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Magnetometer Sun Sensor (MSS)

Customer User Guide

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Revisions

Revision	Date	Changes
01	6/27/2025	• Initial Revision
02	5/28/2026	• Section 5.1 – Updated connector information • Section 6.2 – Updated telemetry table • Section 6.3 – Provided additional clarification on commands • Appendix B – Updated MICD

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1.0 Objective

This document offers guidance on integrating the Umbra Magnetometer Sun Sensor (MSS). The MSS combines a magnetometer and a coarse sun sensor (CSS) to measure Earth's magnetic field and determine the spacecraft's orientation relative to the sun. Designed for and proven on Falcon 9 rideshare missions to Low Earth Orbit (LEO), the MSS provides standard output formats compatible with other flight control systems and supports easy, "plug and play" integration with Umbra GNC Avionics.

2.0 Document References

This section contains the document number and description for documents that are referenced herein.

2.1 Umbra Documents

Number	Description
5041D0003	MAGNETOMETER SUN SENSOR MICD

2.2 Standard Documents

Number	Description
AS22759	WIRE, ELECTRICAL, FLUOROPOLYMER-INSULATED, COPPER or COPPER ALLOY
GSFC-STD-7000	GENERAL ENVIRONMENTAL VERIFICATION STANDARD (GEVS)
MIL-STD-461	MILITARY STANDARD: ELECTROMAGNETIC INTERFERENCE
SAE-AS50881	WIRING, AEROSPACE VEHICLE

3.0 Document Authority

In the case of a conflict between any dimensional, mounting pattern, or pinout information defined within this document and other information sources, the released mechanical and electrical drawings shall supersede this document.

3.1 Document Disclaimer

DISCLAIMER: This User Guide is intended to provide a summary of our knowledge and guidance on the use of this item. The information contained herein has been compiled from sources considered by Umbra Lab, Inc. to be reliable and is accurate to the best of Umbra's knowledge. It is not intended to be an all-inclusive document on worldwide hazard communication regulations. This information is offered in good faith. Each user of this material needs to evaluate the conditions of use and design appropriate protective measures to prevent employee exposure, personal injury, property damage, or the release of any hazardous substances into the environment. Umbra assumes no responsibility for injury, damage, or loss sustained by the recipient or third parties, or for any damage to any property resulting from misuse of the product. Purchase and use of the product(s) identified herein are governed by the terms of sale under which you purchase the product(s) from Umbra Lab, Inc.

4.0 Hardware Handling

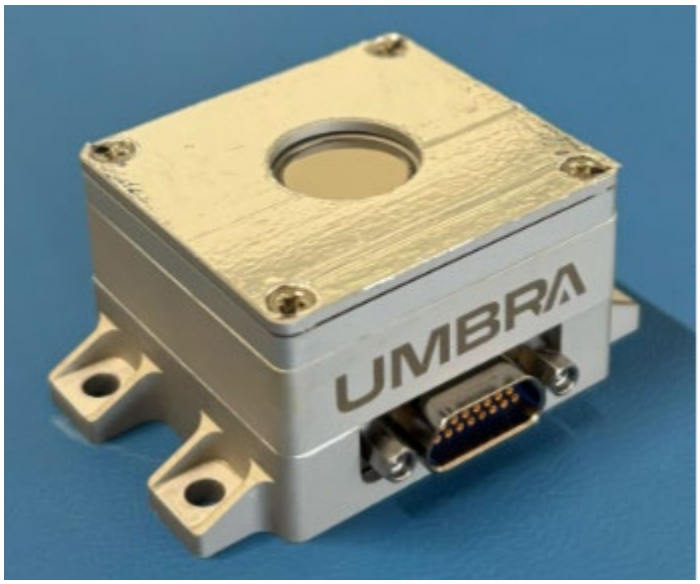


Figure 1. Magnetometer Sun Sensor (MSS)

4.1 Mechanical Handling

Avoid touching or contaminating the optical filter surface of the Umbra Magnetometer Sun Sensor (MSS).

Contact Umbra if any Umbra Magnetometer Sun Sensor (MSS) fails any procedure as described in this document or the User Guide. Do not continue the use of any Umbra Magnetometer Sun Sensor (MSS) with a suspected failure.

1. Ensure that any transportation of the Umbra Magnetometer Sun Sensor (MSS) occurs in an environment described in the “Storage and Transport Environments” section.
2. Do not drop the Umbra Magnetometer Sun Sensor (MSS). Only lift the Umbra Magnetometer Sun Sensor (MSS) by the chassis.
3. Do not disassemble the Umbra Magnetometer Sun Sensor (MSS)
4. To prevent damage to the sensor, do not lay the Umbra Magnetometer Sun Sensor (MSS) on the optical face surface of the component.

4.1.1 Hazards

The Umbra Magnetometer Sun Sensor (MSS) does not contain any hazardous materials subject to exposure during intended use.

4.1.2 ESD Sensitivity



The Umbra Magnetometer Sun Sensor (MSS) is sensitive to electrostatic discharge (ESD).

An ESD ground strap shall be worn by the person(s) handling the hardware. Refer to the ESD Standard for space hardware.

Failure to follow ESD requirements and recommendations may result in damage to components and/or personnel injury.

Follow ANSI/ESD S20.20 while handling ESD-sensitive components.

4.1.3 Unpacking

- If applicable, check shock detection stickers
- Remove assembly from transportation container
- Perform visual inspection for damage
- Take pictures as received
- Inspect connections, then reapply protective dust caps

4.2 Remove Before Flight (RBF) GSE

Items listed in Table 1 must be removed during hardware integration to the customer space vehicle bus.

Table 1. RBF Items

Item	Critical/Optional	Notes
Connector Dust Cap	Critical	J1 Connector

4.3 Electrical Mate & Demate

For further information, please refer to the MICD in Appendix B.

Table 2. Electrical Connector

Connector Designator	Assembly Connector	Mating Flight Connector
J1	MMDS-015-H2-N01	MMDP-015-H2

4.4 Connector Cable Strain Relief

See Appendix B MICD. It is recommended to secure all harnessing interfacing to the Umbra Magnetometer Sun Sensor (MSS) per the guidance in SAE-AS50881, which describes the installation of wiring harnesses.

4.5 Storage and Transport Environment

- Do not store the Umbra Magnetometer Sun Sensor in direct sunlight.
- Do not store the Umbra Magnetometer Sun Sensor in such a way that damages part markings.
- Ensure that critical RBF components are in place during all transport of the Umbra Magnetometer Sun Sensor.

Table 3. Storage and Transport Environment

Parameter	Value
Storage Temperature	5°C to 35 °C
Storage Humidity	< 50% Relative Humidity

4.6 Operating Environment

Intended for LEO space radiation environment within specified operating temperatures.

Table 4. Operating Environment

Parameter	Value
Operational Temperature	-40°C to +80 °C

4.7 Survival Environment

Table 5. Survival Environment

Parameter	Value
Survival Temperature	-40°C to +100°C
Vibration	Qualified to 14.16 g RMS profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels.

Parameter	Value
Shock	Qualified to 1000 g peak profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels.
Minimum Survivable Total Ionizing Dose	Designed to withstand at least 30 krad TID

4.8 Mounting Information

See Appendix B for the MICD for the Umbra Magnetometer Sun Sensor (MSS), which provides mounting information.

5.0 Electrical Properties

Table 6. Electrical Properties

Property	Typical Value	Notes
Operating Voltage	5 ± 1 V	
Over-Voltage Tolerance	≤ 36 V	
Average Power Draw	≤ 50 mW	At 5 V operating
Peak Power Draw	≤ 50 mW	At 5 V operating

5.1 Connector Pinouts

The Umbra Magnetometer Sun Sensor (MSS) connector (MMDS-015-H2-N01) is shown in Appendix B. Refer to Table 7 for pinout and Figure 2 for the mating face view.

Table 7. Connector Pinout

Pin	Signal
1	Input Power
2	Input Power
3	Ground
4	Ground
5	RS422 RX + (Host to MSS)
6	RS422 RX - (Host to MSS)

Pin	Signal
7	RS422 TX + (MSS to Host)
8	RS422 TX – (MSS to Host)
9	Input Power
10	Input Power
11	Ground
12	N/C
13	N/C
14	N/C
15	N/C

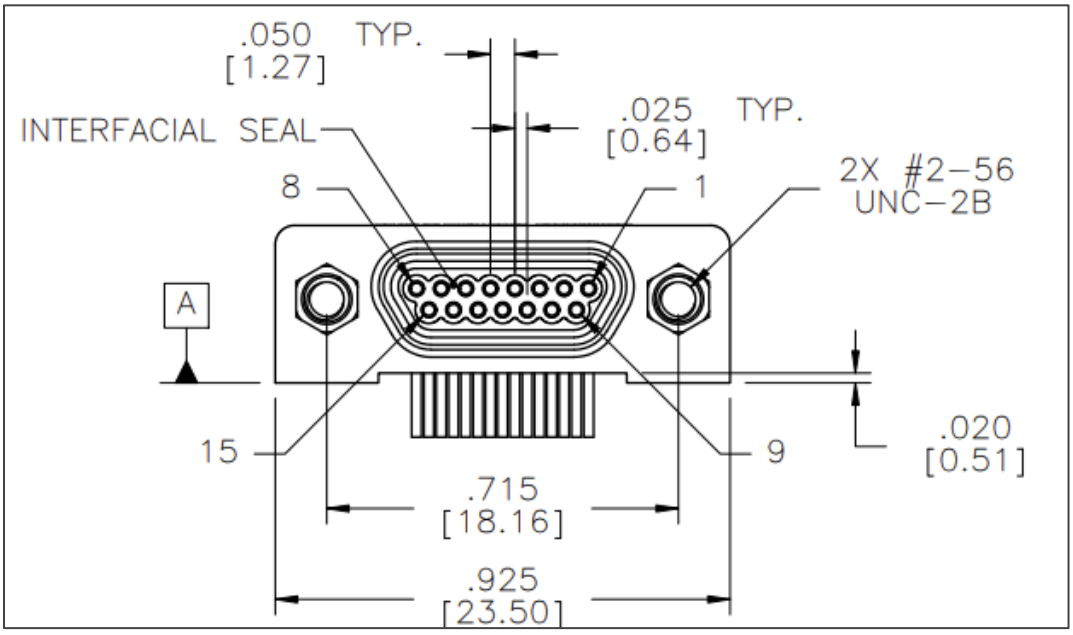


Figure 2. MMDS-015-H2-N01 Connector Mating Face View

5.2 Harnessing Recommendations

Space-rated harnesses connecting to the Umbra Magnetometer Sun Sensor (MSS) should use wire in accordance with SAE AS22759, specification M22759.

5.3 Grounding Block Diagram

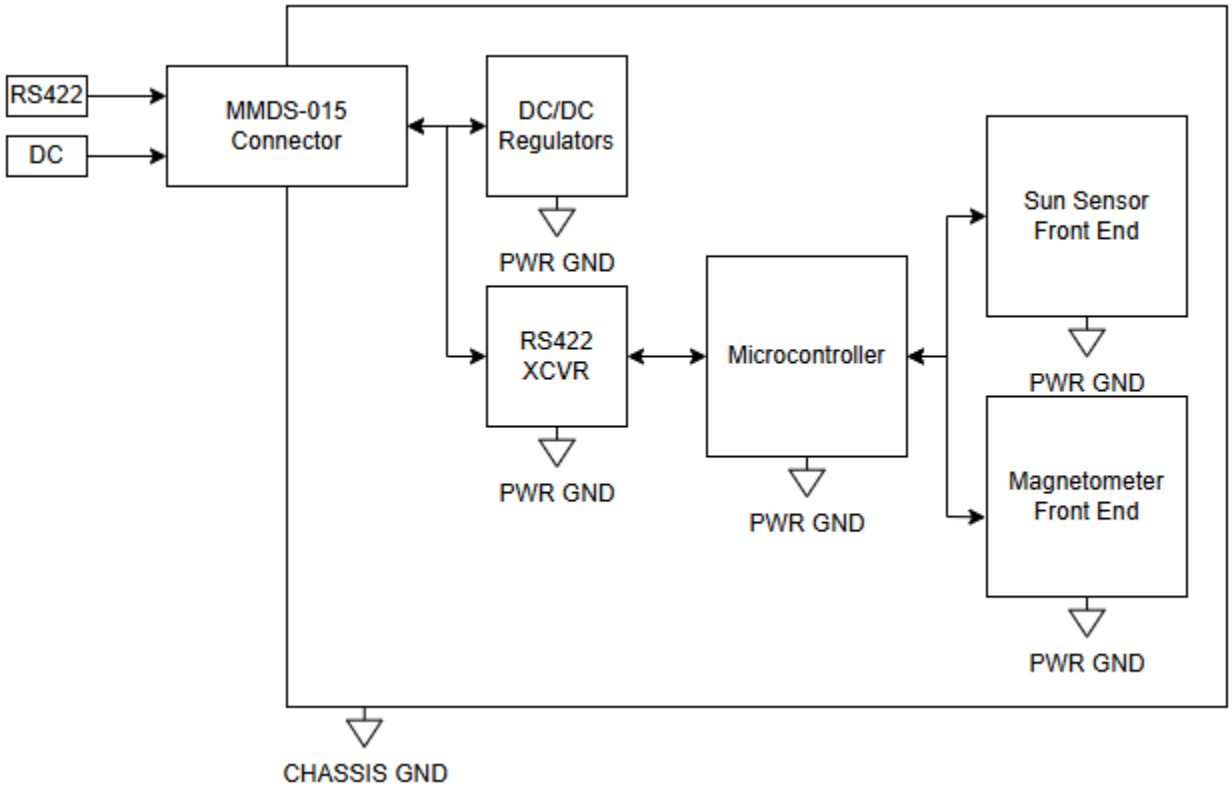


Figure 3. Grounding Block Diagram

5.4 EMI/EMC Properties

The Umbra Magnetometer Sun Sensor (MSS) contains a sensitive magnetometer and is therefore sensitive to Electromagnetic Interference.

The Umbra Magnetometer Sun Sensor (MSS) has not been tested for Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) per MIL-STD-461. It has been successfully tested for self-compatibility with X-Band, S-Band, and L-Band radios. Contact Umbra for more information.

5.5 Material Properties

All Umbra products are manufactured from materials deemed space-rated for their low outgassing and survivability in space environments. See Appendix B for the Umbra Magnetometer Sun Sensor (MSS) MICD for more information on material properties.

6.0 Software

6.1 Communication

The Umbra Magnetometer Sun Sensor (MSS) communicates via RS-422 and, by default, continuously streams telemetry as response packets with a telemetry payload defined in 6.2. The unit may also be commanded as defined in 6.3.

6.2 Telemetry

The Umbra MSS operates in push mode, transmitting data to the host at 20 Hz. Telemetry will be formatted as a response packet with the following payload:

Table 8. Telemetry Payload Fields

Payload Byte Index	Telemetry Name	Type	Value
0	mag_values_x	Float32	Magnetometer X value (Gauss)
4	mag_values_y	Float32	Magnetometer Y value (Gauss)
8	mag_values_z	Float32	Magnetometer Z value (Gauss)
12	css_vector_x	Float32	Sun Sensor (CSS) X unit vector (0-1)
16	css_vector_y	Float32	Sun Sensor (CSS) Y unit vector (0-1)
20	css_vector_z	Float32	Sun Sensor (CSS) Z unit vector (0-1)
24	mss_temps_0	Float32	Degrees (°C)
28	mss_temps_1	Float32	Degrees (°C)
32	frame_count	uint16	Telemetry frame count since boot, wraps at 65535
34	css_data_raw_0	Float32	Current-like CSS diode (dark_bias - ADC)
38	css_data_raw_1	Float32	Current-like CSS diode (dark_bias - ADC)
42	css_data_raw_2	Float32	Current-like CSS diode (dark_bias - ADC)
46	css_data_raw_3	Float32	Current-like CSS diode (dark_bias - ADC)

Notes:

- `css_data_raw` values are raw, uncalibrated sensor measurements, used for advanced applications or troubleshooting. They are current-like values used by onboard CSS processing.
- `frame_count` is used to verify stream continuity and detect dropped frames.

6.3 Commanding

The MSS supports command/response serial control over an RS-422 physical interface.

6.3.1 Framing, Escaping, and CRC

All command and response packets use SLIP-style framing with CRC16-CCITT-FALSE.

Table 9. SLIP-Style Frame Encoding Definition

Item	Value	Notes
Frame delimiter (`FEND`)	`0x7E`	Marks both the start and end of each frame.
Escape byte (`FESC`)	`0x7D`	Indicates that the following byte is an escaped value.
Escaped `0x7E`	`0x7D 0x5E`	`FESC TFEND`
Escaped `0x7D`	`0x7D 0x5D`	`FESC TFESC`
CRC type	CRC-CCITT-FALSE	polynomial = `0x1021` initial value = `0xFFFF` no reflection xorout = `0x0000`
CRC placement	Last 2 bytes before trailing `0x7E`	Computed over unescaped payload bytes
CRC byte order	Little-endian	Low byte first, then high byte

Packet construction order:

1. Build unescaped packet bytes.
2. Compute the CRC-16/CCITT-FALSE value over the unescaped packet bytes
3. Append the CRC to the packet body in little-endian order: low byte first, then high byte.
4. Apply escaping to the packet body and appended CRC (`0x7E` → `0x7D 0x5E`, `0x7D` → `0x7D 0x5D`)
5. Add `0x7E` frame delimiter at the beginning and end of the escaped packet.

Note: Escaping is applied after CRC calculation. The receiver reverses escaping before validating the CRC.

6.3.2 Command & Response Unescaped Packet Format

The following is the definition of the command and response packets before SLIP-style escaping and framing is applied:

Table 10. Command Unescaped Packet

Byte Offset	Field	Type	Notes
0	cmd_type	uint8	Corresponds to Command ID
1...N	payload	variable	
N+1...N+2	crc16	uint16	

Table 11. Response Unescaped Packet

Byte Offset	Field	Type	Notes
0	response_type	uint8	Returns 0x7F
1	cmd_type	uint8	Corresponds to Command ID
2	status	uint8	status = 1 if accepted
3...N	payload	variable	
N+1...N+2	crc16	uint16	Little endian

6.3.3 Commands

The following are available commands for the MSS unit:

Table 12. Command IDs

Item	Value	Notes
SET_TELEMETRY_CADENCE_HZ	0x01	Payload: 1 Hz resolution, Up to 20 Hz
SET_MSS_CONSTANTS	0x02	Payload: mask (uint16) + persist (uint8) + constant (10 x float32)
APPLY_MSS_DEFAULTS	0x03	No Payload
RETURN_MSS_CONSTANTS	0x04	No Payload; Returns Constants

6.3.3.1 SET_TELEMETRY_CADENCE_HZ Command Details

Sets the streaming telemetry rate from the MSS unit. Acceptable rates are integer values from 1 to 20 Hz (20 Hz is the default).

Table 13. SET_TELEMETRY_CADENCE_HZ Payload Layout (Little-endian)

Byte Offset	Field	Type	Notes
0	telemetry_rate	uint8	Value from 1 to 20 Hz

6.3.3.2 SET_MSS_CONSTANTS Command Details

Defines constants used by the MSS using the following payload format. Persist allows for writing values to NVM (see 6.4 for more details.)

Note: Modifying constants may affect factory calibration and is not recommended without guidance from the Umbra support team.

Table 14. SET_MSS_CONSTANTS Payload Layout (Little-endian)

Byte Offset	Field	Type	Notes
0..1	mask	uint16	See Mask Bits table. Mask bits set to 1 will update with corresponding constant array value
2	persist	uint8	persist = 1 to write to NVM
3..42	constants[10]	10 x float32	See the Float Array table

Table 15. SET_MSS_CONSTANTS Mask Bits

Bit	Constant Value	Applies To
0	g	constants[0]
1	h	constants[1]
2	d	constants[2]
3	dx_bias	constants[3]
4	dy_bias	constants[4]
5	theta_deg	constants[5]
6	dark_bias	constants[6]

Bit	Constant Value	Applies To
7	mag_offset_x	constants[7]
8	mag_offset_y	constants[8]
9	mag_offset_z	constants[9]

Table 16. SET_MSS_CONSTANTS constants[10] Float32 Array Order

Array Index	Constant
0	g
1	h
2	d
3	dx_bias
4	dy_bias
5	theta_deg
6	dark_bias
7	mag_offset_x
8	mag_offset_y
9	mag_offset_z

Table 17. SET_MSS_CONSTANTS Frame Sizing

Metric	Value	Notes
Payload bytes	43	before CRC/SLIP framing (2 + 1 + 10*4)

6.3.3.3 RETURN_MSS_CONSTANTS Command Details

Returns the constants currently loaded on the MSS unit in the following payload format:

Table 18. RETURN_MSS_CONSTANTS Response Payload Layout

Byte Offset	Field	Type	Notes
0..39	constants[10]	10 x float32	Same order as SET_MSS_CONSTANTS
40	fw_version_major	uint8	
41	fw_version_minor	uint8	
42	fw_version_patch	uint8	
43..46	fw_release_date	uint32	YYYYMMDD
47..48	last_frame_count	uint16	
49	sensor_errors	uint8	
50..51	serial_number	uint16	Unit serial number

Table 19. RETURN_MSS_CONSTANTS Payload Size

Metric	Value	Notes
Payload bytes	52 bytes	Before CRC/SLIP framing

6.3.3.4 APPLY_MSS_DEFAULTS Command Details

Sets MSS constants to factory defaults (not calibrated values). Not recommended to use unless directed by the Umbra support team.

6.4 Memory

Calibration/configuration values may be applied in RAM or persisted to non-volatile memory.

Persistence control:

- Use `SET_MSS_CONSTANTS` with `persist = 0` for runtime-only updates
- Use `SET_MSS_CONSTANTS` with `persist = 1` to write values to NVM

`APPLY_MSS_DEFAULTS` restores factory default constants. Warning: Calibration data will be lost.

6.5 Error Mitigation

Contact Umbra if measured telemetry deviates from expected values.

7.0 Performance Specifications

The Umbra Magnetometer Sun Sensor (MSS) detects peak solar values using a 4-quadrant APD to generate accurate solar pointing angle coordinates for the host spacecraft. Precise magnetic field data is also provided for all 3 axes.

7.1 Field of View (FOV)

The Umbra Magnetometer Sun Sensor (MSS) has a Field of View (FOV) of 110 degrees x 110 degrees.

7.2 Measurement Range

Single axis magnetic range of +/- 4 Gauss

7.3 Accuracy

The accuracy of the Umbra Magnetometer Sun Sensor (MSS) at boresight is < 1 degree.

The accuracy of the Umbra Magnetometer Sun Sensor (MSS) edge FOV is 8 degrees.

7.4 Sensitivity

Single Axis Magnetic Sensitivity: 1 mGauss

Single Axis Magnetic Accuracy: ± 50 mGauss

8.0 Operational Procedures



Follow all requirements and recommendations in Section 4.1 Mechanical Handling while carrying out all procedures in this section. The Umbra Magnetometer Sun Sensor (MSS) may be damaged if mechanical handling requirements and recommendations are not followed.

8.1 First Use Procedure

The following must be completed before any other procedures in this user guide are carried out.

1. Inspect the connector and ensure it is free of FOD.
2. Power on the Umbra Magnetometer Sun Sensor (MSS) and read the telemetry from the RS-422 interface. See Section 6.2 Telemetry for packet structure.

8.1.1 Assembly

Not Applicable

8.1.2 Initial Checkout

1. Power on the MSS unit and verify the RS-422 telemetry stream
2. Expose the unit to a magnetic field up to 4 Gauss, and verify reading correctly to within ± 1 mGauss.
3. Verify the four CSS diode telemetry channels respond to illumination changes and dark conditions. Interpret these channels as current-like values (`dark_bias` - ADC), not ADC counts.
4. Repeat Steps 1 – 3 with the full available avionics suite running to ensure there is no magnetic interference or cross-talk.
5. For final sun sensor checkout, ensure the +Z face is pointing up. Record the sun pointing vector and then illuminate the MSS with an ambient light pointed from the +Z axis at the device, and ensure the host spacecraft telemetry for the sun pointing vector indicates a change in the Z-axis pointing vector. It is advised to obtain a baseline reading with the sensor covered before reading with an ambient light source present.

8.1.3 Initial Configuration

Not Applicable

8.2 Sample Procedure

Not Applicable

8.2.1 Success Criteria

Not Applicable

8.2.2 Configuration and Equipment

Not Applicable

Table 20. Equipment List

Part Number	Part Name	Configuration	Quantity
N/A			

8.2.3 Test Procedure

Not Applicable

8.3 On-Orbit Checkout

With the Umbra Magnetometer Sun Sensor (MSS) powered on, perform the following checks to verify operation:

1. Read the XYZ sun-pointing vectors (`css_vector_x`, `css_vector_y`, `css_vector_z`) and verify the reported direction is consistent with the spacecraft orbital position and attitude at the measurement time.
2. Verify the four CSS diode telemetry channels (`css_data_raw_0` through `css_data_raw_4`) respond to solar illumination changes; values should increase/decrease with sun-pointing conditions and drop under dark conditions. These channels are current-like values (`dark_bias` - ADC), not raw ADC counts.
3. Read the XYZ magnetometer telemetry (`mag_values_x`, `mag_values_y`, `mag_values_z`) and verify the measured field vector is reasonable for the spacecraft orbital location and attitude during the measurement interval.
4. Read MSS temperature telemetry (`mss_temps_0`, `mss_temps_1`) and verify both values remain within the MSS operational range (-40 to 80°C).

Note: Pointing vector data will vary based on orbital specifics at the time of the readings.

Appendix A

Acronyms and Abbreviations

A.1 Acronyms and Abbreviations

CSS	Coarse Sun Sensor
ESD	Electrostatic Discharge
FOD	Foreign Object Debris
FOV	Field Of View
GEVS	General Environmental Verification Standard
GSE	Ground Support Equipment
LEO	Low Earth Orbit
MSS	Magnetometer Sun Sensor
MICD	Mechanical Interface Control Document
RBF	Remove Before Flight
TBD	To Be Determined
TBR	To Be Revised
TID	Total Ionizing Dose

A.2 Units

°C	Degrees Celsius
A	Ampere
Hz	Hertz
kΩ	Kiloohms
krad	Kilorad
m²	Square Meters
ms	Millisecond
V	Volts
W	Watts

Appendix B

Mechanical Interface Control Documentation

