Space Weather Follow-On (SWFO) Program: Rideshare Schedule Presents Challenges and Lack of Backup Option Warrants NOAA Attention

FINAL REPORT NO. OIG-23-015-A
MARCH 13, 2023

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 13, 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: *Space Weather Follow-On (SWFO) Program: Rideshare Schedule Presents Challenges and Lack of Backup Option Warrants NOAA Attention*
Final Report No. OIG-23-015-A

Attached is the final report on our audit of the National Oceanic and Atmospheric Administration's (NOAA's) Space Weather Follow-On Program (SWFO). Our objective was to identify SWFO program challenges that may affect cost, schedule or overall mission performance and assess the extent to which NOAA is addressing them.

We found the following:

I. SWFO-L1 should have launch contingency options commensurate with its role as a critical, high-profile national mission.
II. The SWFO program should improve its lessons learned processes.
III. The SWFO program should improve its contract oversight.
IV. NOAA should update space weather requirements in accordance with validation criteria.

As an other matter, we also noted that the SWFO antenna network contract has potential performance and cost management risks.

In response to our draft report, NOAA concurred with all recommendations and generally described approaches it has taken or will take to meet them. NOAA's response is included in appendix D.

Pursuant to Department Administrative Order 213-5, please submit to us an action plan that addresses the recommendations in this report within 60 calendar days. The final report will be posted on the Office of Inspector General's website pursuant to sections 404 and 420 of the Inspector General Act of 1978, as amended (recodified at 5 U.S.C. §§ 404 & 420).

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 or Kevin Ryan, Director for Audit and Evaluation, Systems Analysis and NOAA Programs, at (202) 695-0791.

Attachment

cc: Benjamin Friedman, Deputy Under Secretary for Operations, NOAA
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Report in Brief

March 13, 2023

Background

The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) acquires and operates Earth and space weather observation satellites for the nation. NOAA's Space Weather Follow-On (SWFO) program will provide essential solar observations and space weather measurements that support the National Weather Service Space Weather Prediction Center's forecasting mission.

Space weather describes the conditions of the space environment due to solar activity. Solar activity can damage satellite electronics, reduce global positioning system accuracy, and increase astronauts' and airline flights' exposure to radiation. It can also cause variations in the Earth's magnetic field that can disrupt electric power grids. The two primary space weather phenomena that the Space Weather Follow-On to Lagrange Point 1 (SWFO-L1) mission will monitor are solar wind and coronal mass ejections (CMEs). Satellites currently observing space weather at Lagrange Point 1 are nearing the end of their lives. Lagrange Point 1 is an orbit location approximately 1 million miles from Earth.

The SWFO-L1 mission will replace the operational capabilities of three satellites at Lagrange Point 1, continuing measurements of the solar wind and CME imagery. NOAA directed that SWFO-L1 would fly as a rideshare (a method of launching multiple satellites into orbit on a single launch vehicle) on the launch vehicle of the Interstellar Mapping and Acceleration Probe (IMAP), a National Aeronautics and Space Administration (NASA) research mission. The Department considers the SWFO-L1 mission as a critical, high-profile effort.

Why We Did This Review

Our audit objective was to identify SWFO program challenges that may affect cost, schedule, or overall mission performance and assess the extent to which NOAA is addressing them.

National Oceanic and Atmospheric Administration

Space Weather Follow-On (SWFO) Program: Rideshare Schedule Presents Challenges and Lack of Backup Option Warrants NOAA Attention

OIG-23-015-A

WHAT WE FOUND

We found the following:

I. SWFO-L1 should have launch contingency options commensurate with its role as a critical, high-profile national mission.

II. The SWFO program should improve its lessons learned processes.

III. The SWFO program should improve its contract oversight.

IV. NOAA should update space weather requirements in accordance with validation criteria.

WHAT WE RECOMMEND

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

1. Work with the NASA Science Mission Directorate Associate Administrator to determine if an agreement for contingent launch schedule flexibility is feasible for the SWFO-L1 mission if IMAP or SWFO-L1 are unable to meet launch timing.

2. Coordinate with the Director, National Weather Service, to update the Space Weather – Geomagnetic Storm Warning Gap Mitigation Plan for Space-Based Observations (June 2020) to reflect current contingencies.

We recommend that the NOAA Deputy Under Secretary for Operations ensure that NESDIS does the following:

3. Ensure that the SWFO program updates its plans for lessons learned and conducts appropriate learning sessions.

We recommend that the NOAA Deputy Under Secretary for Operations direct NESDIS to do the following:

4. Ensure the SWFO Ground Project Quality Assurance Surveillance Plan defines sufficient criteria and frequency of surveillance to provide adequate government oversight of contractor performance.

5. Assess the program control activities defined in the SWFO Program Plan to incorporate controls that provide reasonable assurance of timely management reviews of process changes.

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

6. Direct the National Weather Service to work with the Office of Observations and the Space Weather Prediction Center to either update the validation documents in the Space Weather Observational User Requirements Document consistent with level 2 validation criteria or amend the validation levels of requirements to reflect the cited documentation.

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) National Environmental Satellite, Data, and Information Service (NESDIS) acquires and operates Earth and space weather observation satellites for the nation. NOAA's Space Weather Follow-On (SWFO) program will provide essential solar observations and space weather measurements that support the National Weather Service (NWS) Space Weather Prediction Center's (SWPC's) forecasting mission.

Space Weather

Space weather describes the conditions of the space environment due to solar activity. Solar activity can damage satellite electronics, reduce global positioning system accuracy, and increase astronauts' and airline flights' exposure to radiation. It can also cause variations in the Earth's magnetic field, known as geomagnetic storms, that can disrupt electric power grids.

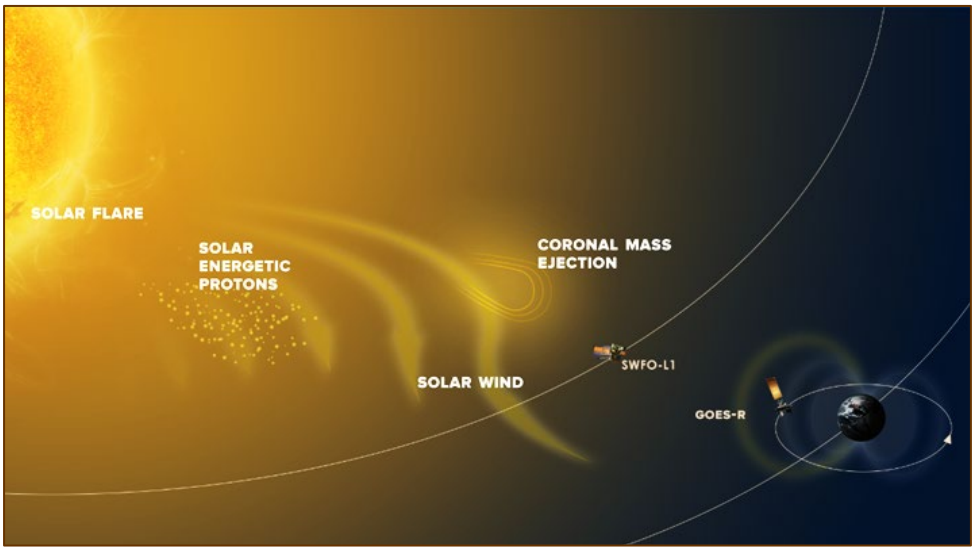
The two primary space weather phenomena that the Space Weather Follow-On to Lagrange Point 1 (SWFO-L1)[1] mission will monitor are solar wind and coronal mass ejections (CMEs).

> **Solar wind**. Solar wind continuously flows outward from the Sun and consists mainly of protons and electrons that move within an embedded magnetic field. Different regions on the Sun produce different solar wind flow speeds and densities. The Earth's orientation with respect to the solar wind influences whether there will be space weather impacts such as geomagnetic storms. Measurements of solar wind particles and magnetic fields at the L1 orbit position increase SWPC space weather forecast and warning accuracy for impacts on Earth.
>
> **CMEs**. CMEs are large releases of plasma and magnetic field from the Sun's corona, or outermost layer. They can eject billions of tons of solar mass and carry a strong, embedded magnetic field. Imagery of the Sun's corona is critical to forecast the impacts of CMEs. The fastest Earth-directed CMEs can affect Earth in as little as 15 hours. Sudden increases in solar wind density, speed, and magnetic field strength at the L1 orbit location can indicate the arrival of a CME. This can provide up to 60 minutes advanced warning of geomagnetic storm effects on Earth.

See figure 1 for a conceptual depiction of SWFO-L1 and space weather phenomena.

[1] The orbit location known as Lagrange Point 1 (L1) is approximately 1 million miles from Earth toward the Sun. For comparison, the Geostationary Operational Environmental Satellites (GOES) and Joint Polar Satellite System satellites are approximately 22,000 miles and 500 miles from Earth, respectively.

Figure 1. SWFO-L1 and Space Weather Phenomena



Source: SWFO program documentation

Current Space Weather Satellites

Satellites currently observing space weather at Lagrange Point 1 are critical to space weather forecasting and nearing the end of their lives. NOAA's Deep Space Climate Observatory (DSCOVR) and National Aeronautics and Space Administration (NASA's) Advanced Composition Explorer (ACE) measure the solar wind. DSCOVR launched in 2015 and was designed for a 2-year mission. ACE was launched in 1997 and is expected to run out of fuel by 2026.

CME imagery is provided by the joint NASA/European Space Agency (ESA) Solar and Heliospheric Observatory (SOHO). However, SOHO launched in 1995 and is not expected to have power after 2025.

In addition, NOAA plans to include an instrument on its GOES-U satellite that will observe CME imagery, but it cannot maintain uninterrupted coverage due to its geostationary orbit. See table 1 for a listing of current and planned space weather satellites.

The SWFO-L1 Mission

The SWFO-L1 mission will replace the operational capabilities of three satellites at Lagrange Point 1, continuing measurements of the solar wind and CME imagery. For a description of the SWFO-L1 instrument capabilities, see appendix B.

In 2014 and 2015, NOAA proposed stand-alone space weather observation missions for launch in 2022 and 2027 to replace aging NASA and NOAA satellites, but they were not approved by the administration due to other priorities. In 2018, NOAA directed work toward a SWFO-L1 mission to meet operational space weather requirements.

NOAA directed that SWFO-L1 would fly as a rideshare[2] on the launch vehicle of the Interstellar Mapping and Acceleration Probe (IMAP), a NASA research mission. NOAA and NASA approved the rideshare agreement in July 2019, making it the first NOAA operational satellite to fly as a rideshare on a NASA mission. NOAA obtained formal Department of Commerce (the Department) approval for the SWFO-L1 project in November 2019, beginning a rapid development schedule. IMAP was originally scheduled to launch in October 2024 but has since slipped to February 2025.

Table 1. Current and Planned NOAA Space Weather Observation Sources

Mission	Launch	Orbit	Primary Use	End-of-Life Projection	Notes
SOHO	1995	L1	CME Imagery	2025	NASA-ESA; fuel-limited
ACE	1997	L1	Solar Wind	2026[c]	NASA; fuel-limited
DSCOVR	2015	L1	Solar Wind	2026	NOAA; data interruptions
GOES-U (CCOR-1)	2024[a]	Geostationary	CME Imagery	2040	NOAA; periodic imagery blackout due to orbit
SWFO-L1	2025[b]	L1	Solar Wind and CME Imagery	2035	NOAA (NASA)

a. Planned launch; spacecraft and compact coronagraph[3] (CCOR) planned for on-orbit storage through 2031.

b. Planned launch as a secondary payload on NASA's IMAP mission.

c. Subsequent to our fieldwork, NESDIS advised us that NASA refined its fuel availability estimate to 2029.

Source: Office of Inspector General (OIG) analysis of NOAA, NASA, and SWFO program documentation.

The Department considers the SWFO-L1 mission as a critical, high-profile effort. It is NOAA's first satellite designed from inception as an operational space weather observation satellite.[4] It would provide needed continuity in CME imagery and solar wind monitoring, potentially avoiding a gap in capability that could significantly impact NWS' ability to provide space weather warnings and forecasts.

[2] A rideshare is a method of launching multiple satellites into orbit on a single launch vehicle that has a primary satellite and one or more secondary (subordinate) satellites.

[3] A coronagraph is a telescope modified to block the Sun's light so it can take images of the edge of the Sun's outer atmosphere, or corona.

[4] DSCOVR was converted from a NASA research satellite called Triana, that was to take measurements of sunlight reflected and emitted from Earth. The Triana mission was canceled in 2001, and the satellite was put into storage until 2008 when it was modified for the DSCOVR mission.

Objective, Findings, and Recommendations

Our audit objective was to identify SWFO program challenges that may affect cost, schedule, or overall mission performance and assess the extent to which NOAA is addressing them. To satisfy our objective, we reviewed the SWFO program acquisition strategy, identified challenges in key program milestone activities, assessed program control activities, and analyzed selected issues and risks. See appendix A for a full description of our scope and methodology.

We identified SWFO-LI's dependence on the NASA IMAP research mission for its launch capability as the most significant challenge for the program. SWFO-L1 is a secondary payload that must meet the technical and schedule accommodation requirements of the IMAP program. As of November 2022, the SWFO program had adequate schedule margin to meet its launch date. See appendix C for additional information on SWFO-L1 challenges.

We found that NOAA needs to ensure that SWFO-L1 has launch contingency options commensurate with its role as a critical, high-profile mission and that the SWFO program should improve its lessons learned processes and contract surveillance oversight. We also found that NOAA should update its space weather observation requirements in accordance with its validation criteria. Without NOAA attention as described in this report, the inflexibility of the launch plan could lead to a gap in space weather observation capability that would impact forecasting services. Additionally, further actions to improve lessons learned collection and contract oversight may help to address current, as well as future, program challenges.

I. SWFO-L1 Should Have Launch Contingency Options Commensurate With Its Role As A Critical, High-Profile National Mission

Like the Geostationary Operational Environmental Satellites (GOES) and Polar Weather Satellites programs, the Department has categorized SWFO as a mission-critical program.[5] The SWFO program supports NOAA's goal to reduce the impact of severe space weather events and NESDIS' strategic principles.

Beyond the SWFO-L1 mission, NOAA has no other means to completely replace the capabilities of the current satellites: ACE, DSCOVR, and SOHO. SWFO-L1 is a secondary payload in the agreement to rideshare with the NASA IMAP research mission. Without updated contingency plans and additional flexibility to mitigate unexpected launch issues, NOAA may not have all the observational capabilities it needs to execute its space weather forecasting mission.

[5] This means that the program warrants special management attention or is deemed high risk and/or entails expenditure of significant resources. See DOC, May 26, 2015. *Acquisition Project Management*, Department Administrative Order (DAO) 208-16. Washington, DC: DOC, section 3.05.a.1.

A. *NESDIS and the SWFO program lack a contingency launch plan for SWFO-LI*

The Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act of October 2020 (the PROSWIFT Act)[6] directs NOAA to secure reliable backup baseline capability for observations required for space weather forecasts. Additionally, NASA procedures and the SWFO Program Plan state that an integral part of the risk management process is developing potential program descope candidates.[7]

We found that NESDIS and the SWFO program have no contingency launch plan—including descope candidates that would provide schedule flexibility—to avoid or respond to the loss of SWFO-LI's rideshare on NASA's IMAP mission. Such a plan would provide greater assurance of meeting the PROSWIFT Act's directive to secure a baseline space weather observation capability. NESDIS and the program confirmed there is no funding or contingency launch option if SWFO-L1 does not meet the IMAP schedule or if IMAP delays or cancels.

As a secondary payload, the SWFO program has no formal authority to force the primary NASA mission to accommodate its needs. Three scenarios illustrate potential risks of the rideshare agreement.

- If SWFO-L1 does not meet its designated delivery date to IMAP, it could lose its launch capability.
- If IMAP is significantly delayed, it could jeopardize the SWFO-L1 launch timing for mitigating the space weather observation gap.
- If IMAP is cancelled, SWFO-L1 could also lose its launch capability.

NOAA and NASA have a history of satellite program partnership, and this rideshare arrangement is a new type of operational collaboration. It provides NOAA a way to meet its increasingly urgent space weather observation needs in the near term, but the SWFO-L1 mission criticality should warrant additional consideration. The three scenarios mentioned previously show that NESDIS could benefit from increased flexibility in the rideshare agreement to mitigate the launch risk.

However, the NASA Science Mission Directorate Rideshare Office told us that NASA determines general rideshare suitability between primary and subordinate payloads, leaving agreement details up to the participants. Without additional flexibility, NOAA currently does not have options to launch its critical mission if any of the above scenarios occur.

[6] Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act of October 2020, 51 U.S.C. § 60603(c) (2020).
[7] NASA, August 3, 2021. NASA Procedural Requirements 7120.5F, *NASA Space Flight Program and Project Management Requirements,* describes project descope plans and shows that descopes are related to the project's threshold performance requirements.

B. NOAA's space weather gap mitigation plan is out of date

The PROSWIFT Act directs NOAA to develop an operational contingency plan to provide continuous space weather forecasting in the event of an unexpected failure of the SOHO mission.[8] NOAA published a space weather gap mitigation plan in June 2020 prior to the PROSWIFT Act, which it considered responsive to the legislation. According to the plan, it is required to be updated on an annual basis until the SWFO-L1 satellite mission is launched.

We found that NOAA's plan identified mitigations for the impact of a potential data gap if SWFO-L1 does not launch as planned, but it contains outdated information and has not been updated in more than 2 years. Without an updated plan, NOAA may not be able to optimally coordinate alternatives to mitigate a space weather gap.

For example, the NASA Polarimeter to Unify the Corona and Heliosphere (PUNCH) low Earth orbit mission was identified in the plan as a potential alternate source of CME imagery. NOAA and NASA signed an initial $1.2 million reimbursable service order agreement for a contract to develop initial PUNCH algorithms for SWPC end-item evaluation after launch, with a performance period through September 2024. This agreement was signed in 2020 based on an early 2023 launch, but PUNCH is a rideshare on another NASA mission, which has now been slipped until 2025.[9]

NESDIS officials said that the overall conclusion of the plan is still accurate: SWFO-L1 is the only planned mission that can replace the capabilities provided by the current satellites (SOHO, ACE, and DSCOVR). They also told us NESDIS has been making updates to mitigations without publishing a new plan.

Recommendations

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

1. Work with the NASA Science Mission Directorate Associate Administrator to determine if an agreement for contingent launch schedule flexibility is feasible for the SWFO-L1 mission if IMAP or SWFO-L1 are unable to meet launch timing.
2. Coordinate with the Director, National Weather Service, to update the Space Weather – Geomagnetic Storm Warning Gap Mitigation Plan for Space-Based Observations (June 2020) to reflect current contingencies.

[8] Id. at 51 U.S.C. § 60603(c).

[9] The PUNCH mission will launch no earlier than April 2025.

II. The SWFO Program Should Improve Its Lessons Learned Processes

It is NASA policy to ensure that its technical and project knowledge is captured and accessible to meet future challenges.[10] According to its program plan, SWFO-L1 should conduct Pause and Learn (PaL)[11] sessions as the primary mechanism for collecting and documenting lessons learned. The plan calls for flight and ground projects, at a minimum, to hold PaL sessions after completing major milestone reviews[12] and for those sessions to include both flight and ground personnel and be formally documented.

We found that the SWFO program did not capture lessons learned following major lifecycle milestones. The SWFO-L1 flight project conducted a PaL session in January 2021 unrelated to a project milestone but had limited documentation of who attended or other formal record of the event.[13] The program did not conduct PaLs after the system requirements review, preliminary design review, and critical design review, as required, and did not provide evidence of a structured approach to lesson learned collection.

The SWFO-L1's fast-paced schedule limits time available for lessons learned activities. We also noted that the SWFO Program Plan refers to outdated procedural requirements for lessons learned, suggesting a lack of attention to such processes.[14] Because the PaL process is the primary mechanism for collecting and documenting lessons learned, it is important that the PaL process be integrated into project milestones. It is a critical project management tool that guides the collection of experience-based information from major events immediately after they occur. Without following a structured approach to capturing lessons learned, the program risks missing key learning opportunities that could help address acquisition environment and technical challenges as described in appendix C.

Recommendation

We recommend that the NOAA Deputy Under Secretary for Operations ensure that NESDIS does the following:

3. Ensure that the SWFO program updates its plans for lessons learned and conducts appropriate learning sessions.

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[10] See NASA, December 16, 2019. NASA Policy Directive (NPD) 7120.6A, *Knowledge Policy for Programs and Projects*. Washington, DC: NASA, 1. Additionally, see appendix C for unique SWFO-L1 challenges that highlight the importance of collecting lessons learned for future missions.
[11] NASA GSFC Knowledge Management describes a PaL session as a structured discussion that focuses on recent project developments, challenges, and critical milestones.
[12] The SWFO Program Plan specifically identifies the system requirements review, preliminary design review, critical design review, and system integration review.
[13] The session was a virtualized event and not part of milestone review activities. Documentation included two presentation slides focused on project documentation and COVID-19 mitigation.
[14] The June 2021 SWFO Program Plan cites adherence to NASA Procedural Requirement (NPR) 7120.6 *NASA Lessons Learned Process*, but this NPR was cancelled by newer NASA policy in December 2019 (NPD 7120.6A: *Knowledge Policy for Programs and Projects*), which was 17 months prior to the approval of the SWFO Program Plan.

III. The SWFO Program Should Improve Its Contract Oversight

The SWFO antenna network (SAN) contract[15] is part of the ground project effort to support satellite operations. The contract includes building two antennas in the United States and purchasing services that are outside the range of the U.S. antennas to ensure global communications with the SWFO-L1 satellite. The SAN contract's Quality Assurance Surveillance Plan (QASP) revision "A" required that the ground project submit quarterly written surveillance reports to the contracting officer. The written quarterly reports would enable the government to demonstrate whether the contractor is meeting objectives and performance standards. An appropriately executed QASP is particularly important for cost reimbursement contracts to provide reasonable assurance that efficient methods and effective cost controls are utilized.

We found that the required contract surveillance was not documented in accordance with their plan since the SAN contract award, from April 2021 through March 2022. We requested the quarterly reports required by the original QASP. The program provided us an unsigned draft of a single, annual surveillance report and an unsigned draft of a new QASP that were both dated after our request. Ground project leadership and staff told us they had decided to perform annual surveillance instead of quarterly surveillance because of their frequent communication with the contractor. They also said they wanted to revise the QASP to relax the surveillance criteria.

However, there was no formal documentation of the QASP changes by the program, projects, contracting officer, and contractor. Documentation we received, such as emails and a change notice, were dated after our request. The ground project had four different contracting officers assigned since the contract was awarded in April 2021. This could result in limited continuity and more challenging oversight.

In accordance with federal standards, internal control systems should be designed to provide reasonable assurance that the objectives of an entity will be achieved. The government needs to know if the contractor is meeting the stated objectives and performance standards. Control activities and monitoring should include the timely review of process changes and documentation to identify issues affecting program objectives.[16] Timely contract surveillance and effective contract performance oversight are necessary to execute the program in an efficient and effective manner.

[15] The SAN contract is cost-plus-fixed-fee contract with a base period of performance from April 2021 through April 2026.

[16] See U.S. Government Accountability Office, September 2014. *Standards for Internal Control in the Federal Government*, GAO-14-704G. Washington, DC: 5 (OV 1.01); 56 (12.05); 65 (Principle 16).

Recommendations

We recommend that the NOAA Deputy Under Secretary for Operations direct NESDIS to do the following:

4. Ensure the SWFO Ground Project Quality Assurance Surveillance Plan defines sufficient criteria and frequency of surveillance to provide adequate government oversight of contractor performance.
5. Assess the program control activities defined in the SWFO Program Plan to incorporate controls that provide reasonable assurance of timely management reviews of process changes.

IV. NOAA Should Update Space Weather Requirements in Accordance With Validation Criteria

NOAA's *Space Weather Mission Service Area Observational User Requirements Document* (OURD) states that the OURD validation process creates a baseline of objectively verifiable observation requirements to help leadership set priorities based on mission needs and stakeholder input.[17] The requirements are categorized according to four validation levels that indicate the relevance of documentation supporting them. All SWFO-L1 key performance parameter (KPP) observation requirements and most mission-critical requirements[18] in the space weather OURD are categorized as validation level 2.[19]

According to the OURD, validation level 2 requirements include documentation that the data are being used in current operations. Examples include operational user guides, outside agency customer requirements, or similar directly stated justifications. The four validation levels are described as follows:

- Validation level 1. A study proving that if the data are not available at the specified accuracy or resolution, the mission of the program will be degraded. This is the most scientific way of validating the observational user requirements. *Examples are data denial studies, observing system simulation experiments, or similar objective studies*.

- Validation level 2. A document showing that the data are being used in current operations. This may not prove the need for the data at the specified accuracy or resolution but provides justification for maintaining status quo. *Examples are operational user guides, software documentation, or endorsement by high level bodies such*

[17] We previously reported on NOAA's requirements management practices. See DOC OIG, June 8, 2022, *The Success of NOAA's Next-Generation Satellite System Architecture Depends on Sound Requirements Management Practices*, OIG-22-022-A, finding 1. Washington, DC: DOC OIG, 3-9.
[18] A KPP is a program-specific performance threshold required for mission success. In the OURD, a requirement listed as mission-critical (priority 1) means SWPC could not meet operational objectives without this data.
[19] 98.5 percent of all requirement attributes are listed as validation level 2. The OURD lists each requirement with up to five measurement specifications called *attributes.* In this report, we refer to requirements and their associated attributes as requirements. Validation levels are applied to requirements and their attributes.

as U.S. government advisory boards and international bodies such as the World Meteorological Organization.

- Validation level 3. In absence of validation documents, formal subject matter expert statements may validate the need for the data. *Example would be a properly formatted statement that the data are needed for operations.*

- Validation level 4. No validation documentation exists, or the documentation provided does not validate the observational user requirements at the specified attribute level.

We found that SWFO-L1's KPP requirements lack documentation to meet NOAA's validation level 2 criteria. The validation documents are descriptions of early systems or research papers.[20] For example, the validation documents cited for coronal imagery from the L1 orbit include a GOES solar imager workshop discussion in 2001 and a design proposal from 2005 for a coronagraph that preceded the current CCOR instrument. Neither document addresses how required data are being used in the current operational setup.

Documented rationale for requirements is important to SWFO's efforts to gain stakeholder support. SWPC personnel told us that NESDIS has been a strong advocate for space weather data in recent years. However, there has been at least one example in which space weather capabilities lost support for inclusion in satellite observing systems.[21]

Both SWPC and NESDIS personnel told us that communicating the scope and criticality of space weather observations has been a challenge. Considering the challenge that NOAA faced getting approval for the initial SWFO program,[22] updating the OURD with operational validations could more strongly support the scope and criticality of space weather observations.

According to SWPC personnel, once a requirement is validated in an OURD, it is not revalidated in subsequent OURDs. The Space Weather OURDs were published in 2009 and 2017. SWPC participates in requirement revalidation processes with the NWS Office of Observations, but they could not identify triggers for those processes that would require an OURD to be revalidated, nor had they considered updating validations that were already established in the OURD.

We were able to find evidence that space weather data are used in operations and therefore, should be documented to provide validation level justifications for space weather

[20] This is consistent with what we found in our prior reporting with respect to magnetometer requirements on GOES-R satellites. See DOC OIG, August 12, 2019. *Geostationary Operational Environmental Satellite–R Series: Program Success Requires Added Attention to Oversight, Risk Management, Requirements, and the Life-Cycle Cost Estimate*, OIG-19-022-A, finding II. Washington, DC: DOC OIG, 8–11.

[21] An example of this occurred between the GOES-I and GOES-N series. GOES-12, the last of the GOES-I series satellites, measured low energy protons and solar flare radiation. SWPC said the requirement was not included in the next GOES series (GOES-N), which had impacted their forecasting capability.

[22] See the introduction of this report.

observation requirements. SWPC personnel described examples of current space weather observation data that are used in high-priority SWPC products and services for agencies such as Department of Homeland Security and National Security Council that would satisfy the level 2 validation criteria. We also found SWPC current operational product inputs described in a North American electrical regulatory authority's procedure related to geomagnetic disturbances. However, none of these examples are contained in the OURD.

Recommendation

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

6. Direct the National Weather Service to work with the Office of Observations and the Space Weather Prediction Center to either update the validation documents in the Space Weather OURD consistent with level 2 validation criteria or amend the validation levels of requirements to reflect the cited documentation.

Other Matter

SWFO Antenna Network Contract Has Potential Performance And Cost Management Risks

As discussed in this report, NOAA's rideshare decision required an aggressive program schedule to meet the IMAP launch schedule. To meet the program's cost and schedule constraints, the SWFO ground project designed a hybrid approach to ground antenna services: build two U.S. mainland antenna ground stations and procure remaining outside-the-contiguous-U.S. (OCONUS) global communication needs using contracted services. The ground project preferred a contractor that could both build the U.S. antennas and manage all services, due to cost and schedule considerations. However, after reviewing SWFO requirements, contracts, and the service model, we noted potential performance and cost management risks that deserve attention.

As we discussed briefly in finding III, NOAA awarded a cost-plus-fixed-fee contract to a single prime contractor for managing antenna construction and procuring the required satellite OCONUS communication services. The OCONUS part of the services is significant, as it accounts for approximately 60 percent of total ground antenna contact time with the SWFO-L1 satellite. The prime contractor arranged for a separate contract with another service provider, for which NOAA has no contractual or direct relationship.

As of this report, the prime contractor determines the performance acceptability of subcontracted satellite services. Under the cost-plus-fixed-fee contract, NOAA does not have the performance management tools that other satellite programs have with cost-plus-award-fee contracts. According to the contracting officer, this arrangement was selected based on cost and administrative burden. However, without a direct interface to the service provider for the majority of satellite ground contact time, it may be challenging to address areas of concern that emerge after launch.

After reviewing the service level agreement between the prime contractor and service provider, we also found potential cost uncertainty regarding average antenna usage rates. The service level agreement cites a maximum usage rate threshold that, if exceeded, would result in additional fees to the prime contractor and presumably, to NOAA. The ground project personnel told us that exceeding the threshold would be an exceptional case, if it ever occurred, so it was not a significant cost risk. However, the methodologies and details of contractor estimates, or quantitative government cost or risk assessments, were not available for our review.

During the audit, the contracting officer told us the project had initiated an action for the prime contractor to determine performance monitoring options, which was a positive development. We encourage the program to closely monitor the progression of the service model to ensure that cost and performance risks are appropriately managed.

Summary of Agency Response and OIG Comments

On February 16, 2023, we received NOAA's response to our draft report. In response to our draft report, NOAA concurred with all recommendations and generally described approaches it has taken or will take to meet them. NOAA's response is included in appendix D.

We are pleased with NOAA's response to the report and look forward to reviewing its action plan for implementing the recommendations.

Appendix A: Objective, Scope, and Methodology

Our audit objective was to identify SWFO program challenges that may affect cost, schedule, or overall mission performance and assess the extent to which NOAA is addressing them. We announced this audit on December 16, 2021, and completed our fieldwork in October 2022. We discussed our findings with the auditee on September 7, 2022, and January 4, 2023.

To identify SWFO program challenges that may affect cost, schedule, or overall mission performance, we reviewed Department acquisition guidance; NOAA requirements; NASA project management guidance; program strategy to acquire the spacecraft, instruments, and ground system; the formulation authorization and agreement; Department milestone review board materials; NESDIS direction memorandum; program and independent cost estimates; program plan; program requirements; and contracts.

To assess the extent to which NOAA is addressing challenges, we analyzed NOAA interagency agreements, phase/milestone decision materials and reviews, contingency planning, risks, issues, recurring status reviews, and management oversight activities. We attended or reviewed (virtually) ground segment critical design reviews, avionics critical design review, spacecraft critical design review, program critical design review, monthly status reviews, and joint agency program management council reviews. We interviewed personnel and/or executive leadership at the Department of Commerce Office of Acquisition Management, NASA Rapid Spacecraft Development Office, NASA Rideshare Office, NOAA's National Weather Service Space Weather Prediction Center, NESDIS Office of Projects, Planning and Analysis, SWFO program and project management offices, ground project contracting officer and contracting officer representative, and the SWFO antenna network contractor.

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

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

We conducted our audit from December 2021 through October 2022 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 April 26, 2013, as amended October 21, 2020. We performed our fieldwork remotely from OIG offices headquartered in Washington, DC.

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

Appendix B: SWFO Program Instruments

The SWFO-L1 satellite hosts several space weather observation instruments including the CCOR, solar wind plasma sensor (SWiPS), and magnetometer (MAG), which are all KPP instruments. It also hosts a supra thermal ion sensor (STIS) and the SWFO program has an agreement with the GOES-R program to host an additional CCOR on the GOES-U satellite.[23]

CCOR was developed to observe the solar corona and detect CMEs. CCOR provides the earliest possible notice of impending geomagnetic activity. CCOR-1 will fly on the GOES-U satellite and a nearly identical CCOR-2 will fly on SWFO-L1. There are technical differences between CCOR-1 and CCOR-2 in the field-of-view, spatial resolution, and imaging availability due to the different L1 and geostationary satellite orbits. Due to the geostationary orbit geometry, CCOR-1 will miss capturing one or more images on 42 percent of the days in a year.

SWiPS was developed to measure properties of the solar wind plasma flowing past SWFO-L1, such as density, velocity, and temperature. SWiPS measures solar wind changes that can provide early warning of conditions that may affect the geomagnetic environment. These measurements provide real-time identification and timing of events like CMEs and space weather conditions that can adversely impact Earth.

MAG was developed to measure the magnetic field carried by the solar wind. SWFO-L1 will fly two identical units as inboard and outboard sensors. MAG monitors the interplanetary magnetic field for abrupt changes which can result from phenomena like CMEs and high-speed solar wind streams that can result in geomagnetic storms at Earth. MAG makes observations of the magnetic field at its L1 orbit position directly upstream from Earth, providing early warning of geomagnetic activity.

STIS was developed to collect high-speed ions in the solar wind. STIS makes observations of higher-speed ions that can provide an earlier warning of geomagnetic activity before the slower bulk of the CME arrives at the SWFO-L1 orbit position. These ions provide space weather forecasters with information that improves warning accuracy.

[23] The X-ray Flux Monitor, a European Space Agency instrument, was planned to fly on SWFO-L1 but was removed from the project in June 2022 due to schedule challenges.

Appendix C: SWFO Program Acquisition Environment and Challenges

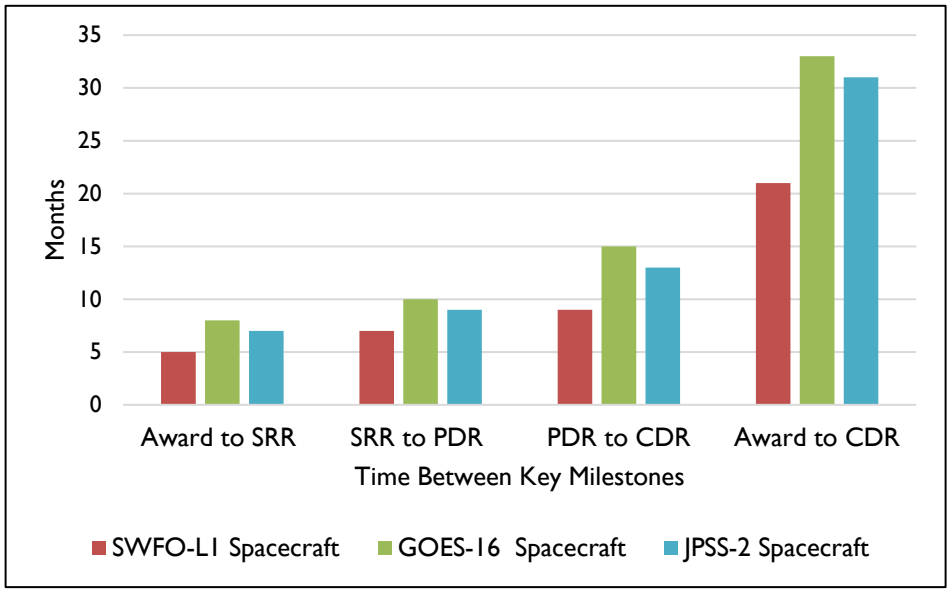
NOAA selected a rideshare arrangement to help facilitate program approval, initially estimating savings of $180 million versus a dedicated SWFO-L1 launch.[24] SWFO program challenges related to the rideshare, acquisition environment, and other technical areas are described below.

Rideshare Costs. The program has accounted for $462,000 in rideshare accommodation costs so far, but that does not include $28 million of SWFO-L1 delay costs caused by an IMAP program delay.[25] Program personnel said that there is cost associated with a rideshare launch that is difficult to estimate without historical data. Following our discussions with program personnel, they said it would be paying closer attention to rideshare-related cost data. This is an area where lessons learned could benefit NASA and NOAA in future rideshare arrangements.

Spacecraft Acquisition. The SWFO program used the NASA Rapid Spacecraft Development Office for its spacecraft acquisition.[26] The SWFO program did not have time for in-depth acquisition studies of SWFO's unique requirements due to the aggressive schedule for delivery to IMAP. Following acquisition, the development schedule continued at a fast pace through spacecraft design. See figure C-1 for SWFO spacecraft acquisition times from contract award to, and between, key milestones compared to GOES-16 and Joint Polar Satellite System (JPSS)-2.[27]

[24] This was a rough estimate based on available information at the time of program initiation and the program did not have detailed cost estimate data available for our review.
[25] The program tracks the IMAP delay cost impact as a COVID-related cost.
[26] The Rapid Spacecraft Development Office process is designed to significantly shorten spacecraft acquisition time using firm fixed price contracts from a catalog of spacecraft meant to service missions without extensive unique requirements.
[27] As a caveat, program personnel told us the SWFO spacecraft is not as complex as a GOES spacecraft.

Figure C-1. Spacecraft Design Intervals (months)



SRR: system requirements review
PDR: preliminary design review
CDR: critical design review
Source: OIG analysis of NOAA, NASA, and SWFO program documentation

Current Technical Challenges

The program is working through multiple technical challenges as it incorporates design changes since its program CDR.

Spacecraft Structural Panels. Late in development, the spacecraft structural panels failed representative sample testing. The program is investigating the root cause as well as potential impact to flight hardware. After the failures occurred, the flight project ordered long-lead materials to facilitate either timely repair or replacement corrective action. The program had not formally identified the potential schedule impact as of the end of our audit fieldwork in October 2022.

Field Programmable Gate Arrays (FPGAs).[28] The FPGAs that were included in standard designs were not certain to meet the requirements NOAA needed for operation through solar storms without additional testing.[29] The FPGA for the main avionics data interface had to be redesigned, but indications are that it will meet SWFO-L1 requirements. However, delivery of the unit is delayed until May 2023 and it is the primary critical path for SWFO-L1. The avionics unit is a foundational component for developing spacecraft and flight software that could eventually cause delays during integration and testing.

Contractor Work Priority. The program has begun using federal priority procurement status to gain a higher work rating with subcontractors to ensure adequate project staffing is

[28] FPGAs are programmable integrated circuits found on the spacecraft and instruments.
[29] The program manager told us this situation was an intersection of payload risk classification, rideshare, and having demanding program level 1 requirements such as an operate-through-solar storm requirement.

maintained.[30] Earlier in the program, there were instances of contractor staff being shifted to work on higher priority federal procurements. The program has now addressed this to the extent possible, but according to project personnel, this may continue to be a challenge.

Contamination Control Plan. The satellite's contamination control plan was not approved by the program's CDR, as required. The plan is needed to ensure there is no contamination of the satellite and instruments during integration and testing. To expedite corrective action after the spacecraft contractor did not deliver an adequate plan, NASA GSFC took over plan development.

[30] 15 C.F.R. § 700.11.

Appendix D: Agency Response

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

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: *Space Weather Follow-On (SWFO) Program: Rideshare Schedule Presents Challenges and Lack of Backup Option Warrants NOAA Attention*
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 the Space Weather Follow-on program. We reviewed the report and concurred with the recommendations.

We appreciate the opportunity to review and respond to your draft report. If you have 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
Space Weather Follow-On (SWFO) Program: Rideshare Schedule Presents Challenges and Lack of Backup Option Warrants NOAA Attention
(January 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 the audit of the NOAA's Space Weather Follow-On Program (SWFO). NOAA reviewed the draft report and concurs with the OIG's recommendations. General comments and responses to the six recommendations are provided below.

NOAA Response to OIG Recommendations

Recommendation 1: Work with The NASA Science Mission Directorate Associate Administrator to determine if an agreement for contingent launch schedule flexibility is feasible for the SWFO-L1 mission if IMAP or SWFO-L1 are unable to meet launch timing.

NOAA Response: NOAA concurs. National Environmental Satellite, Data, and Information Service (NESDIS) continues to coordinate and monitor the Interstellar Mapping and Acceleration Probe (IMAP) regularly with the National Aeronautics and Space Administration (NASA). If the IMAP launch or our rideshare status in the launch looks to be at risk, the program will work with NESDIS and with NASA as our acquisition agent to start rapid procurement for another launch opportunity.

Recommendation 2: Coordinate with the Director, National Weather Service, to update the Space Weather – Geomagnetic Storm Warning Gap Mitigation Plan for Space-Based Observations (June 2020) to reflect current contingencies.

NOAA Response: NOAA concurs. Internally, NESDIS, working with the National Weather Service (NWS) and NASA, captured updates in an addendum to the Gap Mitigation Plan, first prepared in November 2021 and updated November 02, 2022. NESDIS will coordinate with NWS to update the plan annually until the SWFO Lagrange Point 1 (SWFO-L1) launch. We anticipate that the next update will be completed by the end of Q3 FY2023.

Recommendation 3: Ensure that the SWFO program updates its plans for lessons learned and conducts appropriate learning sessions.

NOAA Response: NOAA concurs. In the next 45 days, NESDIS will review and modify the knowledge management practices in our Program Plan as appropriate, including the use of the NASA Goddard Space Flight Center (GSFC) "Pause and Learn (PaL)" structured process and documentation for lessons learned.

Recommendation 4: Ensure the SWFO Ground Project Quality Assurance Surveillance Plan defines sufficient criteria and frequency of surveillance to provide adequate government oversight of contractor performance.

NOAA Response: NOAA concurs. NESDIS has reviewed its SWFO antenna network (SAN) contract's Quality Assurance Surveillance Plan (QASP) and confirmed that it defines sufficient criteria and frequency of surveillance to provide adequate government oversight of contractor performance. All QASP updates that had been marked draft at the time of Inspector General (IG) review are now on the SAN contract. The Contracting Officer's Representative (COR) will submit QASP reporting under the direction of the Contracting Officer.

Recommendation 5: Assess the program control activities defined in the SWFO Program Plan to incorporate controls that provide reasonable assurance of timely management reviews of process changes.

NOAA Response: NOAA concurs. In the next 90 days, NESDIS will review the program control activities contained in the SWFO Program Plan and, as necessary, update them to incorporate additional management controls to improve the timely review and implementation of process changes within the program. NESDIS will review updates to the program plan at the next lifecycle review -- the Mission Operations Review (MOR) presently scheduled for Q3 FY 2023. The MOR review board is a Goddard Systems Review Team (GSRT) convened under the authority of the Goddard Safety and Mission Assurance Directorate (Code 300).

Recommendation 6: Direct the National Weather Service to work with the Office of Observations and the Space Weather Prediction Center to either update the validation documents in the Space Weather OURD consistent with level 2 validation criteria or amend the validation levels of requirements to reflect the cited documentation.

NOAA Response: NESDIS has provided this recommendation to NWS. NWS concurs with the recommendation and will update the reference validation documents in NOAA's Space Weather Mission Service Area Observational User Requirements Document (OURD) to reflect the appropriate validation criteria. NWS will work toward a Q3 FY2024 completion date.

Recommended Changes for Factual/Technical Information

- None

Editorial Comments

- None

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