

Geostationary Operational Environmental Satellite–R Series: Program Success Requires Added Attention to Oversight, Risk Management, Requirements, and the Life-Cycle Cost Estimate

FINAL REPORT NO. OIG-19-022-A
AUGUST 12, 2019



U.S. Department of Commerce
Office of Inspector General
Office of Audit and Evaluation



August 12, 2019

MEMORANDUM FOR: Dr. Neil Jacobs
Assistant Secretary of Commerce for Environmental Observation
and Prediction, Performing the Duties of Under Secretary of
Commerce for Oceans and Atmosphere
National Oceanic and Atmospheric Administration

A handwritten signature in black ink, appearing to read "F. Meny, Jr." with a stylized flourish at the end.

FROM: Frederick J. Meny, Jr.
Assistant Inspector General for Audit and Evaluation

SUBJECT: *Geostationary Operational Environmental Satellite–R Series:
Program Success Requires Added Attention to Oversight, Risk
Management, Requirements, and the Life-Cycle Cost Estimate
Final Report No. OIG-19-022-A*

Attached for your review is our final report on the audit of the National Oceanic and Atmospheric Administration's (NOAA's) Geostationary Operational Environmental Satellites-R (GOES-R) series. Our primary objective was to assess the adequacy of the GOES-R program's satellite development and testing, and the transition of launched satellites into operations. Our second objective was to monitor the program's progress on contracting actions and changes to minimize cost increases.

For our first objective, we identified inadequacies in the development, testing, and operations of the satellites. For our second objective, we found that the program's life-cycle cost will increase due to the complexities of its ground system technical refresh. Specifically, we identified the following:

- I. Advanced Baseline Imager issues highlight the need for increased oversight in technical, programmatic, and contractual areas.
- II. GOES-R series magnetometers are less accurate than the previous series, revealing opportunity for NOAA to refine its threshold requirement.
- III. The GOES-R program did not identify and manage risk to the availability of GOES-East and GOES-West orbital positions.
- IV. Ground system server replacement will increase the program's life-cycle cost and presents risk management challenges.

On July 15, 2019, OIG received NOAA's response to the draft report. NOAA agreed with all recommendations, noting that it has either already implemented, or is in the process of implementing, corrective action to address OIG's recommendations.

Pursuant to Department Administrative Order 213-5, please submit to us an action plan that addresses the recommendations in this report within 60 calendar days. This final report will be posted on OIG's website pursuant to sections 4 and 8M of the Inspector General Act of 1978, as amended (5 U.S.C. App., §§ 4 & 8M). We appreciate the cooperation and courtesies

extended to us by your staff during our audit. If you have any questions or concerns about this report, please contact me at (202) 482-1931 or Kevin Ryan, Director for Audit and Evaluation, at (202) 695-0791.

Attachment

cc: Benjamin Friedman, Deputy Under Secretary for Operations, NOAA
Stephen Volz, Assistant Administrator for Satellite and Information Services, NOAA
Rhonda Lawrence, Audit Liaison, NOAA



Report in Brief

August 12, 2019

Background

National Oceanic and Atmospheric Administration's (NOAA's) Geostationary Operational Environmental Satellites-R (GOES-R) series is NOAA's latest generation of weather satellites that orbit in space at a speed matching the Earth's rotation, allowing them to maintain fixed positions above the Western Hemisphere.

The GOES-R program is a collaboration between NOAA and the National Aeronautics and Space Administration (NASA). NOAA provides funding and is responsible for overall program integration, management, and operational mission success. It defines program requirements, is responsible for acquisition of the ground segment, and performs mission operations. NASA oversees the acquisition of the spacecraft, instruments, and launch vehicles, and manages the launches of the satellites.

The program consists of two launched satellites—GOES-16 and GOES-17—as well as two satellites that are under development: GOES-T and GOES-U. GOES-R series satellites are lettered until successfully reaching orbit, and then designations are converted to numbers (GOES-R and GOES-S were designated as GOES-16 and GOES-17, respectively, once they reached orbit).

Why We Did This Review

Our primary objective was to assess the adequacy of the GOES-R program's satellite development and testing, and the transition of launched satellites into operations. Our second objective was to monitor the program's progress on contracting actions and changes to minimize cost increases.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Geostationary Operational Environmental Satellite–R Series: Program Success Requires Added Attention to Oversight, Risk Management, Requirements, and the Life-Cycle Cost Estimate

OIG-19-022-A

WHAT WE FOUND

We identified inadequacies in the development, testing, and operations of the satellites, specifically:

1. ABI issues highlight the need for increased oversight in technical, programmatic, and contractual areas.
2. GOES-R series magnetometers are less accurate than the previous series, revealing opportunity for NOAA to refine its threshold requirement.
3. The GOES-R program did not identify and manage risk to the availability of GOES-East and GOES-West orbital positions.
4. Ground system server replacement will increase the program's life-cycle cost and presents risk management challenges.

We found potential monetary benefits of \$284,440,445 related to the fourth finding.

In an "Other Matter" section, we found that processes for reserving orbital positions may not be adequate to meet demands of an increasing number of satellites.

WHAT WE RECOMMEND

We recommend that the Assistant Administrator for Satellite and Information Services

1. Ensure the GOES-R program addresses anomalies on instruments fulfilling essential mission requirements using a distinct process that is proportional to the criticality of a key performance parameter.
2. Ensure an independent review of changes to the ABI contract's PEP occurs to determine their rationale, appropriateness, and need for further actions.
3. Ensure the GOES-R program updates reliability analyses for ABI, the satellite, and constellation, specifically given the unique conditions of the hardware on GOES-16 and GOES-17 and any design changes for GOES-T and GOES-U.
4. Ensure the GOES-R program documents its magnetometer design, integration, and on-orbit experience so that it is available to future GOES programs and contractors.

We recommend that the Deputy Under Secretary for Operations

5. Ensure that NOAA conducts analysis to determine distinct geomagnetic field measurement accuracy threshold and objective requirement specifications and ensure appropriately supported requirements are reflected in GOES-R program documents.
6. Ensure the NOAA Space Weather Prediction Center updates its geomagnetic field observation accuracy requirement validation documentation.
7. Ensure NOAA assesses whether GOES are the optimal satellites to achieve geomagnetic field observation requirements, using an analysis of alternatives or similar cost-benefit approach.

We recommend that the Assistant Administrator for Satellite and Information Services

8. Ensure that the GOES-R program formally manages risk to geostationary orbital positions for both current and future satellite programs.
9. Ensure the GOES-R program updates its LCCE incorporating results from Department's independent assessment.
10. Ensure the GOES-R program completes a prioritized list of off-ramps with triggering dates for server replacement activities.
11. Ensure the GOES-R program develops a plan to limit the risk of vendor lock-in for ground system sustainment.

Contents

Introduction 1

Objectives, Findings, and Recommendations..... 3

I. ABI Issues Highlight Need for Increased Oversight in Technical, Programmatic, and Contractual Areas..... 3

A. Program’s actions to address integration and test anomalies for ABI were not sufficient to reduce risk for a KPP instrument.....4

B. After the occurrence of ABI anomalies, the program removed contract performance evaluation criteria that would have lowered its evaluations of on-orbit performance5

C. Thermal anomaly affects the reliability of ABIs, the satellites, and the availability of GOES imagery and data.....7

Recommendations..... 7

II. GOES-R Series Magnetometers Are Less Accurate Than Previous Series, Revealing Opportunity for NOAA to Refine its Threshold Requirement..... 8

A. GOES-R series magnetometer data are less accurate than previous GOES series9

B. NOAA’s threshold accuracy requirement needs refinement and relevant validation..... 10

Recommendations..... 11

III. The GOES-R Program Did Not Identify and Manage Risk to the Availability of GOES-East and -West Orbital Positions..... 11

Recommendation 12

IV. Ground System Server Replacement Will Increase the Program’s Life-Cycle Cost and Presents Risk Management Challenges..... 13

A. Program life-cycle cost estimate does not reflect current technical and programmatic assumptions 13

B. Ground system server replacement effort will reduce hardware and increase virtualization, but program needs to mitigate cost, schedule, and performance risks 15

C. Risk of vendor lock-in for ground system contracts requires attention..... 17

Recommendations..... 18

Other Matter 19

Processes for Reserving Orbital Positions May Not Be Adequate to Meet Demands of an Increasing Number of Satellites..... 19

Summary of Agency Response and OIG Comments..... 21

Appendix A: Objectives, Scope, and Methodology 22

Appendix B: Comparison of On-Orbit Performance Evaluation Criteria for ABI 25

Appendix C: Potential Monetary Benefits 27

Appendix D: Agency Response 28

Cover: Herbert C. Hoover Building main entrance at 14th Street Northwest in Washington, DC. Completed in 1932, the building is named after the former Secretary of Commerce and 31st President of the United States.

Introduction

National Oceanic and Atmospheric Administration's (NOAA's) Geostationary Operational Environmental Satellites-R (GOES-R) series is NOAA's latest generation of weather satellites that orbit in space at a speed matching the Earth's rotation, allowing them to maintain fixed positions above the Western Hemisphere.

The GOES-R program is a collaboration between NOAA and the National Aeronautics and Space Administration (NASA). NOAA provides funding and is responsible for overall program integration, management, and operational mission success. It defines program requirements, is responsible for acquisition of the ground segment, and performs mission operations. NASA oversees the acquisition of the spacecraft, instruments, and launch vehicles, and manages the launches of the satellites.

The program consists of two launched satellites—GOES-16 and GOES-17—as well as two satellites that are under development: GOES-T and GOES-U. GOES-R series satellites are lettered until successfully reaching orbit, and then designations are converted to numbers (GOES-R and GOES-S were designated as GOES-16 and GOES-17, respectively, once they reached orbit).¹

Instruments discussed in this report

GOES-R series satellites have advanced instruments and capabilities that include additional spectral information, improved resolution, and faster scanning ability than previous generations.² The key performance parameter (KPP)³ for the program is cloud and moisture imagery provided by the primary instrument, the Advanced Baseline Imager (ABI). ABI provides forecasters with high-resolution images to track storms and offers a wide range of applications related to weather, oceans, land, climate, and hazards such as fires, volcanoes, hurricanes, and tornadoes.

A secondary instrument, the magnetometer, provides measurements of the Earth's magnetic field that help NOAA's Space Weather Prediction Center, and those that use its products, understand solar disturbances impacting Earth and high-energy particles that can negatively affect spacecraft.

¹ For the purposes of this report, we use the letter-designations of satellites when discussing prelaunch issues and use number-designations when discussing on-orbit issues.

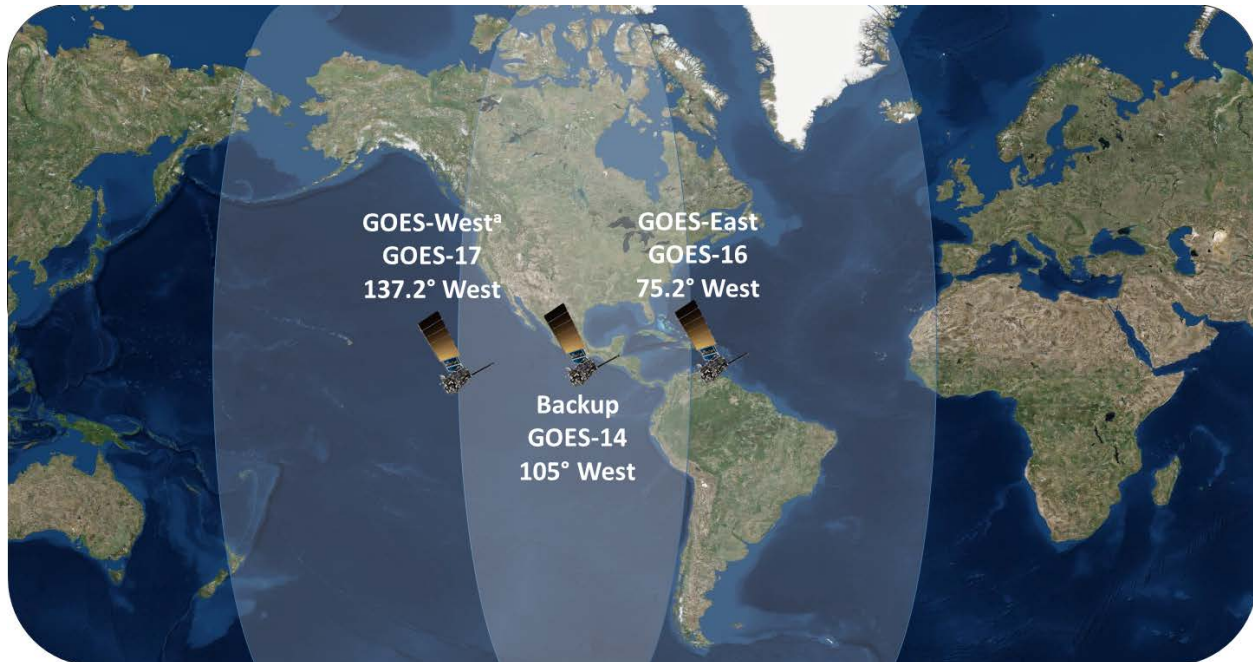
² For a full description of all the GOES-R instruments, see our related work regarding this program: U.S. Department of Commerce Office of Inspector General, February 2, 2017. *Audit of the Geostationary Operational Environmental Satellite-R Series: Improvements in Testing, Contract Management, and Transparency Are Needed to Control Costs, Schedule, and Risks*, OIG-17-013-A. Washington, DC: DOC OIG, appendix B.

³ A *key performance parameter* is a capability or characteristic related to the health and safety and/or operational performance considered most essential for mission accomplishment.

NOAA's geostationary satellite orbital positions cover the Western Hemisphere

NOAA's policy is to have three GOES orbiting the Western Hemisphere to maintain a constant view from approximately 22,300-miles above Earth (see figure 1). NOAA operates two primary satellites—GOES-East and GOES-West—and one backup satellite in a storage position to respond in the event of failures of the operational satellites. Four satellites are currently on orbit: GOES-16 (the GOES-East satellite), GOES-17 (the GOES-West satellite), GOES-15 (further supporting the GOES-West mission),⁴ and GOES-14 (the backup).

Figure 1. Location and Area of Coverage of the GOES Constellation



Source: OIG, adapted from GOES-R program

^a GOES-15 is not shown in this graphic; it operates at 128°W.

Ground System

The GOES-R ground system sends commands to and receives data from the satellites, generates products, and distributes them to users such as the National Weather Service (NWS). It includes two primary operational locations in Maryland and Virginia, as well as a backup facility in West Virginia that protects against system or communications failures. The GOES-R program is planning to replace its ground system servers that were originally provided by IBM.

⁴ At the conclusion of our fieldwork, NOAA planned to operate GOES-15 and GOES-17 in tandem through early July 2019 due to an anomaly with GOES-17's imager.

Objectives, Findings, and Recommendations

Our primary objective was to assess the adequacy of the GOES-R program's satellite development and testing, and the transition of launched satellites into operations. To meet our objective, we focused on selected development, testing, and performance aspects of the program—including ABI performance on GOES-16 and -17, the performance of GOES-R series magnetometers, and changes to the GOES-East and -West positions. We identified inadequacies in the development, testing, and operations of the satellites, specifically:

- ABI issues highlight the need for increased oversight in technical, programmatic, and contractual areas.
- GOES-R series magnetometers are less accurate than the previous series, revealing opportunity for NOAA to refine its threshold requirement.
- The GOES-R program did not identify and manage risk to the availability of GOES-East and GOES-West orbital positions.

Our second objective was to monitor the program's progress on contracting actions and changes to minimize cost increases. We narrowed our focus for this objective to ground system factors after the program identified a shortfall in its ground system sustainment budget. We found that the ground system server replacement will increase the program's life-cycle cost and presents risk management challenges.

See appendix A for a full description regarding our objectives, scope, and methodology.

I. ABI Issues Highlight Need for Increased Oversight in Technical, Programmatic, and Contractual Areas

The GOES-R series ABI instrument provides capabilities to meet the program's only KPP requirements, generating imagery of the Western Hemisphere not duplicated by any other U.S. satellite platform. ABI is the most essential instrument for mission success of the GOES-R satellites.

In April 2018, the GOES-17 ABI malfunctioned, resulting in a partial loss of imagery. The instrument's thermal subsystem—which helps regulate heat transfer from items such as sensors and electronics—is not transferring heat away from the instrument sufficiently. The impaired thermal subsystem causes ABI operating temperatures to increase higher than normal, which reduces its ability to produce imagery as specified in mission requirements. Similarly, but to a lesser extent, GOES-16's ABI is also not optimally managing heat transfer while on orbit. In both cases, the thermal subsystems are not operating as designed.

We found that the program's actions to address integration and test anomalies for ABI were not sufficient to reduce risk for a KPP instrument. Additionally, we determined the program removed ABI performance evaluation criteria that may have penalized the contractor after the occurrence of instrument performance anomalies. Finally, we found

that the thermal anomaly affects the reliability of ABIs, the larger satellites, and ultimately the GOES-R constellation.

A. Program's actions to address integration and test anomalies for ABI were not sufficient to reduce risk for a KPP instrument

The GOES-R program is required to follow Goddard Space Flight Center (GSFC) rules that define fundamental principles and practices applicable to the design, development, verification, and operation of space flight systems. Under these rules, the program must follow a “Test as You Fly — Fly as You Test” approach on the basis that testing of all critical mission-operation elements as they will be flown greatly reduces the risk of negative impacts upon mission success, whether from partial or full loss of capability.⁵ This rule particularly applies to ABI, as it provides the most essential mission capability as the only GOES-R series KPP.

In March 2017, the program was conducting thermal vacuum testing⁶ of the GOES-S satellite (which became GOES-17 on orbit) and discovered that an ABI thermal subsystem was not working as designed. In addition, this was approximately the same time the GOES-16 ABI experienced a thermal anomaly on orbit. In an attempt to resolve the issue on GOES-S, the program modified its ABI thermal subsystem, while noting that it did not understand all aspects of the anomaly.⁷ To test the modifications, the program only verified that the thermal subsystem would start at ambient temperature and pressures; it did not confirm the modification corrected the thermal anomaly that occurred during the satellite thermal vacuum test. In order to proceed based on these results, the program obtained a waiver—approved by the GSFC Safety and Mission Assurance Directorate—from the *Test as You Fly — Fly as You Test* rule. It accepted the risk of not re-performing the thermal vacuum testing of the satellite and proceeded to launch. We found this level of verification for ABI to have been insufficient given its importance to the KPP capability for the mission.

Because the satellite had met its integration and test performance requirements in the thermal vacuum test, Program Mission Assurance personnel did not categorize the thermal anomaly as a failure. Consequently, the program conducted a lower level review of the issue rather than convene a failure review board, which more rigorously investigates root cause and holds authority to direct corrective actions. After the program accepted the residual risk from the modifications, the anomaly was not a candidate for the label of an open risk or issue, which reduced the amount of organizational scrutiny, expertise, and resources dedicated to its resolution.⁸ We found

⁵ NASA Goddard Space Flight Center, June 30, 2016. *Rules for the Design, Development, Verification, and Operation of Flight Systems*, GSFC-STD-1000G. Greenbelt, MD: NASA, rule 1.09.

⁶ The satellite is performance tested inside a sealed chamber designed to simulate the extreme hot and cold conditions of space.

⁷ To mitigate this uncertainty, the program considered using a maneuver in space that might reduce excessive solar heating should the thermal subsystem not adequately regulate ABI's temperature.

⁸ The program documented a *residual risk* from the thermal anomaly, which indicated its acceptance of risk and that further mitigations would affect cost, schedule, or technical performance.

that based on the importance of ABI's critical mission requirement, the program should have assigned a higher priority to the anomaly because of potential negative impacts on the GOES-R series KPP instruments' capabilities for GOES-17, as well as the unlaunched (GOES-T and GOES-U) satellites in development.

A more thorough resolution of the integration and test problems could have reduced the likelihood of failure after the satellite launched. In particular, re-testing the modified instrument and satellite in thermal vacuum could have provided a higher confidence level in the verification of the modification or potentially additional actions to preclude failure on orbit. In May 2018, the GOES-17 ABI's thermal subsystem still failed to transfer heat effectively, causing a partial loss of sensor capability and its ability to meet KPP requirements.

NOAA's requirement is that GOES-R series satellites provide continuous data (with outages less than 6 hours per year) from the KPP instrument. As of October 2018, NOAA predicted that all 16 ABI channels on GOES-17 will be available all day during the cold season, which occurs twice per year—roughly the months of May through July and November through January. However, during the warm season—roughly the months of August through October and February through April—only seven channels will be available all day, with the other nine channels having outages of 2–6 hours per day.

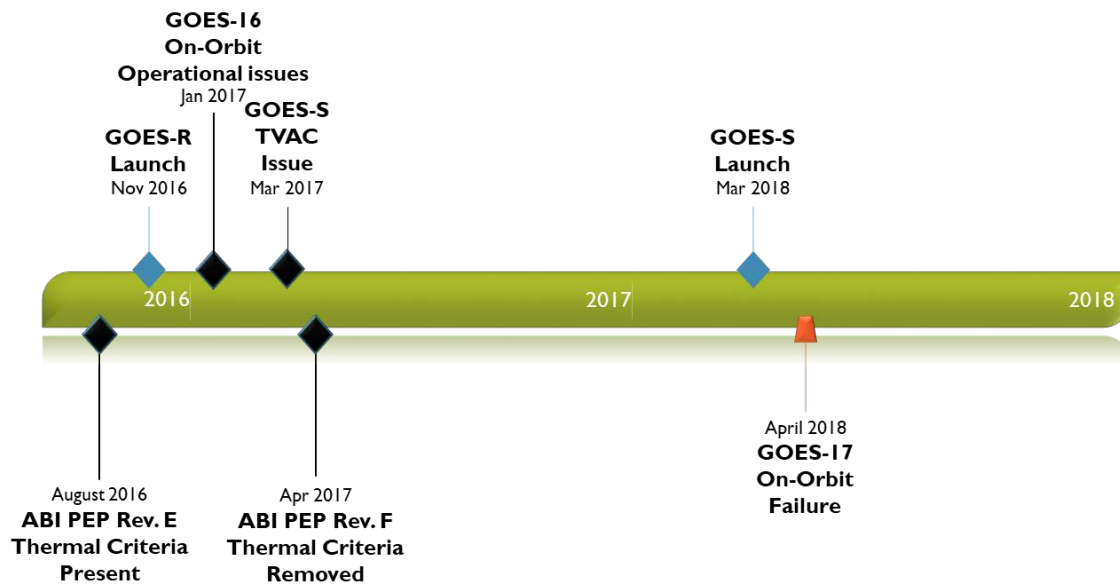
B. After the occurrence of ABI anomalies, the program removed contract performance evaluation criteria that would have lowered its evaluations of on-orbit performance

On April 27, 2017, the program revised the ABI contract's performance evaluation plan (PEP) and removed evaluation criteria that pertained to the instrument's control of temperature and ability to calibrate. This change followed the occurrence of temperature anomalies on GOES-16's ABI, first identified January 22, 2017, and temperature anomalies discovered during thermal vacuum testing of the GOES-S satellite, reported March 14, 2017.

Indications of problems with temperature control also existed in ABI calibration components. Contractor reports indicated that both the GOES-16 infrared calibration target⁹ on orbit (on January 7, 2017) and the GOES-S infrared calibration target in thermal vacuum testing were too hot. Yet, the program also removed performance criteria related to the infrared calibration target from the contract's PEP.

Figure 2 depicts a timeline of the change with respect to the program's discovery of temperature and calibration issues with GOES-16 on orbit and on GOES-S during ground testing.

⁹ The infrared calibration target (ICT) is an internal device that is used for calibration of the ABI while on orbit.

Figure 2. Timeline of Temperature Issues and Contract Events for ABI

Source: OIG-created timeline based on analysis of NOAA documentation
 TVAC — thermal vacuum test.

The specific evaluation criteria removed from the PEP would have classified instrument performance as either “degraded,” meriting a reduction of up to 40 percent of award fees or “severely degraded,” which merits up to 75 percent reduction. The current version of the PEP stipulates that the listed performance criteria are examples and not definitive or all encompassing, which suggests the program could consider non-listed evaluation criteria. However, we found these specific changes notable given the preceding history of ABI performance problems and the likelihood for continued performance problems on GOES-16 and GOES-17. Further, NASA’s supplement¹⁰ to the Federal Acquisition Regulation¹¹ states that only the evaluation factors in the PEP shall be used to determine award fee scores, which indicates that the PEP should list all necessary evaluation factors.

A NASA memorandum indicated that one of the purposes of the revisions was to “clarify the evaluation criteria for on-orbit performance to align with the expected performance inputs from the funding agency,” (that is, NOAA).¹² The GOES-R System Program Director told us that the program removed the criteria because it was considered a subset of other criteria related to the instruments’ radiometric performance. However, our examination of the changes made to the ABI contract PEP found that criteria related to the thermal system and infrared calibration target were the only ones removed from the degraded and severely degraded classifications (see

¹⁰ 48 CFR 1816.405-274(i), *Award fee evaluation factors*.

¹¹ The FAR is codified in title 48 of the Code of Federal Regulations.

¹² This memorandum for the record, dated March 15, 2017, explained planned changes to the schedule of on-orbit evaluations and the on-orbit criteria for all GOES-R spacecraft and instrument PEPs.

appendix B), soon after the program became aware of thermal and calibration issues with the ABIs on GOES-16 and GOES-S. We found that these issues would have likely reduced the contractor's award fees for on-orbit performance without this revision.

Given that we could not fully explore this matter, it will be pertinent for senior management to investigate further these particular changes to performance evaluation criteria to ensure the government adequately evaluates the contractor's performance.

C. Thermal anomaly affects the reliability of ABIs, the satellites, and the availability of GOES imagery and data

The reliability of ABI—the probability that it will perform its intended function for a specified period of time, under a given set of conditions—is determined through analyses performed by the contractor. These ABI reliability analyses become inputs to analyses of the satellites' reliability. Finally, NOAA incorporates the satellite reliability analyses into its determinations of the probability that the GOES constellation¹³ will provide imagery and data over time, which is known as the constellation availability.

The unique performance problems of ABIs on orbit have led NOAA to operate the instruments and satellites under different conditions than planned. The ABI on GOES-17, in particular, is now operating at warmer temperatures and with modified heater settings, which are mitigations to the performance problems of its thermal subsystem. These changes will affect the reliability of the instruments, satellites, and ultimately, the constellation availability. Further, potential design changes to the thermal systems of the GOES-T and GOES-U ABIs will have ramifications for the programs' analyses.

Recommendations

We recommend that the Assistant Administrator for Satellite and Information Services do the following:

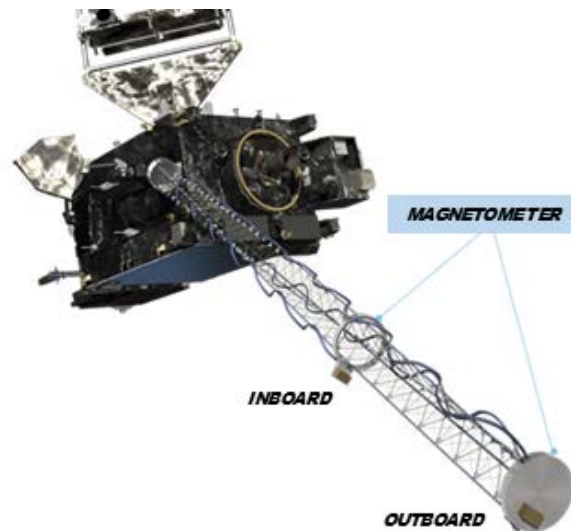
1. Ensure the GOES-R program addresses anomalies on instruments fulfilling essential mission requirements using a distinct process that is proportional to the criticality of a key performance parameter.
2. Ensure an independent review of changes to the ABI contract's PEP occurs to determine their rationale, appropriateness, and need for further actions.
3. Ensure the GOES-R program updates reliability analyses for ABI, the satellite, and constellation, specifically given the unique conditions of the hardware on GOES-16 and GOES-17 and any design changes for GOES-T and GOES-U.

¹³ The GOES constellation refers to the grouping of GOES satellites in orbit.

II. GOES-R Series Magnetometers Are Less Accurate Than Previous Series, Revealing Opportunity for NOAA to Refine its Threshold Requirement

The magnetometers on NOAA's geostationary satellites measure the strength and direction of the Earth's magnetic field at the satellite's position in space. Electrical signals are sent and returned to sensors along an extended boom that is positioned far enough away from the spacecraft to be clear of known interference caused by other parts of the satellite. To provide redundancy and help remove interference from the spacecraft, GOES-R satellites have dual (inboard and outboard) sensor instruments (see figure 3). Positioning the instruments on the satellite is a challenge because variations in the strength of the background geomagnetic field¹⁴ can be weak compared to magnetic fields generated by the spacecraft's other systems.¹⁵

Figure 3. GOES Magnetometer Boom with Inboard and Outboard Instruments



Source: GOES-R program with OIG annotation

We found that current GOES-R series magnetometers are less accurate than previous versions and that NOAA's requirement for geomagnetic field measurement accuracy does not distinguish between critical (i.e., *threshold*)¹⁶ and desired (i.e., *objective*)¹⁷ mission data priorities as defined in NOAA's requirements documents.

¹⁴ That is, the magnetic field most attributable to the Earth and its interactions with the solar wind.

¹⁵ Electricity and magnetism (electromagnetic) effects are interrelated.

¹⁶ *Threshold* is the minimum acceptable requirement specification. A requirement with a level 1 mission critical priority means it is needed in order to meet satisfactory mission performance.

¹⁷ *Objective* is the optimal specification that, if met, would significantly enhance meeting the mission. A requirement with level 2 mission optimal priority is not critical, but would provide significant improvement to operational capability.

A. *GOES-R series magnetometer data are less accurate than previous GOES series*

GOES-16's magnetometer¹⁸ has been less accurate than magnetometers on the previous generation satellites (GOES-13, -14, -15) and GOES-17. GOES-17's magnetometer has also not met its accuracy requirements. The Space Weather Prediction Center continues to rely on the previous generation of satellites for these measurements, due to delays in the readiness of ground processing software.

The original requirement for GOES-R series' geomagnetic field measurement was for an accuracy of 1 nanotesla¹⁹ (1 nT) over the full instrument sensing range through the end of its life.²⁰ This was the same accuracy requirement specified in NOAA documents for prior GOES series missions.²¹ For the GOES-R series, however, the program determined the preliminary observatory design could not achieve 1 nT accuracy without adding an additional orientation sensor to the boom. However, the program considered the additional sensor too risky to the boom's operation, so it obtained NOAA approval to provide a lesser 2.3 nT initial accuracy that may degrade to 4.0 nT by end of service life.

The GOES-R program had limited options to improve GOES-16's magnetometer performance on orbit, which did not meet its accuracy specification after launch. However, the program took additional steps to improve the magnetometers on the not-yet-launched GOES-S (i.e., GOES-17), GOES-T, and GOES-U. These included design adaptations, better magnetic handling procedures, and test improvements implemented prior to launch. GOES-17's magnetometer has shown improvement, but it is still not meeting requirements, and the performance issues will very likely propagate to GOES-T and GOES-U.

We found that new contractors and incomplete sharing of lessons learned combined to produce magnetometer performance challenges for the GOES-R program. Although the basic sensor concept had not changed significantly since GOES-I series, the prime contractor told us that no technical approaches or lessons learned from the earlier series were shared regarding the magnetometer or boom. To adjust, the program added expertise to both the contractor and flight project within the program. The program also told us that technical data from the previous GOES series magnetometer contractor was unavailable to the new prime contractor due to contract restrictions. As

¹⁸ We use the term *magnetometer* to represent both the inboard and outboard instruments and the boom as an integrated system unless noted otherwise.

¹⁹ A tesla (T) is an international standard unit for magnetic field strength, and a nanotesla, abbreviated as nT, represents 10^{-9} T. A 1 nT accuracy specification means that the measurement is expected to be within 1 nT of the actual value of geomagnetic field strength.

²⁰ In 2011, the program began amending this requirement through formal deviations and performance waivers.

²¹ According to NOAA stakeholders, when those missions encountered data contamination issues that degraded measurement accuracy, correction algorithms were applied to meet 1 nT accuracy.

a result, the program planned to publish a paper to capture lessons learned, reducing reliance on personal knowledge conveyance in the future.

B. NOAA's threshold accuracy requirement needs refinement and relevant validation

We also found that NOAA listed the threshold (needed) and objective (desired) specification for geomagnetic field measurement accuracy as the same value: 1 nT. This was not consistent with definitions in NOAA's space weather observational requirements document, which state that a "threshold [requirement] is the minimum acceptable specification. Objective is the optimal specification that, if met, would significantly enhance meeting the mission."²²

In certain cases, there may be justification to have the values the same; in this case, NOAA subsequently accepted and will use less accurate measurements than what it originally specified for the GOES-R series magnetometer requirement—indicating that its threshold was the revised, lower value. In short, distinguishing threshold and objective requirements reflect a "needs versus wants" prioritization approach. If customers document wants as needs, resource gaps could force programs to make trade-offs in other areas.

National Weather Service officials said NOAA's threshold and objective specification values were the same because 1 nT accuracy was a reasonably achievable goal for the GOES-R program (given the state of the science) and were the same as the last series. The 1 nT accuracy specification had been reviewed and validated within NOAA's process, but we found that the two documents cited as validation for the geomagnetic field measurement attributes are non-NOAA documents from 33 and 40 years ago, and are not directly related to measurement accuracy.

The GOES-R program told us that achieving a 1 nT accuracy is at the forefront of science-class magnetometers and, while achievable, is a challenge on large, complex satellites like the GOES-R series. The technical difficulty of measuring Earth's magnetic field in the vicinity of the spacecraft's electromagnetic influences is evident in the increased boom length, which was approximately 10 feet for GOES-I, but almost 28 feet long for GOES-N and GOES-R. The program told us it was planning to consider an option for flying the magnetometer on a dedicated satellite, thus avoiding the accommodation complexity experienced on GOES-R.

NOAA helped to mitigate the GOES-R challenge for achieving 1 nT accuracy by approving a less demanding 2.3 nT specification.²³ Accurate knowledge of mission-critical needs and impacts could help enable timely tradeoffs, optimize value to NOAA, and foster greater efficiency for the GOES-R program. Identifying the difference between a

²² NOAA, November 15, 2017. *NOAA Space Weather Mission Service Area Observational User Requirements Document*. Washington, DC: NOAA, 22.

²³ NOAA National Environmental Satellite, Data, and Information Service, November 2011. "Geostationary Operational Environmental Satellite Series R Level 1 Requirements Document Deviations Request" memorandum to the NOAA Deputy Under Secretary for Operations. Silver Spring, MD: NOAA NESDIS.

threshold and objective specification as early as possible in the acquisition process could inform such decisions.

Recommendations

We recommend that the Assistant Administrator for Satellite and Information Services do the following:

4. Ensure the GOES-R program documents its magnetometer design, integration, and on-orbit experience so that it is available to future GOES programs and contractors.

We recommend that the Deputy Under Secretary for Operations do the following:

5. Ensure that NOAA conducts analysis to determine distinct geomagnetic field measurement accuracy threshold and objective requirement specifications and ensure appropriately supported requirements are reflected in GOES-R program documents.
6. Ensure the NOAA Space Weather Prediction Center updates its geomagnetic field observation accuracy requirement validation documentation.
7. Ensure NOAA assesses whether GOES are the optimal satellites to achieve geomagnetic field observation requirements, using an analysis of alternatives or similar cost-benefit approach.

III. The GOES-R Program Did Not Identify and Manage Risk to the Availability of GOES-East and -West Orbital Positions

NOAA has been compelled to relocate the GOES-East and GOES-West orbital positions because other satellite systems that are certified to operate in the same orbital locations have caused radio frequency interference and conjunction issues.²⁴ However, the GOES-R program did not identify this potential risk and develop risk mitigation plans prior to discovering these issues. Fortunately, the relocations required only minor changes to ground system software. Risk to its orbital positions, if not managed, could threaten cost and schedule baselines in the future.

Since 1977, NOAA has operated a GOES-West and a GOES-East satellite at their respective geostationary orbital locations. The program's formal requirements call for GOES-West to be positioned at 137.0°W longitude and GOES-East at 75.0°W longitude to ensure the satellites can view the required operational coverage area. However, the GOES-R program has had to change the positions of its satellites due to the presence of other satellites.

During development of the original GOES-R series requirements in 2007, a U.S. Department of Defense satellite operating in the same communications band led the program to change the GOES-West position from its customary 135.0°W to 137.0°W to avoid radio frequency interference, according to program personnel. In 2016, the planned

²⁴ *Conjunctions* are scenarios where satellites approach close enough to each other that there is risk of collision.

launch of a Brazilian satellite led the program to negotiate a change in position of GOES-16 (operating as GOES-East) to 75.2°W. More recently, in September 2018, the program discovered that a commercial U.S. satellite had received permission from the Federal Communications Commission (FCC) to move into the 137.0°W geostationary orbital location. Although this satellite does not interfere with GOES radio frequencies, the two parties agreed to maintain a 0.2° separation to avoid conjunction issues. The commercial satellite will operate at 137.0°W and GOES-17 at 137.2°W.

The program's risk management plan defines a risk as the combination of the likelihood that a program will experience an uncertain event and the consequence of the event, were it to occur. Additionally, it states that risk management is a continuous, iterative, and proactive process to manage risk and achieve mission success. However, despite the repeated occurrence of changes to its orbital positions and the increasing number of satellites in space, the program has not proactively or formally managed risk to its required orbital positions. The program has no record of orbital position risks in its risk database. While the program has thus far avoided significant cost increases, schedule delays, or performance impacts, we found there is potential for these if more significant changes to the orbital positions were to occur.

The changes to orbital positions of GOES-16 and GOES-17 were within the plus or minus 0.5° parameters written into the ground system's software code. Given that the move was within these parameters, only minor software modifications to the ground system were required.²⁵ Program personnel stated that if the satellites were to move outside of these parameters, it would require costly software modifications. How costly and how long those modifications would take is unclear, however, given that the program has not formally documented potential impacts of this risk, something it would likely do under its formal risk management processes.

Further complicating the program's orbital position risk, we learned that there is no formal process to account for potential conjunction issues and places responsibility for that type of coordination at the program level (see the Other Matter section of this report for additional discussion). This factor provides further evidence of the program's need to apply formal risk management to its orbital positions.

Recommendation

We recommend that the Assistant Administrator for Satellite and Information Services do the following:

8. Ensure that the GOES-R program formally manages risk to geostationary orbital positions for both current and future satellite programs.

²⁵ The configuration of the GOES Rebroadcast and product monitoring systems also required minor modifications to display the new orbital location.

IV. Ground System Server Replacement Will Increase the Program's Life-Cycle Cost and Presents Risk Management Challenges

When the GOES-R program replaces its ground system servers between 2019 and 2022, the existing servers will have operated for more than 5 years. The ground system will need to meet new security standards and fulfill requirements to implement other functionality that simplifies the physical architecture. However, because the complexity of the server replacement has increased, it will cost more than what is included under the current life-cycle cost baseline for the program. For this and other reasons, the program's life-cycle cost estimate (LCCE) no longer reflects program assumptions. In addition, the server replacement effort carries risk.

A. Program life-cycle cost estimate does not reflect current technical and programmatic assumptions

Best practice calls for programs to maintain up-to-date LCCEs that consider changes in technical and programmatic assumptions.²⁶ Such assumptions include current requirements or changes in scope, and major events or external factors beyond the program manager's control that have significant ramifications for cost, schedule, or performance. Contract modifications—such as engineering change proposals—and changes to program schedules should inform updates to the LCCE, which is the basis for the program's performance management baseline.²⁷

The GOES-R program has not updated its LCCE since February 2012 (see table 1).

Table 1. Formal Life-Cycle Cost Estimates Completed by GOES-R Program

Date	LCCE	Independent Cost Estimate (ICE)
September 20, 2007 ^a	\$7.6 billion	\$9.2 billion
May 27, 2011	\$10.9 billion	\$11.5 billion
February 27, 2012	\$10.7 billion	\$11.2 billion

Source: GOES-R program with OIG annotation

^a September 2007 estimates were based on a two-satellite program. Later estimates were for a four-satellite program.

Since then, significant budgetary and requirements changes have affected program assumptions.

²⁶ U.S. Government Accountability Office, March 2, 2009. *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP. Washington, DC: GAO, 11 & 273.

²⁷ *Ibid.*, 1-2, 273, & 275.

Change to funding assumptions

In April 2013, sequestration and rescission mandates required NOAA to reduce FY 2013 funding for the program by \$54 million. As a result of this funding cut, NOAA determined that the program's life-cycle cost would increase by \$150 million and, in December 2013, updated the *GOES-R Program Commitment Agreement*, but did not formally update its LCCE to explicitly identify which program elements would increase in cost.^{28, 29}

Changes to technical requirements

In January 2014, Congress enacted a law that restricts the use of computer hardware connected to Chinese businesses.³⁰ In September 2014, IBM sold its server business to Lenovo, a Chinese-owned company. As a result, the program must replace all IBM servers in its ground system. Original program plans (i.e., before the law was enacted) envisioned a technical refresh of ground system hardware in 2017–2018 with a piecemeal replacement of the IBM servers with newer IBM equipment, which is now not possible.

In April 2016, the program determined it had insufficient budget to replace the IBM servers because of the need to perform a much more complex and extensive hardware replacement (while continuing to operate a ground system with satellites both on orbit and still to be launched). The combination of (1) a more complex technical refresh (server replacement), (2) planning and executing the launches of GOES-R and GOES-S satellites, and (3) getting a return on investment for the original ground system designed in 2012, has resulted in a delay of the ground system technical refresh until 2019–2022. In March 2019, NOAA awarded the Harris Corporation a \$284 million increase in contract value for core ground system server replacement and contract extension.³¹

Changes to sustainment budget projections

In December 2017, the program identified another shortfall (separate from server replacement costs) in its sustainment budget. The program had not yet determined the

²⁸ Ibid, 19. As discussed in GAO-09-3SP, reductions in funding during a development phase can extend schedules and increase costs.

²⁹ The *Program Commitment Agreement* is the program's (and NOAA's) commitment to develop and operate the satellite systems within a specified cost and schedule.

³⁰ The Consolidated Appropriations Act, 2014 (Pub. L. No. 113-76, Division B, Title V, Sec. 515) restricts select federal agencies, including the Department, from using appropriated funds to acquire high- or moderate-impact information system produced, manufactured, or assembled by the People's Republic of China unless the Department conducts certain risk assessments, including a cyber threat assessment with the Federal Bureau of Investigation. The program is currently compliant with the law because the Department and Committee on Foreign Investment in the United States negotiated an agreement with IBM to provide support for the servers until their expected replacement in 2022.

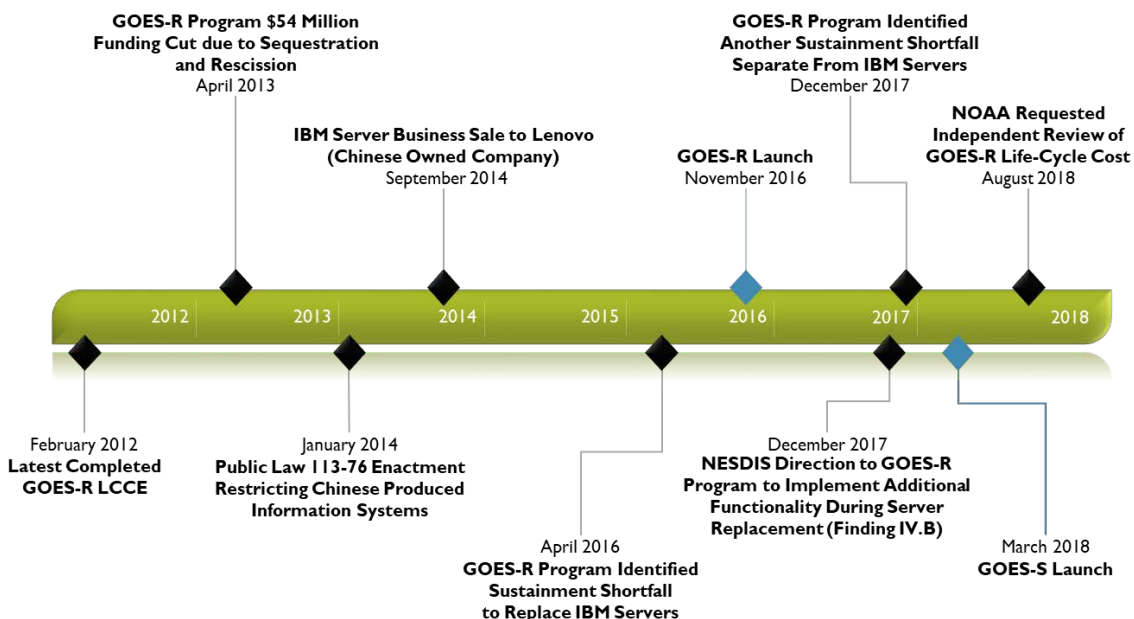
³¹ Harris Corporation, "NOAA Awards Harris Corporation \$284 Million GOES-R Series Ground Segment Contract Extension," news release, May 16, 2019 [online]. www.harris.com/press-releases/2019/05/noaa-awards-harris-corporation-284-million-goes-r-series-ground-segment (accessed August 12, 2019).

extent of the shortfall but indicated that it would request an increase in a future budget submission, which will further increase the life-cycle cost of the program.

In August 2018, NOAA requested the Department perform an independent review of the GOES-R life-cycle cost before NOAA submitted a proposed life-cycle cost increase for the server replacement. The Department’s Office of Acquisition Management (OAM) plans to complete an independent cost estimate (ICE) of the entire program in fall of 2019. OAM was basing its ICE on the 2012 LCCE and program execution data since that estimate was completed. The program intended to update its LCCE after OAM’s review.

Figure 4 shows a timeline of significant events—including budgetary and requirements changes that have affected the program’s life-cycle cost—which have occurred since the last LCCE was completed in 2012.

Figure 4. Timeline of Significant Events Affecting GOES-R Life-Cycle Cost



Source: OIG

Until the program has updated its LCCE, NOAA does not have complete and accurate information upon which to base its budget requests to Congress. As well, the program is unable to adequately measure cost and schedule performance without an updated performance measurement baseline.

- B. Ground system server replacement effort will reduce hardware and increase virtualization, but program needs to mitigate cost, schedule, and performance risks*

On December 13, 2017, the Deputy Assistant Administrator for Satellite and Information Services directed the GOES-R program to implement several functions as

part of the server replacement, including the use of virtualization,³² Enterprise Cybersecurity Monitoring and Operations (ECMO), and security updates.³³ Implementation of these functions includes cost, schedule, and performance risks.

Risks in implementing functions during server replacement

In December 2017, the GOES-R program identified risks associated with its server replacement plans. The program indicated there is a possibility that virtualized servers may not provide sufficient availability and would require additional hardware design and implementation. For ECMO, program personnel are concerned that the actual implementation will be more complex than the baseline plan, requiring additional engineering and material to complete. In addition, changes to the draft National Institute of Standards and Technology (NIST) Special Publication (SP) 800-53, revision 5 standard may require the program to adjust security functionality. Realization of these risks could result in cost increases, schedule delays, or performance issues.

Planned mitigations for implementation risks

To mitigate risk that virtualized servers may not meet availability requirements, the program prototyped virtual server performance for critical mission management and data operations. The program will assess performance and update server replacement design to accommodate any functions that it cannot virtualize by December 2019. The program has also identified initial off-ramps³⁴ for this risk to address any performance issues that occur.

To reduce cost and schedule risk to ECMO, the program has coordinated with elements of the National Environmental Satellite, Data, and Information Service (NESDIS) responsible for implementing ECMO on the Environmental Satellite Processing and Distribution Services system. In November 2018, the program established an off-ramp to isolate impacts of implementing ECMO from other server replacement tasks. By April 2020, the program plans to assess the design for alignment with enterprise goals. It will then deploy required changes to the current site baseline by May 2021.

A final version of the NIST SP 800-53, rev. 5 security standard is due in summer 2019. By August of 2020, the program plans to assess the requirements and address required updates, and then deploy changes to the site baseline by May 2021.

³² Virtualization uses software to create a “virtual computer” that acts like a real computer. Software executed on virtual machines “thinks” it is on a real computer, when in fact is separated from the underlying physical resources.

³³ These updates are intended to be included in the latest revision of National Institute of Standards and Technology (NIST) Special Publication (SP) 800-53, rev. 5. It is currently in draft and provides “a catalog of security and privacy controls for federal information systems and organizations to protect organizational operations and assets, individuals, other organizations, and the Nation from a diverse set of threats including hostile attacks, natural disasters, structural failures, human errors, and privacy risks.”

³⁴ An *off-ramp* is a deferral or removal of a capability to maintain schedule.

NOAA noted in its sole source justification for the server replacement that its selection of implementation and deployment options will seek to balance mission risk against increased cost and schedule, while also ensuring server replacement makes maximum use of commercial-off-the-shelf hardware and software. Further, to enhance future competitive contract actions in support of the ground system, an open architecture is preferred.

Program needs to prioritize off-ramps to further mitigate risk

Although the program has identified initial off-ramps to address some of the risks, it has not yet provided a comprehensive set of prioritized off-ramps to the NOAA/NASA Program Management Council in order to further mitigate risks that could result in increased cost, schedule delays, or performance problems. In March 2019, the program modified the core ground system contract to include the server replacement effort. It now has a complete scope of work to be performed from which to choose off-ramps. Well-planned off-ramps would help the program manage risks and control cost associated with the server replacement effort. As a result, the inclusion of off-ramps will provide the program better assurance that the contract value increase of \$284.4 million for server replacement and contract extension will be used efficiently (see appendix C).

C. *Risk of vendor lock-in for ground system contracts requires attention*

The ground system will continue to use the contractor's custom software after the server replacement is completed in FY 2022. As such, a risk of vendor lock-in will persist while the system is reliant on the vendor's software.

Due to the custom-built nature of the ground segment and limited time to replace the IBM servers, the program decided to retain its contractor with a sole-source selection for this effort. The program determined that any change in the contractor during development, integration and test, and deployment of the ground system would cause unacceptable risk. The program's schedule analyses determined that another vendor chosen through a competitive procurement process could not complete the server replacement until well after IBM support ends. The program also determined that use of a competitor for server replacement would have increased the risk of hardware failures that could affect its mission.

NOAA told us that it has taken steps to make it easier to competitively source future sustainment contracts, including using a more "open-rack-mounted" approach and prototyping the use of virtual servers. However, the ground system will still use its current contractor's complex and unique software.

A risk of vendor lock-in increases cost risk for future ground system sustainment. In addition, the ground system's vendor-specific, custom, and complex software could present a challenge for competitors to support the system in future sustainment periods—potentially limiting the actual competition and cost savings that should otherwise occur.

Recommendations

We recommend that the Assistant Administrator for Satellite and Information Services do the following:

9. Ensure the GOES-R program updates its LCCE incorporating results from Department's independent assessment.
10. Ensure the GOES-R program completes a prioritized list of off-ramps with triggering dates for server replacement activities.
11. Ensure the GOES-R program develops a plan to limit the risk of vendor lock-in for ground system sustainment.

Other Matter

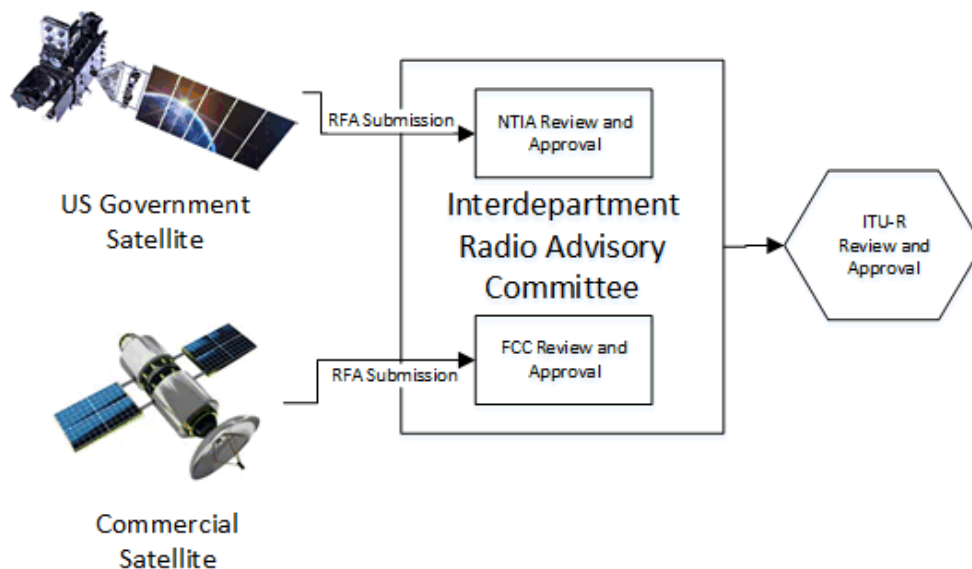
Processes for Reserving Orbital Positions May Not Be Adequate to Meet Demands of an Increasing Number of Satellites

Globally, there currently exists a formal regulatory process to manage the use of radio frequencies in space. However, the process does not formally resolve potential conjunctions of satellites planned to operate in the same or similar orbits (i.e., scenarios where satellites approach close enough to each other that there is risk of collision).

In order to select an orbital position, satellite operators in the United States follow the United Nations International Telecommunication Union responsible for radio communication (ITU-R), Radio Regulations, which assumes that the satellite program office or organization has performed “administrative due diligence” to ensure a conjunction issue will not occur.³⁵

Currently, the United States has a formal regulatory process to manage the use of satellite radio frequencies through the Interdepartment Radio Advisory Committee (IRAC). As part of this process, the National Telecommunications and Information Administration performs a frequency review and certification for government assets and the FCC—as a liaison to the IRAC—does the same for all non-federal assets. In the case of GOES-R, NESDIS submits a Radio Frequency Application (RFA) into the ITU-R database system. The IRAC then reviews the RFA and, if approved, provides the RFA to the ITU-R for its review and approval (see figure 5).

Figure 5. U.S. and International Radio Frequency Review and Approval Process



Source: OIG graphic describing process

³⁵ International Telecommunication Union, 2016. *The Radio Regulations*, Resolution 49. Part c.

However, this process does not account for potential conjunction issues and places responsibility for that type of coordination at the satellite program level. While an RFA includes orbital positioning information as part of the submission, if there is no frequency interference issue, the IRAC and ITU-R assume that the satellite program office or organization has performed administrative due diligence to ensure a conjunction issue will not occur. Relatedly, the NESDIS frequency manager indicated that selecting an orbital position is becoming an increasingly difficult issue due to an increasing number of satellites at NOAA's required orbital locations.

On June 12, 2018, the Secretary of Commerce announced the Space Council's initiative to create a "one-stop shop" for space commerce at the Department, responsible for civil and commercial satellite planning, frequency and position de-confliction, and sector growth by 2024. Then on June 18, 2018, the President signed Space Policy Directive-3, which states that there is a need for improved and increasingly dynamic methods to coordinate activities in both the physical and spectral domains (i.e., orbital locations and frequency allocations).³⁶ It further states that the government should investigate the advantages of addressing spectrum in conjunction with space traffic management systems, standards, and best practices.

The Director of the NESDIS Office of Space Commerce—to whom these responsibilities will most likely fall—also acknowledged that there is a disconnect between frequency management and physical orbital positioning, and expects frequency certification information from the IRAC and positioning information to flow through that office for further coordination and a full picture of frequency and position. However, the director also stated that currently their office does not have the resources or authorization to perform such coordination at this time.³⁷

³⁶ The White House, June 18, 2018. *National Space Traffic Management Policy*, Space Policy Directive-3. Washington, DC: White House, sec. 5(c)(ii).

³⁷ On October 15, 2018, the Secretary submitted to Congress a legislative proposal to establish the Bureau of Space Commerce, which would elevate the position of Director of the Office of Space Commerce within NESDIS to Assistant Secretary for Space Commerce, reporting directly to the Secretary.

Summary of Agency Response and OIG Comments

In response to our draft report, NOAA agreed with all of our recommendations and described actions it has taken, or will take, to address them. NOAA's complete response, which also included technical comments, is in appendix D.

In agreeing with recommendation 3, NOAA stated that there are no specific ABI reliability updates planned for the GOES-16 satellite because none of the component settings have been changed on-orbit. However, documentation indicates that the GOES-R program intentionally turned off a segment of the GOES-16 ABI thermal subsystem and changed settings on the operational segment to allow proper cooling control on-orbit.

In a technical comment on finding II.B, NOAA asserted that objective and threshold requirement values may be the same if (1) an operationally significant value above threshold is not useful, or (2) if meeting the objective requirement is technically feasible. With respect to (1), the lower accuracy of the GOES-R series used by NOAA indicates that the initial requirement specification was an operationally significant value above the threshold (i.e., the original specification was, in practice, an *objective* requirement). With respect to (2), we found significant evidence that the GOES-R program was challenged by the technical feasibility of meeting the original accuracy requirement for the magnetometer. We are pleased that NOAA concurs with recommendation 5 to determine distinct threshold and requirement specifications.

We considered all of NOAA's comments and made changes in the final report where appropriate. We are pleased that NOAA concurs with our recommendations and look forward to reviewing its proposed audit action plan.

Appendix A: Objectives, Scope, and Methodology

Our primary objective was to assess the adequacy of the GOES-R program's satellite development and testing, and the transition of launched satellites into operations. Through the course of the audit, we focused on ABI testing, validation, and performance on GOES-16 and -17, the performance of GOES-R series magnetometers, and changes to GOES orbital positions. During our fieldwork, the program was conducting an investigation of the ABI performance anomaly on GOES-17. Given the precedence of this activity, our access to certain program documents, personnel, and the ABI contractor was limited. As such, the scope of our findings related to ABI were limited.

Our second objective was to monitor the program's progress on contracting actions and changes to minimize cost increases. We narrowed our focus for this objective to ground system factors after the program identified a shortfall in its ground system sustainment budget.

To assess the adequacy of the program's test and validation of ABI and the instrument's performance on GOES-16 and -17 satellites, we reviewed unit and satellite-level test documentation to understand the anomaly and the program's corrective action modifications. We interviewed GOES-R personnel to discuss issues on GOES-16 and GOES-S during testing and to understand actions taken, the underlying rationale for decisions, and regression test considerations. We further reviewed incident reports, test reports, and analyses to develop an understanding of the issue and resolutions the program explored. We examined risk activity within the program to determine the extent to which the program elevated the GOES-S ABI anomaly as a candidate for risk or issue. We reviewed the program's risk database and program status reports and compared that information with requirements in the GOES-R risk management plan. In addition, we reviewed the program's application of risk processes to the GOES-S ABI anomaly and GOES-16 on-orbit issues to assess their adequacy with respect to a KPP instrument.

We reviewed the ABI contract's PEP to understand performance evaluation criteria and compared different versions of the plan to identify changes to the criteria. We compared the performance evaluation criteria with the test and performance anomalies on GOES-16 and GOES-S/17 ABIs to assess the ramifications of the changes to the PEP.

In addition, we reviewed ABI and spacecraft reliability documents and compared them to subsequent assessments completed for GOES-17's ABI post-failure. We also reviewed associated program requirements for reliability and best practices for reliability calculations to compare with the program's reliability analyses.

To assess GOES-R series magnetometer performance, we interviewed contractor and NASA personnel to understand the design and testing changes from GOES-16 to -17. In order to determine performance gaps, we compared program and independent performance reports to system and functional performance specifications. To assess gap mitigations, we reviewed program analyses, design and testing changes, and instrument operating adjustments. We

interviewed NOAA personnel to understand the basis of geomagnetic field measurement requirements at geostationary orbit and the process used for validating National Weather Service geostationary satellite observation requirements. We reviewed NOAA Space Weather Mission Service Area Observational User Requirements Documents, and assessed validation sources for currency and relevancy.

To assess changes in orbital positions of GOES-East and -West, we interviewed NOAA, NASA, National Telecommunications and Information Administration, and other Department of Commerce personnel to understand the orbital position coordination process. We reviewed GOES-R level one requirements to determine the required orbital positioning. We reviewed ITU-R Radio Regulations to determine the process used within the U.S. and internationally to acquire frequency certifications at a given orbital position. We reviewed the Space Policy Directive-3 to determine how the NESDIS Office of Space Commerce should align its functions.

To assess NOAA progress in developing and reporting on contracting and budgeting actions, and changes to minimize cost increases, we interviewed NOAA personnel to gain an understanding of the ground server replacement and the program's LCCEs. We interviewed the director and a cost estimator from the Department's OAM to understand the independent assessment requested by NOAA of all GOES-R program costs with a focus on the costs to replace the servers, and operations, maintenance, and sustainment costs. We reviewed NESDIS' Cloud Computing Strategy to understand its vision for the transition from the current NESDIS Ground Enterprise. We interviewed the director and an engineer from NESDIS' Office of Satellite Ground Services to understand how their office is helping define requirements for the server replacement.

In addition, we assessed internal control significant within the context of our objectives. This included examining the design of program management controls as documented in NASA procedural requirements. We also assessed the implementation of internal control through document reviews and observations of program and project management life-cycle reviews to determine the program's adherence to its standards, procedures, and plans. In satisfying our objectives, we did not rely on computer-processed data; therefore, we did not test the reliability of NOAA and NASA information technology systems. The findings and recommendations in this report include our assessments of internal control.

Although we could not independently verify the reliability of all the information we collected, we compared it with other available supporting documents to determine data consistency and reasonableness. Based on these efforts, we believe the information we obtained is sufficiently reliable for this report.

We conducted our review from January 2018 through February 2019 under the authority of the Inspector General Act of 1978, as amended (5 U.S.C. App.), and Department Organization Order 10-13, dated April 26, 2013. We performed our fieldwork at the GOES-R program office in Greenbelt, Maryland; NOAA offices in Silver Spring, Maryland; NOAA Office of Satellite and Product Operations in Suitland, Maryland; Department of Commerce headquarters in Washington, DC; and Lockheed Martin's facility in Littleton, Colorado.

We conducted this performance audit in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence that provides a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix B: Comparison of On-Orbit Performance Evaluation Criteria for ABI

Table B-1. Degraded

Revision E (8/12/2016) (40 percent reduction in fee)	Revision F (4/27/2017) (16 to 40 percent reduction in fee)
<ul style="list-style-type: none"> Non-recoverable degraded radiometric performance in any channel of Group 1 after switching to redundant detectors and Side B electronics 	<ul style="list-style-type: none"> Non-recoverable degraded radiometric performance
<ul style="list-style-type: none"> Degraded star sensing or INR [image navigation and registration] performance (spec non-compliance) 	<ul style="list-style-type: none"> Frequent or sustained degradation of INR performance
<ul style="list-style-type: none"> Loss of telemetry impacting health and safety of the instrument 	<ul style="list-style-type: none"> Loss of telemetry impacting health and safety of the instrument
<ul style="list-style-type: none"> Noise in processed data in 1 to 3 spectral bands of Group 1 (performance non-compliance) Loss of 2 of the 4 channels in Group 2 	<ul style="list-style-type: none"> Loss of more than one spectral channel
[Not present]	<ul style="list-style-type: none"> Significant loss of field of view or Earth imaging coverage
<ul style="list-style-type: none"> IR/VIS [infrared/visible] calibration system degradation (not meeting specs) or failure of calibration mechanism(s) that do not impact imaging function 	[Omitted]
<ul style="list-style-type: none"> Detector cooling system unable to maintain detector temperature stability around temperature set point 	[Omitted]

Source: PEP for ABI for GOES-R/S/T/U; Contract No. NNG04HZ07C, Revisions E and F. OIG presentation of criteria to facilitate comparison. Criteria highlighted in red were removed in Revision F of the PEP, which is discussed in greater detail in finding I.B.

Table B-2. Severely Degraded

Revision E (8/12/2016) <i>(75 percent reduction in fee)</i>	Revision F (4/27/2017) <i>(41 to 75 percent reduction in fee)</i>
<ul style="list-style-type: none"> Multiple channels (>3) in Group 1 exhibit severe, random, or coherent noise after processing while operating on side B detectors or electronics 	<ul style="list-style-type: none"> Multiple channels exhibit severely degraded radiometric performance
<ul style="list-style-type: none"> Loss of some critical telemetry 	<ul style="list-style-type: none"> Loss of critical telemetry leading to instrument damage or adding significant operational burden
<ul style="list-style-type: none"> Loss of 3 to 4 of the 4 channels in Group 2 	<ul style="list-style-type: none"> Loss of more than one-third of the spectral channels
<ul style="list-style-type: none"> Loss of star sensing 	<ul style="list-style-type: none"> Severely degraded INR performance
<ul style="list-style-type: none"> Degraded scanner function, loss of some scan functions impacting coverage 	<ul style="list-style-type: none"> Significant loss of field of view or Earth imaging coverage impacting ability to produce full disk imagery every 30 min
<ul style="list-style-type: none"> Detector cooling system unable to reach operational temperature (set point) 	[Omitted]
<ul style="list-style-type: none"> Failure of VIS/SW [VIS/short wave infrared] calibration mechanism 	[Omitted]

Source: PEP for ABI for GOES-R/S/T/U; Contract No. NNG04HZ07C, Revisions E and F. OIG presentation of criteria to facilitate comparison. Criteria highlighted in red were removed in Revision F of the PEP, which is discussed in greater detail in finding I.B.

Appendix C: Potential Monetary Benefits

Description	Funds to Be Put to Better Use
Increase in core ground system contract value for server replacement and contract extension	\$284,440,445 ^a

Source: OIG analysis of NOAA and NASA documentation

^a This figure is the negotiated increase in value of the ground system contract, specifically to replace servers and extend the contract—as discussed in finding IV.B. Funds for the contract increase would be used more efficiently, and some would be potentially saved, through the identification of a prioritized list of off-ramps, as described under finding IV.B. and recommendation 10.

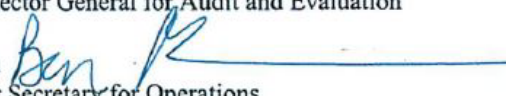
Appendix D: Agency Response



UNITED STATES DEPARTMENT OF COMMERCE
The Deputy Under Secretary for Operations
Washington, D.C. 20230

July 15, 2019

MEMORANDUM FOR: Frederick J. Meny, Jr.
Assistant Inspector General for Audit and Evaluation

FROM: Ben Friedman 
Deputy Under Secretary for Operations

SUBJECT: *Geostationary Operational Environmental Satellite–R Series:
Program Success Requires Added Attention to Oversight, Risk
Management, Requirements, and the Life-Cycle Cost Estimate
Draft OIG Audit Report*

The National Oceanic and Atmospheric Administration (NOAA) is pleased to submit the attached response to the Office of Inspector General's draft report on NOAA's Geostationary Operational Environmental Satellite–R Series. We agree with all recommendations and included comments in the attached response.

We appreciate the opportunity to review and respond to your draft report. If you have questions, please contact Rhonda C. Lawrence, Acting-Director, Audit and Information Management Office on (301) 628-0948.

Attachment

**Department of Commerce
National Oceanic and Atmospheric Administration
Comments to the OIG Draft Report Entitled
“Geostationary Operational Environmental Satellite–R Series: Program Success Requires
Added Attention to Oversight, Risk Management, Requirements,
and the Life-Cycle Cost Estimate”
(May 2019)**

General Comments

The Department of Commerce’s National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review and comment on the Office of the Inspector General’s (OIG) draft report on the Geostationary Operational Environmental Satellite–R Series (GOES–R) Series Program. NOAA reviewed the report and agrees with OIG’s 11 recommendations. The response to each recommendation is provided below. Additionally, NOAA recommends factual and technical changes to the report, which are provided to ensure that the information presented is complete, accurate, and up-to-date.

Recommended Changes for Factual/Technical Information

Page 1, last paragraph: The report states that “A secondary instrument, the magnetometer, provides measurements of the Earth’s magnetic field that help NOAA understand the impact of high-energy particles traveling from the Sun to Earth. These particles can negatively affect spacecraft. Magnetometers provide inputs to models used by NOAA’s Space Weather Prediction Center.” While the magnetometer helps our understanding of the in-situ lower energy trapped radiation belt particles, it would be more accurate to state “A secondary instrument, the magnetometer, provides measurements of the Earth’s magnetic field that helps NOAA’s Space Weather Prediction Center, and those that use their products, understand solar disturbances impacting Earth and high-energy particles in Earth’s radiation belts. These particles can negatively affect spacecraft.”

Page 5, Section B: The report states that “After the occurrence of ABI anomalies, the program removed contract performance evaluation criteria that would have lowered its evaluations of on-orbit performance.” The GOES-17 ABI on-orbit performance evaluation has not yet occurred. The statement as written implies that the program purposely removed evaluation criteria that would have lowered on orbit performance; the overarching criteria of radiometric performance remains an evaluation criterion, and the proper functioning of all instrument subsystems (including the thermal subsystem) is required to produce good radiometric performance. Retaining radiometric performance as a criterion allows the Fee Determining Official (FDO) to make a determination of fee based on the KPP quality. We believe this is consistent with NASA’s supplement to the Federal Acquisition Regulation which indicates that the PEP should list all necessary evaluation factors.

Page 6, second paragraph: “However, our examination of the changes made to the ABI contract PEP found that criteria related to the thermal system and infrared calibration target were the only ones removed from the degraded and severely degraded classifications...” Other factors were also removed, including those related to visible/infrared calibrations, which were deemed redundant with the remaining criteria.

Page 8, first paragraph, line 1: We recommend that the sentence be modified to read “The magnetometers on NOAA’s geostationary satellites measure the strength and direction of the Earth’s magnetic field at the satellite’s position in space.”

Page 8, first paragraph, lines 4 and 5: Dual instruments are not just for redundancy and data comparison, but for aiding in the removal of possible magnetic signatures from the satellite. Recommend the sentence be modified to read “For redundancy and for removing spacecraft interference...”

Page 8, first paragraph, lines 6-8 We recommend modifying the sentence to read “Positioning the instruments on the satellite is a challenge because variations in the strength of the background geomagnetic field can be weak compared to magnetic fields generated by the spacecraft’s other systems”

Page 8, subscript 14: The magnetic field observed by GOES is a combination of the Earth’s internal field and the magnetic field due to currents that result from the interaction of Earth’s field with the solar wind. Therefore, recommend that the statement should read: “That is, the magnetic field most attributable to the Earth and its interaction with the solar wind.”

Page 9, first paragraph, lines 3 and 4: The report states “As a result, NOAA’s Space Weather Prediction Center continues to rely on the previous generation of satellites for these measurements.” We request that this statement be removed from the OIG final report. The magnetometer accuracy is not the reason Space Weather Prediction Center (SWPC) relies on a previous generation of satellites; rather, it resulted from delays in the readiness of ground processing software, which are being resolved. SWPC will begin using the GOES-R magnetometer data once the ground system is fully operational.

Page 10, first paragraph, second sentence: The report states “This is not in accordance with agency guidance.” We request that this statement be removed from the OIG final report. The report states that having a threshold requirement that is the same as the objective requirement is “not in accordance with agency guidance.” However, SWPC is not aware of any applicable NOAA guidance or policy. We agree that a threshold requirement is the minimum acceptable specification and the objective is the optimal specification that, if met, would significantly enhance meeting the mission. We believe that an objective value may be the same as the threshold if an operationally significant increment above threshold is not significant or useful, or meeting an objective requirement is technically feasible, or has been demonstrated.

NOAA Response to OIG Recommendations

Recommendation 1: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program addresses anomalies on instruments fulfilling essential mission requirements using a distinct process that is proportional to the criticality of a key performance parameter.

NOAA Response: Concur. The GOES-R program will continue to enforce the Failure Review Board process as documented in the ABI Mission Assurance Requirements document, section 2.1.1.3 Failure Review Board (FRB) and the reporting of non-conformances in accordance with the same contractual document.

Recommendation 2: That the Assistant Administrator for Satellite and Information Services ensure an independent review of changes to the ABI contract's PEP occurs to determine their rationale, appropriateness, and need for further actions."

NOAA Response: Concur. The GOES-R program will ensure an independent review of ABI PEP changes before the initial GOES-17 on-orbit fee evaluation and provide that information to the FDO and NESDIS AA as part of the fee determination process.

Recommendation 3: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program updates reliability analyses for ABI, the satellite, and constellation, specifically given the unique conditions of the hardware on GOES-16 and GOES-17 and any design changes for GOES-T and GOES-U."

NOAA Response: Concur. This is already underway and will be documented with updates to ABI and GOES system reliability analyses. For GOES-16, there are no specific ABI reliability updates planned since none of the components settings have been changed on-orbit.

Recommendation 4: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program documents its magnetometer design, integration, and on-orbit experience so that it is available to future GOES programs and contractors."

NOAA Response: Concur. This is already complete, see:

- The GOES-16 Spacecraft Science Magnetometer by T.M. Loto'aniu et al; in Space Science Review (2019) 215:32
- Lessons Learned from Flight Observations of the GOES-R Magnetometer, R. Schnurr et al at 2019 ESA Workshop on Aerospace EMC; 20-22 May 2019.

Recommendation 5: That the Deputy Under Secretary for Operations ensure that NOAA conducts analysis to determine distinct geomagnetic field measurement accuracy threshold and objective requirement specifications and ensure appropriately supported requirements are reflected in GOES-R program documents."

NOAA Response: Concur. We will re-examine the threshold and objective accuracy requirement through an examination of current and future magnetometer operational uses.

Recommendation 6: That the Deputy Under Secretary for Operations ensure the NOAA Space Weather Prediction Center updates its geomagnetic field observation accuracy requirement validation documentation.

NOAA Response: Concur. NOAA will use the results from Recommendation 5, including validation documentation, to update the GOES magnetometer accuracy requirement through the Consolidated Observing User Requirement List (COURL) process.

Recommendation 7: That the Deputy Under Secretary for Operations ensure NOAA assesses whether GOES are the optimal satellites to achieve geomagnetic field observation requirements, using an analysis of alternatives or similar cost-benefit approach.

NOAA Response: Concur. This will be done as part of the next generation satellite program formulation activities.

Recommendation 8: That the Assistant Administrator for Satellite and Information Services ensure that the GOES-R program formally manages risk to geostationary orbital positions for both current and future satellite programs.

NOAA Response: Concur. NESDIS will formally manage risk to geostationary orbital positions for its satellite programs. GOES-16 and -17 are operational in orbital slots that support NOAA's mission; the remaining GOES-R series satellites will continue to occupy these slots in the future. NESDIS will identify and track the risk of the availability of geostationary spots to support its satellite programs.

Recommendation 9: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program updates its LCCE (life-cycle cost estimate) incorporating results from Department's independent assessment.

NOAA Response: Concur. NOAA has requested the Department's Office of Acquisition Management to conduct an Independent Cost Estimate (ICE); the program will reconcile its LCCE with the ICE.

Recommendation 10: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program completes a prioritized list of off-ramps with triggering dates for server replacement activities.

NOAA Response: Concur. The GOES-R Ground Segment Project will develop an off-ramp methodology for maintaining and executing the GOES-R Ground System schedule. The Project is in the process of defining and adding off-ramps focused on launching GOES-T on schedule.

Recommendation 11: That the Assistant Administrator for Satellite and Information Services ensure the GOES-R program develops a plan to limit the risk of vendor lock-in for ground system sustainment.

NOAA Response: Concur. The GOES-R program will develop a programmatic/contractual and technical plan, to mitigate the risk of vendor lock-in for future ground system sustainment.

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