GOES-R PSE to help improve the cal/val mission. Figure 2 below describes the responsibilities and accountability of each of the main parties involved in the creation of the RIMPs. This delineation is required because GOES-R operations are to be handed over from the GOES-R Program to NOAA OSPO at the end of the PLT period, yet the process of validating product maturity will continue. This changing nature of accountability during the process must be acknowledged. Accountability of the RIMPs changes at Operations Handover from NASA to NOAA and is aligned with the level of each RIMPs' validation maturity objective. Accountability determines which organization owns documentation, process, and procedures. Responsibility determines which organization creates, executes, and maintains specific activities.

GOES-R Product (L1b and L2+) Maturity Levels

Beta Validation

Preparation Activities
- Initial calibration applied (L1b).
- Rapid changes in product input tables, and possibly product algorithms, can be expected.
- Product quick looks and initial comparisons with ground truth data (if any) are not adequate to determine product quality.
- Anomalies may be found in the product and the resolution strategy may not exist.

End state
- Products are made available to users to gain familiarity with data formats and parameters.
- Product has been minimally validated and may still contain significant errors.
- Product is not optimized for operational use.

Provisional Validation

Preparation Activities
- Validation and quality assurance (QA) activities are ongoing, and the general research community is now encouraged to participate.
- Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing.
- Incremental product improvements may still be occurring.
- Users are engaged in the Customer Forums (L2+ products only), and user feedback is assessed.

End state
- Product performance (L1b or L2+) has been demonstrated through analysis of a small number of independent measurements obtained from selected locations, periods, and associated ground-truth/field program efforts.
- Product analysis are sufficient to communicate product performance to users relative to expectations.
- Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.
- Testing has been fully documented.
- Product ready for operational use and for use in comprehensive calibration/validation activities and product optimization.

Full Validation

Preparation Activities
- Validation, QA, and anomaly resolution activities are ongoing.
- Incremental product improvements may still be occurring.
- Users are engaged and user feedback is assessed.

End state
- Product performance for all products is defined and documented over a wide range of representative conditions via ongoing ground-truth and validation efforts.
- Products are operationally optimized, as necessary, considering mission parameters of cost, schedule, and technical competence as compared to user expectations.
- All known product anomalies are documented and shared with the user community.
- Product is operational.

Figure 1. GOES-R product maturity levels.

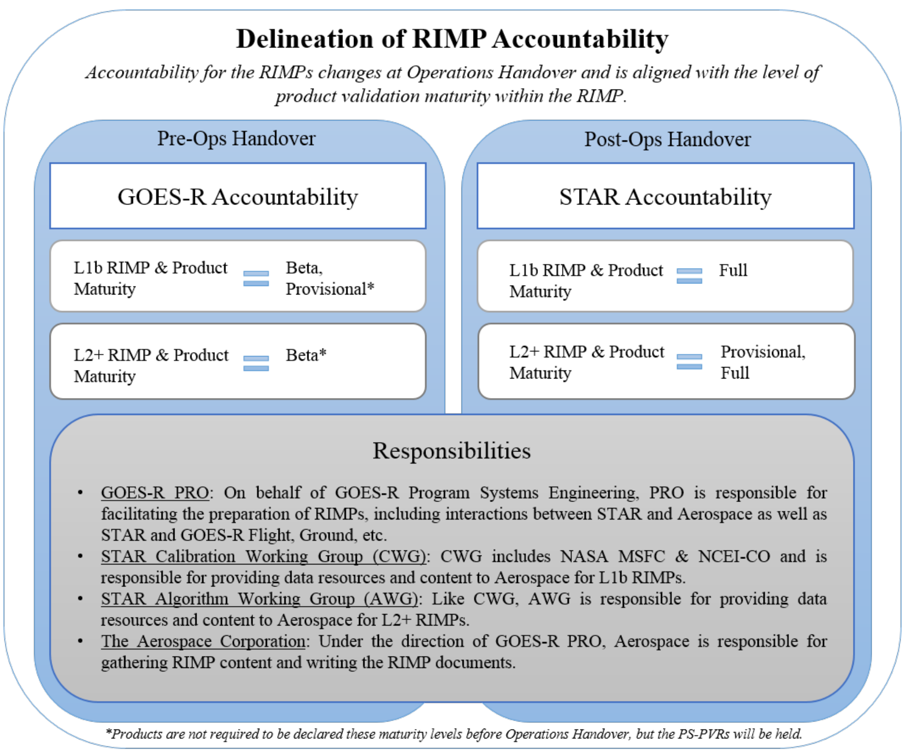

Figure 2. Delineation of accountability between GOES-R and STAR.

1. Surface Downward SW Radiation (DSR) and TOA Reflected SW Radiation (RSR) Validation Overview

This Readiness, Implementation, and Management Plan (RIMP) covers validation stages of the GOES-R Advanced Baseline Imager (ABI) Surface Downward and Top of Atmosphere (TOA) Reflected SW Radiation (DSR-RSR) Level 2 products. There are three stages in the validation process: Beta, Provisional, and Full. Each stage is defined by Post-Launch Product Tests (PLPTs), which guide the overall validation process. The RIMP includes a summary of the methods and tools employed to prove that DSR-RSR has met a given validation stage. Appendices present more detail on each PLPT and detail on the different data sets employed in the validation of the DSR-RSR products.

Eight PLPTs have been defined to attain Beta maturity.[1] The first five events verify that: when the sensor is in Mode 3, the Full Disk (FD), CONUS, and mesoscale products are generated within the expected measurement ranges; and when the sensor is in Mode 4, that FD and CONUS products are generated within the expected measurement ranges. These initial events are one week in duration, occur in parallel, and commence at the start of the program PLPT phase. The remaining three Beta PLPTs provide an initial assessment of performance of the FD, CONUS, mesoscale products, when the sensor is in Mode 3. Note that the mesoscale product is produced only for DSR. These initial performance assessments for Beta maturity are five weeks in duration and occur in parallel.

The two criteria for declaring Beta maturity are to: (1) provide a quantitative performance assessment with limited set of data; and (2) identify issues with product. The performance assessment will provide an initial characterization of overall product accuracy and precision regardless of scene type or season. PLPT events that support Beta maturity are listed below; details are in Appendix A:

- **ABI-FD_DSR01** and **ABI-FD_RSR01:** verify that Mode 3 hourly FD products are within range.
- **ABI-CONUS_DSR02** and **ABI-CONUS_RSR02:** verify that Mode 3 hourly CONUS products are within range.
- **ABI-MESO_DSR03:** verify that Mode 3 hourly mesoscale products are within range.
- **ABI-FD_DSR04 and ABI-FD_RSR04:** verify that Mode 4 hourly FD products are within range.
- **ABI-CONUS_DSR05** and **ABI-CONUS_RSR05:** verify that Mode 4 hourly CONUS products are within range.
- **ABI-FD_DSR06** and **ABI-FD_RSR06:** initial assessment of FD product accuracy and precision.
- **ABI-CONUS_DSR07** and **ABI-CONUS_RSR07:** initial assessment of CONUS product accuracy and precision.
- **ABI-MESO_DSR08:** initial assessment of mesoscale product accuracy and precision.

Three PLPTs to attain Provisional maturity are designed to quantify DSR-RSR accuracy and precision for an expanded, though not necessarily seasonally representative, number of independent measurements, sufficient to establish that the products are ready for operational use. The GOES-R Operations phase begins at the end of PLPT and marks the start of the three Provisional PLPTs (for FD, CONUS, and for DSR only, mesoscale) which occur concurrently over 24 weeks. While the products do not have to meet accuracy and precision specifications to reach Provisional maturity, if they don't, the reason must be identified with remediation strategies in place. PLPT events that support Provisional maturity are listed below; details are in Appendix A:

- **ABI-FD_DSR09** and **ABI-FD_RSR09:** assessment of FD product accuracy and precision.
- **ABI-CONUS_DSR10** and **ABI-CONUS_RSR10:** assessment of CONUS product accuracy and precision.
- **ABI-MESO_DSR11:** assessment of mesoscale product accuracy and precision.

Three PLPTs have been defined to attain Full maturity by further extending the conditions under which the DSR-RSR product accuracy and precision performance are quantified to include a seasonally representative number of independent measurements. The three Full PLPTs (FD, CONUS, and for DSR only, mesoscale) occur concurrently over a 36 week period at the end of which performance must be shown to meet, or nearly meet, the accuracy and precision specifications for the products to be declared Full maturity. If the performance does not meet the specifications, product can still be declared to have reached Full maturity if the cause is due to non-algorithm errors and the reason is documented. In addition users must concur that Full maturity has been demonstrated. PLPT events that support Full maturity are listed below; details are in Appendix A:

- **ABI-FD_DSR12** and **ABI-FD_RSR12:** assessment of FD product accuracy and precision.
- **ABI-CONUS_DSR13** and **ABI-CONUS_RSR13:** Assessment of CONUS product accuracy and precision.
- **ABI-MESO_DSR14:** assessment of mesoscale product accuracy and precision.

The following Table identifies the frequency of each scan type for Modes 3 and 4. It includes the required cadence of the DSR-RSR product as defined by both the GOES-R Functional and Performance Specification (F&PS) and the Product User's Guide (PUG). The bottom line reflects, for each appropriate scan type, the frequency of that product used for verification purposes. Routine, automated display of all products, regardless of scan Mode and frequency, is planned once per day. Routine evaluation of all products with "truth" is performed once per day for each day; monthly statistics are calculated once per month.

** Mode 3 Meso applies to DSR only.*
*** There is no CONUS scan type for Mode 4, but required CONUS products are derived from the FD output*

Mode	Mode 3			Mode 4		
Scan Type	FD	CONUS	Meso*	FD	CONUS	Meso
Freq	15 min	5 min	30 sec	5 min	5 min**	N/A
DSR-RSR Freq per F&PS	60 min	60 min	N/A	60 min	60 min	N/A
DSR-RSR Freq per PUG	60 min	60 min	60 min	60 min	160 min	N/A
DSR-RSR Verification Freq	once/day: all 60 min products	once/day: all 60 min products	once/day: all 60 min products	once/day: all 60 min products	once/day: all 160 min products	N/A

Table 1. DSR-RSR product and verification cadences.

The reference data to be used throughout the validation activities include Ground SW radiation measurements (SURFRAD and COVE), space based retrievals (GOES Surface and Insolation products and Clouds and the Earth's Radiant Energy System [CERES] Fast Longwave and Shortwave Radiative Fluxes [FLASHFlux] products), and field campaign measurements. Moderate Resolution Imaging Spectroradiometer (MODIS) TOA reflectances (along with ancillary products needed to run the ABI Shortwave Radiation Budget [SRB] algorithm), as well as the Visible Infrared Imaging Radiometer Suite (VIIRS) shortwave reflectances, were used as proxy during prelaunch testing. Baseline Surface Radiation Network (BSRN) data were used in prelaunch testing with the global MODIS proxy retrievals, but will not be used in on-orbit verification because they are not available in real time (it takes greater than 12 months for a release of a complete year of BSRN-quality data and it's unlikely to be available in time). Surface downward shortwave radiation measured at the ground in the Field Campaign planned for GOES-R validation will be used the same way as the SURFRAD data are used. The details of each reference data set are in Appendix B.

The validation processes and procedures, monitoring and analysis methods, tools, and expected output artifacts are described in the following sections.

2. Schedule of Events

Figure 3 shows the GOES-R validation schedule. System Performance Operation Test (SPOT) begins 44 days after launch when ABI L1b and the L2 Cloud and Moisture Imagery (CMI) Key Performance Beta evaluation begins and these data should be declared Beta maturity by L+87 days. One day later, the GOES Rebroadcast (GRB) will be populated with that data. The L2 products must reach Beta maturity by handover at L+197 days, the same time that ABI L1b and CMI reach Provisional. Given that L2 Beta tests require at least 6 weeks, L2 Beta testing must get underway by L+155 days, but can begin as soon as the ABI L1b and CMI reach Beta (L+87 days).

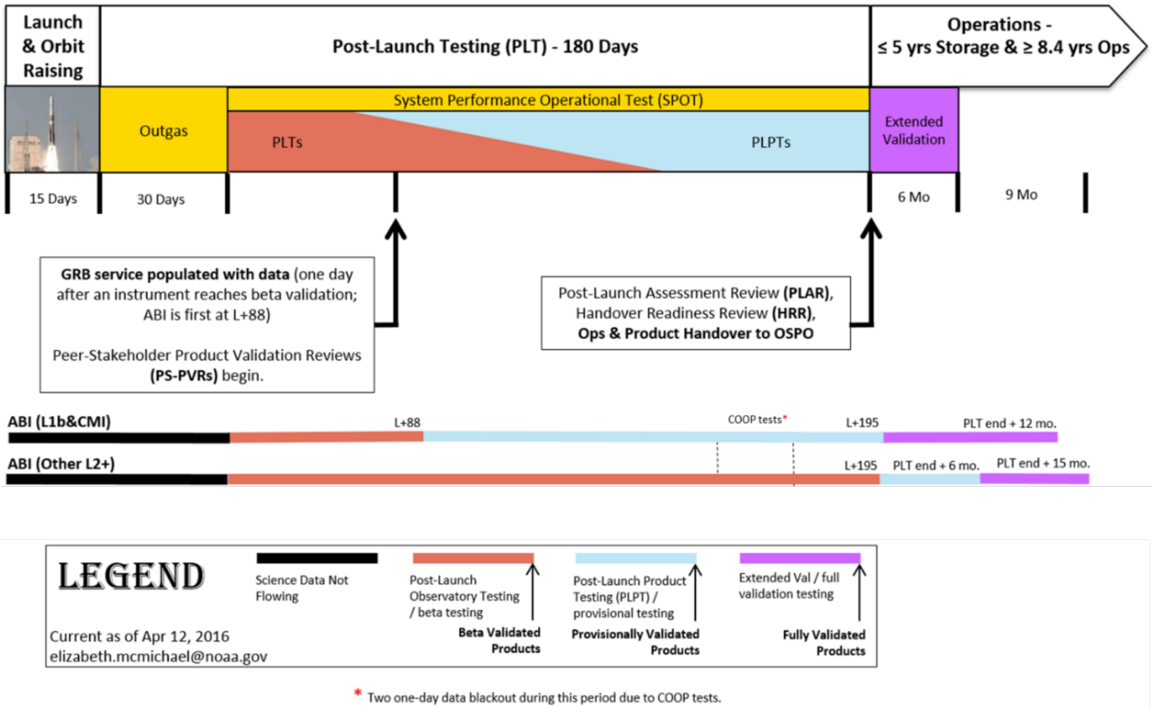

Figure 3. Schedule of events.

The schedule of pre-launch preparation activities is as follows:

- July 2015 – December 2015: initial testing of validation tool with DSR-RSR derived from Himawari-8 observations.
- January 2016: completion of DSR-RSR validation tools.
- October 2015 – July 2016: testing and demonstration of validation tool with RSR derived from Himawari-8 data.
- July 2016: version 1 web-based display of validation tool results is ready.
- September 2016: version 2 web-based display of validation tool results is ready.

The GOES-R Operations phase begins after handover marking the start of a 12 month Extended Validation period for ABI L1b and CMI, which is coincident with the start of the 6 month L2 Provisional evaluation, followed by another nine months period for L2 products to reach Full maturity 15 months after handover.

3. Roles and Responsibilities

3.1 Primary Point of Contact

The primary point of contact (POC) for leading the DSR-RSR validation effort and algorithm updates is Istvan Laszlo. Istvan Laszlo is the POC for coordination with the L1b team (POC Xiangqian [Fred] Wu) with the other L2 teams, namely cloud mask (POC Andrew Heidinger), via direct email to team lead and through the Calibration Working Group and Algorithm Working Group. The program is looking into a web-based method (wiki etc.) for sharing information. Istvan Laszlo is the POC for the algorithm change responsibilities.[2]

3.2 GOES-R Point of Contact

The primary POC at GOES-R for the DSR-RSR validation effort is Wayne MacKenzie.

3.3 Test Analyst/Engineer

Hye-Yun Kim is the primary test analyst/engineer of the PLPTs and Hongqing Liu will serve as a backup analyst.

3.4 GOES-R Feedback

Formal feedback to the GOES-R program regarding DSR-RSR products will be provided by the cloud product lead Jaime Daniels.

3.5 Level of Effort

The analysis is projected to require 0.15 FTE (Kim: 0.1 FTE; Liu: 0.05 FTE) for each of the five DSR and four RSR one-week concurrent PLPT Beta range and null check tests. This is a total 1.35 FTE level of effort in the first week. Each of the remaining three DSR and two RSR Beta PLPTs for initial accuracy and precision performance assessments that occur in parallel over the remaining 5 weeks of PLPT require 0.25 FTE (Kim: 0.2 FTE; Liu: 0.05 FTE) each for a total of 1.25 FTE level of effort throughout. This 1.25 FTE level of effort is expected to continue throughout the Provisional and Full maturity assessments after handover.

Hongqing Liu and Hye-Yun Kim has developed the in-house tools which will be used for field campaign data, though an additional 0.04 FTE will be required to develop a data-ingest module specific to the field data once the data formats are defined.

4. Tools

The ABI SRB tools perform instantaneous monitoring of DSR-RSR; collocation of ABI and reference DSR-RSR; and routine validation over ground stations. They present results as maps, scatter plots, and tables. These tools are described in the following sections and will be utilized throughout all validation stages. The DSR and RSR tools are detailed in Appendix C.

5. Analysis Methods

The ABI SW RB algorithm retrieves the surface DSR and TOA RSR from other ABI products (cloud, aerosol, surface albedo, ozone and water vapor) or from selected ABI SW-channel reflectances when the requisite ABI products (cloud, aerosol, and surface albedo) are not available. Since not all of the inputs are Baseline products, the latter, indirect path algorithm for SW radiation flux is used. Therefore, the validation methods described here pertain to the indirect algorithm.

The validation strategy must consider unique features of the product, i.e., a large range of values (0 – 1000+ W/m^2) and is primarily driven by cloudiness and solar position. These lead to relatively high correlation between ground and satellite data even when the retrieval has problems, so correlation coefficient alone is not a very meaningful metric. ABI metrics (accuracy, precision) and other widely-used metrics (root-mean-square error, maximum and minimum error) will be calculated to facilitate comparison with published results.

The method of analysis falls into two general categories: (1) Inspection of DSR-RSR to establish their ranges; (2) Comparison of ABI-retrieved DSR-RSR to reference data to characterize product quality. Routine monitoring processes will begin during PLPT for the Beta assessment. The same processes will be continued in the Extended Validation period with the only difference being longer duration of data, more cases, and more robust statistics. Below are details on tools used for the analysis methods:

5.1 Inspection:

The analyst will run the "ABI SRB Data Acquisition and Matchup Tool" to acquire ABI hourly DSR-RSR fields in the morning of every day for the previous day, and will run the "ABI SRB Statistics Tool" to generate statistics for all three domains (FD, CONUS, and mesoscale). She/he then runs the "ABI SRB Visualization Tool" from which the minimum and maximum values are established and then compared to the expected range. Though product range will be validated in the first week of Beta testing, these range checks will be performed throughout all stages of validation.

5.2 Routine Instantaneous Monitoring:

Every day the analyst will examine the results of the "ABI SRB Data Acquisition and Matchup Tool" and the "ABI SRB Visualization Tool" (run automatically by a script to generate maps of ABI DSR-RSR every hour). During working hours the analyst will visually inspect the DSR-RSR fields, and will use the "ABI SRB Visualization Tool" to display and examine corresponding quality flags and the ASCII metadata output. Instantaneous monitoring.pro is used to read in and display fields of the ABI-derived DSR-RSR and to show metadata. GOES Surface and Insolation Product is monitored routinely this way by automatically generating plots of key inputs and all outputs.

5.3 Routine Validation over Ground Stations:

This comparison uses both ground Surface Radiation Budget (SURFRAD) and independent satellite-based (CERES FLASHFlux) reference data. The analyst will start a script at the beginning of PLPT that will run the "ABI SRB Data Acquisition and Matchup Tool" to acquire ABI hourly DSR-RSR fields and ground and satellite reference data after midnight every day for the previous day. This tool generates matchup between the ABI and reference data, but only over ground station (SURFRAD) sites. The analyst will run the "ABI SRB Statistics Tool" on the matchup data generated over the ground sites to calculate statistics for all three domains (FD, CONUS, mesoscale). This script also runs the "ABI SRB Visualization Tool" that plots the diurnal cycle of hourly ABI and reference DSR, their difference, scatterplot of ABI vs. ground DSR and their time series. Similar plots are also generated for ABI RSR and CERES. The analyst will examine the plots every day in the morning and will manually start all three tools if automatic processing was not possible for some reason. During the last week of the PLPT she/he will run the "ABI SRB Statistics Tool" and the "ABI SRB Visualization Tool" to generate scatterplots and time series plots of ABI DSR-RSR products and reference data for the previous 5-week period. The same tools will be applied during the Provisional and Full maturity validation phases to generate scatter plots and time series of accuracy and precision for each of the ground (reference) sites separately and for all sites together. Most data will also be analyzed in the deep dive process and will result in accuracy and precision statistics stratified according to scene type, season, and retrieval path.

5.4 Deep-Dive Validation over Ground Stations:

Deep dive analysis is an expansion of routine validation over ground stations using diagnostic variables and various options including:

- Scene types (all or snow, clear, water cloud, ice cloud).
- Retrieval path (Direct, Indirect, or Hybrid). For the indirect path, TOA matching and Surface albedo are "all", "succeed", or "failed."

In the indirect path, DSR is derived by calculating the surface albedo and transmittance by matching the ABI-derived TOA albedo with TOA albedos pre-calculated from a radiative transfer model for a range of aerosol and cloud optical depths and for pre-defined spectral dependence of the surface reflectance. Sometimes the ABI-derived TOA albedo can be outside of the range of the pre-calculated values, so in this case there is no match between the two TOA albedos. When this happens DSR is estimated from the extreme values of the calculated TOA albedo. Sometimes, the surface albedo retrieval (scaling of the reference spectral albedos) can lead to unphysical (negative or larger than one) values, in which case the retrieval uses the reference albedo. The tool allows examining the fluxes regardless of the success of TOA albedo matching or surface albedo retrieval ("all"), or the analyst can select only DSR when matching and/or surface albedo retrieval was successful ("succeed"), or when these failed ("failed").

Deep dive_validation_over_ground.pro which includes subroutines for calculating statistics and visualization. The outputs (scatter plots, time series, and tables of statistics depending on scene type) are then examined in depth.

5.5 Deep-Dive Validation with CERES:

Deep dive analysis is an expansion of routine validation with CERES using "deep dive validation with_ceres.pro" which includes subroutines to calculate statistics and visualization. The analysis is performed to characterize the accuracy and precision as functions of:

- Scene types (all or snow, clear, water cloud, ice cloud).
- Retrieval path (Direct, Indirect, or Hybrid). For the indirect path, TOA matching and Surface albedo are "all", "succeed", or "failed."

The tools work with multiple day data sets and the analyst can specify the date of interest and select it (load it) for display or analysis. Products the analyst selects from 'Validation' menu are:

- ABI TOA RSR retrieval; CERES observation; ABI RSR - CERES difference.
- Images depending on scene type, surface type, and retrieval path can be displayed and errors depending on them can be recognized.
- Statistics (scatter plot; statistics in ASCII file: shows retrieval range, comparison of retrievals and reference in magnitude, and error statistics depending on scene type, surface type, and retrieval path).

Deep dive analysis will not normally occur during Beta but will be conducted during the Extended Validation period.

6. Output Artifacts

6.1 Beta Maturity Artifacts

Performance assessment and product issues will be documented at the conclusion of each maturity assessment phase. At the end of the first week of PLPT, the results from the range testing will be summarized in a report that will be made available for review by the Program. During the weeks 2-6 of PLPT the validation results from the Analysis Methods in Section 5 will be made available in the Web-based display. At the completion of the Beta phase a report detailing the methods used and the results obtained will be prepared. To the extent supported by the data available during PLPT, the following will be reported:

- Accuracy and precision stratified according to scene type (clear/cloudy), surface type (e.g., water and land surface categories), solar and viewing angles, etc.
- Domain average hourly, daily and monthly accuracy and precision statistics stratified with respect to observational geometry, time of day, location, and season.

6.1.1 These tests of priority 1 all must pass their success criteria defined in Appendix A in order to achieve Beta maturity:

- ABI-FD_DSR01
- ABI-FD_RSR01
- ABI-CONUS_DSR02
- ABI-CONUS_RSR02
- ABI-MESO_DSR03
- ABI-FD_DSR04
- ABI-FD_RSR04
- ABI-CONUS_DSR05
- ABI-CONUS_RSR05
- ABI-FD_DSR06
- ABI-FD_RSR06
- ABI-CONUS_DSR07
- ABI-CONUS_RSR07
- ABI-MESO_DSR08.

6.1.2 The DSR-RSR Beta maturity validation effort does not include any priority 2 tests.

6.2 Provisional Maturity Artifacts

At the conclusion of the Provisional maturity validation stages, results will be presented at Peer Stakeholder - Product Validation Reviews (PS-PVR) detailing the methods used and providing results in terms of accuracy and precision of DSR-RSR stratified according to the categories as described above for Beta, but covering a longer period of record. If the product does not meet a performance specification, the reason will be documented along with remediation strategies. Any challenges with upstream dependencies will be identified. Finally, the Provisional presentations will include a summary of user feedback received during the respective validation periods.

6.2.1 The following test of priority 1 must pass their success criteria defined in Appendix A in order to achieve Provisional maturity:

- ABI-FD_DSR09
- ABI-FD_RSR09
- ABI-CONUS_DSR10
- ABI-CONUS_RSR10
- ABI-MESO_DSR11

6.2.2 The DSR-RSR Provisional maturity validation effort does not include any priority 2 tests.

6.3 Full Maturity Artifacts

At the conclusion of the Full maturity validation stages, results will be presented at another PS-PVRs containing the same information as for Provisional but covering a longer period of record that includes seasonal effects. As before, if the product does not meet a performance specification, the reason will be documented along with remediation strategies. Any challenges with upstream dependencies will be identified and a summary of user feedback received during the validation periods will be included.

6.3.1 The following test of priority must pass their success criteria defined in Appendix A in order to achieve Full maturity:

- ABI-FD_DSR12
- ABI-FD_RSR12
- ABI-CONUS_DSR13
- ABI-CONUS_RSR13
- ABI-MESO_DSR14

6.3.2 The DSR-RSR Full maturity validation effort does not include any priority 2 tests.

6.4 Key Artifacts

The key artifact for the DSR-RSR validation effort is the statistical analysis of accuracy and precision which will be covered in the Beta report and the Provisional and Validated presentations described above.

6.5 More Output Artifacts

6.6 Delivery Schedule

The delivery schedule of artifacts for the DSR-RSR validation coincides with the completion of the associated maturity stages as shown in Section 2. All statistical analysis necessary to prove a given validation stage will be included in a power point presentation in time for the appropriate PS-PVR.

7. Pre-launch

Simulated CONUS ABI imagery; SURFRAD, GOES Surface and Insolation retrievals, and CERES products were used to test the algorithms. Web-based displays of validation tool will be ready by July (v1) and September (v2) of 2016. Output from pre-launch DOE tests will continue to be used throughout pre-launch to verify tools correctly process the GOES-R ABI DSR-RSR product formats including diagnostic data.

8. References

The references listed below were used to generate this document, augmented with written and/or verbal feedback with the STAR product team. Superscripts are invoked within the text of this document to indicate a reference that can provide additional detail for the reader.

[1] PLPT_VE_List_L2_v1_0_20141022.xlsx.
[2] GOES-R Series Ground Segment Project Algorithm Change Management Plan, G416-R-ALGCMP-0285.
[3] L2 Product Validation Tools_05-12-2015.xlsx.
[4] CalValPlan_Vol2_L2_v1-1-draft-redlines_inc-ERB_comments_v2a - Clean - BobEdits.docx.
[5] CV Workshop charts: Application_Team_Validation_LST_v1.ppt.
[6] GOES-R Mission Requirements Specification (MRS), 410-R-MRD-0070, Version 3.17.

A. Appendix A: Validation Events

A.1 PLPT events that Support Beta Maturity

A.1.1 **ABI-FD_DSR01** and **ABI-FD_RSR01**

Objective: Verify that hourly products are within range.
Start Time: Start of PLPT.
Duration: 1 week.
ABI Mode: Mode 3.
GOES-R Data Type(s): FD.
Beta Success Criteria: Range results indicate product is sufficiently reasonable to begin accuracy assessment.
Dependencies: Cloud mask quality.
PLPT Lead: Istvan Laszlo.
PLPT Analysts: Hye-Yun Kim, Hongqing Liu; 0.15 FTE (Kim: 0.1 FTE; Liu: 0.05 FTE) Total 0.3 FTE level of effort for both RSR and DSR PLPTs (Kim: 0.2 FTE; Liu: 0.1 FTE).
Validation Data: None.
Monitoring and Analysis Method: Inspection.

A.1.2 **ABI-CONUS_DSR02** and **ABI-CONUS_RSR02**

Same as for ABI-FD_DSR01 and ABI-FD_RSR01, except for:
GOES-R Data Type(s): CONUS.

A.1.3 **ABI-MESO_DSR03**

Same as for ABI-FD_DSR01, except for:
GOES-R Data Type(s): Mesoscale.

A.1.4 **ABI-FD_DSR04** and **ABI-FD_RSR04**

Same as for ABI-FD_DSR01 and ABI-FD_SR01, except for:
ABI Mode: Mode 4.

A.1.5 **ABI-CONUS_DSR05** and **ABI-CONUS_RSR05**

Same as for ABI-CONUS_DSR02 and ABI-CONUS_RSR02, except for:
ABI Mode: Mode 4.

A.1.6 **ABI-FD_DSR06** and **ABI-FD_RSR06**

Same as for ABI-FD_DSR01 and ABI-FD_RSR01, except for:
Objective: Assess accuracy of FD product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization of product accuracy to the user community.
Duration: 5 Weeks.
Beta Success Criteria:

- Product measurement accuracy and precision quantified using the ABI data collected during the PLPT period. These may be compared with specifications, but non-compliance will not mean the product is not at Beta level.
- Issues with the product are identified.

PLPT Analyst: Hye-Yun Kim, Hongqing Liu; 0.25 FTE (Kim: 0.2 FTE; Liu: 0.05 FTE) Total 0.5 FTE Level of Effort for both RSR and DSR PLPTs (Kim: 0.4 FTE; Liu: 0.1 FTE).
Validation Data: Ground SW radiation measurements (SURFRAD), GOES Surface and Insolation retrievals, MODIS, VIIRS, and CERES FLASHFlux products.

A.1.7 **ABI-CONUS_DSR07** and **ABI-CONUS_RSR07**

Same as for ABI-FD_DSR06 and ABI-FD_RSR06, except for:
GOES-R Data Type(s): CONUS.

A.1.8 ABI-MESO_DSR08

Same as for ABI-FD_DSR06, except for:
GOES-R Data Type(s): Mesoscale.

A.2 Verification Events that Support Provisional Maturity

A.2.1 **ABI-FD_DSR09** and **ABI-FD_RSR09**

Objective: Assess accuracy of FD products for an adequate number of independent measurements to characterize accuracy and precision adequately for the user to determine the product is ready for operational use.
Start Time: At completion of Beta Analysis and start of Operational phase.
Duration: 6 months (24 weeks).
ABI Mode: Mode 3.
GOES-R Data Type(s): FD.
Provisional Success Criteria:

- Accuracy and precision determined over a large and wide range of representative conditions (scene type (clear/cloudy), surface type (e.g., water and land surface categories), solar and viewing angles, location, time of day, etc.):
  - DSR-RSR Accuracy[6]:
    - 85 W/m^2 at high end of range (1000 W/m^2).
    - 65 W/m^2 at typical value/midpoint (350 W/m^2).
    - 110 W/m^2 at low end of range (100 W/m2) (DSR only).
  - DSR-RSR Precision[6]:
    - 100 W/m^2 for low and high values (100 and 1000 W/m^2).
    - 130 W/m^2 at typical value/midpoint (350 W/m^2).
- The specifications apply out to at least 70 deg LZA for day conditions (Solar Elevation Angle >25 deg) and pertain to the FD, CONUS, and for DSR only, MESO products. If the accuracy and precision specifications are not met, the product can still be declared to have reached Full maturity if the cause is due to non-algorithm errors and the reason is documented.
- Upstream challenges identified.
- Remediation strategies in place for known issues.
- Product is ready for potential operational use (user decision) and for use in scientific publications.

Dependencies: Cloud mask quality.
PLPT Lead: Istvan Laszlo.
PLPT Analyst: Hye-Yun Kim, Hongqing Liu; 0.25 FTE (Kim: 0.2 FTE; Liu: 0.05 FTE) Total 0.5 FTE Level of Effort for both RSR and DSR PLPTs (Kim: 0.4 FTE; Liu: 0.1 FTE).
Validation Data: Ground SW radiation measurements (SURFRAD), GOES Surface and Insolation retrievals, MODIS, VIIRS, and CERES FLASHFlux products.

A.2.2 **ABI-CONUS_DSR10** and **ABI-CONUS_RSR10**

Same as for ABI-FD_DSR09 and ABI-FD_RSR09, except for:
GOES-R Data Type(s): CONUS.

A.2.3 ABI-MESO_DSR11

Same as for ABI-FD_DSR09, except for:
GOES-R Data Type(s): Mesoscale.

A.3 Verification Events that Support Full Maturity

A.3.1 ABI-FD_DSR12 and ABI-FD_RSR12

Objective: Assess accuracy of FD products to characterize accuracy and precision for a wide range of conditions including seasonal variability.
Start Time: At completion of Provisional Analysis.
Duration: 9 months (36 weeks).
ABI Mode: Mode 3.
GOES-R Data Type(s): FD.
Full Success Criteria:

- Accuracy and precision determined over a large and wide range of representative conditions (scene type (clear/cloudy), surface type (e.g., water and land surface categories), solar and viewing angles, location, time of day, season, etc.).
- Product performance meets or is close to meeting accuracy and precision specifications:
  - DSR-RSR Accuracy[6]:
    - 85 W/m^2 at high end of range (1000 W/m^2).
    - 65 W/m^2 at typical value/midpoint (350 W/m^2).
    - 110 W/m^2 at low end of range (100 W/m^2).
  - DSR-RSR Precision[6]:
    - 100 W/m^2 for low and high values (100 and 1000 W/m^2).
    - 130 W/m^2 at typical value/midpoint (350 W/m^2).
- The specifications apply out to at least 70 deg LZA for day conditions (Solar Elevation Angle >25 deg) and pertain to the FD, CONUS, and for DSR only, mesoscale products. If a specification is not met, the reason must be established with remediation steps in place.
- User concurs with Full maturity.

Dependencies: Cloud mask quality.
PLPT Lead: Istvan Laszlo.
PLPT Analyst: Hye-Yun Kim, Hongqing Liu; 0.25 FTE (Kim: 0.2 FTE; Liu: 0.05 FTE) Total 0.5 FTE Level of Effort for both RSR and DSR PLPTs (Kim: 0.4 FTE; Liu: 0.1 FTE).
Validation Data: ground SW radiation measurements (SURFRAD), GOES Surface and Insolation retrievals, MODIS, VIIRS, and CERES FLASHFlux products.

A.3.2 ABI-CONUS_DSR13 and ABI-CONUS_RSR13

Same as for ABI-FD_DSR09 and ABI-FD_RSR09, except for:
GOES-R Data Type(s): CONUS.

A.3.3 ABI-MESO_DSR14

Same as for ABI-FD_DSR09, except for:
GOES-R Data Type(s): Mesoscale.

B. Appendix B: GOES-R and Validation Reference Data

B.1 Data Set #1: SURFRAD

Description: Primary validation truth data source. High-quality routine ground radiation measurements over Western Hemisphere. Measurements used are: surface SW downward, upward fluxes; surface SW downward direct, diffuse fluxes; solar zenith angle; quality flag.
Storage Location: ftp://aftp.cmdl.noaa.gov/data/radiation/surfrad/realtime/.
Access Process: Data are uploaded to the FTP site every 15 min but it will be accessed only every hour. The file size is 340 KB per station for a day. The data are to be stored locally and downloaded automatically.
POC: Kathleen Lantz (kathy.o.lantz@noaa.gov).
Spatial Coverage: Currently 7 stations.
Temporal Coverage: 1 min average of measurements.
Contingency: None.

B.2 Data Set #2: COVE (CERES Ocean Validation Experiment)

Description: High-quality routine ground radiation measurements of surface SW downward fluxes, and surface SW downward direct and diffuse fluxes over an ocean site. Measurements are made as part of the CERES Ocean Validation Experiment at the Chesapeake Lighthouse off the coast of Virginia.
Format: ASCII.
Storage Location: http://cove.larc.nasa.gov/NOAA-GSIP/.
Access Process: 120 KB accessed daily. Automatically downloaded by the "ABI SRB Data Acquisition and Matchup" tool; data are stored in original format on local computing system.
POC: Greg Schuster, NASA Langley Research Center, Mail Stop 420, Hampton, VA 23681 (cove@larc.nasa.gov).
Spatial Coverage: 1 station.
Temporal Coverage: One-minute averages.
Contingency: None.

B.3 Data Set #3: CERES FLASHFlux

Description: CERES FLASHFlux are TOA upward SW flux measurements and surface downward SW flux retrievals. They are part of the suite of products generated in the CERES processing at NASA Langley. However, in contrast to the "standard" CERES products that have a latency of several months, it provides global near real-time surface and TOA radiative fluxes. It is derived from CERES and MODIS TOA observations with fast radiation algorithms within about a week of satellite measurements. Data sets used are:

- SW TOA upwards flux: derived RSR by angular correction of measured broadband SW radiance.
- Clear/layer/overlap percent coverage: Fraction of clear-sky and cloud within FOV.
- Shortwave flux – downward – at surface.

Storage Location: http://ceres.larc.nasa.gov/products.php?product=FLASHFlux-Level2.
Access Process: 1.3 GB CERES FLASHFlux product will be downloaded manually at the end of each day for the previous day (with up to 7 days lag), and stored in their original (Hierarchical Data Format (HDF)) format.
POC: Paul Stackhouse (Paul.W.Stackhouse@nasa.gov).
Spatial Coverage: Global.
Temporal Coverage: Hourly product.
Contingency: None.

B.4 Data Set #4: GOES Surface and Insolation Retrievals[1]

Description: The GOES Surface and Insolation Product (GSIP) system generates DSR-RSR from operational GOES satellites every hour for the extended North hemisphere and every three hours for the FD. Nominal spatial resolution of the product is 4 km.
Storage Location: satepsanone.nesdis.noaa.gov.
Access Process: FTP every hour.
POC: Istvan Laszlo and Hanjun Ding.
Spatial Coverage: GOES East and West Northern Hemisphere and FD.
Temporal Coverage: Every hour for the Northern Hemisphere and every three hours for FD.
Contingency: None.

B.5 Data Set #5: Field Campaign Data

Description: Measurements of downward shortwave radiation (downward irradiance) at ground level over land and oceanic locations together with correlative data of aerosol optical depth, amount of water vapor and ozone (TBD), and surface reflectance. These are to be used with the deep dive tools.
POC: Steve Goodman, Frank Padula (Frank.Padula@noaa.gov).
Access Process: TBD.
Frequency of Transmission: TBD from GOES-R Field Campaign Data Portal.
Contingency: none.

C. Appendix C: Tools

C.1 Tool #1: ABI SRB Data Acquisition and Matchup Tool

Location: Local computing facility at College park, MD.

Description: The purpose of this tool is to prepare matchup data for the validation of ABI-derived DSR-RSR with reference data over selected locations. The reference data for DSR are ground observations of DSR at SURFRAD sites. The reference data for RSR are satellite-derived RSR data from CERES for SURFRAD site locations. The tool reads ABI DSR-RSR data as well as ground-based (SURFRAD, COVE) DSR and satellite-based (CERES FLASHFlux) DSR-RSR reference data. It generates matchup data of ABI and reference data over ground sites by collocation, temporal and spatial averaging.

Collocation of ABI retrievals and ground validation data is performed at the instantaneous time scale. Satellite retrievals averaged spatially are matched with ground measurements averaged temporally. The Averaging window size is flexible. The process flow for matchups is: (1) initialization; (2) get station information; (3) get matched retrieval with spatial averaging. Then it loops over each station to get ground measurements with temporal averaging then save match-up data for current station.

Collocation between ABI and CERES is carried out by averaging CERES data to the retrieval grids on a daily basis. Current retrievals use MODIS data as input. As CERES is on same platform, there is no need for temporal matching. The process flow for ABI-CERES matchups is: (1) initialization; (2) loop over granule; (3) read retrieval results; (4) match CERES with retrievals; (5) save match-up data for current granule.

Program names: Gnd_Measurement.f90 (reads reference DSR data); CERES_Measurement.f90 (reads CERES RSR and DSR data); Sat_Retrieval.f90 (reads ABI DSR and RSR); Match.f90 (generates matchup data – collocation, spatial and temporal averaging).

Developer: Hongqing Liu and Hye-Yun Kim.

Development Schedule: Development work is complete. The tool can read and match 15-min near real-time SURFRAD reference data, as well as DSR retrieved from simulated ABI data, as well as observed Himawari-8 data. The only development work remaining is completion of web-based display of tool results; version 1 is due in July and version 2 in Sept of 2016.

Data Dependencies: GOES-R ABI DSR and RSR FD and CONUS, and DSR mesoscale; SURFRAD, COVE, CERES and GSIP.

Testing Accomplished or Planned: The tool has been tested with DSR-RSR derived from MODIS proxy data and from GOES (in GSIP) using SURFRAD, BSRN, COVE as reference for DSR and CERES as reference for RSR. Testing has also been accomplished using DSR-RSR retrieved from simulated ABI and observed Himawari-8 data and will continue throughout pre-launch.

POC: Hongqing Liu.

C.2 Tool #2: ABI SRB Statistics Tool

Location: Local computing facility at College Park, MD.

Description: From the matchup data generated by the "ABI SRB Data Acquisition and Matchup Tool" this tool calculates Accuracy/Precision, RMSE, and Minimum/Maximum Error taking into account Metadata.

Program Names: Subroutine VG_Val_Plot in validation_over_ground.pro, subroutine VC_Scatter_plot in validation_with_ceres.pro, Deepdive_VG_Val_Plot and Deepdive_VG_stat in deepdive_validation_over_ground.pro, and Deepdive_VC_Fig_Plot and Deepdive_VC_stat in deepdive_validation_with_ceres.pro.

Developer: Hongqing Liu.

Development Schedule: Development is complete. The tool has been updated to read matchup data generated from 15-min near real-time SURFRAD data, from simulated ABI, and observed

Himawari-8 data. The only development work remaining is completion of web-based display of tool results; version 1 is due in July and version 2 in Sept of 2016.

Data Dependencies: Matchup data generated by the "ABI SRB Data Acquisition and Matchup Tool".

The ABI matchup data are:

- Ground measurement time: mean observation time within the temporal averaging period.
- Number of retrievals: sample size of retrievals for averaging.
- Ground mean fluxes: averaged ground measurements of downward total/direct/diffuse and upward SW fluxes.
- ABI measurement time: mean ABI measurement time within the spatial averaging domain
- Retrieval grid longitude and latitude.
- Retrieved all-sky fluxes: TOA upward, surface downward for each retrieval within the averaging domain.
- Input quality flag for each retrieval.
- Retrieval quality flag for each retrieval.
- Diagnosis quality flag for each retrieval.

The CERES matchup data are:

- Retrieval grid longitude and latitude.
- Retrieved surface downward SW flux.
- Retrieved TOA upward SW flux.
- QC Flag (Retrieval).
- QC Flag (Diagnostics).
- CERES measured RSR.
- CERES cloud fraction.
- CERES surface type.

Testing Accomplished or Planned: The tool has been tested with DSR-RSR derived from MODIS proxy data and from GOES (in GSIP) using SURFRAD, BSRN, COVE as reference for DSR and CERES as reference for RSR. The tool has also been tested with matchup data generated from DSR retrieved from simulated ABI and with observed Himawari-8 data and this testing will continue throughout pre-launch.

POC: Hongqing Liu.

C.3 Tool #3: ABI SRB Visualization Tool

Location: Local computing facility at College Park, MD.

Description: IDL GUI displays plots generated from data by tools "ABI SRB Data Acquisition and Matchup Tool" and "ABI SRB Statistics Tool". Figures are generated in PNG format (or GIF, JPEG, EPS if needed).

Program Names: Subroutine VG_Val_Plot in validation_over_ground.pro, subroutine VC_Scatter_plot in validation_with_ceres.pro, Deepdive_VG_Val_Plot and Deepdive_VG_stat in deepdive_validation_over_ground.pro, and Deepdive_VC_Fig_Plot and Deepdive_VC_stat in deepdive_validation_with_ceres.pro.

Developer: Hongqing Liu.

Development Schedule: Development is complete. The tool was updated to display matchup data and statistics generated from 15 min near real-time SURFRAD data, and from simulated ABI data. The only development work remaining is completion of web-based display of tool results; version 1 is due in July and version 2 in Sept of 2016.

Data Dependencies: Matchup data generated by the "ABI SRB Data Acquisition and Matchup Tool" and statistics from "ABI SRB Statistics Tool".

Testing Accomplished or Planned: The tool has been tested with DSR-RSR derived from MODIS proxy data and from GOES (in GSIP) using SURFRAD, BSRN, COVE as reference for DSR and CERES as reference for RSR. The tool has also been tested with matchup data generated from DSR retrieved from simulated ABI and with observed Himawari-8 data and this testing will continue throughout pre-launch.
POC: Hongqing Liu.

D. Appendix D: Acronym List

Acronym	Definition
ABI	Advanced Baseline Imager
ASCII	American Standard Code for Information Interchange
AWG	Algorithm Working Group
BSRN	Baseline Surface Radiation Network
Cal/Val	Calibration and Validation
CCR	Configuration Change Request
CERES	Clouds and Earth's Radiant Energy System
CMI	Cloud and Moisture Imagery
CONUS	Continental United States
COVE	CERES Ocean Validation Experiment
CWG	Calibration Working Group
DOE	Data Operations Exercise
DSR	Surface Downward SW Radiation
EPS	Encapsulated PostScript
FD	Full Disk
FLASHFlux	Fast Longwave and Shortwave Radiative Fluxes
F&PS	Functional and Performance Specification
FTE	Full-Time Equivalent
FTP	File Transfer Protocol
GIF	Graphics Interchange Format
GOES	Geostationary Operational Environmental Satellite
GOES-R	GOES R-Series
GORWG	GOES-R Series Operational Requirements Working Group
GRB	GOES Rebroadcast
GSIP	GOES Surface and Insolation Product
GUI	Graphical User Interface
HDF	Hierarchical Data Format
HRR	Handover Readiness Review
IDL	Interactive Data Language
JPEG	Joint Photographic Experts Group
L1b	Level 1b
L2	Level 2
MODIS	Moderate Resolution Imaging Spectroradiometer
MOST	Mission Operations Support Team
MRD	Mission Requirements Document
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration

Acronym	Definition
NCEI	National Centers for Environmental Information
NCEI-CO	NCEI - Colorado
NWS	National Weather Service
OSPO	Office of Satellite and Product Operations
PLAR	Post-Launch Assessment Review
PLPT	Post-Launch Product Test
PLT	Post-Launch Test
PNG	Portable Network Graphics
POC	Point of Contact
PRO	Product Readiness and Operations
PSE	Program System Engineering
PS-PVR	Peer Stakeholder-Product Validation Review
PUG	Product User's Guide
QA	Quality Assurance
QC	Quality Control
RIMP	Readiness, Implementation and Management Plan
RMSE	Root Mean Square Error
RSR	TOA Reflected SW Radiation
SPOT	System Performance Operational Test
SRB	Shortwave Radiation Budget
STAR	Center for Satellite Applications and Research
SURFRAD	Surface Radiation Budget
SW	Shortwave
TBD	To Be Determined
TOA	Top Of Atmosphere
VIIRS	Visible Infrared Imaging Radiometer Suite