Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Solar coronagraph (SCOR)

Performance and Operational Requirements Document (PORD)

Baseline Version

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Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

1 Scope

1.1 Identification

This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Solar Coronagraph (SCOR).

1.2 Mission Review

The SCOR is part of the SIS suite of instruments, but is currently designated a pre-planned product improvement instrument. This SCOR **shall** be mounted to a SCOR mounting panel, which will interface with the spacecraft.

The government reserves the right to issue a separate procurement for the SCOR implementation phase.

The primary function of a solar coronagraph is early detection of coronal mass ejections (CMEs). The instrument will provide white light imagery of the inner corona at a high cadence, with the aim of determining the speed, direction, spatial extent and mass (or relative brightness) of detected CMEs. Detection of CME's and determination of the specified properties aid significantly in the forecasting of geomagnetic storms. SCOR will also assist in providing situational awareness during energetic proton storms.

The SCOR instrument provides data to the Ground System, designated as SCOR-GS in this document, via the spacecraft communication system. The SCOR-GS takes the SCOR data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates products for the NOAA users. This requirements document only applies to the SCOR instrument, but the SCOR contractor must have an understanding of the total system to assure that the SCOR-GS will be able to provide the required data.

The requirements in this SCOR PORD pertain to the SCOR 'system', which may include optics, detectors, signal processing electronics and software. The SCOR contractor is not responsible for SCOR-GS, but certain specifications may require some level of ground processing after collection but before data distribution, i.e. decompression, re-sampling, navigation and calibration.

1.3 Document Overview

This document contains all performance requirements for the SCOR and the Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the SCOR Unique Instrument Interface Document (UIID) define all instrument to spacecraft interfaces for the SCOR.

1.4 Terminology

The term "(TBD)" which means "to be determined", applied to a missing requirement means that the instrument contractor determines the missing requirement.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriateness and subject to revision. The contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.5 Definitions

Throughout this document, the following definitions apply:

Accuracy: Refers to the error in a measurement, that is the difference between the measured and true value. It includes both systematic and random errors. Systematic errors must be estimated from an analysis of the experimental conditions and techniques. Random errors can be determined, and reduced, through repeated measurements under identical conditions and a Standard Deviation calculated. The magnitude of a random error **shall** be taken as three standard deviations (3σ).

All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GIRD, SCOR PORD or the SCOR Unique Instrument Interface Requirements Document (SCOR UIID).

B/B_{SUN}: Ratio of the image brightness to the mean brightness of the solar disk. B_{sun} may be calculated using Allen's Astrophysical Quantities, 4^{th} edition, A. Cox, Ed., Table 14.13, paragraph 14.6, p. 353.

Cadence: The time interval between the start of successive data collection sequences.

Data Latency: The time interval between the end of a data collection sequence and the time that the data is available at the spacecraft interface.

Detector sample or element: Refers to the output of a physical detector after the Analog-to-Digital (A/D) converter and Time Delay and Integration (TDI) processing, if applicable.

Eclipse: Defined as when the solar disk is completely or partially occulted by the Earth or Moon as viewed from the spacecraft.

Flux Resolution: Minimum difference in flux which can be measured; usually determined by the Analog-to-Digital Converter.

Full Disk: Defined as 42 arc-min diameter - 1.3 times the visible solar diameter.

Fully Functional Configuration: Being able to collect the full complement of science data; determine instrument response changes; acquisition of sensor health and status data; generation of sensor, calibration, monitoring, health and status data streams; and reception and execution of command and control data.

Goal: A requirement that is desirable to achieve as closely as possible.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle.

Measurement Resolution: Resolution of the A/D converter.

Pixel: Applies to calibrated and navigated data samples (after resampling during the ground processing if required).

Precision: Refers to the standard deviation (1σ) of a statistically meaningful number of samples of a measurement.

Resolution: Ability to distinguish two adjacent features in the spectral, spatial or temporal domain.

Scanline: Refers to any line of pixels that extends in an East-West direction across the Sun or space in the format of GOES SCOR data.

Station Keeping: On-orbit spacecraft maneuver that corrects for orbital drifts.

Threshold: A requirement which must be met.

Transfer Orbit: The sequence of events that transpires to establish the GOES-R series satellite on-station after the GOES-R series satellite has separated from the launch vehicle.

Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronics unit and sensor unit.

Yaw Flip: An on-orbit maneuver that rotates the spacecraft 180º about the spacecraft z axis (yaw). The net effect reverses the signs of the roll and pitch axes while maintaining yaw pointing at nadir.

1.6 Requirement Applicability

All requirements apply over the entire life of the SCOR. All requirements in this SCOR PORD apply to data after all ground processing except as indicated.

1.7 Requirement Weighting Factors

The requirements stated in this SIS PORD are not of equal importance or weight. The following paragraphs define the weighting factors incorporated in this document.

- Shall designates the most important weighting level; that is, mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the NASA contracting officer.

- Will designates a lower weighting level. These will requirements designate the intent of the Government and are often stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, noncompliance with the will requirements does not require approval of the NASA contracting officer and does not require documented technical substantiation.

- May designates the lowest weighting level, possibility, or discretion of the Government or contractor.

2 Applicable Documents

Various parts of this requirements document refer to some of these documents.

CCSDS Recommendation for Space Data System Standard, Lossless Data Compression, CCSDS 121.0-B-1, May 1997.

Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996.

General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988.

Space Mechanisms Handbook, Document Number NASA-TP-1999-206988.

General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components, Document Number GSFC GEVS-SE, June 1, 1996.

Eastern and Western Range Policies and Procedures, Document Number EWR-127-1, October 23, 2000.

Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, September 4, 1992.

2.1 Reference Documents

Allen's Astrophysical Quantities, 4th edition, A. Cos, Ed., Table 14.13, paragraph 14.6, p. 353.

3 Sensor Requirements

3.1 Sensor Definition

3.1.1 SCOR Modes

The SCOR **shall** execute commands to individually enable and disable each autonomous function.

The SCOR **shall** initiate all commanded mode transitions within 10 seconds after receipt of command.

The SCOR **shall** make limits and triggers of autonomous functions changeable by command.

The SCOR **shall** transition from its current mode to any other mode without causing permanent damage to itself.

The SCOR **shall** indicate the mode of the instrument in housekeeping telemetry.

The SCOR **shall** provide command and housekeeping telemetry functions in all powered modes.

3.1.1.1 Safe Mode

The SCOR **shall** implement a Safe Mode.

The SCOR **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.

The SCOR **shall** enter Safe Mode upon detection of internal faults that are capable of causing permanent damage to the instrument.

Transitions to Safe Mode, whether commanded or autonomous, **shall** require no more than 1 second to initiate.

Transition from Safe Mode to Normal Operational Mode **shall** not exceed 10 minutes.

3.1.1.2 Normal Operational Mode

The SCOR **shall** implement a Normal Operational Mode. In Normal Operational Mode, the instrument **shall** be in a fully functional configuration.

3.1.1.3 Instrument Diagnostic Mode

The SCOR Instrument **shall** implement an Instrument Diagnostic Mode. In Instrument Diagnostic Mode the instrument **shall** be in a fully functional configuration.
In Instrument Diagnostic Mode, the instrument **shall**, as a minimum, have the following capabilities:

- Send data from all detectors.

- Send the same data both compressed and uncompressed to allow ground evaluation of the impact of compression on the data.

- Send all bits from the A/D converter.

- Perform electronic in-flight calibration.

In all of the above requirements, the data channels to be sent to the spacecraft will be selected to stay within the allocated data rate.
The SCOR **shall** by command send dwell data (increased samples per second of a particular telemetry measurand) while in Diagnostic Mode.

3.1.1.4 On-orbit Storage Mode

In the On-orbit Storage State, the SCOR **shall** provide protection to the entrance aperture from contamination and micrometeorites.

3.1.2 On-Orbit Operations

The SCOR **shall** be able to conduct regular operations, i.e., Normal Operational Mode, while flying aboard a 3-axis stabilized, geostationary spacecraft with orbital limit constraints as stated in the General Interface Requirements Document (GIRD) and/or the SCOR Unique Interface Document (UIID).

The SCOR **shall** be capable of interrupting Normal Operations and Instrument Diagnostics by command and starting the acquisition of a new image observation sequence after a new image sequence upload, within 30 seconds. If it is powered down to conserve spacecraft power it **shall** be capable of returning to full operations within 10 minutes after power is applied.

3.1.2.1 Reserved

3.1.2.2 Reserved

3.1.2.3 Eclipse

The SCOR **shall** be capable of continuous operation through eclipse periods.

From the time immediately following eclipse until four hours (TBR) after eclipse, the SCOR line of sight **shall** be pointed to within ±2 arcminutes, 3σ, of the sun center
From the time immediately following eclipse until four hours (TBR) after eclipse, the SCOR line of sight pointing **shall** not drift during an exposure more than ±13 arcseconds, 3σ.
From the time immediately following eclipse until four hours (TBR) after eclipse, the line of sight pointing knowledge **shall** be ±50 arcseconds, 3σ.
All pointing requirements of section 3.1 of this PORD **shall** be met within four hours (TBR) after eclipse.

3.1.2.4 Operations After Maneuvers

3.1.2.4.1 Yaw Flip

The SCOR **shall** be able to operate in a spacecraft yaw flip mode. The spacecraft contractor is required to provide the capability to perform a biannual flip about the yaw axis, where the yaw axis is defined as the nadir-pointing axis, such that the nominal north face of the spacecraft points south.

The SCOR **shall** meet all requirements within 10 minutes (TBR) after the spacecraft interface has returned to being within specification following a yaw flip.

3.1.2.4.2 Station Keeping

The SCOR **shall** meet all requirements within 10 minutes (TBR) after the spacecraft interface has returned to being within specification following spacecraft station keeping maneuvers.

3.1.2.4.3 Post Storage Activation

The SCOR **shall** meet all requirements within 1 day of instrument turn-on after on-orbit storage activation.

3.2 Solar Coronagraph Requirements

3.2.1 Solar Coronagraph (SCOR) Pointing Requirements

3.2.1.1 Pointing Accuracy

During Normal Operations, the SCOR line of sight **shall** be pointed to within ±1 arc-min, 3σ, of the Sun center.

3.2.1.2 Pointing Stability

The pointing **shall** not drift by more than ±6.25 arc-sec, 3σ, during an exposure.

3.2.1.3 Pointing Knowledge

The line of sight pointing knowledge of the SCOR **shall** be ±25 arc-sec, 3σ, (Goal: ±12.5 arc-sec). The direction of solar north **shall** be known to within ±1° (Goal: ±0.5°).

3.2.2 Field of View

The field of view (FOV) **shall** be an annulus, centered on the Sun. The inner radius of the annulus **shall** be 3.7 R_{sun} (1.0^o) (Goal: $2R_{SUN}$ (0.5^o)). The outer radius of the annulus **shall** be $17R_{sun}$ (4.5^o). The annulus **shall** image at least 355° of the corona in position angle (Goal: 360°).

Each image picture element (pixel) FOV **shall** be square of a size that supports the point response described below.

3.2.3 Point Response

The image spatial resolution **shall** be at least 50 arc-sec as defined by the required Modulation Transfer Function (MTF) in the following table. This includes all effects such as optics, CCD, vignetting, in the presence of jitter, after any ground processing and if resampled, when averaged over all resampling phases of the detector sample grid to pixel grid, and after any lossy compression/decompression. This requirement **shall** be met at the radius which is the average of the inner and outer radii of the FOV.

Spatial Period	Spatial Frequency	System MTF
Arc sec/cycle	Cycles/radian	
400	515	0.9
200	1,031	0.73
133.3	1,547	0.55
100	2,062	0.32

3.2.4 System Spectral Response

The SCOR **shall** collect imagery in a bandpass, the width of which and the central wavelength of which are TBD. The bandpass selected **shall** be 'white-light', that is, lie within 5000-8000Å. The ability to use polarization techniques to separate the K-corona signal from other signals may be provided.

3.2.4.1 Out-of-Band Response

Out-of-band response from IR, visible, UV, EUV and/or X-ray radiation and in-band stray radiation **shall** be minimized as needed to meet the minimum detectable flux and noise requirements.

3.2.4.2 Spatial Response Uniformity

The image **shall** be correctable so that when illuminated by a uniform source the image **shall** not vary by more than 5% across the field of view.

3.2.4.3 Flux Resolution

The measurement precision (or flux resolution) **shall** be at least $1x10^{-12}$ B/B_{sun}/pixel in the outer (unvignetted) part of the FOV. In the inner part of the FOV (vignetted) the flux resolution **shall** be at least $5x10^{-11}$ B/B_{sun}/pixel (Goal: $1x10^{-11}$ B/B_{sun}/pixel).

3.2.4.4 Measurement Range

The measurement range minimum **shall** not exceed $1x10^{-11}$ B/B_{sun}.

The measurement range maximum **shall** be at least $1x10^{-8}$ B/B_{sun} (Goal: $5x10^{-8}$ B/B_{sun}).

The straylight measured at the focal plane **shall** not exceed $5x10^{-12}$ B/B_{sun} (Goal: $1x10^{-12}$ B/B_{sun}).

The requirements in this section apply at the radius that is the average of the inner and outer radii.

3.2.5 Photometric Accuracy and Repeatability

3.2.5.1 Absolute Accuracy

The SCOR data **shall** be calibrated to an absolute accuracy of 25% (Goal: 10%).

3.2.5.3 Defective Pixels

A single exposure of a raw data image **shall** have less than 0.1% defective pixels. No more than one tenth of the defective pixels **shall** be adjacent. A defective pixel is one that is not compliant with any requirement listed in this PORD.

3.2.5.4 In-Flight Calibration

The SCOR **shall** include a ground-commandable internal illumination source that can be used on-orbit, during pre-launch testing, and during spacecraft integration and test, as well as in flight to verify the integrity of the SCOR camera and to provide a constant, relative photometric standard throughout the instrument lifetime. As a goal it should provide information to normalize the gain of the system (flat fielding).

Verification of the pre-flight calibrations **shall** be conducted during a post-launch testing phase.

3.2.6 Temporal Resolution

3.2.6.1 Data Cadence

The SCOR **shall** be capable of achieving a cadence of at least one full-FOV image in less than 15 min.

The SCOR **shall** be capable of meeting the requirements with an exposure time of less than 15 seconds (Goal: <7.5 seconds).

3.2.6.2 Data Latency

Data latency, from the completion of image integration to the transmission of the last image bit to the spacecraft data bus, **shall** be no more than 2 minutes (Goal: <30 s).

3.2.7 Data and Control Capability

3.2.7.1 Partial Image Readout

The SXI **shall** be capable of providing partial images of the FOV via partial detector readout. The center and size of this partial readout region **shall** be configurable. An on-board memory table **shall** be provided such that the location and size of the partial readout can be loaded as a function of time to account for feature motion with solar rotation. The intent is to enable a mode of operation analogous to Imager and Sounder "mesoscale rapid scan" operations whereby a small region is imaged at a higher cadence than normal full disk cadence.

3.2.7.2 Data Compression

The SXI **shall** be able to provide pixel data in at least one lossless and at least one 'lossy' compression mode in addition to being able to provide the full, uncompressed data values.

3.2.7.3 Binning and Summing of Pixels

The SXI **shall** be capable of and post-readout summing of pixels.

3.3 Design Requirements

3.3.1 Reliability

The SCOR **shall** have Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.

The SCOR **shall** have a Mean Mission Duration (MMD) of 8.4 years for a design life of 10 years.

The SCOR **shall** withstand without damage the sudden removal of operational power.

3.3.2 Mechanical Requirements

Each SCOR unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements.

3.3.2.1 Design Limit Loads

The structure **shall** be capable of withstanding all limit loads without loss of any required function.
Limit loads are defined as all worst case load conditions including temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.

3.3.2.2 Nonlinear Loads

The SCOR structures **shall** be capable of withstanding redistribution of internal and external loads resulting from nonlinear effects including deflections under load.

3.3.2.3 Yield Strength

The SCOR structures **shall** be able to support yield loads without detrimental permanent deformation. Yield loads are limit loads multiplied by the appropriate protoflight yield factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype yield factor of safety is 1.4.

While subjected to any operational load up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the SCOR flight units. Operational load is defined as the expected on-orbit loads while the SCOR is operating.

3.3.2.4 Ultimate Strength

The SCOR structures **shall** be able to support ultimate loads without fracture or collapse for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Ultimate loads are limit loads multiplied by the appropriate protoflight ultimate factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype ultimate factor of safety is 1.6.

3.3.2.5 Structural Stiffness

Stiffness of the SCOR structures and their attachments **shall** be designed by consideration of their performance requirements and their handling, transportation and launch environments.

Special stowage provisions **shall** be used if required to prevent excessive dynamic amplification during handling, transportation and transient flight events.

3.3.2.6 Unit Stiffness

The fundamental resonant frequency of the SCOR **shall** be 50 Hz or greater when the flight unit is rigidly constrained at its spacecraft interface and the SCOR is in its launch configuration.

3.3.2.7 Material Properties

Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.

Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.

The instrument contractor **shall** specify the source and statistical basis of all material properties used in the design.

3.3.2.8 Critical Members Design Values

For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence. Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units.

3.3.2.9 Redundant Members Design Values

For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity.

3.3.2.10 Selective Design Values

As an exception to Sections "Critical Members Design Values" and "Redundant Members Design Values", greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.

3.3.2.11 Structural Reliability

The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the SCOR resulting in the loss of any mission objective.

Accounting for the presence of stress concentrations and the growth of undetectable flaws, the SCOR structures **shall** withstand loads equivalent to four complete service lifetimes.

While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual SCOR structures **shall** not interfere with the operation of the SCOR.

After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the SCOR.

3.3.2.12 Mechanisms

Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.

All SCOR mechanisms **shall** meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector.

Moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GEV-SE using a NASA approved classification of each instrument mechanism.

For all operating points of the actuators, all rotational actuators **shall** have available a continuous maximum torque output greater than 7.0 milli-Newton meters.

For all operating points of the actuators, all linear actuators **shall** have available a continuous maximum force output greater than 0.28 N.

For SCOR mechanisms using closed-loop control, gain and phase margins **shall** be greater than 12 dB, and greater than 40 degrees, respectively, including the effects of the dynamic properties of any flexible structure.

All SCOR mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.

All SCOR mechanisms requiring restraint **shall** be released from a caged condition by command.

All SCOR mechanisms requiring restraint **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.

3.3.2.13 Pressurized Units

SCOR pressurized systems **shall** follow the requirements in accordance with EWR-127-1 and MIL-STD-1522A for the design of pressurized systems.

The SCOR **shall** have no open fluid reservoirs when delivered to the spacecraft contractor.

3.3.2.14 Alignment Reference

The SCOR **shall** have a permanent flight worthy optical alignment reference composed of a minimum 2.54 cm alignment cube and a mounting surface datum.

The SCOR **shall** have a flight worthy cover for the optical alignment cube.

The SCOR sensor unit **shall** have fiduciary marks locating the X, Y, and Z axes of the unit.

3.3.3 Thermal Requirements

3.3.3.1 Temperature Limits

The SCOR contractor **shall** establish Mission Allowable Temperatures (MAT) for the SCOR with at least 5 K of analytical/test uncertainty. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.
The SCOR **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.

3.3.3.2 Non Operational Temperature

The Non-Operational Temperatures (NOT) range **shall** extend at least 20 K warmer than the hot MAT and at least 20 K colder than the cold MAT.

The cold NOT **shall** be 248 K or colder.

3.3.3.3 Thermal Control Hardware

There **shall** be two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.

The SCOR heaters **shall** be sized to have 25% margin for worst case conditions.

When the instrument is off, instrument survival heaters **shall** maintain independent unit temperatures above non-operational limits.

SCOR survival heaters **shall** be thermostatically controlled.

3.3.4 Onboard Processor Requirements

3.3.4.1 Flight Load Non-Volatile Memory

The entire flight software image **shall** be contained in non-volatile memory at launch.

3.3.4.2 Commandable Reinitialization

The On-board Processor **shall** provide for reset by-command.

3.3.4.3 Deterministic Power-on Configuration

The On-board Processor **shall** initialize upon power-up into a predetermined configuration.

3.3.4.4 Fail-safe Recovery Mode

The SCOR **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.

3.3.5 Flight Software Requirements

3.3.5.1 Language and Methodology

All software developed for the SCOR **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. Minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers with NASA approval.

3.3.5.2 Flight Software Upload

The flight software **shall** be reprogrammable on-orbit without computer restart.

The flight software **shall** be capable of being uploaded in Computer Software Units (CSUs) and is usable immediately after completion of the modified unit upload.
Activation of the modified CSUs **shall** not require completion of an upload of the entire flight software image.

3.3.5.3 Flexibility and Ease of Software Modification

The SCOR flight software **shall** be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.

All software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.

The definition of instrument commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.

3.3.5.4 Version Identifiers

All software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.

This software identifier **shall** be keyed to the configuration management process.

3.3.5.5 Flight Processor Resource Sizing

During development, flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

3.3.5.6 Software Event Logging

The flight software **shall** include time-tagged event logging in telemetry.

The event messages **shall** include all anomalous events, mode transitions, and system performance events.

All flight software components **shall** utilize a common format for event messages.

The flight software **shall** provide a means for command to enable and disable queuing of individual event messages.

The flight software **shall** buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground.

The event message queue **shall** be configurable by command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.

The flight software **shall** maintain counters for:
a) the total number of event messages generated
b) the number of event messages discarded because of queue overflow
c) the number of event messages not queued due to being disabled.

3.3.5.7 Warm Restart

The flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.

3.3.5.8 Memory Tests

The flight software **shall** provide a mechanism to verify the contents of all memory areas.

3.3.5.9 Memory Dump

The flight software, and associated on-board computer hardware, **shall** provide the capability to dump any location and any size of on-board memory to the ground upon command.

The flight software memory dump capability **shall** not disturb normal operations and instrument data processing.

3.3.5.10 Telemetry

Telemetry points sampled by the instrument **shall** be controlled by an on-orbit modifiable table.

The sample rate of every instrument telemetry point **shall** be controlled by an on-orbit modifiable table.

3.3.6 Power Requirements

3.3.6.1 Power Regulators and Supplies

The SCOR power regulators and supplies **shall** have a phase margin of greater than 35 degrees.

The SCOR power regulators and supplies **shall** have a gain margin of greater than 20 dB.

3.3.6.2 Fuses

The SCOR **shall** not contain fuses.

3.3.6.3 Test Connectors

The SCOR **shall** have flight qualified covers for all test point connectors.

3.3.7 Magnetic Properties

The change in the magnetic field produced by the SCOR sensor, electronics, or power supply modules **shall** be less than 30 nano Tesla peak-to-peak for any operating mode, up to a single low pass bandwidth of 1.0 Hz, in any axis when measured at a distance of 1 meter from any face of a module.

3.3.8 Spacecraft Level Ground Testing

The SCOR **shall** accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum in at least the following two orientations:

1) Spacecraft +Y axis aligned with the gravity vector and pointed down.
2) Spacecraft -X axis aligned with the gravity vector and pointed down.

3.3.9 Ground Support Equipment and Development Facilities

3.3.9.1 Electrical System Test Equipment

The Electrical System Test Equipment (ESTE) **shall** operate the SCOR and ground support equipment during performance verification and calibration testing.

The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.

The ESTE **shall** include all test equipment necessary to operate and control the SCOR in all phases of operation and test modes.

The ESTE **shall** generate and maintain command logs.

The ESTE **shall** limit check all health and safety data.

The ESTE **shall** capture and archive all raw SCOR data.

The ESTE **shall** provide near-real time and off line data analysis of all SCOR data necessary to determine the performance characteristics of the instrument.

The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor's facility to extract SCOR science and engineering data.

The ESTE **shall** prohibit hazardous or critical commands being sent to the SCOR without operator verification.

3.3.9.2 Flight Software Development Environment

The Flight Software Development Environment (FSDE) **shall** consist of the hardware and software systems used for realtime, closed loop testing on flight like hardware to develop, test, validate, and demonstrate the flight software is ready for Government acceptance.

The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.

The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.

The FSDE **shall** contain engineering (hardware) models of necessary flight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.

3.3.9.3 Shipping Container

The SCOR shipping container **shall** be compatible with shipment by air or air-ride van.

The SCOR shipping container **shall** be climate controlled and purgable.

The SCOR shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.

The SCOR shipping container **shall** have shock recorders.

The SCOR shipping container **shall** meet all contamination control requirements imposed on the SCOR instrument units.

The SCOR shipping container **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

The SCOR GSE shipping containers **shall** be compatible with shipment by air or air-ride van.

The SCOR GSE shipping containers **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

4 Acronyms

A/D	Analog to Digital
ACA	After Contract Award
AI	Action Items
AIR	Action Item Review
ANSI/ISO	American National Standards Institute / International Organization of Standards
CCP	Contamination Control Plan
CDR	Critical Design Review
cm	centimeter
CME	Coronal Mass Ejection
CMP	Configuration Management Plan
CMS	Configuration Management System
CPU	Central Processing Unit
CSU	Computer Software Unit
DEM	Differential Emission Measure
DOORs	Dynamic Object-Oriented Requirements System
ESD	Electro Static Discharge
ESTE	Electrical System Test Equipment
EUV	Extreme Ultra Violet
EUVS	Extreme Ultraviolet Sensor
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
FMP	Financial Management Plan
FOV	Field of View
FPCCR	Formulation Phase Concept and Cost Review
FSDE	Flight Software Development Environment
FTA	Fault Tree Analysis
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hz	Hertz
ICD	Interface Control Document
IR	Infra Red
IV&V	Independent Verification and Validation
K	Kelvin
MAID	Master Action Item Database
MAR	Mission Assurance Requirements
MAT	Mission Allowable Temperature
MeV	Mega Electron Volts
MLI	Multi Layer Insulation
MMD	Mean Mission Duration
MRD	Mission Requirements Document
MTF	Modulation Transfer Function
MTR	Midterm Review
N/A	Not Applicable

NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
nm	Nanometer
NOAA	National Oceanic and Atmospheric Administration
NOT	Non-Operational Temperature
OAT	Out-gassing Allowable Temperature
PDR	Preliminary Design Review
PMP	Project Management Plan
PORD	Performance and Operational Requirements Document
PR	Progress Review
PRA	Probabilistic Risk Assessment
R	Reliability
RA	Recommended Approach
RAM	Random Access Memory
RFA	Request for Action
RFI	Request for Information
RMP	Risk Management Plan
ROM	Read Only Memory
SCOR	Solar Coronagraph
SCOR-GS	SCOR Ground System
SDP	Software Development Plan
SEL	Single Event Latch-up
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SEU	Single Event Upset
SIS	Solar Imaging Suite
SIS-GS	SIS Ground System
SLOC	Software Lines Of Code
SOW	Statement of Work
SXI	Solar X-Ray Imager
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Specified
TDI	Time Delay and Integration
TRL	Technology Readiness Level
TS	Trade Study
UIID	Unique Instrument Interface Document
UV	Ultra Violet
VP	Verification Plan
XRS	X-Ray Sensor
XUV	Soft X-ray to EUV