Satellite Integration and Test Phase Improvements Are Needed to Ensure the Success of Future Polar Weather Satellite Missions

REDACTED FINAL REPORT NO. OIG-23-027-A

SEPTEMBER 5, 2023

~~CONTROLLED UNCLASSIFIED INFORMATION~~

~~*Final Report Contains Information Marked*~~
~~***CONTROLLED UNCLASSIFIED INFORMATION***~~

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

UNITED STATES DEPARTMENT OF COMMERCE
Office of Inspector General
Washington, D.C. 20230

~~CUI~~

September 5, 2023

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: *Satellite Integration and Test Phase Improvements Are Needed to Ensure the Success of Future Polar Weather Satellite Missions*
Final Report No. OIG-23-027-A

Attached is the final report on our audit of the National Oceanic and Atmospheric Administration's Polar Weather Satellites program. Our objective was to assess the program's execution of selected development activities.

We found the program should:

I. Take additional steps to ensure instruments on JPSS-3 and JPSS-4 are protected from contamination and tested as they will fly.
II. Improve its lessons-learned process so it and other programs can learn from its experiences.
III. Improve its requirements verification process before JPSS-3 and JPSS-4 verification efforts begin.

In its response to our draft report, NOAA concurred with our recommendations and provided comments with additional context as well as considerations it will need to make to address the recommendations. NOAA's response is included in appendix B. 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 the Office of Inspector General's website pursuant to sections 4 and 8M of the Inspector General Act of 1978, as amended (recodified at 5 U.S.C. §§ 404 & 420). In accordance with a recommendation from the Department of Commerce Office of General Counsel, we have redacted sensitive business information from the public version of this report.

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) 793-2938;

Kevin Ryan, Director for Audit and Evaluation, Systems Analysis and NOAA Programs, at (202) 750-5190; or Edward Kell, Director for Audit and Evaluation, Satellite Programs, at (202) 753-6125.

Attachment

cc: Jainey K. Bavishi, Assistant Secretary of Commerce for Oceans and Atmosphere and Deputy NOAA Administrator
Michael C. Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction, NOAA
Benjamin Friedman, Deputy Under Secretary for Operations, NOAA
Stephen Volz, Assistant Administrator for Satellite and Information Services, NOAA
Karen Hyun, Chief of Staff, NOAA
Kelly Turner, Chief of Staff, NOAA-NESDIS
Tim Walsh, Director of the Office of Low Earth Orbit Observations, NOAA
Henry Hope, JPSS Chief of Staff, NOAA
Mary Ann Mausser, Audit Liaison, Office of the Secretary
Tanisha Bynum-Frazier, Director, Audit and Information Management Office, NOAA
Joel Yoffee, Alternate Audit Liaison, NOAA

Report in Brief

September 5, 2023

Background

The National Oceanic and Atmospheric Administration's (NOAA's) polar weather satellites provide weather data to support forecasts and warnings of severe weather events. Polar satellites pass over the North and South Poles while continuously circling the planet. They contribute approximately 85 percent of the data for numerical weather prediction models.

Acquisition, development, and support for these satellites are managed by the Joint Polar Satellite System (JPSS) program. The program is a collaboration between NOAA and the National Aeronautics and Space Administration (NASA). NOAA provides funding and retains overall responsibility and authority for the program. It manages the acquisition and development of the ground system. NASA manages the satellites' acquisition and development.

In March 2015, the program awarded the spacecraft contract for the second JPSS satellite, JPSS-2. In 2022, the program led JPSS-2 through several major activities before its launch in November 2022. JPSS-2 completed post-launch testing and is operating as NOAA-21.

The program is now building JPSS-3 and JPSS-4, with plans to finish developing and testing both satellites by 2026 and to launch them in 2027 and 2032.

Why We Did This Review

Our audit objective was to assess the Polar Weather Satellite program's execution of selected development activities. To satisfy our objective, we examined aspects of the program's environmental test campaign and pre-launch readiness efforts for JPSS-2.

National Oceanic and Atmospheric Administration

Satellite Integration and Test Phase Improvements Are Needed to Ensure the Success of Future Polar Weather Satellite Missions

OIG-23-027-A

WHAT WE FOUND

Generally, the program was successful in the testing and readiness efforts we reviewed for JPSS-2. However, we found the program should do the following:

I. Take additional steps to ensure instruments on JPSS-3 and JPSS-4 are protected from contamination and tested as they will fly. We found issues with contamination controls in a test the JPSS-2 contractor conducted to demonstrate that the satellite could operate in the vacuum and extreme temperatures seen in space.

II. Improve its lessons-learned process so it and other programs can learn from its experiences. Recording lessons learned provides opportunities to improve satellite integration and other processes for NOAA/NASA missions.

III. Improve its requirements verification process before JPSS-3 and JPSS-4 verification efforts begin. Requirements verification provides evidence that satellites meet contractual requirements.

WHAT WE RECOMMEND

We recommend the NOAA Deputy Undersecretary of Operations direct the Assistant Administrator for Satellite and Information Services to do the following:

1. Ensure that controls are in place requiring the program to measure and compare contamination levels with defined limits before considering a waiver to Test as You Fly requirements for JPSS-3 and JPSS-4.
2. Ensure the spacecraft contractor revises its contamination controls to provide reasonable assurance that silicone contamination near the Ozone Mapping and Profiler Suite instrument remains below defined limits during JPSS-3 and JPSS-4 satellite integration and testing.
3. Ensure the JPSS program updates its JPSS Program Plan and JPSS Flight Project Plan to describe a lessons-learned approach that is executable and meets the needs of the program and NASA. The update should include specific management controls that ensure these needs are met.
4. Ensure the program defines and provides guidance to the spacecraft contractor on the expected level of documentation and artifacts necessary to support verifications.
5. Ensure the program identifies improvements to the verification review process, including the follow-on review of previously rejected verifications.

We provided a draft of this report to NOAA for review and response. NOAA concurred with our recommendations and provided comments with additional context as well as considerations it will need to make to address the recommendations.

Contents

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) polar weather satellites provide weather data to support forecasts and warnings of severe weather events. Polar satellites contribute approximately 85 percent of the data for numerical weather prediction models. The satellites pass over the North and South Poles while continuously circling the planet, viewing the entire Earth's surface twice a day over the course of approximately 14 orbits. NOAA's polar satellites support the Commerce Department's primary mission essential functions to provide satellite imagery and meteorological forecasts critical to public safety.

NOAA resources these satellite missions under its Polar Weather Satellites budget program. Acquisition, development, and support activities are managed by the Joint Polar Satellite System (JPSS) program (hereafter, the program). The program is a collaboration between NOAA and the National Aeronautics and Space Administration (NASA). NOAA provides funding and retains overall responsibility and authority for the program. It manages the acquisition and development of the ground system (this is known as the ground project). NASA's Goddard Spaceflight Center (GSFC) manages the acquisition and development of the satellites (this is known as the flight project).

In March 2015, the program awarded the JPSS-2 spacecraft contract, which provides the spacecraft, integration of the instruments (the spacecraft and instruments together compose the satellite), and satellite-level test efforts. Options for JPSS-3 and JPSS-4 were exercised later. In 2022, the program led the JPSS-2 satellite through several major activities before its launch in November 2022. Generally, the program was successful in these efforts; however, we identified the following areas where improvements are needed:

- **Contamination controls for thermal vacuum (TVAC) testing;** TVAC demonstrates satellites can operate in the vacuum and extreme temperatures seen in space. We evaluated these controls during JPSS-2's TVAC testing, which occurred from March to June 2022.
- **Recording lessons learned** provides opportunities to improve satellite integration and other processes for NOAA/NASA missions. We evaluated how JPSS-2's lessons learned were recorded and applied to JPSS-3, JPSS-4, and other missions.
- **Requirements verification** provides evidence that satellites meet contractual requirements. We evaluated how JPSS-2's verification activities progressed, including before the Pre-shipment Review (PSR) in August 2022 and up to when JPSS-2 was shipped to the launch site.

JPSS-2 completed postlaunch testing and is operating as NOAA-21. The program is now building JPSS-3 and JPSS-4, with plans to finish developing and testing both satellites by 2026 and to launch them in 2027 and 2032.[1]

[1] On April 17, 2023, the Assistant Administrator for Satellite and Information Services approved the program's plans to launch JPSS-4 in the 2027 launch slot because it is hosting a new instrument, Libera, that NOAA and NASA wish to place in operation as soon as possible. JPSS-3 is hosting just the core set of JPSS instruments, without Libera.

Objective, Findings, and Recommendations

Our audit objective was to assess the Polar Weather Satellite program's execution of selected development activities. To satisfy our objective, we examined aspects of the program's environmental test campaign and pre-launch readiness efforts for JPSS-2. See appendix A for a full description of our scope and methodology.

We found that the program should (1) take additional steps to ensure instruments on JPSS-3 and JPSS-4 are protected from contamination and tested as they will fly, (2) improve its lessons-learned process so it and other programs can learn from its experiences, and (3) improve its requirements verification process before JPSS-3 and JPSS-4 verification efforts begin. Better management of contamination and adherence to best testing practices are needed to ensure JPSS-3 and JPSS-4 launch with fully functional instruments. Without fully capturing lessons learned and improving requirements verification processes, the program may repeat mistakes, leading to inefficient use of resources and schedule delays.

I. The Program Should Take Additional Steps to Ensure Instruments on JPSS-3 and JPSS-4 Are Protected from Contamination and Tested as They Will Fly

The Ozone Mapping and Profiler Suite (OMPS) instrument is one of four scientific instruments installed on JPSS-2. It provides critical data for monitoring the health of the ozone layer and tracking volcanic ash to provide aviation safety warnings. It also helps fulfill U.S. treaty obligations related to global ozone concentrations. OMPS is susceptible to silicone contamination, which could reduce its ability to detect ozone and aerosols.

GSFC's *Rules for the Design, Development, Verification, and Operation of Flight Systems* have helped NASA spaceflight missions be consistently successful. These rules are NASA requirements for spaceflight programs and partnerships. Under these rules:

1. The program's satellite testing is required to follow a "Test as You Fly, Fly as You Test" (TAYF) approach. Testing all critical elements as they will be flown greatly reduces the risk to mission success for space programs. JPSS-2's TVAC testing was an important TAYF evaluation for the satellite and its instruments. To deviate from this approach, the program must request and obtain a waiver from GSFC authorities.
2. The program must identify specific contamination control requirements and processes that support mission objectives. It is critical that satellite components do not degrade due to exposure to contaminants. The program defined limits for silicone contamination and required the spacecraft contractor to ensure that the contaminant levels stayed below these limits throughout JPSS-2's handling, shipping, integration and testing, and launch.

However, silicone contamination became an issue during JPSS-2's TVAC testing. The program originally planned to open OMPS' instrument doors four times during testing to show the doors would reliably open in space. However, shortly before TVAC testing began, silicone was detected in the test chamber; to reduce the risk of contamination, the program reduced the planned openings from four to one. Then, in an early phase of the TVAC testing, an unrelated issue with another instrument caused the contractor to pause the testing and open the TVAC chamber. At that point, the program discovered silicone had migrated onto the outside of the OMPS instrument and decided to pursue a TAYF waiver from GSFC to eliminate OMPS' door testing entirely.

The program's submission for a TAYF waiver reported silicone levels as "significant." However, the spacecraft contractor's original reporting of silicone to the program described the silicone levels only as "some" and "trace." According to program officials, the spacecraft contractor did not determine how much silicone was present in relation to the contract's contamination limits, and the program did not ask the contractor to do so. The OMPS contractor believed the risk of any silicone contamination to the instrument was higher than the risk of the doors not opening on orbit and recommended OMPS' doors remain closed. NASA approved the program's TAYF waiver without knowing whether the silicone levels were above limits.

We found that the silicone contamination limits the program imposed on the spacecraft contractor differed from the OMPS contractors' expectations for the testing environment.

CUI

[redacted]

As a result, the program gave requirements to the spacecraft contractor that allowed its test environments to have a small amount of silicone. Program officials indicated that JPSS-2 satellite testing was their first attempt to quantify a level of silicone contamination that would effectively meet the OMPS contractor's expectations.

Although the program reduced OMPS' potential silicone contamination risk by waiving a TAYF requirement, it increased the risk that OMPS' doors might not open on orbit. From the program's perspective, the risk of not testing this functionality in TVAC was reduced because the doors had been tested before OMPS was installed on the spacecraft. However, these "lower level" tests do not fully represent the integrated satellite configuration that is seen in flight. While the JPSS-2 satellite's OMPS doors have opened on orbit, the program's waiver removed testing of a major aspect of OMPS' functionality. Following the TAYF rules more closely during testing of the JPSS-3 and JPSS-4 satellites would help ensure success for these future missions.

Our work and previous NASA lessons learned have demonstrated that adhering to TAYF requirements is an important factor in the success of satellite missions.[2] The integration and

[2] Report OIG-19-022-A, *Geostationary Operational Environmental Satellite–R Series: Program Success Requires Added Attention to Oversight, Risk Management, Requirements, and the Life-Cycle Cost Estimate*, dated August 12, 2019, identifies waiving TAYF requirements as a contributing factor to Geostationary Operational Environment Satellite-17's Advanced Baseline Imager failing on orbit in May 2018.

testing of JPSS-3 and JPSS-4 will occur in the same contractor facility as JPSS-2, and the TAYF waiver for OMPS may provide a precedent for accepting similar waivers on future missions rather than correcting silicone contamination at the facility.

Recommendations

We recommend the NOAA Deputy Undersecretary of Operations direct the Assistant Administrator for Satellite and Information Services to do the following:

1. Ensure that controls are in place requiring the program to measure and compare contamination levels with defined limits before considering a waiver to Test as You Fly requirements for JPSS-3 and JPSS-4.
2. Ensure the spacecraft contractor revises its contamination controls to provide reasonable assurance that silicone contamination near the Ozone Mapping and Profiler Suite instrument remains below defined limits during JPSS-3 and JPSS-4 satellite integration and testing.

II. The Program Should Improve Its Lessons-Learned Process so It and Other Programs Can Learn from Its Experiences

NASA defines lessons learned as captured knowledge or understanding gained through experience that, if shared, would benefit the work of others. A healthy lessons-learned process helps prevent a program from repeating prior mistakes. The program identified several key project events—major milestones and design reviews—as opportunities requiring the team to look back at what happened and why and to capture positive and negative lessons learned.

Given that JPSS-2 is the first of three satellites to be integrated by the current spacecraft contractor, lessons from its JPSS-2 effort are important to the success of its efforts for JPSS-3 and JPSS-4. We found that the program briefed lessons learned at major reviews and in some dedicated discussions. The program was also recognized by a review board after the PSR for incorporating lessons learned from previous missions into JPSS-2. However, the program's current practices are inconsistent with its internal plans and do not meet the intent of NASA guidance.

A. The program has not completed lessons-learned activities in accordance with its plans and best practices

The program's internal plans identify "Pause and Learn" sessions as the primary method for capturing lessons learned. According to the *JPSS Flight Project Plan,* the program will conduct these sessions after each key project event to combine and share the event's lessons learned across the program. While the plan does not specify how soon to complete a session after a key event, program officials told us the sessions should ideally be held within a couple of months, while lessons are still fresh in people's minds. References included within GSFC guidance suggest holding Pause and Learn sessions sooner: within 2 weeks of a key event.

We examined the program's lessons-learned records and found that for four out of the six JPSS-2 key project events, the program did not hold Pause and Learn sessions at all. For the other two, the program took 7 or more months after the event to conduct the sessions (see table 1).

Table 1. Gap Between JPSS-2 Key Project Events and Pause and Learn Sessions

JPSS-2 Key Project Event	Event Date	Pause and Learn Date	Number of Months from Event to Pause and Learn
Preliminary Design Review	May-2018	Not Held	N/A
Critical Design Review	Sept-2018	Not Held	N/A
PSRs of Four Instruments	Mar-2018 to Apr-2020	Dec-2020	7 to 32[a]
Satellite Integration Complete	Mar-2021	Nov-2021	7
Pre-Environmental Review	Jun-2021	Not Held	N/A
Satellite PSR	Aug-2022	Not Held	N/A

Source: Key project event dates come from JPSS program documentation

[a] JPSS-2 had separate PSRs for four instruments in March 2018, June 2019, March 2020, and April 2020, but the program held a single Pause and Learn to cover all four. The shortest time between the key event and the Pause and Learn was 7 months, for the Cross-track Infrared Sounder instrument; the longest was 32 months, for the Visible Infrared Imaging Radiometer Suite instrument.

In addition to the requirement to collect lessons learned through Pause and Learn sessions, the *JPSS Program Plan* states the program will consolidate all lessons learned into a final report within 60 days of each satellite launch.

We found that the program did not produce a final lessons-learned report for the first satellite in the series, JPSS-1, following its launch in 2017. As of the date we drafted this report, the program had not yet produced one for JPSS-2, which launched in November 2022. According to program personnel, the delay is a result of the program's desire to incorporate lessons from a technical anomaly JPSS-2 experienced after launch.

We found that two factors contributed to the program's lack of adherence to its planned lessons-learned activities. First, neither the *JPSS Program Plan* nor the *JPSS Flight Project Plan* specify how soon Pause and Learn sessions should occur after a key project event. And second, program leadership has delegated responsibility for lessons-learned activities to the project level, but flight project personnel indicated they approached lessons learned differently from the practices documented in their plans.

The flight project held lessons-learned events throughout JPSS-2's development but used facilitated Pause and Learn sessions only on limited occasions (see table 1). Project personnel told us that despite the *JPSS Flight Project Plan*'s requirements for Pause and

Learn sessions, the project had discretion when to hold such formal events. Additionally, project personnel believed that their inclusion of lessons learned at key events leading up to JPSS-1's launch was a sufficient alternative to consolidating lessons into a final report after launch. Given the project's practice of using undocumented alternative approaches to lessons learned, the program would benefit from an evaluation of whether these approaches are meeting its needs and should update its management controls accordingly.

Regardless of the approach the program chooses, it must complete lessons-learned activities in a timely manner. Otherwise, information may be forgotten by those closest to the event and not shared with others who are implementing similar activities. As an added concern, the program is planning to reduce staffing between now and the launches of JPSS-3 and JPSS-4; if lessons-learned activities are not held soon after key events, employees with knowledge of the issues may leave before their lessons are captured.

B. The program is not following NASA guidance for retaining and communicating lessons learned

NASA's *Knowledge Policy for Programs and Projects* communicates agencywide knowledge-management goals to all NASA personnel. A primary goal of the policy is to continuously improve NASA programs' performance by ensuring the programs capture knowledge, including lessons learned, and make it accessible across NASA. NASA also recommends separately that a program maintain a collection of lessons learned throughout its lifecycle to efficiently capture and retain knowledge. Because the program is a partnership between NOAA and NASA, it must adhere to NASA's guidance.

We found that the program has captured lessons learned that may apply to other NASA programs, but it has not submitted its lessons for use across NASA. For example, the program found that not enough government personnel were available to do mandatory inspections during late-night testing. The program addressed the issue by training NASA personnel to perform the inspections when needed. This lesson may apply to any program that has mandatory inspections and does work outside business hours.

Additionally, while the program briefs lessons learned at major reviews, it does not maintain a repository of lessons learned for the benefit of all personnel. This means there is no centralized place for someone inside or outside the program to review all the program's lessons on a given topic. Instead, personnel must piece lessons together from information stored in multiple locations and different formats. As an example, when we asked for the program's lessons learned during our fieldwork, it provided over 20 documents from multiple meetings and Pause and Learn sessions, along with lessons-learned slides from multiple major reviews. This does not demonstrate an efficient system for capturing, retaining, or using past knowledge.

Although the *JPSS Program Plan* states that new knowledge will be shared across NASA, it does not require personnel to document how their lessons learned might apply to other programs. It also does not define a single system or repository for maintaining lessons learned throughout the program's lifecycle.

Program-level officials have also delegated oversight of the lessons-learned process to the project level beneath them. Project-level personnel indicated they have implemented lessons-learned activities for project-level events like real-time updates of test procedures, which benefits JPSS satellite missions. However, they have not taken a broader perspective and shared lessons that could benefit other NASA programs. Program-level officials stated they rely on project-level personnel to elevate lessons learned that need higher visibility, but they had no examples of this occurring.

Because the program is not communicating lessons learned across NASA and is not storing them in a single location for ease of use, other NASA programs are not benefiting from the program's lessons learned. This impairs NASA's efforts to continuously improve the performance of its programs, including the programs where it partners with NOAA. Additionally, the program itself may not benefit as much as it could from its lessons learned because the lessons are not in one easily accessible place.

When we discussed our preliminary findings with program officials in March 2023, they told us they were working to improve the lessons-learned process. We later informed the program that GSFC's Chief Knowledge Office had shared a recommended lessons-learned structure with GSFC programs in December 2022. This structure includes identification of a "broader lesson," which encourages thought about the lesson's applicability to other programs and the completeness and validity of the lesson. The program should consider incorporating this recommended structure into its improved lessons-learned processes.

Recommendation

We recommend the NOAA Deputy Undersecretary of Operations direct the Assistant Administrator for Satellite and Information Services to do the following:

3. Ensure the JPSS program updates its *JPSS Program Plan* and *JPSS Flight Project Plan* to describe a lessons-learned approach that is executable and meets the needs of the program and NASA. The update should include specific management controls that ensure these needs are met.

III. The Program Should Improve Its Requirements Verification Process Before JPSS-3 and JPSS-4 Verification Efforts Begin

The purpose of a requirements verification process is to show proof of compliance with program requirements through an activity such as a test, analysis, inspection, or demonstration. The spacecraft contractor must complete all verification activities to show that the integrated satellite (that is, the spacecraft and its instruments) has met its requirements.

The program must then review and approve the contractor's documents verifying that the requirements have been met. Once the contractor completes the verification activity, it sends documentation describing the results and supporting artifacts (evidence of the verification) to the program for review and acceptance. A verification is not complete until it is "closed" (meaning the program has reviewed and accepted the documentation).

At PSR, the program is required to demonstrate that it has successfully completed all system verification activities and that the system meets its requirements. The expectation is that the program has closed all its verifications except for those it cannot complete until later, such as launch site verifications.

Over a year before JPSS-2's PSR, a review team noted that the program risked getting to the PSR with an "unacceptable" number of open verifications. Despite this warning, the program arrived at PSR in August 2022 with 743 verifications (approximately 13 percent of the total) still open. The PSR review team again expressed concern over the number of open verifications and asked the program to address the issue.

Ultimately, the review team approved the program to ship JPSS-2 from the manufacturing facility to the launch site but requested a plan to close the open verifications. To satisfy the review team, the program and contractor addressed 550 verifications in approximately 2 weeks during and after the review. An additional 189 were closed before JPSS-2's launch in November 2022.[3]

The program's rapid closure of verifications raised another concern: whether the program had adequately evaluated the verification artifacts. One review team member wrote the number of open verifications at PSR was "an indication that the project did not have a demonstrated commitment to implement the earlier review findings" and the program's last-minute efforts to close them "raises the question of whether they are now rushing and being superficial in their evaluation of products."

Two factors contributed to the high number of open verifications. First, the program did not set expectations, in response to the contractor's verification plan or otherwise, for the level of documentation and supporting artifacts it needed from the contractor. Additionally, the program and spacecraft contractor did not meet before the JPSS-2 verification process began to agree about what made an artifact sufficient. In practice, the program expected more-detailed verifications than the contractor was accustomed to providing for similar satellites. Program officials stated that expectations are hard to align among the large number of people who work verification activities; however, a Project Management Institute study notes that aligning expectations has a positive impact on a project's success.[4]

The second reason was the program's multistep process for reviewing and approving verification artifacts. If the program rejects the contractor's verification documentation, the process starts again from the beginning. Rejected verifications for JPSS-2 took on average

[3] Four remaining verifications were deemed low priority and closed after launch.

[4] Lechler, T. and Gao, T. 2012. *Explaining project success with client expectation alignment: An empirical study*. Paper presented at PMI® Research and Education Conference, Limerick, Munster, Ireland. Newtown Square, PA: Project Management Institute. Available at https://www.pmi.org/learning/library/project-success-client-expectation-alignment-6357 (accessed May 4, 2023).

265 days, twice as long as verifications that were accepted on the first submission, to go through the review process.

The large number of open verifications at JPSS-2's PSR meant the program could not demonstrate that JPSS-2 had fully met requirements, leading to uncertainty amongst review team members as to whether they should approve the satellite's shipment for launch preparation. Without improvements to the verification review process and the spacecraft contractor's understanding of the program's expectations of artifacts, the program could experience similar delays and resultant risk for JPSS-3 and JPSS-4 verifications.

Recommendations

We recommend that the NOAA Deputy Under Secretary for Operations direct the Assistant Administrator for Satellite and Information Services to do the following:

4. Ensure the program defines and provides guidance to the spacecraft contractor on the expected level of documentation and artifacts necessary to support verifications.
5. Ensure the program identifies improvements to the verification review process, including the follow-on review of previously rejected verifications.

Summary of Agency Response and OIG Comments

In response to our draft report, NOAA concurred with all recommendations and included comments "to provide additional context to outline considerations NOAA will have to take to address the recommendations." NOAA's full response is included in appendix B.

In its comments on finding 1, NOAA described what the program considers when it evaluates risk and makes decisions such as the TAYF waiver for OMPS, detailed in the report. Referring to our recommendations, NOAA stated that "significant changes to the contract, such as major additional contamination controls could have significant negative cost and schedule impacts to the JPSS-3 and JPSS-4 firm fixed price contract."

Our report notes that the spacecraft contract requires the contractor to limit contamination to specified levels. However, the program did not measure the actual extent of silicone contamination to compare it with the contractually defined limits, which could have better informed its decision on how to test the OMPS instrument. Recommendation 1 intends to ensure the program measures the contamination to understand its extent before testing JPSS-3 and JPSS-4. Recommendation 2 intends to ensure that the program takes steps to provide reasonable assurance that the contractor complies with its requirements for limiting contamination. In our view, both recommendations amount to the program enforcing the terms of the fixed-price contract.

NOAA's comments on finding 3 discuss the program's commitment to the verification process and the challenges present when closing verifications at the end of a satellite's integration and test cycle. NOAA states that the verification effort for JPSS-2 established a level of understanding with the contractor about the required artifacts and content. With additional guidance to the contractor (in accordance with recommendation 4), the program expects to complete higher percentages of verifications for JPSS-3 and JPSS-4 in shorter timeframes.

We appreciate NOAA's comments, and we are pleased that it concurs with our recommendations. We look forward to reviewing NOAA's action plan.

Appendix A: Objective, Scope, and Methodology

Our objective was to assess the Polar Weather Satellite program's execution of selected development activities.

To assess the program's execution, we focused on the assembly, integration, and test of the JPSS-2 satellite, which was ongoing during our audit fieldwork. To further narrow our focus, we reviewed historical documentation from the JPSS program, including major milestone reviews for JPSS-2, management control documents, and recent anomaly investigation materials. We also attended the JPSS-2 satellite's combined PSR/Operational Readiness Review shortly after the audit began. Our initial survey identified contamination control, lessons learned, and the verification process as potential areas of concern.

To assess TVAC contamination controls, we identified criteria from contractual documents and NASA standards, including GSFC's *Rules for the Design, Development, Verification, and Operation of Flight Systems*. We collected and analyzed program milestone reviews and resulting actions, risk reports, TAYF waivers, and failure review board decisions. We met with contamination experts from the program, spacecraft contractor, and instrument contractors to understand instrument sensitivity to contamination, conditions at the spacecraft contractor's facility, communication of requirements from instruments to the spacecraft, and the sequence of events during JPSS-2's TVAC testing.

To analyze the JPSS lessons-learned process, we identified criteria from NASA policies, the GSFC Chief Knowledge Office, the NASA Lessons Learned Information System, and program plans. To assess the program's adherence to internal and external criteria, we requested and analyzed documentation of the program's lessons-learned activities, including its lessons-learned database, Pause and Learn sessions, slide packages from major reviews, and final reports. We also interviewed GSFC and program personnel to understand how NASA expects its programs to support lessons-learned activities and the program's approach.

To assess the program's verification process, we interviewed program and spacecraft contractor officials and review team members about the verification review process, open verifications at reviews, oversight of verifications, artifact expectations, and how JPSS verifications compared to other programs. We reviewed NASA guidance and requests for action from major program reviews for applicable criteria. We also reviewed documentation from major program reviews to identify the number of open verifications at the start of each review. We examined a report of JPSS verification data to analyze the length of time it took the program to review and close verifications, comparing those closed on first review with those rejected on first review.

In addition, we assessed the program's internal controls within the context of our objective. As described in finding II, we found that the program was not following its internal plans for lessons learned.

In satisfying our objective, we reviewed computer-processed data from the Dynamic Object-Oriented Requirements System. The data included the acceptance date and signoff tracker for JPSS-2's level 3 and level 4 requirements. Although this data was downloaded from the system and provided by the program, we conducted electronic tests and identified no significant issues with data reliability.

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 held the entrance conference for this audit on July 26, 2022, and completed our field work on April 20, 2023. We conducted our audit under the authority of the Inspector General Act of 1978, as amended (5 U.S.C. §§ 401–424), and Department Organization Order 10-13, dated October 21, 2020. We performed our fieldwork remotely from the OIG office 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: Agency Response

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

August 9, 2023

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

FROM: Benjamin P. Friedman
Deputy Under Secretary for Operations
National Oceanic and Atmospheric Administration

SUBJECT: *Satellite Integration and Test Phase Improvements Are Needed to Ensure the Success of Future Polar Weather Satellite Missions*
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 Polar Weather Satellite Missions. We reviewed the report and concurred with the recommendations.

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

Attachment

Department of Commerce
National Oceanic and Atmospheric Administration
Response to the OIG Draft Report Entitled
Satellite Integration and Test Phase Improvements Are Needed to Ensure the Success of Future Polar Weather Satellite Missions
(June 2023)

General Comments

The National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review the Office of Inspector General's (OIG) draft report on next-generation satellite system architecture. NOAA reviewed the draft report and concurs with the OIG's recommendations. NOAA would like to submit the comments below to provide additional context to outline considerations NOAA will have to take to address the recommendations. NOAA believes this context is important to determine the best approach to appropriately address each recommendation.

"The Program Should Take Additional Steps to Ensure Instruments on JPSS-3 and JPSS-4 Are Protected from Contamination and Tested as They Will Fly".

The Joint Polar Satellite System (JPSS) Program has the responsibility to help ensure the mission meets the level 1 requirements as specified by the program office. In doing so, the JPSS Program continually manages all the programmatic cost, schedule, and performance constraints for the development of the flight system. The Program outlines and follows a plan created at the beginning of the mission and evaluates risks to full system success as they present themselves throughout the mission. The Program takes cost, schedule, and technical factors into consideration when determining the best path forward and acts in the best interest of the U.S. Government and the public trust.

The decision to limit the motion of the Ozone Mapping and Profiler Suite (OMPS) mechanism during the final cycle of the observatory level thermal vacuum (TVAC) test considered options and inputs from the appropriate technical experts. After weighing all the options, the best and lowest risk option was selected. Alternate actions had the potential for increasing technical risk to the OMPS instrument and other mission elements, including cost and schedule. The Program's decision and justification were provided in a "Test As You Fly" (TAYF) waiver. The TAYF waiver was processed, reviewed, and approved by the appropriate National Aeronautics and Space Administration (NASA) engineering authorities. The Program's decision was also justified by the successful launch of the JPSS-2 mission and its demonstration, and verification, of the level 1 requirements.

All missions plan to TAYF, but due to technical, cost, and/or schedule constraints, there are exceptions. In the formulation phase of a program's life the technical team evaluates all aspects of the mission, through requirements definition, concept development, formulation, build, and test. NASA Goddard requires that the Program evaluate the test program through all mission phases and identify areas where the mission is unable to meet the TAYF guidance. All missions have TAYF requirements that are difficult to achieve, due to technical, cost, and/or schedule constraints. Examples of challenging mission requirements include the testing of an observatory in the true weightlessness of space or the deployment of mechanisms (e.g. solar array deployment, cooler cover deployments, gimble movements, etc.) in a TVAC environment. Most

1

missions do not have the resources to perform these types of activities, as they present more risks than they propose to mitigate. Thus, the deployment and mechanism operations are typically performed in an ambient environment where conditions are safer and more easily controlled.

Recognizing that recommendations from the OIG are intended to have broader applications to improve processes beyond the Program that was audited, NOAA concurs that additional controls can further reduce risk to instruments in future missions. NOAA notes that significant changes to the contract, such as major additional contamination controls could have significant negative cost and schedule impacts to the JPSS-3 and JPSS-4 firm fixed price contract. The program will evaluate the collective risks of cost, schedule, and performance for the PWS program. The OMPS mechanism operation on the fully integrated satellite in TVAC testing was a challenging activity, similar to the TAYF exceptions noted above. The mechanism was fully tested in the ambient and contamination controlled TVAC environment at the instrument level as well as the ambient environment at the observatory level. During observatory level TVAC testing, the environment surrounding the observatory changed and it was deemed unnecessary to operate the OMPS mechanism in the TVAC chamber because the risk of contaminating the OMPS instrument optics and adversely affecting the instrument science could not be discovered until on-orbit. Historical evidence supporting the very low risk profile was supported by the previous OMPS instrument level testing and the instrument history with the two previous missions (Suomi National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (SNPP) and JPSS-1). The program can prepare guidelines to use to minimize the risk of contamination, and will carefully consider the technical risk in light of the other programmatic risks as it defines the path forward.

"The Program Should Improve Its Lessons-Learned Process so It and Other Programs Can Learn from Its Experiences."

The JPSS Program is responsible for holding lessons-learned activities and scheduling lessons-learned events. The timing of lessons-learned activities takes into consideration the current events with all the observatories (JPSS-2/3/4) and instruments (Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS), OMPS, and Visible Infrared Imaging Radiometer Suite (VIIRS)). The Project and Program plans were written to provide guidance as to when the lessons-learned activities are to be held and how the data is collected. The Project and Program teams are expected to use past knowledge and experiences to identify the appropriate timing of these lessons-learned activities in order to ensure that lessons are effectively passed from mission to mission. In short, the plans are written as guidelines, not requirements.

The lessons-learned data may be collected by different methods: Pause and Learned Sessions, Lesson Learned Sessions, and Technical Working Groups. Though these methods have different names, there is one common goal: to capture lessons and employ them for the future. The majority of the lessons are mission specific and not always applicable to other missions. In some cases, there is mission to mission applicability. These will continue to be elevated to the NASA Goddard Space Flight Center level as necessary.

The Program will update the Program Plan and Flight Project Plan to more accurately describe the process currently followed, and the improvements to that process. The Program Plan and Flight Project Plan do not accurately capture the current approach in which the Program always holds lessons-learned activities after every major mission milestone and reports the status to the independent review teams. The Program will more accurately document how this has been completed for all the major milestones for JPSS-2/3/4 And will compile the post review reports from the Goddard Systems Review Team (GSRT) and the Standing Review Board (SRB) that independently document the Program status. Below are examples of the most recent milestones where lessons learned were reported:

- JPSS-2 Pre-Ship Review (PSR)
- JPSS-2 Operational Readiness Review (ORR)
- JPSS-2 Post Launch Acceptance Review (PLAR)
- JPSS-3 Systems Integration Review
- JPSS-3 Pre-Environmental Review (PER)

In addition to the improved documentation, the Program will also maintain a centralized repository to continue to track and identify lessons learned and the work with the instrument and spacecraft partners on the implementation of these lessons. This will include the feedback from the independent assessments and help strengthen a rigorous lessons-learned process that has been in place since the launch of SNPP. The lessons are and will continue to be noted sensibly and promptly and incorporated to ensure past mistakes are not repeated and that well performed implementation is continued.

"The Program Should Improve Its Requirements Verification Process Before JPSS-3 and JPSS-4 Verification Efforts Begin".

The JPSS Program takes system level verification very seriously to ensure 100 percent of the requirements are verified, dispositioned, and documented appropriately. The Program's flight systems engineering team oversees the verification of requirements and ensures that the Program is meeting its technical commitments to the U.S. Government and the public trust. At the time of the JPSS-2 PSR, 100 percent of the requirements necessary for shipment had been verified through test, inspection, or analysis. The assessments of the Flight Project and the independent review team were that the observatory was ready for shipment to the launch site as planned. The particulars of the requirements verification sell off, for those that remained open, were dependent on the final delivery of the documents and artifacts, necessary to contractually complete the requirements verification process.

Full contractual verifications, with the vendors, is completed in stages. For requirements verified by test, the process begins with the verification of the performance at the time of test and is followed by the collection of the test data artifacts, the documenting of the artifacts, and finally the contractual delivery of the documentation. The Program's flight engineers support all test activities, at the time of the test, to ensure the testing runs as planned and that the test is completed successfully. At the point of test completion, the Program engineers review the result as part of the consent to break review to assure that the observatory meets expected performance or, in some rare cases performance that is acceptable with a waiver. Over the life of the JPSS-2 mission, the systems engineering team verified, documented, and archived 5,808 requirements. At the time of the PSR approximately 85 percent of the total requirements were fully verified, documented, and approved. The remaining open requirements, at the time of shipment, had all successfully completed the necessary verification activities, with only the formal documentation and final verification approval outstanding. During the PSR, the Program proposed a plan for

3

closing out on the full set of requirement verifications. The process for closure was done with the same rigor as that performed prior to shipment. The speed at which the requirements artifacts were documented and closed is attributed to completion of the test program and the time needed to complete the process through contracts. In short, with the completion of the test program, the team was able to put additional focus on the review of verification artifacts and complete the final approval of the requirements verification that allowed for the speedy closure.

For JPSS-3 and JPSS-4, the Program will define and provide guidance to the spacecraft contractor on the expected level of documentation and artifacts necessary to support verifications and ensure that the program identifies improvements to the verification review process, including the follow-on review of previously rejected verifications. It is anticipated that the closure will be much more efficient than that for JPSS-2. The JPSS-2 verification effort established a baseline for the verification artifacts to provide, along with their expected content. Most of the design and analysis related requirements are common for all three observatories, which means the verification artifacts are also common, requiring minimal effort to approve the requirement verifications. The lessons learned process did identify some areas where the verification process could be streamlined, allowing some requirements to be verified much earlier in the verification program. As such, with the additional guidance to the contractor, it is expected that the percentage complete for the future JPSS-3 and JPSS-4 observatories will be much higher compared to JPSS-2 at the same mission milestones. The JPSS-3 mission recently completed its pre-environmental review and at the time of the review, approximately 95 percent of the requirements had been completed through formal contractual documentation release and final verification approval process.

NOAA Response to OIG Recommendations

Recommendation 1: Ensure that controls are in place requiring the program to measure and compare contamination levels with defined limits before considering a waiver to Test as You Fly requirements for JPSS-3 and JPSS-4.

NOAA Response: We concur.

Recommendation 2: Ensure the spacecraft contractor revises its contamination controls to provide reasonable assurance that silicone contamination near the Ozone Mapping and Profiler Suite instrument remains below defined limits during JPSS-3 and JPSS-4 satellite integration and testing.

NOAA Response: We concur.

Recommendation 3: Ensure the JPSS program updates its JPSS Program Plan and JPSS Flight Project Plan to describe a lessons-learned approach that is executable and meets the needs of the program and NASA. The update should include specific management controls that ensure these needs are met.

NOAA Response: We concur.

4

Recommendation 4: Ensure the program defines and provides guidance to the spacecraft contractor on the expected level of documentation and artifacts necessary to support verifications.

NOAA Response: We concur.

Recommendation 5: Ensure the program identifies improvements to the verification review process, including the follow-on review of previously rejected verifications.

NOAA Response: We concur.

Recommended Changes for Factual/Technical Information

The Program has no factual or technical changes.

Editorial Comments

The Program has no editorial comments.

31NOAA031430