Geostationary Operational Environmental Satellite (GOES) – R Series

Magnetometer (MAG) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

July 2021

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SIGNATURE PAGE
Magnetometer Beta, Provisional and Full Validation
Readiness, Implementation and Management Plan (RIMP)

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Document Change Record
Magnetometer Beta, Provisional and Full Validation
Readiness, Implementation and Management Plan (RIMP)

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PREFACE

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 calibration and validation (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 science teams’ data and resource requirements. Cal/val testing is likely to reveal necessary algorithm and look-up table (LUT) changes to evolve the product quality through the maturity levels. The Algorithm Change Management Plan (ACMP) will be used to track and implement these software changes.

The evolving cal/val maturity of GOES-R products 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 GOES-R Level III requirement documents. Once Beta maturity of the L1b products is achieved, validation activities for Level 2+ (L2+) products can begin. 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 a brief description of the three maturity levels are:

**Beta:** the product is minimally validated based on product quick looks using the initial calibration parameters and may still contain significant errors. Product is made available to users to gain familiarity with data formats and parameters.

**Provisional:** product performance has been demonstrated through a select number of independent measurements and periods. The analysis is sufficient to communicate known product performance and issues to end users, and the product is ready for 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. The product is operational.

Product quality 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 GOES-16 and GOES-17 L1b products, Beta maturity PS-PVRs are held once each instrument’s Post-Launch Tests (PLTs) have been successfully completed by the GOES-R Flight Project and the instrument vendors. For GOES-18 and GOES-19, Beta maturity will leverage early PLT results and the performance and characterization needed for the first public image/data release. After an L1b product has achieved Beta maturity, the product is added to the GOES Rebroadcast (GRB) stream, so that operational users can begin familiarizing themselves with the product format and parameters. Beta PS-PVRs for ABI L2+ products were only held for GOES-16; for subsequent satellites, ABI L2+ Beta maturity is assumed when the L1b product is Beta due to the maturity of the

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Ground Processing Algorithms (GPAs). After an L1b or L2+ product has achieved Provisional maturity, the product is approved for distribution from Product Distribution and Access (PDA) and Comprehensive Large Array-data Stewardship System (CLASS). 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), National Weather Service (NWS), Calibration Working Group (CWG; L1b products) and/or Algorithm Working Group (AWG; L2+ products), NESDIS Office of Satellite Ground Services (OSGS), NESDIS Scientist, GOES-R Scientist, and GOES-R Product Readiness and Operations (PRO). The outcome of the PS-PVR is determined by the panel Chair. PS-PVR artifacts will be publicly available at https://www.noaasis.noaa.gov/GOES/product_quality.html.

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 Program System Engineering, the Flight Project and the Ground Segment. 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 RIMP’s validation maturity objective. Accountability describes which organization owns documentation, process, and procedures. Responsibility describes 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 is 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.**

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### Delineation of RIMP Execution Accountability

Accountability for RIMP changes at Operations Handover and is aligned with the level of product validation maturity within the RIMP.

#### Pre-Ops Handover

<table>
<thead>
<tr>
<th>GOES-R Accountability</th>
<th>CWG/AWG Accountability</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1b RIMP &amp; Product Maturity</td>
<td>Beta, Provisional</td>
</tr>
<tr>
<td>L2+ RIMP &amp; Product Maturity</td>
<td>Beta</td>
</tr>
<tr>
<td>L1b RIMP &amp; Product Maturity</td>
<td>Full</td>
</tr>
<tr>
<td>L2+ RIMP &amp; Product Maturity</td>
<td>Provisional, Full</td>
</tr>
</tbody>
</table>

#### Responsibilities

- **GOES-R PRO:** On behalf of GOES-R Program Systems Engineering, PRO is responsible for facilitating the preparation of RIMPs, including interactions between CWG/AWG and GOES-R Flight, Ground, etc., ensuring the CWG and AWG have the data necessary for PLPT analysis, and coordinating PS-PVRs.
- **Calibration Working Group (CWG):** CWG includes STAR, NASA MSFC & NCEI-CO and is responsible for providing data resources and content for L1b RIMPs, executing PLPT analyses, and presenting results at L1b PS-PVRs.
- **Algorithm Working Group (AWG):** Like CWG, AWG is responsible for providing data resources and content for L2+ RIMPs, executing PLPT analyses, and presenting results at L2 PS-PVRs.

Figure 2. Delineation of RIMP execution accountability between GOES-R and CWG/AWG.
1. MAG VALIDATION OVERVIEW

The GOES-R Series Magnetometer (MAG) provides magnetic field measurements with a temporal resolution 5 times greater (10 Hz) than that of the heritage GOES-NOP system. The GOES-R MAG system consists of 2 boom-mounted fluxgate magnetometers. The inboard MAG is located approximately 6.3 m from the baseplate of the boom, and an outboard magnetometer located at approximately 8.5 m from the baseplate of the boom. Measurements from both of these sensors are available to the user, though it may be preferable to use one sensor or a combination of the two sensors for the greatest data accuracy.

![Figure 3. Artistic representation of GOES-R with the magnetometer (MAG) location noted.](image)

The GOES-R Series MAG system on GOES-16 and GOES-17 consists of Macintyre Electronic Design Associates (MEDA)-constructed magnetometers provided by Lockheed Martin (LM). For GOES-T and GOES-U, Goddard Space Flight Center (GSFC)-provided magnetometers will be used. With this instrument vendor change, there will also be some changes to the telemetry data within Application IDs (APIIDs) 200 and 202, with subsequent changes needed to the Ground Processing Algorithm (GPA) code for converting L0 data to L1b data. Although the L1b data will look similar regardless of instrument vendor, if a particular model needs to be discussed, it will be referred to as MEDA MAG or GMAG, respectively. Otherwise, any references to “MAG” are applicable to both MAG systems.

This document describes the management and implementation of GOES-R MAG L1b Post-Launch Product Testing (PLPT). This document is focused on the PLPTs and all information pertinent to PLPT is documented here. Post-Launch Testing (PLT) is also discussed, as needed, but the detailed information is documented and configuration managed in various Flight documents, which are referenced in Section 6. There is additional information on PLTs in Appendix C (final approved list available in Operations Configuration Management System).

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PLT validates MAG calibration and qualitative and limited quantitative L1b product integrity. It also includes validation of Ground Segment (GS) calibration/L1b product processing and data storage, monitoring and distribution functions. During this time, operational calibration and L1b algorithms will be updated as necessary before system functioning would be considered nominal. Once this nominal state has been reached, PLPT begins which represents a continuation of the MAG L1b product science validation. It is also composed of further in-depth analysis of MAG calibration that establishes a beginning-of-life snapshot of MAG calibration in the satellite on-orbit environment. This snapshot can be used as an initial benchmark for long-term trending of MAG performance.

Only PLTs support MAG Beta maturity, and those tests are listed in Table 1 with details in Appendix C. The PLPTs required for Provisional and Full Validation are listed in Table 2 and Table 3, respectively, with each test’s details provided in Appendix A. Within each entry in Appendix A, the entry “Reference MRD” gives the reference numbers from the Mission Requirements Document (MRD). The performance baseline given by Massachusetts Institute of Technology – Lincoln Laboratory (MIT LL) demonstrates how these MRD requirements were verified pre-launch. The objective of the testing described in this RIMP is to determine through instrument and product characterization if the deliverable products satisfy their intended use in the intended environment, which also permits certification of the on-orbit performance against the pre-launch performance baseline. Therefore, the expectation is for the MAG science team at National Centers for Environmental Information – Colorado (NCEI-CO) to execute PLPTs necessary and sufficient to perform both objectives to the best of their ability. The references to specific MRD requirements are provided as justification for including each PLPT in the cal/val effort. These references are based on the analysis and recommendations of NCEI-CO, MIT LL and The Aerospace Corporation subject matter experts. The listing of MRD items does not fully enumerate the possible results from each PLPT, including those that may address other Performance Baseline results, but are the priority items according to the science teams. Due to the limitations of post-launch testing, it may be difficult, if not impossible, to characterize some products or product characteristics to the same precision and accuracy as the performance baseline.
Beta Maturity Activities

The PLTs that support Beta maturity are listed in Table 1. PLTs are led by the GOES-R Flight Project. PLT G*-C-MAG-001 is transitional, meaning it is initially assigned to Flight and then transitioned to NCEI-CO to continue the calibration activities for Mission Life.

For GOES-16 and GOES-17, all PLTs were run before a Beta PS-PVR was held to determine that the product had reached Beta maturity. For GOES-18 and GOES-19, the minimum criteria for MAG Beta product maturity – as agreed upon by a working group of Subject Matter Experts (SMEs) from CWG, Flight, and MIT LL – is that PLTs G*-E-MAG-002 through G*-E-MAG-005 are run.

Table 1. MAG PLTs that support Beta maturity in the GOES-R Series (16, 17, 18, and 19). Table also indicates which PLTs are transitional. The star (*) in each ID represents the satellite number (i.e., 16, 17, 18, or 19). Blue color denotes test was / will be done. Gray shading indicates test was not / will not be done, or is a reserve test.

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<th>17</th>
<th>18/19</th>
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<td>G*-C-MAG-001</td>
<td>GMAG Initial Bias and Alignment Calibration Maneuver</td>
<td>Yes</td>
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<td>G*-E-MAG-002</td>
<td>Goddard Magnetometer Health Check</td>
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<td>G*-E-MAG-004</td>
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<tr>
<td>G*-E-MAG-005</td>
<td>Magnetometer Thermal Sensitivity</td>
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Provisional Maturity Activities

The MAG PLPTs that support Provisional maturity are listed in Table 2 with test details in Appendix A. NCEI-CO has primary responsibility for execution of the PLPTs, unless otherwise specified in the test details. All Provisional PLPTs are required to be completed to proceed to Full maturity testing.

Table 2. MAG PLPTs that support Provisional Validation in the GOES-R Series (16, 17, 18, and 19). Purple color denotes test was / will be done.

<table>
<thead>
<tr>
<th>PLPT Test ID</th>
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<th>17</th>
<th>18/19</th>
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<td>PLPT-MAG-001</td>
<td>Comparison to quiet field models</td>
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<tr>
<td>PLPT-MAG-002</td>
<td>Cross-satellite intercalibration (low resolution 1 minute data)</td>
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<tr>
<td>PLPT-MAG-003</td>
<td>Noise Performance</td>
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</table>

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Full Maturity Activities

The PLPTs listed in Table 3 advance the MAG L1b product to Full maturity, and are extensions of the Provisional PLPTs with more testing time provided to add rigor to the Full Validation analysis of the product. Also, the Full Validation version of PLPT-MAG-002 uses the 10 Hz full resolution MAG L1b product in the test analysis. The Full Validation test details are described in Appendix A.

<table>
<thead>
<tr>
<th>PLPT Test ID</th>
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<td>PLPT-MAG-001</td>
<td>Comparison to quiet field models</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>PLPT-MAG-002*</td>
<td>Cross-satellite intercalibration (full resolution 10 Hz data)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PLPT-MAG-003</td>
<td>Noise Performance</td>
<td>✔</td>
<td>✔</td>
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</table>

*Continued into Full Validation phase for full resolution data validation

The validation processes and procedures, monitoring and analysis methods, tools, and expected output artifacts are described in the following sections. The details of each PLPT are contained in Appendix A and of each reference data set in Appendix B. The details of each PLT are in Appendix C and any tools used in the validation process are in Appendix D.
2. SCHEDULE OF EVENTS

Figure 4 shows the high level post-launch science product validation schedule\(^1\). The schedule for PLT is owned by the GOES-R Flight Project and under configuration management. The details should be expected to change up to Launch (L) and possibly even during the PLT period if major anomalies are found.

Once PLPT begins, MAG tests will be conducted simultaneously according to the criteria listed within each PLPT description (see Appendix A) for each maturity level. The historical and projected maturity schedules for MAG are summarized by satellite in Table 4.

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**Figure 4.** The post-launch science product validation schedule.

### Table 4. Post-launch science product validation schedule for MAG. The first column shows the nominal schedule in time from launch (L) plus months. The second column shows the same for days. The GOES columns with colored cells denote actual date, while the white cells denote expected date; the values in parentheses show L+days.

<table>
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<th>Nominal (days)</th>
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<th>GOES-17</th>
<th>GOES-18</th>
<th>GOES-19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>L+0</td>
<td>L+0</td>
<td>11/19/16 (L+0)</td>
<td>3/1/18 (L+0)</td>
<td>12/7/21</td>
<td>4/1/24</td>
</tr>
<tr>
<td>Boom Deploy</td>
<td>L+0.75</td>
<td>L+21</td>
<td>12/7/16 (L+18)</td>
<td>3/2/21 (L+21)</td>
<td>12/28/21</td>
<td>4/22/24</td>
</tr>
<tr>
<td>Beta</td>
<td>L+3.5</td>
<td>L+105</td>
<td>5/25/17 (L+187)</td>
<td>8/8/18 (L+160)</td>
<td>3/21/22</td>
<td>7/14/24</td>
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<tr>
<td>Provisional</td>
<td>L+6</td>
<td>L+180</td>
<td>8/29/18 (L+648)</td>
<td>3/14/19 (L+378)</td>
<td>6/7/22</td>
<td>10/1/24</td>
</tr>
<tr>
<td>Full</td>
<td>L+18</td>
<td>L+545</td>
<td>2/25/21 (L+1559)</td>
<td>2/25/21 (L+1092)</td>
<td>6/7/23</td>
<td>10/1/25</td>
</tr>
</tbody>
</table>

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\(^1\) See also the GOES-R Series Calibration and Product Validation Strategy (410-R-CALVAL-0192) section on the GOES-R Calibration and Product Validation Schedules.

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The following subsections describe the nominal MAG product schedule on the assumption that a satellite is going to Operations. The goal is for Beta and Provisional Validation to be completed before Handover at L+6 months, at which point the satellite will either go into Operations or storage mode.

2.1 BETA MATURITY TESTING

For GOES-16 and GOES-17 a Beta PS-PVR was held to show the results of the PLT activities and determine if the product demonstrates on-orbit performance adequate to begin detailed product testing. In lieu of a Beta PS-PVR, for GOES-18 and GOES-19 the results from a subset of PLTs will be used for a Beta Certification. A cross-collaborative working group, including the cal/val team, GOES-R Program, and the Flight vendor, have defined those PLTs as G*-E-MAG-002 through G*-E-MAG-005.

2.1.1 Beta Entrance Criteria:

Completion of launch, orbit raising, and boom deploy, expected by L+21 days. The MAG must be turned on and in nominal operational mode before boom deployment.

2.1.2 Duration of Beta Testing:

The Flight- and vendor-led PLT activities begin during the Beta phase and for GOES-16 and GOES-17 Beta maturity was achieved at L+187 and L+160 days, respectively. However, for GOES-18 and GOES-19 the prerequisites and activities leading up to the Beta maturity declaration will be streamlined and are expected to be achieved around L+105 days. Although Beta Certification will be given before all PLTs have been completed, the PLT activities will continue beyond this point into the PLPT period.

2.1.3 Beta Testing Artifacts:

The PLT reports will be generated by the Flight and vendor teams. These will be discussed at the Post Test Data Review (PTDR) meetings and stored on the GOES-R portal. There will be a summary report in the form of a README that will describe the instrument and L1b data status.

2.1.4 Exit Criteria and Readiness for Beta Certification:

The general criterion for Beta product maturity is that the product has demonstrated on-orbit performance adequate to begin detailed product testing. Specific criteria for completing the PLTs necessary for establishing Beta maturity are described in the PLT forms.
2.2 PROVISIONAL MATURITY TESTING

2.2.1 Provisional Entrance Criteria:

PLPT activities begin during Flight-led PLT activities - after the first public image release.

2.2.2 Duration of Provisional Testing:

Data collection for PLPTs must start as soon as the respective sensors are commanded into their nominal operating mode and during geomagnetically quiet conditions (Kp values based on GFZ indices) in order to achieve Provisional maturity prior to Handover. The target completion times for the MAG PLPTs are as follows:

- PLPT-MAG-001 – 7 quiet days (Kp ≤ 2)
- PLPT-MAG-002 – 7 quiet days (|Dst| ≤ 30 nT)
- PLPT-MAG-003 – 7 quiet days (Kp ≤ 2)

Note that all MAG PLPTs will be able to survive or otherwise ignore satellite configuration changes or any other interruption of the MAG data stream.

Provisional testing is scheduled for completion and the Provisional PS-PVR presented by L+180 days. In the event that less than the nominal amount of time for data collection is available beyond Beta Certification, the Provisional PS-PVR will still be held prior to L+180 days and the risks and caveats from those PLPTs that did not meet their success criteria must be described.

2.2.3 Provisional Testing Artifacts:

Output artifacts will be reported in weekly reports and provided to Calibration/Validation Coordination Team (CVCT) and other interested parties during the PLPT period as needed. A slide deck that documents the results of the Provisional PLPTs with tables and figures to substantiate the conclusions will be created. The success criteria for each individual Provisional PLPT are listed in the PLPT descriptions within Appendix A. There will also be a summary report in the form of a README that will describe the instrument and L1b data status.

2.2.4 Exit Criteria and Readiness for Provisional PS-PVR:

All PLPTs supporting Provisional Validation need to be summarized in a slide deck and presented at a PS-PVR prior to Handover.

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use
2.3 FULL MATURITY TESTING

2.3.1 Full Entrance Criteria:

Data are Provisionally mature. If the satellite has gone into storage immediately after Provisional Validation, Full maturity PLPTs will start after the satellite is moved out of storage location.

2.3.2 Duration of Full Testing:

One year of testing with Provisional data is the scheduled duration for Full maturity validation. During this Full testing period, the nominal target completion times for the Full PLPTs are as follows:

- PLPT-MAG-001 – 90 quiet days (Kp ≤ 2)
- PLPT-MAG-002 – 90 quiet days (|Dst| ≤ 30 nT)
- PLPT-MAG-003 – 90 quiet days (Kp ≤ 2)

2.3.3 Full Testing Artifacts:

A slide deck that documents the results of the Full PLPTs with tables and figures to substantiate the conclusions will be created. The success criteria for each individual Full PLPT are listed in the PLPT descriptions within Appendix A. There will also be a summary report in the form of a README that will describe the instrument and L1b data status.

2.3.4 Exit Criteria and Readiness for Full PS-PVR:

Product performance is defined, product is operationally optimized, and all known product anomalies are documented and shared with the user community. Full Validation is expected by L+545 days if the satellite is not placed into storage.

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use
3. ROLES AND RESPONSIBILITIES

The GOES-R Calibration/Validation Plan Volume 1: L1b Data (cal/val plan) is the governing document defining organizational responsibilities for GOES-R product testing, including the analysis, review, approval, and anomaly resolution processes required for product validation. The cal/val plan takes precedence over the following summary of specific PLT responsibilities.

GOES-18 and GOES-19 PLT assessments of MAG instrument functionality, non-nominal operations, and initial data quality are conducted by the MOST with instrument support by Flight. MAG will achieve Beta Validation during these early PLT assessments. Subsequent PLPT activities to advance product maturity to Provisional Validation involves detailed data analysis conducted under guidance of the NCEI-CO and GOES-R Program management by members of the cal/val team at NOAA, NASA, and industry. The roles and responsibilities of specific individuals and organizations during each satellite's PLT period are listed in Table 5 (names and affiliations subject to change).

Table 5. MAG roles and responsibilities.

<table>
<thead>
<tr>
<th>Role</th>
<th>GOES-16</th>
<th>GOES-17</th>
<th>GOES-18/19</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG PLPT Lead</td>
<td>Paul Loto’aniu (CIRES, NCEI); Backup: Rob Redmon (CIRES, NCEI)</td>
<td>Paul Loto’aniu (CIRES, NCEI); Backup: Samuel Califf (CIRES, NCEI)</td>
<td>Paul Loto’aniu (CIRES, NCEI)</td>
</tr>
<tr>
<td>GOES-R Product Quality Lead</td>
<td>Jon Fulbright (PRO)</td>
<td>Elizabeth Kline (PRO)</td>
<td>Elizabeth Kline (PRO)</td>
</tr>
<tr>
<td>Ground Segment</td>
<td>Jon Fulbright (PRO); Alternate: Elizabeth Kline (PRO)</td>
<td>Jon Fulbright (PRO); Alternate: Elizabeth Kline (PRO)</td>
<td>Jon Fulbright (PRO); Alternate: Elizabeth Kline (PRO)</td>
</tr>
<tr>
<td>Product Readiness and Operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cal/Val Coordination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLT Test Engineer(s)</td>
<td>Melissa Dahya (MOST)</td>
<td>Melissa Dahya (MOST)</td>
<td>Michael Otero (MOST)</td>
</tr>
</tbody>
</table>
| MAG Product Quality Feedback        | William Denig (NCEI); Backup: William Rowland (CIRES, NCEI), Paul Loto’aniu (CIRES, NCEI) | William Rowland (CIRES, NCEI); Backup: Paul Loto’aniu (CIRES, NCEI) | William Rowland (CIRES, NCEI); Backup: Paul Loto’aniu (CIRES, NCEI) |}

Check the GOES-R Portal at [https://goesportal.ndc.nasa.gov](https://goesportal.ndc.nasa.gov) to verify correct version prior to use
4. TOOLS

For MAG, the primary analysis and monitoring tools to be used by NCEI-CO for PLT/PLPT analysis are the MAG Calibration Analysis Software Package (CASP) and other in-house Python tools. CASP integrates pieces of the other PLT and PLPT tools developed in-house by NCEI-CO and provides a very simple GUI that can be added to as needed. CASP provides simple time series plotting of L0 and L1b MAG and (subsetted) spacecraft housekeeping data.

Vendor tools are provided for analysis during PLT and into mission life. LM is responsible for the GOES-16 and GOES-17 tools, and the GOES-R Flight Project is responsible for any new tools needed for GOES-18 and GOES-19. LM has handed over a MEDA MAG GPA code (L0 to L1b) to NCEI-CO. This GPA tool will need to be adjusted prior to GOES-T launch to account for changes in GMAG data. The GOES-R Flight Project has handed over the Calibration Maneuver Analysis Matlab software for use with the transitional PLT G*-C-MAG-001 for mission life testing of GMAG. More tool details are given in Appendix D.
5. PRE-LAUNCH

The major pre-launch activities for GOES-18 and GOES-19 are the Data Operations Exercises (DOEs). DOEs are operational rehearsal exercises of the data operations segment of the Product Generation (PG)/Product Distribution (PD) to demonstrate incremental readiness towards launch. For MAG, the DOEs are used mostly to validate the data flows rather than exercise the functionality of the L1b algorithms and PLPT analysis tools. The DOEs will run live data from either GOES-EAST or GOES-WEST through a GOES-18 or GOES-19 configured GS. To mitigate risks, inconsistencies in the format and content of each L1b test product will be noted and tracked within the Algorithm Action Review Team (AART). In addition, NCEI-CO will test their software tools with the L1b test product from the DOEs as well as their own L1b proxy data.
6. REFERENCES

The following government documents have information relevant to this RIMP document. Unless otherwise noted, all documents with a “410-R” or “417-R” prefix are located in the GOES-R Library (in the Windchill repository). All other program documents can be found in the GOES-R Program Portal at [https://goesportal.ndc.nasa.gov/](https://goesportal.ndc.nasa.gov/).

Unless otherwise noted, the current versions of the following documents apply.

- 410-R-CALVAL-0192, GOES-R Series Calibration and Product Validation Strategy
- 410-R-CONOPS-0008, GOES-R Series Concept of Operations (CONOPS)
- 410-R-MRD-0070, GOES-R Series Mission Requirements Document (MRD)
- 410-R-PLN-0101, GOES-R Series Calibration/Validation Plan Volume 1: Level 1b Data
- 417-R-PLN-0246, GOES-R Series Post-Launch Testing (PLT) Plan
- GOES-R PLT and Active PLPT Forms on the GOES-R Program Portal:
  Repository > 01 GOES R > 02 GOES R - Flight Project > 04 Mission Operations > 900 CM Docs > 935 PLT - GOES-R
  Repository > 01 GOES R > 02 GOES R - Flight Project > 04 Mission Operations > 900 CM Docs > 936 PLT - GOES-S
  Repository > 01 GOES R > 02 GOES R - Flight Project > 04 Mission Operations > 900 CM Docs > 937 PLT - GOES-T
- GOES-R Passive L1b PLPT Forms on the GOES-R Program Portal:
  Repository > 01 GOES R > 02 GOES R - Flight Project > 04 Mission Operations > PLT > GOES-18 Passive PLPT forms

Check the GOES-R Portal at [https://goesportal.ndc.nasa.gov/](https://goesportal.ndc.nasa.gov/) to verify correct version prior to use.
A. APPENDIX A: POST-LAUNCH PRODUCT TESTS

Unless otherwise noted in the individual test description, each PLPT is performed for each satellite of the GOES-R Series, and the point of contact (POC) is the MAG PLPT Lead (see Table 5).

A.1 PLPTs that support BETA maturity

None – only PLTs support Beta maturity.

A.2 PLPTs that support PROVISIONAL maturity

A.2.1 Comparison to quiet field models [PLPT-MAG-001]

Objective: Validate MAG L1b product for geomagnetically quiet conditions (Kp ≤ 2) by comparing to accepted models of the Earth's internal plus external magnetospheric field.

Reference MRD: 2019

Start Time: Beginning of PLPT

Duration: 7 days (need not be contiguous)

Mode: Normal

GOES-R Data Type(s): Spacecraft subsystems data, metadata, MAG L0 and geomagnetic field L1b (L1b-GEOF; including spacecraft location)

Provisional Success Criteria: The data are successfully read from the instrument and downlinked to the Ground System; Data used are from geomagnetically quiet periods (Kp ≤ 2); Data used should be taken no further than ± 2 hours from local magnetic noon; Data used are from times that the arcjet is not in operation; once analyzed, the data demonstrate that MAG measurements are close to magnetic field model values. Data volume required for product validation: 7 days (need not be contiguous), where on each day there is at least one 3 hour interval of continuous quiet (Kp ≤ 2) activity. Hence, 3 hours from each day will be used for validation.

Dependencies: See success criteria. Data can be collected as soon as instrument is turned on, but results are formalized after completion of PLTs G*-C-MAG-001 and G*-E-MAG-005.


Comparison/Reference Data: Quiet field model data.

Monitoring & Analysis Method: Time-series analysis comparing GOES-R Series MAG with quiet field model along spacecraft (s/c) trajectory. Scatter plot comparisons.

Tools Needed: MAG CASP

A.2.2 Cross-satellite intercalibration (1 min data) [PLPT-MAG-002]

Objective: Validate MAG L1b product by comparing it to operational GOES-R Series (primary comparison), other GOES (if available and necessary), and non-GOES (if necessary) in situ Magnetometer measurements.

Reference MRD: 2019

Start Time: Beginning of PLPT

Check the GOES-R Portal at [https://goesportal.ndc.nasa.gov](https://goesportal.ndc.nasa.gov) to verify correct version prior to use
Duration: 7 days (need not be contiguous)
Mode: Normal
GOES-R Data Type(s): Spacecraft subsystems data, metadata, MAG L0 and L1b-GEOF (including spacecraft location)

Provisional Success Criteria: The data are successfully read from the instrument and downlinked to the Ground System; Other spacecraft less than or equal to 1.0 earth radii in radial distance from the GOES-R Series satellite and three hours or less in local time from the GOES-R Series satellite; Geomagnetically quiet period (|Dst| ≤ 30 nT); Data used are from times that the arcjet is not in operation; Once analyzed, the data demonstrate that MAG observations are consistent with other spacecraft observations. Data volume required for product validation: 7 days (need not be contiguous).

Dependencies: See success criteria. Data can be collected as soon as instrument is turned on, but results are formalized after completion of PLTs G*-C-MAG-001 and G*-E-MAG-005.

Comparison/Reference Data: Nearby spacecraft magnetometer measurements.
Monitoring & Analysis Method: Technique of Tsyganenko et al., 2005. Time-series analysis of trending parameters and MAG data alongside of other s/c data. Scatter plot comparisons.
Tools Needed: MAG CASP

A.2.3 Noise Performance [PLPT-MAG-003]
Objective: Determine the noise level of the product and compare it to the MRD values of no more than 0.3 nT on each axis.
Reference MRD: 2019
Start Time: Beginning of PLPT
Duration: 7 days (need not be contiguous)
Mode: Normal
GOES-R Data Type(s): Spacecraft subsystems data, metadata, MAG L0 and L1b-GEOF (including spacecraft location)

Provisional Success Criteria: The success criteria is that the noise level of the product has been determined during times that the arcjet is not in operation and compared to 0.3 nT requirement. Data used are from geomagnetically quiet periods (Kp ≤ 2).

Dependencies: See success criteria.
Procedural References: Similar analysis to Loto’aniu et al., 2019
Comparison/Reference Data: Data from previous GOES and results in Loto’aniu et al., (2019)
Monitoring & Analysis Method: Similar analysis to Loto’aniu et al., 2019
Tools Needed: MAG CASP, In-house Python tools
A.3 PLPTs that support FULL VALIDATION maturity

A.3.1 Comparison to quiet field models [PLPT-MAG-001]

Unless otherwise noted below, see the Provisional test description for PLPT-MAG-001.

**Duration:** 90 days (need not be contiguous)

**Full Success Criteria:** The data are successfully read from the instrument and downlinked to the Ground System; Data used are from geomagnetically quiet (Kp ≤ 2) periods; Data used should be taken no further than ± 2 hours from local magnetic noon; Data used are from times that the arcjet is not in operation, and the test is repeated for inclusion of arcjet firing periods; Once analyzed, the data demonstrate that MAG measurements are close to magnetic field model values. Data volume required for product validation: 90 days (need not be contiguous), where on each day there is at least one 3 hour interval of continuous quiet (Kp ≤ 2) activity. Hence, 3 hours from each day will be used for validation.

A.3.2 Cross-satellite intercalibration (full resolution data) [PLPT-MAG-002]

**Objective:** Validate MAG L1b product by comparing it to operational GOES-R Series (primary comparison), other GOES (if available and necessary), and non-GOES (if necessary) in situ magnetometer measurements.

**Reference MRD:** 2019, 2022

**Start Time:** Beginning of PLPT

**Duration:** 90 days (need not be contiguous)

**Mode:** Normal

**GOES-R Data Type(s):** Spacecraft subsystems data, metadata, MAG L0 and L1b-GEOF (including spacecraft location)

**Full Validation Success Criteria:** The data are successfully read from the instrument and downlinked to the Ground System; Other spacecraft less than or equal to 1.0 earth radii in radial distance from GOES-R and three hours or less in local time from GOES-R; Geomagnetically quiet period (|Dst| ≤ 30 nT); Data used are from times that the arcjet is not in operation, and the test is repeated for inclusion of arcjet firing periods; Once analyzed, the data demonstrate that MAG observations are consistent with other spacecraft observations. Data volume required for product validation: 90 days (need not be contiguous).

**Dependencies:** See success criteria

**Procedural References:** Similar to analysis in Tsyganenko 2005.

**Comparison/Reference Data:** Nearby spacecraft magnetometer measurements.

**Monitoring & Analysis Method:** Technique of Tsyganenko et al., 2005; time-series analysis.

**Tools Needed:** MAG CASP
A.3.3 Noise Performance [PLPT-MAG-003]

Unless otherwise noted below, see the Provisional test description for PLPT-MAG-003.

**Objective:** Determine the noise level of the product, possible sources and possible corrections algorithms to meet 0.3 nT MRD requirement.

**Duration:** 90 days (need not be contiguous)

**Full Success Criteria:** The success criteria is that the noise level of the product has been determined during times that the arcjet is not in operation and compared to 0.3 nT requirement. The noise level is also determined during times the arcjet is in operation to evaluate the effectiveness of the arcjet signature removal. Results determine a path forward to any correction algorithm. Data used are from geomagnetically quiet periods (Kp ≤ 2).
B. APPENDIX B: GOES-R SERIES AND VALIDATION REFERENCE

DATA

B.1 Data set 1: Name: GOES-R MAG L0
Storage Location: Level Zero Storage Service (LZSS)
Access Process: Environmental Satellite Processing Center (ESPC) subscription/
Satellite Product Analysis and Distribution Enterprise System (SPADES)
Spatial Coverage: Magnetic field at spacecraft
Temporal Cadence: Full resolution reconstructed unprocessed MAG data, and
engineering and diagnostic data along with their instrument calibration parameters, Orbit
and Attitude (O&A)/Angular Rate (OAR) telemetry data, containing orbit ephemeris and
satellite position extracted from selected telemetry packets.
and GOES-17 only)
Special Considerations: MAG L0 contains s/c attitude (in APID 202).

B.2 Data set 2: Name: GOES-R MAG L1b
Storage Location: LZSS/PDA
Access Process: ESPC subscription/SPADES
Spatial Coverage: Magnetic field at spacecraft
Temporal Cadence: 10 Hz (instrument)
Contingency: CLASS
Special Considerations: None

B.3 Data set 3: Name: GOES-R location
Storage Location: Mission Management Flight Ready (MMFR) at NOAA Satellite
Operations Facility (NSOF)
Access Process: electronic GOES-R Export Service (eGRES)
Spatial Coverage: N/A
Temporal Cadence: Ephemeris cadence
Contingency: LM
Special Considerations: None

B.4 Data set 4: Name: GOES-R subsystems (MAG temp, RU calibration current, heaters,
temps)
Storage Location: LZSS
Access Process: ESPC subscription/SPADES
Spatial Coverage: N/A
Temporal Cadence: Housekeeping cadence
Contingency: None
Special Considerations: None

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use
B.5 **Data set 5:** Name: GOES-R command log (from MOST)  
**Storage Location:** MMFR@NSOF  
**Access Process:** eGRES  
**Spatial Coverage:** N/A  
**Temporal Cadence:** At cadence of command logs as defined by the MOST team.  
**Contingency:** None  
**Special Considerations:** None

B.6 **Data set 6:** Name: LM spacecraft dipole  
**Storage Location:** LM, NCEI  
**Access Process:** Internal to NCEI-CO  
**Spatial Coverage:** N/A  
**Temporal Cadence:** When the MAG calibration table is updated  
**Contingency:** None  
**Special Considerations:** None

B.7 **Data set 7:** Name: LM sims (spacecraft model)  
**Storage Location:** LM, NCEI  
**Access Process:** Internal to NCEI-CO  
**Spatial Coverage:** N/A  
**Temporal Cadence:** Upon sims software update  
**Contingency:** None  
**Special Considerations:** None

B.8 **Data set 8:** Name: Heritage GOES MAG data  
**Storage Location:** NCEI archives  
**Access Process:** Publicly available via FTP  
**Spatial Coverage:** all MLT  
**Temporal Cadence:** 2010apr – 2017dec (G13); 2011dec – 2020mar (G15)  
**Contingency:** None  
**Special Considerations:** Used for GOES-16 and GOES-17 PLT only

B.9 **Data set 9:** Name: Geomagnetic activity  
**Storage Location:** NASA  
**Access Process:** https://cdaweb.gsfc.nasa.gov/index.html/  
**Spatial Coverage:** N/A  
**Temporal Cadence:** N/A  
**Contingency:** None  
**Special Considerations:** None

Check the GOES-R Portal at [https://goesportal.ndc.nasa.gov](https://goesportal.ndc.nasa.gov) to verify correct version prior to use
B.10 Data set 10: Name: Field model data (Op77, T89, Ts04)
   Storage Location: N/A (generated on demand from Data Set 9)
   Access Process: Public
   Spatial Coverage: Any orbit
   Temporal Cadence: ~5 minutes
   Contingency: None
   Special Considerations: None

B.11 Data set 11: Name: Nearby s/c data
   Storage Location: Stored locally at NCEI-CO as needed
   Spatial Coverage: Varies
   Temporal Cadence: Varies
   Contingency: None
   Special Considerations: None

B.12 Data set 12: Name: MVTDS – synthetic science: LL modified MAG data employing MAG vendor simulated data
   Storage Location: On-hand at NCEI-CO
   Access Process: On-hand at NCEI-CO
   Spatial Coverage: 11-13 MLT
   Temporal Cadence: 2 hours; decimated; quiet and storming
   Contingency: N/A
   Special Considerations: Used for GOES-16 and GOES-17 tests only

B.13 Data set 13: Name: MVTDS – ETE3: TVAC; saturated
   Storage Location: On-hand at NCEI-CO
   Access Process: On-hand at NCEI-CO
   Spatial Coverage: N/A
   Temporal Cadence: 2 hours
   Contingency: N/A
   Special Considerations: Used for GOES-16 and GOES-17 tests only
C. APPENDIX C: PLT DETAILS

Approved final list and details can be found in the individual PLT forms. The list is repeated here for convenience and is not necessarily the final approved list. The stars (*) in the Test IDs are place holders for the GOES-R Series satellite number (i.e., 16, 17, 18, or 19). Note that some PLTs are updated with GMAG-specific instrument capabilities in mind, and thus the below PLT summaries have been updated accordingly; however, older versions of these PLTs were done for MEDA MAG if GOES-16 or GOES-17 is listed in the “Required for satellites” lines.

C.1 Test ID: G*-C-MAG-001
*Required for satellites: 16, 17, 18, 19
Test Name: GMAG Initial Bias and Alignment Calibration Maneuver
Test Duration: 04:30 (hh:mm) total execution time with 82 minutes of spacecraft slews on two days and 04:00 (hh:mm) total execution time with 54 minutes of spacecraft slews on one day; Analysis will take 1 week per test.
Objective: Measure the magnetic field on the X-, Y-, Z-axes sensors of the GMAG IB and GMAG OB sensors during the calibration maneuver to determine the zero-offset for each fluxgate in each magnetometer and update the values, if needed. Also use the measurements to determine IB/OB misalignments.
Success Criteria: (1) Zero-offsets for each magnetometer have been determined. (2) Zero-offset in Ground Processing Algorithm (GPA) updated, if needed.
Prerequisites/Dependencies: Spacecraft magnetic field should remain constant during the time period, meaning that systems with a large magnetic signature (e.g., arcjets) must not be used during the calibration slews. No major spacecraft mode/configuration changes should occur during the test. Cannot be performed during an eclipse. Ambient magnetic field should be quiet ($Kp \leq 2$, $Dst$ close to zero nanoTesla) and constant during the maneuver. Data should be centered around Noon in Magnetic Local Time. See PLT form for additional prerequisites and dependencies.
Data Requirements: MAG L1b data extracted from LZSS during PLT and from PDA for future calibrations. Flight will analyze data using existing Flight tools. NCEI-CO will process post-Handover maneuvers using Flight-delivered tools.

C.2 Test ID: G*-E-MAG-002
*Required for satellites: 16, 17, 18, 19
Test Name: Goddard Magnetometer Health Check
Test Duration: 6 minutes. Analysis will take 2 weeks.
Objective: The Goddard Magnetometer integrated into the GOES-18 spacecraft provides the functionality to place a known incremental step on all axes of a specified sensor. These values are preconfigured and not intended to represent the full range of expected on orbit magnetic field values.
Success Criteria: The effect of the calibration pulses is registered in all 3 axes of the sensor and is in family with pre-launch ground testing.
Prerequisites/Dependencies: Both Mags are on and in normal operations. No major observatory configuration changes may occur during the GMAG Health Test.

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use.
Data Requirements: Flight Project will extract magnetometer counts and use CASSIE or Matlab to plot for comparison to ground measurements.

C.3 Test ID: G*-E-MAG-003
*Required for satellites: 16, 17, 18, 19
Test Name: Magnetometer Sensitivity to Interference
Test Duration: Passive Test performed over duration of Observatory Activation; Analysis will take 2 months.
Objective: Quantify magnetic field changes for all three axes of each magnetometer due to satellite time-varying and constant fields.
Success Criteria: Once analyzed, the data demonstrate that no stray fields greater than the magnetometer noise level were observed at the magnetometers or do not exceed predicted values.
Prerequisites/Dependencies: Ensure Mag sensors are in Normal Ops mode
Data Requirements: GOES-R Flight Project performs the analysis on raw magnetometer data in coordination with NCEI-CO.

C.4 Test ID: G*-E-MAG-004
*Required for satellites: 16, 17, 18, 19
Test Name: GMAG sensor difference comparison
Test Duration: 24 hours (repeat daily – 3 month period); Analysis will take 6 weeks.
Objective: GOES MAG sensor difference comparison, MAG sensor ratio comparison.
Success Criteria: Processing L1b data shows inboard and outboard MAG observations are within family with each other. For uncalibrated (neither factory nor on-orbit bias applied) the initial difference for each axis is expected to be: -8 < (OBx - IBx) < 4 nT; -7 < (OBy + IBy) < 5 nT; -6 < (OBz + IBz) < 6 nT. The ratio of absolute value of magnitude of OB/IB is expected to be within 0.90 and 1.1. The change in difference should not exceed +/- 2 nT per axis from the 24 hour average of the daily difference.
Prerequisites/Dependencies: Both MAGs are in nominal operational mode. Observatory subsystems are powered.
Data Requirements: GMAG Flight performs the analysis on raw magnetometer data using CASSIE. Difference plots will be included in daily trending items.

C.5 Test ID: G*-E-MAG-005
*Required for satellites: 18, 19
Test Name: Magnetometer Thermal Sensitivity
Test Duration: At least 24 hours for each temperature step (10 total days of data collection); Analysis will take 3 weeks.
Objective: Quantify the bias due to temperature set point variations independently for the inboard and outboard magnetometers.
Success Criteria: Once analyzed, the data demonstrate that the variation in the bias as a function of temperature is less than or equal to the allowable variation in the error budget (0.5 nT) over the actual observed on-orbit temperature variation.
Prerequisites/Dependencies: Ensure Mag sensors are in Normal Ops mode. The temperature switch commanding should be executed +/- 2 hours centered around SLT.

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use.
1200, and should be executed in such a way as to avoid significant activities that will affect the magnetic field readings (i.e. Augmented AJT firings) around that time.

**Data Requirements:** GOES-R Fight Project performs the analysis on raw magnetometer data using CASSIE or Matlab.
D. APPENDIX D: TOOLS

D.1 Tool #1: MAG Calibration Analysis Software Package (CASP)
Location: NCEI-CO
Description: CASP integrates pieces of other PLT and PLPT tools developed by NCEI-CO and provides a very simple GUI that will be added to as needed. CASP provides simple time series plotting of L0 and L1b MAG and (subsetted) spacecraft housekeeping data.
Developer: Paul Loto’aniu, Rob Redmon, William Rowland (NCEI-CO).
Development schedule & handover plan: Development complete. In-house tool, so no handover necessary.
Data Dependencies: GOES-R Data: Spacecraft subsystems data, metadata, MAG L0 and L1b-GEOF (including spacecraft location and attitude), LM spacecraft dipole, command log. Non-GOES-R Data: Previous GOES (e.g., NOP) and nearby spacecraft data; Field model data (Tsyganenko, IGRF, OP77Q); LM simulations; geomagnetic activity.
Testing accomplished or planned: Testing complete.
POC: NCEI-CO

D.2 Tool #2: Vendor Ground Processing Algorithm (GPA) code (L0 to L1b)
Location: LM, NCEI-CO
Description: Offline implementation of the L0 to L1b processing code.
Developer: LM
Development schedule & handover plan: Vendor tool was handed over.
Data Dependencies: MAG L0 and CDRL079 input.
Testing accomplished or planned: Code has been tested.
POC: NCEI-CO

D.3 Tool #3: Calibration Maneuver Analysis Matlab software
Location: GSFC, NCEI-CO
Description: Analyze MAG calibration maneuver and provide bias and alignment updates.
Developer: Derrick Early, Michael Grotenhuis, Delano Carter (GOES-R Flight Project)
Development schedule & handover plan: Tool was handed over from Flight to NCEI-CO in September 2020.
Data Dependencies: LUT with calibration data, MAG L1b data that encompasses the MAG calibration maneuver from PLT G*-C-MAG-001
Testing accomplished or planned: GSFC testing complete. NCEI-CO testing is planned to take place during 2021.
POC: GOES-R Flight Project

Check the GOES-R Portal at https://goesportal.ndc.nasa.gov to verify correct version prior to use
E. APPENDIX E: ACRONYMS

The acronym list below covers a select set of acronyms associated with MAG and general GOES-R procedures. To see a more comprehensive list of acronyms used within the GOES-R Program, see the GOES-R Series Acronyms webpage at https://www.goes-r.gov/resources/acronyms.html.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AART</td>
<td>Algorithm Action Review Team</td>
</tr>
<tr>
<td>ACMP</td>
<td>Algorithm Change Management Plan</td>
</tr>
<tr>
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