# SETUP AND OPERATION MANUAL FOR THE IRON PLANET 24 VDC LI BOS 2000-120 POWER SYSTEM

PRELIMINARY DRAFT

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Preliminary Draft

Updated: 20230322

## Important Product Safety Information and Instructions

This manual contains important safety instructions that must be followed during the installation and operation of this product. Read all instructions and safety information contained in this manual.

Exercise caution when handling or operating equipment. Live power may be present.

# Safety Information Labels

Your safety and the safety of others is very important.

Always read and obey all safety messages.

⚠ This is the safety alert symbol. This symbol alerts you to potential hazards that can kill you or hurt you and others. All safety messages will follow the safety alert symbol and the word "DANGER", "WARNING", or "CAUTION". These words are defined as:

**⚠DANGER** Indicates a hazardous situation which, if not avoided, will result in death or serious injury.

**⚠WARNING** Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

**⚠CAUTION** Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

All safety messages will tell you what the potential hazard is, how to reduce the chance of injury, and what can happen if the instructions are not followed.

# General

- Do not short (+) and (-) terminals.
- Do not submit to excessive mechanical stress.
- Do not directly heat, do not solder or throw into fire. Such unsuitable use can cause leakage or spout vaporized electrolyte fumes and may cause fire or explosion.
- Immediately disconnect the BOS Battery if, during operation, they emit an unusual smell, feel hot, change shape, or appear abnormal in any other way.
- Do not open BOS 2000 case unless specifically trained and authorized to do so.
- Do not mix Li-ion batteries and lead-acid or most other types of Li-ion batteries because their operational parameters and capacities are likely to differ. Mixing battery types can lead to dangerous outcomes such as charging at too high voltage resulting in off gassing and possible thermal runaway.

# Fire Hazard

### Fire Types

**Class A fire** - Fires in ordinary combustibles such as wood, paper, cloth, trash, and plastics.

**Class B fire** - Fires in flammable liquids such as gasoline, petroleum, oil, and paint.

**Class C fire** - Fires involving energized electrical equipment such as motors, transformers, and appliances. Remove the power source and the class C fire becomes a class A or B fire.

# Recommended Fire Extinguisher

NSN 4210-00-288-7219 Fire Extinguisher, Carbon Dioxide, 10 lb
Carbon dioxide is a liquefied gas, which is highly effective fighting class B and C fires. These extinguishers are ideal for areas where contamination and/or cleanup are a concern, such as data processing centers, labs, and telecommunication rooms.

**WARNING**

Only $CO_2$ (carbon dioxide) fire extinguishers should be used with Solar Stik equipment.


### Using the Fire Extinguisher

When using the extinguisher on a fire, remember PASS:

**P**ull the pin.
**A**im the nozzle or hose at the base of the fire from a safe distance.
**S**queeze the operating lever to discharge the fire extinguishing agent.
**S**weep the nozzle or hose from side to side until the fire is out. Move forward or around the fire as the fire diminishes.

Watch the area for reignition until the cause has been fixed.

**Large fires:** use large quantities of water for the surrounding fire and to prevent propagation. If water is used on batteries in operation, caution should be taken to avoid the electrical hazard that may be present.

**SPECIAL FIRE FIGHTING PROCEDURES:** Fire fighters should wear self-contained breathing apparatus. Use approved / certified vapor respirator to avoid breathing toxic fumes. Wear protective clothing and equipment to prevent potential body contact with electrolyte solution. It is permissible to use any class of extinguishing medium, specified above, on these batteries or their packing material. Cool exterior of batteries if exposed to fire to prevent rupture.

**PARTICULAR HAZARDS RESULTING FROM EXPOSURE TO THE SUBSTANCE/PREPARATION, TO COMBUSTION AND GAS PRODUCTS:** The cell can spout vaporized or decomposed electrolyte fumes with fire when being heated over +100°C (+212°F) or disposed in fire. Solvents within the electrolyte are flammable liquids and must be kept away from any kind of ignition source.

Risk of irritation occurs only if the cell is mechanically, thermally or electrically abused to the point of compromising the integrity of the enclosure. If this occurs, irritation to the skin, eyes and respiratory tract may occur.

# Electric Shock Hazard

| ⚠ WARNING |
| --- |
| Standing water around the electrical equipment and/or intrusion of water into the System components can increase the risk of electrical shock. |

DON'T LET THIS BE YOU!

# First Aid Measures

**EYE CONTACT:** Immediately flush eyes with copious amount of water for at least 15 minutes. Seek immediate medical attention.

**SKIN CONTACT:** Remove contaminated clothing and flush affected areas with plenty of water for at least 15 minutes. Wash skin with soap and water. If skin irritation persists, call for a medical attention.

**INHALATION:** Remove to fresh air and seek immediate medical attention. Obtain medical advice.

**INGESTION:** Clear mouth with water and afterwards drink plenty of water. Do not induce vomiting. Seek immediate medical attention.

# Limitations on Liability

Since the use of this manual and the conditions or methods of operation, use, and maintenance of this product are beyond the control of Solar Stik, this company does not assume responsibility and expressly disclaims liability for loss, damage, or expense—whether direct, indirect, consequential, or incidental—arising out of or anyway connected with such operation, use, or maintenance.

Due to continuous improvements and product updates, the images shown in this manual may not exactly match the unit purchased.

This equipment CAN BE USED FOR CONNECTION WITH LIFE SUPPORT SYSTEMS OR OTHER MEDICAL EQUIPMENT or devices; however, without limiting the generality of the foregoing, Solar Stik makes no representations or warranties regarding the use of the System in connection with life support systems or other medical equipment devices.

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## Revision History

| Section | Page(s) | Description | Date |
|---|---|---|---|
| | | First release as **Preliminary Draft** | 21 March 2023 |
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# General Information

# Scope

This Operator and Maintenance Technical Manual (TM) contains instructions for operating and maintaining the 24VDC Li BOS 2000-120 Power System. The 24VDC Li BOS 2000 contains a Saft Xcelion 6T-Energy (X6TE) battery as the primary energy storage building block. The Power System consists of the 24VDC Li BOS 2000-120, the DC PDM, a Solar Venter 420W Array Kit with a built-in MPPT charge controller and a Power Cable to connect the BOS 2000 with the DC PDM. The System, which may be configured in a variety of ways, is demonstrated in the autonomous mode in this TM. Multiple charging sources may be employed to charge the BOS internal battery.

# Preparation for Storage or Shipment

Instructions including in-storage monitoring, charging are found Troubleshooting and Maintenance.

# Transportation

All transportation of Li-ion cells and batteries in the public domain is controlled by federal law regulating shipment of hazardous materials. The general regulations are stated in 49 CFR 172.101 and 173.185. For land and air transport of the 24VDC Li BOS 2000 (see Li BOS Transport)

# Warranty

1-year materials and workmanship. See detailed Warranty Terms page 49.

# List of Abbreviations/Acronyms

**BOS -** Balance of Systems
**BMS** - Battery Management System
**CAN bus** - Controller area network. CAN is a multi-master serial bus standard for connecting electronic control units (ECUs) also known as nodes.
**DRMO** - Defense Reutilization and Marketing Office
**EOL** - End of Life
**ESM** - Energy Storage Module/Battery
**HPS** - Hybrid Power System
**HWSA** - Hazardous Waste Storage Area
**IP**xx - Ingress Protection Code
**$LiFePO_4$** - Lithium Iron Phosphate
MPPT- Maximum Power Point Tracking
**Pb** - Lead (as in lead-acid battery)
**SOC** - State of Charge
**SOH** - State of Health

**Electrical Units**
**A** - amps
**Ah** - amp hours
**AC** - Alternating current
**DC** - Direct current
**V** - volts
**W** - watts
**Wh** - watt hours

**Useful Equations**
Volts x Amps = Watts

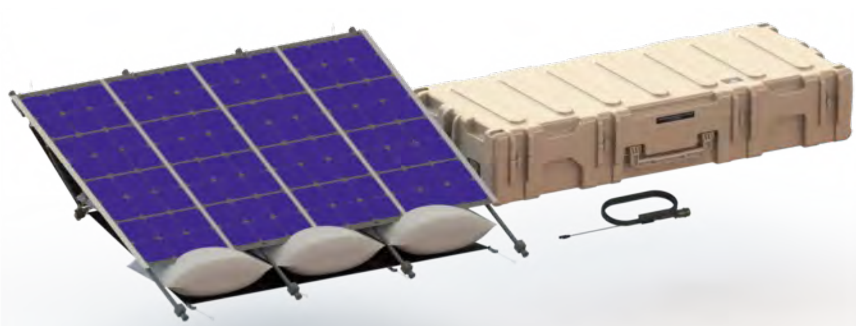
# Equipment Description and Data

# Equipment Characteristics, Capabilities, and Features

- Communication of battery state of charge, temperature, and other key parameters via J1939 CAN Bus
- Networkable battery monitoring (J1939 CAN bus)
- Fast charging under varying conditions
- 5-stage State of Charge Indicator
- Built-in self-balancing
- Built-in test at start-up and during operation
- Cell heating allows full battery capability over operating temperature
- Self-shutdown in unsafe conditions
- Battery has internal protection for overcharge, over-discharge, overload and short-circuit
- Impact resistant case with molded-in stacking ribs
- Solar Array with integrated MPPT Charge Controller
- Support of AC and multiple DC loads
- Energy storage expansion capability
- USB small device charging
- Unique, polarized connectors for each circuit

# System Inventory

P/N: 20-0205198 24VDC LI BOS 2000-120



P/N: 19-1000040 SOLAR VENTURE 420W W/CHARGE CONTROLLER KIT

P/N: 14-1000110 DC POWER DISTRIBUTION BOX

P/N: 13-1000409 POWER CABLE, ,

Figure 1. 24VDC Li BOS 2000-120 System Inventory

# Specifications, Environmental Control and Handling Requirements

## 24VDC Li BOS 2000-120

| General | |
|---|---|
| Battery | (1) Saft X6TE $LiFePO_4$ |
| Nominal Voltage | 24 VDC |
| Nominal Capacity | 2.0 kWh (82 Ah) |
| Max Charge/Discharge Rate | 100 A continuous |
| Self-discharge Rate* | <5% per month |
| Cycle Life* | ≥ 3000 Cycles to 80% State of Health |
| Shelf Life* | 5.6 years to 80% State of Health<br>7.0 years to 75% State of Health |
| Battery Voltage Range | 24.4 - 30 VDC (programmable) |
| Battery Status Indicator | E-Ink display with push button refresh |
| AGS Compatibility | In Development |
| Case** | Pelican 1620 |
| Transportation | UN3481 Lithium-ion battery contained in equipment |
| Warranty | 1-year materials and workmanship |

**@ 77 °F/ 25 °C*
*** Standard color: tan; Optional color: black*

| Inverter Specifications (@77 °F/25 °C) | |
|---|---|
| Nominal AC Output Voltage | 120 VAC ± 5% |
| Rated Current | 2.1 A |
| Output Frequency and Accuracy | 60 Hz ± 0.1 Hz |
| Continuous Output Power | 250 W |
| Efficiency | >87% |
| Waveform | Pure sine wave |
| Max Surge Power | 300 W |

| AC Charger Specifications (@77 °F/25 °C) | |
|---|---|
| Input Voltage | 90-305 VAC |
| Input Frequency | 47–63 Hz |
| Charging Stages | CC/CV |
| Continuous Output Current | 42 A |
| Charging Efficiency | 95% |

| Safety | |
|---|---|
| Breaker(s) | (1) Battery Disconnect, 100 A<br>(1) DC IN/OUT Expansion, 100 A<br>(1) 12-36 VDC Input, 100 A<br>(1) Solar Input, 30 A<br>(1) DC Output, 30 A<br>(1) AC output, 5 A<br>(1) AC Input, 15 A |
| Fuse(s) | 2A for USB output |
| Ground Fault | Grounding lug for connection to earth ground |
| Certifications | UN 38.3<br>Designed to MIL-STFD-810H<br>Compatible with MIL-STD-1275E |

| Connections | |
|---|---|
| Input(s) | (1) 9-36 VDC, 150 W (Cannon CB2-18-10PC)<br>(1) Solar (Cannon CB2-22-2SC)<br>(1) 120-230 VAC (Schurter 6100-3300-32) |
| Output(s) | (1) 120 VAC (NEMA 5-15/20R)<br>(1) 24 VDC, 30 A (Cannon CB2-20-19SC)<br>(2) USB 5V, 2.1 A (type-A) |
| Input/Output(s) | (1) ESM Expansion, 24 VDC, 100 A (Deltran 224-0061-BK)<br>(1) Gen Comm port for generator interface<br>(1) Data Port for battery communication (PT02SE12-10SW) |

| Environmental | |
|---|---|
| Operating Temperature*** | -4 °F to 122 °F (-20 °C to +50 °C) |
| Storage Temperature**** | -50.8 ºF to 159.8 ºF (-46 ºC to 71 ºC) |

****Inverter & charger controller derate above 30 ºC*
*****Sustained high temperature storage will reduce battery life*

| Weights and Dimensions (L x W x H) | |
|---|---|
| Weight | 110 lb (50 kg) |
| Dimensions | 24.76 x 19.57 x 13.90 in (62.9 x 49.7 x 35.3 cm) |

# DC Power Distribution Module

| General | |
|---|---|
| DC Output Connectors | CONNECTOR, BOX MOUNT, SZ22, BAYONET, 2POS (x6) |
| DC Input Connector | NATO RECEPTACLE 24VDC |
| Case | Pelican 1200 Tan |

| Environmental | |
|---|---|
| Operating Temperature | -40 °F to 140 °F (-40 °C to 60 °C) |
| Charge Temperature | -40 °F to 140 °F (-40 °C to 60 °C) |
| Storage Temperature | -50.8 °F to 159.8 °F (-46 °C to 71 °C) |
| Ingress Protection | Designed to IP67 |

| Weights and Dimensions (L x W x H) | |
|---|---|
| Weight | 8.1 lb (3.7 kg) |
| Dimensions | 4.9 x 12.5 x 11.3 in (12.5 x 31.8 x 28.7 cm) |

| Safety | |
|---|---|
| Breaker(s) | 30 A, 1 Pole (x2) |
| Reverse Polarity | Polarized Connectors |
| Case Pressure Relief Valve | 0.5 PSI |
| Certifications | • Designed to MIL-STD-810H |

# Soar Venture 420W with Charge Controller Kit

| General | |
|---|---|
| Frame Construction | Stainless Steel/Aluminum/Plastic Compounds |
| Frame Deployment Angles | 0°, 30° and 60° |
| Solar Panel Construction | Carbon Fiber Composite |
| Ground Securing | Meshes and Sandbags |
| Setup/Stowage Time | 3-5 minutes |
| Transport Weight | ~100 lb (45.4 kg) |
| Transport Dimensions (L x W x H) | 62 x 23 x 10 in; (157.5 x 58.4 x 25.4 cm) |
| Warranty | 1-year materials and workmanship |

| Solar Performance Specifications (@ 77 °F / 25 °C) | |
|---|---|
| | **Array** |
| Max Power ($P_{max}$) | 420 W |
| Rated Voltage ($V_{mp}$) | 37.8 V |
| Open Circuit Voltage ($V_{oc}$) | 43.8 V |
| Rated Current ($I_{mp}$) | 11.6 A |
| Short Circuit Current ($I_{sc}$) | 12.2 A |
| Cell Type | Monocrystalline silicone |
| Cell Efficiency (%) | > 24.1% |

| MPPT Charge Controllers Specifications (@ 77 °F / 25 °C) | |
|---|---|
| Output Volts | 28.8 VDC |
| Output Current | ~14.6 ADC (~7.3 ADC per controller) |
| Output Power | 420 W |

| Weights | |
|---|---|
| Description | Weight in lb (kg) |
| Panel | 19. (8.6) |
| Stand, | 13.3 (6.0) |
| Cable, 25 ft | 8.2 (3.7) |
| Hard Case | 55.5 (25.2) |
| Ground Securing Kit, | 3.2 (1.5) |

| Dimensions (L x W x H) | |
|---|---|
| Panels | 54.5 x 65 x 0.125 in; (188 x 330 x 0.5 cm);<br>Area: 22.4 ft²; (2.1 m²) |
| Maximum deployed footprint (at 0°) | Area: 22.4 ft², (2.1 m²) |

# Environmental and Handling Precautions

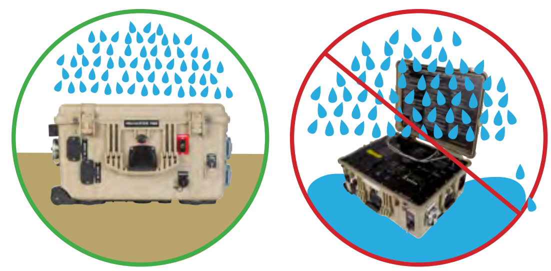
All Solar Stik components are ruggedized, yet there are a few things the operator can do to prevent failures and prolong the operational life of the product.

## Wind

It is imperative that the solar panels are properly secured to the ground so that they do not become dangerous projectiles in high winds.

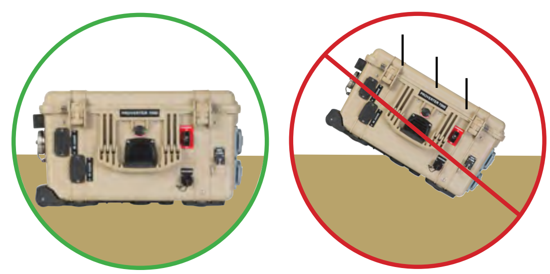
## Water

If outdoor operation is necessary, the lids of all components should be closed and latched. During operation, cases should be placed upright, especially during inclement weather. Lids should be open only to access operator controls and closed at all other times.



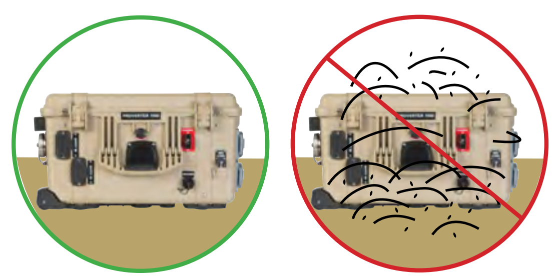
## Impact

Equipment should not be dropped onto hard surfaces at a height greater than one foot when transporting or during operation.



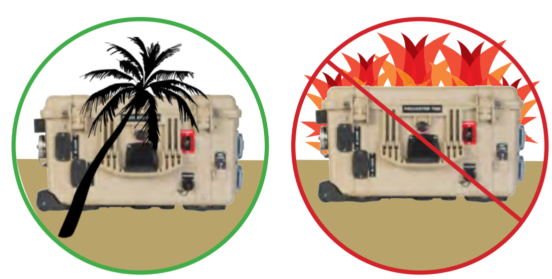
## Dust/Foreign Object Intrusion

Air intake filters should be cleaned once per month, or more frequently when conditions warrant. As a general rule, minimize exposure to high levels of particulates and foreign object debris by exercising common-sense placement and protection during both operation **and** storage.



## Heat

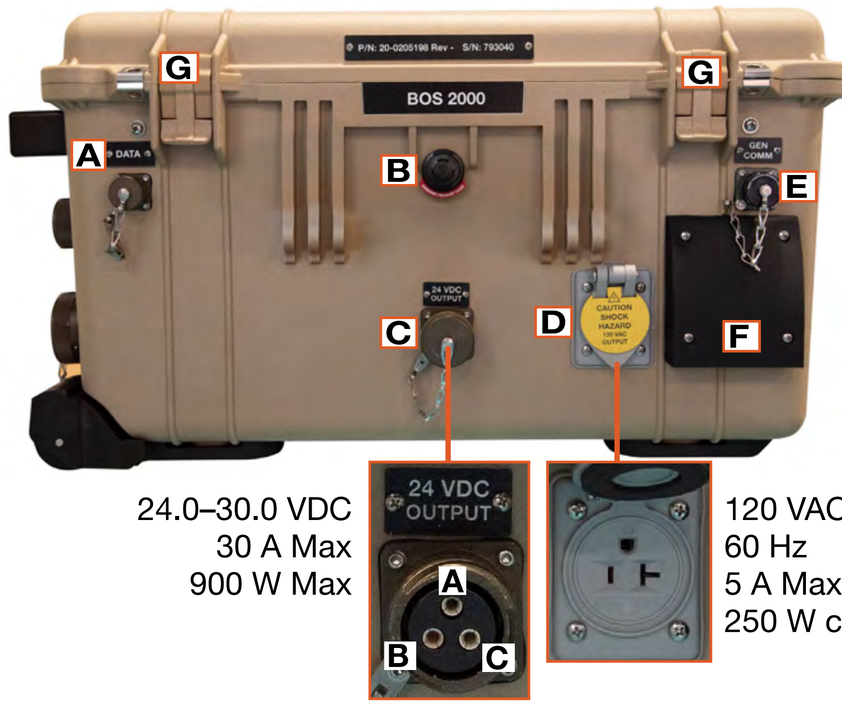
Heat and solar loading reduces efficiency and life expectancy. Shade components (except PV panels) to prevent the negative effects of heat.



# Location and Description of Major Components

# 24VDC Li BOS 2000-120

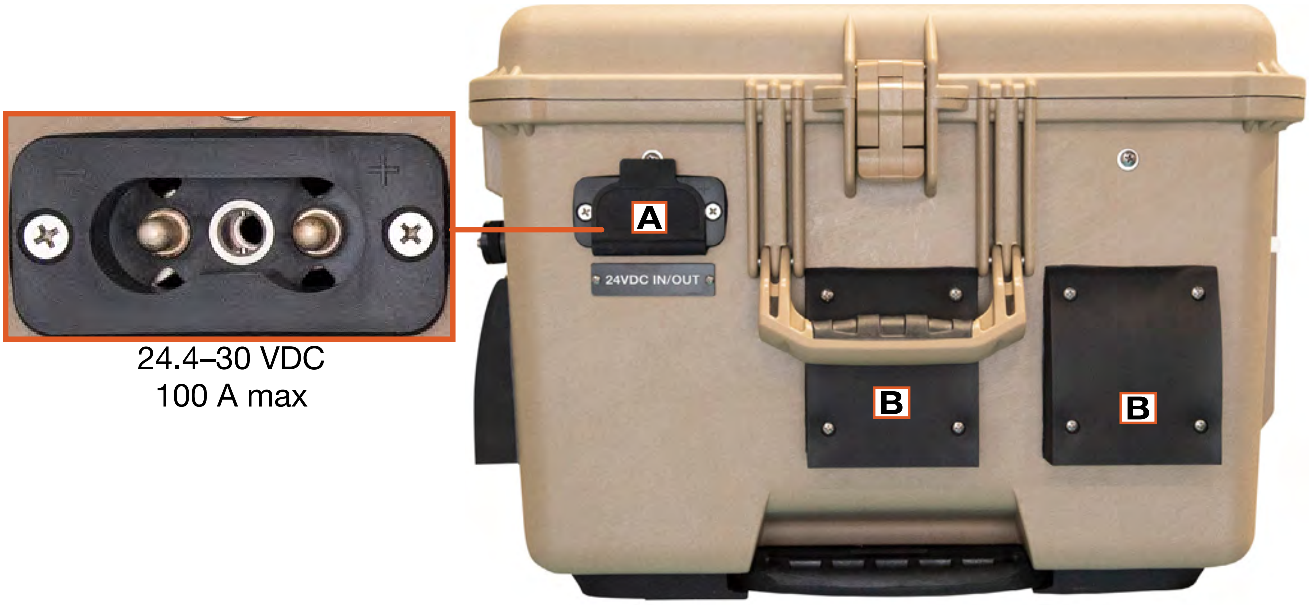
## Front: Power Outputs




- **A. Data Port:** Remote monitoring and internal battery data, CAN bus (J1939). Contact Solar Stik for further information.
- **B. Breather valve:** Prevents pressure differentials between interior and exterior of case.
- **C. 24 VDC Output**: Connector for DC Power Distribution Box. Connector: Pin A (+), Pin B (-), Pin C (unused)
- **D. 120 VAC Output:** Connection for AC loads $\leq$ 250 W continuous
- **E. Gen Comm:** For CAN bus (J1939) remote control of generator. For future development. Contact Solar Stik for further information.
- **F. Air Intake Vent Cover:** Has filter. Do not block.
- **G. Locking Latches:** Secures the top section of the case to the bottom section.

Figure 2. BOS 2000 front, power outputs

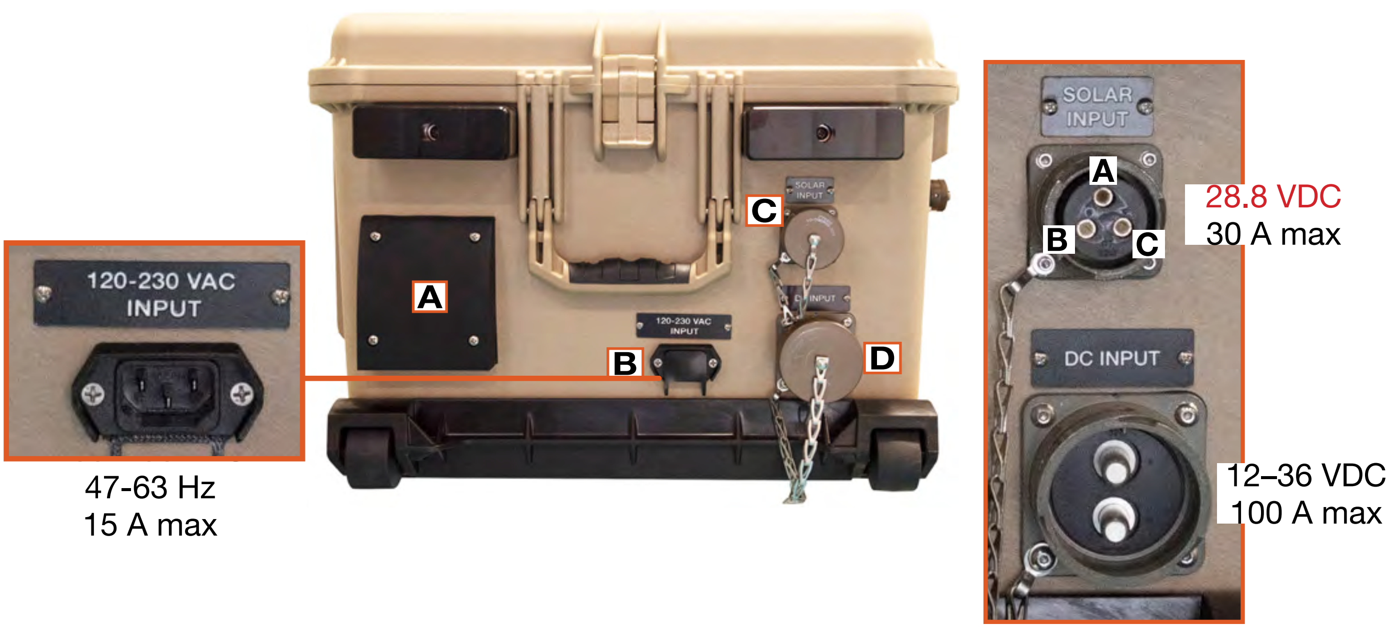
## Right Side: Power IN/OUT




**A. 24 VDC INPUT/OUTPUT Port:** For Expanding energy storage (e.g., 24VDC Li ESM 2000).
**B. Exhaust Vent Cover:** No filter. Do not block.

Figure 3. BOS 2000 right side

## Left Side: Power Inputs




**A. Air Intake Vent Cover:** No filter. Do not block.
**B. 120-230 VAC INPUT Port:** Power input for charging internal battery.
**C. Solar Power Input Port:** Connector for regulated DC power input from Solar Array with built in charge controller. Connector: Pin A (-), Pin C (+), Pin B (unused)
**D. 12-36 VDC Power Input:** Port for connecting 9-36 VDC power source. Power within this voltage range converted to 28.8 VDC power to charge internal battery.

Figure 4. BOS 2000 left side

## Back


**A. BOS 2000 Grounding Lug:** System must be grounded. Multiple grounding methods may exist depending on how System is configured.

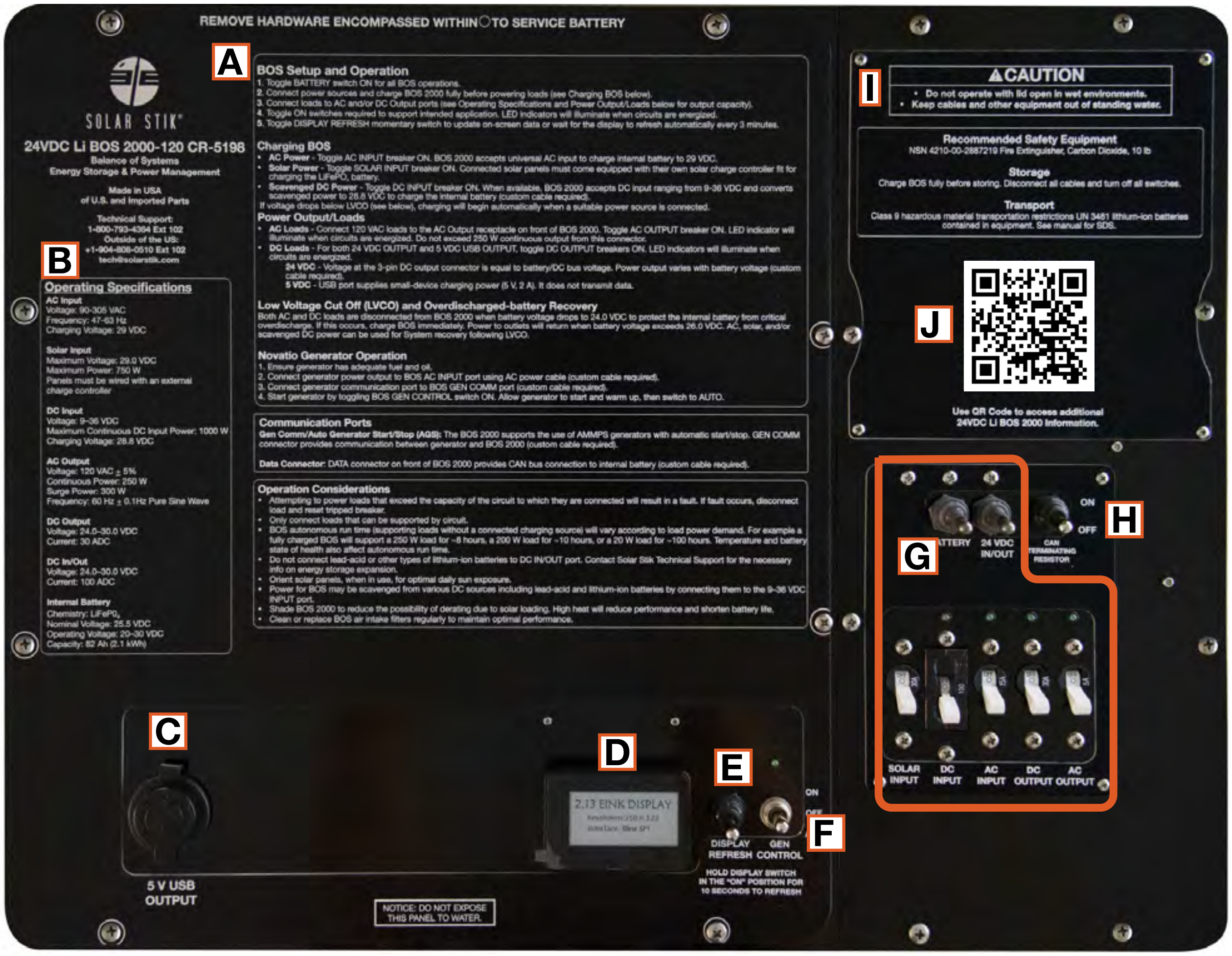
Figure 5. BOS 2000 back

## Top

Operator information placards.


Figure 6. BOS 2000 top

# Faceplate




Critical information on BOS setup, operation, and monitoring is provided directly on the BOS Faceplate.

- **A.** BOS setup and operation instructions, Comm port information and operational considerations
- **B.** Operational specifications. Provides limits for AC and DC BOS circuits and internal battery specifications.
- **C.** 5 VDC USB charging ports (x2) do not transmit data (for device charging only).
- **D.** Internal battery status display reports battery voltage, current (A), state of charge, status (fault or OK), date, and time of day.
- **E.** Battery status display refresh toggle switch
- **F.** Generator auto start/stop control switch. Currently inactive, for future development.
- **G.** Breaker switch panel and circuit-activity LEDs. See BOS 2000-120 Electrical Circuits for details.
- **H.** CAN Terminating Resistor. **This switch should remain in the ON position unless additional CAN-communicating equipment (e.g., 24VDC Li ESM 2000, AMMPS generators) is to be used.**
- **I.** Operational safety information
- **J.** QR Code that links to this document.

Figure 7. BOS 2000 Faceplate details

# DC Power Distribution Module (PDM)

The DC Power Distribution Module provides expanded support for DC loads. It receives and distributes unregulated DC power from the BOS 2000-120.

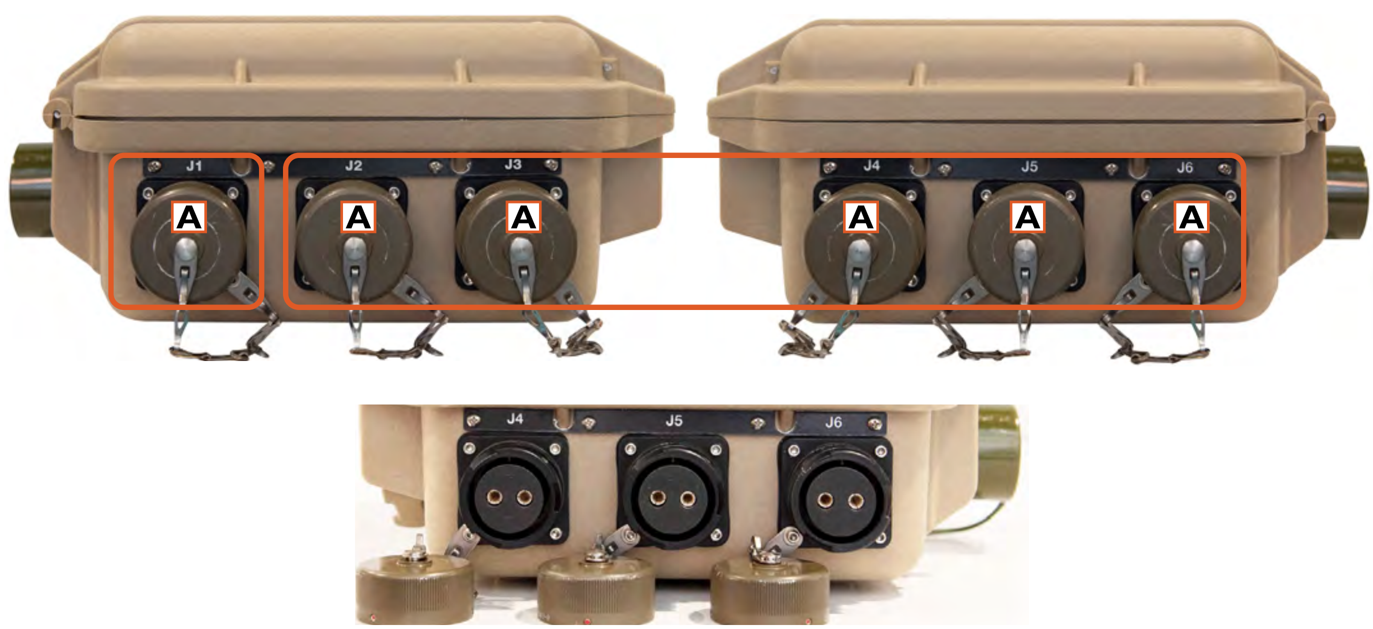
## Front: Power Input


**A. NATO DC Power Input Port:** Connection point for DC power from the BOS 2000-120.

Figure 8. DC PDM NATO power input port

## Sides: Power Output

There are six (6), 2-pin, DC power output ports, three (3) on each side and labeled J1–J6. Each port provides unregulated DC power at battery voltage (24.0–29.0 VDC). J1 is on an independent electrial branch with its own 30 A breaker; J2-J6 are all on a separate branch with a 30 A breaker.




**A. DC Output Port:** Expanded DC power for multiple DC loads.

Figure 9. DC PDM power output ports

# DC Power Distribution Module (PDM)

## Back: Locking Latches


Figure 10. DC PDM case front

A. **Waterproof air pressure equalization valve:** Eliminates potential for pressure differentials.
B. **Locking latches:** Locks case lid to protect Faceplate from water and particulate intrusion.

## Top

Operator information, part name and number placards. Also shown connected to Power Cable to BOS. The NATO Power Input port on the front connects to the power cable, linking it to the BOS 2000. See System Connection Diagram, Figure 17 on page 29).

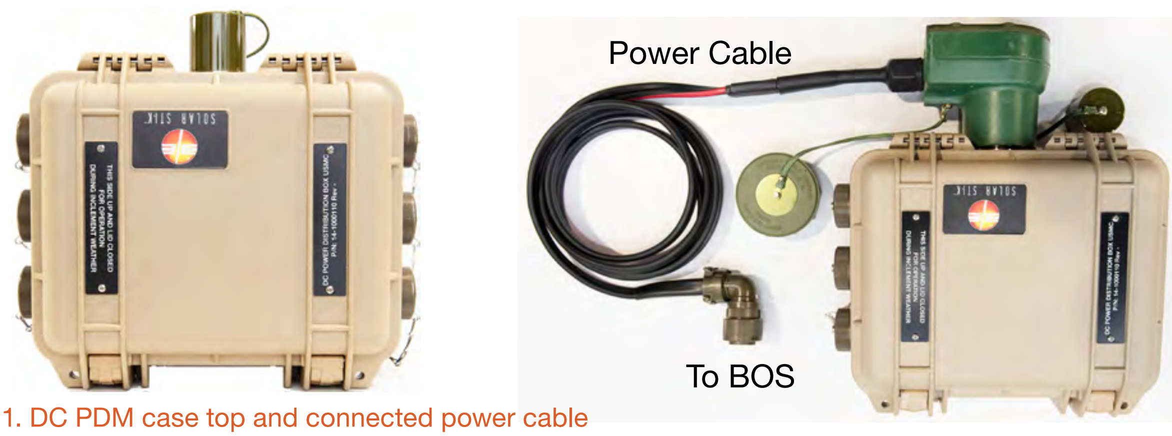



Figure 11. DC PDM case top and connected power cable

## Faceplate

Located inside the case.


A. **DC Input Status LED:** Illuminated when DC power from BOS 2000 has energized PDM DC bus.
B. **DC Power Output Breaker for J1 Output Port and LED:** 30A Breaker allows use of J1 alone for loads between 720–890W. Maximum output power dependent on battery voltage.
C. **DC Power Output Breaker for J2–J6 Output Ports and LED:** 30 A Breaker regulates use of J2-J6 for combined loads between 720–890 W. Maximum output power dependent on battery voltage.

The DC PDM can supply 60 A total current. Please see Operator Instructions for more details about the limitations of using either one or both of these options.

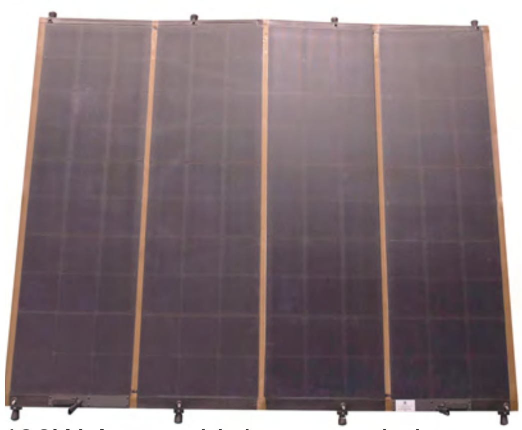
Figure 12. DC PDM Faceplate breakers and LEDs

# Solar Venture 420 W Solar Array

See Solar Venture Array Setup Section for details

420W Array Hard Case (x1)

All of the equipment below is contained in the case above. See Setup Instructions for component details.



420W Array with integrated charge controller (x1)

420W Array Support Frame (x1)

Mesh Hold Down, 30° (x1)

Mesh Hold Down, 30° (x1)

Solar Power Cable SAE/Bayonet 25' (x1)

Sandbags (x7)

Figure 13. Solar Venture 420 W Solar Array kit components

# Theory of Operation

## Keys to Optimize the BOS System Performance

- The BOS internal battery should be charged using available AC and DC power inputs. Charge the BOS fully before placing into storage.
- Turn BOS 2000 BATTERY switch to OFF when idle/not in use to prevent overdischarge.
- Do not submit to excessive mechanical stress.
- Shade the BOS to reduce heat-related derating.
- Connect Energy Storage Modules (ESMs) only with identical specifications (e.g., 24VDC Li ESM 2000).

## The BOS Energy Storage Module

An Energy Storage Module (ESM; battery) is an integrated component of the BOS. When ESMs are employed in a power system, they can serve many different functions:

- Backup power for critical loads when the primary power source fails
- Power when periods of “silent” operation are critical
- Use of renewable power generation is desirable
- Decreased reliance on grid-utility power is desirable (peak shaving)

While ESM roles may vary widely, their function is quite simple: ESMs charge and discharge (storing and dispensing power) repeatedly, over time. This is called “cycling”. Batteries have an inherent, finite cycle-life and several factors determine how many cycles a battery can endure before it is depleted. These include, but are not limited to:

- Operational environments and conditions
- Charging and discharging rates
- Storage conditions (even though it may not be actively cycling, the chemical reaction in a battery never stops.)

**All batteries have a finite lifespan and as such it must be understood that batteries are “consumable” parts of the BOS 2000.**

## Battery Management System (BMS)

The BOS 2000 contains $LiFePO_4$ cells and an advanced BMS that performs, in very general terms, two vital functions:

1. The BMS manages all battery functions and promotes healthy cycling at the individual cell level.
2. BMS protection circuits protect the battery and the operator from dangerous conditions related to cell voltages, temperatures, and current flowing in or out of the battery.

When all operating conditions are satisfactory, current can flow in/out of the battery cells (cycling). If temperature, voltage, or current is outside of programmed limits, the BMS protection circuits engage and remove the cells from service, disabling the battery at its terminals until proper operating conditions are restored.

Information from the BMS such as State of Charge, State of Health and Faults are reported on the Battery Status Indicator.

# BOS State of Charge (SOC)

The BMS State of Charge (SOC) algorithm is based on a combination of open-circuit cell voltages, coulomb counting, and other cell-level telemetry. The algorithm computes and reports SOC for the entire battery on the Battery Status Indicator in five (5) segments or bars that fill/empty as the ESM charges/discharges respectively. The SOC reported in Figure 14 is somewhere between 60 and 80%. When the battery is charged to 81%, the fifth bar will fill completely. A numerical SOC report can be found on the diagnostic screen (see Figure 25 on page 33).

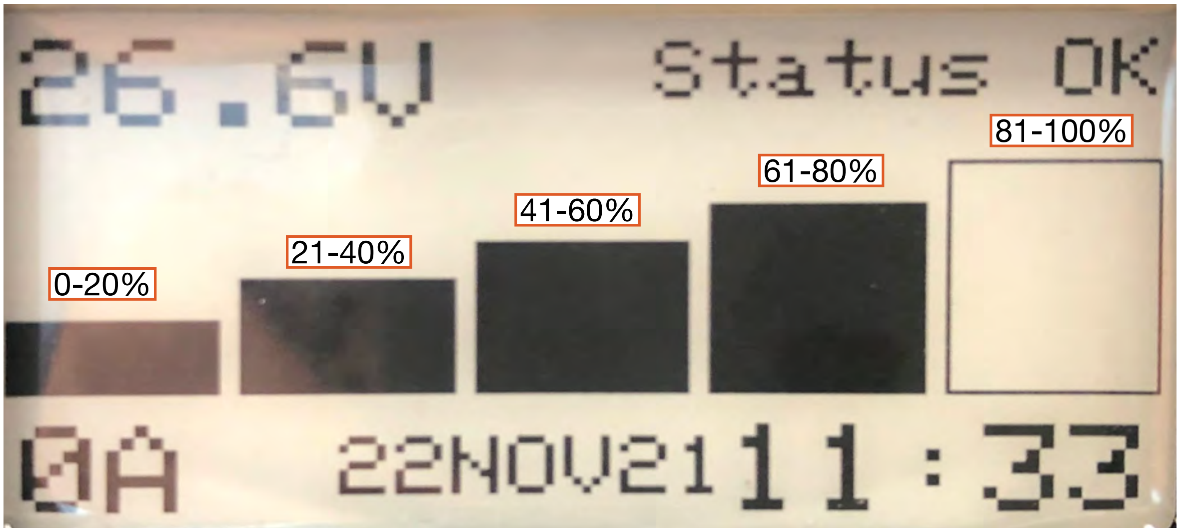



Figure 14. Battery Status Indicator SOC 5-segment report

# BOS State of Health (SOH)

The battery implements a State of Health algorithm that predictively estimates the useful lifetime of the battery cells. As shipped at beginning of life, the BOS internal ESM is configured to deliver a nameplate capacity of 82 Ah. As the battery is charged/discharged, heated/cooled, and calendar time elapses, the cells will age and their useful capacity will decrease. The SOH algorithm keeps track of many battery parameters and uses them along with characteristics from the cells themselves to estimate the battery's life.

Batteries including the one in the BOS 2000 are consumable components of a Hybrid Power System. Monitoring and understanding BOS performance with respect to the battery SOH will assist in knowing when to replace the internal battery. Generally speaking, as the SOH decreases, generator runtime (if connected) will increase, fuel consumption will increase and the ability to support surge loads may be compromised. If the BOS is being used for an uninterruptible power supply (UPS), the length of time they can maintain the load in the absence of prime power will decrease as SOH decreases. Proper planning is required to ensure the usable battery capacity is sufficient to support the application or mission.

# BOS 2000 End of Life (EOL)

A new, unused BOS 2000 has a rated useful capacity of 82 Ah. The "industry standard" states a battery is at EOL when the battery SOH drops to 80%. Therefore, when the battery status meter reads 0% state of health, 66 Ah storage capacity remains (see Figure 15). This feature of the BMS is hard wired and can not be changed. The battery can be used beyond an SOH reading of 0% but a replacement battery should be on hand.

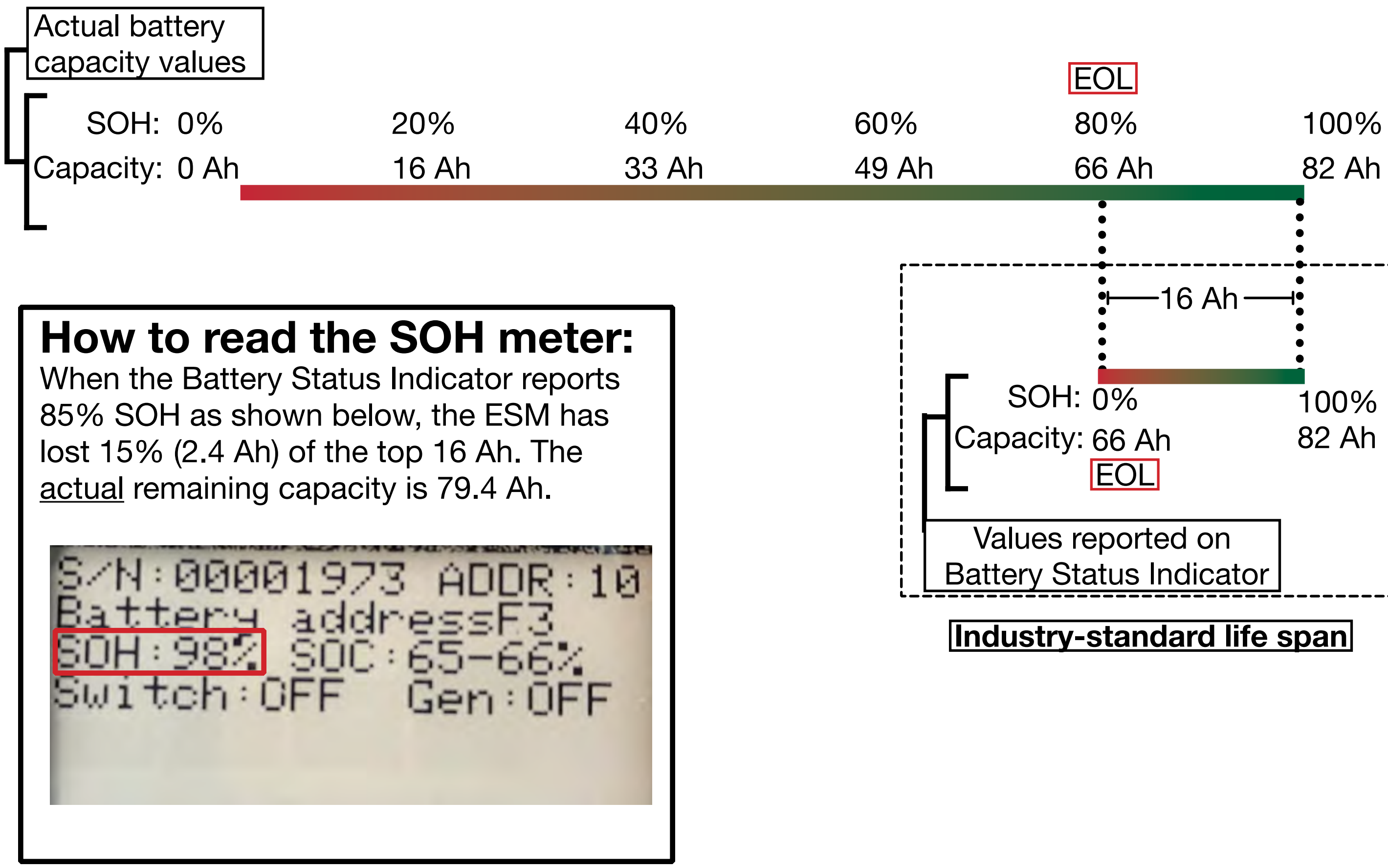



Figure 15. SOH value reported by BOS 2000 and End of Life

# Internal Battery Heater

Lithium-Ion batteries allow maximum charge and discharge at warmer temperatures. To maintain optimal internal temperatures, the BOS 2000 internal battery is equipped with heaters that automatically keep the internal battery temperature at 20°C when the BOS is operating in cold temperatures. The heaters themselves consume ~640 W when operating. The heater is either on at full power or off, drawing no power. The power required by the heaters may be supplied by the BOS ESM and/or charging by the BOS. The battery will stop heating when the cells are warm enough to support maximum loads, or if the BMS determines that the heaters alone are discharging the battery to the point of being overdischarged. In such a case, the BMS will turn off the heaters to prevent critical overdischarge.

There is a five-(5) second delay after the Main BATTERY switch is turned on prevent the heaters from turning on unintentionally during start-up. During this time, the Battery Status Indicator will report zero (0) A current. The only exception to this is if there is a charge current greater than 50 A. This exception prevents damage to the cells by charging at too high of a rate in very cold temperatures.

If the Battery Status Indicator reports a negative current value (~20 A) with no other load drawing current from the BOS ESM, this is an indication that the heater is operating.

# BOS ESM Modes

## Storage Mode

When the BOS BATTERY switch toggled to OFF, the BMS software disconnects the BOS ESM power terminals from the battery cells and enters a low-power state. While the BOS ESM is in Storage Mode, the BMS does not communicate with the Battery Status Indicator because the circuitry is powered down to extend battery shelf life. (Note: The BOS ESM may also enter Storage Mode, without toggling the BATTERY switch to OFF, after 60 minutes in Protected Mode. See Protected Mode below)

## Operational Mode

When the BOS BATTERY switch is toggled to ON the BMS software performs a series of self-tests referred to as Power-up Built-In-Test (PBIT). If the PBIT is passed, the BMS enables charging and discharging of the BOS ESM and transfer of information from the BMS to the Battery Status Indicator. The BOS ESM will remain in Operational Mode as long as the BATTERY switch is toggled to ON UNLESS a fault occurs.

## Protected Mode

If a critical fault or other potentially unsafe condition within the BOS ESM is detected, the BMS will disconnect the BOS ESM power terminals from the internal battery cells (Protected Mode) even with the BOS BATTERY switch in the ON position. The BMS will continue to communicate with the Battery Status Indicator for up to 60 minutes while the ESM is in Protected mode allowing the Operator to diagnose and correct the fault. The ESM internal battery will enter Storage mode after 60 minutes (even with the BOS BATTERY switch in the ON position) so that the battery does not discharge itself to the point of irreversible cell damage. If the fault condition that caused the BOS ESM to enter Protected mode clears on it’s own, the ESM will automatically return to Operational Mode.

# DC Power Distribution Module (PDM)

The DC PDM expands the number of DC loads that can be supported by power from the BOS. There is a single (1) power input port (NATO connector) and six (6) power output ports (bayonet connectors; J1-J6). All power output ports are on a single DC bus. One output connector, J1 is on a circuit protected by a 30 A breaker. Power output ports J2-J6 are all on a second 30 A breaker therefore, all loads connected to J2-J6 must not exceed 30 amps combined. Thirty amps at 27 VDC is ~ 800 W. J1, on a single 30 A breaker can support loads of ~ 800 W.

A single LED will illuminate when DC power is available to the DC PDM; an LED above each breaker switch will illumiate when power is available to loads connected to power output ports.

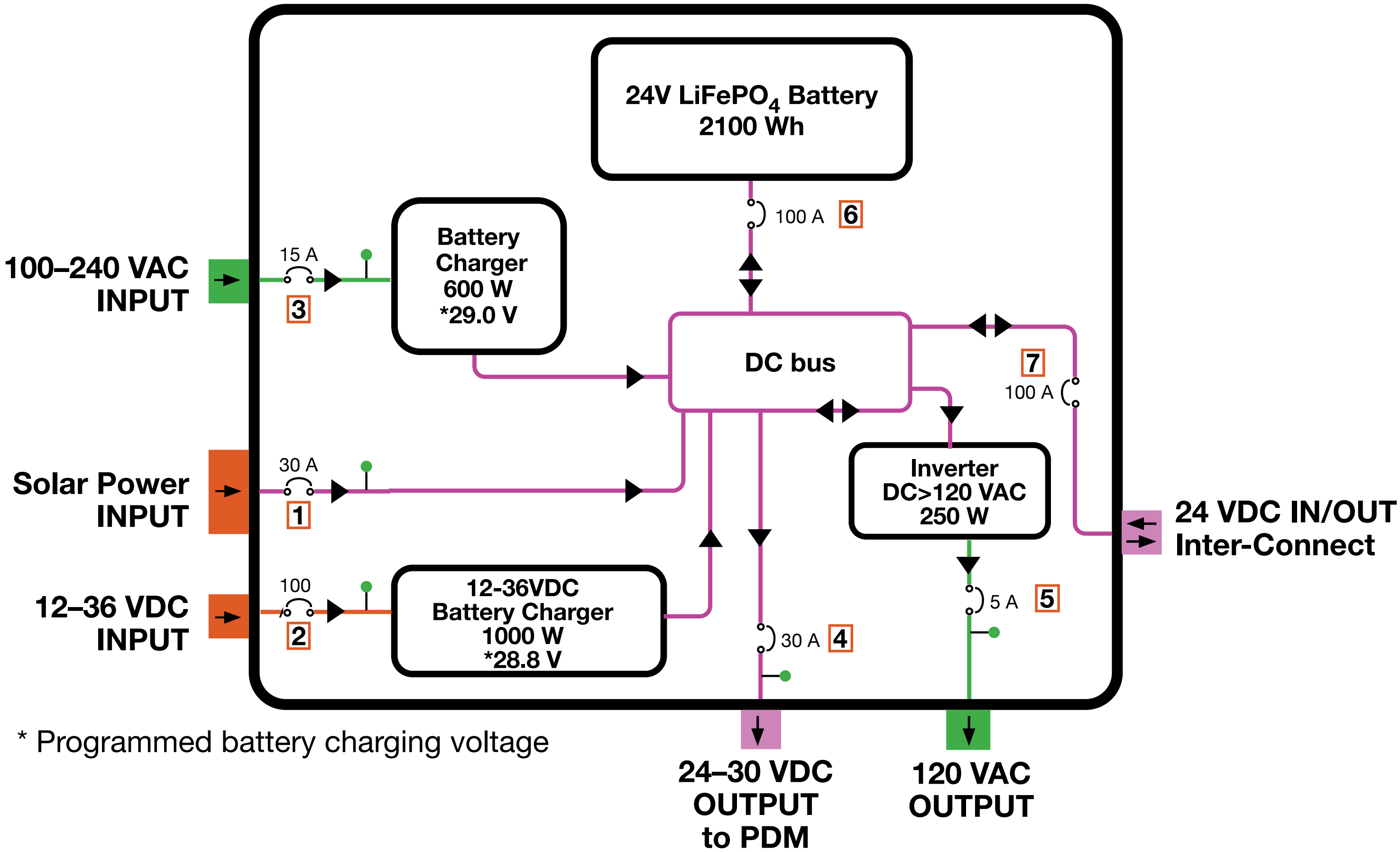
# Solar Venture 420 W Solar Array

Unlike most solar arrays, the Solar Venture Array has an integrated MPPT solar charge controller. Most often, unregulated power provided by a solar array is pumped into a separate component of the power system where it is then conditioned to a voltage appropriate for charging batteries connected to a system. Power exiting the cable connecting the Solar Venture Array to the BOS 2000 is a constant 29.0 VDC. The current from the array will vary to maximize power output under changing light exposer.

The Solar Venture cam be deployed at 30º, 60º angles WRT the supporting surface or flat on the ground. Once deployed and oriented for maximum daily sun exposure, the Array must be secured to the ground with sandbags. The large surface area and light weight of Array allow it to act as a sail in high winds. Failure to secure the array can result in damage to connected equipment and injury to personnel in a high-wind event.

# BOS 2000-120 Electrical Circuits

The diagram below illustrates the BOS AC and DC circuits, and subcomponents. Circuit breakers/ switches, LEDs that illuminate to demonstrate circuit activity and direction of power flow (arrows) are also illustrated. The diagram legend provides a key for symbols used. Each circuit breaker is numbered on the image of the Faceplate and in the diagram. LED locations (line side/load side) in the circuits are literal.




* Programmed battery charging voltage


## Diagram legend

- LED circuit activity indicator
- Circuit breaker location
- 24 VDC bus circuit
- 120 VAC circuits
- Unregulated DC power input

Figure 16. Diagram of BOS 2000-120 internal components and circuits

# System Setup and Operation Instructions

## System Connection Diagram

The configuration below provides autonomous operation.

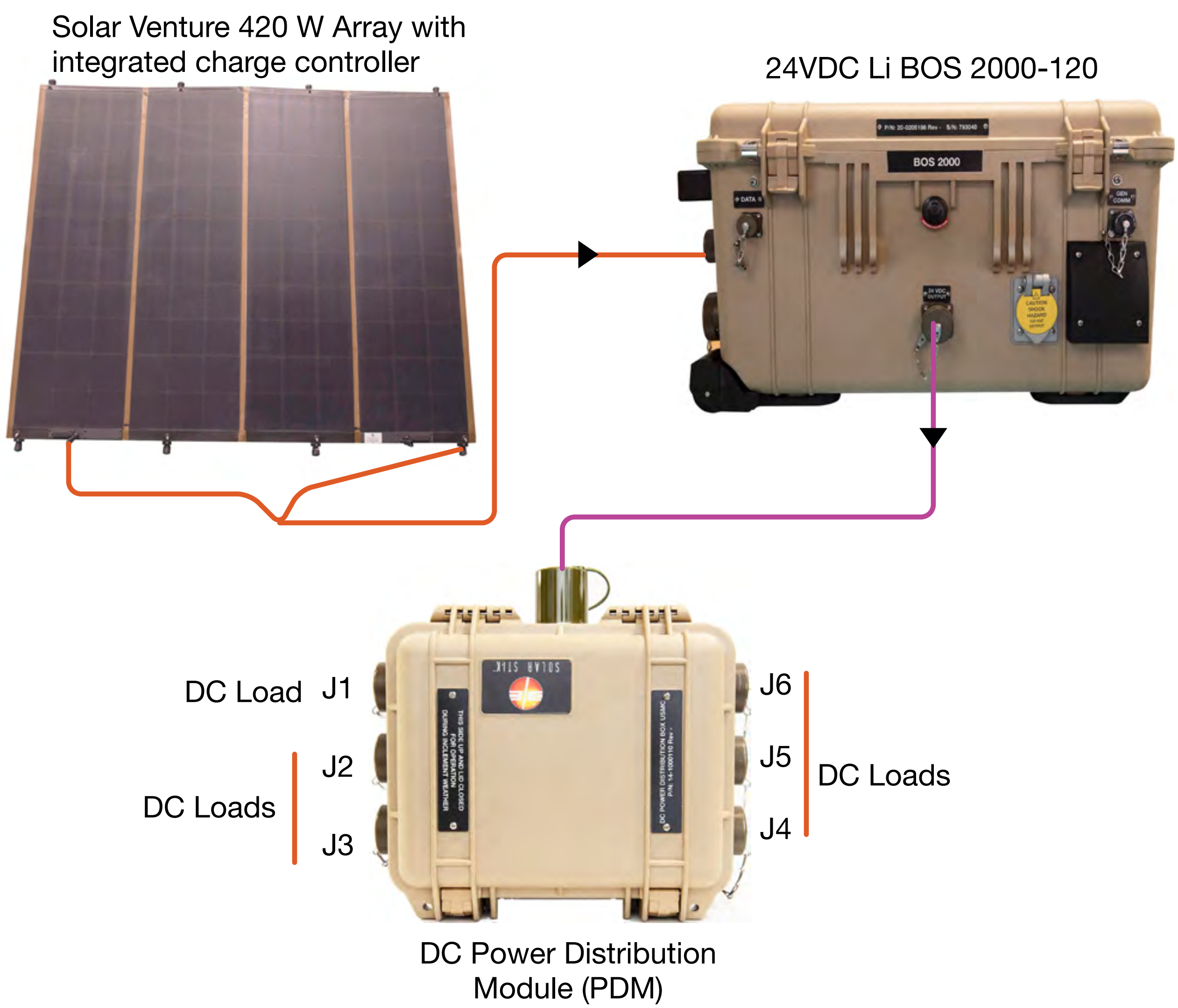
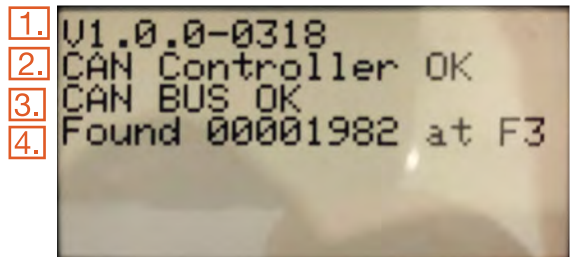



Figure 17. Autonomous Operation Configuration

# Setup and Operation Instructions

1. Assemble Solar Venture 420 W Solar Array if it is to be used (See Instructions).
2. Connect System Components as shown in System Connection Diagram. See Figure 11 for details about connecting PDM to BOS.
3. Toggle BATTERY switch (6; Figure 18) ON for all BOS operations. Confirm CAN TERMINATING RESISTOR is toggled ON.

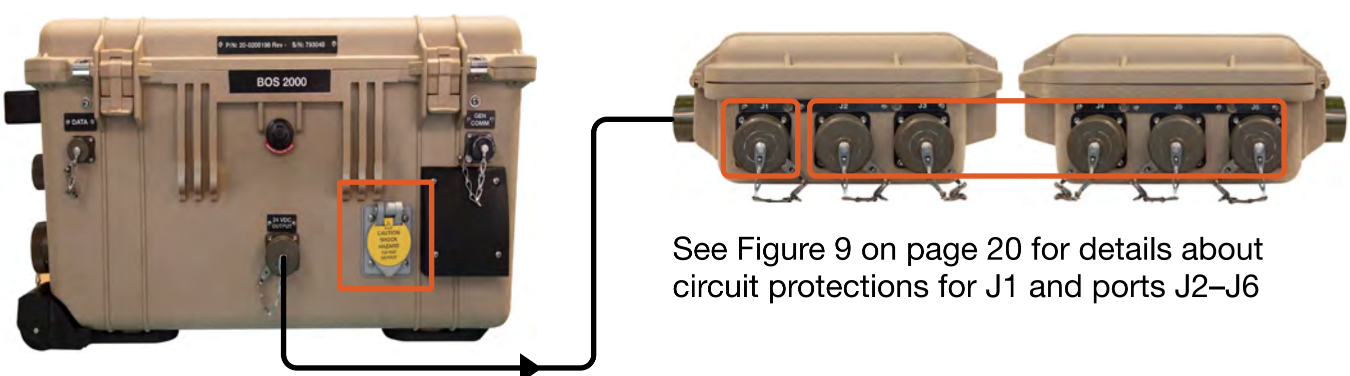

1. Firmware version and date
2. CAN bus self test
3. CAN bus communication operational
4. Connecting to battery comms

Figure 18. BOS 2000 switches and Battery Status Indicator Startup Screen

4. Connect power sources and charge BOS 2000 fully before power loads (see Charging BOS).
5. Connect loads to AC and/or DC Output ports (Consult Operating Specifications and Power Output/Loads below for output capacity). DC loads connected to PDM will be supported by unregulated power at battery voltage. AC loads connected to the BOS will be supported by 120 VAC, 60 Hz, pure sine wave power. The BOS USB charger (Faceplate, Figure 7) charges small devices at 5 V, 2 A and does not transmit data.

**BOS 120 VAC Loads**

**PDM DC Loads**




See Figure 9 on page 20 for details about circuit protections for J1 and ports J2–J6

See Figure 2 on page 16 for details about AC output specs.

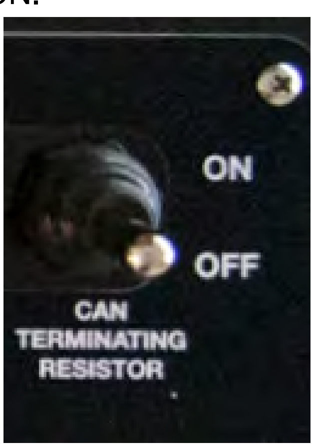
Figure 19. Connecting AC and DC loads to BOS 2000 System

# Setup and Operation Instructions

6. Toggle breakers/switches (Figure 18) required to support intended application. LED indicators above switches will illuminate when circuits are energized. This information is provided automatically after the BATTERY SWITCH is toggled ON. For more information on the firmware, contact Solar Stik Technical Support.
7. Toggle DISPLAY REFRESH momentary switch to update on-screen data or wait for the display to refresh automatically every 3 minutes


Figure 20. Battery Status Display Refresh momentary switch

**Notice:** The CAN TERMINATING RESISTOR switch must be toggled ON when BOS when remote monitoring, an AMMPS generator or 24VDC Li ESM 2000s are connected. If the CAN TERMINATION RESISTOR switch is OFF when the BOS BATTERY switch is toggled ON, a CAN BUS Error : 3 will appear (CAN BUS Error : 1 may also appear). If either of these errors occur, toggle the BATTERY switch OFF, toggle the CAN TERMINATION RESISTOR switch ON then toggle the BATTERY switch to ON.



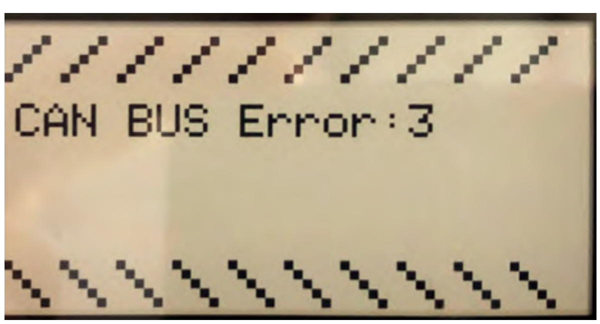



Figure 21. CAN TERMINATING RESISTOR SWITCH

# Monitoring BOS Battery Status

### Home Screen

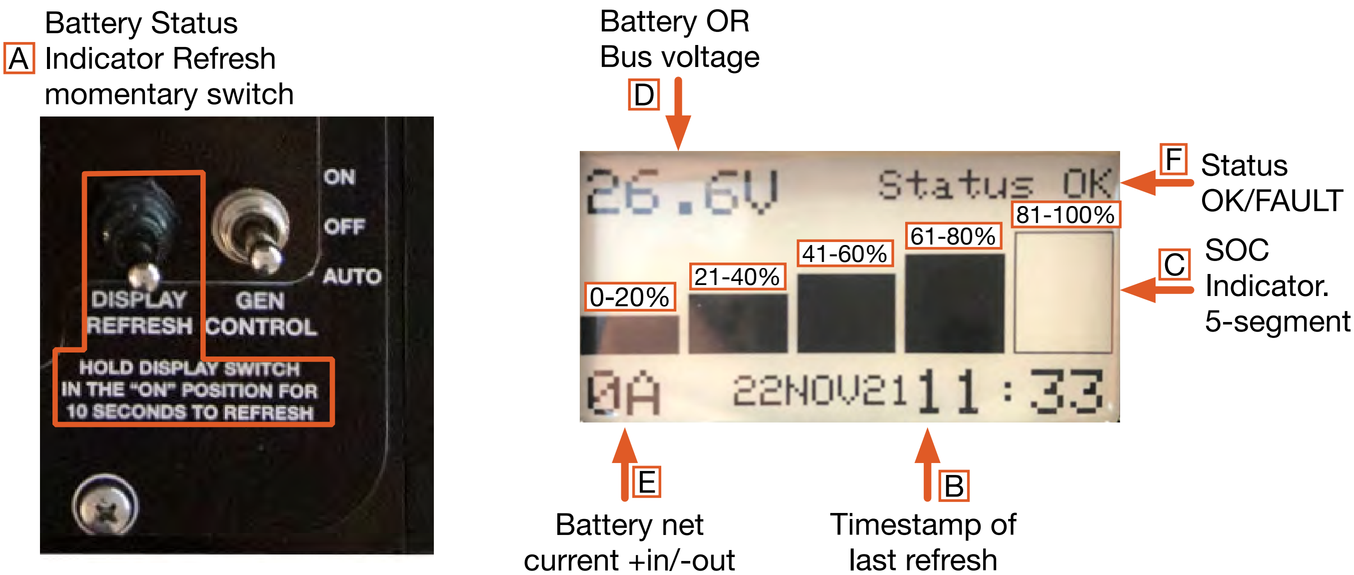



Figure 22. Battery Status Indicator – Home Page, normal operation

**A.** During normal operation, the display is updated automatically at intervals of three (3) minutes. The "DISPLAY REFRESH" momentary button can be pressed to update the display at any time during normal operation.

**B.** A timestamp for the last "refresh" is updated and displayed, whether it occurred automatically or by pushing the refresh button.

**C.** The SOC is reported visually by a five-segment "fuel gauge". Each segment represents 20% increments up to 100%. Each segment fills completely when the SOC reaches the lowest percentage for that segment. For example, the segment on the right will fill completely when the SOC reaches 81%.

**D.** If the BOS 2000 is connected to a battery bank, the voltage reported (**D**) is bus voltage. If the BOS 2000 is not connected to external 24VDC Li ESM 2000s, the value reported here is battery voltage. Nominal voltage = 26.4 VDC; voltage @ 100% SOC ≈ 30.4 VDC; voltage @ 0% SOC ≈ 20.0 VDC.

**E.** The net current (A) with respect to the BOS internal battery. It is positive when the BOS ESM is charging (from solar, AC or scavenged power) and negative when the ESM is discharging.

**F.** If/when a battery fault occurs, the word "FAULT" appears in the upper right corner of the display. If the fault is unattended for three (3) minutes, "FAULT" appears in large font, filling the screen (Figure 24). If the fault is not corrected within 60 minutes, the BOS ESM will enter storage mode even with the BATTERY switch in the ON position.

Additional information about the fault can be found on the second "page" (Diagnostic Screen) of the Battery Status Indicator, accessed by toggling the Refresh Display button twice.

# In-service Battery Status Information


Figure 23. Battery Status Indicator home page “dead battery”


Figure 24. Battery Status Indicator - home page unattended fault warning

The Battery Status Indicator automatically refreshes at three (3)-minute intervals when it the ESM is operating normally. The “REFRESH DISPLAY” momentary button can be pressed to update the display at any time while the BOS 2000 is operating.

See Figure 22 for a detailed description of the Battery Status Indicator information fields.

An exclamation mark (“!”) will appear in the left-most bar when SOC drops to 0% (Figure 23).

If/when a battery fault occurs, the word “FAULT” appears in the upper right corner of the display. If the fault is unattended for three (3) minutes, “FAULT” appears in large font, filling the screen (Figure 24). If the fault is not cleared within 60 minutes, the ESM will enter storage mode even with the BATTERY switch in the ON position.

Additional information about the fault(s) can be found on the second page of the Battery Status Indicator.

# Diagnostic Screen

To access the diagnostic screen, push the refresh button once to refresh display then a second time for the diagnostic screen.

Figure 25 is an example of the information on the diagnostic screen that is present when the BOS 2000 is operating normally. The SOC value range will narrow as the battery cycles.

Table 1 on page 44 lists the faults that may appear and procedures to clear them.

A. Battery serial number
B. CAN address for Battery Status Indicator
C. CAN bus termination status of battery
D. CAN address of battery
E. State of Health
F. State of Charge

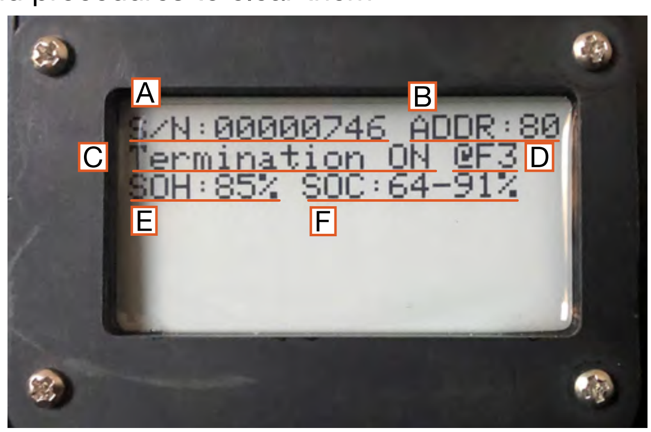



Figure 25. Battery Status Indicator diagnostic screen

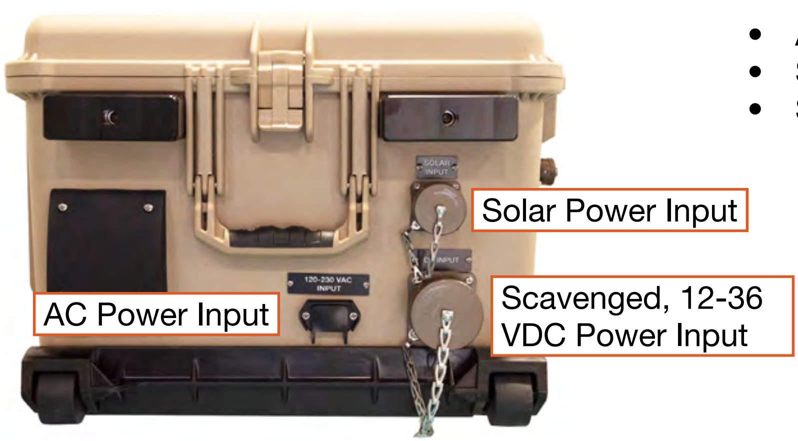
# Low Voltage Cut OFF (LVCO) and Overdischarged-battery Recovery

Both AC and DC loads are disconnected from BOS 2000 when battery voltage drops to 24.0 VDC to protect the internal batty from critical overdischarge. If this occurs, charge BOS immediately. Power to outlets will return when battery voltage exceeds 26.0 VDC. AC, solar and scavenged DC power can be used for System recovery following LVCO.

# Charging BOS Internal Battery

1. **AC Power** - Toggle AC INPUT breaker ON. BOS 2000 accepts universal AC input power to charge internal battery to 29.0 VDC.
2. **Solar Power** - Toggle SOLAR INPUT breaker ON. Connected solar panels must be equipped with their own solar charge controller with a charging profile appropriate the for the internal battery.
3. **Scavenged DC Power** - Toggle DC INPUT breaker ON. When available, BOS 2000 accepts DC power input between 12 and 36 VDC and converts the power to 28.8 VDC to charge internal battery (custom cable required).

If internal battery voltage drops below LVCO, charging will begin automatically when a suitable power source is connected,




- AC power charges at 29.0 VDC,
- Scavenged power charges at 28.8 VDC
- Solar power charges at 29.0 VDC.

Figure 26. BOS 2000 Charging options

# Solar Venture Array Setup

## Electric Shock Hazard Related to Solar Panels

**⚠ WARNING**

- Solar Panels produce electricity when exposed to sunlight.
- Live power may be present at multiple terminals.
- Never route the cables through standing water.
- All cables and connections should remain dry and should be inspected regularly to ensure safe operating conditions.
- Do not disconnect Solar Cables when under load.
- Eliminate Panel exposure to sunlight before disconnecting Solar Cables to prevent arcing.

Connecting and disconnecting Solar Cables may result in arc flash when the cables are under load (carrying current) from an active Solar Panel or Array.

## 1. Unpack Solar Array Components

Solar Array with integrated charge controller is top layer of case contents.

The remaining Solar Array components are on the bottom layer. The two (2) layers of components are separated by a thick gray foam layer.

Figure 27. Solar Array Case contents and packing formation

## 2. Extend and Lock Array Stand

Disconnect the velcro transport strap securing the foldable Array Stand (Figure 28A). Remove the two (2) locking pins (Figure 28B) to allow the Array Stand to expand. Expand the Array Stand (Figure 22C) and install the locking pins in the “deployed” position (Figure 28D) after the Array Stand is fully extended (Figure 28E).

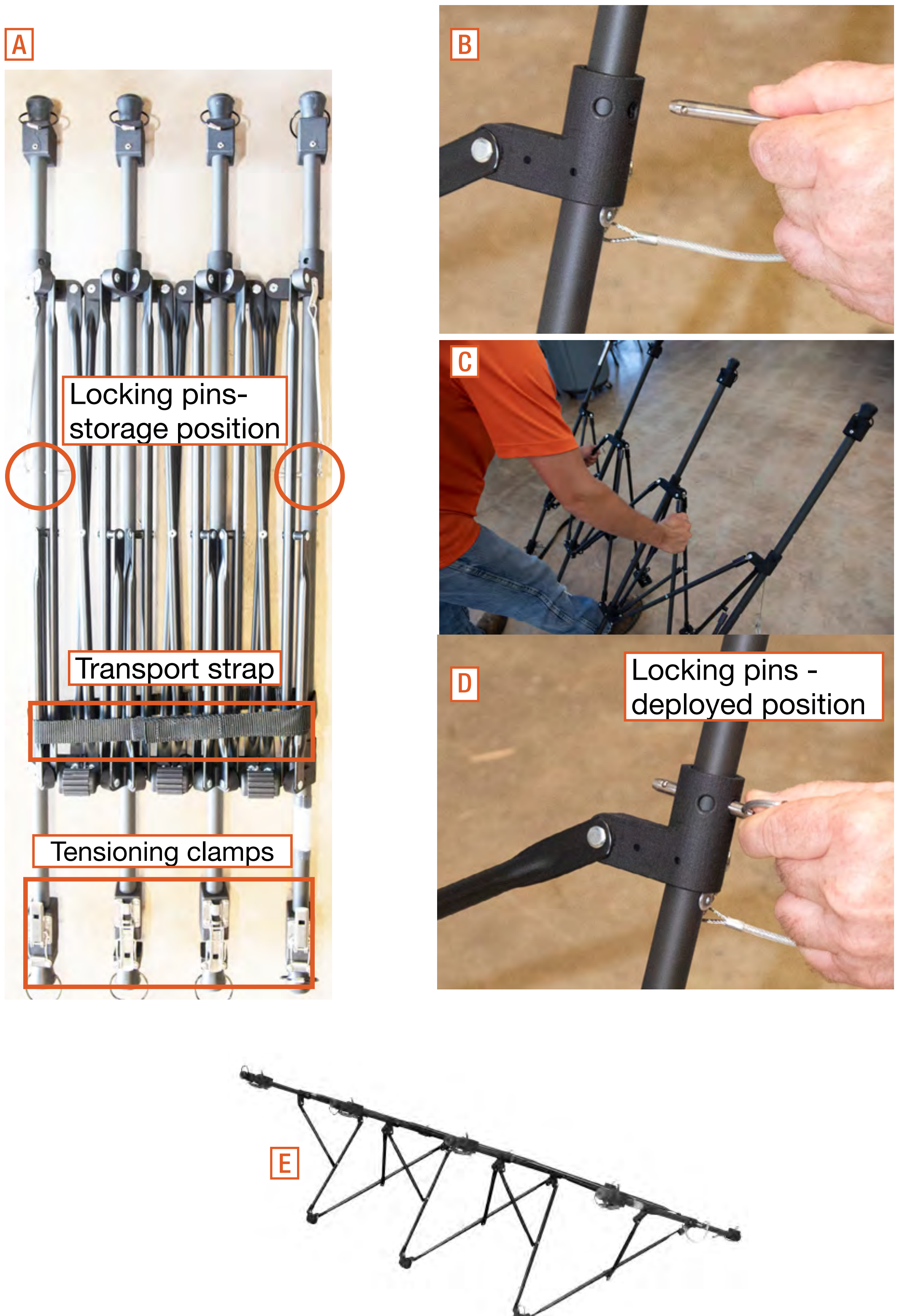



Figure 28. Deploying Array Stand

# 3. Install 30° Mesh Hold Down

The 30° Mesh hold down attachment has three (3) clips on the short side and four (4) on the long side (Figure 29A). The clips on the short side connect to the rings on the three (3) cleats (Figure 29B) of the Array Stand. Connect the four (4) clips on the long side of Mesh to the wire loops (Figure 29C) at the low end of the support frame bar (Figure 29D). The Mesh will be stretched tight when all of the connections are made.

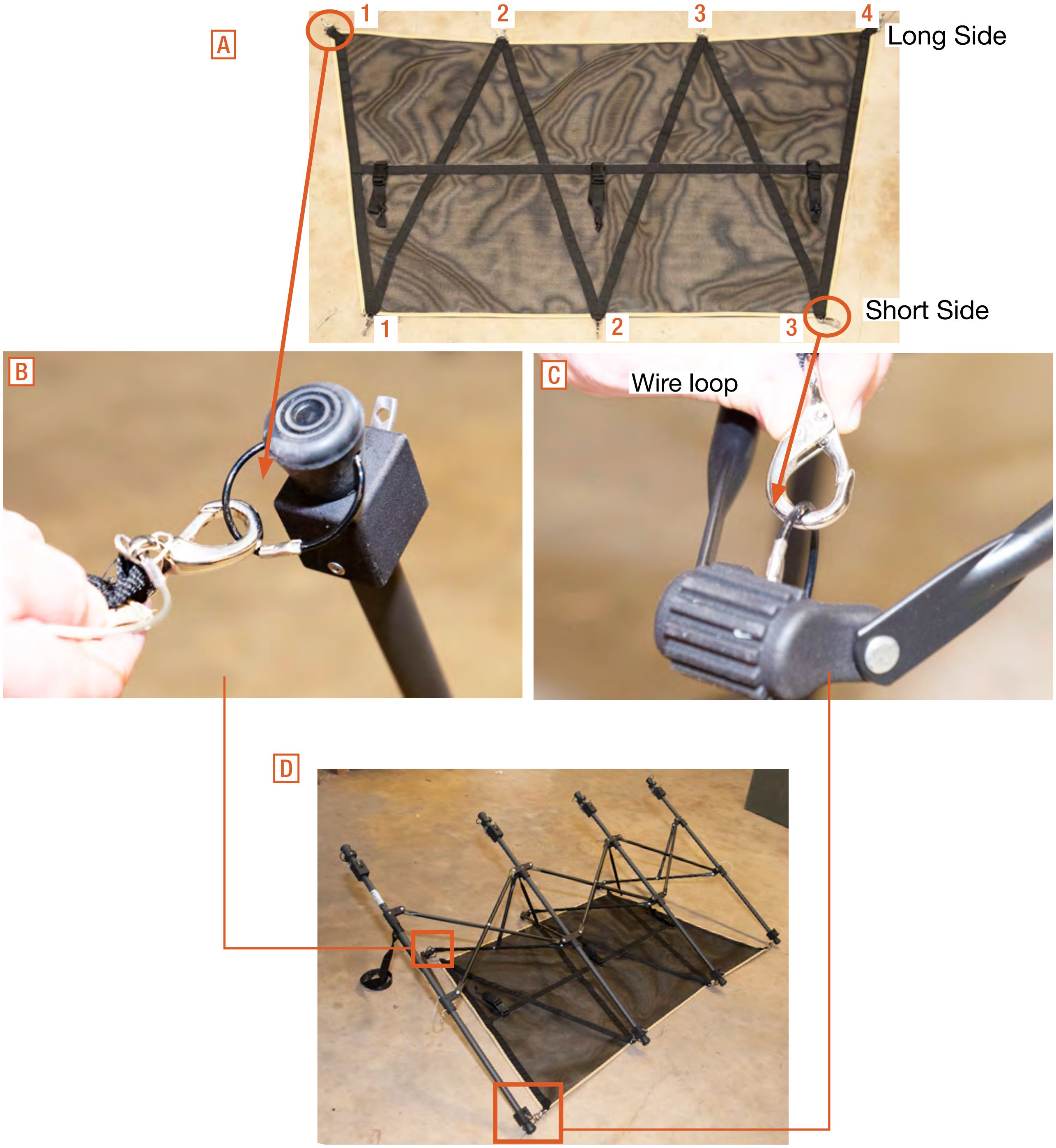



Figure 29. 30° Mesh Hold Down installation

# 4. Install 60º Mesh Hold Down

The 60° Mesh Hold Down has three (3) clips on the short side and four (4) on the long side (Figure 30A). The clips on the long side connect to the wire rings (Figure 30B) on the round feet associated with the tensioning latch. The three (3) clips on the short side connect to the three (3) support frame cleats (Figure 30C).

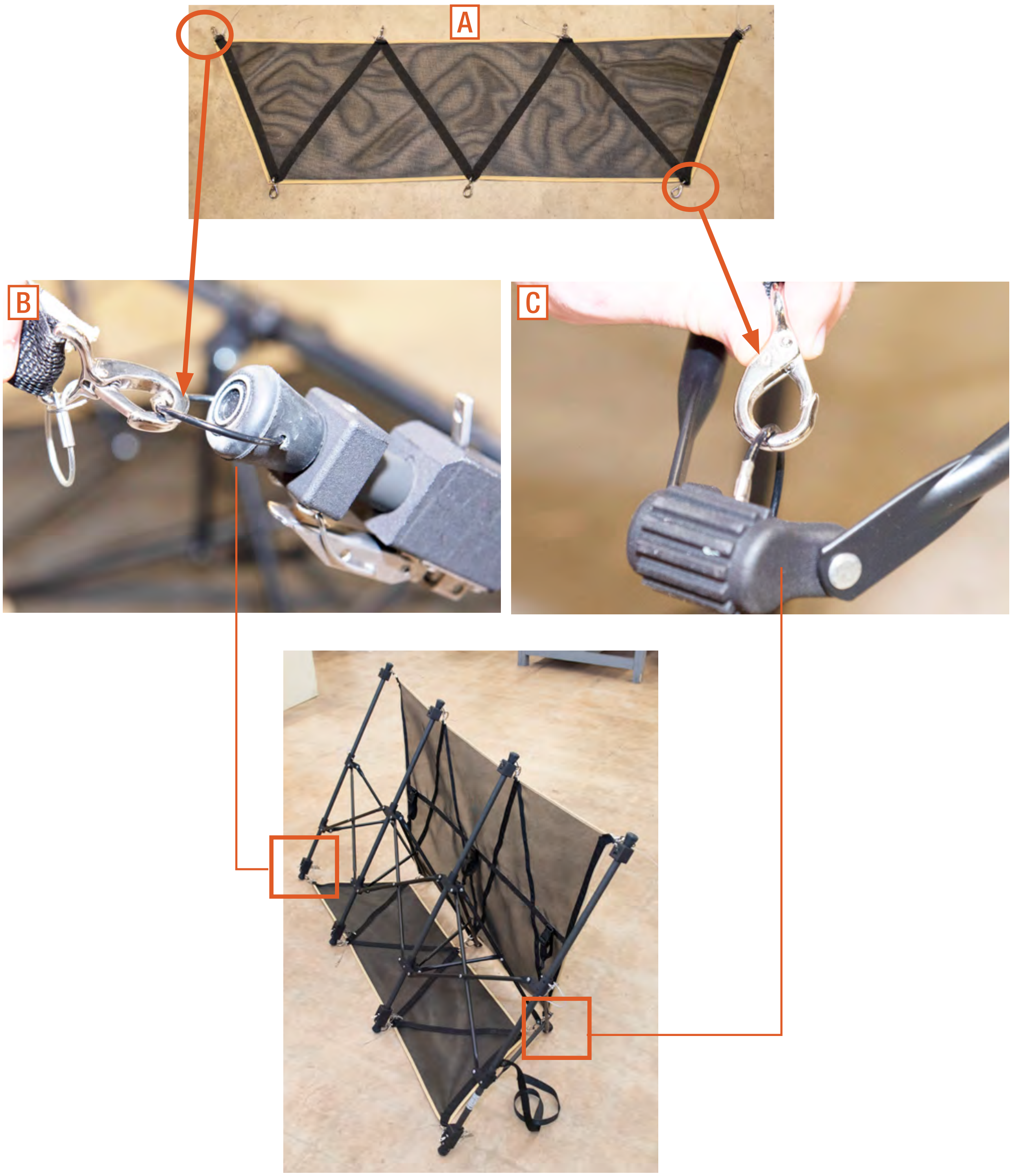



Figure 30. 60° Mesh Hold Down installation

## 5. Mesh Configuration for 30º and 60º Deployments

Connect the large and small Meshes as shown in Figure 31 to deploy the Array at 30º (A) or at 60º (B).

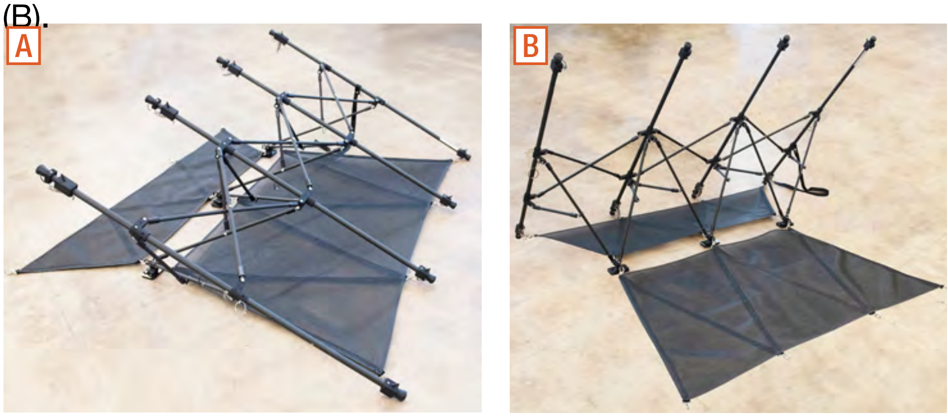



Figure 31. Ground-securing Mesh configuration for 30° and 60° Array deployment

## 6. Install Panel onto Array Stand

Each Panel has eight (8) grommet-reinforced holes, four (4) on the top and four (4) on the bottom (Figure 32A, orange circles. The Array Stand has eight (8) complementary Panel mounting hooks (Figure 32B). The latching mechanism on this side of the frame is fixed. Connect the Panel to this row of fixed mounting hooks first (Figure 32B). Mount Panels onto Array Stands in the same orientation.

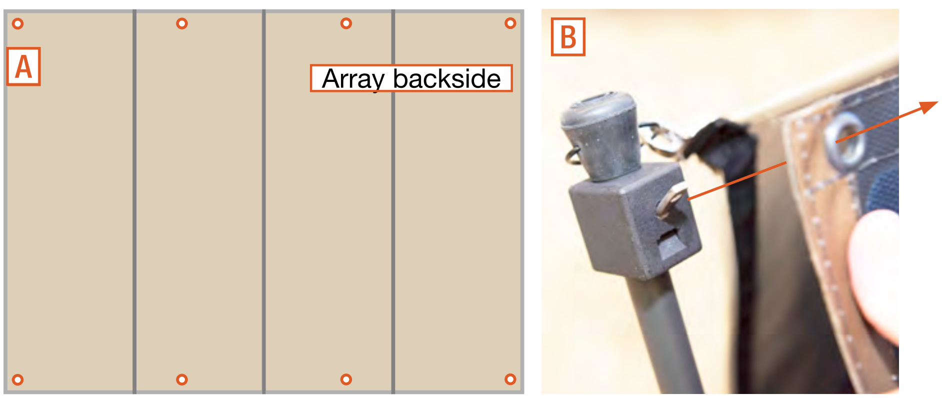



Figure 32. Connecting Array to Array Stand

The hooks on other side of the Panel are part of a sliding tensioning clamp. Figure 33A shows the Array Stand in the storage configuration with tensioning clamps in locked and unlocked positions. Unlock the clamp lever to allow the hook to slide (Figure 25B). Place the hook into the hole, then tighten (Figure 33C) and lock the clamp (Figure 33D). Repeat for each of the four (4) mounting holes until the Array is secured to the support frame.

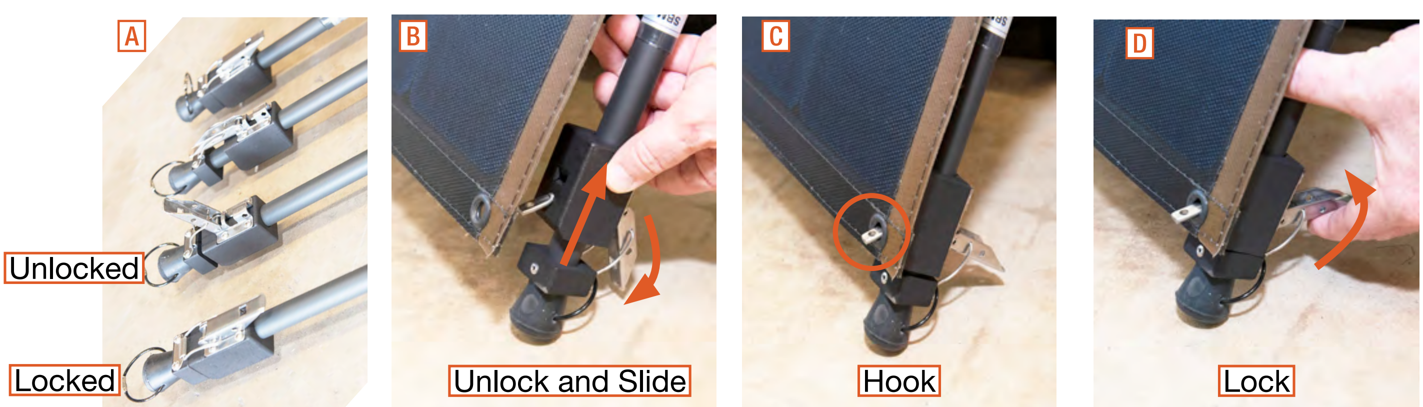



Figure 33. Locking the Array into place on the Array stand

# 7. Secure Arrays to Ground

**Do not secure the Arrays to the ground before establishing proper location and orientation.**

Before the Arrays are secured to the ground, be observant and take care to ensure the support frame is not twisted. If the support frame is twisted, the Array will be exposed to torsional strain, which can cause damage to the cells.

**⚠ WARNING**

Failure to properly secure Array(s) to ground with sandbags could result in Array damage, personnel injury, or death in high winds. Wind damage can render Arrays nonfunctional or significantly reduce their functional life expectancy. Arrays must be properly secured to the ground even in low-wind environments.

**⚠ CAUTION**

**DO NOT DAMAGE THE ARRAY SUPPORT FRAME.**
**DO NOT DROP SANDBAGS ONTO THE ARRAY SUPPORT FRAME.**

The Array must be secured with sandbags to reduce the potential for displacement or damage in high winds. The 420 Array kit provides 7 sandbags. Wind-testing data indicate that the Arrays will withstand displacement in winds of 60 mph (97 kph) when weighted with seven (7) sandbags/Pane. Use the best available information when determining how many sandbags to use.

Sandbags should weigh a minimum of 50 pounds (23 kg) each. Place sandbags on the ground-securing Mesh under the Panel and on the Mesh behind the Panel as shown below (Figure 34)

## Ground-securing for 30º and 60º Deployments

Configure the Mesh for the desired angle of deployment (Figure 34). Ensure the Array is oriented for maximum energy harvesting and that the Solar Cable will reach the BOS 2000. Generally speaking, the lower angle (30º) will harvest energy more efficiently in the summer when the sun is overhead. During the winter, the steep angle (60º) will be more efficient.

Place seven (7), 50-lb (23 kg) sandbags on the Mesh as shown below. Sandbags are illustrations and not to scale.

30º - Best for summer

60º - Best for winter

Figure 34. Sandbag placement for 30° and 60° Array deployment

## Mesh Configuration and Ground-securing for Flat (0º) Deployments

The Array Stand is not used when deploying the Array at 0°, or flat. Instead, the 30° and 60° Mesh pieces are connected to the back side of each Solar Panel and then to each other to form a “pouch” into which sandbags are inserted. The number of sandbags required to secure the Array will vary by terrain and environmental conditions.

**DO NOT kneel on or place weight on the Solar Panel while installing the ground securing Mesh as Panel cells may be damaged. If a suitable working surface is not available, connect the Meshes with Panels standing on edge.**

1. Place Panel solar cell-side (“face”) down on a surface that will not damage the solar cells/Panel. Place the ground-securing Mesh (nylon strap side up) on the back of the Panel as shown in Figure 35B. The smaller of the two Meshes must be on top of the larger one.

2. Slide the looped wire through the grommet then secure in the clip (Figure 35A). Repeat step for each of the eight (8) points of connection [four (4) on each section of Mesh; orange boxes in B].

3. Secure the nylon strap into the clip (Figure 35C). Repeat step for each of the three (3) points of connection in the middle of the Panel (orange circles in B)

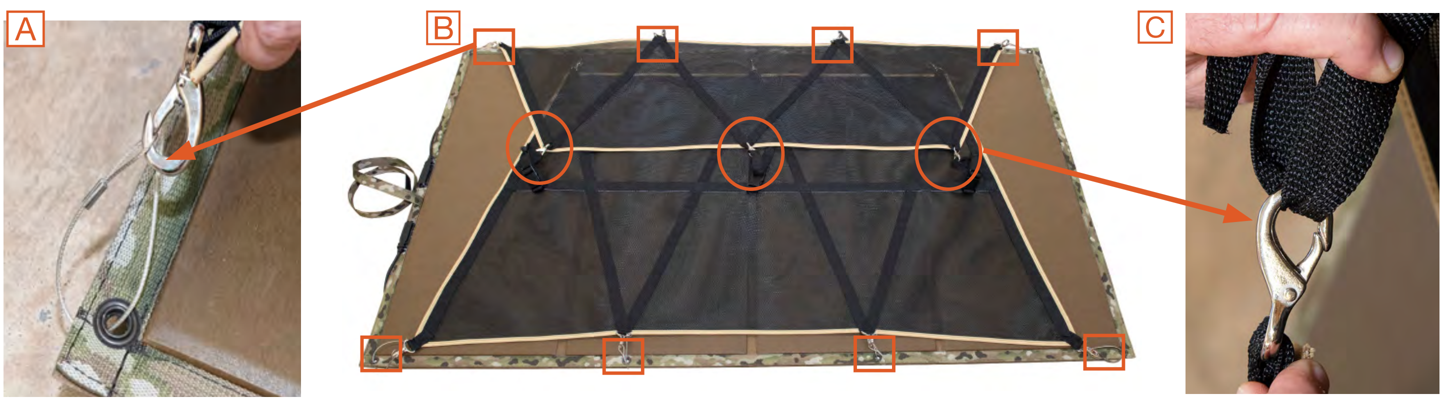



Figure 35. Configuring ground-securing Mesh for flat (0º) deployment

4. Flip over Panel so Mesh is on underside.

5. Place sandbags between Mesh and Panel.

Figure 36. Sandbags placement for 0° deployment

# 8. Connect Solar Cable to Solar Array Leads

Connect the leads on Panel to the Solar Cable as illustrated below in (Figure 37). The connectors on both ends of the Cable are polarized to prevent improper connection. Power exiting the cable connecting the Solar Venture Array to the BOS 2000 is a constant 29.0 VDC. The current from the array will vary to maximize power output under changing light exposer.

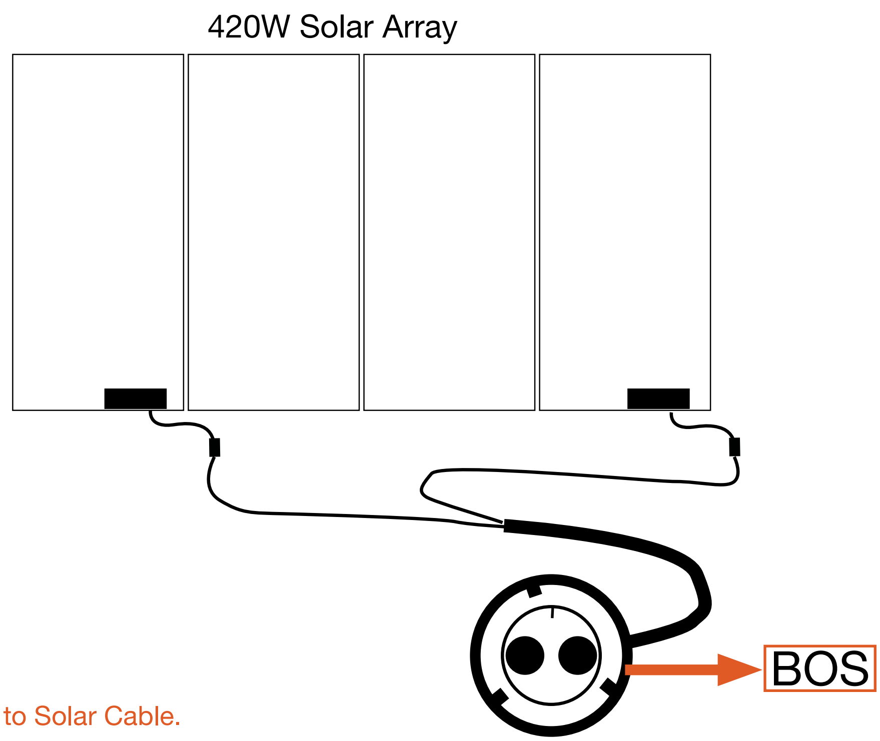



Figure 37. Connecting Array to Solar Cable.

# 9. Connect Array(s) to BOS

Connect Solar Cable to the solar power input ports on the side of the BOS 2000. The Solar Array must be within 25 ft. of the BOS as this is the length of the Solar Cable. Do not secure Arrays to the ground until adequate cable length to the BOS 2000 has been verified and Arrays have been oriented for optimal daily sun exposure.

## 10. Position Arrays for Optimal Power Generation

The setup location should have good exposure to sunlight and be away from other structures or potential hazards such as vehicle thoroughfares.

**Array Orientation for Optimum Power Generation**
Power generation requires direct sunlight for maximum performance. Optimal power generation is achieved by orienting all Arrays in the same direction and at the same angle.

> **Note:** Harvesting energy will not improve by orienting subsets of Arrays to capture morning, midday, and evening sun. In the Northern Hemisphere, the Arrays should be positioned so that they face the noon sun, which is usually true south in the Northern Hemisphere and true north if in the Southern Hemisphere. The Arrays may also be deployed flat and aimed straight up when conditions warrant.

**Seasonal Adjustment of Array Tilt to Improve Output**
Array performance may be improved by adjusting the tilt and orientation of the Panels seasonally. The angle of the Array, relative to the sun, can be adjusted to 0º, 30° or 60° prior to securing to the ground. In the Northern Hemisphere, the sun is higher overhead during the summer and lower on the horizon during the winter.

**Shading**
The Arrays must be positioned so they are not shaded. During periods of inclement weather or if the Array is not positioned optimally, daily power generation levels may be reduced.

# Measuring Solar Venture Array Power Output

Power (watts) output from the Solar Venture may be calculated by disconnecting all loads and all power (charging) sources from the BOS **except** the Solar Venture Array. In this configuration, the net current as reported by the BOS Battery Status Monitor is the charging current from the Solar Array and the voltage reported by the Battery Status monitor is the battery voltage at that time. Simply multiply the net current and the voltage (both on the Home Screen) and the resulting value is an accurate approximation of the power from the Solar Array. Keep in mind that if a load and/or an additional charging source is connected to the BOS 2000, this method for determining Solar Array power output will not provide an accurate result. Taking multiple, consecutive measurements by refreshing the display will provide a more accurate picture of Array power output because light intensity may vary considerably over time (e.g., clouds).

# Derating, Solar Loading, and Airflow

Derating occurs when the power output is diminished below rated values. Arrays may accumulate excessive amounts of heat due to solar loading and lack of airflow, resulting in derating.
Locate Arrays where airflow is unobstructed to reduce the impact of solar loading–induced derating.

# Disconnecting Array

Solar Panels should not be disconnected when under load because doing so could produce arc flash. Solar Panels produce electricity when exposed to light. Options for eliminating the load include: placing panel “face down” on an a flat surface, waiting until night time, or covering the panel with an opaque material. If none of these is a reasonable option, disconnect the connectors very slowly while wearing insulated gloves and protective eye wear. Disconnecting slowly significantly reduces the potential for arc flash and ensures that if it occurs, it will be contained within the insulating shield of the connector.

# Troubleshooting and Maintenance
# BOS Internal ESM 2000

Frequent visual monitoring of BOS ESM 2000 Battery Status Indicator is the best method to ensure the battery is operating normally.

## Notifications and Faults

Notifications and faults are found on the diagnostic screen. To access the diagnostic screen, push the refresh button once to refresh the display then a second time for the diagnostic screen.

### Notifications:

**Battery Offline** – This notification indicates that the Battery Status Indicator lost communication with the battery. It may have taken itself offline to protect from over-discharge. Toggle the BOS BATTERY switch to clear notification. If this doesn't clear the fault, apply a charging source with the BATTERY switch turned ON for at least two (2) minutes. If this fails to clear the fault, contact Solar Stik.

**Battery Voltage Low** – "Battery voltage low" fault occurs when the BOS battery voltage falls below 20 VDC. It is only a notification. It does not cause the battery to shut off. This notification automatically clears after charging brings voltage to >20 VDC.

### Faults:

The battery may report one or more faults at a time on the diagnostic screen. If a condition other than the ones shown below appears, contact Solar Stik for assistance. Faults place the BOS ESM into Protected mode until the fault is corrected and the BOS ESM returns to Operational mode **or**, if the fault is not cleared in 60 minutes, the BOS ESM will enter Storage mode even if the BATTERY switch remains in the ON position.

Table 1. Faults reported on ESM diagnostic screen: and solutions

| Fault Name | Value Exceeded | Clear Value |
|---|---|---|
| Critical Cell Overvoltage for 2 minutes | Max Cell V ≥ 4.2000 V | Max Cell V < 3.8000 V |
| Critical Cell Undervoltage | Cell Voltage ≤ 2.00 V @ ≤ 120 A discharge (battery voltage ≤ 16.0 VDC) | Automatically clears fault one time after 2-minute delay. If fault occurs again without charging battery for 2 minutes, must clear by charging for 2 minutes or toggling the BATTERY switch ON>OFF>ON. |
| Critical Cell Temp High | Max Cell Temp ≥ 76 °C | Reduce Cell Temp to ≤ 65 °C |
| Critical Board Temp High | Max Elec Temp 1 or 2 ≥ 120 °C | Reduce Max Elec Temp to ≤ 90 °C |
| Hardware Overload | Current ≥ 3000 A | 2-minute cool down, followed by toggling the BATTERY switch ON>OFF>ON |
| Fast Software Overload | Current ≥ 1500A 30 ms | 2-minute cool down, followed by toggling the BATTERY switch ON>OFF>ON |
| Software Overload | Max Elec Temp 3 ≥ 135 °C | 2-minute cool down, followed by reducing Elec Temp 3 to ≤ 90 °C |

## Other Error Messages That May Be Encountered

If either message (A) or (B) appears on the Battery Status Monitor when the BATTERY switch is turned off, turn the BATTERY switch back on. Alternatively, if the BATTERY switch is already on, the battery may be fully discharged but also concurrently connected to an active charging source. In this case continue charging until the battery wakes up.

The message in (A) could also be that the CAN terminator switch was changed or something changed on the CAN network external to the BOS that broke the CAN network. This situation is more likely when the BOS is controlling an AMMPS generator or has additional 24VDC Li ESMs connected.

A


B


Figure 38. Other Battery Status Monitor “error” messages

# BOS Storage Information

The Battery Status Indicator will display the last status acquired before the BATTERY switch was turned OFF. However, battery voltage will decrease during storage due to self-discharge. Toggle ON the BATTERY switch to update in-storage battery status.

***Never store a BOS 2000 ESM in a discharged state! Charge BOS ESM fully before placing in storage.***

***Never store an BOS 2000 with the BATTERY switch in the ON position.***

### Temperature-dependent self-discharge

The self-discharge rate increases as storage temperature increases. See In-storage Preventive Maintenance Checks and Services for charging instructions. If the BOS is stored at temperatures above 90 °F (32 °C), then intervals between maintenance checks and / or charges should be reduced to three (3) months.

# In-storage Battery Status Refresh: Voltage, SOC and SOH

When the BOS 2000 BATTERY switch is toggled OFF, the Battery Status Indicator will continue to report the last-recorded battery status; it does not refresh automatically during storage. The Battery Status indicator must be refreshed to report the current status while in storage.

1. Toggle BATTERY switch to ON.
2. The Battery Status Indicator Screen will populate with up-to-date information.
3. Check the voltage and SOC on the Home Screen
4. Press REFRESH DISPLAY button to move to the Diagnostic Screen to check SOH.

# Maintenance Charging

The 24VDC BOS 2000 ESM has a high current capacity. For this reason, a constant voltage-type maintenance charger should be used with the voltage fixed at the optimum charging voltage (29.5 – 30.5 VDC) for the BOS 2000. Any non-Solar Stik charger will need a custom cable to connect to the DC IN/OUT port of the BOS 2000.

If charging at any temperature lower than 68 °F (20 °C), use a charger with a current capability >25 A. The internal battery may need to heat to charge optimally (power to heat takes precedent over charging). The internal heater alone requires 20-25 A to operate. To charge and heat simultaneously, the charger must supply >25 A. If the charging source provides less than 25 A, the battery will use its stored energy to heat itself. This will drain the battery instead of charging. This situation will be apparent if the Battery Status Indicator reports a negative current value during charging and when there is no other load connected to the ESM.

1. Connect a constant voltage charging source to the BOS 2000 with the voltage set between 27.5 and 30.5. A voltage of at least 29.5 is needed to charge to 100% SOC.

   **NOTE** – if the ESM battery was previously **over-discharged**, it will need to be connected to the charge source for at least 2 minutes, or power-cycled (toggling BATTERY switch ON>OFF>ON) before charge current will begin to flow

2. Enable the charging source and allow the BOS 2000 to charge. Remember, the battery may heat itself before charging if the BOS internal battery is colder than 68 °F (20 °C).

3. The BOS ESM should continue to charge, balance, and taper until it reaches the voltage setpoint at less than 0.5 A. At this point the BOS ESM can be considered to be fully charged.

## BOS In-storage Preventive Maintenance Checks and Services (PMCS)

The BOS ESM is designed to be capable of not less than two (2) years of warehouse storage, without any maintenance during storage at a temperature of 72 ±5 °F (22 ±5 °C). However, storage temperature can vary widely from this relatively mild temperature. Rates of self discharge increase as temperature increases. If storage temperature is higher than 72 °F (22 °C), maintenance charging intervals must be shortened to less than two (2) years.

Even under ideal conditions (22 °C) we recommend quarterly SOC checks and charging when necessary.

| Item # | Item to be Inspected | Interval* at 91-140 °F (33-60 °C) Storage Temp | Interval* at ≤ 90 °F (≤ 32 °C) Storage Temp | Procedures | Non-mission Capable (NMC) |
|---|---|---|---|---|---|
| 1 | Visual inspection of 24VDC Li BOS 2000 | Q[1] | S[2] | 1. Inspect case for visible damage and missing items.<br>2. Clean excessive dust or dirt accumulation from the exterior and ports.<br>3. Close all unused port covers. | If case is broken or split or if port is damaged, contact Solar Stik Technical Support. |
| 2 | In-storage SOC Check | Q[1] | S[2] | 1. Toggle BATTERY switch to refresh Battery Status Monitor Indicator.<br>2. If SOC less than or equal to 50%, charge to 100% SOC.<br>See Maintenance Charging | The Li BOS ESM does not hold a charge after 48 hours of charging. |
| 3 | In-storage SOH Check | Q[1] | S[2] | Check SOH prior to deployment to ensure remaining capacity is sufficient to support mission. | Determining end of life based on SOH for BOS 2000 ESM will be application specific. |

[1]Quarterly (Q)—every three months [2]Semiannually (S) – every 6 months

# Solar Venture 420 W Array In-storage PMCS

| Item # | Item to be Inspected | Interval | Procedures | Non-mission Capable |
|---|---|---|---|---|
| 1 | Visual inspection of PV Arrays | M[1] | 1. Inspect PV panels and support frame for visible damage<br>2. Clean excessive dust or dirt from the surface.<br>3. Inspect cables and connections. Ensure there is no damage and that cables are not in standing water. | ~If the PV panels and/or the frame are damaged to the point of being non-functional, the PV array is NMC, replace. |
| 2 | Inspection of PV array ground securing | M | 1. Check the integrity of the ground securing mesh panels.<br>2. Ensure ground securing sandbags are full and situated properly.<br>3. Ensure that none of the sandbags is positioned in a way that places stress on any part of the PV array. | ~ If any aspect of the ground securing components is damaged or missing to the point the PV array cannot be secured to the ground, the PV array is NMC. Contact FSR to repair or replace the PV array. An unsecured PV array can become a wind-driven projectile posing risk of injury to personnel and damage to any connected equipment. |
| 3 | PV array output | Q[2] | 1. Ensure each PV array is oriented for optimal sun exposure.<br>2. Independently check (on the Power Hub User Interface) the power output from each array. | ~ If power output of an array is less than half the rated value, follow the instructions in this document to identify and solve the issue. |

[1]Monthly (M)—every month [2]Quarterly (Q)—every three months

# DC PDM PMCS

| Item # | Item to be Inspected | Interval | Procedures | Non-mission Capable |
|---|---|---|---|---|
| 1 | Visual and electrical inspection of DC PDM | Q[2] | 1. Inspect and test continuity for all connectors.<br>2. Clean excessive dust or dirt from the surface.<br>3. Confirm functionality of breaker switches and associated LEDs. | ~If connectors are damaged or non-functional, the DC PDM is NMC. |

[1]Monthly (M)—every month [2]Quarterly (Q)—every three months

# Warranty Terms

Solar Stik warrants, unless otherwise agreed to between buyer and seller (Solar Stik Inc), for a period of one year from Solar Stik's delivery of such Products, the Products shall be free from defects in materials and workmanship and shall conform to the contractual specifications or to specification sheet of the Product. This warranty does not cover defects or failure caused by improper handling, storage, maintenance, or repair or by any modification, mis-connection, abuse, abnormal use of such Products (inter alia overloading or overcharging) or use not complying with Solar Stik's user manual provisions if any.

Warranty claims must be made to Solar Stik immediately after discovering the defect and within the warranty period or are forever waived.

The foregoing warranty is exclusive of any other warranties, express, implied or statutory. In particular, this warranty shall not apply to failure arising from defect in design when the design has been completed in part by the Customer or a third party. Unless otherwise agreed, the warranty shall not apply to the compliance of Products to Customer's needs. Should the Products warranty be breached, Customer's exclusive remedy against Solar Stik, and Solar Stik's sole obligation, shall be limited to, at Solar Stik's option, repairing or replacing the defective Products.

The Product shall be considered defective if the failure may be duplicated by Solar Stik, it being understood nonconformity shall be determined by reference to the contractual specifications applicable to the allegedly defective Products.

# About Solar Stik, Inc.

SOLAR STIK®

**Mission Statement**
Saving lives across the globe through innovative power solutions

**STIKopedia**
STIKopedia is a compilation of everything you would ever want to know about portable Hybrid Power Systems, including the philosophy and mechanics of high-efficiency circuits, and the individual technologies used to create them.

**Solar Stik Training and Education**

- **Solar School (St. Augustine, FL)** provides an introduction to the design and support of small-scale, renewable-energy, power generation systems, with detailed explanation of system components. Advanced configuration options with hands-on deployment of actual systems will enhance student understanding.

- **Solar Stik New Equipment Training (on site)** teaches Hybrid System configuration options with hands-on deployment of actual systems to enhance student understanding.

Solar Stik Training Courses are tailored to the specific needs of the students. To schedule Solar Stik Training or to learn more about the curriculum, please contact us.

## Contact

Technical Support:
1-800-793-4364 Ext 102
Outside of the US:
+1-904-808-0510 Ext 102
tech@solarstik.com
(24 hours a day, 365 days a year)

**Address**
Solar Stik, Inc.
226 West King Street
Saint Augustine, Florida 32084

**Website**
www.solarstik.com

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## Li BOS 2000 Air and Ground Transport

The following information is a summary of the conditions that apply to the 24VDC Li BOS 2000 for air and ground transport:

- **Dangerous Goods Training.** The international and U.S. transportation regulations require personnel involved in shipping the 24VDC Li BOS 2000 to complete the appropriate level of HAZMAT training.
- **Classification.** The 24VDC Li BOS 2000 is classified as Class 9 hazardous material.
- **Testing.** The $LiFePO_4$ cells of the Li BOS 2000 and the battery itself have passed UN 38.3 T1 – T8 tests.
- **Short Circuit Protection**. The 24VDC Li BOS 2000 is protected against short circuit and unintended movement.
- **Accidental Activation.** The 24VDC Li BOS 2000 is protected against accidental activation.
- **Net Weight Limit.** The net weight of the lithium batteries in the 24VDC Li BOS 2000 is 20.7 kg and is below the maximum of 35 kg net weight limit.
- **Marking and Labeling.** The 24VDC Li BOS 2000 shipping container must bear the following labels: Class 9 hazard and Cargo Aircraft Only labels. Packages must also be marked with Proper Shipping Name (UN3481 Lithium Ion Batteries Contained in Equipment) and Shipper and Consignee addresses.
- **Shipper's Declaration for Dangerous Goods.** A Shipper's Declaration for Dangerous Goods must be filled out and accompany the 24VDC Li BOS 2000 for air transport. The certifying official must have the requisite training.
- **Master Air Waybill.** The Master Air Waybill or Bill of Lading (BOL) is the document that travels with and describes the shipment.

## Disposal – $LiFePO_4$ Battery

**The battery should not be opened. The battery should not be destroyed or incinerated since the battery may cause fire or the ingredients contained in the cells could be harmful if exposed.**

As a general rule, lithium-ion batteries are managed as universal waste under the Resource Conservation and Recovery Act. However, battery disposal regulations vary on national, state/provincial, and installation levels. Disposal must be conducted in accordance with all applicable regulations. ANY breached or leaking battery is managed as hazardous waste.

Before initiating the disposal process for the Li BOS ESM, it must be fully discharged. Consult your local Hazardous Waste Storage Area (HWSA), Defense Reutilization and Marketing Office (DRMO), or other local authorities for the standard operating procedure for packaging, quantity, labeling, shipping, and tracking requirements. If an HWSA or DRMO is not available or does not accept the Li ESM, contact your servicing environmental compliance organization. Solar Stik is also able to handle disposal of the Li BOS ESM at a cost to the customer. Solar Stik may be contacted at 800-793-4364.

The Li BOS ESM contains recyclable materials, and recycling is encouraged over disposal if a lithium battery recycling facility is available.

The box in which the replacement battery was shipped is UN rated and should be used to ship the defective battery to the appropriate disposal location.

# Supplemental Information

## Replacement Battery SDS

**Material/Product Safety Data Sheet**
**(MSDS-PSDS)**

| MP / VL products<br>Revision 8<br>Date 02/2009 | Lithium-Ion single cells and multi-cell battery pack |
|---|---|

| 1. Identification of the Substance or Preparation and Company | | |
|---|---|---|
| **Product** | **Rechargeable lithium-ion single cells and multi-cell battery packs** | |
| **Production sites** | Saft America Inc.<br>313 Crescent Street<br>Valdese<br>North Carolina 28690<br>USA<br>Tel. No. +1 (828) 874 4111<br>Fax No. +1 (828) 874 2431 | Saft<br>Rue Georges Leclanché<br>BP 1039<br>86060 Poitiers cedex 9<br>FRANCE<br>+33 (0)5 49 55 48 48<br>+33 (0)5 49 55 48 50 |
| | www.saftbatteries.com (section "Contact") | |
| **Emergency contacts** | +1 (703) 527 3887 (CHEMTREC U.S. Service Center)<br>within the USA : 800 424 9300 | |

**2. Composition and Information on Ingredients**

Each cell consists of a hermetically sealed metallic container containing a number of chemicals and materials of construction of which the following could potentially be hazardous upon release.

There is no potential for exposure to these ingredients unless the cell leaks, or opens, following high temperature, mechanical or electrical abuse.

| Ingredient | Content* (wt. %) | CAS # | ACGIH (TLV) | OSHA (PEL) |
|---|---|---|---|---|
| Lithium metal | 0<br>*(in spite of their name, these batteries do not contain lithium metal)* | | | |
| $LiCoO_2$<br>*(Lithium cobalt oxide)* | 19-35 % | 12190-79-3 | 0.02 mg/m$^3$ 8 hours as dust and fumes | 5 mg/m$^3$ as dust and fumes |
| Organic solvents | 12-15 %<br>EA *(Ethyl Acetate)*<br>EC *(Ethylene Carbonate)*<br>DMC<br>*(Di Methyl Carbonate)* | 141-78-6<br>96-49-1<br>616-38-6 | None established | None established |
| $LiPF_6$<br>*(Lithium Hexafluoro phosphate)* | ≈ 3 % | 21324-40-3 | None established | None established |

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| | | | | |
|---|---|---|---|---|
| PVDF | < 1 % | 24937-79-9 | None established | None established |
| Copper *(Cu)* | 9-18 % | 7440-50-8 | 0.2 $mg/m^3$ as fume<br>1.0 $mg/m^3$ as dust and mist | 0.1 $mg/m^3$ as fume<br>1.0 $mg/m^3$ as dust and mist |
| Aluminium *(Al)* | 17-27 % | 7429-50-5 | 10.0 $mg/m^3$, as dust | 2.0 $mg/m^3$, as soluble salt |
| Graphite and Carbon | 13-18% | 7782-42-5<br>1333-86-4 | 3.5 $mg/m^3$, TWA for carbon | 2.0 $mg/m^3$, as dust |
| Steel, Nickel, and inert components | Balance | | Balance | |

* Quantities may vary a little with cell model
ACGIH : American Council of Governmental Industrial Hygienists
TLV : Threshold Limit Value is personal exposure limit, determined y ACGIH.

## 3. Hazards Identification

The rechargeable lithium-ion batteries described in this Product Safety Data Sheet are sealed units which are not hazardous when used according to the recommendations of the manufacturer and as long as their integrity is maintained.

Do not short circuit, puncture, incinerate, crush, immerse in water, force discharge or expose to temperatures above the declared operating temperature range of the product. Risk of fire or explosion.

Under normal conditions of use, the active materials and liquid electrolyte contained in the cells and batteries are not exposed to the outside, provided the battery integrity is maintained and seals remain intact. Risk of exposure only in case of abuse (mechanical, thermal, electrical) which leads to the activation of safety valves and/or the rupture of the battery container. Electrolyte leakage, electrode materials reaction with moisture/water or battery vent/explosion/fire may follow, depending upon the circumstances.

## 4. First Aid Measures (in case of leaking or accidentally opened cells)

In case of accumulator breakage or burst, please evacuate employees from the contaminated area and ensure maximal ventilation in order to break-up corrosive gas, smoke and unpleasant odors.

If it occurs, by accident, following measures must be taken:

| | |
|---|---|
| **Inhalation** | Not anticipated under normal use.<br>Remove from exposure. Remove to fresh air. Rest and keep warm.<br>In severe cases obtain medical attention. |
| **Skin contact** | Not anticipated under normal use.<br>Wash off skin thoroughly with water. Remove contaminated clothing and wash before reuse. In severe cases obtain medical attention. |
| **Eye contact** | Not anticipated under normal use.<br>Irrigate thoroughly with water for at least 15 minutes. Obtain medical attention. |
| **Ingestion** | Not anticipated under normal use.<br>Wash out mouth thoroughly with water and give plenty of water to drink. Obtain medical attention. |
| **Further treatment** | All cases of eye contamination, persistent skin irritation and casualties who have swallowed this substance or been affected by breathing its vapours should be seen by a doctor. |

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| 5. Fire Fighting Measures |
|---|
| Dry chemical type or $CO_2$ extinguishers, Halon, or copious quantities of water or water-based foam can be used to cool down burning Li-ion cells and batteries. During water application, caution should be exercised as burning pieces of flammable particles may be ejected from the fire.<br>In case of fire, it is recommended to wear self-contained breathing apparatus, to avoid contact with irritant fumes. Evacuate all persons from immediate area of fire.<br>Do not re-enter the area until it has been adequately purged of the fire vapour and extinguishing agent. |

| 6. Accidental Release Measures |
|---|
| In case of electrolyte leakage from a cell or battery, do not inhale the gas as possible.<br>Remove personnel from area.<br>If the skin has come into contact with the electrolyte, it should be washed thoroughly with water.<br>Using protective glasses and gloves, sand or earth should be used to absorb any exuded material.<br>Seal leaking battery (unless hot) and contaminated absorbent material in plastic bag and dispose of as Special Waste in accordance with local regulations. |

| 7. Handling and Storage | |
|---|---|
| **Handling** | Do not crush, pierce, short (+) and (-) battery terminals with conductive (i.e. metal) goods, which would end up into excessive heating.<br>Do not directly heat or solder. Do not throw into fire.<br>Do not mix batteries of different types and brands. Do not mix new and used batteries.<br>Keep batteries in non conductive (i.e. plastic) trays.<br>Do not disassemble, mutilate or mechanically abuse cells and batteries. |
| **Storage** | Store in a cool (preferably below 30°C) and ventilated area, away from moisture, sources of heat, open flames, food and drink. Keep adequate clearance between walls and batteries. Temperature above 70°C may result in battery leakage and rupture. Since short circuit can cause burn, leakage and rupture hazard, keep batteries in original packaging until use and do not jumble them. |
| **Other** | Follow Manufacturers recommendations regarding maximum recommended currents and operating temperature range.<br>Applying pressure on deforming the battery may lead to disassembly followed by eye, skin and throat irritation.<br>Do not immerse in water.<br>The Li-ion cells and batteries are not designed to be recharged from external power sources besides specific Li-ion charger models approved by Saft.<br>Connecting to inappropriate power supplies can result in fire or explosion. |

| 8. Exposure Controls & Personal Protection | |
|---|---|
| **Occupational exposure standard** | See section 2 |

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|---|
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|---|
| In case of electrolyte leakage from a cell or battery, do not inhale the gas as possible.<br>Remove personnel from area.<br>If the skin has come into contact with the electrolyte, it should be washed thoroughly with water.<br>Using protective glasses and gloves, sand or earth should be used to absorb any exuded material.<br>Seal leaking battery (unless hot) and contaminated absorbent material in plastic bag and dispose of as Special Waste in accordance with local regulations. |

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|---|---|
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| **Storage** | Store in a cool (preferably below 30°C) and ventilated area, away from moisture, sources of heat, open flames, food and drink. Keep adequate clearance between walls and batteries. Temperature above 70°C may result in battery leakage and rupture. Since short circuit can cause burn, leakage and rupture hazard, keep batteries in original packaging until use and do not jumble them. |
| **Other** | Follow Manufacturers recommendations regarding maximum recommended currents and operating temperature range.<br>Applying pressure on deforming the battery may lead to disassembly followed by eye, skin and throat irritation.<br>Do not immerse in water.<br>The Li-ion cells and batteries are not designed to be recharged from external power sources besides specific Li-ion charger models approved by Saft.<br>Connecting to inappropriate power supplies can result in fire or explosion. |

| 8. Exposure Controls & Personal Protection | |
|---|---|
| **Occupational exposure standard** | See section 2 |

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| | |
|---|---|
| **Respiratory protection** | In all fire situations, use self-contained breathing apparatus. |
| **Hand protection** | In the event of leaking or ruptured cells, wear gloves. |
| **Eye protection** | Safety glasses are recommended in case of leaking or ruptured cells |
| **Other** | In the event of leakage or ruptured cells, wear chemical apron. |

| **9. Physical and Chemical Properties** | |
|---|---|
| Note: The following points are not applicable unless in case of leaking or damaged batteries with internal components sipping out. | |
| **Appearance** | Solid object with cylindrical or prismatic shape |
| **Odour** | Odourless (unless in case of damaged product with leaking electrolyte) |
| **pH** | Not applicable |
| **Flash point** | Not applicable |
| **Flammability** | Not applicable |
| **Relative density** | > 2 $g/cm^3$ |
| **Solubility (water)** | Not applicable, unless inner components are exposed |
| **Solubility (other)** | Not applicable |

| **10. Stability and Reactivity** | |
|---|---|
| The product is stable under conditions described in Section 7. | |
| **Conditions to avoid.** | Heating above 70°C or incinerate. Deformation. Mutilation. Crushing. Piercing. Disassembly. Short circuiting. Exposition over a long period to humid conditions. |
| **Materials to avoid** | Strong mineral acids, alkali solutions, strong oxidising materials and conductive materials |
| **Hazardous decomposition Products** | HF, CO, $CO_2$ |

| **11. Toxicological Information** | |
|---|---|
| **Signs & symptoms** | None, unless battery ruptures. In the event of exposure to internal contents, corrosive fumes will be very irritating to skin, eyes and mucous membranes. Overexposure can cause symptoms of non-fibrotic lung injury and membrane irritation. |
| **Inhalation** | Lung irritant. |
| **Skin contact** | Skin irritant |
| **Eye contact** | Eye irritant. |
| **Ingestion** | Tissue damage to throat and gastro-respiratory tract if swallowed. |
| **Medical conditions generally aggravated by exposure** | In the event of exposure to internal contents, eczema, skin allergies, lung injuries, asthma and other respiratory disorders may occur. |

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| 12. Ecological Information | |
|---|---|
| **Mammalian effects** | None known if used/disposed of correctly. |
| **Eco-toxicity** | None known if used/disposed of correctly. |
| **Bioaccumulation potential** | None known if used/disposed of correctly. |
| **Environmental fate** | None known if used/disposed of correctly. |

**13. Disposal Considerations**

Do not incinerate, or subject cells to temperatures in excess of 70°C. Such abuse can result in loss of seal, leakage, and/or cell explosion. Dispose of or recycle in accordance with appropriate local regulations.

**14. Transport Information**

Note: when manufacturing a new battery pack, one must assure that it is tested in accordance with the UN Model Regulations, Manual of Tests and Criteria, Part III, subsection 38.3

| | |
|---|---|
| **Label for conveyance** | For the single cell batteries and multi-cell battery packs that are non-restricted to transport, use lithium-ion batteries inside label.<br>For the single cell batteries and multicell battery packs which are restricted to transport (assigned to the Miscellaneous Class 9), use Class 9 Miscellaneous Dangerous Goods and UN Identification Number labels.<br>In all cases, refer to the product transport certificate issued by the Manufacturer. |
| **UN number** | UN 3480, for Li-ion batteries transported in bulk<br>UN 3481, for Li-ion batteries contained in equipment or packed with it |
| **Shipping name** | Lithium-ion batteries |
| **Hazard classification** | Depending on their nominal energy, some single cells and small multi-cell battery packs may be non- assigned to Class 9 (Refer to Transport Certificate) |
| **Packing group** | II |
| **IMDG Code** | 9033 |
| **CAS** | |
| **EmS No.** | 4.1-06 |
| **Marine pollutant** | No |
| **ADR Class** | Class 9 |

**15. Regulatory Information**

Regulations specifically applicable to the product:

- ACGIH and OSHA: see exposure limits of the internal ingredients of the battery in section 2.
- IATA/ICAO (air transportation): UN 3480 or UN 3481
- IMDG (sea transportation) : UN 3480 or UN 3481
- Transportation within the US-DOT, 49 Code of Federal Regulations

**16. Other information**

This information has been compiled from sources considered to be dependable and is, to the best of our knowledge and belief, accurate and reliable as of the date compiled.

This information relates to the specific materials designated and may not be valid for such material used in combination with any other materials or in any process. It is the user's responsibility to satisfy himself as to the suitability and completeness of this information for his particular use.

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Saft does not accept liability for any loss or damage that may occur, whether direct, indirect, incidental or consequential, from the use of this information. Saft does not offer warranty against patent infringement.

**Edition 8 – February 2009**

Signature

Nicolas Paquin
Lithium Product Manager