The Joint Polar Satellite System: Program Can Increase the Likelihood of Mission Success by Further Applying NASA Processes to Its Spacecraft Development Efforts

FINAL REPORT NO. OIG-20-021-A

MARCH 24, 2020

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

March 24, 2020

MEMORANDUM FOR: Neil Jacobs
Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere
National Oceanic and Atmospheric Administration

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

SUBJECT: *The Joint Polar Satellite System: Program Can Increase the Likelihood of Mission Success by Further Applying NASA Processes to Its Spacecraft Development Efforts*
Final Report No. OIG-20-021-A

Attached is our final report on our audit of National Oceanic and Atmospheric Administration's (NOAA's) Joint Polar Satellite System (JPSS) program. Our objective was to assess the cost, schedule, and technical performance of the Program's spacecraft acquisition and development efforts. Specifically, we sought to (1) determine the extent to which cost and schedule changed from the original Program baselines, and (2) identify changes and challenges to the Program's technical baseline.

We found that from March 2015 to November 2019, the cost of the JPSS-2 spacecraft firm-fixed-price contract increased by $28.6 million—or 12 percent—to $273.4 million, and the schedule for completing the spacecraft had been delayed 14 months. We identified several technical performance issues that contributed to the cost increase and schedule delays. Notably, completing development of field programmable gate arrays (FPGAs) in the payload interface electronics continues to be a major challenge towards finalization of the JPSS-2 spacecraft.

Specifically, we found the following:

I. The Program can reduce risk by implementing a more comprehensive methodology for FPGA development.

II. The Program can further reduce risk to FPGAs by applying National Aeronautics and Space Administration guidance for software development.

III. Metrics related to payload interface electronics development have improved, but the Program needs additional measures to understand and track FPGA development progress.

In response to our draft report, NOAA agreed with all of our recommendations and described actions it has taken, or will take, to address them. NOAA's formal response is included within the final report as 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 OIG's website pursuant to sections 4 and 8M of the Inspector General Act of 1978, as amended (5 U.S.C. App., §§ 4 & 8M).

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

Attachment

cc: Benjamin Friedman, Deputy Under Secretary for Operations, NOAA
Stephen Volz, Assistant Administrator for Satellite and Information Services, NOAA
Gregory Mandt, JPSS System Program Director, NOAA
Brian Doss, Acting Audit Liaison, NOAA
Lisa Lim, Alternate Audit Liaison, NOAA

Report in Brief

March 24, 2020

Background

National Oceanic and Atmospheric Administration's (NOAA's) Joint Polar Satellite System (JPSS) satellites orbit approximately 520 miles above Earth. Environmental data collected by the satellites are critical inputs for numerical weather models' 3- to 7-day forecasts, which allow for early warnings and enable emergency managers to make timely decisions to protect lives and property.

The JPSS program (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 development and operations for the entire Program. It also manages ground system operations and infrastructure. NASA manages the acquisition and development of the satellites (spacecraft and instruments), flight simulators, and launch services.

Why We Did This Review

Our objective was to assess the cost, schedule, and technical performance of the Program's spacecraft acquisition and development efforts. Specifically, we sought to (1) determine the extent to which cost and schedule changed from the original Program baselines, and (2) identify changes and challenges to the Program's technical baseline.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The Joint Polar Satellite System: Program Can Increase the Likelihood of Mission Success by Further Applying NASA Processes to Its Spacecraft Development Efforts

OIG-20-021-A

WHAT WE FOUND

We found that from March 2015 to November 2019, the cost of the JPSS–2 spacecraft firm-fixed-price contract increased by $28.6 million—or 12 percent—to $273.4 million. This price increase was primarily due to government-directed engineering changes, including one that changed the payload interface electronics (PIE) field programmable gate arrays (FPGAs) to a reprogrammable architecture. This change in FPGAs was done to mitigate schedule risk that may be caused by the discovery of design or interface issues during integration and test, which would have required the original FPGAs to be replaced.

Completing development of the PIE continues to be a major challenge towards finalization of the JPSS–2 spacecraft. In addition to issues with interface requirements and technical readiness of the PIE, we found that

- the Program can reduce risk by implementing a more comprehensive methodology for FPGA development;
- the Program can further reduce risk to FPGAs by applying NASA guidance for software development; and
- metrics related to PIE development have improved, but the Program needs additional measures to understand and track FPGA development progress.

At the completion of our fieldwork, we discussed these issues with Program personnel in order to provide them with the greatest amount of time prior to completion to take appropriate action. Addressing issues related to PIE FPGAs will reduce cost, schedule, and technical risks, as well as increase the likelihood of mission success.

WHAT WE RECOMMEND

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

1. Direct the Program to review Goddard Space Flight Center methodology for FPGA development and determine necessary actions to reduce the risk of its FPGA developments.
2. Direct the Program to determine the extent to which it can apply NASA software requirements and guidance to FPGA developments in order to reduce mission risk.
3. Direct the Program to determine the extent to which it can implement additional FPGA-level metrics that allow Program management to track the design according to NASA guidance.

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

Introduction

National Oceanic and Atmospheric Administration's (NOAA's) Joint Polar Satellite System (JPSS) satellites orbit approximately 520 miles above Earth. Environmental data collected by the satellites are critical inputs for numerical weather models' 3- to 7-day forecasts, which allow for early warnings and enable emergency managers to make timely decisions to protect lives and property.

The JPSS program (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 development and operations for the entire Program. It also manages ground system operations and infrastructure. NASA manages the acquisition and development of the satellites (spacecraft and instruments), flight simulators, and launch services.

The Program is composed of five satellites. Its two current operating missions are Suomi National Polar-orbiting Partnership (Suomi NPP) and JPSS-1. Missions under development are JPSS-2, -3, and -4.[1] Plans for each of these future missions include the following four instruments:

1. Advanced Technology Microwave Sounder (ATMS)
2. Cross-track Infrared Sounder (CrIS)
3. Ozone Mapping and Profiler Suite (OMPS)
4. Visible Infrared Imaging Radiometer Suite (VIIRS).[2]

Under separate contracts, the government procures these four instruments, which are then integrated with the spacecraft to become the satellite.

JPSS-2, -3, and -4 spacecrafts

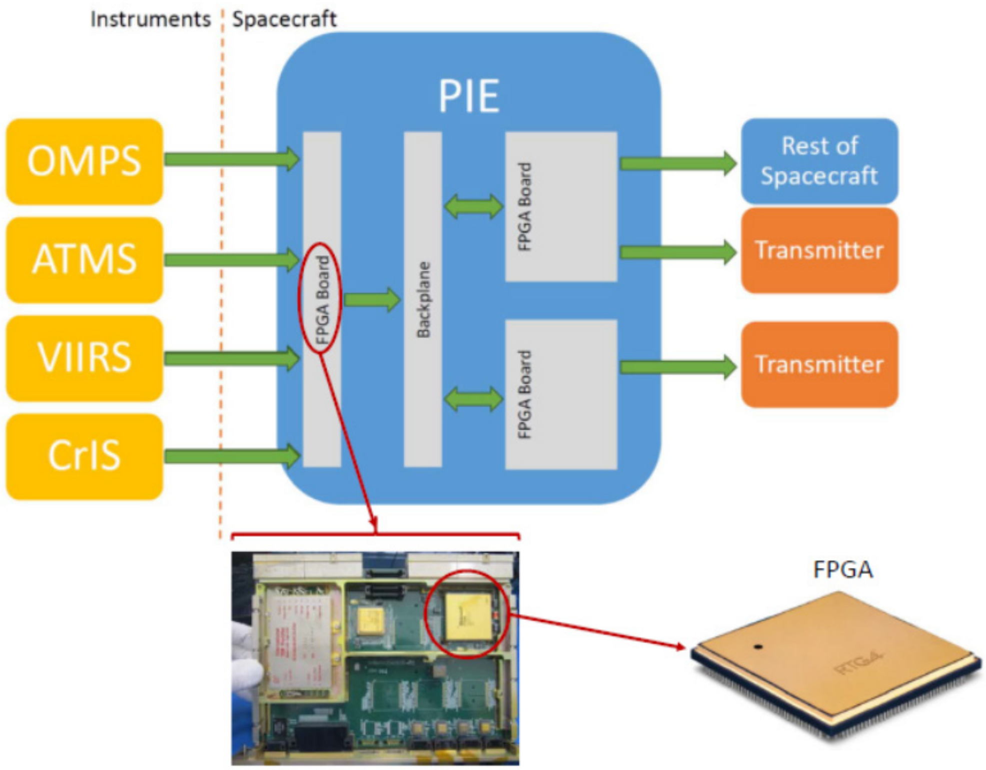
The Program selected a new contractor, Orbital ATK—now, Northrop Grumman Space Systems (NGSS)—to build the JPSS-2, -3, and -4 spacecrafts.[3] The change to a new contractor necessitated updating instrument interface control documents and completing engineering changes to the new spacecrafts' payload interface electronics (PIE) module to facilitate compatibility. The PIE receives data from the satellite's instruments, processes and stores that information, and controls the flow of that information from the instruments and spacecraft to the ground (see figure 1). Once the JPSS-2 PIE is fully developed and tested, the Program's plan is to use copies for JPSS-3 and -4.

[1] NOAA has two funding lines for JPSS: Program of record funds the Suomi NPP, JPSS-1, and JPSS-2 missions, whereas the Polar Follow-On program funds the JPSS-3 and JPSS-4 missions.

[2] Suomi NPP and JPSS-1 each have a fifth instrument known as the *Clouds and the Earth's Radiant Energy System*.

[3] Ball Aerospace & Technologies Corporation built the spacecraft for Suomi NPP and JPSS-1 satellite missions. For additional information, see U.S. Department of Commerce Office of Inspector General, April 26, 2016. *The Joint Polar Satellite System: Further Planning and Executive Decisions Are Needed to Establish a Long-term, Robust Program*, OIG-16-026-I. Washington, DC: DOC OIG, 31.

Figure 1. Block Diagram of Select Spacecraft Components



Source: PIE graphic created by OIG, adapted from Program documentation. Photograph of FPGA board reprinted by permission from NGSS. Photograph of RTG4 chip reprinted from Microsemi, *Space Solutions Brochure*, Microchip Product Brochure (Chandler, AZ, October 2019).

The JPSS-2 PIE uses several field programmable gate arrays (FPGAs) to perform its functions.[4] A design error in an FPGA used on NASA's Wide-field Infrared Explorer (WIRE) mission resulted in that mission's failure soon after launch on March 4, 1999.[5] The investigation of the WIRE failure found that there were opportunities during development where the program could have identified the fatal design error.[6] Given that the PIE has a critical function on the JPSS-2, -3, and -4 satellites, the successful completion of FPGAs is similarly critical to the success of the missions.

In 2017, the contractor identified the PIE as a high-risk item due to the new development, high complexity, and some initial design changes. Since the spacecraft must interface with the instruments and ground system, delays in the development of the PIE could delay integration and test of the satellite, and ultimately the launch of JPSS-2.

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[4] FPGAs are programmable hardware circuits used to carry out one or more logical operations.

[5] National Aeronautics and Space Administration, June 8, 1999. *WIRE Mishap Investigation Board Report*. Washington, DC: NASA, 8.

[6] *Ibid*.

Objective, Findings, and Recommendations

Our objective was to assess the cost, schedule, and technical performance of the Program's spacecraft acquisition and development efforts. Specifically, we sought to (1) determine the extent to which cost and schedule changed from the original Program baselines, and (2) identify changes and challenges to the Program's technical baseline. See appendix A for a full description of our objective, scope, and methodology.

We found that from March 2015 to November 2019, the cost of the JPSS-2 spacecraft firm-fixed-price contract increased by $28.6 million—or 12 percent—to $273.4 million.[7] This price increase was primarily due to government-directed engineering changes, including one that changed the PIE FPGAs to a reprogrammable architecture.[8] This change in FPGAs was done to mitigate schedule risk that may be caused by the discovery of design or interface issues during integration and test, which would have required the original FPGAs to be replaced.

The schedule for completing the spacecraft and preparing the satellite for launch slipped multiple times. Programming of the PIE FPGAs has been partially responsible for these delays, which have continued. In February 2019, the Program had made no progress completing the PIE over the previous 6 months. As of November 2019, the total spacecraft development delay was 14 months. In addition, the window of time to complete the remainder of activities needed to achieve launch readiness had narrowed by approximately 12 months; this "schedule compression" increases risk to the effort. However, the Program maintained schedule margin in excess of its requirement, which provides protection from uncertainty and risk.

We identified several technical performance issues that contributed to the cost increase and schedule delays for the JPSS-2 spacecraft. First, the Program was late to define in a complete manner the interface requirements between the spacecraft and instruments. The Program's systems engineering guidance indicates that these requirements should be well-defined before the Preliminary Design Review (PDR) of a space system development effort.[9] However, after the JPSS-2 spacecraft PDR in August 2016, the Program made extensive changes in December 2016 to documents that define instrument interface requirements, and then again made further design changes with interfaces in November 2017. These late changes required additional effort and delayed the maturity of the spacecraft's design.

Second, there is a requirement in the spacecraft contract that the maturity of component technologies must be at a certain level by the PDR. The contract requires components achieve Technical Readiness Level (TRL) 6, meaning that there is a proven, fully-functional prototype or

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[7] This contract value does not include pre-priced changes or the value of contract options for JPSS-3 and -4 that the Program executed on May 25, 2018.

[8] The changes included (1) a revision to schedule due to a protest of the contract award; (2) additional testing; (3) design changes to an antenna, instrument interface plate, and PIE FPGAs; (4) changes to the instrument and mechanical interface control documents; and (5) acquisition of additional spare equipment.

[9] NASA Goddard Space Flight Center, January 13, 2016. *Systems Engineering*, GPR 7123.1B. Greenbelt, MD: NASA GSFC, section 4.2.2, 28.

model.[10] However, years after the spacecraft PDR, the PIE had still not met TRL 6 requirements.

Completing development of the PIE continues to be a major challenge towards finalization of the JPSS-2 spacecraft. In addition to issues with interface requirements and technical readiness of the PIE, we found that

I. the Program can reduce risk by implementing a more comprehensive methodology for FPGA development;

II. the Program can further reduce risk to FPGAs by applying NASA guidance for software development; and

III. metrics related to PIE development have improved, but the Program needs additional measures to understand and track FPGA development progress.

At the completion of our fieldwork, we discussed these issues with Program personnel in order to provide them with the greatest amount of time prior to completion to take appropriate action. Addressing issues related to PIE FPGAs will reduce cost, schedule, and technical risks, as well as increase the likelihood of mission success.

I. The Program Can Reduce Risk by Implementing a More Comprehensive Methodology for FPGA Development

One lesson learned from the failure of the WIRE mission was that detailed and independent technical peer reviews are essential. These reviews are designed to expose functional design and implementation risk areas, particularly those in which multiple/complex interfaces exist.[11]

Subsequently, NASA's Goddard Space Flight Center (GSFC) published a methodology for FPGA development that delineates the process from concept through realization to ensure robust performance in space environments.[12] The methodology includes 17 major steps to document a systematic plan to manage, design, develop, test (verification, validation, and qualification), document, and review all FPGAs.[13]

This methodology came from best practices derived from the development of critical spaceflight electronics.[14] It incorporates lessons learned for FPGAs—including that multiple detailed and independent peer reviews are needed—from missions such as WIRE.

[10] NASA, April 18, 2013. *NASA Systems Engineering Processes and Requirements*, NPR 7123.1B. Washington, DC: NASA, appendix E, 103.

[11] NASA, *WIRE Mishap Investigation Board Report*, 23.

[12] NASA, June 3, 2013. *Field Programmable Gate Array (FPGA) Development Methodology*, 500-PG-8700.2.8A. Greenbelt, MD: NASA GSFC, 1.

[13] *Ibid*, 3–4.

[14] *Ibid*, 1.

We found the Program has not implemented detailed and independent technical peer reviews for FPGAs. The Program only conducts a single peer review for each FPGA. This review only verifies that the FPGA produces consistency in outputs instead of verifying the design and validating its functionality.[15] Peer reviews conducted by the contractor lack required independence given that the contractor's chief engineer—who is integral to the development process—leads them.

The GSFC methodology indicates that FPGA design packages should be delivered prior to each peer review.[16] However, under the terms of the contract, the contractor is only required to provide a single design package after the FPGA development process is complete, rather than several design packages throughout development. Without these design packages, the government's peer reviews are not able to examine FPGA development based on complete information.

Additionally, we found that the contractor's plan for FPGA development is less comprehensive than the GSFC methodology. As one example, the contractor's plan does not call for accumulating application notices from FPGA manufacturers that describe known issues, instructions, and recommendations beyond the scope of normal reference manuals. The lack of implementing instructions from such an application notice was a contributing factor in the failure of the WIRE mission.

Program personnel told us that while the GSFC development methodology is mandatory for *government-developed* FPGA efforts, it is not mandatory for contracted efforts, such as JPSS. However, the GSFC procedural document states that it applies to both in-house and second-/third-party developers providing products in support of GSFC projects.[17] The Program can tailor the GSFC methodology to its needs, but must provide justification and gain approval from appropriate technical authorities.[18]

The primary goal of the GSFC methodology is to ensure that the design meets all requirements, and verify that the design will function as intended. Using the contractor's less comprehensive FPGA development plan instead of the GFSC methodology increases the risk of technical failure. If any of the PIE's FPGAs fail, the instruments will not be able to communicate. Given the challenges with FPGA development that the Program and its contractor have had, following the guidance would benefit the Program's FPGA development efforts and reduce risk of mission failure.

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[15] The goal for the peer reviews is to evaluate that (1) the design meets all its requirements, (2) the FPGA has been designed per guidelines, and (3) all analyses and simulations have been performed to verify it will work in the intended application, over the temperature range and for the life of the mission.

[16] The design package should include (1) requirements review; (2) design overview; (3) interface descriptions; (4) code structure; (5) code walkthrough; (6) the use of intellectual property cores; (7) implementation discussion; (8) test plan discussion; and (9) results from simulation, synthesis, place and route, timing, interface and board implementation. *See* 500-PG-8700.2.8A, 12–14.

[17] 500-PG-8700.2.8A, 1.

[18] We also note that the Geostationary Operational Environmental Satellite–R Series (GOES-R) spacecraft contract requires the use of both 500-PG-8700.2.7B and 500-PG-8700.2.8A for FPGA developments.

Recommendation

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

1. Direct the Program to review GSFC methodology for FPGA development and determine necessary actions to reduce the risk of its FPGA developments.

II. The Program Can Further Reduce Risk to FPGAs by Applying NASA Guidance for Software Development

NASA's *Software Safety Guidebook* states that "Programmable Logic Devices (PLDs[19]) blur the lines between hardware and software. Circuitry is developed in a programming language (such as VHDL[20])…. While the resulting device is 'hardware,' the process of programming it is 'software.'"[21] The contractor writes code to program the FPGA circuitry. Once complete, there will be no software executing on the FPGAs. The *Software Safety Guidebook* states that since PLDs are programmed, software errors can result in incorrect hardware configuration that may not be tested and may result in problems. Therefore, the process used to develop code for programming FPGAs is important in order to give confidence that the device will function properly.

The contract for the spacecraft includes language that requires the contractor to treat the development of "programmable logic arrays,"[22] (which constitute PLDs) as software. Given this, a number of software guidance and requirements apply to the PIE FPGAs, which could reduce risk of technical failures.[23]

The Program, however, has not applied these software guidance and requirements to its development of FPGAs because the FPGAs do not contain processors that execute code. This justification for not applying software requirements is based on the Program's interpretation of other NASA guidance that makes a distinction for PLDs that contain processors.[24] However, this other guidance does not preclude the application of software

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[19] PLDs include FPGAs.

[20] Very High Speed Integrated Circuit Hardware Description Language (VHDL) is programming code used for the conceptual design of integrated circuits. This is the programming language that the contractors use to program the FPGAs.

[21] NASA, March 31, 2004. *NASA Software Safety Guidebook*, NASA-GB-8719.13. Washington, DC: NASA, 247.

[22] NASA, July 22, 2014. *Joint Polar Satellite System-2 (JPSS-2) Satellite Statement of Work*, 472-00259, Rev. B. Greenbelt, MD: NASA, section 4.3.8, SOW-446, 66.

[23] Software guidance and requirements can be found in the following publications:
(1) NASA-GB-8719.13;
(2) NASA, August 2, 2019. *NASA Software Engineering Requirements*, NPR 7150.2. Washington, DC: NASA;
(3) NASA GSFC, June 30, 2016. *Rules for the Design, Development, Verification, and Operation of Flight Systems*, GSFC-STD-1000G. Greenbelt, MD: NASA GSFC, chapter 3; and
(4) NASA, July 28, 2004. *Software Assurance Standard*, NASA-STD-8739.8. Washington, DC: NASA.

[24] NASA, December 2, 2013. *NASA Technical Handbook*, NASA-HDBK-4008. Washington, DC: NASA, section 7.7, 49.

requirements to FPGAs that do not contain processors.[25] Further, we note that the GOES-R spacecraft contract includes these same requirements, and the GOES-R program adheres to NASA-prescribed software guidance and requirements.

Given the complexity of these devices, it is important to treat the development of these FPGAs as both hardware *and* software. Once launched, these FPGAs cannot be reprogrammed to correct errors, unlike other flight software found on JPSS. Therefore, the Program's current approach carries greater risk of technical failure. Applying safety requirements for software, in accordance with the contract's definition for FPGAs, could benefit the PIE development effort by lowering the risk.

Recommendation

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

2. Direct the Program to determine the extent to which it can apply NASA software requirements and guidance to FPGA developments in order to reduce mission risk.

III. Metrics Related to PIE Development Have Improved, but the Program Needs Additional Measures to Understand and Track FPGA Development Progress

Management of major technical programs requires product (such as FPGAs) assessments to quantify progress and remaining work. NASA procedural requirements define technical performance measures that track progress toward achieving goals and objectives.[26] NASA guidance delineates metrics applicable to FPGAs.[27] However, the Program did not delineate specific metrics for the contractor to routinely report in order to better understand and track FPGA development.

Although the Program has worked with the contractor to improve metrics related to the PIE development, the current metrics are inadequate because they do not identify missing design features at the FPGA-level, which prevents a complete understanding of progress toward completion. As a result, the contractor cannot accurately report, and the Program cannot fully understand, the status of the PIE effort.

Due to limited metrics, the Program did not identify issues with PIE development in a timely manner, which led to unpredictable and significant schedule delays. Initially, the Program only tracked bug count (i.e., issue count) with the goal to find and fix problems during the code development phase. The development was inherently unpredictable, as the Program could not forecast the total number of bugs. Additionally, sometimes the development experienced significant delays because the bugs were discovered during hardware tests that could require de-integration and circuit redesign.

[25] *Ibid*.

[26] NPR 7123.1B, appendix A, 43.

[27] NASA-HDBK-4008, section 5.2.2, 21–22.

In the summer of 2019, the Program improved PIE-related metrics significantly, but not at the FPGA level. By using metrics similar to those prescribed by NASA guidance—such as functional coverage[28]—the contractor could more accurately measure FPGA development progress.

Recommendation

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

3. Direct the Program to determine the extent to which it can implement additional FPGA-level metrics that allow Program management to track the design according to NASA guidance.

[28] According to the Institute of Electrical and Electronics Engineers (IEEE), functional coverage is a user-defined metric that measures how much of the design specification, as enumerated by features in the test plan, has been exercised. It can be used to measure whether interesting scenarios, corner cases, specification invariants, or other applicable design conditions—captured as features of the test plan—have been observed, validated, and tested. *See* IEEE, February 22, 2018. *IEEE Standard for System Verilog–Unified Hardware Design, Specification, and Verification Language*, IEEE Std. 1800-2017. New York City, NY: IEEE.

Summary of Agency Response and OIG Comments

In response to our draft report, NOAA agreed with all of our recommendations and did not propose any factual or technical changes. In agreeing with recommendations 1 and 2, NOAA indicated that it would also determine actions it could apply to future environmental satellite missions. In agreeing with recommendation 3, NOAA refers to additional metrics the Program began using in July 2019 as complying with NASA guidance. NOAA's formal response is included within this final report as appendix B.

We are pleased that NOAA concurs with our recommendations and look forward to reviewing its proposed audit action plan. With respect to recommendation 3, we understand NOAA's response given the Program was nearing completion of its FPGAs. As it is doing for recommendations 1 and 2, we encourage NOAA leadership to consider the need for additional *FPGA-level* metrics to track such designs in future satellite missions.

Appendix A: Objective, Scope, and Methodology

Our objective was to assess the cost, schedule, and technical performance of the Program's spacecraft acquisition and development efforts. We focused our audit work on the JPSS-2 spacecraft development and issues that may affect the development of JPSS-3 and -4.

We started this audit on April 18, 2019. We communicated our initial findings to the Program on October 7, 2019, in an attempt to provide the greatest amount of time prior to completion to allow the Program to take appropriate action to reduce risk and provide increased mission assurance.

To assess cost performance, we reviewed the spacecraft contract and contract modifications to determine cost changes from the original cost baseline. We also reviewed the rationale for the modifications to identify government-directed changes to the firm-fixed-price contract.

To assess schedule performance, we reviewed the spacecraft contract and contract modifications for the spacecraft launch readiness date to determine contractual schedule delays. We also reviewed milestone dates from schedule charts from contractor and Program monthly status reviews, and Joint Agency Program Management Council Reviews, from July 2015 through September 2019, and compared the changes in dates to determine schedule compression.

To assess technical performance, we met with Program personnel to understand Program issues, PIE risks, and the impacts of the late PIE delivery and mitigations. We reviewed the JPSS spacecraft contract to determine the requirements related to the PIE and the JPSS-2 spacecraft development effort. We interviewed Program and contractor personnel regarding PIE TRL, interface requirements, FPGA requirements, software requirements, and metric requirements.

We compared TRL requirements in the *NASA Systems Engineering Handbook* (NASA/SP-2007-6105) and the JPSS-2 spacecraft contract with the TRL of the PIE under development for JPSS-2. We interviewed Program staff to understand the progress of FPGA development and how that compared with milestones for PIE development.

We compared the Program's efforts to mature interface control documents with requirements specified in the spacecraft contract and those described in Goddard Procedural Requirements 7123.1B, *Systems Engineering*. We analyzed spacecraft contract modifications to identify changes to interface requirements throughout the duration of the contract. We interviewed Program personnel to understand when interface control documents were developed. We also interviewed contractor personnel at NGSS to understand how interface control documents affected the Program.

We reviewed the NASA Center-Wide Procedures and Guidelines—*Design of Space Flight Field Programmable Gate Arrays*, 500-PG-8700.2.7B, and *Field Programmable Gate Array (FPGA) Development Methodology*, 500-PG-8700.2.8A—and JPSS-2 spacecraft contract requirements for the design of FPGAs. We interviewed Program and contractor personnel to determine the extent to which the Program and contractor had implemented NASA requirements and guidelines.

We interviewed Program personnel to understand the extent to which software requirements may be applicable to the PIE FPGAs. We reviewed the JPSS spacecraft contract to understand requirements for programmable logic arrays, including FPGAs. We also reviewed the GOES-R contract to understand that contractor's responsibilities for software components. We examined relevant language in the *NASA Programmable Logic Devices Handbook*, NASA-HDBK-4008, and the *NASA Software Safety Guidebook*, NASA-GB-8719.13, and assessed the Program's application of this guidance to its development of FPGAs.

We compared metrics the Program is using for the PIE and FPGA development with best practices described in the *NASA Programmable Logic Devices Handbook*, NASA-HDBK-4008.

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

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

We conducted our review from April 2019 through September 2019 under the authority of the Inspector General Act of 1978, as amended (5 U.S.C. App.), and Department Organization Order 10-13, dated April 26, 2013. We performed our fieldwork at Program offices in Lanham, Maryland; and NGSS facilities in Dulles, Virginia, and Gilbert, Arizona.

We conducted this performance audit in accordance with generally accepted government auditing standards. These standards require that OIG plans and performs the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for its findings and conclusions based on its audit objectives. 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
The Deputy Under Secretary for Operations
Washington, D.C. 20230

MAR 1 3 2020

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

FROM: Ben Friedman
Deputy Under Secretary for Operations

SUBJECT: *The Joint Polar Satellite System: Program Can Increase the Likelihood of Mission Success by Further Applying NASA Processes to Its Spacecraft Development Efforts*
Draft OIG Audit Report

The National Oceanic and Atmospheric Administration (NOAA) is pleased to submit the attached response to the Office of Inspector General's draft report on NOAA's Joint Polar Satellite System. We agree with all recommendations in the attached response.

We appreciate the opportunity to review and respond to your draft report. If you have questions, please contact Brian Doss, Acting Director, Audit and Information Management Office on (301) 628-0945.

Attachment

Department of Commerce
National Oceanic and Atmospheric Administration
Comments to the OIG Draft Report Entitled
"The Joint Polar Satellite System: Program Can Increase the Likelihood of Mission Success by Further Applying NASA Processes to Its Spacecraft Development Efforts"
(March 2020)

General Comments

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review and comment on the Office of the Inspector General's (OIG) draft report on the Joint Polar Satellite System (JPSS). NOAA reviewed the report and agrees with OIG's three recommendations. The response to each recommendation is provided below. The JPSS Program Office provided feedback to OIG as they were in the process of drafting this report and NOAA does not have any recommended factual or technical changes.

NOAA Response to OIG Recommendations

Recommendation 1: That the NOAA Assistant Administrator for Satellite and Information Services direct the Program to review Goddard Space Flight Center (GSFC) methodology for field programmable gate array (FPGA) development and determine necessary actions to reduce the risk of its FPGA developments.

NOAA Response: We concur. This is consistent with the approach the JPSS Program takes in the development of our spacecraft. The Program adheres to NASA guidance in the development of our spacecraft systems. The Program will review NASA's GSFC methodology for field FPGAs development to determine if there are any necessary actions to reduce this risk, and could be applied to future collaborative environmental satellite missions between NOAA and NASA.

Recommendation 2: That the NOAA Assistant Administrator for Satellite and Information Services to direct the Program to determine the extent to which it can apply NASA software requirements and guidance to FPGA developments in order to reduce mission risk.

NOAA Response: We concur. This is consistent with the approach the JPSS Program takes in the development of our spacecraft. The Program adheres to NASA guidance in the development of our spacecraft systems. The Program will review the NASA software requirements and guidance to determine the extent to which they could be applied to future collaborative environmental satellite missions between NOAA and NASA.

Recommendation 3: That the NOAA Assistant Administrator for Satellite and Information Services direct the Program to determine the extent to which it can implement additional FPGA-level metrics that allow Program management to track the design according to NASA guidance.

NOAA Response: We concur. This is consistent with changes the JPSS Program has made to improve the management of the JPSS-2 spacecraft development. The Program began using additional, more comprehensive FPGA-level metrics in July 2019 which comply with NASA guidance and are used in reports to senior NOAA and NASA leadership.

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