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RESTORE
VISION SENSOR SUBSYSTEM
CAMERA PERFORMANCE
SPECIFICATION

October, 2014

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

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SATELLITE SERVICING CAPABILITIES OFFICE

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Restore Vision Sensor Subsystem Camera Performance Specification

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to outline the technical specifications that define the Restore Vision Sensor Subsystem (VSS) camera.

1.2 SCOPE

This specification describes the electrical, mechanical, operating environment, and verification testing requirements for a space-qualified, Vision Sensor Subsystem (VSS) camera for a Goddard Space Flight Center (GSFC) payload, the Restore Servicing Vehicle (RSV).

1.3 HARDWARE DESCRIPTIONS

1.3.1 Flight Model

A flight model is the actual developmental end item that is intended for deployment and operations in a space environment. It is subjected to formal functional and environmental acceptance testing. A flight unit will be subject to all sections and specifications within this document.

1.3.2 Protoflight Model

A protoflight model of the VSS camera is the developmental end item on which a partial or complete protoflight qualification test campaign has been performed. A protoflight model may be used for spaceflight.

1.3.3 Engineering Model

An Engineering Model (EM) of the VSS camera is a full scale, high-fidelity unit that demonstrates critical aspects of the engineering processes involved in the development of the operational flight unit. It demonstrates function, form, fit or any combination thereof at a scale that is deemed to be representative of the final product operation in its operational environment. Engineering test units are intended to closely resemble the final product to the maximum extent possible. EM's are built and tested so as to establish confidence that the design will function in the expected environments. The EM is representative of the future operational system in form, fit and function, without full redundancy and high reliability parts. The EMs are used for functional qualification, except redundancy verification, failure survival demonstration and parameter drift checking. The EM is also used for final validation of test facilities and Ground Support Equipment (GSE) and the related procedures.

2.0 DOCUMENTATION AND DEFINITIONS

2.1 APPLICABLE DOCUMENTS

The following documents, of the exact revision shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced and the detailed contents of this specification, the requirements specified herein shall govern.

Document No.	Title
GSFC-STD-7000A	Goddard Space Flight Center General Environmental Verification Standard (GEVS)
RESTORE-PLAN-000513	Restore Servicing Vehicle (RSV) EMI/EMC & RF Compatibility Control Plan
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware
541-PG-8072.1.2	Goddard Space Flight Center Fastener Integrity Requirements
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating
IPC J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies
IPC J-STD-001ES	Space Electronics Hardware Addendum
NASA-HDBK-4002	Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects
NASA-HDBK-4006	Low Earth Orbit Spacecraft Charging Design Handbook
NASA/ JSC-SN-C-0005C.	Space Shuttle: Contamination Control Requirements
SSCO-RQMT-000013	Satellite Servicing Capabilities Office On-Orbit Payloads Level 2 Design and Performance Requirements
SSCO-RPT-000497	Radiation Environment for the Restore Mission

3.0 REQUIREMENTS

All of the written requirements in this document must apply at the end of spacecraft (SC) life (EOL) as defined in Section 3.6.

3.1 GENERAL REQUIRMENTS

3.1.1 Lifetime

The VSS camera shall operate within specification during the component mission life as defined in Section 3.6.

3.1.2 Warm-Up Time

The VSS camera shall meet performance requirements within one (1) minute of the application of power, for any of the specified environmental conditions, to the end of life.

3.1.3 Maintainability

The VSS camera shall meet all performance requirements over its operational life span without maintenance of any kind including calibration. No maintenance shall be required during the component shelf life for up to ten (10) years of storage under the conditions specified below.

Temperature:	16 to 28°C (SSCO-SPEC-000484)
Humidity:	20 to 60%
Pressure:	Sea Level to Vacuum (10^-6 Torr).

3.2 OPTICAL REQUIREMENTS

3.2.1 Focal Plane Array Requirements

3.2.1.1 Image Sensor Type

The VSS camera shall contain a solid state Complementary Metal-Oxide Semiconductor (CMOS) focal plane array.

3.2.1.2 Wavelength Sensitivity

The VSS camera shall contain a focal plane array sensitive to visible wavelengths (~400 to ~750 nanometers).

3.2.1.3 Color Imagery

The VSS camera shall contain a focal plane array capable of providing color imagery via a Bayer pattern Color Filter Array (CFA).

3.2.1.4 Image Resolution

The VSS camera shall contain a focal plane array capable of providing high-resolution video and imagery with a minimum 1280 x 1024 pixel resolution. Native sensor resolution may be higher.

3.2.1.5 Frame Rate

The VSS camera shall contain a focal plane array capable of (a) providing high-resolution video and imagery at a minimum rate of 10 frames per second (fps) at the resolution stated in Section 3.2.1.4 and (b) outputting all pixels of the full frame image at a rate of at least 1 fps.

3.2.1.6 Optical Format

The VSS camera shall contain a focal plane array that can meet the requirement stated in Section 3.2.1.4 when paired with a 2/3” optical format lens producing an ~11mm diameter image circle.

3.2.1.7 Analog-to-Digital Conversion

The VSS camera shall contain a focal plane array with an Analog-to-Digital (ADC) resolution of between 8 and 12 bits, on chip.

3.2.1.8 Windowing Capability

The VSS camera shall contain a focal plane array capable of Region-of-Interest (ROI) (aka Windowing) control. Manual control via command of both the window size and window location is required.

3.2.1.9 Shutter Mode

The VSS camera shall contain a focal plane array capable of implementing either an electronic rolling shutter or global (snapshot) shutter mode.

3.2.1.10 Subsampling Mode

The VSS camera shall contain a focal plane array capable of implementing row and column skip modes to reduce the output resolution of the camera imagery without reducing the camera Field-of-View (FOV).

3.2.2 Auto-Exposure

The VSS camera shall employ an Automatic Gain & Exposure Control (AGEC) algorithm running internal to the camera to adjust for dynamic on-orbit lighting conditions.

3.2.3 Manual Commanding of Camera Parameters

The VSS camera shall be capable of accepting manual commands for the following focal plane array parameters:

- Integration Time (discrete pre-determined values)
- Gain (discrete pre-determined values)
- Frame Rate (discrete pre-determined values)
- Gamma Correction (On / Off)
- Automatic Gain & Exposure Control (On / Off)
- Region of Interest Control for window size and location

3.2.4 Bright Source Protection

The VSS camera shall be capable of sustaining continuous and direct exposure to the sun within its FOV without permanent damage or degradation of the focal plane array.

3.2.5 Delivered Lens

The VSS camera shall be delivered with a standard non-flight COTS C-Mount lens with the following specifications:

- Optical format of the lens to be suitable for the image sensor used within the VSS camera. (i.e. no vignetting when the largest possible image size is outputted)
- Maximum geometric distortion at the outer edge of the field shall be less than +/- 5%. (positive = pincushion vs. negative = barrel)
- Lens to have manual aperture adjustment.
- Focus to be achieved either by a separate focus ring or by installation depth into the C-mount adapter.
- Focal length shall be reviewed and approved post awarding of contract to Contractor.

3.3 MECHANICAL CHARACTERISTICS

3.3.1 Mass

The total weight of the VSS camera without lens shall be less than or equal to 400 grams.

3.3.2 Envelope

The VSS camera shall have bounding box dimensions of equal to or less than 5.715 (W) x 5.715 (L) x 5.715 (H) centimeters, not including the lens. If this bounding box proves problematic, an increase in the length (L) of the camera shall be reviewed and approved prior to awarding procurement contract to Contractor.

3.3.3 Lens Mount

The VSS camera shall include a C-mount type lens mount capable of accepting any C-Mount lens with a 17.52mm flange focal distance and an ANSI 1-32 UN 2A thread.

3.3.4 Camera Mount

The VSS camera shall include mechanical mounting solutions that include multiple threaded fastener holes on each of the three adjoining orthogonal sides of the camera chassis. One of these sides shall be defined as the Primary Mounting Interface for the camera. Fastener holes shall be blind and not penetrate the interior of the camera housing. The camera mounting interface shall be defined in the camera's Interface Control Document (ICD).

3.3.5 Focal Plane Array-to-Mounting Interface Alignment

The VSS camera focal plane array shall be aligned to the camera's primary mounting interface to within ± 10 arcminutes in roll, pitch and yaw.

3.3.6 Optical Axis-to-Lens Mount Alignment

The optical axis of the VSS camera as defined by the center pixel of the focal plane array shall be aligned to the camera's C-Mount interface horizontally and vertically to within ± 30 arcminutes.

3.3.7 Camera-to-Lens Optical Alignment

The VSS camera shall provide mechanical tolerances in the C-Mount lens thread such repeated installations of the same lens does not change the total angle of the chief ray through the lens by more than 15 arcminutes.

3.3.8 Electrical Connectors

The VSS camera shall have all electrical connectors that implement power, video, commanding and telemetry located on the camera face opposite of the face containing the camera lens.

3.3.9 Chassis Grounding

The VSS camera shall provide a dedicated electrical chassis ground point conforming to Section 3.5.5.10. Grounding method shall be approved by the GSFC Contracting Officer Technical Representative (COTR).

3.3.10 Identification and Marking

Each unit shall be permanently marked with the part number and a unique sequential serial number in the area designated on the interface control drawing in a manner to be approved by the GSFC COTR.

3.4 MATERIALS

All requirements in Section 4.2 of NASA-STD-6016 are applicable, with the following additions:

3.4.1 Tin

The requirements in GEIA-STD-0005-1 and for level 2C hardware in GEIA-STD-0005-2 for Pb-free tin solders and surface finishes are also applicable in addition to the requirements in the section of NASA-STD-6016. These requirements address required documentation, detection and control, and tin whisker mitigation. Pb-free tin is defined to be pure tin or any tin alloy with <3% lead content by weight. This means that some Pb-free finishes other than pure tin, such as tin-bismuth and tin-copper, are considered to be "tin" for the purposes of this standard (GEIA-STD-0005-2).

3.4.2 Thermal Vacuum Stability

Nonmetallic materials shall be tested per ASTM-E595, with acceptance criteria of ≤0.1 percent Collected Volatile Condensable Materials (CVCM) and ≤1.0 percent Total Mass Loss (TML). A Materials Usage Agreement (MUA) shall be submitted to the Materials and Processes Engineer or appropriate Materials and Processes Control Board for any material that does not meet these criteria. The ASTM-E1559 method may be used to evaluate the acceptability of a material that fails the ASTM-E595 requirements. The Materials and Processes Engineer shall coordinate the review of any MUA related to outgassing with the RESTORE Contamination Control Engineer.

3.4.3 Material Nondestructive Inspection (NDI)

3.4.3.1 Nondestructive Evaluation (NDE) Plan

A Nondestructive Evaluation (NDE) Plan is only required for fracture critical flight hardware as defined in NASA-STD-5009: "Classification that assumes that cracks in the hardware, component, or part could lead to a catastrophic failure, an event that results in loss of life, serious personal injury, loss of the manned flight system, or national asset." If it is determined that none of this flight hardware meets this definition, then a NDE Plan is not necessary.

3.4.3.2 Nickel Plating

The requirements in this section of NASA-STD-6016 are applicable as written. In addition, the use of electrodeposited (electrolytic) nickel is prohibited unless it can be demonstrated that it does not result in Electro Magnetic Interference (EMI).

3.4.3.3 Fastener Installation

The requirements in this section of NASA-STD-6016 are applicable as written including those in sections 4.2.6.5.1 and 4.2.6.5.2, except as discussed below. Any corrosion-resistant sealant still needs to meet the outgassing requirements for RESTORE. 541-PG-8072.1.2 shall be used instead of NASA-STD-6008 to define the fastener management and control policy, responsibilities, and practices for structural fasteners, fracture-critical fasteners, and safety-critical fasteners that are procured, received, tested, inventoried, or installed in Restore flight hardware or critical nuts and bolts used on GSE.

3.4.4 Printed Wiring Boards (PWBs)

The fabrication of printed wiring boards shall be in accordance with IPC-6012B, Class 3/A for rigid boards. Any differences to these standards will be submitted to GSFC on a waiver for approval.

The Contractor shall provide Printed Wing Boards (PWB) test coupons to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation for evaluation per the appropriate procurement specification.

3.4.4.1 Water-Soluble Flux

Any use of Water-Soluble Flux (WSF) should be identified on the Materials Identification and Usage List (MIUL). The Materials and Processes Engineer will inform the RESTORE Chief Safety and Mission Assurance Officer (CSO) and GSFC Workmanship for disposition of any proposed use of WSF. The MEB can support the verification of the proposed soldering process (usually through digital radiography) as well as the verification the cleanliness of a board after soldering and cleaning.

3.4.4.2 PWB Solvents and Cleaners

The MEB is responsible for reviewing and approving cleaning solvents that aren't already approved for use in the NASA-STD-8739 Workmanship documents. A review board within the MEB shall review and/or approve the proposed use of any cleaning solvent not already approved in the NASA-STD-8739 documents and provide a recommendation to the CSO and GSFC Workmanship.

3.4.5 Materials Identification and Usage Lists (MIULs)

Materials and Processes usage shall be documented in an electronic searchable parts list or separate electronic searchable MIUL, as described in Section 4.1.2.3 of NASA-STD-6016. MIULs shall be submitted to GSFC for review and approval. MUA forms shall be prepared and submitted to GSFC for all Materials that do not meet the requirements specified in this document, as described in Section 4.1.3 of NASA-STD-6016.

3.4.6 Fracture Control

Metallic materials used in the construction of the assembly shall be subject to a Fracture Control Program in accordance with NASA-STD-5019. It is desired—but not required—to assign all materials (other than fasteners) as Controlled/Fail-Safe or Low Risk fracture classification.

3.4.7 Material Test Reports

The supplier shall provide actual physical and chemical analysis test reports in accordance with the applicable specifications. For electrical wire or cable, and RF cable, the report shall include electrical inspections and tests in accordance with the applicable specifications. Manufacturer of material and lot number must be identified on each document.

3.5 ELECTRICAL REQUIREMENTS

3.5.1 Power Interface

3.5.1.1 Operating Voltage Level

The VSS camera shall be designed to operate over the secondary bus voltage of 5.0 ± 10% VDC at its primary input.

3.5.1.2 Power Input Configuration

Power to the VSS camera will be remotely switched using properly derated lines. The DC power and return will be routed to the VSS camera as twisted pairs and will be shielded as required. The power inputs and their associated returns shall not use adjacent pins on the connector.

3.5.1.3 Power Consumption

Maximum steady state power shall not exceed 2.5 Watts. Maximum in-rush current shall not exceed 5.0 Amps. Maximum power duration will not exceed 10 seconds.

3.5.2 Video Interface

3.5.2.1 Video Physical Layer

The VSS camera shall employ Multipoint Low-Voltage Differential Signaling, M-LVDS (LVDM), as the physical video interface via four (4) twisted pairs. Maximum allowable bandwidth down any given pair used to transmit video data, regardless of camera settings shall not exceed 50 Mbps. See section 3.5.4 regarding the potential of using an additional twisted pair (for a total of five) for the video interface if deemed necessary by the Contractor.

3.5.2.2 Video Data Format

The VSS camera shall output the raw Bayer pattern data from the image sensor via the video interface by default.

3.5.2.3 Demosaicing Algorithm

3.5.2.3.1 Ground Implementation

The demosaicing algorithm that interpolates color imagery from the raw Bayer pattern video data from the camera shall reside in a location separate from the VSS camera. GSFC's preferred options are:

- Within a Video Processer Unit (VPU) as a separate part of the camera Electrical Ground Support Equipment (EGSE). This VPU can serve as a "black box" that accepts the video data from the camera and exports color interpolated imagery to the EGSE for viewing.

- Within the EGSE control computer itself, with the color interpolation happening behind the scenes as part of the software interface that connects to, controls, and views imagery from the VSS camera.

3.5.2.3.2 Flight Implementation

The demosaicing algorithm that interpolates color imagery from the raw Bayer pattern video data from the camera shall be made available to GSFC in the following forms:

- Pseudo-code: a top level description of the implementation of the demosaicing algorithm.
- Algorithm Description Document (ADD): A document detailing the mathematics that power the demosaicing algorithm.

GSFC does not require specific access to the Contractor's source code for the demosaicing algorithm, but will accept it in lieu of the items described above.

3.5.3 Command Interface

3.5.3.1 Command Interface

The VSS camera shall employ Low-Voltage Differential Signaling (LVDS) via a single (1) twisted pair for commanding.

3.5.4 Telemetry Interface

The VSS camera shall provide telemetry specified in the camera Interface Control Document. The telemetry shall indicate the health and operational status of the camera. Telemetry shall be provided in one of two ways:

- M-LVDS via a single (1) twisted pair.

- Embedded as a header file into the digital video output. In this case, this single twisted pair may be used for the video interface to yield a total of five (5) available twisted pairs.

An Hardware Description Language Simulation Model of the VSS camera shall be supplied.

3.5.5 General Electrical Requirements

3.5.5.1 Camera Input Safety

The presence or absence of any combination of the input signals applied in any sequence shall not damage the VSS camera, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not. No sequence of command shall damage the VSS camera, reduce its life expectancy, or cause any malfunction.

3.5.5.2 Input Power Transients

Normal Transients: The component shall operate within specifications in the presence of a normal transient of ± 150 mV from steady-state.

Abnormal Transients: During abnormal transients, the input voltage will be 800 mV peak. The duration of abnormal transients will not exceed 500 microseconds. The component shall survive abnormal transients without permanent damage. The loss of stored data or a change of state of circuitry under these conditions is acceptable.

3.5.5.3 Internal Fusing / Over-Current Protection

There shall be no internal fusing in the VSS camera. If required, components may use resettable solid-state switches for over-current protection.

3.5.5.4 External Commands

External commands as needed by the VSS camera shall be defined in the Interface Control Document.

3.5.5.5 Test Inputs

If required, component test interfaces shall follow the test signal rules below.

- The component may include test signals at test connectors that are not directly wired to a flight circuit (isolated) and that are used for ground test operations.
- Test connectors shall meet the same specifications as any flight connector on the component.
- The Contractor shall provide flight-approved RF, static control covers and connector savers for all connectors.
- Circuits wired to the test connectors shall be designed to prevent damage due to an external short, test equipment malfunction, or ESD.

Component power shall not be applied or accessed at or through a test connector.

3.5.5.6 Flight Connectors

External box connectors shall be chosen from those in the EEE-INST-0002. If the component requirements cannot be met using one of these connectors, equivalent alternates may be used if it meets the derating criteria of EEE-INST-0002, or after successful completion of a qualification program based upon the guidelines contained therein.

The contractor shall provide flight-approved RF, static control covers and connectors savers for each of the flight connectors.

3.5.5.7 Soldering Practices

The solder joints and soldering practices used in the assembly shall be compatible with the requirements of IPC J-STD-001ES.

3.5.5.8 Staking and Conformal Coating Practices

The staking and conformal coating practices of printed wiring boards and electronic assemblies used in the assembly shall be compatible with the requirements of IPC J-STD-001.

3.5.5.9 Wiring

Conventional wire used in any of the internal camera harnesses or any of the subsystem harnesses shall conform to the requirements listed in GSFC EEE-INST-0002.

3.5.5.10 Grounding

All services within the camera shall be referenced to a common ground.

Mating surfaces shall be free from nonconductive finishes and shall maximize contact surface area. Connector shells shall be electrically bonded to the chassis through an electrical resistance not exceeding 2.5 mΩ. Unless specifically approved by the GSFC COTR, the component's ground connection shall be made through its mounting interface.

3.5.5.11 External Surface and Differential Charging Mitigation

The external conductive surfaces of the camera shall be grounded with less than a 1 MΩ resistance to the chassis mount. Any partially conductive surfaces such as paints and coatings, applied over a conductive substrate shall have a bulk resistivity of less than 10^{11} ohm-cm. Any partially conductive surfaces applied over a non-conductive (dielectric) substrate shall be grounded at the edges and shall have a surface resistivity of less than 10^{9} ohms per square.

3.5.5.12 Surface Conductivity and External Discharge Protection

A surface charging analysis shall be performed including an inventory of all surface materials and their resistivity and thickness. An inventory shall include triple points, floating conductors and multiple conductor element components. All external surfaces > 6 cm^2 shall be conductive with a resistivity of less than 10^9 ohms per square. This resistivity shall be complied by but not limited to the use of (a) conversion coating on AL, (b) NS43G, or (c) nickel black and ensuring all of these surfaces are grounded. The surfaces with resistivity greater than 10^9 ohm per square shall be limited to 60 cm^2 total, per any 1 m^2 area, with no single surface area with resistivity greater than 10^9 ohms per square greater than 6 cm^2.

3.5.5.13 Internal Charging

The component design of the VSS camera shall prevent internal charging/discharging effects that can damage the internal components or disrupt operations. Internal charging effects shall be controlled by shielding all electronics elements with greater than or equal to 200 mil aluminum equivalent thickness so that the internal charging rate is benign.

Internal dielectric materials of the camera shall have a bulk resistivity less than 10^{12} ohms-cm, or a surface resistivity less than 10^{12} ohms per square. The camera shall ground all of its internal floating conductors with surface area > 1 in^2 with less than 10^{11} ohm resistance.

All exceptions or deviations to these requirements shall be assessed and approved by GSFC.

Further investigation into these effects and mitigations of internal charging can be found in the NASA document, Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects, NASA-HDBK-4002.

3.5.5.14 Dielectric Strength

To minimize the electrical discharge caused by the internal charging of dielectrics, the strength of the electrical field in the dielectrics should be kept less than 10^6 V/m. At a junction point between a conducting surface and dielectric surface, a positive maximum of 1 kV differential potential shall be allowed to avoid an ESD charge. A negative potential difference shall be limited to 100 volt.

In order to limit differential voltage, a maximum current density of 10 nA/cm^2 through the dielectric shall be used to calculate the maximum resistivity of the dielectric materials.

For the Bulk Dielectrics (>0.0254 cm thick), the VSS camera shall provided 0.508 cm aluminum shielding.

3.5.5.15 Insulation Resistance

When high-resistance material surfaces need to have higher insulation values, charging analysis of high-resistance material surfaces shall be conducted to show that the electrical potential of the insulators does not exceed 1 kV.

3.5.5.16 Corona

The VSS camera design shall ensure protection against damage and measurable degradation due to RF breakdown (both corona and arcing). Components with high-voltage circuits shall be immune to corona and arcing while in a nominal orbital vacuum environment. All VSS camera components shall preclude measureable degradation due to multipaction and corona at critical pressures in vacuum environments. See NASA-HDBK-4006 for more information.

3.6 LIFE REQUIREMENTS

3.6.1 Mission Life

The VSS camera on-orbit life shall be five years as defined herein.

3.6.2 Shelf Life

The component shall not suffer any degradation in performance when stored for ten years when packaged using agreed-to procedures.

3.6.3 Demise

The Contractor shall provide information and data to allow GSFC to perform a demisability study for spacecraft disposal and re-entry.

3.7 CONTAMINATION CONTROL

Individual parts and assembly of the VSS camera shall conform to the Contractor's accepted cleanliness practices for assembly of space-flight hardware. The Contractor shall make detailed cleaning procedures available to NASA GSFC for review.

The VSS camera assembly will be cleaned to SSCO specifications prior to incorporation into the next assembly. The nominal cleaning solution preferred by SSCO is IPA, occasionally acetone and hexane will be used. The Contractor should specify parts that are not compatible with these solvents.

Following acceptance testing, the camera assembly shall receive a final cleaning to a Visibly Clean, Highly Sensitive plus Ultra-Violet inspection level in accordance with NASA/ JSC-SN-C-0005C. The assembly shall be double-bagged in heat-sealed, waterproof, vaporproof, ESD-shielded bags

3.7.1 Vacuum Bakeout Requirements

Space-flight rated assemblies shall undergo thermal vacuum bakeout and positively establish a CVCM of 0.1% or less and a TML of 1.0% or less.

3.8 ENVIRONMENTAL REQUIREMENTS

The component shall be designed to withstand (without degradation of specified performance) the operational and non-operational environments specified in the following section.

3.8.1 Static Loads

The VSS camera shall be designed to withstand the load shown in Figure 3-1 based on the VSS camera's weight. Loads are considered to act in any direction, individually. Structural analyses shall be performed to show positive margins of safety using a factor of 1.25X with regard to yield and 1.4X with regard to ultimate material strength.

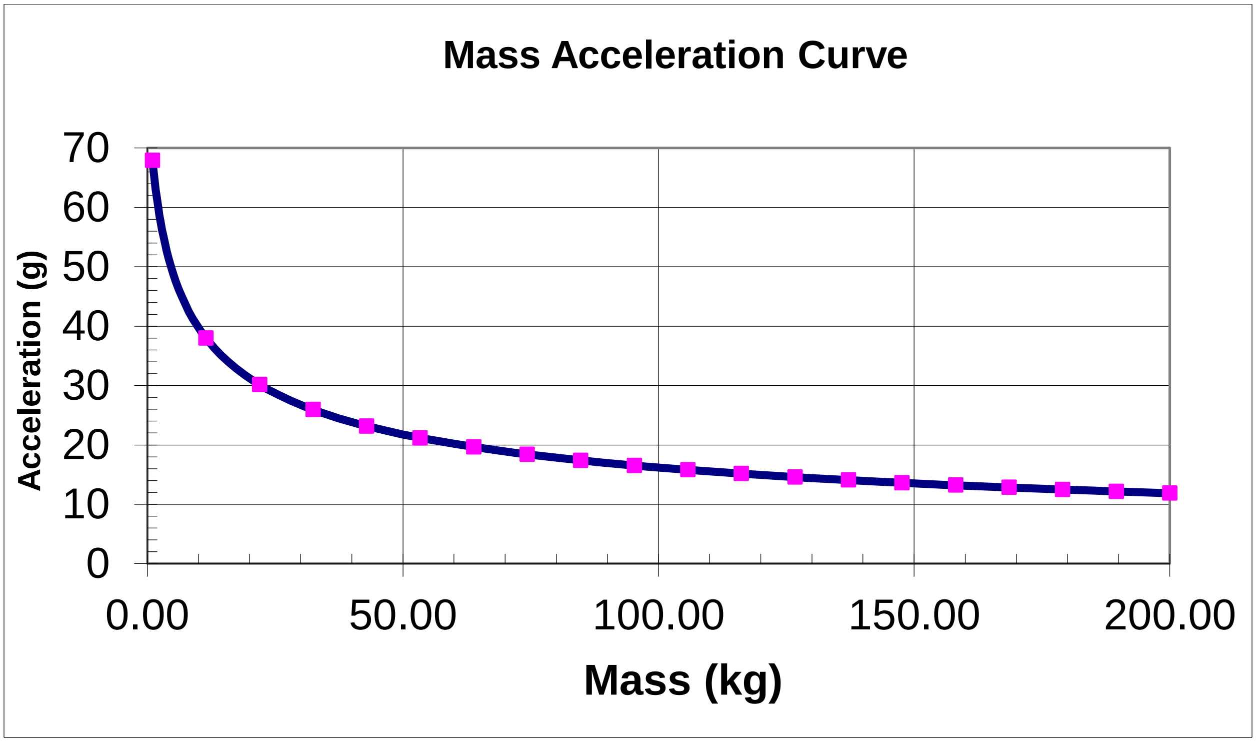

Figure 3-1 Secondary Structure Mass Acceleration Curve

3.8.2 Vibroacoustic Loads

The VSS camera shall be capable of withstanding the random vibration levels shown in Table 3-2, individually applied to three mutually orthogonal axes. These values are best estimates for the current mission architecture and are subject to revision as the notional mission design matures. These limits may be superseded by mission-specific analysis.

Table 3-1: Random Vibration

FREQUENCY (HZ)	Acceptance (Flight) LEVELS (g2/Hz)	Qualification (PROTOFLIGHT and PROTOTYPE) LEVELS (g^2/Hz)
20	.013	0.026
20-50	+6dB/oct	+6dB/oct
50-800	.08	0.16
800-2000	-6dB/oct	-6dB/oct
2000	.013	0.026
Overall Grms	10.0 Grms	14.1 Grms

3.8.2.1 Acoustic

The VSS camera shall be able to survive acoustic levels at the spacecraft system level testing as defined in Figure 3-2 and must be capable of withstanding the protoflight acoustic environment. The contractor is not required to verify and test this requirement.

Freq	1/3 Octave Band SPL (dB) Atlas 551
32	123
40	124.8
50	126.2
63	127.5
80	128.3
100	128.8
125	129
160	128.7
200	127.5
250	126
315	124.6
400	123.3
500	121.9
630	120.5
800	119.1
1000	117.8
1250	116.4
1600	115
2000	113.6
2500	112.3
3150	110.9
4000	109.5
5000	108.1
6300	106.8
8000	105.4
10000	104
OASPL	**138.1**

Figure 3-2: Acoustic Levels for Atlas V Series 551 Flight Acoustic Environments

3.8.3 Thermal

The VSS camera shall be capable of operation with mounting interface temperatures defined in Table 3-4.

Table 3-2: Temperature Limits at Mounting Interface

Condition	Cold Limit [°C]	Hot Limit [°C]
Operational Temperature	-25	+40
Acceptance Temperature	-30	+50
Qualification Temperature	-40	+55
Non-Operational (Survival)	-50	+60

3.8.4 Vacuum

The VSS camera shall be capable of meeting all performance requirements of section 5.4 at ambient pressure as well as when exposed to a vacuum environment of 1 x 10-6 Torr, or less.

3.8.5 Atomic Oxygen

Materials used in the construction of the VSS camera assembly shall not generate contamination products resulting from the interaction with an atomic oxygen environment. The camera shall be designed to operate normally for the defined five year mission life subject to exposure to an atomic oxygen fluence of $7.2e^{20}$ atoms/cm^2.

3.8.6 Radiation – Total Ionizing Dose

The VSS camera design shall support a minimum of 5-year mission life with full functional integrity within a LEO, GEO or interplanetary (2 AU) environment.

The VSS camera shall survive a total ionizing dose of 100 Krad-Si for a minimum of 5-year mission with a factor of 2-design margin.

3.8.7 Non-Destructive Single Events Effects (SEE)

- The Contractor shall demonstrate that for non-destructive SEE, such as single event upset (SEU), the minimum LET for each component shall be greater than 80 MeV-cm2/mg.

- The Contractor must consider that there is no geomagnetic shielding some of the proposed orbits in which the VSS camera will operate, so that high LET particles are not considered attenuated.

- If a device is not immune to SEE's as defined in (a) above, analysis for SEE rates and effects must be performed based on threshold LET of the candidate devices. Effects due to both the galactic cosmic heavy ion and solar heavy ion environment shall be assessed and approved by the GSFC COTR.

3.8.8 Destructive Single Events Effects

The Contractor shall demonstrate that for destructive SEE, such as single event latch-up (SEL), the minimum LET for components shall be 100 MeVcm^2/mg. Minor deviations in the minimum LET for components may be approved on a case-by-case basis by the COTR

Power MOSFET or bipolar transistors must be derated into their safe operating areas to prevent single-event gate rupture (SEGR) and single-event burnout (SEB).

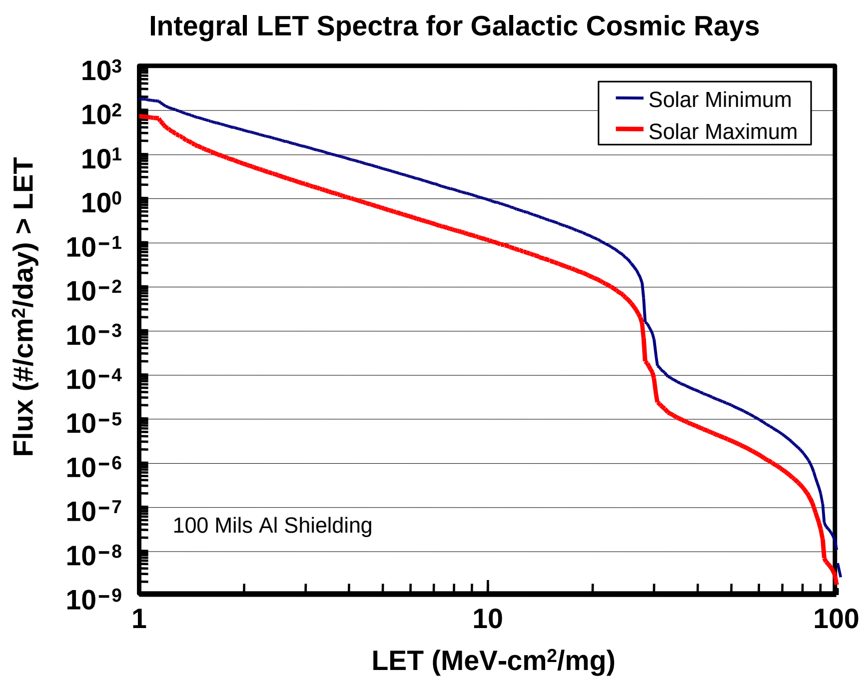

Figure 3-3: LET Spectra for Single Event Effects

3.8.9 Long-Term Displacement Damage

The VSS camera shall be capable of meeting requirements over the course a 5-year mission when subjected to radiation environments that cause long-term displacement damage. The camera shall survive a displacement damage test with a 10 Mev particles at a fluence of $3x10^{11}$ protons/cm^2 without compromising the functional integrity of the camera.

Appropriate radiation environments for a GEO-based mission can be found in the Radiation Environment for the Restore Mission document (SSCO-RPT-000497). Displacement damage is also caused by secondary neutrons produced by protons interacting with surrounding shielding.

3.8.10 Transient Proton Radiation Flux

Particle interference during solar events is of particular concern because it can impact the observation times of CCDs or CMOS detectors. The elemental composition of a solar particle event consists of about 95% protons, on average. The VSS camera shall be capable of meeting requirements, both during and after, such transient radiation noise events. The maximum proton transient throughout which the VSS camera is expected to meet performance is plotted in the integral energy spectrum of Figure 3-4.

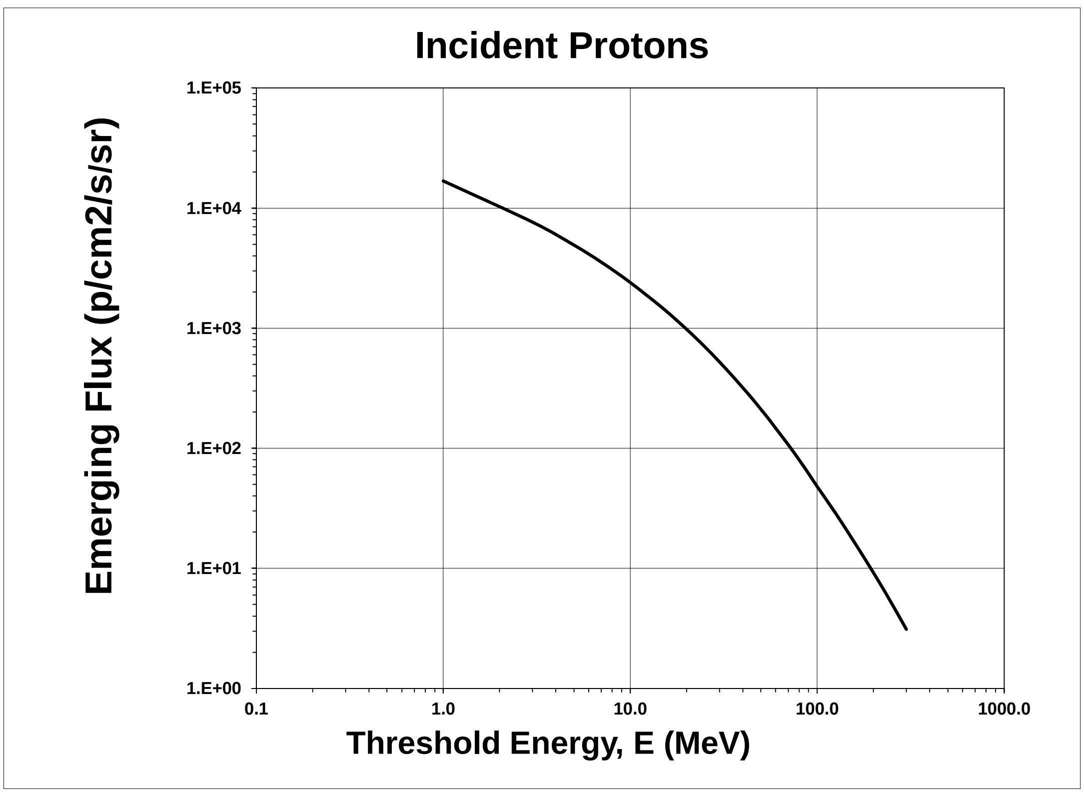

Figure 3-4: Transient Proton Radiation Flux

3.8.11 Humidity

The VSS camera shall be capable of meeting the requirements herein during and after exposure to 20 to 60% relative humidity for 2 years.

The VSS camera shall be capable of operating without degradation while exposed to an external environment of 0% relative humidity during on-orbit operations.

3.8.12 Venting

The VSS camera shall be vented to prevent pressure buildup during the ascent phase of launch. The VSS camera shall survive external depressurization from one atm to 10-5 Torr in 30 seconds.

Camera components not having a minimum of 0.25 square inches of vent area for each cubic foot volume, shall demonstrate the ability to survive the venting rate. If analysis is required, the venting analysis must indicate a positive structural margin at loads equal to the maximum expected pressure differential during launch, with a Factor of Safety of 2.0 applied to the loads.

Location of any applicable vent holes shall be shown in the VSS camera mechanical ICD.

3.8.13 Magnetic Dipole

Any component or piece part exceeding 3 Amp m^2 dipole moment shall be identified and approved for its use by the GSFC COTR.

3.8.14 EMI / EMC

The VSS camera shall be compatible with the EMI/EMC requirements of the Restore Servicing Vehicle (RSV) EMI/EMC & RF Compatibility Control Plan (RESTORE-PLAN-000513). The required EMI/EMC are as follows:

1) Common Mode (CM) Emissions, Bulk Cable, Power and Signal Lines
2) CS114, Conducted Susceptibility, Bulk Cable, Power and Signal Lines
3) CS115, Conducted Susceptibility, Bulk Cable, Power and Signal Lines
4) Conducted Susceptibility, Differential Mode, Power Line
5) RE101, Radiated Emissions, Magnetic Field
6) RE102, Radiated Emissions, Electric Field
7) RS103, Radiated Susceptibility, Electric Field

The test mythology shall be as described in the General Environmental Verification Standard (GEVS) For GSFC Flight Programs and Projects (GSFC-STD-7000A).

3.8.14.1 Common Mode (CM) Emissions, Bulk Cable, Power and Signal Lines

The VSS camera's CM conducted emissions on power leads and signal cables shall not exceed the limits specified in Figure 3-6.

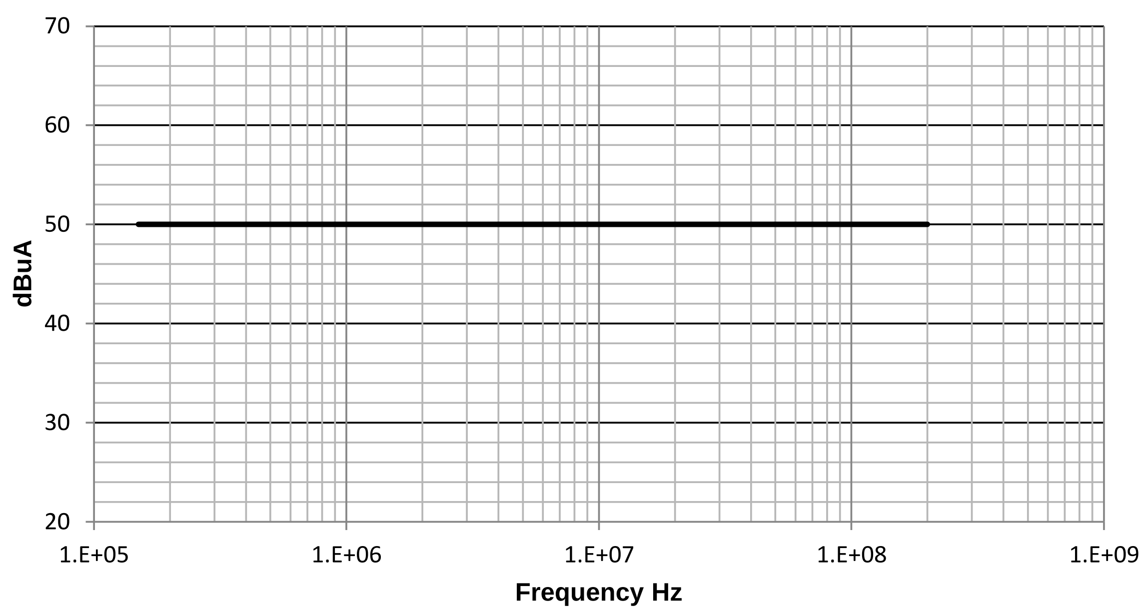

Figure 3-5: Common Mode Conducted Emissions Limit

3.8.14.2 Conducted Susceptibility, Bulk Cable, Power and Signal Lines

The VSS camera shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in its specification when all interconnecting power and signal cables are subjected to the current levels shown in Figure 3-7 plus 6dB.

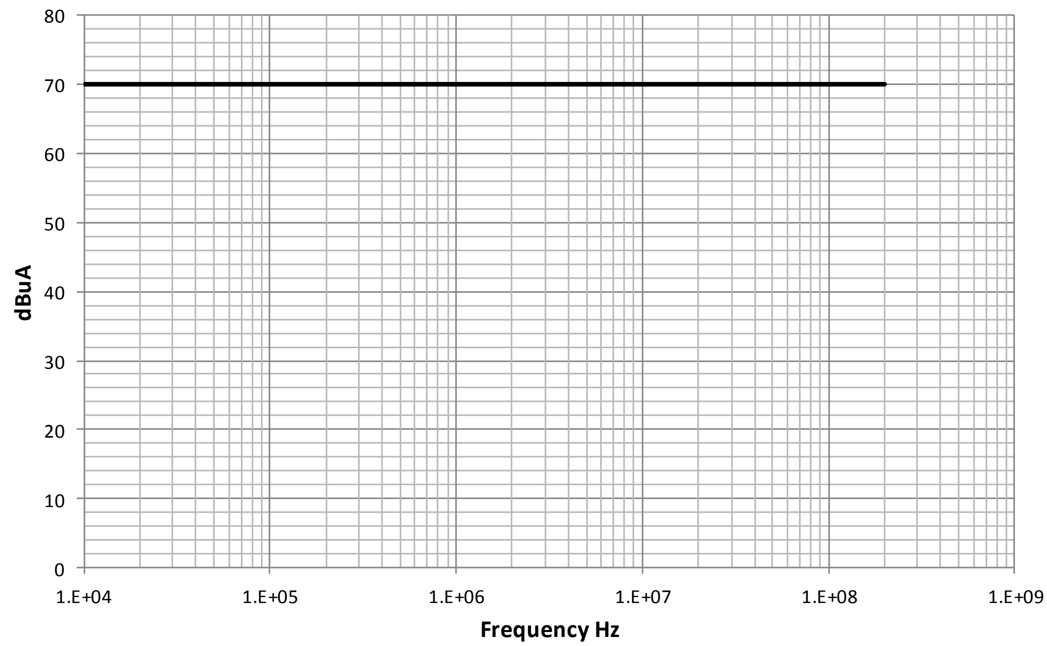

Figure 3-6: CS114 Common Mode Conducted Susceptibility Limit

3.8.14.3 Conducted Susceptibility, Bulk Cable, Power and Signal Lines

The VSS camera shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in its specification when all interconnecting power and signal cables are subjected to a pre-calibrated signal having rise and fall times, pulse width, and amplitude as specified in Figure 3-8 at a 30 Hz rate for one minute.

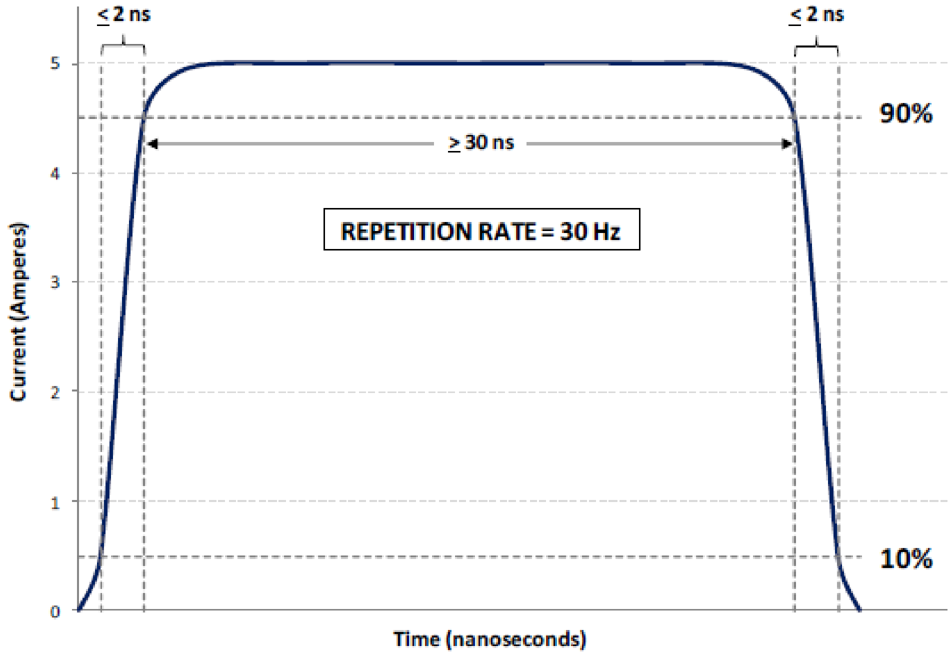

Figure 3-7: CS115 Common Mode Conducted Susceptibility Limit

3.8.14.4 Conducted Susceptibility, Differential Mode, Power Line

The VSS camera will be designed to meet its performance requirements in the presence of noise and ripple voltages on the order of 30 mV peak-to-peak in the 10kHz – 2Mhz range.

3.8.14.5 RE101, Radiated Emissions, Magnetic Field

The VSS camera shall not produce magnetic field emissions in excess of the limit specified in Figure 3-9.

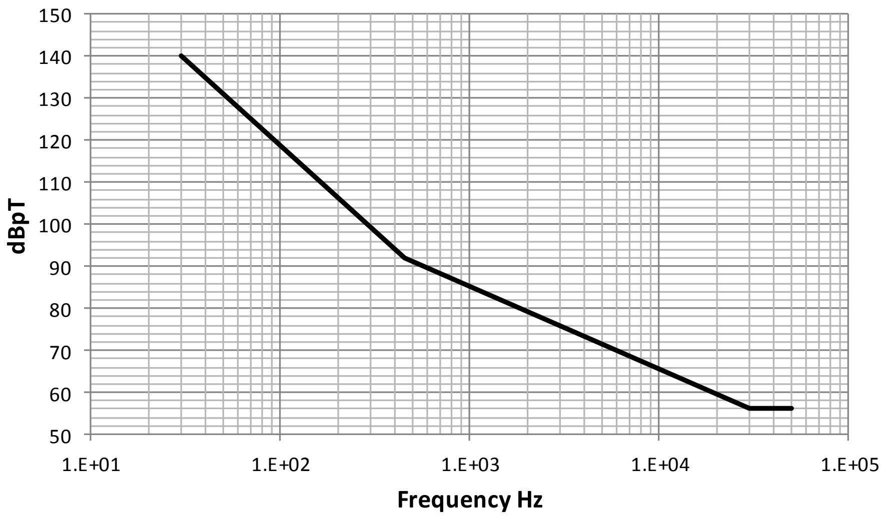

Figure 3-8: RE101 Test Limit

3.8.14.6 RE101, Radiated Emissions, Electric Field

The VSS camera shall not produce electric field emissions in excess of the limit specified in Figure 3-10.

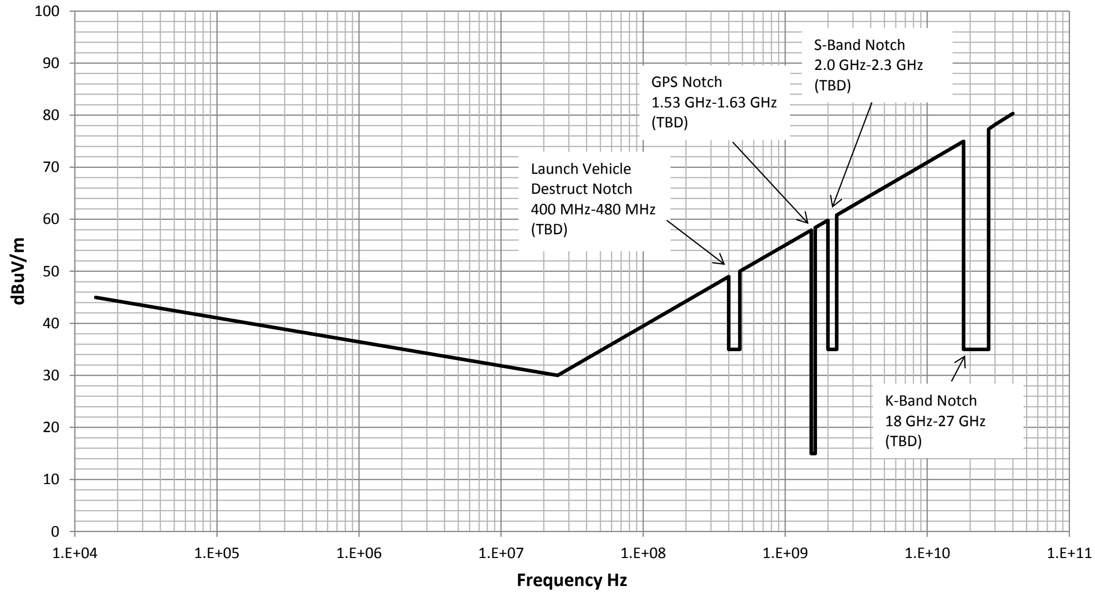

Figure 3-9: RE102 Radiated Emissions Limit

3.8.14.7 RS103, Radiated Susceptibility, Electric Field

The VSS camera shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in its subsystem specification when subjected to the radiated electric fields less than or equal to those specified in Table 3-5 and survive without permanent degradation when subjected to the test levels described in Table 3-6. Above 30 MHz, the requirement shall be met for both horizontally and vertically polarized waves.

The power on Survival test levels may be present during transport to the launch pad and at the launch pad.

Table 3-3: RS103 on Orbit Test Levels

Frequency Range	Test Levels V/m	Modulation
2 MHz to 30 MHz	2	CW
30 MHz to 18 GHz	2	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
Spacecraft S-Band Transmitter Frequency TBD	30 TBD	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
Spacecraft K-Band Transmitter Frequency TBD	40 TBD	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle

Table 3-4: RS103 Powered on Survival Test Levels

Frequency Range	Test Levels V/m	Modulation
2 MHz to 30 MHz	20	CW
30 MHz to 18 GHz	20	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
Spacecraft S-Band Transmitter Frequency TBD	30 TBD	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
2.221 GHz Launch Vehicle S-Band TBD	40 TBD	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
5.765 GHz Launch Vehicle C-Band TBD	40 TBD	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle
Spacecraft K-Band Transmitter Frequency TBD	40	Pulse Modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle

4.0 QUALITY ASSURANCE REQUIREMENTS

The Contractor shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. The Contractor shall provide a verification matrix defining the method of verification for each specific requirement of this document. Verification methods include inspection, analysis, test or a combination of these techniques.

4.1 RESPONSIBILITIES OF THE CONTRACTOR

4.1.1 Quality Assurance System

The Contractor shall have a registered Quality System to meet the requirements of AS9100C. GSFC may request a copy of the Registration Certificate annually as evidence of continued compliance.

4.1.2 In-Process Inspections

The Contractor is responsible for performing all in-process inspections and tests necessary to ensure conformance to this specification.

4.1.3 Source Inspection

Government Source Inspection is required. All work on this order is subject to inspection and test by the Government. The Government Quality Representative who has been delegated the GSFC Quality Assurance function on this procurement shall be notified immediately upon receipt of this order. The Government Representative shall also be notified 5 days in advance of the time articles or materials are ready for inspection or test. Shipment may not be made until inspected by or documented authorization to ship is received from, the Government Representative.

Mandatory government source inspection points include, but are not limited to, the following assembly steps:

- Solder joints and soldering applications in the assembly to inspect compliance with requirements of IPC J-STD-001ES. This inspection shall occur prior to staking and/or conformal coating.

- Staking and conformal coating practices of printed wiring boards and electronic assemblies used in the assembly to inspect compliance with the requirements of IPC J-STD-001. This inspection shall occur prior to camera housing closeout.

Mandatory government source inspections may be waived by a Government CSO. Written approval must be obtained prior to waiving mandatory government source inspections signed by the COTR and CSO.

The Contractor shall provide "Right of Access" to GSFC, their customer and regulatory authorities. Access shall include all facilities and quality records involved in this order. The Contractor will be notified if the access is required.

4.1.4 Counterfeit Parts Prevention

The Contractor must certify in writing that counterfeit parts are not included in this shipment. Should suspect/counterfeit parts be furnished under this order, such items shall be impounded by GSFC. The Contractor shall promptly replace such suspect/counterfeit parts with parts acceptable to the buyer and the Contractor shall be liable for all costs, including but not limited to buyer's internal and external costs.

4.1.5 GIDEP Participation

The Contractor shall participate in the GIDEP program in accordance with the requirements of the GIDEP S0300-BT-PRO-010 and S0300-BU-GYD-010. Contractor shall notify GSFC, prior to delivery, of any GIDEP notices that affect items to be delivered to GSFC, and the disposition which has been taken for the affected hardware.

4.1.6 Sub-tier Suppliers

QA Requirements imposed within this P.O. must be ‘flowed’ to sub-tier suppliers. The Contractor shall determine the QA requirements that are applicable to the sub-tier Suppliers. GSFC shall be notified of any changes in product and/or process, changes of suppliers, or changes of manufacturing facility location. Prior to implementing any of these changes, the Contractor shall obtain GSFC’s approval.

5.0 VERIFICATION REQUIREMENTS

The Contractor shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. The Contractor shall provide a verification matrix defining the method of verification for each specific requirement of this document.

5.1 VERIFICATION RATIONALE

Verification of the assembly shall be by inspection, analysis, testing, or similarity at either the component or the system level. The verification methods are described below:

- Inspection: The assembly (or applicable component) shall be thoroughly inspected or reviewed to validate that the hardware has been built to the individual assembly drawings. Inspection or review shall also be used when it is more efficient or applicable to demonstrate compliance to requirements rather than perform calculable testing or analysis.

- Analysis: The assembly (or applicable component) not previously qualified or flown shall be analyzed when analysis is the most efficient way to demonstrate capability to meet or exceed expected environmental conditions.

- Test: The assembly (or applicable component) shall be tested to simulate the environmental and operational conditions which the flight hardware is expected to encounter. Functional testing or demonstrations shall be performed before, during (if applicable), and after each test. Certification by test includes demonstration of function.

- Similarity: Certification data for assembly components previously qualified or flown shall be reviewed to verify that these components' prior certification requirements meet or exceed the current mission requirements. The review shall cover structures, materials, environmental, and operational requirements.

5.2 INSPECTION

Verification by inspection includes visual inspection of the physical hardware, a physical measurement of a property of the hardware, or the documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

5.2.1 Final Inspection

The Contractor shall perform a final inspection of the completed hardware. The final inspection shall include, as a minimum, the following actions:

- A 100% dimensional inspection to verify conformance to all dimensions, tolerances, and mass as specified by the Contractor ICD.
- A visual inspection for cosmetic defects and workmanship, and for proper marking and serialization.
- An electrical inspection to verify conformance of exterior electrical interfaces.
- A documentation review, either deliverable or via source inspection, to ensure conformance of in-process test and inspection results to the Contractor's established requirements.

5.3 ANALYSIS

Verification of performance or function through detailed analysis, using all applicable tools and techniques, is acceptable with GSFC COTR approval.

5.4 TEST

Represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

Performance parameter measurements shall be taken to establish a baseline that can be used to assure that there are no data trends established in successive tests that indicate a degradation of performance trend within specification limits that could result in unacceptable performance in flight.

5.4.1 Test Failure and Control of Nonconforming Product

In the event of a failure or non-conformance of a test article to its specified design requirement during the certification tests, Materials Review Board (MRB) authority is not delegated. Non-conforming material shall not be forwarded to GSFC without written approval from GSFC. The manufacturer shall notify GSFC of all non-conformances in writing. Approval for use may be granted by MRB, and delivery may be authorized with this written approval. Request for shipment approval must be requested for each specific occurrence.

5.4.2 Failure During Tests

The test shall be stopped if equipment fails during testing in cases where this failure will result in damage to the equipment. Otherwise, the test shall be completed to obtain as much information as possible. No replacement, adjustment, maintenance, or repairs are authorized during testing. This requirement does not prevent the replacement or adjustment of equipment that has exceeded its design operating life during tests, providing that after such replacement, the equipment is given as many tests as are necessary to assure its proper operation. A complete record of any exceptions taken to this requirement shall be included in the test report.

5.4.3 Modification of Hardware

Once the formal acceptance test has started, cleaning, adjustment, or modification of test hardware shall not be permitted.

5.4.4 Re-Test Requirements

If any event, including test failure, requires that a component be disassembled and reassembled, then all tests performed prior to the event must be considered for repeat. If the unit has multiple copies of the same build, then all units must be examined to determine if the problem is common. If all copies require disassembly for repair, then each must receive the same test sequence.

5.5 REQUIRED VERIFICATION METHODS

The following measurements, tests, environments, and inspections are required to be performed by the Contractor for each completed VSS camera assembly to provide assurance that it meets its specified performance, functional, environmental, and design requirements. Each test or demonstration is described below.

- Weight and Envelope Measurements
- Initial Optical Alignment, Performance and Functional Tests
- EMI/EMC Tests
- Loads Test (Protoflight only)
- Sine Vibration
- Random Vibration
- Thermal Vacuum
- Final Alignment, Performance and Functional Tests

5.5.1 Weight and Envelope Measurements

Measurement of the weight and envelope of the VSS camera shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program.

5.5.2 Optical Alignment, Performance and Functional Tests

The VSS camera shall be tested to demonstrate compliance with performance requirements, including alignment if necessary. Performance Tests are detailed functional tests conducted under conditions of varying internal and external parameters with emphasis on all possible modes of operation for the component. A Performance Test shall be conducted at the beginning and end of each acceptance test. Functional Tests are abbreviated Performance Tests done periodically during or following the component environmental testing in order to show that changes or degradation to the component have not resulted from environmental exposure, handling, transporting, or faulty installation.

5.5.3 EMI / EMC Test

The EMI/EMC test indicated in 3.8.15 shall be performed on the Protoflight Unit.
It is encouraged to perform these EMI/EMC tests as early as possible in the development. All tests shall be performed with the component in its most sensitive mode for susceptibility testing and in its most noisy mode as appropriate for the EMI emission test.

5.5.4 Load Tests

Structural design loads per the levels in Table 3.1 shall be applied to protoflight hardware. There is no requirement to strength test flight hardware that has already been strength tested through a protoflight program (ie, there is no “acceptance level” strength test requirement for flight hardware).

Structural Loads testing can be verified by performing either a fixed frequency Sine Burst test, or a series of static loads pull tests.

No permanent deformation may occur as a result of the loads test, and all applicable alignment requirements must be met following the test. Components that require alignment will have an alignment check following loads testing. A performance test will be conducted to verify that no damage occurred due to the loads test. Components do not have to be powered during static loads tests.

5.5.5 Sine Burst

A simple Sine Burst test following the random vibration test in each axis is a convenient method to conduct a structural loads test. This test applies a ramped sine input at a sufficiently low frequency such that the test item moves as a rigid body. An analysis is required to show that a base drive Sine Burst test will not cause over-test or under-test in some areas of the structure.

Duration: 5 cycles of full level amplitude.

5.5.6 Static Pull

Static pull tests are another method to perform loads testing and can be applied at flight interfaces in a static test facility. The loads can be applied either as component loads applied simultaneously, or the single resultant vector load can be applied to the test point. Strain gages are generally positioned around the test point to verify deflection predictions from the analytical model.

Test Duration: 30 seconds

5.5.7 Random Vibration

The VSS camera shall be subjected to a random vibration test along each axis to the appropriate levels shown in Table 3.2. The test item shall be mounted to the test fixture as it would be mounted to the spacecraft. A functional test shall be performed before the start of testing and after a test in each axis.

Prior to the test, a survey of the test fixture/exciter combination will be performed to evaluate the fixture dynamics and the proposed choice of control accelerometers.

The duration for the test shall be 1 minute per axis for Acceptance and Protoflight Test.

5.5.8 Sine Vibration

The VSS camera shall be subjected to swept sine vibration testing to the appropriate levels. These levels will be provided by NASA/GSFC at a later date. The sweep rate shall be 4 octaves/minute for Acceptance and Protoflight Tests.

The Signature Sine sweep will be conducted on each component before and after vibration testing in each axis. This test is a tool to verify no change in structural integrity from testing and to verify the primary resonant frequency meets requirements.

5.5.9 Thermal Vacuum Test

The VSS camera shall be cycled in vacuum at temperatures beyond those predicted on orbit. Each VSS camera unit shall be cycled a total of eight (8) times (see Figure 4.5.7). During these tests, chamber pressure shall be less than 1.33 X 10-3 Pa. (1 X 10-5 torr).

During thermal vacuum testing the VSS camera shall be in flight configuration. Thermal blankets may be omitted to speed the transition times between temperature extremes.

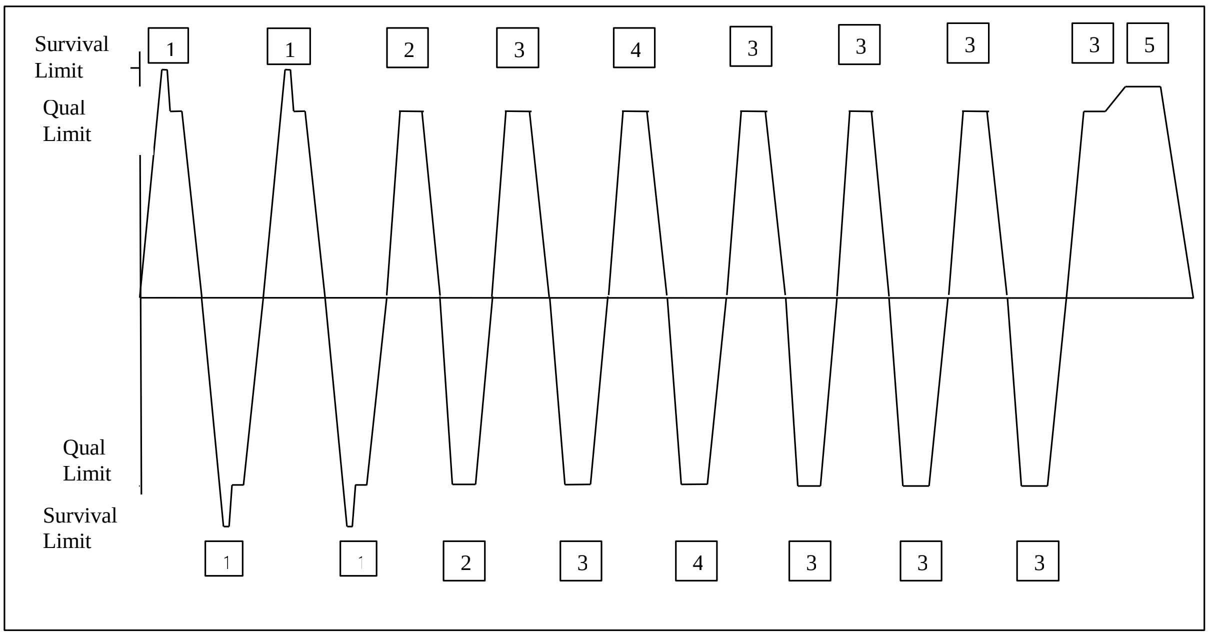

Figure 5-1: Thermal Vacuum Cycling

1= Achieve survival temp, stabilize 1 hour, return to QUAL temperature, turn on, soak at test temperature 4 hours, run performance test.

2= Soak at test temperature 4 hours, run performance test, voltage = 5.5 V

3 = Soak at test temperature 4 hours, run performance test, voltage = 5.0 V

4= Soak at test temperature 4 hours, run performance test, voltage = 4.5 V

5= Bakeout phase

5.5.9.1 Temperature Transitions

Transitions from cold to hot conditions increase contamination hazards because material that has accreted on the chamber walls may evaporate and deposit on the relatively cool test item. Transitions shall be conducted at rates of 1° C/min or less to prevent that from occurring. Testing shall start with a hot soak and end with a hot soak to minimize this risk.

5.5.9.2 Electrical System Performance

The electrical system and performance will also be verified for minimum, maximum, and nominal voltages at minimum and maximum temperatures. The electrical system and functionality will also be verified for minimum, maximum, and nominal voltages during temperature transitions.

Maximum Secondary Voltage:	5.5 V
Nominal Secondary Voltage:	5.0 V
Minimum Secondary Voltage:	4.5 V

Functional tests or performance tests will be conducted during the hot and cold soaks. Immediately following the component thermal vacuum cycling will be the bakeout phase to eliminate volatiles. The camera is not expected to be operational during bakeout testing. See Figure 5-1.

First 2 cycles (all units):

- During the transition from cold to warm, switch component OFF, increase temperature to survival temperature for 1 hour, then return to qualification temperature, verify that component turns ON, and verify nominal performance once the component has reached the qualification temperature. Begin hot soak.

- During the transition from warm to cold, switch component OFF, decrease temperature to survival temp for 1 hour, then return to qualification temperature, verify that component turns ON, and verify nominal performance once the component has warmed to the qualification temperature. Begin cold soak.

Soak time at each temperature: 4 hours, run Performance Test during soak.

Number of complete cycles:

Protoflight Unit:	8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Qualification temperatures per Table 3-4 as the “test temperature.”
Flight / Spare Unit:	8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Acceptance temperatures per Table 3-4 as the “test temperature.”

5.5.9.3 Bake-out / Outgassing Certification Requirements

The VSS camera shall be baked-out prior to delivery to GSFC. The bake-out performance shall be measured using a temperature-controlled Quartz Crystal Microbalance (TQCM) at chamber pressures below 10-5 torr. The bake-out / outgassing certification shall be performed at the VSS camera maximum on-orbit temperature and the TQCM shall be controlled at –40 °C or lower throughout the test to measure total outgassing of Volatile Outgassed Condensables (VOC's), without influence of water vapor condensation. The bake-out / outgassing certification test shall be deemed successful when the outgassing rates are 2.5 x 10-8g/s or below per hour for 5 consecutive hours. The following test data shall be collected and delivered to GSFC: chamber configuration, TQCM reading (taken as a minimum every 0.5 hours), hardware temperature, chamber/ shroud temperature, TQCM temperature, and pressure.

Additional Clarification:

If the Contractor's vacuum chamber uses a shroud to elevate and sustain an item's temperature for bake-out, background TQCM measurements must be conducted before the bake-out with chamber in bake-out configuration in order to determine flight hardware contribution. Provision must be made to measure effectiveness of pump system. The value of a chamber's exit conductance is generally much lower than the rating of its pump alone. This is necessary to relate TQCM deposition rates to source outgassing rates.

If the Contractor uses a bake-out box, the chamber should feature a shroud held at temperatures below the TQCM reading so as not to interfere with it, otherwise the bake-out box should feature a coldplate near the bake-out box vent to collect contaminants that would otherwise interfere with the TQCM readings. In such cases, knowledge of the chamber pump effectiveness is not necessary.

Alternate methods of bakeout may be considered for discussion at any Kick-off Meetings or Critical Design Review.

5.5.9.4 Magnetic Dipole Verification

The magnetic requirement of section 3.9.13 may be satisfied by analysis, but any component or subsystem that exceeds the requirements found in 3.9.13 shall be subjected to a magnetic test. The magnetic test shall be performed on every serial number for components designated for testing.

If performed, the test shall occur after vibration testing. This is because magnetic fields induced by the vibration lab may reside in the component following the vibration test sequence.

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6.0 APPENDIX A: ABBREVIATIONS AND ACRONYMS

Al	Aluminum
CE	Conducted Emissions
COTR	Contracting Officer Technical Representative
CS	Conducted Susceptibility
CSO	Chief Safety and Mission Assurance Officer
CVCM	Collected Volatile Condensable Materials
DA	Double Amplitude
EEE	Electrical, Electronic, and Electromechanical
EGSE	Electrical Ground Support Equipment
EM	Engineering Model
EMI	Electro Magnetic Interference
EOL	End of Life
GEO	Geosychronous Orbit
GSE	Ground Support Equipment
HDL	Hardware Description Language
I&T	Integration and Test
LET	Linear Energy Transfer
LISN	Line Impedance Simulation Network
LVDM	Multipoint Low-Voltage Differential Signaling
LVDS	Low-Voltage Differential Signaling
M ohms	Mega ohms
MEB	Materials Engineering Branch
MIUL	Materials Identification and Usage List
MRB	Materials Review Board
MUA	Material Usage Agreement
NDE	Nondestructive Evaluation
PWB	Printed Wing Boards
RE	Radiated Emissions
RS	Radiated Susceptibility
RSV	Restore Service Vehicle
SC	Spacecraft
SEB	Single Event Burnout
SEGR	Single Event Gate Rupture
SEE	Single Event Effects
SEU	Single Event Upset
SEM	Scanning Electron Microscope
SOW	Statement of Work
SPL	Sound Pressure Level
TID	Total Ionizing Dose
TML	Total Mass Loss
VSS	Vision Sensor Subsystem
WSF	Water-Soluble Flux