Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage

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January 20, 2022

MEMORANDUM FOR: Richard W. Spinrad, Ph.D.
Under Secretary of Commerce for Oceans and Atmosphere
and NOAA Administrator
National Oceanic and Atmospheric Administration

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

SUBJECT: *Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage*
Final Report No. OIG-22-015-A

Attached is our final report on our audit of the National Oceanic and Atmospheric Administration's Geostationary Operational Environmental Satellites (GOES)–R series program. Our objective was to assess the GOES-R series program's progress in achieving launch readiness for the GOES-T mission.

We found the following:

I. The GOES-R series program works toward the earliest achievable launch dates at potentially increased development risk.

II. The National Environmental Satellite, Data, and Information Service (NESDIS) is planning GOES launches sooner than its policy requires without analyzing the costs.

III. NESDIS assumes ground storage of satellites is not viable, but has not formally studied tradeoffs.

On December 17, 2021, we received NOAA's response to our draft report. We also received general comments. Based on those general comments, we made changes to the final report where appropriate. In response to the draft report, NOAA concurred with all of the recommendations and described actions it has taken, or will take, to address them. NOAA's formal response is included within the final report as appendix D.

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 Satellites and Weather Systems, at (202) 695-0791.

Attachment

cc: Benjamin Friedman, Deputy Under Secretary for Operations, NOAA
Stephen Volz, Acting Assistant Secretary of Commerce for Environmental Observation & Prediction and Assistant Administrator for Satellite and Information Services, NOAA
Janet Coit, Assistant Administrator for NOAA Fisheries and Acting Assistant Secretary of Commerce for Oceans and Atmosphere and Deputy NOAA Administrator, NOAA
Karen Hyun, Ph.D., Chief of Staff, NOAA
Pam Sullivan, GOES-R and GeoXO System Program Director, NOAA
Tanisha Bynum-Frazier, Director, Audit and Information Management Office, NOAA
Brian Doss, Alternate Audit Liaison, NOAA
Lisa Lim, Alternate Audit Liaison, NOAA
MaryAnn Mausser, Audit Liaison, Office of the Secretary

Report in Brief

January 20, 2022

Background

The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) acquires and manages the nation's operational environmental satellite systems. NOAA's Geostationary Operational Environmental Satellites (GOES) provide near-real time environmental observations of Earth's Western Hemisphere that are critical for weather forecasting, storm tracking, and severe weather warnings. GOES also provides advanced detection and monitoring of environmental hazards like wildfires, smoke, dust, volcanic ash, drought, and flooding. The key performance parameter (KPP)—the highest-priority data collected by GOES—is cloud and moisture imagery.

NOAA's latest generation of GOES, the GOES-R series (the Program), is a four-satellite program that provides advanced imagery and atmospheric measurements of Earth. On the GOES-R series, the Advanced Baseline Imager instrument provides the KPP imagery. The GOES-R series is expected to operate to 2040. As of September 2021, GOES-T, the third satellite in the series, was scheduled to launch on February 16, 2022.

Why We Did This Review

Our audit objective was to assess the Program's progress in achieving launch readiness for the GOES-T mission.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage

OIG-22-015-A

WHAT WE FOUND

We found the following:

I. The Program works toward the earliest achievable launch dates at potentially increased development risk.

II. NESDIS is planning GOES launches sooner than its policy requires without analyzing the costs.

III. NESDIS assumes ground storage of satellites is not viable, but has not formally studied tradeoffs.

WHAT WE RECOMMEND

We recommend that the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services does the following:

1. Conduct an analysis of alternatives or similar assessment to determine whether to continue the Program's approach of managing schedules toward the earliest possible launch dates.
2. Conduct a cost-benefit analysis of selected geostationary coverage availability thresholds, and update its geostationary launch policy as appropriate.
3. Determine the cost of operating spare satellites on orbit versus alternative options, including consideration of constellation longevity and satellite development risks, to help inform optimal acquisition and launch strategies.
4. Assess the cost effectiveness of satellite ground and on-orbit storage options using current cost, schedule, and technical performance data that can inform NESDIS satellite storage decisions.
5. On future satellite series, document storage option considerations early in the acquisition process to optimize satellite storage alternatives.

Contents

Introduction **1**

Objective, Findings, and Recommendations **3**

I. The Program Works Toward the Earliest Achievable Launch Dates at Potentially Increased Development Risk 3

Recommendation 5

II. NESDIS Is Planning GOES Launches Sooner Than Its Policy Requires Without Analyzing the Costs 5

A. NESDIS plans for higher launch frequency than its policy requires *6*

B. NESDIS has not accounted for the potential value of unused spares *8*

Recommendations 9

III. NESDIS Assumes Ground Storage of Satellites Is Not Viable, but Has Not Formally Studied Tradeoffs 9

A. NESDIS has not formally assessed the potential advantages of satellite ground storage *10*

B. NESDIS instrument requirements provide for ground storage, but satellite requirements do not *11*

Recommendations 11

Summary of Agency Response and OIG Comments **12**

Appendix A: Objective, Scope, and Methodology **13**

Appendix B: GOES-T Changes and Challenges Since the Launch of GOES-17 ..... **15**

Appendix C: Notional Value of Spare Satellites on Orbit **18**

Appendix D: Agency Response **20**

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

The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) acquires and manages the nation's operational environmental satellite systems. NOAA's Geostationary Operational Environmental Satellites (GOES) provide near-real time environmental observations of Earth's Western Hemisphere that are critical for weather forecasting, storm tracking, and severe weather warnings. GOES also provides advanced detection and monitoring of environmental hazards like wildfires, smoke, dust, volcanic ash, drought, and flooding. The key performance parameter (KPP)—the highest-priority data collected by GOES—is cloud and moisture imagery.

NOAA's latest generation of GOES, the GOES-R series (the Program), is a four-satellite program that provides advanced imagery and atmospheric measurements of Earth. On the GOES-R series, the Advanced Baseline Imager (ABI) instrument provides the KPP imagery. The GOES-R series is expected to operate to 2040.[1] As of September 2021, GOES-T,[2] the third satellite in the series, was scheduled to launch on February 16, 2022.[3]

GOES constellation[4] policy, composition, and status

NESDIS policy is to have three GOES satellites above Earth's Western Hemisphere[5] to provide atmospheric cloud and moisture imagery. Among the three satellites, NESDIS operates two—known as GOES-West and GOES-East—to cover the operationally required geographic area, and maintains one backup satellite in a storage orbit position to pick up the -East or -West mission if either one of the primary operational satellites fails.[6]

Table 1 depicts estimated lifetimes and notable status details for GOES-N[7] and GOES-R series satellites. The Program develops the GOES-R satellites to meet a 15-year design life[8] standard. NESDIS currently operates four GOES satellites (-14, -15, -16, -17), and a fifth geostationary

[1] The follow-on generation of satellites to the GOES-R series is in its early stages and is called Geostationary Extended Observations (GeoXO). NOAA is working to ensure these observations are in place by the early 2030s as the GOES-R series nears the end of its operational lifetime.

[2] Prior to launch, GOES satellites have a letter designation suffix, e.g., GOES-T, which is then changed to a sequenced numerical designation after launch; thus, GOES-T would become GOES-18.

[3] NESDIS subsequently agreed with the launch provider to postpone its planned launch of GOES-T from December 7, 2021, to Feb 16, 2022, due to factors external to the Program.

[4] A system of satellites is also referred to as a *constellation*.

[5] Geostationary satellites are at fixed positions along the Earth's equator at approximately 22,300 miles above the surface.

[6] Since it is impossible to predict exactly when a satellite will fail, and difficult to launch a replacement on short notice, NESDIS geostationary policy requires an on-orbit ready spare to restore service quickly in the event of a failed satellite.

[7] GOES-N (-13, -14, -15) satellites are the series that immediately preceded the GOES-R series and were designed for a 10-year lifetime (2 years storage and 8 years operations), which they have exceeded on orbit.

[8] The design life is for 10 years of operations and 5 years of on-orbit storage.

satellite (formerly GOES-13)[9] that is still operating for the United States Space Force over the Indian Ocean.

Table 1. GOES Satellites and Status

	GOES-N Series			GOES-R Series			
	GOES 13	GOES 14	GOES 15	GOES 16	GOES 17	GOES T	GOES U
Launch Date	May 2006	Jun 2009	Mar 2010	Nov 2016	Mar 2018	Feb 2022	Apr 2024
Est. End of Life	2026	2030	2029	2033	2028	2036	2040
Spacecraft	N/A		1 of 3 Star Trackers	Arcjets degraded		Propulsion Redesigns (Pyro Valves, Filters, Flush)	
Imager (KPP)	N/A				Thermal Issues	ABI Thermal System Redesign	
Magnetometer	N/A			Accuracy	Accuracy	New Magnetometer Design	
Notes	To DOD 2019 (Indian Ocean)					Schedule Slipped 554 Days for ABI Redesign	

Source: Office of Inspector General (OIG) analysis of NOAA and Program data as of September 2021

Notes:

a. This table is an independent OIG representation of status. The NOAA Office of Satellite and Product Operations provides up-to-date status information on each spacecraft and its various subsystems on its website.

b. Yellow boxes indicate a condition that may affect the spacecraft's longevity or reliability.[10]

c. Red boxes indicate mission instrument deficiencies that may impact the ability to consistently meet NOAA's observing requirements.[11]

d. GOES-13 is currently known as *Electro-optical Infrared Weather System-Geostationary* after being transferred to the U.S. Department of Defense (DOD). NOAA operates the satellite on behalf of the United States Space Force.

Once launched, GOES-T will become the fifth GOES satellite in orbit (not including the prior GOES-13).

[9] GOES-13 was transferred to the U.S. Department of Defense (DOD) in 2019 and is currently operating for the United States Space Force as *Electro-optical Infrared Weather System-Geostationary*.

[10] For a discussion of the star tracker issue, see 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, 6. For a discussion of arcjet degradation, see appendix B.

[11] DOC OIG, August 12, 2019. *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. Washington, DC: DOC OIG, 3–9.

Objective, Findings, and Recommendations

Our audit objective was to assess the Program's progress in achieving launch readiness for the GOES-T mission. To satisfy our objective, we examined technical performance challenges and changes to technical, schedule, and cost baselines since GOES-S (GOES-17) launched in March 2018. See appendix A for a full description of our objective, scope, and methodology.

As of September 2021, the Program was on track to launch GOES-T in February 2022 after completing comprehensive satellite performance testing during our fieldwork. However, after an 18-month schedule slip to redesign the ABI, magnetometer, and propulsion system, the Program made additional flight and ground readiness efforts in order to preserve GOES-T's revised launch planning date (LPD).[12] See appendix B for a more detailed discussion of changes to the technical, schedule, and cost baselines.

We found that the Program works toward the earliest achievable launch dates at potentially increased development risk. Additionally, NESDIS is planning launches using a higher launch frequency than required without considering the costs of overlapping its geostationary constellation with additional on-orbit spares. We also found that NESDIS assumes on-orbit satellite storage is its best default option for completed satellites, but has not formally studied the potential costs and benefits of ground storage.

I. The Program Works Toward the Earliest Achievable Launch Dates at Potentially Increased Development Risk

The Program's commitment agreement with NOAA requires the Program to work toward the earliest achievable launch dates for its satellite missions. The intent of the agreement is to minimize the risk of a satellite coverage gap. However, working toward aggressive planning dates can also increase pressure on schedules within the Program and potentially cause decisions to be predominantly schedule-driven, which can impact technical or cost performance.

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) has guidance and standards to help minimize development risks. GSFC captures guidelines it intends as institutional requirements in the Goddard Open Learning Design (GOLD) Rules. Additionally, the GSFC General Environmental Verification Standard (GEVS) recommends a systems verification approach in which the entire payload is tested or verified under conditions that simulate the flight's operations and environment as realistically as possible.

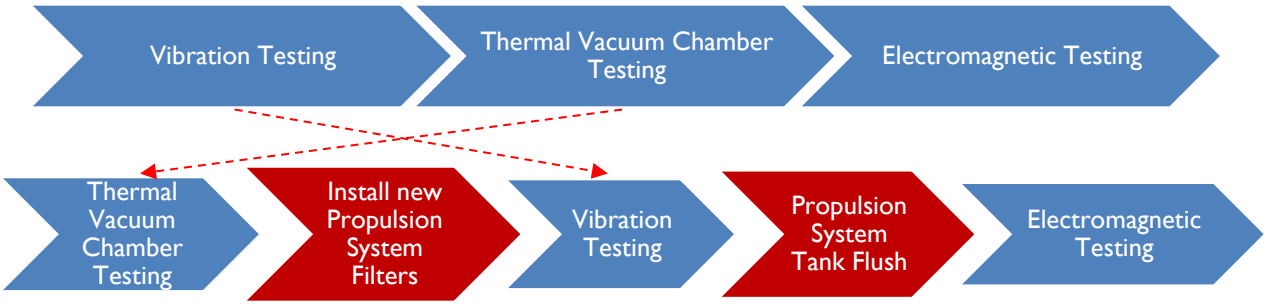
[12] The LPD is an internal management agreement of the earliest launch readiness date the Program works toward. The launch commitment date, which is a higher confidence date, also slipped from the 4th quarter of fiscal year 2020 to the 4th quarter of fiscal year 2022.

GOES-T Test Sequence Changed

In the midst of GOES-T satellite acceptance testing, the Program made changes to the spacecraft propulsion system[13] and test campaign, the latter of which the Program originally devised based on NASA standards. The test changes were to enable the propulsion system work (such as manufacturing and installing newly designed filters, performing tank flushes, and other changes) with minimized interruptions to the test campaign's overall schedule. Changes to the satellite configuration and testing sequence occurred as shown in figure 1, with mid-test process/design changes in red.

Figure 1. GOES-T Test Sequence as Planned and Executed

Test Sequence as Planned Based on NASA Standards



Test Sequence as Executed

Source: OIG analysis of Program test information

In changing the order of thermal vacuum chamber (TVAC) and vibration testing, the test sequence as executed did not simulate a general mission profile from liftoff to orbit. NASA standards[14] recommend implementation of the sequence as originally planned, which would more closely align with subjecting the satellite to mechanical vibration before significant temperature and pressure changes (i.e., TVAC). The Program and the spacecraft contractor told us there is no NASA, company, or industry standard that specifies a required TVAC and vibration test order. They also told us that TVAC tends to be the test phase that reveals workmanship defects, so they would rather see those earlier in the process. However, if defects are not detected at the system level, they may potentially cause hardware anomalies that—in extreme cases—could cause an operational failure.

Additionally, the Program interrupted satellite testing to make the propulsion system design changes and flush the fuel tank. This means that the GOES-T satellite configuration that entered the test campaign was not the same configuration that will launch and fly on orbit, which is not aligned to the GOLD Rule to "test as you fly—fly as you test." This rule holds that testing of all critical mission-operation elements (such as the propulsion system) as they

[13] See appendix B for a brief description of propulsion system changes.

[14] That is, GOLD Rules and GEVS, as discussed above.

will be flown greatly reduces the risk of negative impacts upon mission success, whether from partial or full loss of capability.[15]

Based on our review, changes to the planned testing campaign were predominantly a schedule-driven decision, which we attribute to NESDIS' and the Program's stated approach of aggressively managing schedules toward the earliest possible launch dates in order to mitigate the risk of potential data gaps.[16] If the Program does not assess the effectiveness of aggressive schedule management, it may make schedule-driven decisions without a full accounting of risks and tradeoffs. Overall, a schedule-driven approach focused on an earliest achievable launch date has been a contributing factor toward negative effects on the GOES-R series and could affect future programs if continued.

We have discussed the negative effects of schedule-driven approaches in prior GOES-R series reports.[17] In our 2017 report, we discussed a more than $1 million test mishap that could have catastrophically impacted the GOES-16 satellite, partially due to inadequate task planning and an aggressive, compressed schedule.[18] In 2019, we reported on ABI integration and test anomalies, which occurred after the Program chose not to adhere to the "test as you fly—fly as you test" rule.[19] Since that report, the Program shared lessons learned that stated launching the GOES-17 ABI before understanding the root cause of unstable test performance at the time was a "regrettable choice." The impaired GOES-17 ABI continues to have an impact on current operations and expected satellite lifetime, which caused NESDIS to decide to replace GOES-17 with GOES-T following planned post-launch testing and checkout in 2022.

Recommendation

We recommend that the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services does the following:

1. Conduct an analysis of alternatives or similar assessment to determine whether to continue the Program's approach of managing schedules toward the earliest possible launch dates.

II. NESDIS Is Planning GOES Launches Sooner Than Its Policy Requires Without Analyzing the Costs

The *Policy on NOAA Observing Systems Portfolio Management* requires that NOAA track all considerations for development, deployment, and exploitation of observing systems to ensure cost effectiveness, affordability, and the leveraging of observing assets, among other

[15] National Aeronautics and Space Administration 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.

[16] This is in accordance with its commitment agreement with NOAA, which the NOAA Assistant Administrator for Satellites and Information Services described as "launching as soon as ready and able."

[17] OIG-17-013-A, finding I, and OIG-19-022-A, finding I.

[18] OIG-17-013-A, finding I.

[19] OIG-19-022-A, finding I.

factors.[20] In 2011, NESDIS issued its geostationary satellite launch and spare call-up policy, which established objective criteria for determining contingency launch dates and on-orbit spare activation for the GOES system. It set an 80 percent probability of maintaining mission availability[21] for a two-operational-satellite system—i.e., two-imager coverage by GOES-East and GOES-West satellites. The policy requires a GOES system composed of two operational satellites and one on-orbit spare.

The probability that the two operational satellites will perform their intended function for a specified period is determined through analyses that NESDIS directs the Program and contractors to conduct.[22] NESDIS incorporates these analyses into its determination of the probability that the GOES constellation will provide the required data over time, which is known as the constellation availability. NESDIS documentation showed that, from 2011 to 2020, there was one actual gap in KPP imager data: a lapse of 2 hours and 35 minutes over the eastern United States in 2013.[23]

We found that NESDIS has planned satellite coverage to achieve greater than the 80 percent availability policy without accompanying cost-benefit analyses. This has produced planning scenarios that show a need for new launches earlier than necessary to meet the policy. With GOES-N series satellites that generally exceeded their designed lifetimes, there is a potential to have additional satellites on orbit beyond the spare—well before the newly launched satellites are needed. Earlier launches can cause overlap of satellite lifetimes, which can require a constellation of satellites to be replenished with new satellites earlier than would otherwise be necessary.

A. NESDIS plans for higher launch frequency than its policy requires

Since 2018, NESDIS has been using a 93 percent threshold of two-imager coverage in its constellation availability planning scenarios and preliminary launch date considerations for GOES-R series and its follow-on system, GeoXO.[24] Although the 80 percent policy and GOES-R series requirement remain officially unchanged, the Program told us 93 percent has become NOAA's expectation. NESDIS planners[25] explained that their preference resulted from a review of various percentages of availability, with 95 percent as too expensive due to the resulting increased launch frequency, and 90 percent as

[20] DOC National Oceanic and Atmospheric Administration, October 15, 2016. *Policy on NOAA Observing Systems Portfolio Management*, NAO 212-16. Silver Spring, MD: NOAA, 2. Continuous systemic evaluations of the observing systems and data, including options to maximize observational capabilities and their cost effectiveness, are also specified in Section 106 of the Weather Research and Forecasting Innovation Act of 2017, Pub. L. No. 115-25 (codified at 15 U.S.C. § 8516).

[21] For KPP cloud and moisture imagery.

[22] We previously reported issues with the consistency and transparency of NOAA's geostationary coverage probability calculations in 2017. *See* OIG-17-013-A.

[23] To fill this gap while they troubleshot the failed eastern satellite, NOAA reconfigured the western satellite to image as much of the total area as possible for the next 24 hours while the on-orbit spare (i.e., the third satellite) was enabled. Until the spare was operational, NOAA was not meeting its two-imager coverage requirement.

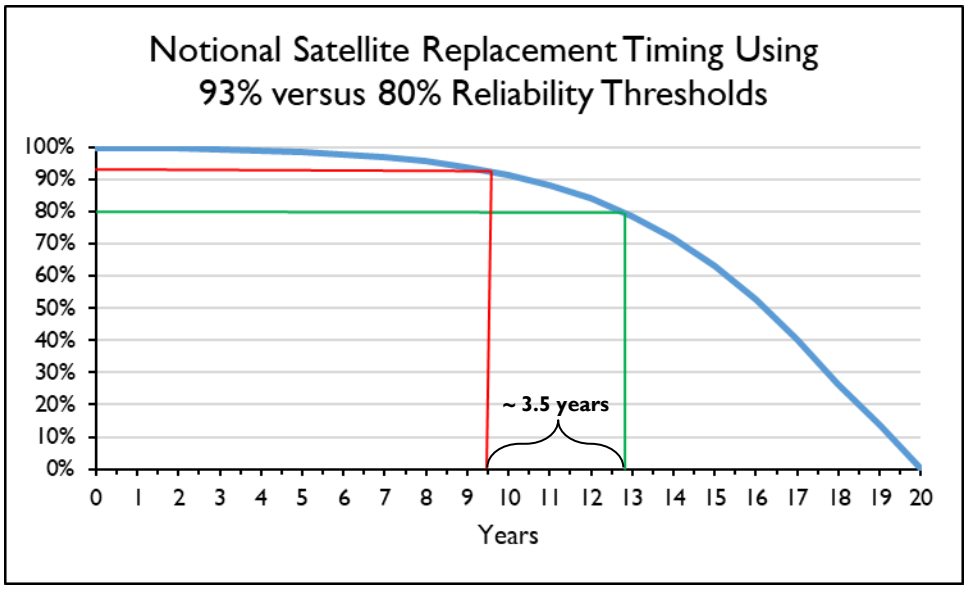
[24] Geostationary Extended Observations.

[25] NESDIS Office of System Architecture and Advanced Planning.

unacceptable to its supported line offices. NESDIS also said the cost and historical observed availability of imagers led to a determination that a 93 percent probability threshold was reasonable. However, NESDIS and the Program were unable to provide any documented analyses as the basis of this determination, including any analyses of differential value between older GOES-N series and newer GOES-R series satellite imagers.

NESDIS planners stated that targeting a higher availability threshold (or probability) results in a higher launch frequency and therefore higher costs. In figure 2, the notional relationship of a higher availability threshold to an accelerated launch schedule is shown. The blue line indicates a representative curve of satellite reliability, expressed as a probability that the satellite is available for operations. The intersection of the blue reliability curve with the red lines represents the year that the reliability would be at 93 percent, while intersection with the green lines represents the year when the reliability would be at 80 percent.

Figure 2. The Effect of a Higher Coverage Threshold on Launch Timing



Source: OIG analysis of NOAA and Program data

Note: Although only a notional representation, the curve is similar to an actual GOES reliability curve and illustrates the reason that launch cadence may be higher for a higher coverage threshold.

For this example, targeting a 93 percent minimum probability value instead of an 80 percent value to determine when to launch a satellite would result in needing a launch in year 9 instead of nearly year 13.

NESDIS planners explained that they based the justification for using the 93 percent value on NOAA Satellite Observing System Architecture analyses during the 2014–18

timeframe by balancing cost with historical observational performance.[26] A detailed analysis of this cost relationship was not available for our review.

NESDIS and the Program offered another explanation for the desire to exceed the policy threshold, which is that NOAA seeks to launch the newest technology as soon as ready and able. Since both the older GOES-N series and newer GOES-R series satellites have been fulfilling the geostationary policy requirements,[27] we asked NESDIS if it could show the level of data exploitation or the impact and value to its customers' mission performance by using the newest technology versus the older. NESDIS did not have that type of data, but it and the Program told us the user community prefers the newest imager data, such as that from the ABI on the GOES-R series.

NESDIS acknowledged targeting a higher coverage probability in its planning and the higher costs associated with more frequent launches. However, the 93 percent value is not consistent with standing geostationary policy and Program requirements, which target 80 percent availability. Further, NESDIS has not formally documented its deviation from the policy or quantified the costs, performance benefits, and exploitation of GOES-R series data over GOES-N series data.

B. NESDIS has not accounted for the potential value of unused spares

In addition to satellite development and launch costs, the higher launch frequency may also lead to other costs associated with having more satellites on orbit than required. With the launch of GOES-T, there will be five GOES on orbit—two more than NESDIS policy requires—that are capable of meeting critical cloud and moisture data requirements. [28] We found that NESDIS has not accounted for the potential value of unused satellite capability that can result from overlapping individual satellite lifetimes due to launching multiple on-orbit spares. [29]

However, it is not clear that launching additional satellites while there are three or more capable satellites on orbit is always a cost-effective or optimal strategy. According to Program managers, they and the spacecraft contractor determine the earliest possible launch date they can achieve for the agreed level of risk. This becomes the recommended LPD.[30] The Program uses the LPD to construct its development schedule and a recommended launch commitment date against which program performance is measured. To help illustrate a notional value of unused satellite capability, please see appendix C.

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[26] We did not find this to be the case in our prior reporting on the topic. *See* OIG-17-013-A, finding IV.

[27] For instance, GOES-15 has been filling in the gaps created by degraded GOES-17 ABI performance.

[28] GOES-14, GOES-15, GOES-16, GOES-17, GOES-T (-18). This does not include the potential capability of GOES-13, which NOAA transferred to the DOD in 2019.

[29] Once a satellite is launched, it starts its wear-out lifetime in space. Thus, if NESDIS expects a satellite to be operationally capable for 15 years on orbit, that 15-year clock is started once the satellite launches.

[30] Subsequent to our field work, the Program told us this was not the process used for GOES-U.

In addition to not fully exploiting the value of satellites already on orbit, replacing satellites that are still functional can have other potential effects. There could be higher costs or technical performance risks to satellites in development due to aggressive schedules,[31] and less optimization of satellite series' lifetimes because they start and end earlier than necessary. For instance, if the current GOES-R series (GOES -16 to -19) planned lifetimes had not been so heavily overlapped with GOES-N series lifetimes (GOES -13 to -15), then it is possible that NESDIS could have launched the next series, GeoXO, later than 2032 as currently estimated.

NESDIS may be able to improve the affordability of its geostationary constellation by more carefully accounting for the value of its operating satellites and reducing the amount of satellites stored on orbit. Efficient exploitation of satellite life can help foster less aggressive development schedules and mitigate increased development risk. Due to the lifecycle phase of the GOES-R Program, our recommendations would be most practical for satellites beyond current GOES-R series plans.[32]

Recommendations

We recommend that the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services does the following:

2. Conduct a cost-benefit analysis of selected geostationary coverage availability thresholds, and update its geostationary launch policy as appropriate.
3. Determine the cost of operating spare satellites on orbit versus alternative options, including consideration of constellation longevity and satellite development risks, to help inform optimal acquisition and launch strategies.

III. NESDIS Assumes Ground Storage of Satellites Is Not Viable, but Has Not Formally Studied Tradeoffs

In its most recent planning timelines, NESDIS has planned longer durations of on-orbit storage, versus operations time, for its geostationary satellites.[33] As we discussed in finding II, NESDIS has also planned coverage that potentially contributes to having more spare satellites on orbit, which can increase relative time spent as a spare versus operating, during the satellites' estimated lifetimes. An alternative to on-orbit storage would be to store satellites on the ground before launching, potentially preserving their estimated lifetimes. However, we found that NESDIS' general approach is to store satellites on orbit and that it

[31] *See* (1) OIG-17-013-A, finding I; (2) DOC OIG, August 2, 2018. *The Joint Polar Satellite System: Program Must Use Realistic Schedules to Avoid Recurrence of Ground Project Delays and Additional Cost Increases*, OIG-18-024-A. Washington, DC: DOC OIG, finding I; and (3) OIG-19-022-A, finding I.

[32] Although GOES-T and GOES-U have not launched yet, schedule delays without technical cause at this late acquisition stage are not realistic, as they would create difficult issues with storage, personnel, budget, and contracts, to name a few.

[33] A NOAA fly-out chart from December 2020 indicated approximately 5 years of on-orbit storage for GOES-T, but NOAA recently announced it will push GOES-T into operational service directly after launch to replace GOES-17. GOES-U on-orbit storage is planned until approximately 7 years after launch.

has no documented analyses supporting its decision. We also found that NESDIS does not include satellite ground storage in level I or level II GOES-R program requirements.[34]

A. NESDIS has not formally assessed the potential advantages of satellite ground storage

Having an option of planned ground storage may help reduce acquisition costs and maintain an efficient production line. NESDIS does not have a policy framework for considering planned ground storage[35] of completed satellites. As a result, when a satellite is not immediately needed for operations but is ready to launch, NESDIS' and the Program's general approach is to launch and store it on orbit, even though storing the satellite on the ground could potentially be a more viable option than in the past.[36]

Although NESDIS has not conducted any recent formal evaluations of storage options to assess cost effectiveness, the Program considers ground storage to be costlier and riskier due to storage costs, maintenance, retesting, and potential human error every time there is interaction with the satellite. The Program's view is that on-orbit storage also eliminates the highest-risk event as early as possible: the launch.

The Program said it analyzes ground storage on a case-by-case basis as needed during satellite development and launch determination decisions. However, the only documentation to support its approach was a bottom-line briefing specific to GOES-U with no underlying analysis. NESDIS has not assessed the effects of satellite storage from an acquisition, development, and mission perspective, likely because there is no formal policy to guide programs' consideration of storage. DOD previously launched satellites as soon as they were built. However, DOD began considering ground storage earlier in the acquisition process, such as at the time of contract award, because satellites were lasting longer than expected. This can push out planned launch dates for newer satellites, extending the operational years received from a constellation.[37]

With satellite ground storage as an option early in the acquisition process, the Program could potentially extend existing satellite series by delaying launches of replacement satellites, or reduce schedule pressure on satellites in development if unexpected design issues arise.

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[34] The level I requirements serve as the top-level requirements documents for the Program. All other requirements documents flow down from the level I documents. *See* DOC NOAA and NASA, January 31, 2013. *Geostationary Operational Environmental Satellites - R Series (GOES-R) Management Control Plan (MCP)*, 410-R-PLN-0067, Version 2.0. Washington, DC: DOC NOAA and NASA, 39. Available online at https://www.goes-r.gov/syseng/docs/MCP_V2.pdf (accessed September 30, 2021).

[35] Planned ground storage would include storage considerations at the time of contract award, versus ad hoc during production.

[36] *See* U.S. Government Accountability Office, December 9, 2014. *Space Acquisitions: DOD Needs More Guidance on Decisions to Store Satellites*, GAO-15-97R. Washington, DC: GAO, 1–3.

[37] GAO-15-97R.

B. NESDIS instrument requirements provide for ground storage, but satellite requirements do not

The GOES-R series level I and level II program requirements include storage provisions as shown in table 2. Current requirements address on-orbit storage for satellites, but do not provide direction for satellite ground storage.

Table 2. GOES-R Series Storage Requirements and Concept

	Level I Requirement Document	Level II Mission Requirement Document
Instruments	*Not Addressed*	**On-orbit and ground**
Satellite (spacecraft + instruments)	**On-orbit only**	**On-orbit only**

Source: OIG analysis of Program data

The absence of planned satellite ground storage as a program option is consistent with NOAA's direction to the Program to achieve the earliest possible launch dates. It also agrees with NESDIS and Program explanations that their default assumption is for completed satellites to be stored on orbit. However, detailed storage cost data could provide NESDIS with information that could result in options for cost efficiencies in managing satellite production and the geostationary constellation.

Recommendations

We recommend that the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services does the following:

4. Assess the cost effectiveness of satellite ground and on-orbit storage options using current cost, schedule, and technical performance data that can inform NESDIS satellite storage decisions.
5. On future satellite series, document storage option considerations early in the acquisition process to optimize satellite storage alternatives.

Summary of Agency Response and OIG Comments

In response to our draft report, NOAA concurred with all recommendations but asked that we clarify two aspects of the report. NOAA requested we reconsider what it termed "OIG's position" with respect to the Program's approach of working toward the earliest possible launch dates and our use of the word "excess" throughout the text.

With respect to the Program's work toward the earliest possible launch dates, this is not "OIG's position" but rather the direction NOAA provides to the Program in its GOES-R series Program Commitment Agreement. This was discussed in key personnel interviews and further described in finding I. We have made slight changes to the final report to clarify this point. We also considered NOAA's argument with respect to the use of the word "excess" and agreed to use alternative wording in the final report, where appropriate.

We are pleased NOAA concurred with our recommendations and look forward to reviewing its audit action plan.

Appendix A: Objective, Scope, and Methodology

Our audit objective was to assess the Program's progress in achieving launch readiness for the GOES-T mission. We announced this audit on March 24, 2020, and completed our fieldwork in September 2021. We discussed our tentative findings with the auditee on April 9, 2021; October 5, 2021; and October 7, 2021.

To assess progress in achieving GOES-T launch readiness, we selected program status as of the GOES-S (-17) launch in March 2018 as the baseline of comparison. We identified changes or challenges to technical performance, as well as the extent to which the costs and schedule have changed, compared to the selected baseline. To better understand auditee perspectives on cost, schedule, and technical performance, we interviewed key personnel from the U.S. Department of Commerce (the Department) Office of Acquisition Management, NESDIS, the Program, GOES-T flight and ground projects, and the spacecraft contractor. We reviewed the impact of COVID-19 on the flight and ground projects. To identify technical performance changes and challenges, we reviewed NOAA/NESDIS policies and plans, NASA project management and technical standards, Program requirement documents, design reviews, and milestone reviews. Performance issues that were of potential relevance to GOES-T were assessed using interviews with key personnel and reviews of waivers, deviations, risk lists, and Program briefings in order to identify the most significant technical performance risks. Using applicable NOAA/NESDIS, NASA, and Program policies, standards and plans, we assessed the effectiveness and efficiency of program approaches to managing significant technical risks.

To determine the extent to and reasons for which costs and schedules have changed since March 2018, we reviewed schedule and cost baselines, adjustments, and status reviews from 2018-21. Using NOAA/NESDIS and Program documentation, we identified significant differences from baselines and the reasons for the differences. We assessed remaining work for the risk of significant future schedule or cost performance impacts on overall Program efficiency or effectiveness.

During our fieldwork in April 2021, we advised the auditee there was no direction or plan for exploiting the capabilities of a spare fifth ABI (the highest-priority GOES instrument) with an estimated value of $200 million. In July 2021, the Program briefed NOAA management on an option for using the spare ABI as risk mitigation for the GOES-R series follow-on satellites, known as GeoXO. This accounts for the spare ABI until a design decision is made for the next-generation imager in 2027.

Additionally, we reviewed the new ground system Remote Access and Development Capability developed to mitigate COVID-19 restrictions, including an assessment of plans of action and milestones, system security plans, known risks and controls, and the scope of new system designs, for factors that could negatively impact the overall information technology security posture.

We assessed internal control significant within the context of our objective. This included examining the design of management controls as documented in program-level management plans, which incorporate NASA procedural requirements. We reviewed the Management Control Plan, Risk Management Plan, Program Commitment Agreement, major design review outcomes, and milestone reviews. We assessed the implementation of internal control through document reviews and interviews with key personnel to determine adherence to standards, procedures, and plans. 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.

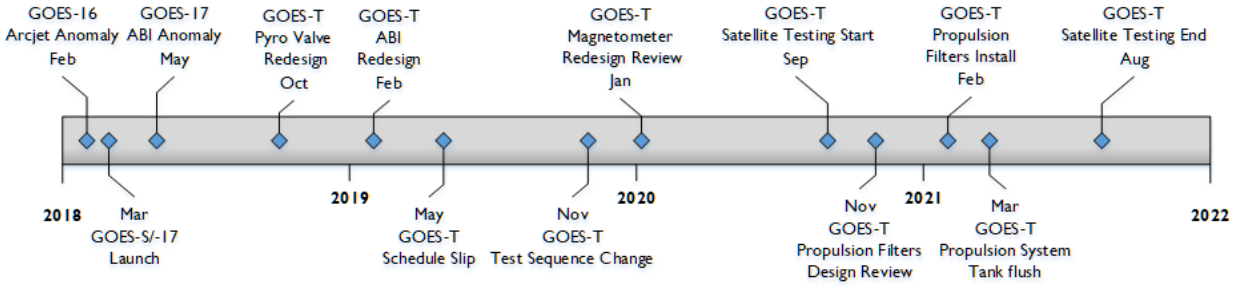
We conducted our review from March 2020 through September 2021 under the authority of the Inspector General Act of 1978, as amended (5 U.S.C. App.), and Department Organization Order 10-13, as amended October 21, 2020. We performed our fieldwork remotely from OIG offices headquartered in Washington, DC.

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

Appendix B: GOES-T Changes and Challenges Since the Launch of GOES-17

As previously depicted in table 1, the Program modified GOES-T (and GOES-U) designs to correct deficiencies on the ABI, magnetometer, and propulsion system that impacted the performance of GOES-16 and GOES-17 after they launched.[38] GOES-T key design and development events are shown in figure B-1.

Figure B-1. GOES-T Timeline of Key Design and Development Events



Source: OIG analysis of Program data

Based on the results of the GOES-T test campaign, the Program expects its design changes to perform according to plan. However, the new designs will be flying on a GOES satellite for the first time—so rather than flying as a proven third copy in the series, GOES-T will have a different satellite configuration than GOES-16 and GOES-17.

Significant GOES-T Design Changes

Three significant design changes to the ABI, magnetometer, and propulsion system are briefly described below.

ABI. The Program redesigned the ABI thermal subsystem following a mishap review board investigation in 2019. Although the GOES-17 ABI was delivering approximately 97 percent of the required data, the daily, multi-hour outages during the orbital warm season[39] impact the National Weather Service, and the degradation is getting worse over time.[40] To mitigate the impact, NOAA has been using GOES-15 to supplement GOES-17 operations. Although the GOES-T ABI is fully tested, the redesigned GOES-U ABI thermal subsystem recently showed unexpected power consumption values during its environmental testing, leading the Program to investigate the anomaly to ensure it does not affect GOES-T.

[38] NESDIS experts told us a GOES-17 ABI thermal subsystem issue is expected to reduce the operational life of the satellite due to higher operating temperatures, while degraded arcjets on GOES-16 may impact the long-term reliability of that satellite. We reported on the ABI and magnetometer deficiencies in our last report; *see* OIG-19-022-A.

[39] Approximately August through October and February through April each year.

[40] As of September 2021, the GOES-17 ABI was delivering 92–93 percent data availability.

Magnetometer. To improve magnetometer performance, the Program decided in September 2019 to replace the contractor-supplied magnetometer instrument with a NASA-built model that has a successful flight history, but not on GOES satellites. The new magnetometer has different power requirements, heaters, and other interface changes. The Program is hopeful the new unit will meet requirements once on orbit, but testing of the magnetometer was not in flight-like configuration. Since one of the primary challenges of magnetometer performance is accounting for local measurement effects once deployed on its extended boom in space,[41] it will not be known if the new unit improves upon prior models until post-launch checkout occurs.

Propulsion system. By 2019, three of the four GOES-16 arcjets had exhibited degraded performance that caused the Program to direct an extensive root cause analysis to understand and address potential implications for the on-orbit satellites as well as GOES-T and GOES-U. The analysis found that fuel tank debris was most likely clogging the fuel line supplying the arcjets. The Program then designed new filters, rerouted fuel lines and heaters, and developed a fuel tank flush procedure that it executed diagnostically on the GOES-U spacecraft to understand the characteristics of the fuel line debris. Once satisfied the tank flush procedure would mitigate the clogging of the fuel line, the Program added the procedure within the GOES-T satellite acceptance testing sequence and then installed the newly designed filters.

Schedule and Cost Changes

In order to implement the changes to the GOES-T technical baseline, the Program slipped the LPD[42] 18 months, from June 2020 to December 2021.[43] Due to the COVID-19 pandemic, ground system development efforts were impacted by restrictions to travel and site access during a crucial time for installing server replacements.[44] The Program directed preservation of the LPD, forcing its ground system project team to replan its schedule by splitting server installations into pre- and post-launch segments and adding remote software development features.[45]

In May 2020, the Program Milestone Decision Authority[46] approved a revised lifecycle cost of $11.7 billion to cover the Program through fiscal year 2036, an increase of $872 million (8 percent) from its prior lifecycle cost baseline. The increase accounted for ground system server replacements ($365 million) and previous incorrect assumptions for ground system sustainment

[41] See OIG-19-022-A, finding II.

[42] See footnote 12.

[43] See footnote 3.

[44] For more detail on ground system server replacement plans, see OIG-19-022-A, finding IV.

[45] The ground project deferred some tasks until after launch, and added risk to GOES-16 and GOES-17 operations due to performing necessary ground system work during periods when support staffing was not optimal. At the conclusion of our fieldwork, the ground project completed its server installation work in time to meet the replanned schedule.

[46] Approved by the Assistant Secretary of Commerce for Environmental Observation and Prediction, who was performing the duties of Under Secretary of Commerce for Oceans and Atmosphere.

($507 million). In addition to revised lifecycle cost, the ground system schedule changes related to COVID-19 cost an estimated $61 million, which the Program covered from its budget reserve.[47]

[47] Budget reserves are amounts withheld to help fund unexpected costs as they arise.

Appendix C: Notional Value of Spare Satellites on Orbit

Table C-1 shows NESDIS' and the Program's geostationary satellite on-orbit status (or planned status) since 2017. Each satellite icon represents a GOES mission-capable satellite.

Table C-1. Notional Value of Spare Satellites in Orbit[a]

Year	Policy Coverage (2 Ops + 1 Spare)	GOES-N Series In-Orbit Spares Exceeding Policy	GOES-R Series In-Orbit Spares Exceeding Policy
2017	3		
2018	3		
2019	3	1	
2020	3	1	
2021	3	1	
2022	3	1	
2023	3	2	
2024	3	2	
2025	3	2	1
2026	3	2	1
2027	3	2	1
2028	3	2	1
2029	3	1	
Total Satellite Years of Notional Unused Value		17	4
Total Dollars of Notional Unused Value		$850 million	$400 Million

Source: OIG analysis of NESDIS and Program data

[a] Notional GOES-N series dollar value is based on OIG's rough order of magnitude (ROM) estimate of $50 million per satellite per year. Notional GOES-R series dollar value is based on a Program ROM estimate of approximately $100 million per satellite per year. Satellite lifetimes are based on the latest (December 2020) NOAA geostationary fly-out chart and constellation availability analysis.

The Policy Coverage column depicts the expected number of satellites that would be available to satisfy the required three satellites on orbit (two operational plus a spare). The satellite icons in the GOES-N and GOES-R series columns represent the expected number of spares that would exceed the policy requirement (i.e., unused spares). The $1.25 billion[48] total of cumulative notional unused value does not represent direct cost, but can be viewed as a

[48] Note that this does not account for the potential unused value of GOES-13, which NOAA decommissioned in 2018 but which is estimated to be able to operate as a DOD asset until 2026. Based on the methodology of table 1, this could represent another $450 million of notional value.

representation of an opportunity cost of launching satellites in excess of requirements, based on the value of the satellites for meeting policy coverage requirements.

Appendix D: Agency Response

UNITED STATES DEPARTMENT OF COMMERCE
Deputy Under Secretary for Operations
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

DEC 17 2021

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

FROM: Benjamin P. Friedman
Deputy Under Secretary for Operations
Performing the duties of the Under Secretary of
Commerce for Oceans and Atmosphere and
NOAA Administrator

SUBJECT: *Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage*
Draft Report

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) is pleased to submit the attached response to the draft report on NOAA's Geostationary Operational Environmental Satellites–R series program. We reviewed the report and concurred with the recommendations.

We appreciate the opportunity to review and respond to your draft report. If you have any questions please contact Tanisha Bynum-Frazier, Director, Audit and Information Management Office at 301-467-0832.

Department of Commerce
National Oceanic and Atmospheric Administration
Comments to the OIG Draft Report Titled "Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage"
November 2021

General Comments

The National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report on the Geostationary Operational Environmental Satellites (GOES)–R series program entitled "Redesigned GOES-T is Ready for Launch, but NOAA Should Reassess Its Assumptions for Satellite Launch Planning and Storage." NOAA has reviewed the draft report and concurs with the OIG's recommendations. The response to each recommendation and general comments are provided below.

Although NOAA agrees with the OIG's recommendations, we request that the OIG clarify two points in its report. The first is the OIG's position that the GOES-R Program should work toward the earliest possible launch date and not consider an option for ground storage. We believe this assertion is true in some circumstances, but given the history of the program we respectfully request that the OIG consider incorporating additional information in its analysis. Specifically, while the assertion is valid for GOES-T in the period following the identification of the GOES-17 Advanced Baseline Imager anomaly, the assertion is not necessarily valid for GOES-U, for which the Program considered cost and benefit of ground storage vs on-orbit storage to select a launch date. The assertion may also not be valid to earlier satellites (before 2018), where a period of ground storage was planned for both GOES-T and U. We also question whether it is valid for Geostationary Extended Observations (GeoXO), where future launches are planned that ensure having three operational Imagers on-orbit.

We also would ask the OIG to consider modifying the word "excess" as it is used throughout the report, including in Recommendation #3. The word "excess" implies that NOAA will continue to operate old satellites that are no longer in use. NOAA has no plans to have "excess" satellites on orbit. Indeed, NOAA has a Memorandum of Agreement with the United States Air Force to consider moving one GOES 14/15 over the Indian Ocean after GOES-T is operational. NOAA is also considering alternatives that allow it to use the additional satellite (14 or 15) for research purposes (e.g., by a guest researcher).

NOAA Response to OIG Recommendations

Recommendation 1: That the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services conduct an analysis of alternatives or similar assessment to determine whether to continue the Program's approach of managing schedules toward the earliest possible launch dates.

NOAA Response: We concur. We agree to revise the GOES-U launch date recommendation analysis, which was last updated in November 2020. We would note, however, that the Program is not managed toward *only* the earliest possible launch dates as the Program must consider

launch dates based on several important variables, including the health and reliability of on-orbit assets, user needs for new observations, and cost of ground storage.

Recommendation 2: That the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services conduct a cost-benefit analysis of selected geostationary coverage availability thresholds, and update its geostationary launch policy as appropriate.

NOAA Response: We concur. NESDIS will perform an analysis of a range of geostationary Imager availability thresholds to identify cost, benefit, and risk at different threshold levels. The launch policy will be updated, if needed, to reflect the conclusion of the analysis. The information developed in response to recommendations 3 and 4 will be considered in this analysis. The result will be applied to recommendation 5, if needed.

Recommendation 3: That the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services determine the cost of operating excess spare satellites on orbit versus alternative options, including consideration of constellation longevity and satellite development risks, to help inform optimal acquisition and launch strategies.

NOAA Response: We concur. NESDIS Office of Satellite and Product Operations will provide an estimate of operating costs for excess spare satellites for use in the geostationary Imager availability threshold analysis performed in response to Recommendation 2.

Recommendation 4: That the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services assess the cost effectiveness of satellite ground and on-orbit storage options using current cost, schedule, and technical performance data that can inform NESDIS satellite storage decisions.

NOAA Response: We concur. The cost of satellite ground storage will be assessed and used in the geostationary Imager availability threshold analysis performed in response to Recommendation 2.

Recommendation 5: That the NOAA Deputy Under Secretary for Operations ensure that the Assistant Administrator for Satellite and Information Services for future satellite series, document storage option considerations early in the acquisition process to optimize satellite storage alternatives.

NOAA Response: We concur. Ground storage is already specified in the GeoXO Phase A instrument and spacecraft studies Statements of Work. Requirements will be updated, if needed, to reflect the results of the geostationary Imager availability threshold analysis performed in response to Recommendation 2.