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Space Weather Follow On (SWFO) Program Preliminary Level 1 Requirements Document (L1RD)

U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)
National Aeronautics and Space Administration (NASA)

Space Weather Follow On (SWFO) Program Preliminary Level 1 Requirements Document (L1RD) Review/Signature/Approval Page

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Preface

This document is under SWFO configuration control. Once this document is approved, SWFO approved changes are handled in accordance with Class I and Class II change control requirements as described in the SWFO Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

SWFO Configuration Management Office
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Change History Log

Revision	Effective Date	Description of Changes (Reference the SCoRe Approval Date)
Revision -	05/21/2021	Initial baseline
Rev A	07/19/2021	Released per CCR-00327, and was approved upon the effective date shown.

Deviations/Waivers Record

Section # / Rqmt.	Deviation / Waiver #	CCR #	Date Approved	Title	Mission
None.	None.	None.	None.	None.	None.

Table of Contents

1 INTRODUCTION ... 1
1.1 Purpose ... 1
1.2 Scope ... 1
1.3 Applicable and Reference Documents ... 2
2 BACKGROUND ... 5
2.1 Space Weather and its Impact ... 5
2.2 System Need ... 6
2.3 Legacy Missions and Observational Gap ... 7
3 LIST OF TBD/TBR ITEMS ... 8
4 PROGRAM DEFINITION ... 9
4.1 Program Elements ... 9
4.1.1 CCOR Development ... 9
4.1.2 SWFO GOES-U ... 10
4.1.3 SWFO-L1 Project ... 10
4.1.4 SWFO Ground Segment ... 10
4.2 Management Approach and Governance Structure ... 10
5 OWNERSHIP AND OVERSIGHT REQUIREMENTS ... 12
5.1 Program Management ... 12
5.2 Requirement Review and Approval ... 12
6 SYSTEM REQUIREMENTS ... 13
6.1 Space Segment ... 13
6.2 Ground Segment ... 14
6.3 Observational KPPs ... 15
6.4 Product Requirements ... 15
6.4.1 Data Latency ... 15
6.4.2 Product Generation ... 15
6.4.3 Product Distribution ... 16
6.4.4 Product Stewardship ... 16
6.5 Data Availability ... 17
6.6 Initial and Full Operational Capability ... 19
6.7 Operational Lifetime ... 19
6.8 Spacecraft and Instrument Requirements ... 20
7 PRODUCT PERFORMANCE REQUIREMENTS ... 21
7.1 Coronal Imaging ... 21
7.2 Solar Wind ... 22
7.2.1 Thermal Plasma Variables ... 22
7.2.2 Vector Magnetic Field ... 24
7.2.3 Suprathermal Ion Differential Flux ... 24
7.2.4 Solar Wind Dynamic Pressure ... 25
8 PROGRAM SUCCESS CRITERIA ... 26
APPENDIX A. ACRONYMS ... 27

List of Figures

Figure 1 SWFO requirements flowdown chart. 2
Figure 2 Selected space weather phenomena and spatial and temporal scales relevant to forecasting. 5

List of Tables

Table 1 Applicable Documents. 2
Table 2 Reference Documents. 4
Table 3 List of Open TBD/TBR Items. 8
Table 4 SWFO requirements document review and approval. 12
Table 5 Space weather data products. 15
Table 6 Coronal White Light Intensity requirement. 22
Table 7 Thermal Plasma Ion Velocity Requirement. 22
Table 8 Thermal Plasma Ion Density requirement. 23
Table 9 Thermal Plasma Ion Temperature requirement. 23
Table 10 Vector magnetic field requirement. 24
Table 11 Flux accuracy as a function of flux level for E=2 MeV. 25
Table 12 Suprathermal Ion Differential Flux requirement where E is the ion energy. 25
Table 13 Solar Wind Dynamic Pressure parameters. 25

1 INTRODUCTION

1.1 Purpose

This document provides the Level 1 requirements for the Space Weather Follow On (SWFO) Program (“Program”) of the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS). The Program goal is to provide critical, operational space weather data to the Space Weather Prediction Center (SWPC) of the National Weather Service (NWS).

SWPC produces watches, warnings, and alerts related to space weather events to protect lives and property. The critical observations in developing these warnings are a) white-light coronal imagery of the Sun to detect Earth-directed Coronal Mass Ejections (CMEs) and b) in situ measurements of the solar wind plasma to assess the geo-effectiveness of solar storms. SWPC currently relies on coronal images and solar wind measurements from earlier satellite missions which are expected to be unavailable by 2026. Imminent failure of these critical observatories drive the need for NOAA to launch SWFO-Lagrange 1 (SWFO-L1) with NASA’s Interstellar Mapping and Acceleration Probe (IMAP) mission in 2025, and launch a coronagraph on GOES-U in 2024. SWFO-L1, NOAA’s new deep-space observatory, will provide both white-light coronal imagery of the Sun and in situ solar-wind measurements. In addition, a coronagraph integrated on the Geostationary Operational Environmental Satellite – U (GOES-U) will provide resiliency of NOAA's observational capability by also collecting white-light coronal images of the Sun.

The purpose of this document is to:

a) Summarize the background, mission need, and fundamental objectives of the Program.

b) List the top-level functional and performance requirements of the Program for generation of lower-level requirements, management control, and policy-level review.

1.2 Scope

The Level 1 requirements of this document are formulated to ensure that the SWFO Program provides continuity of critical, operational space weather data to SWPC. The requirements reflect user needs compiled by NOAA (Fig. 1). The Consolidated Observation User Requirements List (COURL) contains all observational requirements for terrestrial and space weather. The Observational User Requirements Document (OURD) for the Space Weather Mission Service Area is derived from the COURL specifically for space weather. The COURL is used to develop the agency’s observational capabilities, contained in the NOAA Observing System Architecture (NOSA).

The Level 1 requirements include the Key Performance Parameters (KPPs), which are the highest-priority products from the Program’s projects, as well as lower-priority products. Level 2 requirements for individual projects flow from this document.

The requirements change process is described in the SWFO Program Configuration Management Plan.

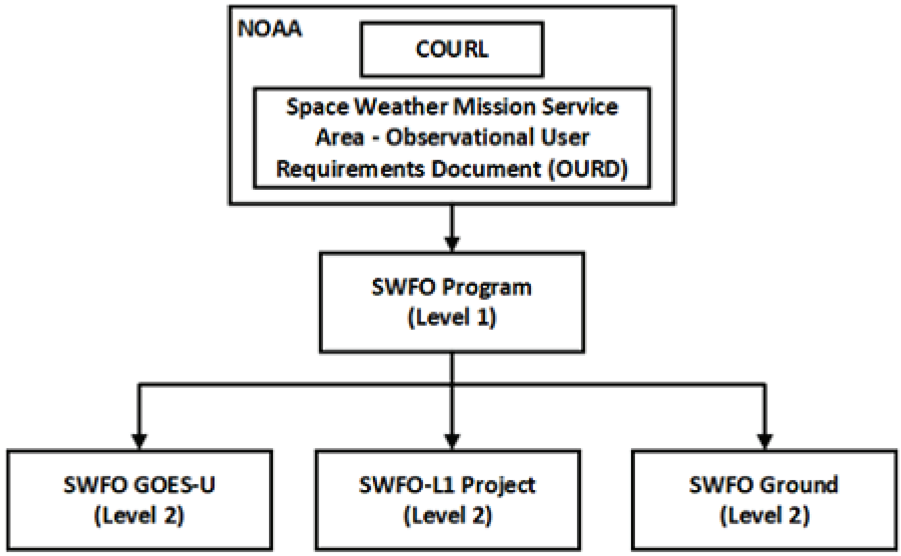

Figure 1 SWFO requirements flowdown chart.

1.3 Applicable and Reference Documents

Applicable documents contain references to additional requirements that are needed for the implementation of the SWFO Program requirements. Unless stated otherwise in this document, Table 1 includes documents and forms that are applicable to the SWFO Program.

Table 1 Applicable Documents.

Document Title	Document Description
NOAA/NESDIS, *NOAA Space Weather Mission Service Area Observational User Requirements Document* (OURD), November 15, 2017	Subset of NOAA's Consolidated Observing User Requirements List (COURL) for space weather
NOAA/NESDIS, NOAA-NASA Satellite Programs and Projects Management Control Plan (MCP), December 21, 2018	Describes agency collaboration on satellite programs
NOAA, Assistant Administrator for Satellite and Information Services Memorandum, *Programmatic Direction for Near-term, Path Forward for Space Weather Observations and Measurements*, January 11, 2018.	Provides direction to NESDIS for SWFO space weather program
NOAA, Assistant Administrator for Satellite and Information Services Memorandum, *Programmatic Direction for Near-term Path Forward for Space Weather Observations and Measurements*, May 18, 2018.	Provides information to NASA/SMD for partnering in SWFO space weather program
NOAA/NESDIS, Interagency Agreement (IAA) between NOAA and NASA, IAA # OPPA2019SWFO01-0000, July 2019	Commitment from NASA to support SWFO via program management, acquisition expertise, systems engineering, and scientific support.

Document Title	**Document Description**
NOAA/NESDIS, SWFO Program Plan, September 2019	Describes the Program
NOAA/NESDIS, SWFO Configuration Management Plan, Doc Num: 411.0-00001, December 3, 2020	Describes the document configuration plan
NOAA, Requirements Management, NOAA Administrative Order (NAO) 216-108, October 31, 2005	Provides guidance for requirements management
NOAA/GOES, GOES-R Series Level I Requirements (LIRD), 410-R-LIRD-0137 Version:4.0, June 12, 2020	Requirements document for GOES-R
NOAA/NESDIS, NESDIS Procedural Requirements for NESDIS Ground Enterprise (NGE), Level 1 Requirements Document, NPR 5167.1, Rev. 1.3, July 28, 2016	Procedural Requirements
NOAA/NESDIS, NSOSA Study – SPRWG Report, March 22, 2018	Describes the long-term plans for the NOAA satellite architecture
Department of Commerce, *Commerce Acquisition Manual 1307.1*, September 2017	Describes acquisition process
NOAA Memorandum to NESDIS/OPPA on Acquisition Review – Conditional Approval for Space Weather Follow-On (SWFO) Program, May 23, 2019	Approves the acquisition of the SWFO Program
Milestone Decision Memorandum (MDM) Approval for Milestone 2/3 for the Space Weather Follow-On Program, November 19, 2019	Approves the Milestone 2/3 of the acquisition process for the SWFO Program
Federal Emergency Management Agency (FEMA), Federal Continuity Directive 1, January 2017	Provides guidance for the coordination of large-scale programs among executive departments and agencies
Federal Emergency Management Agency (FEMA), Federal Continuity Directive 2, June 2017	Provides guidance for the coordination of large-scale programs among executive departments and agencies
NOAA/NESDIS, SWFO Resource Allocation Document, February 2020	Provides details for data product accuracy, latency, and availability
NIST Federal Information Processing Standards (FIPS) 199, February 2004	NIST Standards for Security Categorization of Federal Information and Information Systems
NIST FIPS 200, March 2006	NIST Minimum Security Requirements for Federal Information and Information Systems
National Institute of Standards and Technology (NIST) Special Publications (SP) 800-37, Rev. 2, May 2018	NIST Risk Management Framework for Information Systems and Organizations: A System Life Cycle Approach for Security and Privacy
NIST SP 800-53, Rev. 4, eff. April 2013	NIST Security and Privacy Controls for Federal Information Systems and Organizations

Document Title	Document Description
NIST SP 800-53A, Rev. 4, eff. December 18, 2014	NIST Assessing Security and Privacy Controls in Federal Information Systems and Organizations: Building Effective Assessment Plans
NIST SP 800-82 Rev. 2 Guide to Industrial Control Systems (ICS) Security, May 2015	NIST IT guidance on how to secure Industrial Control Systems (ICS)
NESDIS System Engineering and Program Management Policy (NESDIS-PD-1110.1), eff. July 01, 2017	This directive captures and communicates the NESDIS policy and responsibilities for disciplined systems engineering and program management activities across the NESDIS Enterprise.
Requirements Management Procedural Requirements (NESDIS-PR-1302.1), eff. March 01,2019	Establishes process and criteria by which NESDIS will develop and manage its requirements.
SWFO Formulation Authorization Document (FAD)	Establishes the struction of the SWFO Program, what office(s) the program falls under, and the program goals/objectives.
SWFO Formulation Agreement	Document formalizing the agreement of all necessary parties of SWFO's struction, office(s) affiliation, and goals/objectives.

Table 2 Reference Documents.

Document Title	Document Description
National Science and Technology Council (NSTC), *National Space Weather Strategy and Action Plan*, March 2019	Provides guidance to agencies related to space weather
National Research Council, Solar and Space Physics: *A Science for a Technological Society: An Overview*, 2013	Summarizes the findings and recommendations of the research community on space science and space weather
National Research Council, *Severe Space Weather Events: Understanding Societal and Economic Impacts: A Workshop Report*, 2008	Summarizes the findings and recommendations of the research community for space science and space weather

2 BACKGROUND

Space weather includes all time-varying conditions at a given location in Earth's space environment and especially those with the potential to impact human life and property.

Space weather poses a threat to the nation's economic vitality and its security, as it impacts integrated technological systems upon which the global economy fully depends and which provide stability and security for life and society. It can impact electric power grids, commercial aviation, navigation and communications systems, oil and gas distribution, and transportation, among others, as well as satellites and human space exploration.

These critical technological infrastructures make up a diverse, complex, and interdependent system of systems in which a failure of one could cascade to another. Given the importance of reliable electric power and space-based assets, it is essential that the United States has the ability to mitigate, respond to, and recover from the potentially devastating effects of space weather.

2.1 Space Weather and its Impact

Space weather phenomena include the solar wind as well as disturbances such as solar flares, solar energetic particle (SEP) events, and CMEs. The latter originate on the sun's surface and may become critical if they are directed towards Earth in which case they produce a variety of disturbances. CMEs drive the most severe type of disturbance, the geomagnetic storm.

Figure 2 Selected space weather phenomena and spatial and temporal scales relevant to forecasting.

Space weather disturbances are quantified operationally using NWS scales. High SEP levels are rated using the Solar Radiation Storms scale (S1 - S5) which is used to assess radiation hazards to airline crews and passengers as well as to astronauts, and effects of interference and damage on satellite electronics. The Radio Blackouts scale (R1 – R5, related to the solar flare scale M1-X50), is used to measure the levels of electromagnetic radiation noise, which is emitted primarily from flare regions on the Sun and can overwhelm high-frequency (HF) and other communication and navigation signals. The SWFO Program's spacecraft and instruments will be built to withstand the effects of radiation storms and radio blackouts up to high-activity levels. Large geomagnetic disturbances are rated using the Geomagnetic Storm scale (G1 – G5). Severe space weather refers to conditions with a rating of 4 or higher in one or more of these scales.

2.2 System Need

The NWS/SWPC monitors space weather events and issues a number of products for specific user groups. The products include watches, warnings, and alerts of imminent disturbances as well as forecasts of various lead times. SWPC must integrate data from different observational platforms measuring phenomena happening across spatial and temporal scales of many orders of magnitude (Figure 2). Coronal images and solar wind measurements, such as those the SWFO-L1 observatory is designed to provide, are essential for SWPC's human forecasters and numerical models to provide advance warning of space weather disturbances. NWS coordinates its evaluation and forecast activities with the U.S. Air Force 557th Weather Wing, which is an important SWPC customer.

SWPC uses coronal image data as an input to the Wang-Sheeley-Arge Enlil (WSA-Enlil) model to forecast the arrival of CMEs and other structures at Earth and the occurrence of geomagnetic disturbances. SWPC products are communicated to more than 50,000 users via Internet services. For powerful storms that may threaten critical infrastructure, however, SWPC contacts power grid operators directly via a hotline while at the same time alerting the Federal Emergency Management Agency (FEMA). It has been demonstrated that including CME intensity data improved the successful prediction of geomagnetic storms from 27% to 60% with a success rate of 80% for the strongest storms, in addition to significantly reducing the false-alarm rate. Using the WSA-Enlil model reduces arrival time error from ±12 hours to ±7.5 hours.

Solar wind measurements are essential for predicting geomagnetic storms as well. These data provide a highly accurate estimate of the expected strength of the geomagnetic storm, with an accuracy of greater than 90%, which enables SWPC to issue Geomagnetic Storm Warnings when needed. These data are used as inputs to many SWPC models, with a key one being the University of Michigan Geospace Model. This model uses solar wind data to predict storm intensity as a function of location on Earth, providing regional predictions of geomagnetic storms. The Geospace Model is coupled to a geoelectric model to provide electric grid operators with the electric field data they need to determine the likely impacts on their systems. The solar wind dynamic pressure is an important parameter for estimating the solar wind impact on the magnetosphere and determines, for example, the location of the magnetopause boundary. The magnetopause location is an important proxy for disturbance level and is widely used by operators of spacecraft at geosynchronous orbit. Finally, the levels and energies of suprathermal ions have been shown to provide, for many strong events, limits on the expected strength and arrival times of a geomagnetic storm with forecast lead times longer than any based on other L1 data.

Solar flares are responsible for producing many near-Earth radiation storms, and space weather instruments, such as imagers and particle detectors onboard NOAA's GOES satellites, have been used to determine flare location and intensity. The availability of these images and data allows SWPC forecasters to issue high confidence warnings of impending radiation storms, usually with 20-30 minutes of lead-time. As radiation storms reach Earth, forecasters use GOES particle data to determine storm intensity and issue alerts to customers who at this point include airlines (whose HF communications are impacted), the satellite industry, and NASA for the protection of astronauts.

2.3 Legacy Missions and Observational Gap

NOAA has established SWFO with the goal of sustaining a foundational set of space-based observations of CME imagery and solar wind measurements. The SWFO Program ("Program") will provide continuity and reduce the risk of a measurement gap in the current CME imagery and *in situ* solar wind measurements.

The current source of CME imagery is the Solar and Heliospheric Observatory (SOHO) research mission by the European Space Agency (ESA) and NASA while *in situ* solar wind measurements are taken by NOAA's Deep Space Climate Observatory (DSCOVR) mission. SOHO and DSCOVR are located at the Sun-Earth Lagrange 1 (L1) point. The loss of coronagraph imagery and/or solar wind measurements would essentially constitute the loss of storm forecasting capability, from long-term forecasts to short-term watches and warnings.

SOHO was launched in 1995 and its mission life is currently limited by available power. Power production from its aging solar panels is predicted to fall below sustainable level by 2025. There are no backup sources of CME imagery in the Sun-Earth line.

DSCOVR, launched in 2015, is SWPC's primary source for *in situ* magnetic field and plasma properties. DSCOVR was designed on a low-cost NASA Small Explorer (SMEX) platform; the SMEX are single-string spacecraft, which while typically able to exceed their minimum design life, have low redundancy electronics and are subject to sudden failure. Even though the spacecraft is subject to frequent radiation-produced upsets and has experienced several safeholds, it is considered to be in overall good health and its mission life is presently estimated at 10 years, well beyond its two-year design objective with additional 5 years of fuel. NASA's Advanced Composition Explorer (ACE), launched in 1997, provides a backup capability to DSCOVR. ACE's mission life is limited by available propulsion needed to maintain orbit around L1 and the spacecraft fuel is projected to end by 2026.

Other legacy monitoring capabilities include solar instruments on NOAA's GOES series. The SWFO Program will complement the existing capability with a solar telescope on the future GOES-U satellite.

While most of the legacy solar wind measurements and coronal imaging has taken place from L1 or other points close to the Sun-Earth line, forecasting performance can be improved by including an observational capability from locations off the Sun-Earth line. NOAA has expressed interest in collaborating with ESA so as to improve the observational capabilities of the two agencies.

3 LIST OF TBD/TBR ITEMS

Table 3 List of Open TBD/TBR Items.

Item No.	Object Identifier	411.0-00005 Program Preliminary Level 1 Requirements Document
None.	None.	None.

4 PROGRAM DEFINITION

NOAA's SWFO Program is designed to ensure the continuity of operational space weather observations beyond the current generation of missions, DSCOVR and SOHO. This operational goal requires observational redundancy for continuous delivery of services. For NWS to generate timely and accurate forecasts, watches, and warnings, imagery of CME from the sun and *in situ* measurements of solar wind plasma are required.

The NOAA/NESDIS plan for meeting the OURD requirements is to build the foundational capability needed by SWPC to issue forecasts, watches, and warnings. NESDIS will develop this capability through the SWFO Program by:

1. Building two Compact COROnagraph (CCOR) units.

2. Flying and operating the first CCOR unit at geostationary orbit on the GOES-U satellite planned for launch in 2024.

3. Procuring the SWFO-L1 spacecraft for an operational deep-space mission at the L1 point; procuring the Solar Wind Instrument Suite (SWIS); and integrating the second CCOR and SWIS on the spacecraft.

4. Launching the SWFO-L1 mission and operating it at L1. The CCOR will take coronal images while the SWIS will measure solar wind data at the location of the spacecraft (*in situ*).

5. Building and operating a robust ground architecture that supports all ground services needed in the Program.

6. Utilizing results from the NOAA Satellite Observing System Architecture (NSOSA) study to develop long-term plans for space weather observations and measurements.

7. Maintaining archives at the National Centers for Environmental Information (NCEI) to ensure stewardship of those space-based data essential for model development and benchmarking.

8. Planning future continuity missions as required.

4.1 Program Elements

The SWFO Program will contain several major efforts that are outlined next.

4.1.1 CCOR Development

SWFO is developing an operational compact coronagraph (CCOR) design to provide performance comparable to full size heritage units (LASCO, COR1,2), but small enough to be compatible with a variety of platforms. SWFO is building two CCORs. One will be integrated on GOES-U and another will be integrated on SWFO-L1.

4.1.2 SWFO GOES-U

A CCOR unit will be included, with other sun-viewing instruments, on the GOES-U solar pointing platform with a launch date of 2024. A coronagraph at GEO orbit is highly useful, but limited by Earth-produced eclipses. Partial eclipses start and end approximately 25 days from equinox and progress to total eclipses for approximately 2 hours per day on equinox day (occurring twice a year). The eclipse limitation would be removed if a coronagraph were to be placed on more than one operational satellite.

The existing GOES-R ground system will continuously receive real-time data from the GOES-U spacecraft, when GOES-U is the operational GOES-East or GOES-West spacecraft, and it will transmit CCOR Level 0 data to SWPC. SWPC will produce all Level 1 and higher CCOR data products.

4.1.3 SWFO-L1 Project

The SWFO-L1 mission will be a three-axis stabilized spacecraft compatible with the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) Grande interface. The spacecraft will accommodate a CCOR and an instrument suite for solar wind measurements at the L1 point. The SWIS will include a Solar Wind Plasma Sensor (SWiPS), a set of magnetometers (MAG), and a low-energy ion spectrometer called the SupraThermal Ion Sensor (STIS). Additionally, the SWFO-L1 mission will accommodate an ESA X-ray flux monitor (XFM).

SWFO-L1 will rideshare with NASA's IMAP mission on an ESPA Grande ring for launch in 2025. The rideshare approach significantly lowers overall cost but increases schedule risk for the SWFO-L1 mission.

4.1.4 SWFO Ground Segment

The SWFO Ground Segment (GS) will encompass command and control and the SWFO antenna network for the SWFO-L1 Observatory, and the product generation and distribution for SWFO-L1 and for CCOR on GOES-U. The SWFO GS will continuously receive real-time data from both L1 and geostationary orbit and transmit Level 0 data to SWPC. In addition, the GS will transmit the SWFO-L1 data and telemetry to the Mission Operations Center (MOC). SWPC will produce all Level 1 and higher-level data products for the SWFO instruments. NCEI will generate data products of all levels and archive them, together with several of SWPC's products, in a SWFO Science Center. Networks, data processing and archive will support all flight projects.

4.2 Management Approach and Governance Structure

The SWFO Program is managed as an integrated NOAA-NASA program. NOAA has final decision authority and is responsible for overall program commitment. The NESDIS Assistant Administrator is accountable for the successful implementation of the SWFO Program. This chain of accountability runs through the OPPA Director to the SWFO Program Manager. The NOAA SWFO Program Manager (PM), in coordination with the NASA SWFO Deputy Program

Manager (DPM), are charged with ensuring that all necessary activities are successfully carried out. NASA responsibilities include the SWFO-L1 Project leadership and procurements, mission and project systems engineering, safety and mission assurance, guidance and adherence to NASA policies and procedures, launch accommodation, interfaces to ground, and providing the rideshare launch with IMAP. NASA is NOAA's acquisition agent for the SWFO-L1 observatory. NOAA is responsible for Program Level 1 and Level 2 requirements, Ground Segment Project leadership and procurements, operations, real time data product generation and distribution to operational users, retrospective user product generation and distribution, and archiving. NOAA is direct acquisition authority for the SWFO ground segment.

The Joint Agency NOAA-NASA Program Management Council (APMC) has governing responsibility for the SWFO Program and its projects per the NOAA-NASA Satellite Programs and Projects Management Control Plan (MCP).

The SWFO Program will establish a governance structure that fosters active collaboration with stakeholders who include: NASA, the Naval Research Labortory, GOES-R, international partners (currently ESA), other branches of NOAA such as NWS' SWPC, and other NESDIS offices, such as the Interagency and International Affairs Division (IIAD), the Office of Satellite and Product Operations (OSPO), the Office of Satellite Ground Services (OSGS), and the NCEI to implement these space weather activities.

5 OWNERSHIP AND OVERSIGHT REQUIREMENTS

This L1RD describes validated observational needs (requirements) for the SWFO Program. The SWFO Program should design and operate the system to meet these requirements, but the use of mandatory language in the L1RD to describe such requirements does not limit NOAA's discretion in carrying out the SWFO Program. In this and later sections, the use of the verb “shall” and the notation [REQ] are used to identify requirements and distinguish them from the rest of the narrative. Requirement rationales are listed in Appendix A.

5.1 Program Management

SWFO_1: [REQ] The SWFO Program shall be implemented in accordance with the SWFO Program Plan.

> ***Rationale:*** The plan is designed to provide guidance in the overall development of the SWFO Program.

5.2 Requirement Review and Approval

SWFO_2: [REQ] The SWFO Program requirements documents shall be reviewed and approved as summarized in Table 4.

> ***Rationale:*** Reviewing and approval of documents of different scopes in the Program require different authorities within NOAA.

Table 4 SWFO requirements document review and approval.

Requirements Level	Document	Custodian and Controller	Reviewing Body	Approving Body
NOSA	COURL (including OURD)	NOSC	NOSC	NEC
Level I	SWFO Program Level 1 Requirements Document	SWFO Program	NOSC, NOAA-NASA APMC, NESDIS AA/DAAS	NOAA DUS
Level II	SWFO GOES-U Requirements Document	SWFO Program Systems Engineer	SWFO Program, NEAC, GORWG, GOES-R Program	SWFO PM, GOES-R PM
Level II	SWFO-L1 Project Requirements Document	SWFO Program Systems Engineer	SWFO Program, NEAC, GORWG, GOES-R Program	SWFO PM, GOES-R PM
Level II	SWFO Ground Project Requirements Document	SWFO Program Systems Engineer	SWFO Program, NEAC, GORWG	SWFO PM

The requirements change process is described in the SWFO Configuration Management Plan.

6 SYSTEM REQUIREMENTS

6.1 Space Segment

SWFO_3: [REQ] The SWFO Program shall include a spacecraft operating at the Sun-Earth Lagrange Point 1.

> ***Rationale:*** Placing a spacecraft upstream of the Earth at L1 allows it to a) measure the solar wind before it reaches Earth with enough lead time to provide a warning and b) make coronal observations uninterrupted by eclipses.
>
> Solar wind *in situ* observations of the magnetic field, density, velocity, and temperature are the fundamental inputs needed to estimate CME Earth impact intensity. At the Sun – Earth Lagrange point L1 location, the fastest expected solar wind can be measured 15 minutes prior to reaching Earth, ensuring that the lead-time available for issuing geomagnetic storm warnings is sufficient for customers to respond with meaningful actions. The suprathermal ion observations are used in estimating the storm impact intensity and arrival time.

SWFO_52: [REQ] The SWFO Program shall integrate a CCOR on the spacecraft for operation at Lagrange Point 1.

> ***Rationale:*** A CCOR unit will be placed on SWFO-L1 to make coronal observations.

SWFO_53: [REQ] The SWFO Program shall accommodate an ESA-contributed X-ray flux monitor instrument on the spacecraft for operation at Lagrange Point 1.

> ***Rationale:*** The instrument will measure the solar X-ray flux which is amplified during solar flares. It will be provided by ESA as part of a space weather collaboration. The instrument performance will not be included in mission success criteria. Delivery of the instrument will not be a criterion for spacecraft launch readiness.

SWFO_4: [REQ] The SWFO Program shall integrate a CCOR on the GOES-U satellite.

> ***Rationale:*** A CCOR unit will be placed on NOAA's GOES-U satellite to complement the CCOR on SWFO-L1. Operating both instruments provides resiliency. The GOES-U instrument will be in the Earth's shadow periodically.

SWFO_5: [REQ] The SWFO Program shall provide CME Imagery prior to 2026 to support continuity of operations.

> ***Rationale:*** SWFO is a high-priority program to ensure CME imagery and solar wind weather data continuity to SWPC. The timeframe is set by the projected lifetime of legacy missions SOHO, ACE, and DSCOVR. Current estimates for SOHO end-of-life due to power degradation are for 2026.
>
> One of the SWFO-L1 requirements that flows from this requirement is to be ready for launch as a rideshare on IMAP.

6.2 Ground Segment

SWFO_6: [REQ] The SWFO Program shall use the GOES-R ground system for telemetry, tracking, and control (TT&C) and for transmission of coronal imaging produced by CCOR on the GOES-U satellite.

> ***Rationale:*** The GOES-R ground system will support the GOES-U TT&C via its physical facilities (the antenna and communications network) and operational functions. The GOES-R ground system will provide CCOR L0 data to SWPC and NCEI.

SWFO_7: [REQ] The SWFO Program shall use existing infrastructure to the extent possible for the SWFO-L1 spacecraft operational services, product generation, and product distribution.

> ***Rationale:*** The SWFO-L1 project will utilize the existing infrastructure as much as possible.

SWFO_8: [REQ] The SWFO Program shall utilize backup facilities for TT&C functionality in secondary locations.

> ***Rationale:*** This requirement is needed to meet availability and Critical Space Weather Day requirements.

SWFO_9: [REQ] The SWFO Program TT&C backup facilities shall be located such that they will not be susceptible to the same credible threat as the primary ground operations locations.

> ***Rationale:*** This is consistent with the role of backup facilities in critical operations.

SWFO_10: [REQ] The SWFO Program shall be capable of using domestic partner organization resources for TT&C of the SWFO-L1 spacecraft.

> ***Rationale:*** The SWFO-L1 Program will utilize networks of other agencies (notably NASA's DSN and NEN) for tracking and as needed.

SWFO_11: [REQ] The SWFO Program shall be capable of using contributed international partner organization resources for acquisition of data from the SWFO-L1 spacecraft.

> ***Rationale:*** The SWFO-L1 Program will utilize networks of international partners (such as the Real-Time Solar Wind Network, or RTSWnet) as needed.

SWFO_12: [REQ] The SWFO Program shall implement communication interfaces to relay observational data to SWPC in real time.

> ***Rationale:*** Whether from geostationary orbit or from L1, the SWFO Program will provide data to SWPC from instruments on both the GOES-U and the SWFO-L1 spacecraft.

SWFO_13: [REQ] The SWFO Program shall implement NESDIS-specified DHS and NIST IT security directives in compliance with NWS and NESDIS IT security policies.

> ***Rationale:*** The SWFO Program elements will comply with the IT security policies of the respective line offices within which they reside as specified in security requirements of lower-level requirements documents.

SWFO_14: [REQ] The SWFO Program shall meet the Continuity of Operations requirements in compliance with the Federal Continuity Directives FCD1 and FCD2.

> ***Rationale:*** FCD1 and FCD2 are specified in accordance with requirements from the NESDIS-PD-1070.1 standard (NESDIS Continuity of Operations).

SWFO_49: [REQ] The SWFO Program shall provide a ground segment to configure, monitor, and control SWFO-L1 operations.

Rationale: The GS is needed to monitor and control the SWFO-L1 Observatory.

6.3 Observational KPPs

The SWFO Program space weather data products are listed in Table 5: and detailed in Section 6. The KPPs are defined as Coronal White Light Intensity, Thermal Plasma Ion Velocity, and Vector Magnetic Field.

Table 5 Space weather data products.

Space Weather Data Product	KPP
Coronal White Light Intensity	Y
Thermal Plasma Ion Velocity	Y
Thermal Plasma Ion Density	N
Thermal Plasma Ion Temperature	N
Vector Magnetic Field	Y
Suprathermal Ion Differential Flux	N
Dynamic Pressure	N

6.4 Product Requirements

6.4.1 Data Latency

SWFO_15: [REQ] The SWFO Program shall make Coronal White Light Intensity data available to SWPC forecasters within 30 minutes after image acquisition is complete.

Rationale: Data latency is defined as the time from image acquisition completion by CCOR to SWPC's generation of corresponding Level 3 products. The latency value is set by the SWPC forecasters' time needed for analyzing the images and by the cadence of the center's real-time operational models.

SWFO_16: [REQ] The SWFO Program shall make Solar Wind data available to SWPC forecasters within 5 minutes after data acquisition is complete.

Rationale: Data latency is defined as the time from data acquisition completion at the spacecraft to SWPC's generation of corresponding Level 3 data products. The latency value is set by the SWPC forecasters' time needed for analyzing the data and by the cadence of the center's real-time operational models.

6.4.2 Product Generation

SWFO_17: [REQ] The SWFO Program shall be capable of meeting the requirements for the data products listed in Table 3 over the life of the mission.

Rationale: The SWFO Program will generate products to support NOAA space weather priorities.

SWFO_18: [REQ] The SWFO Program shall utilize NWS SWPC to generate all Level 1a and higher data products intended for operational users.

> ***Rationale:*** SWPC has the responsibility within NOAA and the experience in generating Level 1 and higher products for operational users on a 24/7 basis. As an example it produces the operational Solar Wind products for DSCOVR and ACE. Instrument developers will provide algorithms to SWPC for generating low-level products.

SWFO_19: [REQ] The SWFO Program shall utilize backup facilities for KPP real-time processing functionality in secondary locations.

> ***Rationale:*** The backup facility is needed to meet availability and Critical Space Weather Day requirements. The facility is SWPC's Alternate Processing Site (APS).

SWFO_20: [REQ] The SWFO Program shall utilize NESDIS NCEI to generate all Level 1a and higher data products intended for retrospective users.

> ***Rationale:*** NCEI has the responsibility within NOAA and the experience in generating Level 1 and higher products for retrospective users. Instrument developers will provide algorithms to NCEI for generating low-level products.

6.4.3 Product Distribution

SWFO_21: [REQ] The SWFO Program shall utilize NWS SWPC to distribute SWFO space weather data to the operational user community.

> ***Rationale:*** SWPC is the NWS organization with the responsibility of providing this service.

SWFO_22: [REQ] The SWFO Program shall utilize NESDIS NCEI to distribute SWFO space weather data to the retrospective user community within 5 days of reception.

> ***Rationale:*** NCEI is the national public access facility for space weather data products and supporting engineering telemetry. It is also the organization that supports archive and stewardship for such data and telemetry. Data include raw observational data, relevant spacecraft telemetry, calibration data, and data products of several levels.
>
> Archiving of data is not a real-time task, and NCEI is therefore not a 24/7 organization. Three days are allowed to accommodate the typical 3-day holiday weekend. Two additional days are allowed for staff to troubleshoot unexpected issues.
>
> NCEI will develop a SWFO Science Center similar to its GOES-R Science Center and DSCOVR data portal.

6.4.4 Product Stewardship

SWFO_23: [REQ] The SWFO Program shall utilize NESDIS NCEI for archiving and stewardship of all relevant data in the SWFO Science Center within 5 days of reception.

> ***Rationale:*** NCEI is the national public access facility for space weather data products and supporting engineering telemetry. It is also the organization that supports archive and stewardship for such data and telemetry. Data include raw observational data, relevant spacecraft telemetry, calibration data, and data products of several levels. The types and

levels of data products to be provided by SWFO to NCEI and archived there are listed in lower-level requirements and are described in the SWFO Operational Data Management Plan.

Archiving of data is not a real-time task, and NCEI is therefore not a 24/7 organization. Three days are allowed to accommodate the typical 3-day holiday weekend. Two additional days are allowed for staff to troubleshoot unexpected issues.

NCEI will develop a SWFO Science Center similar to its GOES-R Science Center and DSCOVR data portal.

6.5 Data Availability

SWFO_24: [REQ] The SWFO Program shall deliver to SWPC two Coronal White Light images, acquired no less than 5 minutes apart, for each observable CME traveling towards Earth.

Rationale: The CME speed along the Sun-Earth line (radial speed) is calculated by differencing two successive images.

The fastest CMEs expected (radial speed: 3400 km/s) will take approximately 1 hour to expand from the inner to the outer boundary of FOV. With an image refresh rate of 15 minutes, this means at most four (4) images in 1 hour and, in practice, possibly three (3) images (if either the first or the last image are missed). If so, it is important to have no more than one image missing in the speed calculation for a fast CME, hence the requirement for two or more images. In other words, the largest allowable difference between successive images would be 30 minutes rather than the refresh rate-based 15 minutes.

Note that the requirement specifies Earth-directed CMEs, not all CMEs observed. In practice it is generally not possible for image analysts at SWPC to immediately distinguish between Earth-directed and anti-Earth-directed CMEs; however, the distinction becomes clear after sufficient two or more observations are made. This allows determining the CME's radial movement and/or locating the leading edge of the shock and/or ejecta.

SWFO_25: [REQ] During NWS-declared Critical Space Weather Days, the SWFO Program's *in situ* Solar Wind data gaps shall not exceed 5 minutes per day for planned spacecraft events.

Rationale: Definition: Critical Space Weather is typically any of the following disturbances: S4-S5 solar radiation storms, R4-R5 radio blackouts, and G4-G5 geomagnetic storms. Intervals of Critical Space Weather Days can last between 3 and 21 days.

Main rationale: This short-term data availability requirement is applied when instruments may be impacted by Critical Space Weather. A 5-minute data gap allows extreme events to be observed and data provided to SWPC with time for a warning to be issued.

SWPC actions: When SWPC forecasters are alerted through remote sensing observation to the increased probability of an Earth-directed CME, they can declare a Critical Space

Weather Day. Depending on the situation and timeframe, SWPC may issue forecasts for future critical days or alerts/watches/warnings on imminent activity.

Ground Segment actions: On these days, spacecraft operators can take actions to minimize the duration of data gaps. These include cancelling or postponing all scheduled space and ground segment downtime, keeping backup systems as hot backups and also alerting auxiliary backups systems of the situation. They also include being prepared to minimize recovery time from potential spacecraft safing events; however, it is recognized that recovery from safing events may take longer than 5 minutes.

Planned spacecraft events include trajectory correction maneuvers (TCMs), station keeping, momentum management, planned instrument events, and similar activities.

Goal value: 5 minutes.

SWFO_26: [REQ] During nominal operations, the SWFO Program shall deliver operational Coronal White Light Intensity data to SWPC at least 96 percent of the time measured over each and every 30-day period.

Rationale: "Nominal operations" is a qualifier that defines the time when the spacecraft is capable of performing science measurements, maneuvers, calibrations and other planned functions during the operational lifetime of the mission. Nominal operations do not encompass unplanned fault conditions, including safeholds. Launch operations, early mission operations, and spacecraft and instrument commissioning time periods are excluded from this requirement.

The SWFO Program provides critical, operational, time-sensitive observations used by SWPC, the Department of Defense (DOD), and industry where outages can severely impact sophisticated prediction models that rely on high-cadence data.

SWFO_27: [REQ] During nominal operations, the SWFO Program shall deliver operational Solar Wind data to SWPC at least 96 percent of the time measured over each and every 30-day period.

Rationale: "Nominal operations" is a qualifier that defines the time when the spacecraft is capable of performing science measurements, maneuvers, calibrations and other planned functions during the operational lifetime of the mission. Nominal operations do not encompass unplanned fault conditions, including safeholds. Launch operations, early mission operations, and spacecraft and instrument commissioning time periods are excluded from this requirement.

The SWFO Program provides critical, operational, time-sensitive observations used by SWPC, the DOD, and industry where outages can severely impact sophisticated prediction models that rely on high-cadence data. For example, during a geomagnetic storm, it can take SWPC's Geospace model several hours to recover from a data gap, resulting in no or degraded forecasts for a significant portion of the storm.

SWFO_28: [REQ] The SWFO Program shall meet the mission requirements under any solar radiation storm conditions through a level of S4.

Rationale: In order to fulfill its mission of providing the observational data needed for the SWPC Forecast Office to issue solar storm warnings and watches, the SWFO

Program must be able to make observations during the most intense reasonably expected solar radiation storms and solar flares. Severe space weather of all types can occur at the same time. Previous non-operational missions such as ACE and SOHO have been significantly degraded and unable to make observations at times during the most intense solar storms and flares.

The solar radiation storm intensity scale goes from S1 to S5 (https://www.swpc.noaa.gov/noaa-scales-explanation). A solar storm of intensity S5 has never been observed, but is believed to be physically possible. A solar storm intensity of S4 includes storms where the 10 MeV integral proton fluxes reach at least $1x10^4$ proton flux units but do not reach $1x10^5$ proton flux units.

SWFO_29: [REQ] The SWFO Program shall meet the mission requirements under any solar flare conditions through a level of X50.

Rationale: In order to fulfill its mission of providing the observational data needed for the SWPC Forecast Office to issue solar storm warnings and watches, the SWFO Program must be able to make observations during the most intense reasonably expected solar radiation storms and solar flares. Severe space weather of all types can occur at the same time. Previous non-operational missions such as ACE and SOHO have been significantly degraded and unable to make observations at times during the most intense solar storms and flares.

The radio blackout intensity scale goes from M1 to X50 (https://www.swpc.noaa.gov/noaa-scales-explanation). A solar X-ray burst of intensity X50 includes bursts reaching $5x10^{-3}$ W/m^2 in the 1-8 Angstrom bandpass. Solar X-ray bursts of intensity X50 are believed to have been observed.

6.6 Initial and Full Operational Capability

SWFO_30: [REQ] The SWFO-L1 mission IOC shall be completed within 6 months from spacecraft launch.

Rationale: The IOC duration is based on experience with DSCOVR and other spacecraft.

SWFO_31: [REQ] The SWFO GOES-U IOC shall be completed within 6 months from the GOES-U satellite launch.

Rationale: The IOC duration is based on GOES-R and -S experience.

The SWFO Program will realize Full Operational Capability (FOC) upon the success of IOC for both SWFO-L1 and SWFO GOES-U, and the generation of the full product set and its distribution to users.

6.7 Operational Lifetime

SWFO_32: [REQ] The SWFO Program elements shall have an operational lifetime of 5 years.

Rationale: The duration of the Program is based on agency programmatic priorities, spacecraft capabilities, legacy mission performance, and mission cost control. For flight elements, duration is measured from launch. Operational lifetime is defined as the time constrained by limited-life items.

The 5-year lifetime includes the IOC phase.

SWFO_33: [REQ] The SWFO Program elements shall have 10 years of consumables.
Rationale: NESDIS plans to ensure a long-term data availability for NWS's forecasting needs. It is anticipated that another solar/heliospheric monitoring program will follow SWFO by the end of the 10 years. The 5-year extension for GOES-U refers to project funding while for SWFO-L1, it refers to project funding and spacecraft fuel resources.

6.8 Spacecraft and Instrument Requirements

SWFO_34: [REQ] SWFO-L1 shall meet the criteria of a NASA Class C mission per NPR 8705.4.
Rationale: NASA NPR 8705.4 mission Class C best fits the priority, national significance, complexity, cost, and launch constraints of the SWFO-L1 mission.

SWFO_35: [REQ] SWFO-L1 shall be delivered in time for a launch as a rideshare with NASA's IMAP mission.
Rationale: SWFO is a high-priority program to ensure space weather data continuity to SWPC. The timeframe is set by the launch of NASA's IMAP and the projected lifetime of legacy missions SOHO, DSCOVR, and ACE. SOHO was launched on December 2, 1995 and its slowly degrading power system is not likely to last beyond the end of 2025. For *in situ* solar wind observation, SWPC relies on the DSCOVR spacecraft that is past its mission design life and has already experienced multiple temporary subsystem failures causing interruption of these critical data. When DSCOVR is unavailable, SWPC relies on data from the much older ACE mission launched on August 25, 1997. ACE is projected to run out of fuel in 2026. Imminent failure of these critical observatories drive the need for NOAA to meet the IMAP launch commitment date.

SWFO_36: [REQ] SWFO-L1 and the SWFO Ground Segment shall be compatible with each other for all data link functions.
Rationale: The space and ground segments will have compatible radio communications parameters including frequencies and effective isotropic radiated power (EIRP).

SWFO_54: [REQ] CCOR on GOES-U shall meet the criteria of a NASA Class C tailored payload per NPR 8705.4.
Rationale: NASA NPR 8705.4 payload Class C best fits the priority and national significance of the SWFO Program and the complexity, cost, and launch constraints of the GOES-U satellite.

7 PRODUCT PERFORMANCE REQUIREMENTS

The SWFO Program will operate the SWFO-L1 spacecraft for coronal imaging and solar wind measurements and a CCOR on board the GOES-U spacecraft for coronal imaging capability.

7.1 Coronal Imaging

SWFO_38: [REQ] The SWFO Program shall produce a Coronal White Light Intensity observational product in accordance with Table 6.

Rationale: The Coronal White Light Intensity product is an image of the corona in white light. It is needed as numerical input to advanced heliospheric models and as imagery for forecasters to analyze. The product properties (image size, resolution, accuracy, and others) are determined by the COURL and are described in the Level 2 Requirement Documents for SWFO GOES-U and SWFO-L1.

In the current (November 2017) COURL, the FOV requirement is 3.0-17.0 R_{sun} with a horizontal (spatial) resolution of 50 arcsec at 10% accuracy. An earlier version of the document specified a narrower range, 3.7-17.0 and NRL follows that specification for the CCOR-1 unit on GOES-U. The SWFO-L1 CCOR has a larger FOV of 3.0-22.0 R_{Sun} compensated by a lower spatial resolution of <70 arcsec at the same accuracy of 10%. The resolution and accuracy are defined at one-half of the FOV radius. The resolution reduction from 50 to less than 70 arcsec is considered a modest trade to meeting the FOV objective as this results in a spatial resolution comparable to the SOHO Large Angle and Spectrometric Coronagraph (LASCO) C3 used in operations today.

For both instruments, the specifications ensure at least three images for each CME observed, giving significant margin for determining the CME properties necessary for prediction.

Rather than using spatial resolution, which can be difficult to measure, one considers the angle of sky subtended by a single pixel: that angle in the original design was 19 arcsec and in the revised design 23 arcsec, both of which are below LASCO C3's 56 arcsec.

Note that in addition to the conventional specifications for the coronagraph FOV, several factors (including pointing accuracy, thermal distortion, and vibrations due to launch) have an impact on the instrument performance.

Table 6 Coronal White Light Intensity requirement.

Coronal White Light Intensity	Threshold
Image Center and Orientation	Sun-centered, Solar North-aligned
Field of View (FOV)	3-22 R_{Sun} for SWFO-L1 3.7-17 R_{Sun} for SWFO GOES-U
Minimum Intensity	$1x10^{-11}$ B_{Sun}
Maximum Intensity	$1x10^{-8}$ B_{Sun}
Spatial Resolution	<70 arcsec for SWFO-L1 <50 arcsec for SWFO GOES-U
Maximum Acquisition Time	30 sec
Measurement Accuracy	± 10%
Measurement Location	Lagrange Point 1 for SWFO-L1 GEO for GOES-U
Refresh Rate	15 min

7.2 Solar Wind

7.2.1 Thermal Plasma Variables

SWFO_44: [REQ] The SWFO Program shall produce a Thermal Plasma Ion Velocity observational product in accordance with Table 7.

Rationale: **General statement:** Instrument accuracy will be verified in the lab using particle beams and field sources; and validated under realistic conditions during flight. Verification and validation conditions, approaches, and resulting datasets are generally very different.

These variables are observational requirement documented in the COURL and used by the SWPC Forecast Office. For the density, the goal value for the range is 0.1-150 particles/cm^3 while for the accuracy it is 10%. For the velocity, the goal and threshold values for range and accuracy are identical. For the temperature, the goal value for the range is 40,000-2,000,000 K while for the accuracy it is 10%. The refresh rate satisfies the time resolution needs of real-time operational models.

Table 7 Thermal Plasma Ion Velocity Requirement.

Thermal Plasma Ion Velocity	Threshold
Minimum Velocity	200 km/sec
Maximum Velocity	2500 km/sec
Measurement Accuracy	± 10%
Measurement Location	Lagrange Point 1
Refresh Rate	60 sec

SWFO_45: [REQ] The SWFO Program shall produce a Thermal Plasma Ion Density observational product in accordance with Table 8.

Rationale: **General statement:** Instrument accuracy will be verified in the lab using particle beams and field sources; and validated under realistic conditions during flight. Verification and validation conditions, approaches, and resulting datasets are generally very different.

These variables are observational requirement documented in the COURL and used by the SWPC Forecast Office. For the density, the goal value for the range is 0.1-150 particles/cm^3 while for the accuracy it is 10%. For the velocity, the goal and threshold values for range and accuracy are identical. For the temperature, the goal value for the range is 40,000-2,000,000 K while for the accuracy it is 10%. The refresh rate satisfies the time resolution needs of real-time operational models.

Table 8 Thermal Plasma Ion Density requirement.

Thermal Plasma Ion Density	**Threshold**
Minimum Density	0.1 particles/cm^3
Maximum Density	150 particles/cm^3
Measurement Accuracy	±10%
Measurement Location	Lagrange Point 1
Refresh Rate	60 Sec

SWFO_46: [REQ] The SWFO Program shall produce a Thermal Plasma Ion Temperature observational product in accordance with Table 9.

Rationale: **General statement:** Instrument accuracy will be verified in the lab using particle beams and field sources; and validated under realistic conditions during flight. Verification and validation conditions, approaches, and resulting datasets are generally very different.

These variables are observational requirement documented in the COURL and used by the SWPC Forecast Office. For the density, the goal value for the range is 0.1-150 particles/cm^3 while for the accuracy it is 10%. For the velocity, the goal and threshold values for range and accuracy are identical. For the temperature, the goal value for the range is 40,000-2,000,000 K while for the accuracy it is 10%. The refresh rate satisfies the time resolution needs of real-time operational models.

Table 9 Thermal Plasma Ion Temperature requirement.

Thermal Plasma Ion Temperature	**Threshold**
Minimum Temperature	40,000 K
Maximum Temperature	2,000,000 K
Measurement Accuracy	±10%
Measurement Location	Lagrange Point 1
Refresh Rate	60 Sec

7.2.2 Vector Magnetic Field

SWFO_47: [REQ] The SWFO Program shall produce a Vector Magnetic Field observational product in accordance with Table 10.

Rationale: **General statement:** Instrument accuracy will be verified in the lab using particle beams and field sources; and validated under realistic conditions during flight. Verification and validation conditions, approaches, and resulting datasets are generally very different.

The magnetic field is an observational requirement documented in the COURL and used by the SWPC Forecast Office. The refresh rate satisfies the time resolution needs of real-time operational models.

Table 10 Vector magnetic field requirement.

Vector Magnetic Field	Threshold
Range (each component: x, y, z)	±200 nT
Measurement Accuracy (each component: x, y, z)	±1 nT, 0–25 nT ±4%, > 25 nT
Measurement Location	Lagrange Point 1
Refresh Rate	60 sec

7.2.3 Suprathermal Ion Differential Flux

SWFO_48: [REQ] The SWFO Program shall produce a Suprathermal Ion Differential Flux observational product in accordance with Table 12.

Rationale: **General statement:** Instrument accuracy will be verified in the lab using particle beams and field sources; and validated under realistic conditions during flight. Verification and validation conditions, approaches, and resulting datasets are generally very different.

The ion flux is part of the observational requirements used by the SWPC Forecast Office.

The flux range is bound between 2.48×10^2 $(E/keV)^{-1.6}$ and 1.01×10^7 $(E/keV)^{-1.6}$ particles per cm^2/s/sr/keV where E is the ion energy. It is consistent with a maximum flux of 10,000 particles/cm^2/s/sr/keV based on an ACE/EPAM measurement of 7,979 particles/cm^2/s/sr/keV in the 47-65 keV bandpass [Smith et al. (2004), JGR 109, A01110, doi:10.1029/2003JA010044].

Table 11 below illustrates the linear interpolation for the flux accuracy at 2 MeV mentioned in the requirement for several sample flux levels. The flux accuracy should be better than the given percentage for the quoted flux levels.

Flux accuracy as a function of flux level for E=2 MeV.

Table 11 Flux accuracy as a function of flux level for E=2 MeV.

Ion Flux j_i(E=2 MeV) (#/cm²/s/sr/keV)	Flux Accuracy $\Delta j_i/j_i$ (%)
6.34 x 10^{-6}	100.0
1.27 x 10^{-5}	80.2
2.54 x 10^{-5}	64.3
5.07 x 10^{-5}	51.6
1.01 x 10^{-4}	41.4
2.03 x 10^{-4}	33.2
4.06 x 10^{-4}	26.6
8.12 x 10^{-4}	21.4
1.00 x 10^{-3}	20

Table 12 Suprathermal Ion Differential Flux requirement where E is the ion energy.

Suprathermal Ion Differential Flux	Threshold
Minimum Energy	50 keV
Maximum Energy	2,000 keV
Minimum Flux, $j_{i,min}$	2.48×10^2 * E(KeV)$^{-1.6}$
Maximum Flux, $j_{i,max}$	1.01×10^7 * E(KeV)$^{-1.6}$
Flux Accuracy	For energy E=2 MeV: a) ±100% at $j_{i,min}$ and ±20% at $j_{i,mid}$=0.001 #/cm²/s/sr/keV with linearly interpolated accuracies in the intermediate range: $j_{i,min} < j_i < j_{i,mid}$ b) ±20% for fluxes above $j_{i,mid}$
Measurement Location	Lagrange Point 1
Refresh Rate	300 sec

7.2.4 Solar Wind Dynamic Pressure

The dynamic pressure of the solar wind can be readily obtained from density and velocity and is a lower-priority COURL requirement. Therefore, the SWFO Program will produce a Solar Wind Dynamic Pressure observational product in accordance with Table 13.

Table 13 Solar Wind Dynamic Pressure parameters.

Solar Wind Dynamic Pressure	Threshold
Minimum Pressure	1 nPa
Maximum Pressure	100 nPa
Measurement Accuracy	±25%
Measurement Location	Lagrange Point 1
Refresh Rate	60 sec

8 PROGRAM SUCCESS CRITERIA

Ultimately, the success of the SWFO Program is defined in terms of continuity of space weather data (solar wind measurements and coronal imagery) to be made available to NWS SWPC. The data should be provided accurately and with sufficient lead time to meet program requirements. The instruments to be placed on SWFO-L1 and on GOES-U are intended to update similar instruments on SOHO, ACE, and DSCOVR and the replacement must occur with no or very limited interruptions in observational capability.

Minimum success of the SWFO Program is defined as the successful generation and availability to users of all KPPs.

Full success of the SWFO Program is defined as the successful generation and availability to users of all products in Table 4.

Appendix A. Acronyms

AA	Assistant Administrator
ACE	Advanced Composition Explorer
APMC	Agency Program Management Council
APS	Alternate Processing Site
ARB	Acquisition Review Board
BSun	Solar Brightness
CBU	Consolidated BackUp (facility)
CCOR	Compact Coronagraph
CDR	Critical Design Review
cm	Centimeter
CME	Coronal Mass Ejection
COURL	Consolidated Observational User Requirement List
DAAS	Deputy Assistant Administrator for Systems
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DSCOVR	Deep Space Climate Observatory
DUS	Deputy Undersecretary
ECI	Earth Centered Inertial (coordinate system)
EELV	Evolved Expendable Launch Vehicle
EIRP	Effective Isotropic Radiated Power
ESA	European Space Agency
ESPA	EELV Secondary Payload Adapter
FCD	Federal Continuity Directive
FEMA	Federal Emergency Management Agency
FOC	Full Operational Capability

FOV	Field of View
GFE	Government-Furnished Equipment
GOES	Geostationary Operational Environmental Satellite
GORWG	Geostationary Earth-Orbiting Satellite Operational Requirements Working Group
GS	Ground Segment
GSFC	Goddard Space Flight Center
HF	High Frequency
I&T	Integration and Testing
IT	Information Technology
IAA	Interagency Agreement
IIAD	Interagency and International Affairs Division
IMAP	Interstellar Mapping and Acceleration Probe
IOC	Initial Operational Capability
JASD	Joint Agency Satellite Division
KPP	Key Performance Parameters
L1	Lagrange Point 1
L1RD	Level 1 Requirements Document
LASCO	Large Angle and Spectrometric Coronagraph
MAG	Magnetometer
MCP	Management Control Plan
MDM	Milestone Decision Memorandum
MOC	Mission Operations Center
MRB	Milestone Review Board
MS-2	Milestone 2
NAO	NOAA Administrative Order
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information

NEAC	NESDIS Enterprise Architecture Committee
NEC	NOAA Executive Council
NESDIS	National Environmental Satellite, Data, and Information Service
NGE	NESDIS Ground Enterprise
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOSA	NOAA Observing System Architecture
NOSC	NOAA Observing Systems Council
NPR	NOAA Procedural Requirement
NRL	Naval Research Laboratory
NSOSA	NOAA Satellite Observing System Architecture
NSTC	National Science and Technology Council
NWS	National Weather Service
OPPA	Office of Projects, Planning and Analysis
OSGS	Office of Satellite Ground Services
OSPO	Office of Satellite and Product Operations
OURD	Observational User Requirements Document
PDR	Preliminary Design Review
PM	Program Manager
REQ	Requirement
RO	Radio Occultation
RSun	Solar Radius
SEP	Solar Energetic Particle
SMEX	Small Explorer
SOHO	Solar and Heliospheric Observatory
SPRWG	Space Platform Requirements Working Group
STIS	Supra Thermal Ion Sensor

SWFO	Space Weather Follow On (program)
SWFO-L1	Space Weather Follow On – Lagrange 1 (observatory)
SWiPS	Solar Wind Plasma Sensor
SWIS	Solar Wind Instrument Suite
SWPC	Space Weather Prediction Center
TA	Technical Architecture
TCM	Trajectory Correction Maneuver
TBD	To be Determined
TT&C	Telemetry, Tracking, and Command
WSA-Enlil	Wang-Sheeley-Arge Enlil model
XFM	X-Ray Flux Monitor