Power Package

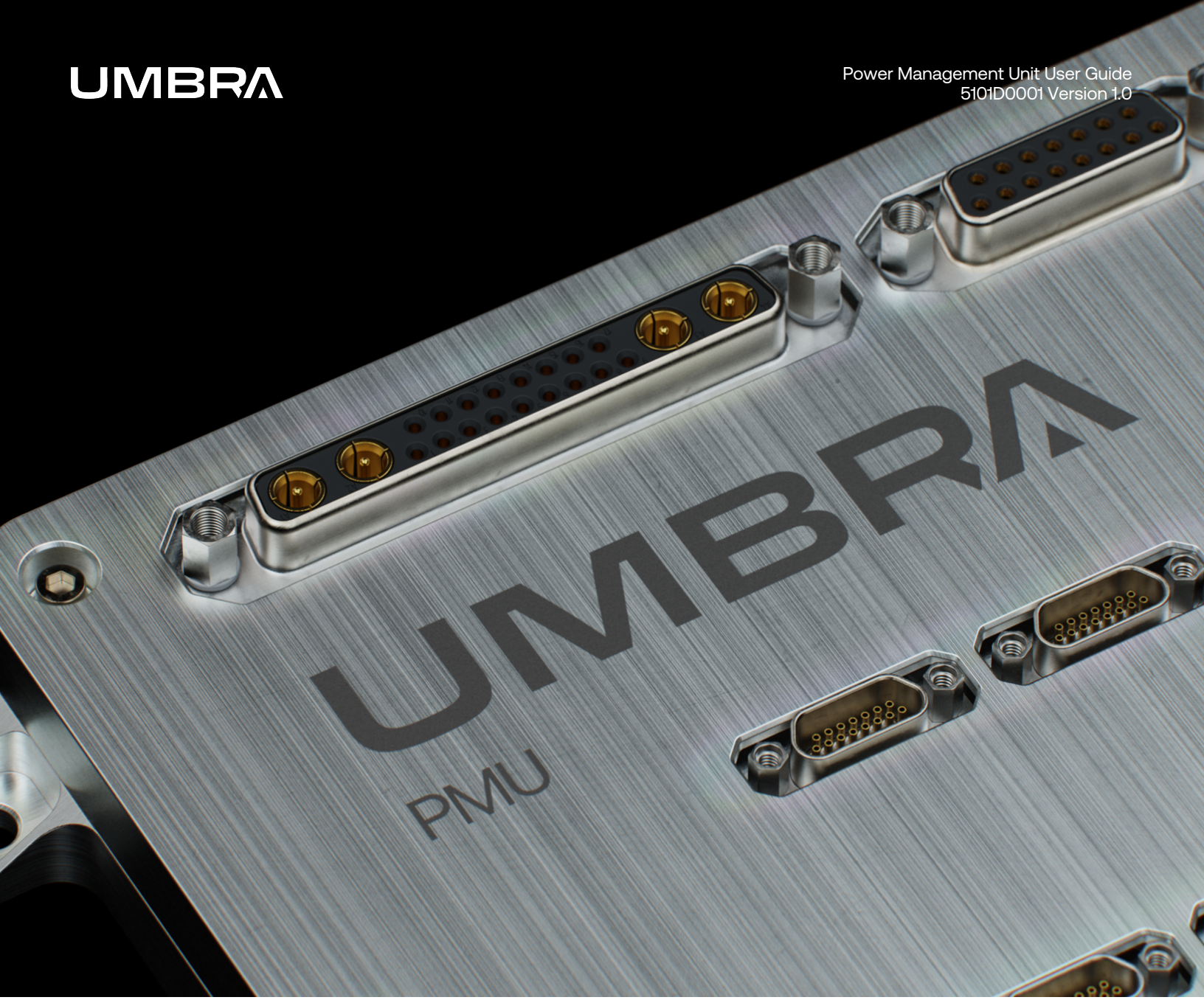
Click to quick navigate

Battery Module
8S1P 8-Cell Model

Battery Module
8S2P 16-Cell Model

Solar Array

Power Management Unit



Power Management Unit User Guide

Distribution Statement	Export Control
No Restrictions	No US Export Control Information

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1.0 Objective

This document provides user guidance for the integration of the Umbra Power Management Unit, referred to in this document as the PMU.

The PMU is designed to actively command and control the Umbra Power Package configuration including up to two 5081H0001 Umbra Solar Arrays (referred to in this document as the Solar Arrays), two 5071H0001 Umbra HDRMs (referred to in this document as the HDRMs), and four 5062H0001 Umbra Battery Module 8S2P (referred to in this document as the Battery Modules). These parts are collectively referred to as Power Package Peripherals.

Umbra Lab Inc. (Umbra) recommends the purchase of the PMU for customers seeking an all-in-one power system solution for their spacecraft. PMU capabilities include HDRM deployment, Solar Array shunting, and Battery Module heater control.

2.0 Document References

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

2.1 Umbra Documents

5101H10000	UMBRA POWER MANAGEMENT UNIT MICD
5062D0001	UMBRA BATTERY MODULE 8S2P USER GUIDE
5081D0001	UMBRA SOLAR ARRAY WITH HDRM USER GUIDE

2.2 Standard Documents

ANSI/ESD S20.20-2021	PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES, AND EQUIPMENT
49 CFR 172	CODE OF FEDERAL REGULATIONS HAZARDOUS MATERIALS TABLE
GSFC-STD-7000	GENERAL ENVIRONMENTAL VERIFICATION STANDARD (GEVS)
MIL-STD-461	MILITARY STANDARD: ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS REQUIREMENTS FOR EQUIPMENT
SAE AS22759	WIRE, ELECTRICAL, FLUOROPOLYER-INSULATED, COPPER OR COPPER ALLOY

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 in Appendix B and in referenced documentation shall supersede this document.

3.1 Revision Notes

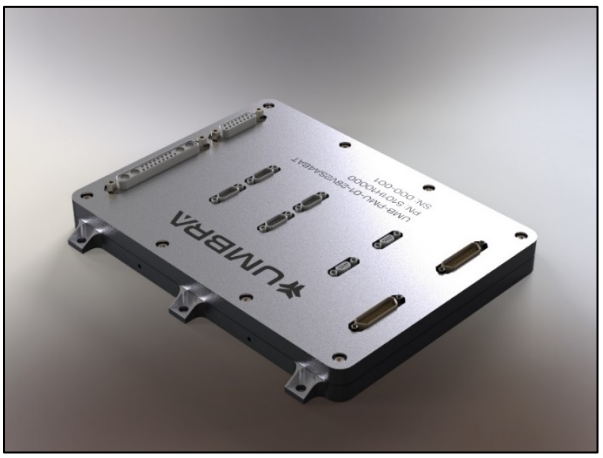
This document is Version 1.0.

3.2 Document Disclaimer

DISCLAIMER: This User Guide is intended to provide a brief summary of our knowledge and guidance regarding the use of this item. The information contained herein has been compiled from sources considered by Umbra to be dependable and is accurate to the best of Umbra's knowledge. It is not meant 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 the appropriate protective mechanisms to prevent employee exposure, personal injury, property damage or release to the environment of any hazardous substances. Umbra assumes no responsibility for injury, damage, or loss sustained by the recipient or third persons 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.

4.0 Hardware Handling

Figure 1. Umbra Power Management Unit (PMU)



All requirements and recommendations for safe handling of each Solar Array with HDRM as described in 5081D0001 must be followed for all PMU usage with each Solar Array and/or HDRM.

All requirements and recommendations for safe handling of each Umbra Battery Module as described in 5062D0001 must be followed for all PMU usage with each Umbra Battery Module.

The PMU is only designed for compatibility with the Power Package Peripherals described in this documentation. Do not substitute the power pack peripherals described in this documentation for any other battery modules or solar arrays, including other Umbra-produced battery modules or solar arrays. Contact Umbra if your mission profile requires the use of Power Package Peripherals not described in this documentation.

4.1 Mechanical Handling

Contact Umbra if PMU fails any procedure as described in this document. Do not continue use of any PMU with a suspected failure.

Ensure that any transportation of the PMU occurs in an environment described in Section 4.5 Storage and Transport Environment.

Do not drop the PMU.

Only lift the PMU by the chassis.

Do not lift the PMU by any attached harness.

Do not disassemble the PMU.

4.1.1 Hazards

The PMU does not contain any hazardous materials as defined by 49 CFR 172.

The PMU regulates the power generated by the Umbra Solar Array. The power generated by the Solar Array can potentially harm the user if not handled properly.

4.1.2 ESD Sensitivity

PMU is electrostatic discharge (ESD) sensitive.

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

- Check shock detection stickers
- Remove from protective case
- Perform visual inspection for damage
- Take pictures as received
- No cleanliness requirements or contamination risks

4.2 RBF/ Red Tag GSE

Items listed in Table 1. RBF Items must be removed before flight.

Table 1. RBF Items

Item	Critical/Optional
J1 Connector Dust Cap	Critical
J2 Connector Dust Cap	Critical
J4 Connector Dust Cap	Critical
J5 Connector Dust Cap	Critical
J6 Connector Dust Cap	Critical
J7 Connector Dust Cap	Critical
J8 Connector Dust Cap	Critical
J9 Connector Dust Cap	Critical
J10 Connector Dust Cap	Critical
J11 Connector Dust Cap	Critical

See Appendix B for more information.

4.3 Electrical Mate/Demate

Table 2. Electrical Connectors

Connector Designator	Assembly Connector	Mating Flight Connector
PMU J1	MMDS-513	MMDP-513
PMU J2	MMDS-513	MMDP-513
PMU J4	MMDP-009	MMDS-009
PMU J5	MMDP-009	MMDS-009
PMU J6	MMDS-015	MMDP-015
PMU J7	MMDS-015	MMDP-015
PMU J8	MMDS-015	MMDP-015
PMU J9	MMDS-015	MMDP-015
PMU J10	SND15S36000G	M24308/4-336
PMU J11	SCBM21WA4S36000G	680M21WA4PL411

See Section 5.1 Connector Pinouts for more information.

4.4 Connector Strain

Harnesses connecting to the PMU should be strain relieved to prevent damage to the system.

4.5 Storage and Transport Environment

Do not store the PMU in direct sunlight.

Do not store the PMU in such a way that damages part markings.

Ensure that critical RBF components are in place during all transport of the PMU.

Table 3. Recommended Storage Environment

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

4.6 Operating Environment

Table 4. Operating Environment

Parameter	Value

Operating Temperature	-30°C to +65°C

4.7 Survival Environment

Table 5. Survival Environment

Parameter	**Value**
Survival Temperature:	-40°C to +85°C
Random Vibration	Qualified to 14.16 Grms profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels
Shock	Qualified to 1000G 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 information about mounting the PMU.

It is recommended that the PMU be mounted within the bus.

5.0 Electrical Properties

Table 6. PMU Electrical Properties

Property	Typical Value	Notes
Operating Output Voltage Range	28 ± 4 V	Nominal Voltage: 28 V
Operating Output Current Range	0 - 40 A	

5.1 Connector Pinouts

See Section 6.1 Communication Parameters for more information on signal packet structure.

All PMU connector bodies are electrically connected to CHASSIS and isolated from GND (power ground) and GND_SA (solar array ground). All harness connector bodies and backshells should be isolated from GND and GND_SA as well – they will be electrically bonded to CHASSIS ground through the mating jackposts and jackscrews. See Figure 7. PMU Grounding Diagram for additional grounding information.

5.1.1 PMU J1 Connector – Solar Array Positive

The PMU J1 connector (MMDS-513) as described in Appendix B connects the PMU to the positive connections on the Solar Array. Refer to Table 7 for pinout and Figure 2 for mating face view.

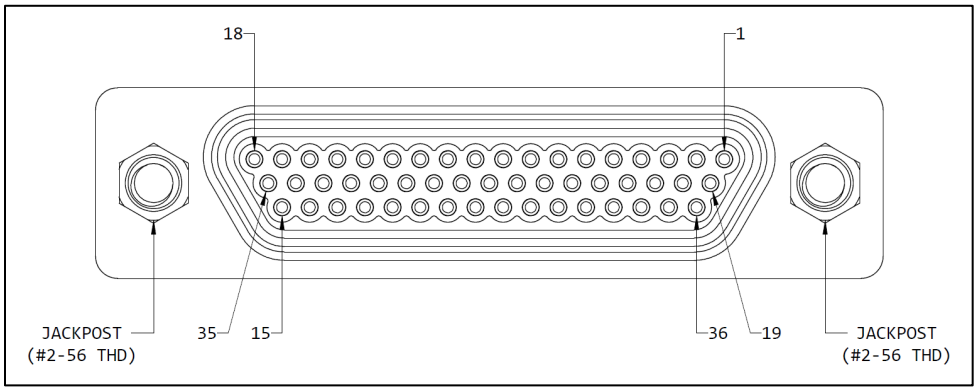
Table 7. J1 Connector Pinout

PIN	SIGNAL
1	PX_SA_TEMP_3+
2	PX_SA_STR_1+
3	PX_SA_STR_2+
4	PX_SA_STR_3+
5	GND_SA
6	GND_SA
7	GND_SA
8	PX_SA_STR_4+
9	PX_SA_STR_5+
10	PX_SA_STR_5+
11	PX_SA_STR_6+

PIN	SIGNAL
12	GND_SA
13	GND_SA
14	GND_SA
15	PX_SA_STR_7+
16	PX_SA_STR_8+
17	PX_SA_STR_9+
18	PX_SA_LIMIT_1+
19	PX_SA_TEMP_2+
20	PX_SA_STR_1+
21	PX_SA_STR_2+
22	PX_SA_STR_3+
23	GND_SA
24	GND_SA
25	GND_SA
26	PX_SA_STR_4+
27	GND_SA
28	PX_SA_STR_6+
29	GND_SA
30	GND_SA
31	GND_SA
32	PX_SA_STR_7+
33	PX_SA_STR_8+
34	PX_SA_STR_9+
35	PX_SA_LIMIT_2+
36	PX_SA_TEMP_1+
37	PX_SA_TEMP_3-
38	PX_SA_TEMP_2-
39	PX_SA_TEMP_1-
40	GND_SA
41	GND_SA
42	GND_SA
43	GND_SA
44	GND_SA
45	GND_SA
46	GND_SA
47	GND_SA
48	GND_SA
49	GND_SA

PIN	SIGNAL
50	PX_SA_LIMIT_1-
51	PX_SA_LIMIT_2-

Figure 2. MMDS-513 Connector Mating Face View



5.1.2 PMU J2 Connector – Solar Array Negative

The PMU J2 connector (MMDS-513) as described in Appendix B connects the PMU to the negative connections on the Solar Array. Refer to Table 8 for pinout and Figure 2 for mating face view.

Table 8. J2 Connector Pinout

PIN	SIGNAL
1	NX_SA_TEMP_3+
2	NX_SA_STR_1+
3	NX_SA_STR_2+
4	NX_SA_STR_3+
5	GND_SA
6	GND_SA
7	GND_SA
8	NX_SA_STR_4+
9	NX_SA_STR_5+
10	NX_SA_STR_5+
11	NX_SA_STR_6+
12	GND_SA
13	GND_SA
14	GND_SA
15	NX_SA_STR_7+
16	NX_SA_STR_8+
17	NX_SA_STR_9+

PIN	SIGNAL
18	NX_SA_LIMIT_1+
19	NX_SA_TEMP_2+
20	NX_SA_STR_1+
21	NX_SA_STR_2+
22	NX_SA_STR_3+
23	GND_SA
24	GND_SA
25	GND_SA
26	NX_SA_STR_4+
27	GND_SA
28	NX_SA_STR_6+
29	GND_SA
30	GND_SA
31	GND_SA
32	NX_SA_STR_7+
33	NX_SA_STR_8+
34	NX_SA_STR_9+
35	NX_SA_LIMIT_2+
36	NX_SA_TEMP_1+
37	NX_SA_TEMP_3-
38	NX_SA_TEMP_2-
39	NX_SA_TEMP_1-
40	GND_SA
41	GND_SA
42	GND_SA
43	GND_SA
44	GND_SA
45	GND_SA
46	GND_SA
47	GND_SA
48	GND_SA
49	GND_SA
50	NX_SA_LIMIT_1-
51	NX_SA_LIMIT_2-

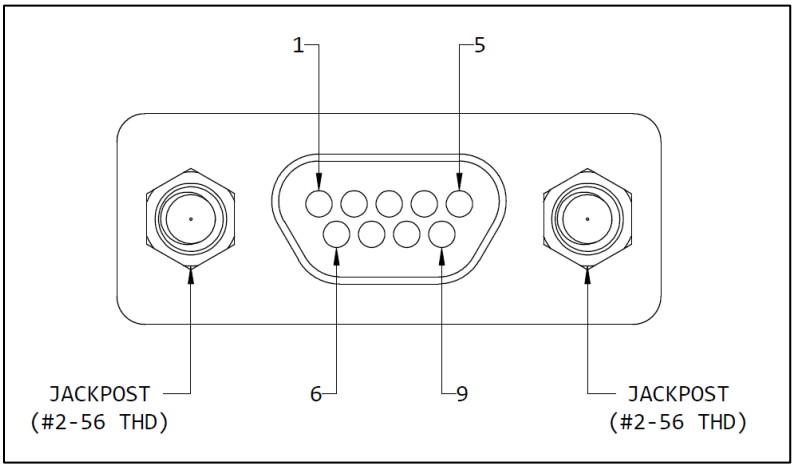
5.1.3 PMU J4 Connector – HDRM

The PMU J4 connector (MMDP-009) as described in Appendix B connects the PMU to the HDRM positive connections. Refer to Table 9 for pinout and Figure 3 for mating face view.

Table 9. J4 Connector Pinout

PIN	SIGNAL
1	PX_HDRM1+
2	PX_HDRM2+
3	GND
4	PX_HDRM1_RTD
5	PX_HDRM2_RTD
6	GND
7	GND
8	GND
9	GND

Figure 3. MMDP-009 Connector Mating Face View



5.1.4 PMU J5 Connector – HDRM

The PMU J5 connector (MMDP-009) as described in Appendix B connects the PMU to the HDRM negative connections. Refer to Table 10 for pinout and Figure 3 for mating face view.

Table 10. J5 Connector Pinout

PIN	SIGNAL
1	NX_HDRM1+
2	NX_HDRM2+
3	GND
4	NX_HDRM1_RTD

PIN	SIGNAL
5	NX_HDRM2_RTD
6	GND
7	GND
8	GND
9	GND

5.1.5 PMU J6, J7, J8, J9 Connectors – Battery

The PMU J6, J7, J8, and J9 connectors (MMDS-015) as described in Appendix B connect the PMU to the Battery Modules. The Umbra Battery Module connector numbering is specified in Table 11.

Table 11. Battery Connector Numbering

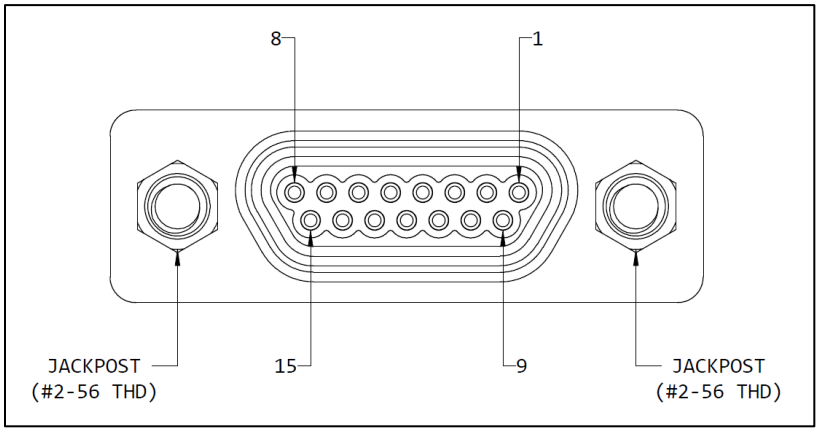
Connector Designator	Battery Pack Number
J6	Battery Module 1
J7	Battery Module 2
J8	Battery Module 3
J9	Battery Module 4

PMU J6 has pinout as specified by Table 11. Battery Connector Numbering, where the “#” is replaced with the battery pack number as shown in Table 11. Battery Connector Numbering. Refer to Figure 5for mating face view.

Table 12. Battery Connector Pinout

PIN	SIGNAL
1	BAT_#_TEMP+
2	BAT_#_TEMP-
3	BAT_#_HEAT+
4	BAT_#_HEAT-
5	GND_BAT
6	BAT_#_POS
7	BAT_#_POS
8	BAT_#_POS
9	GND_BAT
10	GND_BAT
11	GND_BAT
12	GND_BAT
13	BAT_#_POS
14	BAT_#_POS
15	BAT_#_POS

Figure 4. MMDS-015 Connector Mating Face View



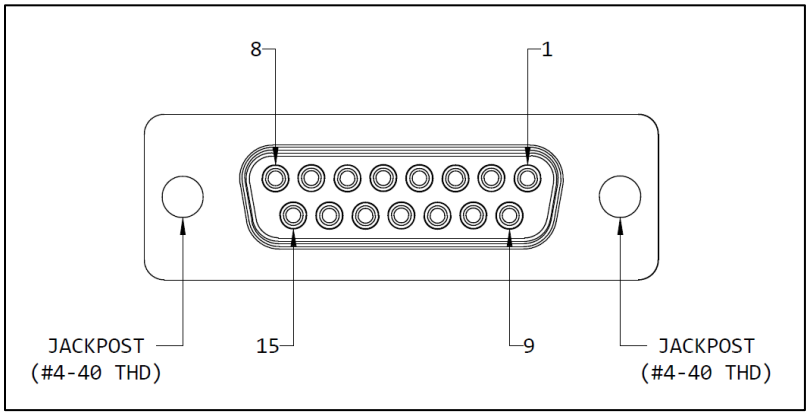
5.1.6 PMU J10 Connector – Inhibits

The PMU J10 connector (SND15S36000G) as described in Appendix B is used for inhibit commanding from the host vehicle. Refer to Table 12 for pinout and Figure 6 for mating face view.

Table 13. J10 Pinout

PIN	SIGNAL
1	BAT_POS
2	BAT_POS
3	GND
4	GND
5	SA_INHIBIT1+
6	SA_INHIBIT0+
7	BAT_INHIBIT_LS+
8	BAT_INHIBIT_HS+
9	BAT_NEG
10	BAT_NEG
11	GND
12	SA_INHIBIT1-
13	SA_INHIBIT0-
14	BAT_INHIBIT_LS-
15	BAT_INIHBIT_HS-

Figure 5. SND15S36000G Connector Mating Face View



5.1.7 PMU J11 Connector – Payload Power and RS422

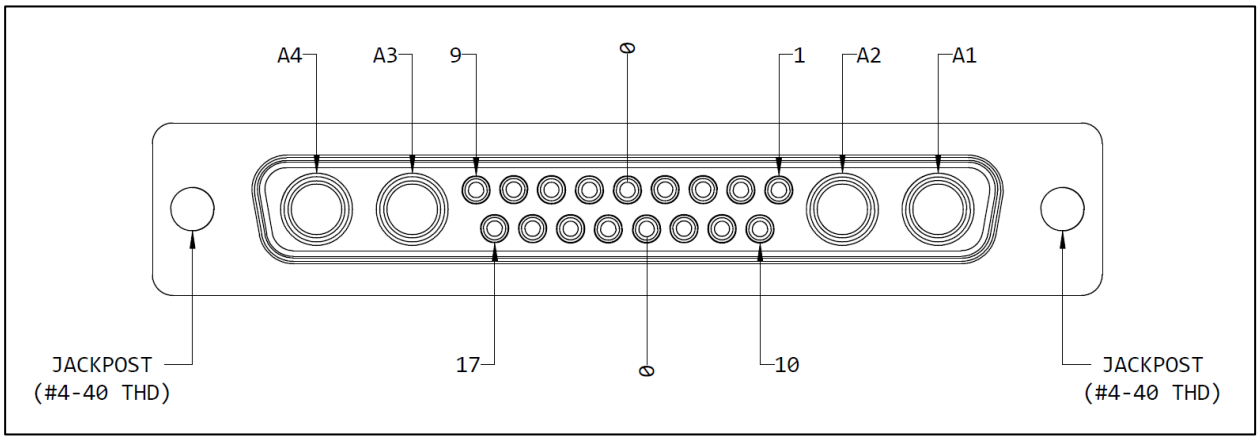
The PMU J11 connector (SCBM21WA4S36000G) as described in Appendix B is used to provide power to the host spacecraft and for commanding over RS422. Refer to Table 13 for pinout and Figure 7 for mating face view.

Table 14. J11 Connector Pinout

PIN	SIGNAL
A1	P28V_CUSTOMER
A2	P28V_CUSTOMER
A3	GND
A4	GND
1	GND
2	GND
3	GND
4	DISABLE_REGULATORS
5	GND
6	RS422_PMU_TO_CUST_P
7	RS422_PMU_TO_CUST_N
8	RS422_CUST_TO_PMU_P
9	RS422_CUST_TO_PMU_N
10	GND
11	GND
12	GND
13	GND
14	GND
15	GND
16	GND

PIN	SIGNAL
17	GND

Figure 6. SCBM21WA4S36000G Connector Mating Face View



5.2 Harnessing Recommendations

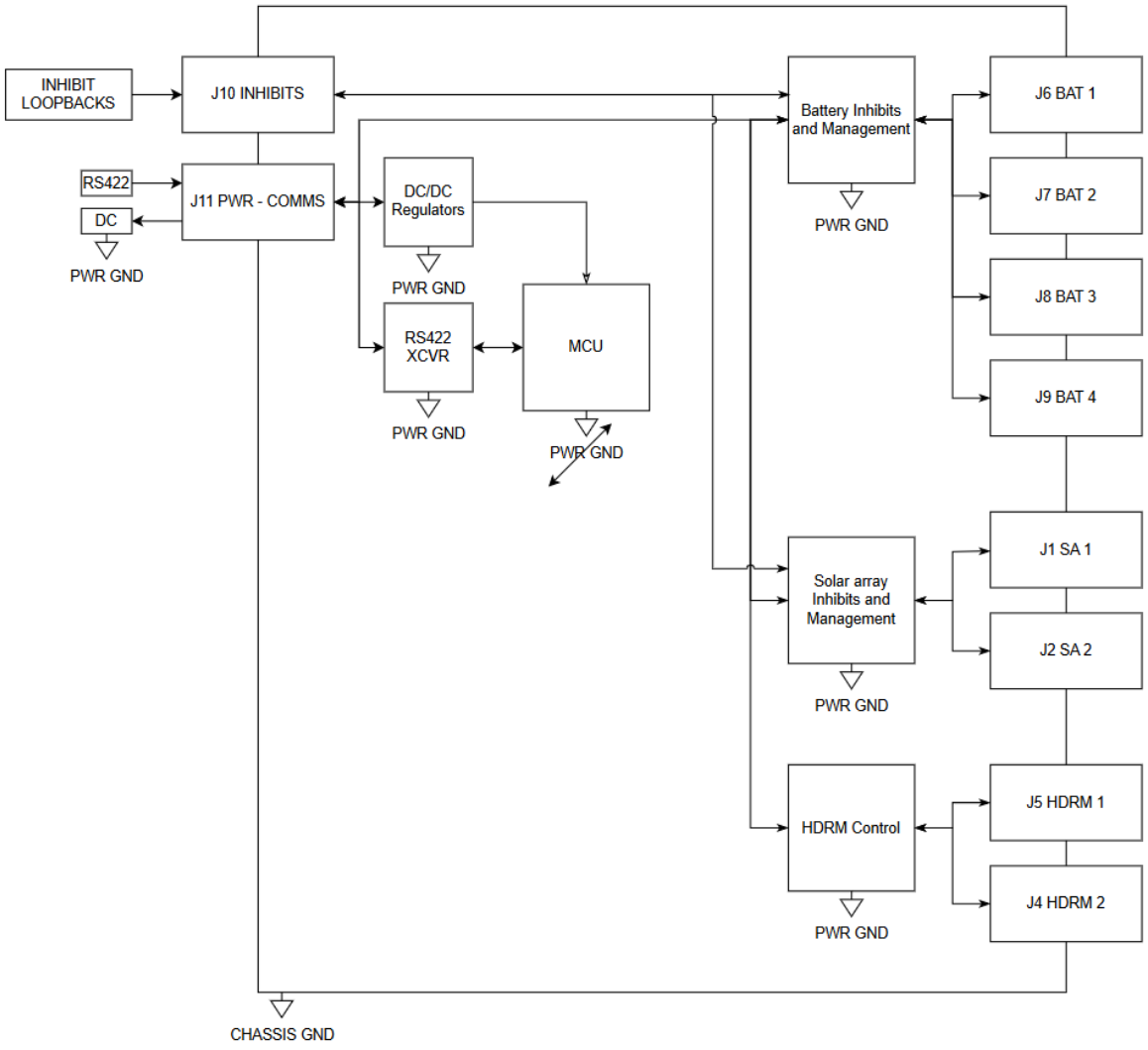
Follow Section 5.2 Harnessing Recommendations in 5081D0001 for recommendations for harnessing each Solar Array to the PMU J1 and J2 connectors and for harnessing each HDRM to the PMU J4 and J5 connectors.

Follow Section 5.2 Harnessing Recommendations in 5062D0001 for recommendations for harnessing each Battery Module to the PMU J6, J7, J8, and J9 connectors.

Space-rated harnesses connecting the PMU J10 and J11 connectors to the host vehicle should use wire following SAE AS22759 for all non “A” pins. Umbra recommends 24AWG wire. “A” pins on J11 should use 10-gauge multistrand cable compatible with crimping to d-sub power pins. Note that harnesses connecting to J11 contain both power and communications, so special care should be taken to avoid EMI while designing harnessing schemes connecting to this connector.

5.3 Grounding Block Diagram

Figure 7. PMU Grounding Diagram



See 5.1 Connector Pinouts for more information about connector pinouts.

5.4 EMI/EMC Properties

The Umbra Power Management Unit is pending test of Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) testing complies with MIL-STD-461. Heritage units have been verified to be self-compatible with X-band and L-band radios onboard a LEO spacecraft.

See Section 5.2 Harnessing Recommendations for recommendations to further reduce EMI.

5.5 Material Properties

All Umbra products are manufactured from materials deemed space-rated based on low outgassing. See Appendix B for more information on material properties of the PMU.

6.0 Software Properties

6.1 Communication Parameters

The PMU is commanded by the host vehicle via its J10 and J11 connectors.

The PMU J10 connector is used for inhibit commanding. This inhibit determines the launch vehicle system (LVS) state of the PMU through physical loopbacks.

The PMU J11 connector is used for commanding the Umbra Power Package peripherals through the PMU, sending Umbra Power Package telemetry from the PMU to the host vehicle, and for power supply from the Umbra Power Package to the host vehicle.

6.2 Telemetry

The following sections describe the telemetry sent by the PMU to the host vehicle via the PMU J11 connector.

6.2.1 Telemetry – Solar Array with HDRM

The Solar Array and HDRM telemetry described in Table 15. Solar Array with HDRM Telemetry is available to the host via the PMU.

Table 15. Solar Array with HDRM Telemetry

Name	Type	Units	Description	Memory	Default Value
Solar-Array-1-Heater-Primary	Integer	N/A	Primary Heater associated with Solar Array 1	Persistent	1
Solar-Array-2-Heater-Primary	Integer	N/A	Primary Heater associated with Solar Array 2	Persistent	1
Solar-Array-1-Heater-Secondary	Integer	N/A	Secondary Heater associated with Solar array 1	Persistent	2
Solar-Array-2-Heater-Secondary	Integer	N/A	Secondary Heater associated with Solar array 2	Persistent	2
Solar-Array-1-Primary-Heater-Current-Sensor	Float	A	Current draw of the primary solar array 1 heater	Volatile	N/A
Solar-Array-2-Primary-Heater-Current-Sensor	Float	A	Current draw of the primary solar array 2 heater	Volatile	N/A

Name	Type	Units	Description	Memory	Default Value
Solar-Array-1-Secondary-Heater-Current-Sensor	Float	A	Current draw of the secondary solar array 1 heater	Volatile	N/A
Solar-Array-2-Secondary-Heater-Current-Sensor	Float	A	Current draw of the secondary solar array 2 heater	Volatile	N/A
Solar-Array-1-Deployment-Switch	Boolean	N/A	When engaged, indicates the solar array is deployed	Persistent	False
Solar-Array-2-Deployment-Switch	Boolean	N/A	When engaged, indicates the solar array is deployed	Persistent	False
Solar-Array-1-HDRM-Temp	Float	°C	Provides the temperature of the HDRM associated with deploying solar array 1	Persistent	TBD
Solar-Array-2-HDRM-Temp	Float	°C	Provides the temperature of the HDRM associated with deploying solar array 2	Persistent	TBD
Shunt1,2,3,4-Heater-Current	Float	A	Reports the current of the associated solar array heater. Used to estimate a state of charge of the system when arrays are bore-sight with the sun. This estimate is to be done on the ground.	Persistent	N/A
Shunt1,2,3,4-Heater-Setpoint	Float	°C	Reports the temperature at which the associated shunt will be engaged.	Persistent	TBD
Shunt1,2,3,4-Heater-Hysteresis	Float	°C	Reports the hysteresis between the setpoint and the shunt turning ON/OFF. Shunt monitoring uses the Setpoint as the mid point and will power OFF the heater if the temp goes above the setpoint+hystereses, and will power ON the heater if the temp falls below the setpoint-hysteresis.	Volatile	N/A
Shunt1,2,3,4-State	Boolean	N/A	Reports the state for the associated shunt.	Persistent	False

6.2.2 Telemetry – Battery

The Battery Module telemetry described in Table 16. Battery Telemetry is available to the host via the PMU.

Table 16. Battery Telemetry

Name	Type	Units	Description	Memory	Default Value
Battery1,2,3,4-Heater-Current	Float	A	Reports the current of the associated battery heater	Volatile	N/A
Battery1,2,3,4-Heater-Setpoint	Float	°C	Reports the temperature at which the associated battery will start heating.	Persistent	TBD
Battery1,2,3,4-Heater-Hysteresis	Float	°C	Reports the hysteresis between the setpoint and the battery turning off. The hysteresis uses the Setpoint as the mid point and will power off the heater if the temp goes above the setpoint+hystereses, and will power on the heater if the temp falls below the setpoint-hysteresis.	Volatile	N/A
Battery1,2,3,4-Heater-State	Boolean	N/A	Reports the load switch state for the associated battery heater.	Persistent	False

6.3 Commanding

The commanding information for the PMU is included in the sections below.

6.3.1 Commanding Packet Format

The PMU commanding packet is slip encoded and includes a CCIT16 CRC.

6.3.2 PMU Commands

The following parameters are provided to control the PMU. These control commands are sent structured in commanding packet format as described above.

Table 17. PMU Commands

Name	Description	Data Type	Range
SolarArrayShuntSetpoint	Sets thresholds for beginning shunting	Float V	24 V to 32 V

Name	Description	Data Type	Range
	of each string of the Solar Array.		
SolarArrayDeploy	Deploys solar arrays via HDRMs. See 7.1.2 Solar Array Deployment for more information.	TBD	TBD
ASetSolarArrayDeploymentStatus	Sets the solar array deployment status which is used to check if **SolarArrayDeploy** can be executed.	String	"deploy_status_never_completed", "deploy_status_failure", or "deploy_status_success"
SetBatteryControlSetpoints	Configures thermal thresholds for the Battery Module heaters.	°C	TBD °C to TBD °C

6.4 Memory

The PMU has non-volatile configuration storage. The PMU memory architecture does not include any memory allocation for logs.

6.5 Error Mitigation

The PMU includes Built in Self-Test (BIST) to discern the health of the Umbra Power Package.

In the event of any Solar Array with HDRM deployment failure, please contact your Umbra Point of Contact (POC).

6.6 Solar Array States

The PMU stores the deployment status of the Solar Array with HDRM as a single “stowed” or “deployed” state. See 5081D0001 Appendix B for information about the inertial state and dimensions of the Solar Array with HDRM in each state.

When the physical state of the Solar Array with HDRM is changed manually via the Umbra Stow Tool, Umbra recommends using the command **SetSolarArrayDeploymentStatus** as needed to ensure that the PMU records the correct state of the Solar Array with HDRM before any PMU usage.

See Figure 8. Solar Array Deployment State Machine for more information about how the PMU transitions between states.

6.6.1 Stowed State

The stowed state indicates the Solar Array and HDRM are stowed.

During ground testing, the Umbra Stow Tool may be used to manually enter this state for the Solar Array and HDRM. More information on this state can be found in Section 8.1.1 Solar Array Stow Tool of 5081D0001.

In software, a successful **SolarArrayDeploy** command automatically moves the system from the stowed state to the deployed state. Once the system is in a deployed state, the stowed state can only be entered via the command **SetSolarArrayDeploymentStatus.**

6.6.2 Deployed State

Once the Solar Array and HDRM have successfully deployed, they are in the deployed state.

During ground testing, the Solar Array GSE Tool may be used to manually enter this state for the Solar Array and HDRM. More information on this state can be found in Section 8.1.1 Solar Array Stow Tool of 5081D0001.

In software, this state can be entered through a successful **SolarArrayDeploy** command. Additionally, the state may be entered manually during testing via the command **SetSolarArrayDeploymentStatus.** This software status may only be exited with the command **SetSolarArrayDeploymentStatus.** The command **SolarArrayDeploy** cannot be used in the deployed state.

7.0 Performance Specifications

The PMU is designed to handle complex commanding of the Solar Array with HDRM and the Battery Module as part of the modular Umbra Power Package.

This document covers a PMU designed to simultaneously manage up to two Solar Arrays, two HDRMs, and four Battery Module.

7.1 Umbra Power Package

The Umbra Battery PMU can only be purchased as part of the modular Umbra Power Package. The PMU is compatible with Umbra Power Package Products as described below.

7.1.1 Power Generation Management

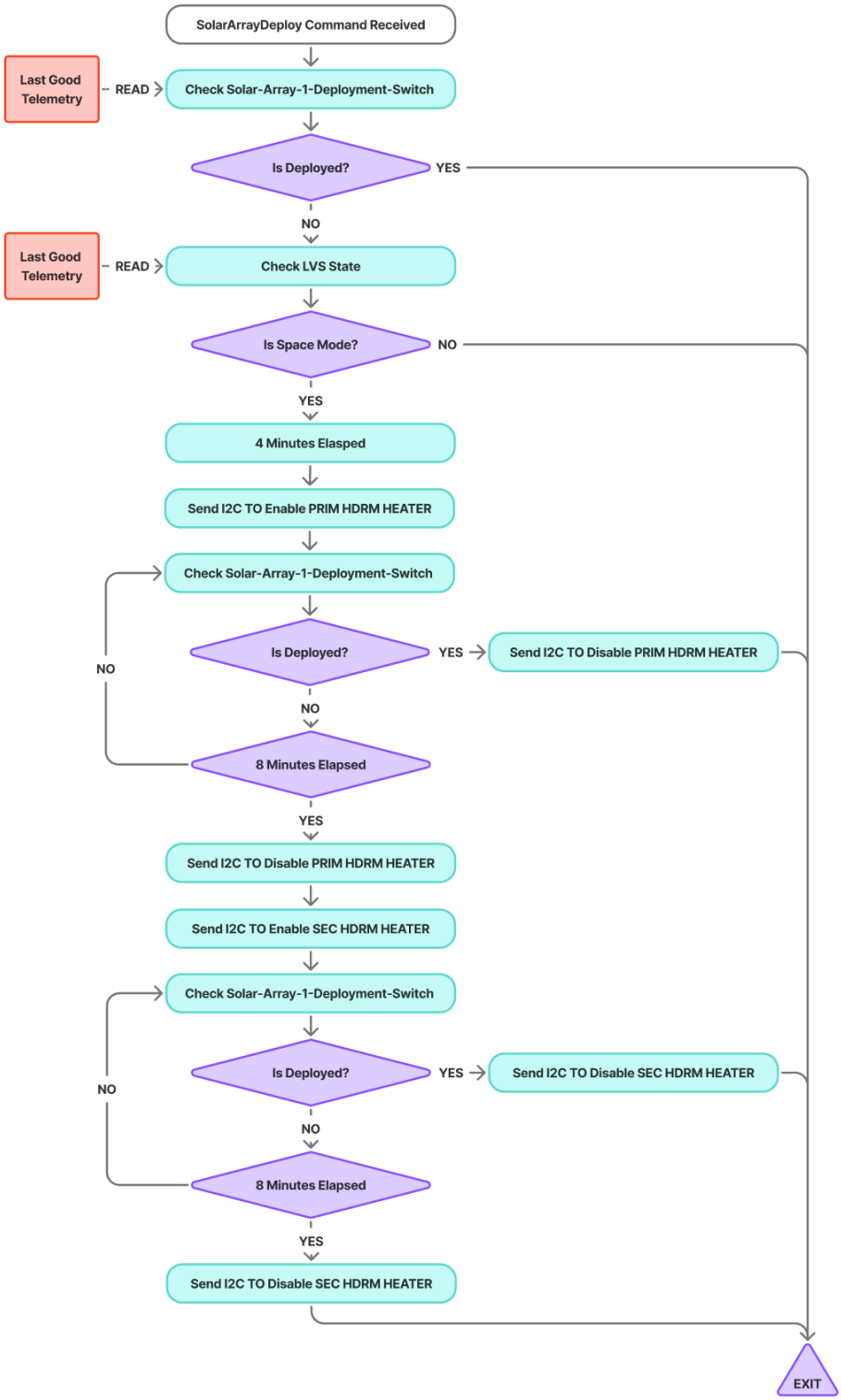
The PMU is designed for power generation management of the Umbra Power Package. Onboard voltage regulation is used to ensure the output power of the PMU is within tolerances described in Table 6. PMU Electrical Properties. When the Solar Arrays are illuminated sufficiently to provide this output power, energy is transferred through the PMU to the host vehicle and the Umbra Battery Modules. When sufficient solar power is not available, the PMU will automatically draw power from the attached Umbra Battery Modules to maintain this output power to the host spacecraft.

Solar Array shunting is also accomplished on the PMU. When the shunting setpoint for a solar array string is reached, power is dissipated into heat within the PMU. This shunting can maintain battery lifetime by ensuring battery charge stays within recommended ranges as described in 5062D0001. The Solar Array central root panel strings as defined in 5081D0001 are exposed when the Solar Array is stowed and must never be shunted for vehicle safety. All other shunt setpoints are configurable within their defined acceptable ranges. Battery discharge voltage thresholds to begin shunting for each string can be commanded through the **SolarArrayShuntSetpoint** command.

7.1.2 Solar Array Deployment

The PMU can be used to command deployment of each Solar Array with HDRM as described in Figure 8. Solar Array Deployment State Machine. In this example, only one solar array is deployed, however two solar arrays may be deployed synchronously via the PMU.

Figure 8. Solar Array Deployment State Machine



The PMU monitors the state of **Solar-Array-1-Deployment-Switch** and **Solar-Array-2-Deployment-Switch** telemetry at all times. When the Solar Array and HDRM are in a pre-deployment state, returning the telemetry status “deploy_status_never_completed,” the command **SolarArrayDeploy** can be used to deploy these systems.

The PMU will only deploy the Solar Array and HDRM when all SA_INHIBITs as described in Table 13. J10 Pinout are deactivated. These inhibits are used to prevent premature deployment of the Solar Array and HDRM during launch. After checking for inhibits, the PMU will delay deployment a further four minutes to prevent accidental activation.

SolarArrayDeploy will use the primary deployment heaters for the first deployment attempt set by **Solar-Array-1-Heater-Primary** and **Solar-Array-2-Heater-Primary**. After sending this command, the PMU will monitor telemetry for eight minutes to check for successful deployment.

Once the solar arrays have been deployed, the deployment switches will engage. **Solar-Array-1-Deployment-Switch** and **Solar-Array-2-Deployment-Switch** will update to indicate a successful deployment. The heaters used will be specified in a reply message and the solar array status will be updated to "deploy_status_success" in FRAM through the command **SetSolarArrayDeploymentStatus** automatically. The HDRM heaters will automatically shut off after their successful deployment.

If a deployment switch has not engaged within eight minutes, that primary deployment heater will deactivate and the associated secondary deployment heater determined by **Solar-Array-1-Heater-Secondary** and **Solar-Array-2-Heater-Secondary** will activate. Deployment switches will be monitored for another eight minutes during secondary heating. If all switches are engaged after secondary heating, solar array deployment is marked as successful, and the Solar Array state is updated accordingly.

If any switches remain disengaged after eight minutes of secondary heating, the system will declare a deployment failure for all HDRM switches that have failed to deploy. The respective solar array status will be updated to "deploy_status_failure" in FRAM through the command **SetSolarArrayDeploymentStatus** automatically.

Once each Solar Array and HDRM are successfully deployed, the command **SolarArrayDeploy** cannot be used. See 6.6 Solar Array States for more information.

See 5081D0001 Section 8.5 On-Orbit Checkout for pre-deployment and post-deployment timing and pointing recommendations. In the event of a Solar Array deployment failure, contact your Umbra POC.

7.1.3 Temperature Management

The PMU controls heaters on the Umbra Battery Module for temperature management. The heater hysteresis (temperature differential for heater activation/deactivation) and thermistor can be configured either individually per Umbra Battery Module or as a global value applied to all battery modules. See 5062D0001 Section 7.2 Thermal Management for more information.

7.2 Performance Verification

Customer recommended checkout is described in this document in Section 8.0 Operational Procedures.

8.0 Operational Procedures

Follow all requirements and recommendations in Section 4.1 Mechanical Handling while carrying out any and all procedures in this section, in addition to all requirements and recommendations for handling and operational procedures in 5081D0001 and 5062D0001.

The PMU and its peripherals may be damaged by carrying out any procedure listed in this section if mechanical handling requirements and recommendations are not followed.

8.1 Ground Support Equipment

All Umbra supplied GSE as described in 5081D0001 and 5062D0001 should be used without substitution. Contact Umbra if any Umbra provided GSE requires replacement.

8.2 First Use Procedure

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

8.2.1 Assembly

No customer assembly required. Remove RBF covers as described in Table 1. RBF Items before flight.

Follow 5081D0001 and 5062D0001 for harnessing recommendations when connecting the PMU to the power package peripherals.

8.2.2 Checkouts

Upon receipt of the PMU, customers should harness the Solar Arrays and HDRMs to the PMU without connecting to the Battery Modules. Users should ensure inhibits on the PMU are looped back.

After confirming loopback, users should install the Battery Modules using Battery Mate GSE.

8.2.3 Initial Configuration

PMU software is native at time of delivery. No updates or flashing are needed out of the box.

At first boot, the PMU software will record the Solar Array and HDRM as in a stowed state. See 6.6 Solar Array States for more information.

See 6.2 Telemetry for initial configuration setpoints.

8.3 Solar Array Deployment through PMU Commanding

The objective of this procedure is to deploy one Solar Array with HDRM through PMU commanding.

8.3.1 Success Criteria

HDRM and Solar Array shall be deployed successfully. PMU telemetry shall correctly report change in status.

8.3.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 18. Solar Array Deployment through PMU Commanding Equipment

Part Number	Part Name	Configuration	Quantity
5101H0001	PMU	N/A	x1
5062D0001	Umbra Battery Module 8S2P	N/A	Up to x4
5081H0001	Solar Array	Stowed	Up to x2
5070H0001	HDRM	Stowed	Same quantity as Solar Array
N/A	Solar Array Support Tool	As described in 5081D0001	Same quantity as Solar Array

8.3.3 Test Procedure

Only hold the Solar Array panels by the edges of the array during this procedure. Touching the Solar Arrays may lead to scratching. Handling the hinges during movement of the arrays may lead to pinching.

Umbra recommends operators carry out the Solar Array with HDRM Deployment Procedure as described in 5081D0001 before carrying out this procedure to gain familiarity with Solar Array with HDRM deployment best practices.

This procedure requires multiple operators.

1. Find a cleared space large enough for the form factor of the deployed Solar Array(s) as described in 5081D0001 free of FOD. These clearances must be observed at all times during this procedure to prevent damage to operators, Solar Arrays, and surroundings.
2. Secure each HDRM.
3. Align the Solar Array center release cup at the top of the HDRM. The center release cup floats in the Solar Array.
4. Ensure each tested Solar Array's hinges have clearances. Items caught in the Solar Arrays may be damaged by pinching. Solar Array hinges may be damaged by items caught in the hinges and limit switches.

5. Gently hold the edges of the inner panel of each tested Solar Array. This panel must be supported throughout the deployment process until solar arrays are supported by the Solar Array Support Tool to prevent damage to the hinges.
6. Harness the PMU to the Power Package peripherals described in Table 18, following all harnessing recommendations.
7. Receive a telemetry packet from the PMU. Ensure each Solar Array with HDRM is recorded as stowed by the PMU. If the PMU reports a “deployed” state, use the command **SetSolarArrayDeploymentStatus** to set the PMU software to a “stowed” state. Ensure SA_INHIBITs as described in Table 13. J10 Pinout are deactivated before commanding deployment.
8. Send a **SolarArrayDeploy** command with desired parameters for the tested solar array(s). Do not touch the HDRM once this command has been sent.
9. Monitor telemetry from the PMU and continue to support the inner panel of the Solar Array until either of the following:
    a. HDRM deployment, leading to Solar Array deployment. If deployment is successful, support the middle panel of the Solar Array once the inner panel has cleared it.
    b. PMU telemetry reports a failure to deploy.
10. Do not handle the HDRM immediately after HDRM deployment or failure to deploy.

8.4 Solar Array Charging of Battery Module through PMU

The objective of this procedure is to charge each Battery Module via the Solar Array(s).

8.4.1 Success Criteria

Umbra Battery Module charge state shall increase. PMU shall report change in charge.

8.4.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 19. Solar Array Charging of Battery through PMU Equipment

Part Number	Part Name	Configuration	Quantity
5101H0001	PMU	N/A	x1
5081H0001	Solar Array	Deployed	Up to x2
5062H0001	Umbra Battery Module 8S2P	N/A	Up to x4
5070G0001	Umbra Stow Tool	N/A	x1

8.4.3 Test Procedure

Umbra recommends validating the charging performance of the Solar Arrays using a trusted illumination source.

If outdoor testing is necessary, this test will require a clear, sunny sky at approximately high noon to maximize the amount of light received by Solar Arrays. Solar Arrays WILL be damaged by rain, snow, particulate in wind, etc. Do not store Solar Arrays outside.

1. Follow 5081D0001 Solar Array Charging Test stowing, transport, and deployment steps.
2. Connect the Power Package Peripherals, following 5.2 Harnessing Recommendations.
3. Monitor PMU telemetry. Ensure the current charge state of the Umbra Battery Modules is below shunting thresholds. If the PMU reports a “stowed” state, use the command **SetSolarArrayDeploymentStatus** to set the PMU software to a “deployed” state. Ensure SA_INHIBITs as described in Table 13. J10 Pinout are deactivated before commanding deployment.
4. Follow 5081D0001 Solar Array Charging Test calculations and charging steps. Monitor PMU telemetry throughout this procedure.
5. Disconnect the PMU from its peripherals.
6. Umbra recommends that users should stow Solar Arrays per 5081D0001 Solar Array with HDRM Manual Stow Procedure and ensure RBF covers are ON if no other testing is planned to prevent damage to the Solar Array.

8.5 On-Orbit Checkout

8.5.1 Telemetry

Confirm that the Solar Arrays list a “stowed” state at first boot on orbit. Confirm temperatures reported in telemetry are within the operating range for the PMU and each Power Package Peripheral.

8.5.2 Solar Array Deployment

SA_INHIBITs as described in Table 13. J10 Pinout must be looped back during launch to prevent premature deployment of the Solar Arrays and HDRMs. Deactivate SA_INHIBITS before sending **SolarArrayDeploy** commands.
See Section 7.1.2 Solar Array Deployment and 5081D0001 Section 8.4 On-Orbit Checkout for timing recommendations for deployment of the Solar Array.

Appendix A

Acronyms and Abbreviations

A.1 Acronyms and Abbreviations

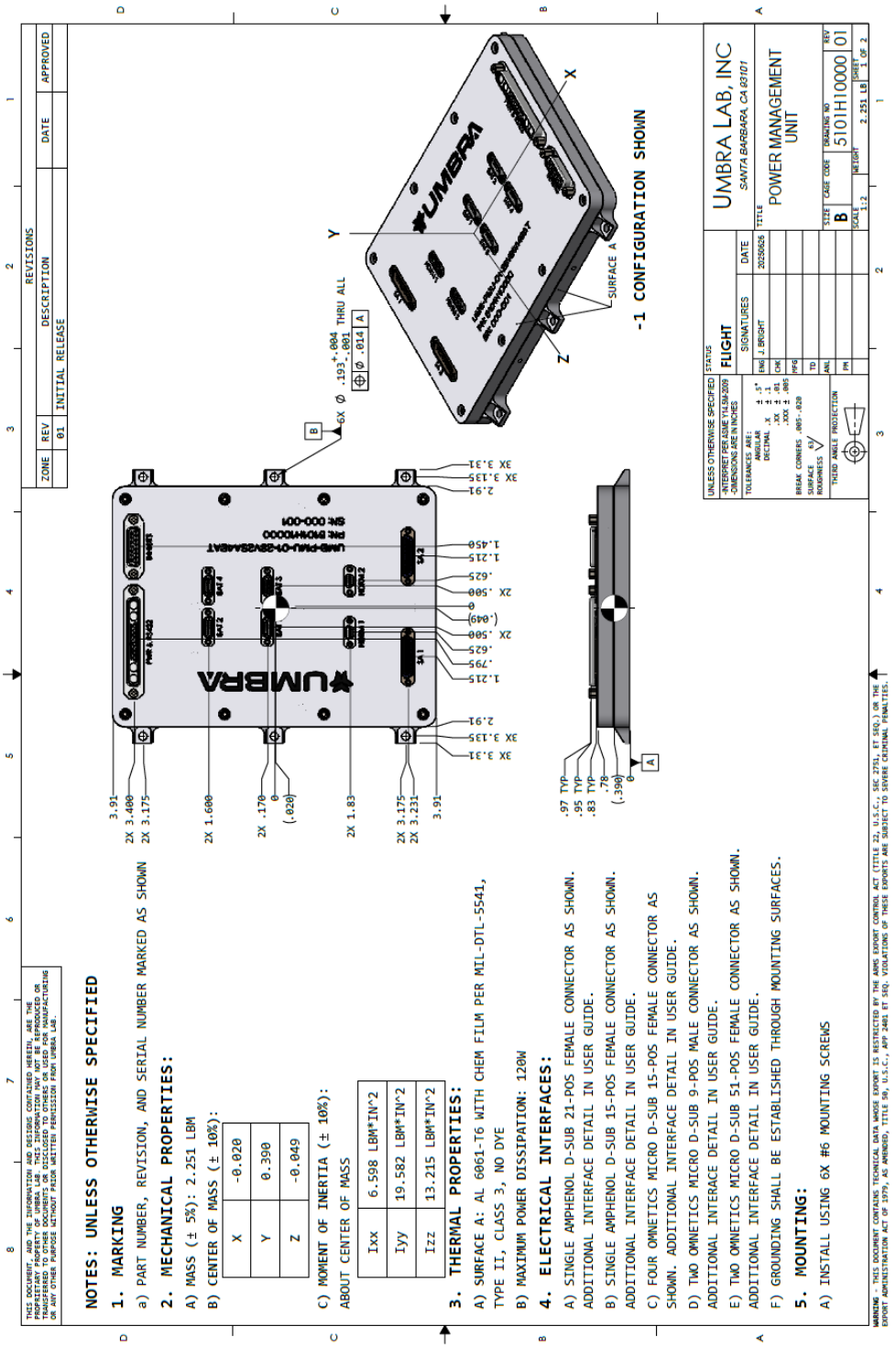
EIDP	End Item Data Package
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FOD	Foreign Object Debris
GND	Ground
GSE	Ground Support Equipment
HDRM	Hold Down and Release Mechanism
LEO	Low Earth Orbit
LVS	Launch Vehicle System
N/A	Not Applicable
PMU	Power Management Unit
POC	Point of Contact
RBF	Remove Before Flight
RMS	Root Mean Squared
SA	Solar Array
TBD	To Be Determined

A.2 Units

A	Amps
°C	Degrees Celsius
G	G-Force
krad	Kilorad
V	Volts
W	Watts

Appendix B

Mechanical Interface Control Documentation



Battery Module User Guide

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8-Cell Model	16-Cell Model

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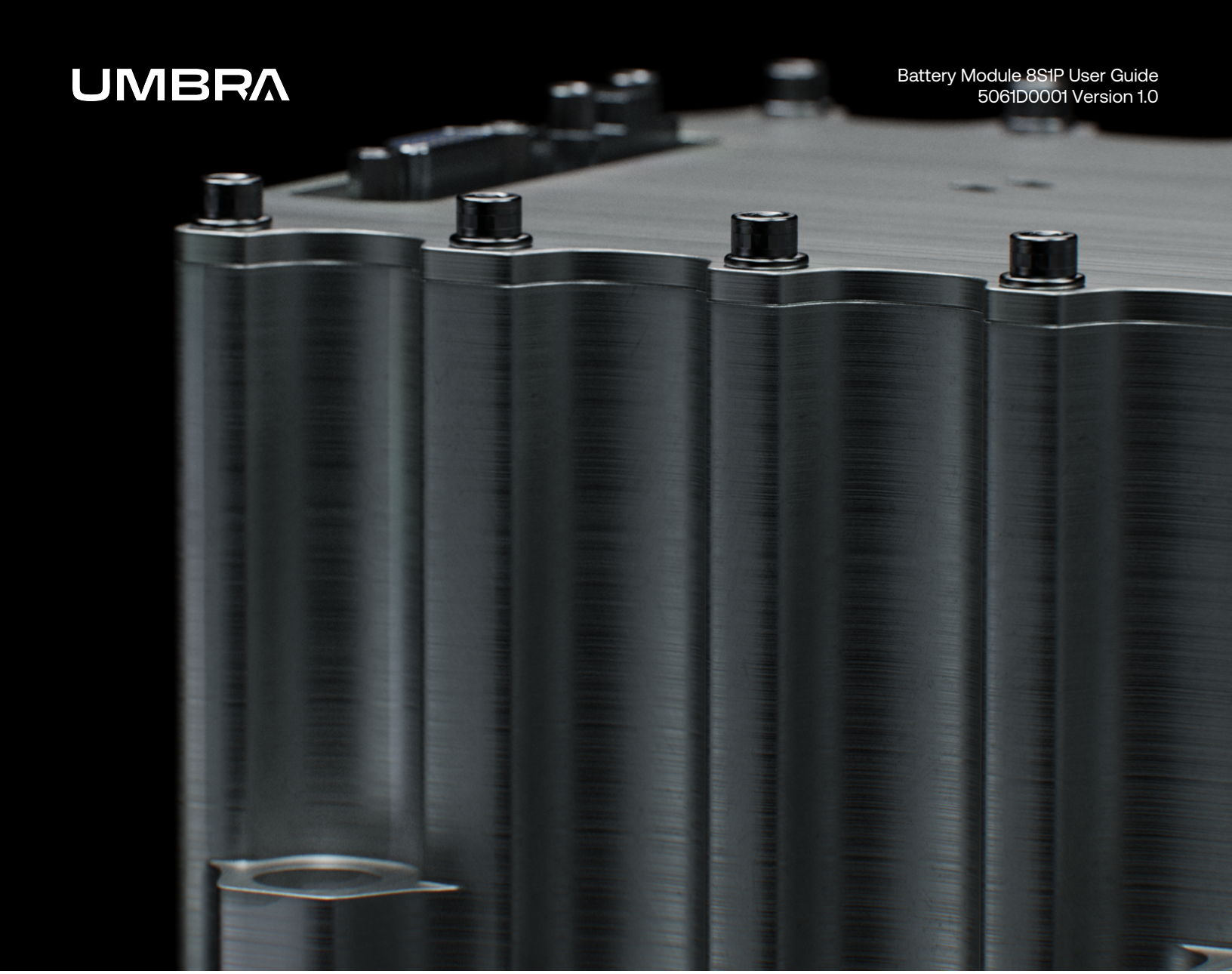


Battery Module 8S1P User Guide

Distribution Statement	Export Control
No Restrictions	No US Export Control Information

Table of Contents

Figures

Tables

1.0 Objective

This document provides user guidance for the integration of the Umbra Battery Module 8S1P.

The Umbra Battery Module 8S1P is a battery module with eight lithium-ion battery cells in 8S1P configuration.

2.0 Document References

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

2.1 Umbra Documents

5061H15000	8S1P BATTERY MODULE MICD

2.2 Standard Documents

ANSI/ESD S20.20-2021	PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES, AND EQUIPMENT
49 CFR B.1.C	CODE OF FEDERAL REGULATIONS: HAZARDOUS MATERIALS REGULATIONS
GSFC-STD-7000	GENERAL ENVIRONMENTAL VERIFICATION STANDARD (GEVS)
MIL-STD-461	MILITARY STANDARD: ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS REQUIREMENTS FOR EQUIPMENT
AS22759	WIRE, ELECTRICAL, FLUOROPOLYER-INSULATED, COPPER OR COPPER ALLOY
AS50881	WIRING, AEROSPACE VEHICLE
UN 38.3	UNITED NATIONS RECOMMENDATIONS ON THE TRANSPORT OF DANGEROUS GOODS: LITHIUM METAL AND LITHIUM ION BATTERIES

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 in Appendix B shall supersede this document.

3.1 Revision Notes

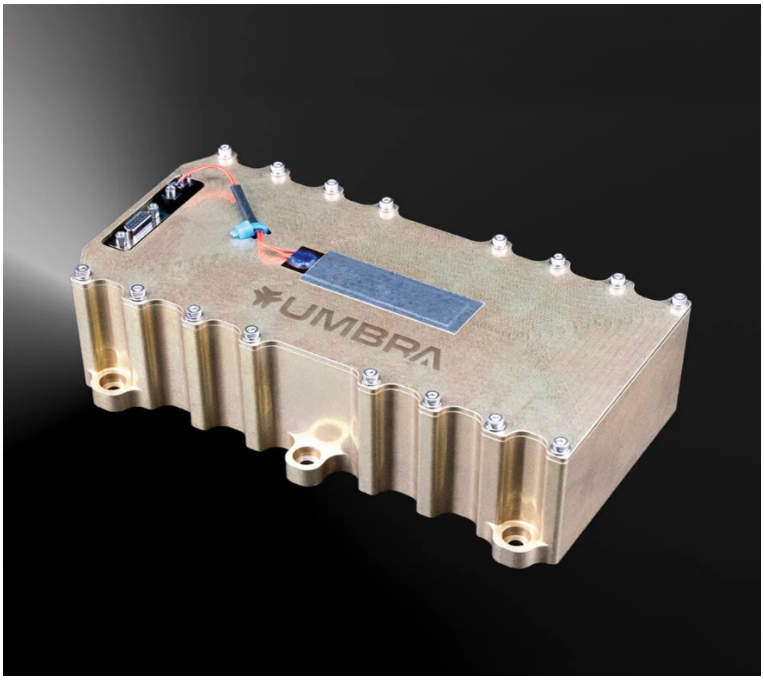
This document is Version 1.0.

3.2 Document Disclaimer

DISCLAIMER: This User Guide is intended to provide a brief summary of our knowledge and guidance regarding the use of this item. The information contained herein has been compiled from sources considered by Umbra Lab, Inc. to be dependable and is accurate to the best of the Company's knowledge. It is not meant 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 the appropriate protective mechanisms to prevent employee exposure, personal injury, property damage or release to the environment of any hazardous substances. Umbra Lab, Inc. assumes no responsibility for injury, damage, or loss sustained by the recipient or third persons 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. Umbra Battery Module 8S1P



4.1 Mechanical Handling

The Lithium-Ion batteries contained in the Umbra Battery Module are volatile. Failure to read and follow the instructions contained in this User Guide may result in damage to the module, operators, and other property if stored, charged, or used improperly.

Contact Umbra if any Umbra Battery Module fails any procedure as described in this document. Do not recharge or continue use of any Umbra Battery Module with any suspected damage, including damage resulting from fire.

Ensure that any transportation of the Umbra Battery Module occurs in an environment described in Section 4.5 Storage and Transport Environment.

Umbra recommends users monitor the Umbra Battery Module throughout the charging process to ensure batteries are properly charged, including taking voltage readings periodically throughout the process. Do not overcharge the Umbra Battery Module. Only charge the Umbra Battery Module in a 10 °C to 45 °C environment.

Do not drop the Umbra Battery Module. Only lift Umbra Battery Modules by the chassis.

Always use a charger meeting the requirements described in this document to charge any Umbra Battery Module. Failure to do so may cause fire or damage the Umbra Battery Module, which may result in personal injury and property damage.

Do not disassemble the Umbra Battery Module.

4.1.1 Hazards

4.1.1.1 Hazardous Materials

The Umbra Battery Module 8S1P contains lithium-ion cells, which are considered hazardous materials. Customer shall follow all regulations for handling, disposal, transport, and any additional regulations relevant to Lithium batteries as pertains to their specific use case. Lithium cells are subject to the DOT's Hazardous Materials Regulations (HMR; 49 CFR Parts 171–180), and Umbra battery modules have been certified for transport under UN 38.3 testing.

Each Umbra Battery Module 8S1P is considered UN3481 equipment and must be transported safely per DOT regulations for equipment with this classification. See 4.5 Storage and Transport Environment for Umbra recommendations for transport of Umbra Battery Module 8S1P in addition to all safety requirements for UN3481 equipment.

4.1.1.2 Fire Hazards

Always have sufficient fire extinguishing agent available for emergency use. Always have a fireproof container available to store the Umbra Battery Module in case of fire. Only trained and qualified personnel should fight a Lithium-Ion fire.

If at any point a user witnesses the battery module leak smoke, swell up, or catch fire, immediately discontinue charging and usage then disconnect the battery and observe it in a safe place for at least 15 minutes. Touching the battery module with bare hands while in this failure mode may lead to injury. Observation should occur outside, away from any combustible material.

After this observation period, the Umbra Battery Module may become combustible again. Trained personnel should move the battery module to a fireproof container when safe to do so. The Umbra Battery Module should not be used after this failure mode is observed.

4.1.2 ESD Sensitivity

The Umbra Battery Module is electrostatic discharge (ESD) sensitive.

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

- Check shock detection stickers
- Remove from protective case
- Perform visual inspection for damage
- Take pictures as received
- No cleanliness requirements or contamination risks

4.2 RBF/ Red Tag GSE

Items listed in

Table 1. RBF Items must be removed before flight.

Table 1. RBF Items

Item	Critical / Optional	Notes
Connector Dust Cap	Critical	Protects connector interface from debris on the ground

See Appendix B for more information.

4.3 Electrical Mate/Demate

Table 2. Electrical Connectors

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

The Umbra Battery Module will contain live batteries. Adequate precautions to prevent current flow on mating should be taken at all times.

See Section 5.1 Connector Pinouts for more information.

4.4 Connector Strain

It is recommended to secure all harnessing interfacing to the Umbra Battery Module per the guidance found in SAE-AS50881 which describes guidance on the installation of wiring harness.

4.5 Storage and Transport Environment

Do not store in direct sunlight.

Do not store in such a way that damages part markings.

Ensure that critical RBF components are in place during all transport of the Umbra Battery Module.

Store the Umbra Battery Module with heater side UP to prevent damage to the system.

Table 3. Recommended Storage Environment

Parameter	Value
Storage State of Charge	To maximize service life, store the Umbra Battery Module at a charge level between 40% charge to 90% charge.
Storage Temperature	-20°C to 50°C
Humidity	< 50% Relative Humidity
Maximum Storage Lifetime	10 years. See Section 8.4 On-Orbit Checkout for additional notes on depth of discharge.

4.6 Operating Environment

Table 4. Operating Environment

Parameter	Value
Operating Temperature (Charge)	10°C to 45°C
Operating Temperature (Discharge)	-20°C to 60°C

4.7 Survival Environment

Table 5. Survival Environment

Parameter	Value
Survival Temperature:	-20°C to 60°C
Random Vibration	Qualified to 14.16 Grms profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels
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 information on mounting the Umbra Battery Module 8S1P.

5.0 Electrical Properties

Table 6. Electrical Properties

Property	Typical Value	Notes
Operating Voltage Range	26.5 ± 4.5 V	Nominal Voltage: 28 V
Energy Capacity	125 Wh	33 Ah
Idle Power Draw	0 W	Heaters off
Maximum Power Draw	9.7 W	Heaters at maximum
Maximum Discharge Rate	12.5 A	

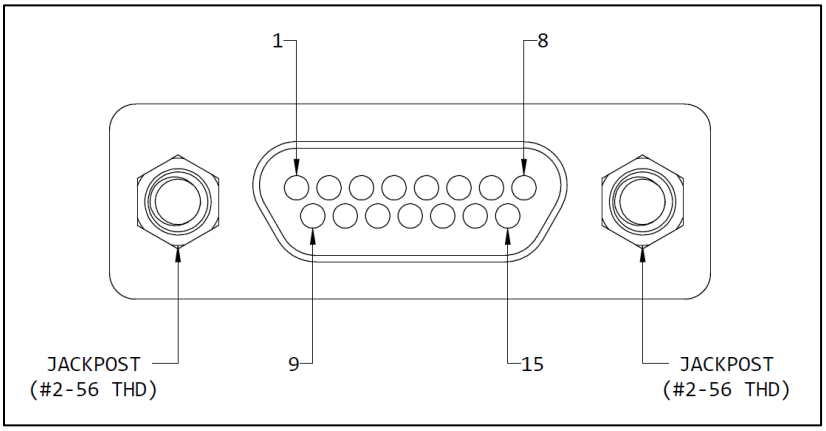
5.1 Connector Pinouts

The Umbra Battery Module J1 connector (MMDP-015) is described in Appendix B. Refer to Table 7 for pinout and Figure 2 for the mating face view.

Table 7. J1 Connector Pinout

PIN	SIGNAL
1	THERM P
2	THERM N
3	HEATER P
4	HEATER N
5	GND
6	POWER SUPPLY
7	POWER SUPPLY
8	POWER SUPPLY
9	GND
10	GND
11	GND
12	GND
13	POWER SUPPLY
14	POWER SUPPLY
15	POWER SUPPLY

Figure 2. MMDP-015 Connector Mating Face View



The assembly connector's body is not electrically connected to GND. The harness connector body and backshell should be isolated from GND as well – they will be electrically bonded to the assembly connector's body through the mating jackposts and jackscrews.

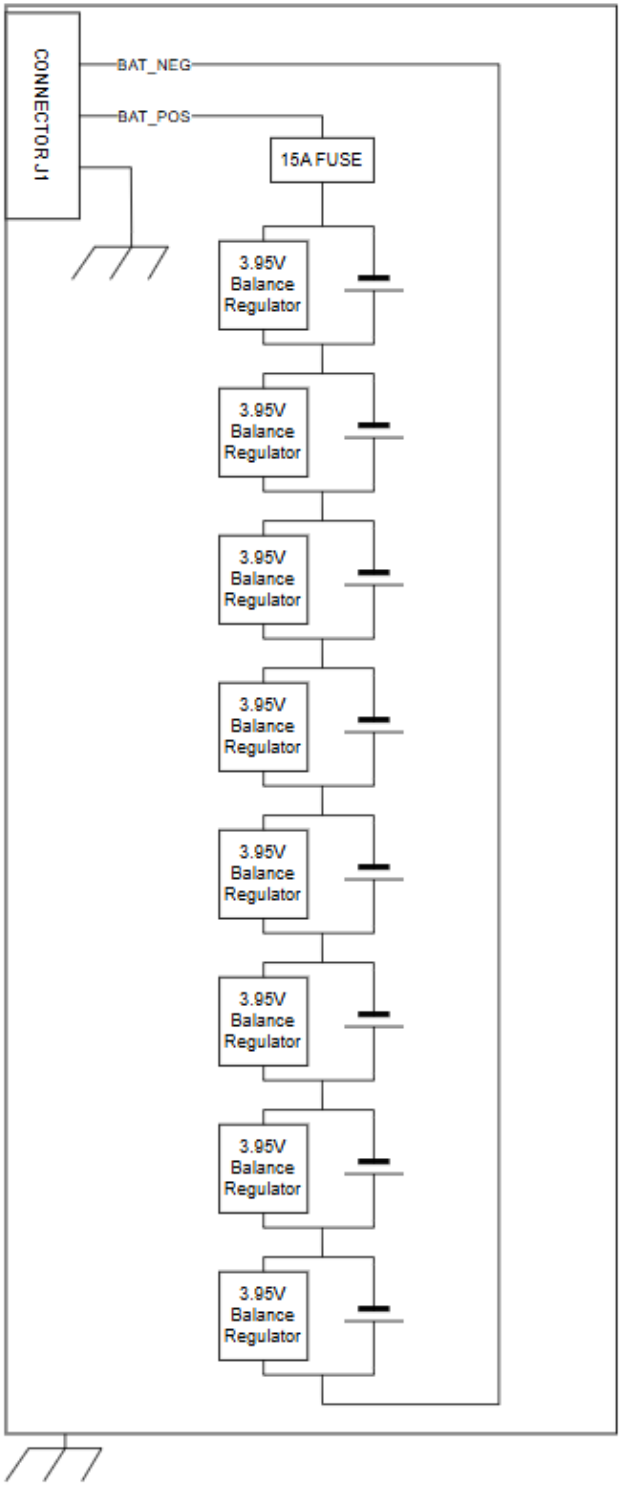
5.2 Harnessing Recommendations

Harnesses connecting to the Umbra Battery Module should use mating connector Female Socket MMDS-015 to connect to the connector described in Section 5.1 Connector Pinouts.

Space-rated harnesses connecting to the Umbra Battery Module should use wire conforming to SAE AS22759. Umbra recommends 24AWG wire.

5.3 Grounding Diagram

Figure 3. Umbra Battery Module 8S1P Electrical Block Diagram



5.4 EMI/EMC Properties

The Umbra Battery Module 8S1P 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 components are manufactured from materials deemed space-rated based on low outgassing. See Appendix B for more information on material properties of the Umbra Battery Module 8S1P.

6.0 Software Properties

Not applicable.

7.0 Performance Specifications

7.1 Charge Balancing

Charge balancing systems ensure that battery cells within a system maintain the same state of charge (SOC). This ensures that a SOC reading from a battery system also applies to the individual battery cells within the system. Since each individual battery cell must remain within its safe charging range to maintain lifetime and allow for discharge without damage, cell balancing increases the lifetime of the battery system. This is especially important when using lithium-ion batteries due to the volatility of this failure mode with this battery chemistry.

The Umbra Battery Module includes a shunt regulator type cell balancing management system. In the 8S1P configuration, this system ensures that each of the eight batteries in series remain at the same voltage. Parallel cells naturally balance to the cells in series through their direct connection.

In the Umbra Battery Module cell balancing system, when additional power reaches the battery module while the SOC has reached its maximum safe threshold, the energy is shunted to heat.

Cell unbalance within safety limits can occur. To rebalance all cells, charge the battery module to full state of charge.

7.2 Thermal Management

The Umbra Battery Module includes an onboard heater and resistance temperature detector (RTD). If voltage is provided to the heater as described in the Section 5.1 Connector Pinouts, the heater will activate.

7.2.1 Heater Information

Table 8. Heater Information

Property	Typical Value
Heater Part Number	HK6901
Heater Rating	NASA qualified, low outgassing
Heater Nominal Voltage	19.5 V
Heater Max Voltage	39.0 V
Heater Nominal Wattage	7.9 W
Heater Max Wattage	15.7 W

7.2.2 RTD Information

Table 8. RTD Information

Property	Typical Value
RTD Part Number	B57230V2103F260
RTD Nominal Resistance	10 kΩ at 25°C

7.3 Umbra Power Package Compatibility

The Umbra Battery Module 8S1P can be purchased as part of the modular Umbra Power Package, with the Umbra Power Management Unit included. See documentation on the Umbra Power Management Unit for more details about compatibility with this system.

7.4 Performance Verification

Customer recommended checkout and qualification testing is described in this document in the Section 8.0 Operational Procedures

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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 Battery Module may be damaged by carrying out any procedure listed in this section if mechanical handling requirements and recommendations are not followed.

8.1 Ground Support Equipment

To ensure operator and equipment safety, ensure Ground Support Equipment (GSE) follows the recommendations laid out in this section.

8.1.1 Charger Requirements

Umbra recommends the use of a qualified battery charger before integration with any payload. Ensure the charger is lithium-ion chemistry compatible. Ensure battery charger connector matches Section 5.2 Harnessing Recommendations before use. Umbra recommends the use of a battery charger capable of monitoring charge current and charge state voltage.

8.1.2 Thermal Sensor Recommendations

Umbra recommends the use of a monitoring circuit to take advantage of the internal temperature sensor. Alternatively, customers may use an external thermal camera or contact temperature sensor during all ground charging operations to monitor shunt heating of the Umbra Battery Module. The temperature sensor should measure the top of the Battery Module chassis for most accurate reading.

8.2 First Use Procedure

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

8.2.1 Assembly

No customer assembly required.

8.2.2 Checkouts

Ensure there are no signs of lithium-ion battery damage upon receipt of the Umbra Battery Module. Check connectors and heater for damage before powering on.

8.2.3 Initial Configuration

The Umbra Battery Module will be shipped in a partially charged state to preserve cell lifetime.

8.3 Battery Charging Procedure

The objective of this procedure is to charge the Umbra Battery Module 8S1P.

8.3.1 Success Criteria

Measured cell voltage shall be 32 V ± 0.5 V.

8.3.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 9. Battery Charging Procedure

Part Number	Part Name	Configuration	Quantity
5061H0001	Umbra Battery Module	Charge State < 90%	x1
N/A	Battery Charger	8.1.1 Charger Requirements	x1
N/A	Temperature Sensor	8.1.2 Thermal Sensor Recommendations	Optional

8.3.3 Test Procedure

Overcharging the Umbra Battery Module 8S1P may result in damage to the module, operator harm, and/or fire. Ensure all safety recommendations in Section 4.0 Hardware Handling are followed as best practices throughout this procedure.

1. Connect the Umbra Battery Module 8S1P to the Battery Charger using a connector compatible with the Battery Module connector.
2. If available, monitor the charging process with a temperature sensor. The temperature sensor should measure the top of the Battery Module chassis for most accurate reading.
3. If the Battery Charger is capable of monitoring charge, record initial voltage reading if available. This charge voltage should be as stated in 8.2.3 Initial Configuration at first receipt of the battery module.
4. Begin charging if needed. Charging is considered to be complete when monitored voltage no longer rises, at a reading of 32 V ± 0.5 V.
5. Do not touch the battery module once measured voltage reaches 32 V ± 0.5 V. See Section 7.1 Charge Balancing for information on how additional energy is converted to heat.
6. Disconnect the charger, still careful to avoid touching the potentially hot surface of the battery modules.
7. Allow the cells to rest for at least 5 min to dissipate heat and reach their final SOC.
8. If desired, measure the final cell voltage.

8.4 On-Orbit Checkout

8.4.1 Depth of Discharge

Umbra recommends maintaining Umbra Battery Module 8S1Ps at a state of charge of 40% to 90% to preserve capacity to over 32 Ah over 600 cycles.

8.4.2 Multiple Module Usage

If multiple Umbra Battery Module 8SPs are connected in series, each module should have a similar current draw.

Appendix A

Acronyms and Abbreviations

A.1 Acronyms and Abbreviations

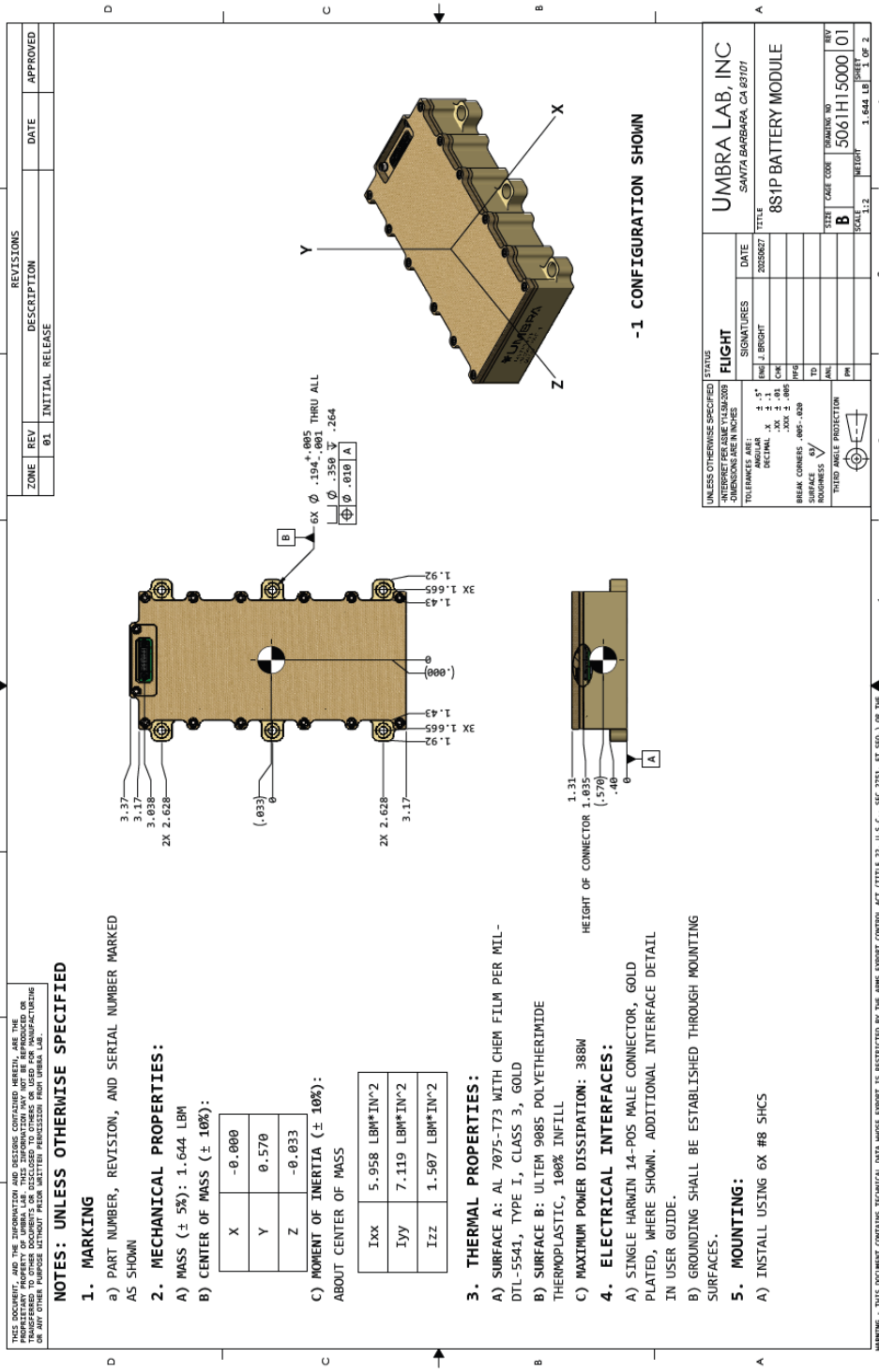
DOT	Department of Transportation
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
GEVS	General Environmental Verification Standard
GND	Ground
GSE	Ground Support Equipment
HMR	Hazardous Materials Regulations
N/A	Not Applicable
RBF	Remove Before Flight
RTD	Resistance Temperature Detector
SOC	State of Charge

A.2 Units

°C	Degrees Celsius
A	Ampere
Ah	Ampere Hours
Grms	root mean square acceleration
Hz	Hertz
kΩ	Kiloohms
krad	Kilorad
min	Minutes
ms	Millisecond
V	Volts
VAC	Volts Alternating Current
W	Watts
Wh	Watt Hours

Appendix B

Mechanical Interface Control Documentation



Battery Module 8S2P User Guide

Distribution Statement	Export Control
No Restrictions	No US Export Control Information

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1.0 Objective

This document provides user guidance for the integration of the Umbra Battery Module 8S2P.

The Umbra Battery Module 8S2P is a battery module with sixteen lithium-ion battery cells in 8S2P configuration.

2.0 Document References

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

2.1 Umbra Documents

5062H16000	82SP BATTERY MODULE MICD

2.2 Standard Documents

ANSI/ESD S20.20-2021	PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES, AND EQUIPMENT
49 CFR B.1.C	CODE OF FEDERAL REGULATIONS: HAZARDOUS MATERIALS REGULATIONS
GSFC-STD-7000	GENERAL ENVIRONMENTAL VERIFICATION STANDARD (GEVS)
MIL-STD-461	MILITARY STANDARD: ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS REQUIREMENTS FOR EQUIPMENT
AS22759	WIRE, ELECTRICAL, FLUOROPOLYER-INSULATED, COPPER OR COPPER ALLOY
AS50881	WIRING, AEROSPACE VEHICLE
UN 38.3	UNITED NATIONS RECOMMENDATIONS ON THE TRANSPORT OF DANGEROUS GOODS: LITHIUM METAL AND LITHIUM-ION BATTERIES

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 in Appendix B shall supersede this document.

3.1 Revision Notes

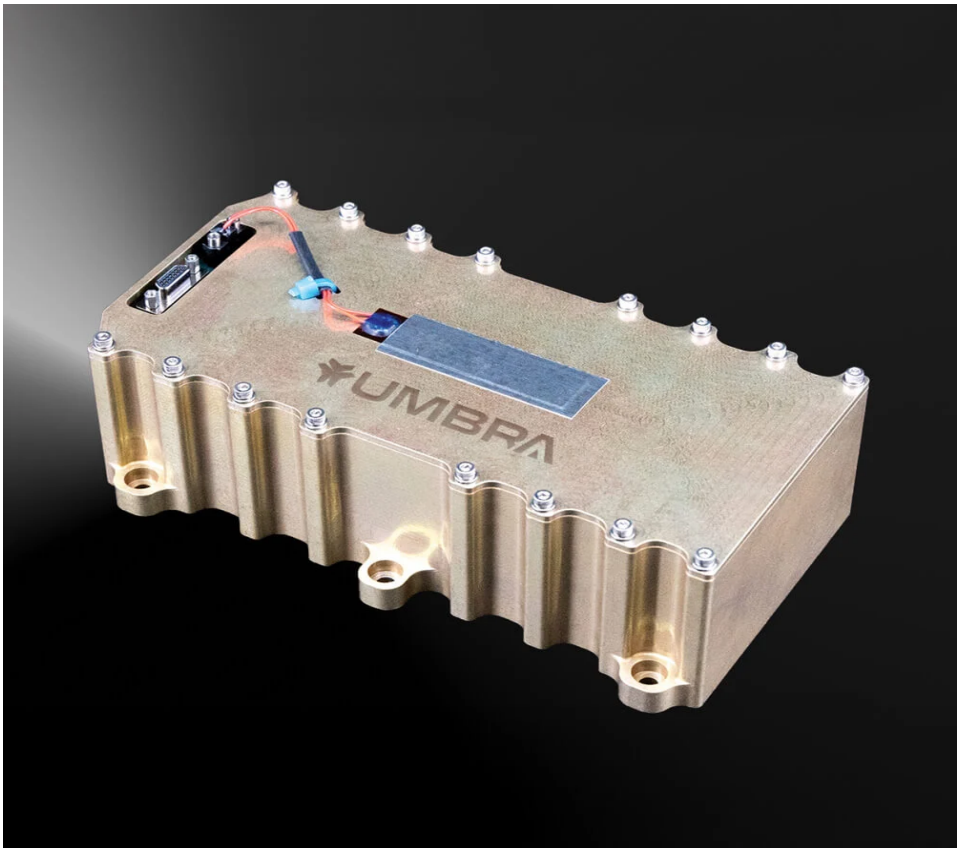
This document is Version 1.0.

3.2 Document Disclaimer

DISCLAIMER: This User Guide is intended to provide a brief summary of our knowledge and guidance regarding the use of this item. The information contained herein has been compiled from sources considered by Umbra to be dependable and is accurate to the best of Umbra's knowledge. It is not meant 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 the appropriate protective mechanisms to prevent employee exposure, personal injury, property damage or release to the environment of any hazardous substances. Umbra assumes no responsibility for injury, damage, or loss sustained by the recipient or third persons 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.

4.0 Hardware Handling

Figure 1. Umbra Battery Module 8S2P



4.1 Mechanical Handling

The Lithium-Ion batteries contained in the Umbra Battery Module are volatile. Failure to read and follow the instructions contained in this user guide may result in damage to the module, operators, and other property if stored, charged, or used improperly.

Contact Umbra if any Umbra Battery Module fails any procedure as described in this document. Do not recharge or continue use of any Umbra Battery Module with any suspected damage, including damage resulting from fire.

Ensure that any transportation of the Umbra Battery Module occurs in an environment described in 4.5 Storage and Transport Environment.

Umbra recommends users monitor the Umbra Battery Module throughout the charging process to ensure batteries are properly charged, including taking voltage readings periodically throughout the

process. Do not overcharge the Umbra Battery Module. Only charge the Umbra Battery Module in a 10 °C to 45 °C environment.

Do not drop the Umbra Battery Module. Only lift Umbra Battery Modules by the chassis.

Always use a charger meeting the requirements described in this document to charge any Umbra Battery Module. Failure to do so may cause fire or damage the Umbra Battery Module, which may result in personal injury and property damage.

Do not disassemble the Umbra Battery Module.

4.1.1 Hazards

4.1.1.1 Hazardous Materials

The Umbra Battery Module 8S2P contains lithium-ion cells, which are considered hazardous materials. Customer shall follow all regulations for handling, disposal, transport, and any additional regulations relevant to Lithium batteries as pertains to their specific use case. Lithium cells are subject to the DOT's Hazardous Materials Regulations (HMR; 49 CFR Parts 171–180), and Umbra battery modules have been certified for transport under UN 38.3 testing.

Each Umbra Battery Module 8S2P is considered UN3481 equipment and must be transported safely per DOT regulations for equipment with this classification. See 4.5 Storage and Transport Environment for Umbra recommendations for transport of Umbra Battery Module 8S2P in addition to all safety requirements for UN3481 equipment.

4.1.1.2 Fire Hazards

Always have sufficient fire extinguishing agent available for emergency use. Always have a fireproof container available to store the Umbra Battery Module in case of fire. Only trained and qualified personnel should fight a Lithium-Ion fire.

If at any point a user witnesses the battery module leak, smoke, swell up, or catch fire, immediately discontinue charging and usage then disconnect the battery and observe it in a safe place for at least 15 minutes. Touching the battery module with bare hands while in this failure mode may lead to injury. Observation should occur outside, away from any combustible material.

After this observation period, the Umbra Battery Module may become combustible again. Trained personnel should move the battery module to a fireproof container when safe to do so. The Umbra Battery Module should not be used after this failure mode is observed.

4.1.2 ESD Sensitivity

The Umbra Battery Module is electrostatic discharge (ESD) sensitive.

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

- Check shock detection stickers
- Remove from protective case
- Perform visual inspection for damage
- Take pictures as received
- No cleanliness requirements or contamination risks

4.2 RBF/ Red Tag GSE

Item listed in Table 1 must be removed before flight.

Table 1. RBF Items

Item	Critical / Optional	Notes
Connector Dust Cap	Critical	Protects connector interface from debris on the ground

See referenced Appendix B for more information.

4.3 Electrical Mate/Demate

Table 2. Electrical Connectors

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

The Umbra Battery Module 8S2P contains live batteries. Adequate precautions to prevent current flow on mating should be taken at all times.

See Section 5.1 Connector Pinouts for more information.

4.4 Connector Strain

It is recommended to secure all harnessing interfacing to the Umbra Battery Module per the guidance found in SAE-AS50881 which describes guidance on the installation of wiring harness.

4.5 Storage and Transport Environment

Do not store the Umbra Battery Module in direct sunlight.

Do not store the Umbra Battery Module in such a way that damages part markings.

Ensure that critical RBF components are in place during all transport of the Umbra Battery Module.

Store the Umbra Battery Module with heater side UP to prevent damage to the system.

Table 3. Recommended Storage Environment

Parameter	Value
Storage State of Charge	To maximize service life, store the Umbra Battery Module at a charge level between 40% charge to 90% charge.
Storage Temperature	-20°C to 50°C
Humidity	< 50% Relative Humidity
Maximum Storage Lifetime	10 years. See Section 8.4 On-Orbit Checkout for additional notes on depth of discharge.

4.6 Operating Environment

Table 4. Operating Environment

Parameter	Value
Operating Temperature (Charge)	10°C to 45°C
Operating Temperature (Discharge)	-20°C to 60°C

4.7 Survival Environment

Table 5. Survival Environment

Parameter	Value
Survival Temperature:	-20°C to 60°C
Random Vibration	Qualified to 14.16 Grms profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels
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 information about mounting the Umbra Battery Module 8S2P.

5.0 Electrical Properties

Table 6. Electrical Properties

Property	Typical Value	Notes
Operating Voltage Range	26.5 ± 4.5 V	Nominal Voltage: 28 V
Energy Capacity	250 Wh	66 Ah
Idle Power Draw	0 W	Heaters off
Maximum Power Draw	9.7 W	Heaters at maximum
Maximum Discharge Rate	12.5 A	

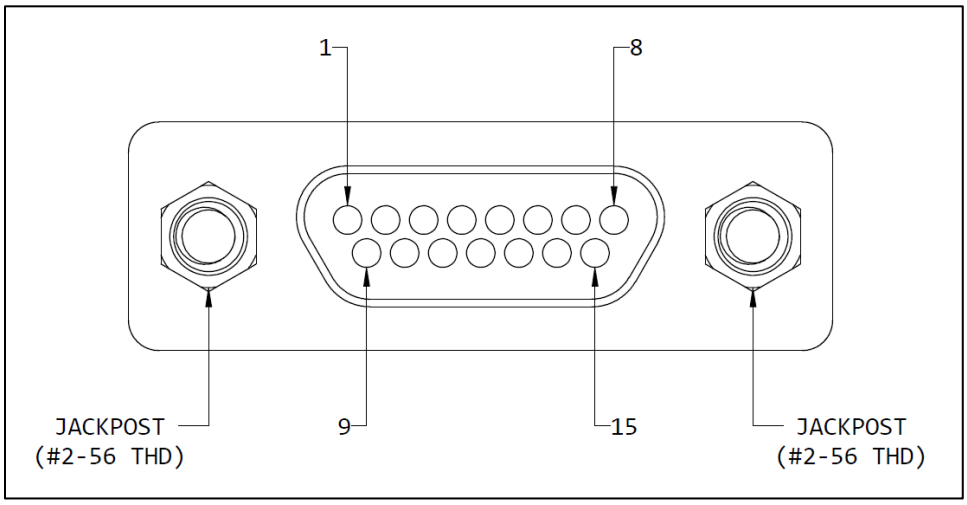
5.1 Connector Pinouts

The Umbra Battery Module J1 connector (MMDP-015) is described in Appendix B. Refer to Table 7 for pinout and Figure 2 for the mating face view.

Table 7. J1 Connector Pinout

PIN	SIGNAL
1	THERM P
2	THERM N
3	HEATER P
4	HEATER N
5	GND
6	POWER SUPPLY
7	POWER SUPPLY
8	POWER SUPPLY
9	GND
10	GND
11	GND
12	GND
13	POWER SUPPLY
14	POWER SUPPLY
15	POWER SUPPLY

Figure 2. MMDP-015 Connector Mating Face View



The assembly connector's body is not electrically connected to GND. The harness connector body and backshell should be isolated from GND as well – they will be electrically bonded to the assembly connector's body through the mating jackposts and jackscrews.

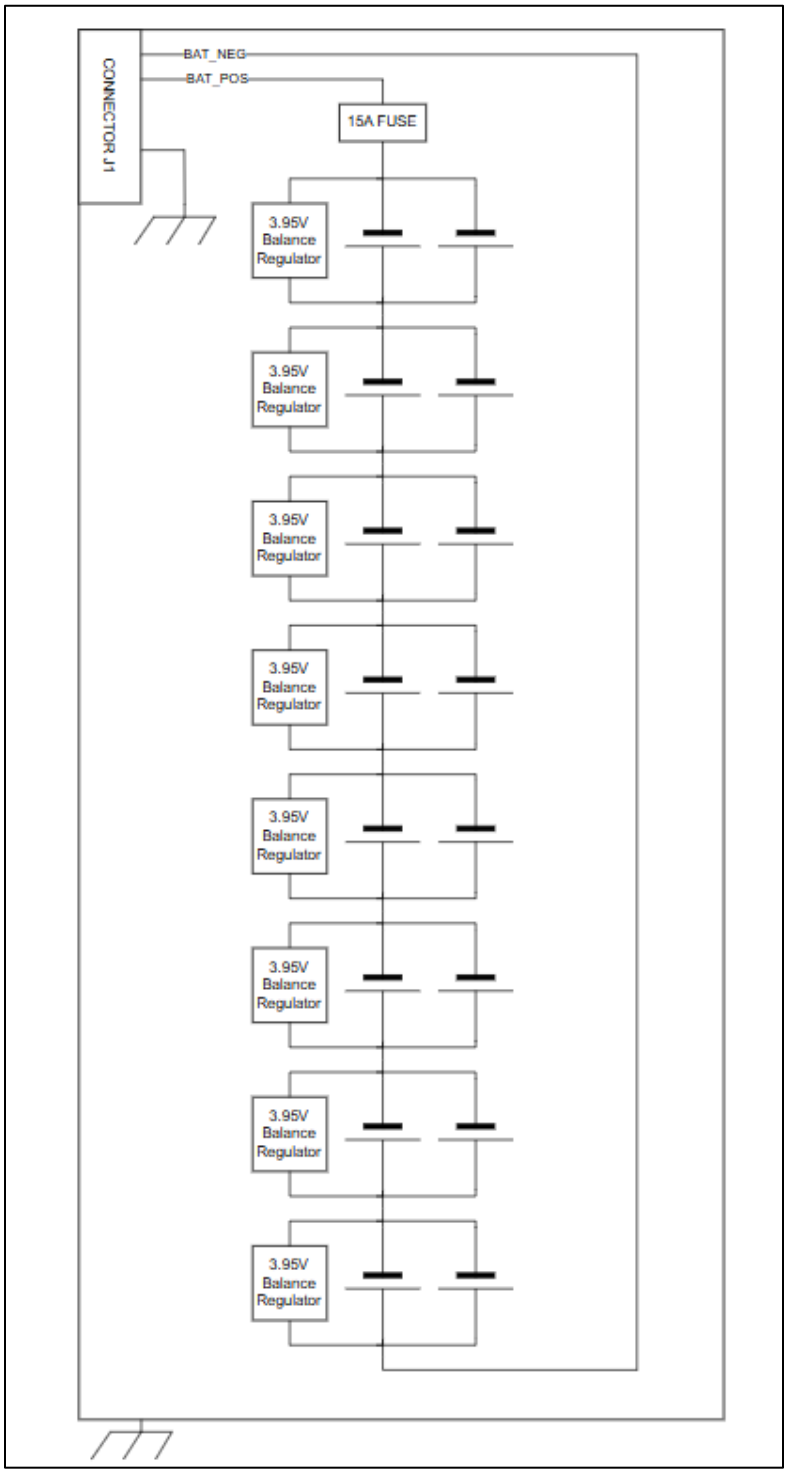
5.2 Harnessing Recommendations

Harnesses connecting to the Umbra Battery Module should use mating connector Female Socket MMDS-015 to connect to the connector described in Section 5.1 Connector Pinouts.

Space-rated harnesses connecting to the Umbra Battery Module should use wire conforming to SAE AS22759. Umbra recommends 24AWG wire.

5.3 Grounding Diagram

Figure 3. Umbra Battery Module 8S2P Electrical Block Diagram



5.4 EMI/EMC Properties

The Umbra Battery Module 8S2P 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 components are manufactured from materials deemed space-rated based on low outgassing. See Appendix B for more information about material properties of the Umbra Battery Module 8S2P.

6.0 Software Properties

Not Applicable

7.0 Performance Specifications

7.1 Charge Balancing

Charge balancing systems ensure that battery cells within a system maintain the same state of charge (SOC). This ensures that a SOC reading from a battery system also applies to the individual battery cells within the system. Since each individual battery cell must remain within its safe charging range to maintain lifetime and allow for discharge without damage, cell balancing increases the lifetime of the battery system. This is especially important when using lithium-ion batteries due to the volatility of this failure mode with this battery chemistry.

The Umbra Battery Module includes a shunt regulator type cell balancing management system. In the 8S2P configuration, this system ensures that each of the eight battery pairs in series remain at the same voltage. Parallel cells naturally balance to the cells in series through their direct connection.

In the Umbra Battery Module cell balancing system, when additional power reaches the battery module while the SOC has reached its maximum safe threshold, the energy is shunted to heat.

Cell unbalance within safety limits can occur. To rebalance all cells, charge the battery module to full state of charge.

7.2 Thermal Management

The Umbra Battery Module includes an onboard heater and resistance temperature detector (RTD). If voltage is provided to the heater as described in the Section 5.1 Connector Pinouts, the heater will activate.

7.2.1 Heater Information

Table 8. Heater Information

Property	Typical Value
Heater Part Number	HK6901
Heater Rating	NASA qualified, low outgassing
Heater Nominal Voltage	19.5 V
Heater Max Voltage	39.0 V
Heater Nominal Wattage	7.9 W
Heater Max Wattage	15.7 W

7.2.2 RTD Information

Table 9. RTD Information

Property	Typical Value
RTD Part Number	B57230V2103F260
RTD Nominal Resistance	10 kΩ at 25°C

7.3 Umbra Power Package Compatibility

The Umbra Battery Module 8S2P can be purchased as part of the modular Umbra Power Package, with the Umbra Power Management Unit included. See documentation on the Umbra Power Management Unit for more details about compatibility with this system.

7.4 Performance Verification

Customer recommended checkout and qualification testing is described in this document in Section 8.0 Operational Procedures.

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 Battery Module may be damaged by carrying out any procedure listed in this section if mechanical handling requirements and recommendations are not followed.

8.1 Ground Support Equipment

To ensure operator and equipment safety, ensure Ground Support Equipment (GSE) follows the recommendations laid out in this section.

8.1.1 Charger Requirements

Umbra recommends the use of a qualified battery charger before integration with any payload. Ensure the charger is lithium-ion chemistry compatible. Ensure battery charger connector matches Section 5.2 Harnessing Recommendations before use. Umbra recommends the use of a battery charger capable of monitoring charge current and charge state voltage.

8.1.2 Thermal Sensor Recommendations

Umbra recommends the use of a monitoring circuit to take advantage of the internal temperature sensor. Alternatively, customers may use an external thermal camera or contact temperature sensor during all ground charging operations to monitor shunt heating of the Umbra Battery Module. The temperature sensor should measure the top of the Battery Module chassis for most accurate reading.

8.2 First Use Procedure

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

8.2.1 Assembly

No customer assembly required.

8.2.2 Checkouts

Ensure there are no signs of lithium-ion battery damage upon receipt of the Umbra Battery Module. Check connectors and heater for damage before powering on.

8.2.3 Initial Configuration

The Umbra Battery Module will be shipped in a partially charged state to preserve cell lifetime.

8.3 Battery Charging Procedure

The objective of this procedure is to charge the Umbra Battery Module 8S2P.

8.3.1 Success Criteria

Measured cell voltage shall be 32 V ± 0.5 V.

8.3.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 10. Battery Charging Procedure

Part Number	Part Name	Configuration	Quantity
5062H0001	Umbra Battery Module	Charge State < 90%	x1
N/A	Battery Charger	See Section 8.1.1 Charger Requirements	x1
N/A	Temperature Sensor	See Section 8.1.2 Thermal Sensor Recommendations	Optional

8.3.3 Test Procedure

Overcharging the Umbra Battery Module 8S2P may result in damage to the module, operator harm, and/or fire. Ensure all safety recommendations in Section 4.0 Hardware Handling are followed as best practices throughout this procedure.

1. Connect the Umbra Battery Module 8S2P to the Battery Charger using a connector compatible with the Battery Module connector.
2. If available, monitor the charging process with a temperature sensor. The temperature sensor should measure the top of the Battery Module chassis for most accurate reading.
3. If the Battery Charger is capable of monitoring charge, record initial voltage reading if available. This charge voltage should be as stated in 8.2.3 Initial Configuration at first receipt of the battery module.
4. Begin charging if needed. Charging is complete when monitored voltage no longer rises, at a reading of 32 V ± 0.5 V.
5. Do not touch the battery module once measured voltage reaches 32 V ± 0.5 V. See Section 7.1 Charge Balancing for information on how additional energy is converted to heat.
6. Disconnect the charger, still careful to avoid touching the potentially hot surface of the battery modules.
7. Allow the cells to rest for at least 5 min to dissipate heat and reach their final SOC.
8. If desired, measure the final cell voltage.

8.4 On-Orbit Checkout

8.4.1 Depth of Discharge

Umbra recommends maintaining Umbra Battery Module 8S2Ps at a state of charge of 40% to 90% to preserve capacity to over 64 Ah over 600 cycles. See documentation on NCR20700B cells for more information.

8.4.2 Multiple Module Usage

If multiple Umbra Battery Module 8S2Ps are connected in series, each module should have a similar current draw.

Appendix A

Acronyms and Abbreviations

A.1 Acronyms and Abbreviations

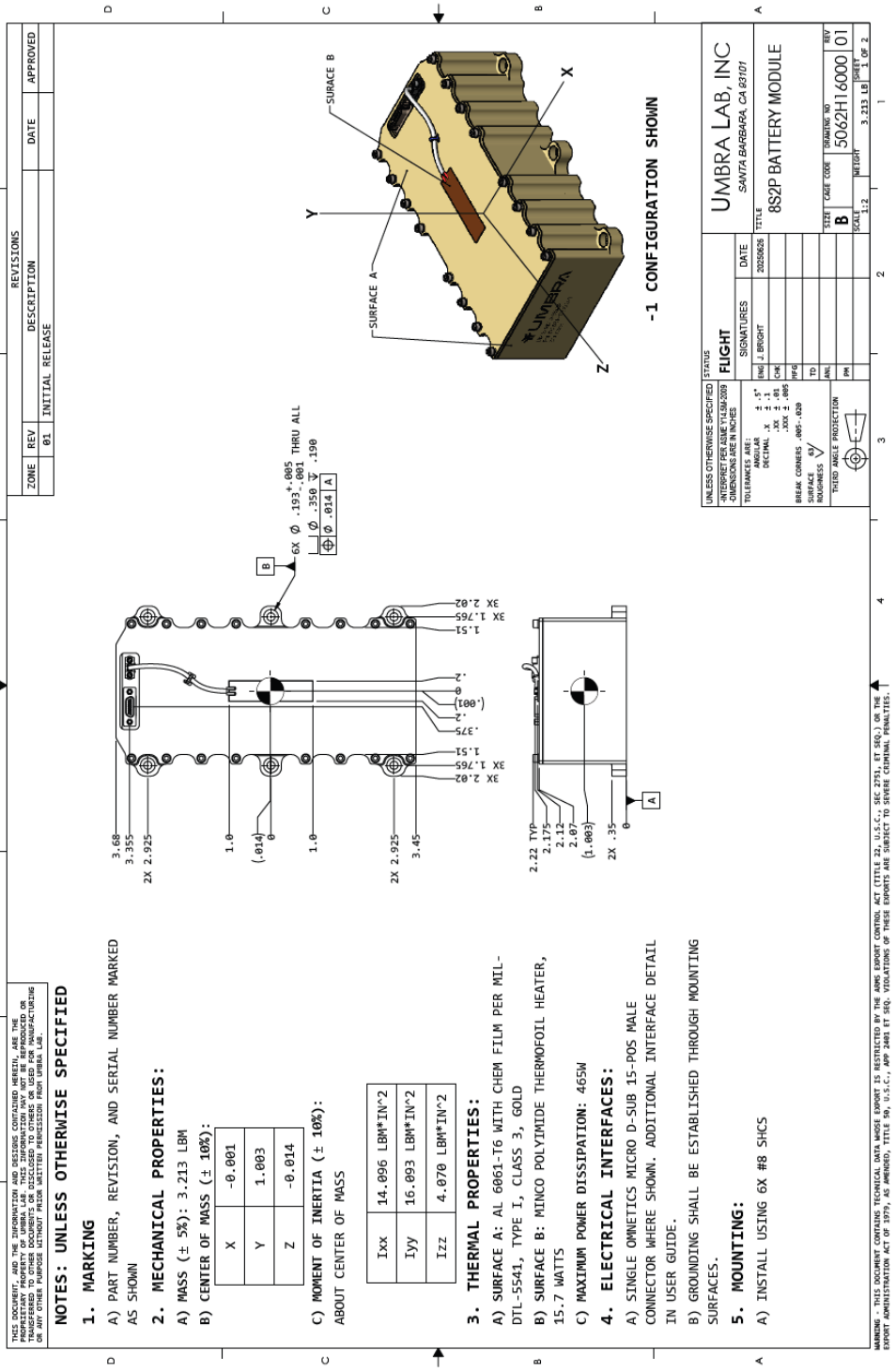
DOT	Department of Transportation
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
GEVS	General Environmental Verification Standard
GND	Ground
GSE	Ground Support Equipment
HMR	Hazardous Materials Regulations
N/A	Not Applicable
RBF	Remove Before Flight
RTD	Resistance Temperature Detector
SOC	State of Charge

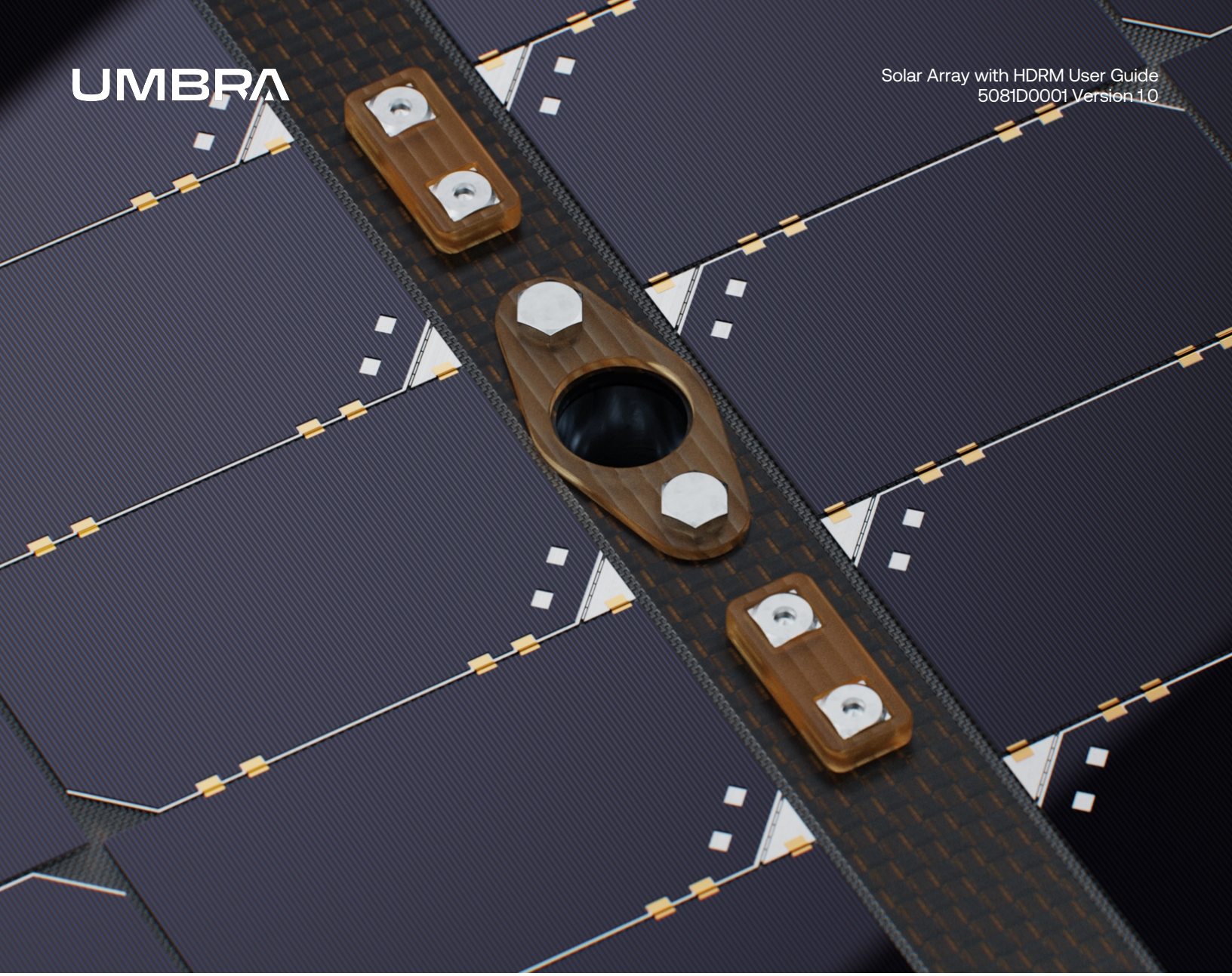
A.2 Units

°C	Degrees Celsius
A	Ampere
Ah	Ampere Hours
Grms	root mean square acceleration
Hz	Hertz
kΩ	Kiloohms
krad	Kilorad
min	Minutes
ms	Millisecond
V	Volts
VAC	Volts Alternating Current
W	Watts
Wh	Watt Hours

Appendix B

Mechanical Interface Control Documentation





Solar Array + HDRM User Guide

Distribution Statement

No Restrictions

Export Control

No US Export Control Information

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Figures

Tables

1.0 Objective

This document provides user guidance for the integration of the Umbra Body Steered Deployable Solar Array, referred to as the Solar Array hereafter.

The Solar Array provides 120 Watts of power using a body steered tri-fold array. There are multiple Solar Array configurations available to support various mission requirements.

The Solar Array configuration described in this document includes the Umbra Hold Down and Release Mechanism, referred to as the HDRM hereafter. This HDRM is a non-explosive resettable restraint-mechanism that holds Solar Arrays in place before launch and allows these Solar Arrays to deploy when activated.

2.0 Document References

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

2.1 Umbra Documents

5081H14000	7X8 H-FOLD SOLAR ARRAY MICD
5070G0001	UMBRA STOW TOOL

2.2 Standard Documents

ANSI/ESD S20.20-2021	PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES, AND EQUIPMENT
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3.1 Revision Notes

This document is Version 1.0.

3.2 Document Disclaimer

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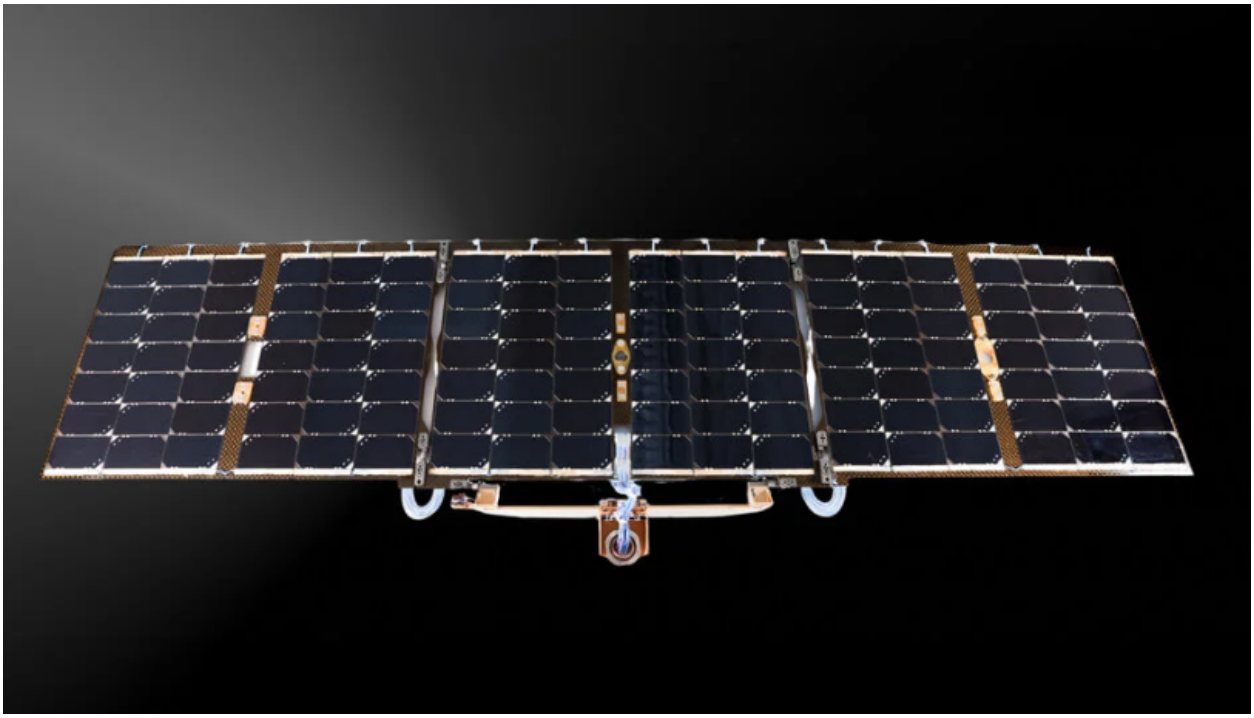
4.0 Hardware Handling

Figure 1. Umbra Solar Array



4.1 Mechanical Handling

Failure to read and follow the instructions contained in this user guide may result in damage to the Solar Array with HDRM, operators, and other property if stored or used improperly.

Contact Umbra if any Solar Array with HDRM fails any procedure as described in this document. Do not continue use of any Solar Array with HDRM with a suspected failure.

Ensure that any transportation of the Solar Array with HDRM occurs in an environment described in Section 4.5 Storage and Transport Environment.

Do not drop the Solar Array and/or HDRM. Impact damage and scratches will affect the performance of the Solar Array.

Only lift the Solar Array by the panel edges or the back of the panels Do not support the Solar Array via the solar array cells, welds, or tabs.

Do not handle HDRM after heater usage. See Section 4.1.1 Hazards for more information.
Do not disassemble the Solar Array and/or HDRM.

Always wear powder-free latex or nitrile gloves while handling the Solar Array. Do not handle the Solar Array while wearing rings or other hard items that may scratch the solar array cells. Gloves will additionally prevent oils from contaminating or damaging the solar array.

When setting the Solar Array on a flat surface, ensure there is clearance and relief for all bundles and wires. See Appendix B.1 Solar Array MICD for location information.

Do not overextend the hinges of the Solar Array. The Solar Array has stops to ensure the deployed state of the Solar Array is stable. These stops may be damaged or broken by overextension of the hinges.

Do not let the Solar Array hang in a state where it is only supported by the root hinge bracket. In the deployed state, the Solar Array must be supported at the hinges at all times while in Earth's gravity to prevent damage to the hinges.

4.1.1 Hazards

The Solar Array does not contain any hazardous materials as defined by 49 CFR 172 that are subject to anticipated exposure when used as indicated.

When deploying the Solar Array and/or HDRM, ensure clearance requirements described in this user guide are met. Snagging during testing or operational deployments may result in operator injury, damage to the Solar Array, damage to the HDRM, damage to surroundings, and/or failure to deploy. The Solar Array limit switches are very sensitive to snagging and may be damaged if clearances are not respected at all times. See Appendix B.1 Solar Array MICD for location information.

The HDRM will become very hot during deployment. Do not handle the HDRM during deployment. Do not handle the HDRM until its temperature has cooled to a safe handling temperature post-deployment. Do not store flammable materials next to the HDRM during or immediately after deployment.

The HDRM utilizes compressed springs to stow the system. Operators should be trained to handle this hazardous energy and follow all stow tooling operation instructions to avoid injury and property damage.

The Solar Array generates power to be used by peripherals, and is recommended to be paired with a power management system such as the Umbra Power Management Unit. The power generated by the Solar Array can potentially harm the user if not handled properly.

4.1.2 ESD Sensitivity

The Solar Array is electrostatic discharge (ESD) sensitive.

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.

The HDRM is not ESD sensitive.

4.1.3 Unpacking

- Check shock detection stickers
- Remove from protective case
- Perform visual inspection for damage
- Take pictures as received
- There are no cleanliness requirements or contamination risks

4.2 RBF/ Red Tag GSE

Items listed in Table 1. RBF Items must be removed before flight.

Table 1. RBF Items

Item	Critical / Optional	Notes
Solar Array J1 Connector Dust Cap	Critical	
HDRM J1 Connector Dust Cap	Critical	
Solar Array Dust Covers	Critical	X3, per each panel

See Appendix B for more information.

4.3 Electrical Mate/Demate

Table 2. Electrical Connectors

Connector Designator	Assembly Connector	Mating Flight Connector
Solar Array J1	TVS07RF-17-35S	MIL-DTL-38999, TVS06RF-17-35P
HDRM J1	M80-5610805	M80-4810805

See Section 5.1 Connector Pinouts for more information.

4.4 Connector Strain

The Solar Array J1 Connector does not require strain relief.

It is recommended to secure all harnessing interfacing to the HDRM per the guidance found in SAE-AS50881 which describes guidance on the installation of wiring harness.

4.5 Storage and Transport Environment

Do not store the Solar Array and HDRM in direct sunlight.

Do not store the Solar Array and HDRM in such a way that damages part markings.

Ensure that critical RBF components are in place during all transport of the Solar Array and HDRM.

Impact damage and scratches will affect the performance of the Solar Array. Do not store items on top of the Solar Array to prevent compression damage.

Only transport the Solar Array in the stowed position. Follow Section 8.6 Solar Array with HDRM Manual Stow Procedure as needed to restow the Solar Array.

Table 3. Recommend Storage Environment

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

4.6 Operating Environment

Table 4. Operating Environment

Parameter	Value
Operating Temperature	-50℃ to 90℃
HDRM Self Actuation Temperature	65℃ (TBR)

4.7 Survival Environment

Table 5. Survival Environment

Parameter	Value
Survival Temperature	-60℃ to 120℃
Random Vibration	Qualified to 14.16 Grms profile enveloping GEVS, Falcon 9, SpaceX Rideshare, and Electron levels
Shock	Qualified to 1000G 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 B.1 Solar Array MICD for information about mounting the Solar Array.

See B.2 HDRM MICD for information about mounting the HDRM.

5.0 Electrical Properties

Table 6. Solar Array Electrical Properties

Property	Typical Value
Peak Power	120 W
Open Circuit Voltage	38.08 V
Maximum Power Voltage	22.68 V
Maximum Power Current	2.3 A

Table 7. HDRM Electrical Properties

Property	Typical Value
Nominal Power at 28 V	8 W per heater

5.1 Connector Pinouts

5.1.1 Solar Array J1

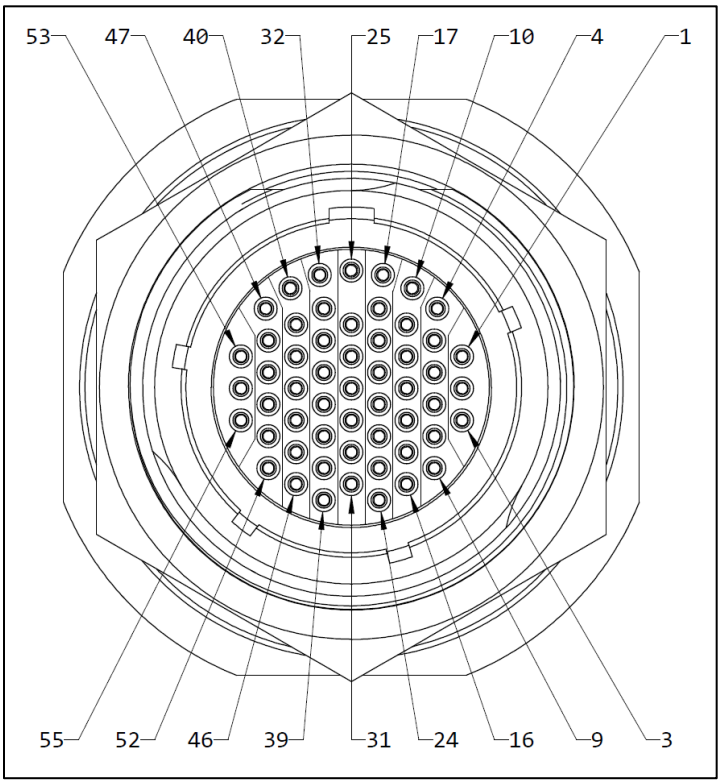
The Solar Array J1 connector (TVS07RF-17-35S) provides connection to the photovoltaic strings and temperature sensors. Refer to Table 8 for pinout and
Figure 2 for the mating face view.

Table 8. Solar Array J1 Connector Pinout

PIN	SIGNAL
1	SA_LIMIT1-
2	SA_LIMIT1+
3	SA_LIMIT2-
4	SA_LIMIT2+
5	SA_TEMP1-
6	SA_TEMP1+
7	SA_TEMP2-
8	SA_TEMP2+
9	SA_TEMP3-
10	SA_TEMP3+
11	SA_STR1-
12	SA_STR1-
13	SA_STR1+
14	SA_STR1+
15	SA_STR2-
16	SA_STR2-
17	SA_STR2+

PIN	SIGNAL
18	SA_STR2+
19	SA_STR3-
20	SA_STR3-
21	SA_STR3+
22	SA_STR3+
23	SA_STR4-
24	SA_STR4-
25	SA_STR4+
26	SA_STR4+
27	SA_STR5-
28	SA_STR5-
29	SA_STR5+
30	SA_STR5+
31	SA_STR6-
32	SA_STR6-
33	SA_STR6+
34	SA_STR6+
35	SA_STR7-
36	SA_STR7-
37	SA_STR7+
38	SA_STR7+
39	SA_STR8-
40	SA_STR8-
41	SA_STR8+
42	SA_STR8+
43	SA_STR9-
44	SA_STR9-
45	SA_STR9+
46	SA_STR9+
47	NC
48	NC
49	NC
50	NC
51	NC
52	NC
53	NC
54	NC
55	NC

Figure 2. TVS07RF-17-35S Connector Mating Face View



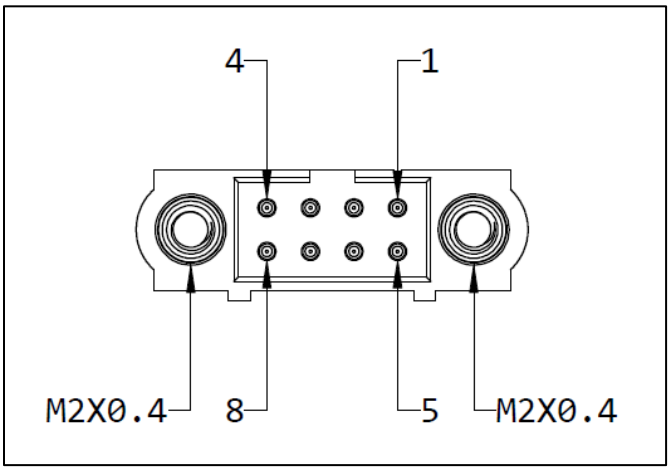
5.1.2 HDRM J1

The HDRM J1 connector (M80-5610805) provides connection to the deployment heaters and temperature sensors. Refer to Table 9 for pinout and Figure 3 for the mating face view.

Table 9. HDRM J1 Connector Pinout

PIN	SIGNAL
1	HEATER 1+
2	RTD 1+
3	HEATER 2+
4	RTD 2+
5	HEATER 1-
6	RTD 1-
7	HEATER 2-
8	RTD 2-

Figure 3. M80-5610805 Connector Mating Face View



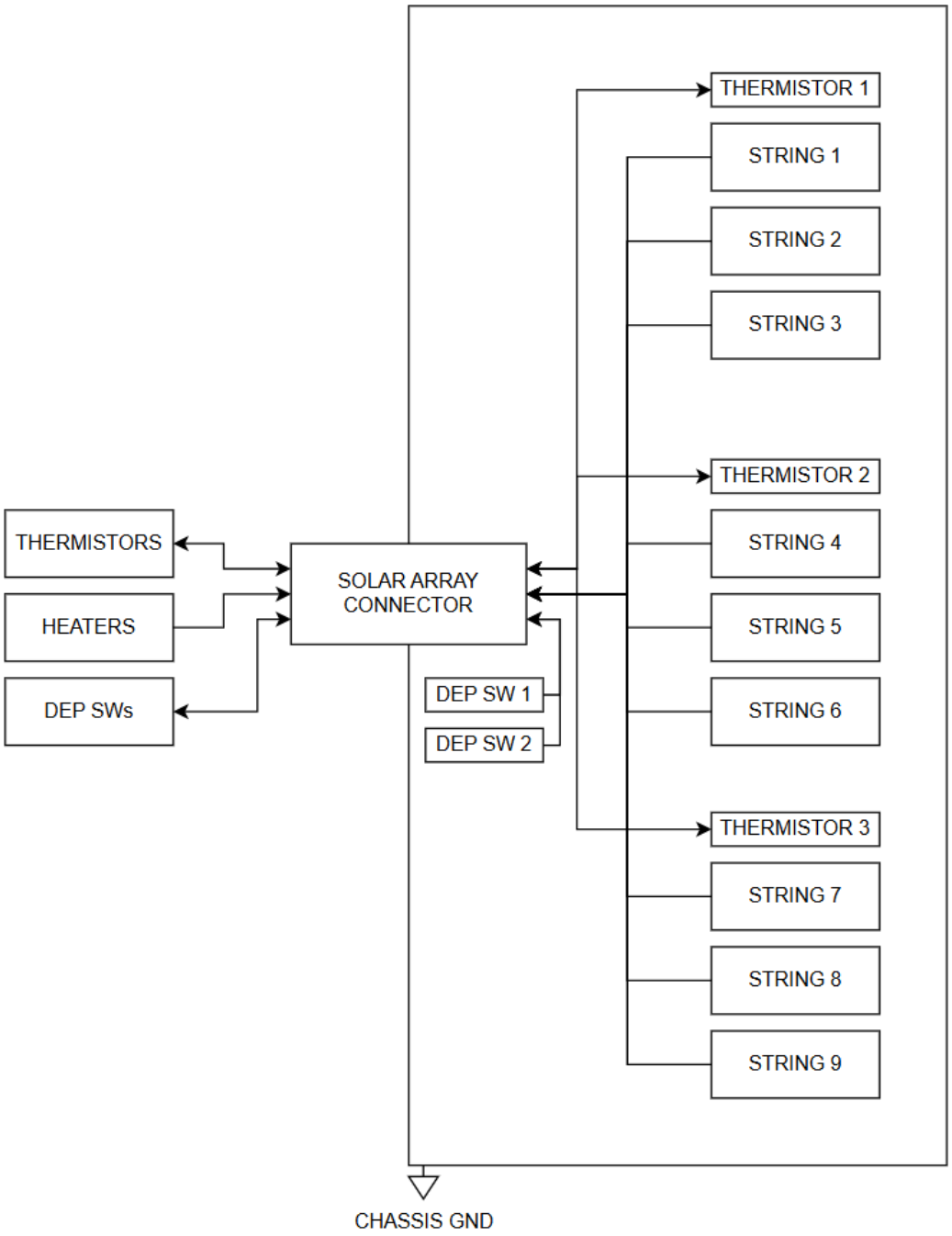
5.2 Harnessing Recommendations

Space-rated harnesses connecting to the Solar Array and/or HDRM should use wire following SAE AS22759. Umbra recommends 24AWG wire.

5.3 Grounding Block Diagrams

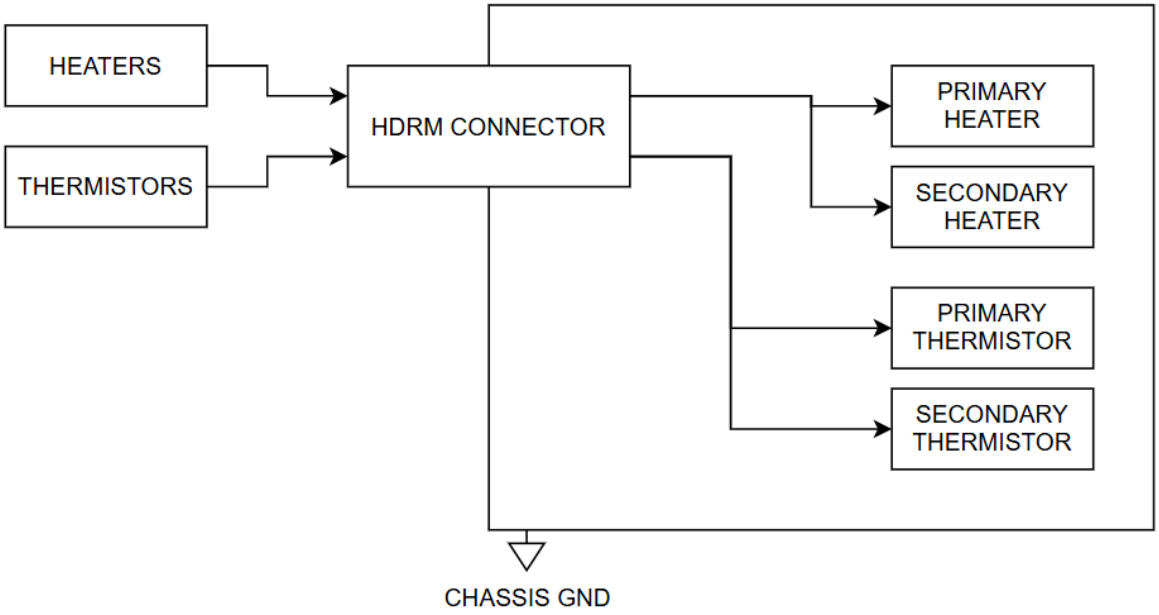
5.3.1 Solar Array Grounding Block Diagram

Figure 4. Solar Array Grounding Block Diagram



5.3.2 HDRM Grounding Block Diagram

Figure 5. HDRM Grounding Block Diagram



5.4 EMI/EMC Properties

The Solar Array and HDRM do not contain components that are responsible for or influenced by Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) requirements.

5.5 Material Properties

All Umbra products are manufactured from materials deemed space-rated based on low outgassing.

See Appendix B for more information on material properties of the Solar Array and HDRM.

6.0 Software Properties

Not applicable.

7.0 Performance Specifications

7.1 Solar Array Performance

The Solar Array utilizes triple junction photovoltaic cells to allow the absorption of a broad range of wavelengths for high energy conversion efficiency and high power to weight ratio.

The Solar Array also utilizes cell bypass diodes. These bypass diodes allow the spacecraft to shunt the arrays for reduced power generation to prevent overcharge of the spacecraft. Each string has its own set of pins (see Table 8) to allow strings to be shunted in groups of three. Customer software will be required to implement shunting schema without the use of the Umbra Power Management Unit as described in Section 7.3 Umbra Power Package Compatibility.

The Solar Array is available with a variety of coverglass options for various mission profiles, including extended mission lifetime and a variety of orbits. Standard Solar Array coverglass is designed for a 5-year mission lifetime in LEO. Please contact Umbra if your mission profile requires a different coverglass.

Prior to deployment, the Solar Array has high stowed packing efficiency due to its ability to deploy. The Solar Array has a stowed state designed for stability and compaction during launch. The Solar Array enters its deployed state when the HDRM actuates. The form factors of these stowed and deployed states are described in Appendix B.1 Solar Array MICD.

When deployed, the Solar Array has high dynamic stability for highly maneuverable spacecraft. The Solar Array hinges have a high torque margin to maintain solar array deployment throughout maneuvers. The composite panels of the Solar Array have high stiffness to ensure their structural stability.

The HDRM is resettable without refurbishment during ground testing. The Solar Array Stow Tool may be used as described in 8.1.1 Stow Tool to manually deploy and restow the Solar Array.

7.1.1 Solar Array J1 Signals

The Solar Array sends signals over its SA_LIMIT pins and SA_TEMP pins. SA_STR pins are used to send power generated by the Solar Array to the host spacecraft. See Section 5.1.1 Solar Array J1 for referenced signals and connector pinouts.

SA_LIMIT pins on the Solar Array are switches that open or close depending on the Solar Array position. When the Solar Array is in the stowed position, the SA_LIMIT signal is nominally closed. When the Solar Array is in the deployed position, the SA_LIMIT signal is nominally open.

SA_TEMP pins on the Solar Array connect to a TS665TKY40BC thermistor.

SA_STR pins send power to the host vehicle. For Solar Array shunting scheme recommendations, see documentation on the Umbra Power Management Unit.

7.2 HDRM Performance

The HDRM is a paraffin-actuated, resettable hold down and release mechanism designed for use with Solar Arrays. Paraffin actuators use heat expansion of a wax block to drive a piston. This piston allows the locking mechanism to retract and the spring system to poise the solar array.

The HDRM is resettable without refurbishment during ground testing. After firing, the paraffin actuator within the HDRM will reset to its stowed position through thermal dissipation. Once the actuator returns to its stowed position, Umbra provided GSE described in Section 8.1.1 Stow Tool may be used to restow the Solar Array to the HDRM.

Two heaters are included in the HDRM. Only one heater is necessary for deployment of the HDRM.

7.2.1 HDRM J1 Signals

The HDRM receives signals via its HEATER pins. RTD (Resistance Temperature Detector) pins send signals used to monitor temperature. See Section 5.1.2 HDRM J1 for referenced signals and connector pinouts.

HEATER+ pins on the HDRM receive to 28 V, 0.5 A to trigger deployment, while HEATER- pins are used for grounding. HEATER 1 pins correspond to the primary HDRM heater and HEATER 2 pins correspond to the secondary HDRM heater.

RTD pins on the HDRM increase in resistance as temperature increases. HEATER.RTD 1 and RTD 2 pins read the same body temperature. Umbra recommends halting any heating of the HDRM when a resistance of 1.350 k-ohm is noted on any RTD pin to prevent damage to the HDRM.

7.3 Umbra Power Package Compatibility

The Solar Array with HDRM can be purchased as part of the modular Umbra Power Package, with the Umbra Power Management Unit included. See documentation on the Umbra Power Management Unit for more details about compatibility with this system.

7.4 Performance Verification

Customer recommended checkout is described in this document in Section 8.0 Operational Procedures.

8.0 Operational Procedures

Follow all requirements and recommendations in Section 4.1 Mechanical Handling while carrying out any and all procedures in this section. The Solar Array and HDRM may be damaged by carrying out any procedure listed in this section if mechanical handling requirements and recommendations are not followed.

8.1 Ground Support Equipment

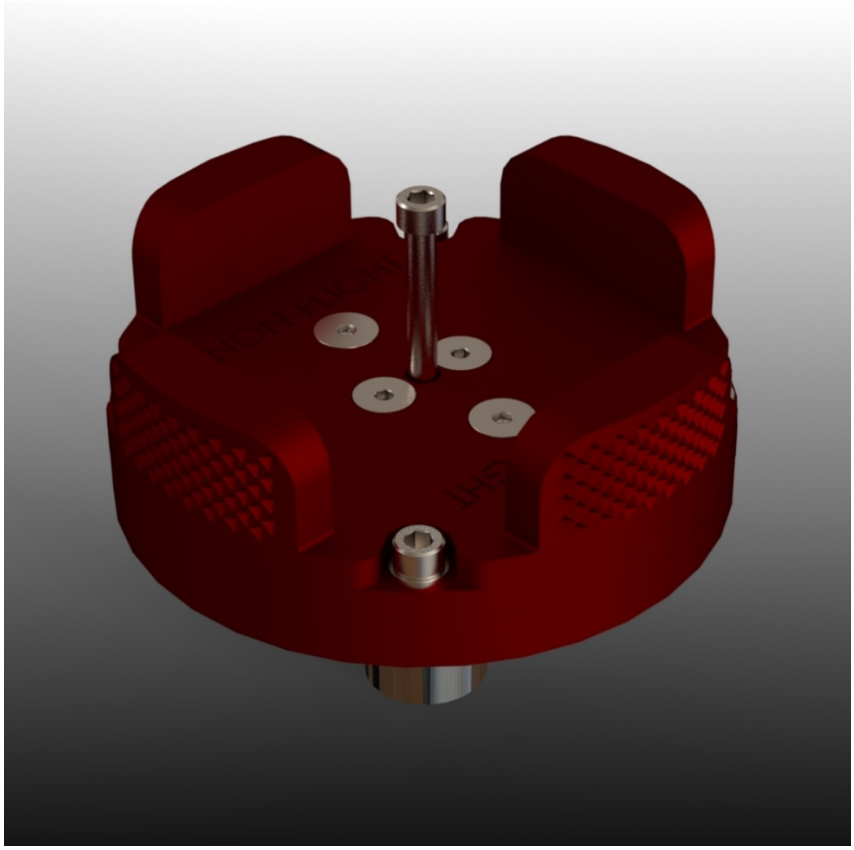
To ensure operator and equipment safety, ensure Ground Support Equipment (GSE) follows the recommendations laid out in this section.

All Umbra supplied GSE should be used without substitution. Contact Umbra if any Umbra provided GSE requires replacement.

8.1.1 Stow Tool

Umbra provides GSE tool 5070G0001 for manual deployment of the Solar Array and HDRM described in this user guide as the “Umbra Stow Tool.”

Figure 6. Umbra Stow Tool



8.1.2 Solar Array Support Tool

Umbra recommends users support Solar Array inner and middle panels at 10 degrees above the bump stops when the Solar Array is deployed. Users should ensure that this support tool does not touch the solar array cells to prevent scratching.

8.2 First Use Procedure

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

8.2.1 Assembly

No customer assembly required.

8.2.2 Checkouts

Users should take pictures of Solar Arrays to record the state of all solar cells and hinges.

Users should also ensure Solar Arrays and HDRMs are clear of FOD.

8.2.3 Initial Configuration

The Solar Array and HDRM will be shipped with partially loaded springs in their initial configuration. Follow Section 4.0 Hardware Handling at all times.

The Solar Array will be delivered in a stowed state to ensure stability during transport. Electrical tape may be used to ensure the Solar Array remains in its stowed state throughout transport.

The HDRM will be delivered in a deployed state.

8.3 HDRM Stow

The objective of this procedure is to stow the HDRM.

8.3.1 Success Criteria

The HDRM shall be manually stowed.

8.3.2 Configuration and Equipment

This procedure shall be carried out with the equipment in the listed configurations and quantities as described in Table 10.

Table 10. HDRM Stow Equipment

Part Number	Part Name	Configuration	Quantity
5070H0001	HDRM	Deployed state	x1
5070G0001	Umbra Stow Tool	N/A	x1

8.3.3 Test Procedure

This procedure should only be carried out if the HDRM is in the deployed position as shown in Appendix B.2 HDRM MICD.

1. Secure the HDRM.
2. Align the screw of the Umbra Stow Tool with the hole at the top of the HDRM.
3. Firmly but carefully press the screw of the Umbra Stow Tool into the hole at the top of the HDRM. The fine threads of the screw may be damaged if pressure is applied without correct alignment.
4. Thread the Umbra Stow Tool screw into the HDRM until secure. This resets the piston of the HDRM. The HDRM top should enter the stowed position.
5. Unthread the Umbra Stow Tool from the HDRM. Now that the HDRM is in the stowed position, it has stored compressive energy. See Section 4.1.1 Hazards for more information on how to handle the HDRM in the stowed state.

8.4 HDRM Heated Deployment

The objective of this procedure is to confirm HDRM functionality.

8.4.1 Success Criteria

The HDRM shall successfully deploy within timed tolerances.

8.4.2 Configuration and Equipment

This test shall be carried out with the following equipment in the listed configurations and quantities.

Table 11. HDRM Heated Deployment Equipment

Part Number	Part Name	Configuration	Quantity
5070H0001	HDRM	Stowed state	x1
5070G0001	Umbra Stow Tool	N/A	x1
N/A	Timer	N/A	x1
N/A	Power Supply	N/A	x1
N/A	Digital Multimeter (DMM)	N/A	x1

8.4.3 Test Procedure

This procedure should only be carried out if the HDRM is in the stowed position as shown in B.2 HDRM MICD.

1. Determine if this test will be used to activate the HDRM primary OR secondary heater. Consistently follow this procedure for the HDRM primary OR secondary heater usage. Do not activate the HDRM primary heater AND secondary heater simultaneously.
2. Secure the HDRM.
3. Attach a compatible harness to the HDRM as described in Section 5.2 Harnessing Recommendations.
4. Harness the DMM to the HDRM RTD1 or RTD2 pins as described in Section 5.1.2 HDRM J1. Note that these signals should be very similar regardless of which HEATER pins are used.
5. Turn on DMM. Set to measure resistance.
6. Harness the power supply to the HDRM primary HEATER pins OR secondary HEATER pins as described in Section 5.1.2 HDRM J1 to activate the primary heater OR secondary heater.
7. Set power supply settings to 28 V, 0.5 A.
8. Simultaneously start a timer and supply power.
9. Continue to supply power until any of the following:
    a. HDRM deployment
    b. Timer reaches 3 minutes 30 seconds without deployment
    c. Resistance measured by DMM reaches 1.350 k-ohm without deployment
10. Turn OFF the power supply.
11. Record success/fail status, time to deploy or end test, and maximum resistance measured.
12. Allow the HDRM to cool before any handling.

If the HDRM has deployed, users may restow the HDRM, following Section 8.3 HDRM Stow. If the HDRM does not deploy, this test may be repeated after the 10 minute cooling time.

Note that Umbra recommends using the provided Umbra Stow Tool during ground testing of the Solar Array as defined in Section 8.5 Solar Array with HDRM Deployment Procedure. Caution must be exercised during any deployment in an on-earth environment as damage may result due to gravitational forces if the Solar Array is not properly supported at all times. Also, keep in mind the potential for pinch or injury as stated elsewhere in this User Guide.

8.5 Solar Array with HDRM Deployment Procedure

The objective of this procedure is to automatically deploy the Solar Array using the HDRM.

8.5.1 Success Criteria

Solar Array shall be deployed by the HDRM.

8.5.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 12. Solar Array with HDRM Deployment Equipment

Part Number	Part Name	Configuration	Quantity
5081H0001	Solar Array	Stowed	x1
5070H0001	HDRM	Stowed	x1
5070G0001	Umbra Stow Tool	N/A	x1
N/A	Solar Array Support Tool	8.1.2 Solar Array Support Tool	x1

8.5.3 Procedure

Only hold the Solar Array panels by the edges of the array during this procedure. Touching the Solar Arrays may lead to scratching. Handling the hinges during movement of the arrays may lead to pinching.

This procedure requires multiple operators.

1. Find a cleared space large enough for the form factor of the deployed Solar Array as described in Appendix B.1 Solar Array MICD free of FOD. These clearances must be observed at all times during this procedure to prevent damage to operators, Solar Arrays, and surroundings.
2. Secure the HDRM.
3. Align the Solar Array center release cup at the top of the HDRM. The center release cup floats in the Solar Array.
4. Ensure the Solar Array hinges have clearances. Items caught in the Solar Arrays may be damaged by pinching. The Solar Array hinges may be damaged by items caught in the hinges and limit switches.
5. Gently hold the edges of the inner panel of the Solar Array. This panel must be supported throughout the deployment process until solar arrays are supported by the Solar Array Support Tool to prevent damage to the hinges.
6. Begin to unscrew the Solar Array counterclockwise using the Solar Array Stow Tool. As the tool is used, the inner panel of the solar array should unfurl.
7. Once the inner panel has unfolded enough to access the middle panel, additionally support the middle panel.
8. While supporting both outer panels of the Solar Array, continue unscrewing the system with the Solar Array Stow Tool until the edges of each Solar Array panel are supported by the Umbra Stow Tool.
9. Do not remove the Solar Array from the Umbra Stow Tool while the Solar Array is in a deployed state. Umbra recommends users follow Section 8.6 Solar Array with HDRM Manual Stow Procedure before any transport of the Solar Array.

8.6 Solar Array with HDRM Manual Stow Procedure

The objective of this procedure is to manually stow the Solar Array using the Umbra Stow Tool.

8.6.1 Success Criteria

Solar Array shall be stowed.

8.6.2 Configuration and Equipment

This procedure shall be carried out with the following equipment in the listed configurations and quantities.

Table 13. Solar Array with HDRM Manual Stow Equipment

Part Number	Part Name	Configuration	Quantity
5081H0001	Solar Array	Deployed	x1
5070H0001	HDRM	Deployed	x1
5070G0001	Umbra Stow Tool	N/A	x1
N/A	Solar Array Support Tool	8.1.2 Solar Array Support Tool	x1

8.6.3 Procedure

Only hold the Solar Array panels by the edges of the array during this procedure. Touching the Solar Array cells may lead to scratching. Handling the hinges during movement of the arrays may lead to pinching.

This procedure requires multiple operators.

1. Ensure all Solar Array panels are clear of all FOD, tools, etc. Stowing the Solar Array with particulate on cells may result in damage to the cells. Stowing the Solar Array with any items on the panels may result in damage to the cells or hinges.
2. Ensure the Solar Array hinges have clearance to fold inwards. Items caught in the Solar Arrays may be damaged by pinching. The Solar Array hinges may be damaged by items caught in the hinges.
3. Gently support the outer edges of the Solar Array panels, not touching the cells and hinges. Both outer panels must be supported throughout the manual deployment process until stow is complete.
4. Insert the Solar Array Stow Tool into the top of HDRM through the Solar Array release hole.
5. Slowly screw the Solar Array Stow Tool clockwise. As the tool is used, the middle panel should begin to fold into the array. The panels should not touch each other until fully folded.
6. Continue using the Solar Array Stow Tool until the inner panel appears to be fully stowed. Continue support of panels until each panel is in stowed position.
7. Remove the Solar Array from the Umbra Stow Tool. If desired, RBF panel covers may now be added to the Solar Array. Umbra recommends gently taping the edges of the solar arrays away from the cells similar to the shipped stowed state during all transport.

8.7 Solar Array Charging Test

The objective of this procedure is to confirm the functionality of the Solar Arrays through outdoor testing.

8.7.1 Success Criteria

Solar arrays generate charge as described.

8.7.2 Configuration and Equipment

This test shall be carried out with the following equipment in the listed configurations and quantities.

Table 14. Solar Array Charging Test Equipment

Part Number	Part Name	Configuration	Quantity
5081H0001	Solar Array	N/A	x1
5070G0001	Umbra Stow Tool	N/A	x1
N/A	Solar Array Test Load	Must be capable of dissipation of maximum Solar Array power generation as described in Table 6. Solar Array Electrical Properties	As needed

8.7.3 Test Procedure

Umbra recommends validating the charging performance of the Solar Arrays using a trusted illumination source.

If outdoor testing is necessary, this test will require a clear, sunny sky at approximately high noon to maximize the amount of light received by Solar Arrays. Solar Arrays WILL be damaged by rain, snow, particulate in wind, etc. Do not store Solar Arrays outside.

1. Stow the Solar Array per Section 8.6 Solar Array with HDRM Manual Stow Procedure and ensure RBF covers are ON.
2. Transport the Solar Array to a flat, dry, cleared space with an unobstructed view of the light source. This space should be large enough for the deployed form factor of the Solar Array as described in Appendix B.1 Solar Array MICD. Keep RBF covers on during transport and ensure all recommendations and requirements described in Section
3. 4.1 Mechanical Handling requirements are met throughout transport.
4. Deploy the solar arrays using the provided GSE as described in Section 8.5 Solar Array with HDRM Deployment Procedure.
5. Identify the SA_STR_#_+ and SA_STR_#_- pins for each string of the Solar Array as shown in Table 8. Solar Array J1 Connector Pinout. These strings should be harnessed to test loads on a per string basis, with all strings in parallel to a load.
6. Connect the Solar Array to a battery module with a harness described in Section 5.2 Harnessing Recommendations. Make sure everything is powered off during connection.
7. With the solar array cells UP, remove RBF covers.
8. Allow the solar array to charge the battery module. Record observed current.
9. Bright red lights may be noted on the solar arrays when they are lit by the sun or a powerful light. These lights are the max potential voltages and are nominal under powerful light sources.
10. Disconnect from battery.

11. Umbra recommends that users should stow Solar Arrays per Section 8.6 Solar Array with HDRM Manual Stow Procedure and ensure RBF covers are ON if no other testing is planned to prevent damage to the Solar Array.

8.8 On-Orbit Checkout

Contact Umbra in the event of any deviation from nominal as described in this section.

Multiple Solar Arrays may be used on the same mission. If multiple Solar Arrays are connected in series, each module should have a similar maximum current on orbit if all cells on each array have an unobstructed view of the sun.

Appendix A

Acronyms and Abbreviations

A.1 Acronyms and Abbreviations

BOL	Beginning of Life
DMM	Digital Multimeter
EOL	End of Life
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FOD	Foreign Object Debris
GSE	Ground Support Equipment
HDRM	Hold Down and Release Mechanism
LEO	Low Earth Orbit
MICD	Mechanical Interface Control Document
N/A	Not Available
RBF	Remove Before Flight
RTD	Resistance Temperature Detector
TBR	To Be Revised
TID	Total Ionizing Dose

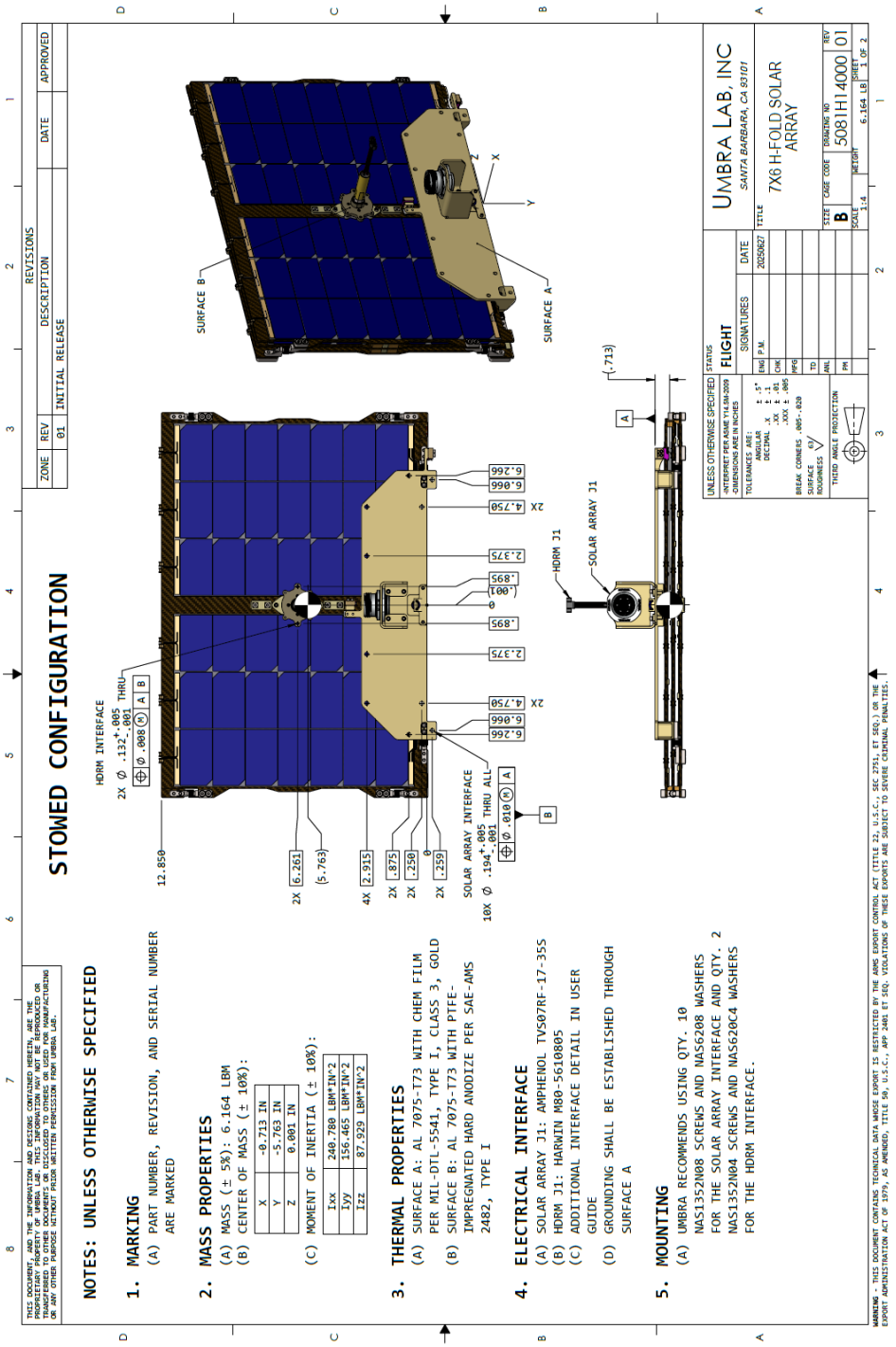
A.2 Units

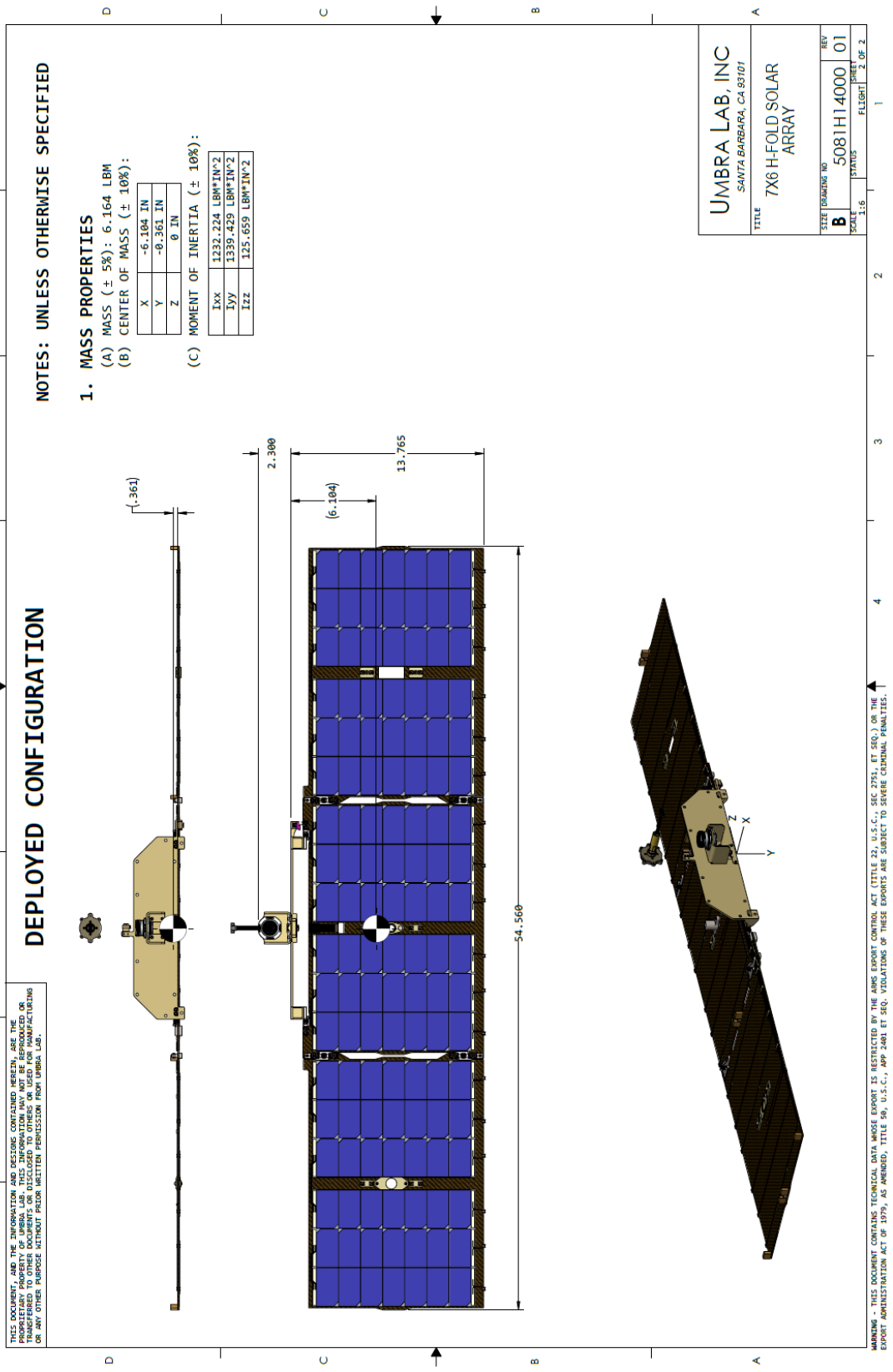
A	Amps
°C	Degrees Celsius
Grms	root mean square acceleration
k-ohm	Kilo-Ohm
krad	Kilorad
m^2	Square Meters
V	Volts
W	Watts

Appendix B

Mechanical Interface Control Documentation

B.1 Solar Array MICD




NOTES: UNLESS OTHERWISE SPECIFIED
1. MASS PROPERTIES
(A) MASS (± 5%): 6.164 LBM
(B) CENTER OF MASS (± 10%):
X -6.104 IN
Y -0.361 IN
Z 0 IN
(C) MOMENT OF INERTIA (± 10%):
Ixx 1232.224 LBM*IN^2
Iyy 1339.429 LBM*IN^2
Izz 125.659 LBM*IN^2
DEPLOYED CONFIGURATION
(.361)
2.300
(6.104)
13.765
54.560
Z
X
Y
UMBRA LAB, INC
SANTA BARBARA, CA 93101
TITLE
7X6 H-FOLD SOLAR ARRAY
SIZE B
DRAWING NO 5081H14000
REV 01
SCALE 1:6
STATUS FLIGHT
SHEET 2 OF 2
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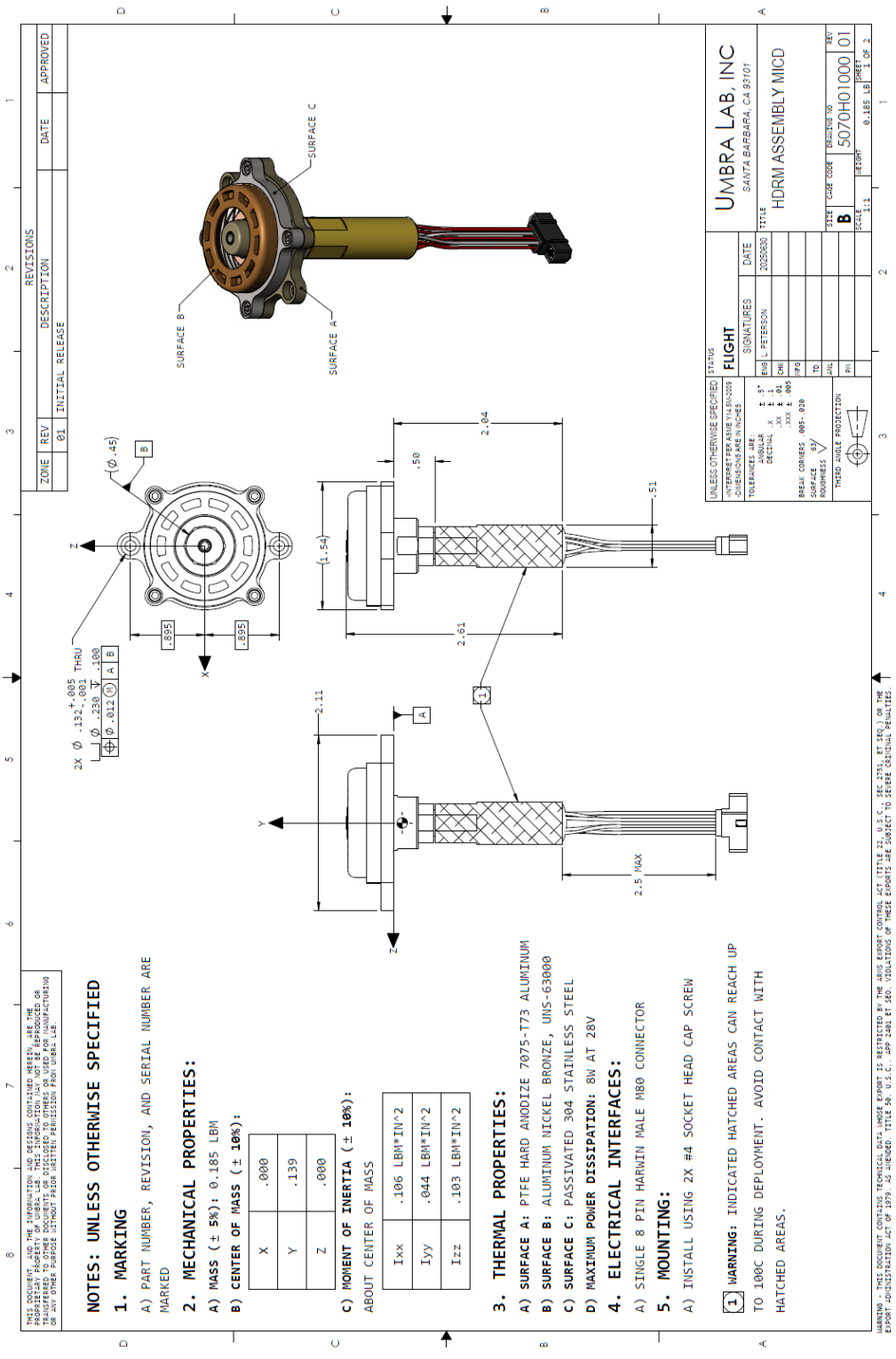
B.2 HDRM MICD


REVISIONS
ZONE | REV | DESCRIPTION | DATE | APPROVED
01 | INITIAL RELEASE
SURFACE A
SURFACE B
SURFACE C
UMBRA LAB, INC
SANTA BARBARA, CA 93101
HDRM ASSEMBLY MICD
5070H01000 01
NOTES: UNLESS OTHERWISE SPECIFIED
1. MARKING
A) PART NUMBER, REVISION, AND SERIAL NUMBER ARE MARKED
2. MECHANICAL PROPERTIES:
A) MASS (± 5%): 0.185 LBM
B) CENTER OF MASS (± 10%):
X .000
Y .139
Z .000
C) MOMENT OF INERTIA (± 10%):
ABOUT CENTER OF MASS
Ixx .106 LBM*IN^2
Iyy .044 LBM*IN^2
Izz .103 LBM*IN^2
3. THERMAL PROPERTIES:
A) SURFACE A: PTFE HARD ANODIZE 7075-T73 ALUMINUM
B) SURFACE B: ALUMINUM NICKEL BRONZE, UNS-63000
C) SURFACE C: PASSIVATED 304 STAINLESS STEEL
D) MAXIMUM POWER DISSIPATION: 8W AT 28V
4. ELECTRICAL INTERFACES:
A) SINGLE 8 PIN HARWIN MALE M80 CONNECTOR
5. MOUNTING:
A) INSTALL USING 2X #4 SOCKET HEAD CAP SCREW
1 WARNING: INDICATED HATCHED AREAS CAN REACH UP TO 100C DURING DEPLOYMENT. AVOID CONTACT WITH HATCHED AREAS.
2.04
.50
2.61
(1.54)
.51
2.11
2.5 MAX
.895
.895