Long Life Battery (LLB) End Item Specification GFE for the EMU

Engineering Directorate
Energy Systems Division

Verify this is the correct version before use
For correct version go to: http://ea.jsc.nasa.gov/eawebfiles/ea-projects/flightgfe/emu/html/emu.htm

November 2007
Revision E

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

PREFACE

The Battery End Item Specification for the Long Life Battery for the EMU represents Government Furnished Equipment (GFE) to be designed, developed, manufactured, tested, and delivered by the JSC Engineering Directorate, as a significant contribution to the EMU Program. This document delineates functional, performance, interface, design-to constraints, and safety and mission assurance requirements, which must be met by the Battery End Item. These requirements flow down from the Project Technical Requirements Specifications, JSC 29929. This document will be configuration managed by the GFE EMU Battery Project Manager.

Prepared by:

Eric Darcy November 9, 2007

JSC/EP5

Concurred by:

11/9/07

Jason Dugas November 9, 2007

JSC/EP5

Approved by:

11/9/07

Samuel Russell November 9, 2007

JSC/EP5

Change Record

Rev.	Date	Originator	Approvals	Description
Basic	Oct 2, 2003	Judith A. Jeevarajan	Eric Darcy	Basic
A	Sept 2004	Eric Darcy	Eric Darcy	Added references to EMU/Battery ICD and Shuttle Air Lock ICD. Added requirements for ALPS compatibility. Modified physical envelope of LIB to maximum that interface can handle. Omitted 20A pulse for health detection. Clarified maximum transient pulse power required. Added power requirement for Bends Treatment Adapter mode. Added maximum must trip requirement for LIB current limiter. Elaborated on mate/demate requirements. Omitted 40g environment associated with Russian vehicle landing with LIB is the EMU. More narrowly specified transport to/from orbit requirements. Modified worst case thermal profiles to include pre and post EVA conditions. Added bonding and grounding requirements. Added condition for when 5-year storage life requirement applies in addition to the unchanged 5-year service life. Removed PDA scarring. Added items necessary to comply with hot mate/demate interpretation memo. Deleted Appendix A with envelope requirement which is replaced with reference to ICD.
B	Sept 2004	Dan Hall	Eric Darcy	Deleted current monitoring capability requirement.
C	Feb 2005	Dan Hall	Eric Darcy	Update references to Rev B of ICD, Rev D of PRC-0009, website url. on cover, and dongle usage. Removed envelope exceptions to ICD. Corrected random vibration spectrum. Deleted failure tolerance requirement for recovery from short circuit.
D	Jan 2006	Dan Hall	Eric Darcy	Updated 3.2.2.11 to 50°C max temperature in range. Sensor can be less than two pins. Corrected ICD reference in 3.2.3.8.4. Modified EMU stowed qualification random vibration level in 3.2.3.2 to be equivalent to that used for the ICD as per the S/AD SV 819600/2 from Hamilton Sundstrand.

E	Nov 2007	Eric Darcy	Sam Russell	All LIB references changed to LLB throughout document, except when referring to LIB Charger. In 3.2.3.2, changed duration of qualification vibration from 25 to 7.5 minutes and replace MPLM vibration spectrum with a higher qualification acceptance vibration spectrum. Changed cycle life requirement from 150 to 100 in 3.3.8.2.

TABLE OF CONTENT

1. INTRODUCTION 1

1.1 SCOPE 1
1.2 RESPONSIBILITY AND CHANGE AUTHORITY 1

2.0 APPLICABLE DOCUMENTS 1

2.2 ORDER OF PRECEDENCE 3

3.0 REQUIREMENTS 3

3.1 DEFINITION OF LITHIUM-ION BATTERY 3
3.1.1 LITHIUM-ION BATTERY DESCRIPTION 3
3.1.2 INTERFACE DESCRIPTION 3
3.1.2.1 LLB System Interfaces 3
3.2 CHARACTERISTICS OF LITHIUM-ION BATTERY 4
3.2.1 PHYSICAL REQUIREMENTS 4
3.2.1.1 Cell Chemistry 4
3.2.1.2 Envelope 4
3.2.1.3 Weight 4
3.2.2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS 4
3.2.2.1 Voltage Output 4
3.2.2.2 Battery Capacity/Energy 4
3.2.2.3 Continuity 4
3.2.2.4 Insulation Resistance 5
3.2.2.5 Peak Current 5
3.2.2.6 Storage State of Charge/Discharge 5
3.2.2.7 Charge Retention 5
3.2.2.8 Charge Interruption 5
3.2.2.9 Rest Time 5
3.2.2.10 Maximum Charge Rate 5
3.2.2.11 Thermal Sensing Capability 5
3.2.2.12 Venting 6
3.2.2.13 Power Consumption 6
3.2.2.14 Existing Charger Compatibility 6
3.2.3 ENVIRONMENTAL REQUIREMENTS 6
3.2.3.1 Humidity 6
3.2.3.2 Random Vibration 6
3.2.3.3 Sinusoidal Vibration 7
3.2.3.4 Acoustics 7
3.2.3.5 Acceleration 7
3.2.3.6 Shock 7
3.2.3.7 Pressure 8
3.2.3.8 Temperature 9
3.2.3.9 Micrometeroids and Orbital Debris 9
3.2.3.10 Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) 10
3.2.3.11 Ionizing Radiation 10
3.2.3.12 Orientation Sensitivity 10
3.2.3.13 ESD Susceptibility 10
3.2.3.14 Magnetic Field Susceptibility 10
3.2.3.15 Conducted Emissions Into Load 10
3.2.4 RELIABILITY 10
3.2.4.1 Failure Tolerance 10
3.2.4.2 Failure Propagation 11
3.2.4.3 Failure Detection, Isolation and Recovery (FDIR) 11
3.2.4.4 Cell Acceptance and Lot Certification 11
3.2.5 MAINTAINABILITY 11
3.2.6 TRANSPORTABILITY 11
3.3 DESIGN AND CONSTRUCTION 11

3.3.1 MATERIALS, PARTS AND PROCESSES 11
3.3.1.1 Materials and Processes 11
3.3.1.2 Electrical, Electronic and Electromechanical (EEE) Parts 12
3.3.2 STRUCTURAL DESIGN 12
3.3.2.1 Fracture Control 12
3.3.2.2 Cell Vent/ Burst Ratio 12
3.3.2.3 Structural Safety Factor 12
3.3.2.4 Point / Kick Load 13
3.3.2.5 Collapse Pressure 13
3.3.3 ELECTRICAL DESIGN 13
3.3.3.1 LLB Electrical Isolation 13
3.3.3.2 Connectors 13
3.3.3.3 Electromagnetic Interference Free Design 13
3.3.3.4 Grounding 14
3.3.3.5 Electrical Bonding 14
3.3.4 WORKMANSHIP 14
3.3.4.1 Printed Boards 14
3.3.4.2 Surface Mount Technology 14
3.3.4.3 Soldered Electrical Connections 14
3.3.4.4 Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices) 14
3.3.4.5 Electrical Cables, Wiring and Harnesses 14
3.3.4.6 Contamination 14
3.3.4.7 Cleanliness 14
3.3.5 INTERCHANGEABILITY/REPLACEABILITY 14
3.3.6 SAFETY 15
3.3.6.1 Design 15
3.3.6.2 Redundancy 15
3.3.7 HUMAN ENGINEERING 15
3.3.7.1 Touch Temperature 15
3.3.7.2 Nameplates and Product Marking 15
3.3.8 LIFETIME 15
3.3.8.1 LLB Service Life 15
3.3.8.2 LLB Cycle Life 15
3.3.8.3 LLB Storage Life 16
3.3.8.4 LLB Refurbished Life 16
3.3.8.5 LLB Service Life with ALPS charging 16
3.3.8.6 Maximum LLB Usage Scenario 16
3.3.8.7 Most Probable LLB Usage Scenario 16
3.3.8.8 Lowest LLB Usage Scenario 16
3.3.8.9 HST Mission Type Scenario 16
3.3.9 SECURITY 16
3.3.10 SOFT GOODS 16
3.4 LOGISTICS 17
3.4.1 MAINTENANCE 17
3.4.1.1 On-Orbit Maintenance 17
3.4.1.2 Ground Maintenance 17
3.4.2 SUPPLY 17
3.4.3 SPARES 17

4.0 PREPARATION FOR DELIVERY 18

5.0 VERIFICATION OF REQUIREMENTS MATRIX 19

APPENDIX A 20

ACRONYMS AND ABBREVIATIONS 20

APPENDIX B 22

DEFINITION OF TERMS 22

1. INTRODUCTION

The purpose of this document is to define the contractually binding requirements between the Energy Systems Division sponsoring the build-up of this battery and the vendor providing a fully built Long Life Battery (LLB) that will power the Extravehicular Mobility Unit (EMU) suit. This document contains the requirements for the battery with respect to its performance, function, environment, interface, maintainability, reliability and safety.

1.1 SCOPE

This specification establishes the requirements for design, performance, and testing of the Li-ion battery for the Extravehicular Mobility Unity (EMU) system. The Battery consists of lithium-ion cells, protective devices (PTCs, thermostats, etc) and an electrical connector all retained in an aluminum case. The Battery provides electrical power to the EMU during EVA.

1.2 RESPONSIBILITY AND CHANGE AUTHORITY

The responsibility for the development of the LLB EIS lies with the Energy Systems Division.

2.0 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. If date or revision number is not identified, use latest version.

Document Number	Revision / Release Date	Document Title
JSC-29929	Basic/ May 2003	Project Technical Requirements Specification for the Lithium-ion Battery GFE for the EMU
SV819600/2	March 2000	Battery Assembly Drawing
MIL-STD-810	Rev E/July 1989	Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
SSP41172	Oct, 1999	Qualification and Acceptance Environmental Test Requirements
JPG 8080.5	April 1991	JSC Design and Procedure Standard
JSC 28322	Rev C/Sept 1999	International Space Station Acoustic Requirements and Testing Documents for ISS Non-Integrated Equipment
FED-STD-101	Rev C	Federal Standard of Test Procedures for Packaging Materials
SSP 30425	Rev B/Feb. 1994	Space Station Program Natural Environment Definition for Design
JSC-SL-E-0002	Book 3/Aug. 2001	Specification, Electromagnetic Interference Characteristics, Requirements for Equipment, for the Space Shuttle Vehicle
SVHS 7802	Rev G/July 2002	Space Shuttle Extravehicular Mobility Unit (EMU) System General Electrical Requirements
MJ070-0001-1	Rev E/ Nov. 2002	Orbiter Vehicle End Item (OVEI) Specification
SSP 50021	Sept 1996	Safety Requirements Document, International Space Station
NSTS 22206	Rev D/ Dec. 1993	Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)
NSTS-21000-IDD-ISS	Rev B/ Jan. 2000	ISS Interface Definition Document
JSC-27301	Rev D/ Feb. 2002	Materials Control Plan for Johnson Space Center (JSC) Flight Hardware
SOP-007.6	Rev A/ Dec. 2001	Material and Fracture Control Certification
NSTS 1700.7	Rev B/ Jan. 1989	Safety Policy And Requirements For Payloads Using The Space Transportation System - Electronics Control Unit (Ecu)

PRC-0009	Rev D/ Mar. 2004	Process Specification for the Resistance Spot Welding of Battery and Electronic Assemblies
MF0004-400	Rev F/ Sept. 2000	Electrical, Electronic and Electromechanical Orbiter Project Parts Requirements (OPPR)
MIL-STD-1580	Rev B/ Jan. 2003	Destructive Physical Analysis for Electronic, Electromagnetic and Electromechanical Parts for destructive physical analysis (DPA)
SSP 30312	Rev H/Mar. 2002	Electrical, Electronic and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program
MIL-W-22759	Rev E/ Dec. 1990	Wire, Electrical Fluoropolymer-insulated copper or copper Alloy
TM 102179	June 1991	Selection of Wires and Circuit Protective Devices for STS Orbiter Vehicle Payload Electrical Circuits
JSC 26626	Rev A/May 1995	EVA Hardware Generic Design Requirements
JSC-25863	Rev A/ Aug. 1998	Fracture Control Plan for JSC Flight Hardware
PRC-7002	Rev C/ Nov. 2000	Process Specification for the Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
PRC-7005	Rev B/ Nov. 2000	Process Specification for the Design of Rigid Printed Circuit Boards
IPC 6012	Rev A/ July 2000	Qualification and Performance Specification for Rigid Printed Boards
NASA-STD-8739.2	Aug. 1999	NASA Workmanship Standard for Surface Mount Technology
IPC J-STD-001	Rev C/ Mar. 2000	Requirements for Soldered Electrical and Electronic Assemblies
PRC-7001	Rev C/ Aug. 1999	Process Specification for the Soldering of Electrical Components
MIL-STD-1686	Rev C/ Oct. 1995	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment.
ANSI/ESD-S20.20-1999	Aug. 1999	Protection of Electrical and Electronic Parts, Assemblies and Equipment
PRC-7003	Rev C/ Aug. 1999	Process Specifications for the Manufacture of Electrical Cables, Wiring, and Harnesses
JSC SN-C-0005	Rev D/ July 1998	Contamination Control Requirements
SSP 30426	Rev D, Jan 1994	SSP External Contamination Control Requirement
JSC-20793	Sept. 1985 (New Rev. in Progress)	Manned Space Vehicle Battery Safety Handbook
SSP 50005	Rev B/ Nov. 1995	International Space Station Flight Crew Integration Standard (NASA-STD-3000/T)
PRC-9002	Rev C/ Mar 2002	Process Specification for Part Marking
DX3-03-02	April 2003	Battery Usage Scenarios
NPG-6000.1	Rev E/April 1999	Requirements for Packaging, Handling and Transportation for Aeronautical and Space Systems Equipment and Associated Components
ICD-4-0012-0C-1	Rev B, March 2005	EMU/Battery Interface Control Document
SSP 30420	Rev D/July 2002	Space Station Program Grounding Requirements
SSP 30245	Rev F/May 2002	Space Station Program Electrical Bonding Requirements

2.2 ORDER OF PRECEDENCE

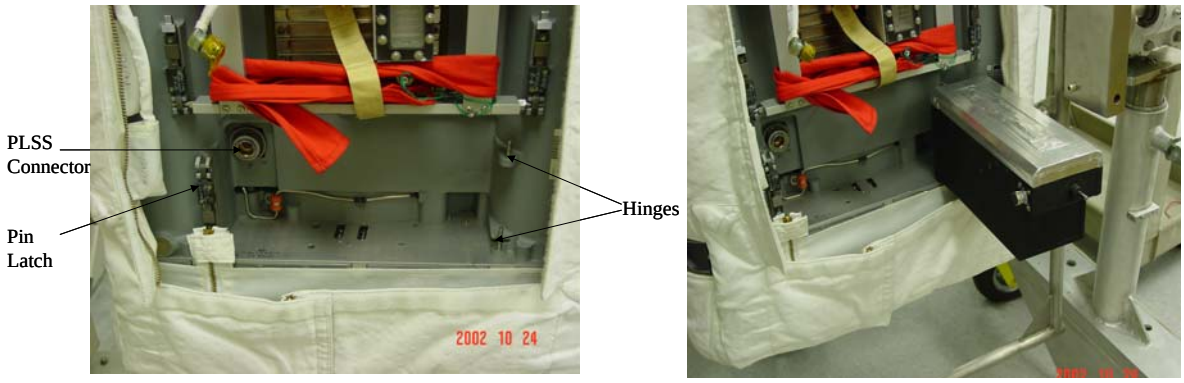
In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence. All specifications, standards, exhibits, drawings or other documents that are invoked as "applicable" in this specification are incorporated as cited. All documents that are referred to within an applicable document are considered to be for guidance and information only, with the exception of ICDs that will have their applicable documents considered to be incorporated as cited.

3.0 REQUIREMENTS

3.1 DEFINITION OF LITHIUM-ION BATTERY

3.1.1 LITHIUM-ION BATTERY DESCRIPTION

The Lithium-ion battery GFE for the EMU will power the EMU space suit. The EMU's portable life support system will draw power from the battery during the entire period of an EVA. Each battery assembly includes cells, wiring, structure, interface connections, and any other features necessary to meet the requirements of this specification. The diagram below (Figure 1), shows the pieces of the GFE in the EMU system and their major functional interfaces:



(a) **(b)**

Figure 1. The PLSS Interface

3.1.2 INTERFACE DESCRIPTION

3.1.2.1 LLB System Interfaces

The LLB has power, thermal, and mechanical interfaces to the EMU or more specifically, the Primary Life Support System (PLSS) of the EMU (Figure 1) as defined in ICD-4-0012-0C-1. These interfaces are the same as that which already exists for the Ag-Zn Increased Capacity Battery (ICB). However, when the EMU is connected to the Air Lock Power Supply (ALPS) charger (*aka* Dual Power Supply & Battery Charger), the battery is left in place in the EMU-PLSS to achieve the charge. Power may be transmitted from the ALPS through a dongle connected at its output, and then through the EMU to get to the LLB. The above-mentioned, electrical interfaces will be mated using the same LLB connector. The purpose of the dongle is to make the ALPS charger, which was designed for the ICB electrochemistry, automatically compatible with the LLB electrochemistry. Alternately, without a dongle, ALPS charge of an LLB will be terminated manually. The LLB has an additional connector to interface electrically with the LIB charger, which will be the preferred charge method.

3.1.2.1.1 Lithium-ion Battery and Charger Interface

The LLB shall have an electrical connector for interfacing to the LIB Charger and Ground Support Equipment (GSE) charger. It will be referred to herein as the J2 connector.

3.1.2.1.2 Interfaces with EMU

The LLB shall comply with all electrical, mechanical, and thermal interfaces specified in ICD-4-0012-0C-1. In the case ICD-4-0012-0C-1 conflicts with the requirements herein, the requirements herein shall take precedence.

3.2 CHARACTERISTICS OF LITHIUM-ION BATTERY

3.2.1 PHYSICAL REQUIREMENTS

3.2.1.1 Cell Chemistry

The Battery Assembly shall utilize a lithium-ion cell design. This is inclusive of Li-polymer designs sharing similar lithium-ion electrochemistry.

3.2.1.2 Envelope

The volumetric envelope of each battery shall be per the dimensions specified in ICD-4-0012-0C-1 unless specified otherwise herein. This volume includes cells, wiring, interface connections, and any other features necessary to meet the requirements of this specification.

3.2.1.3 Weight

The battery weight shall per ICD-4-0012-0C-1.

3.2.2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.2.2.1 Voltage Output

The LLB shall meet all requirements herein while operating within the output voltage of 21.0 to 16.0 Vdc.

3.2.2.2 Battery Capacity/Energy

3.2.2.2.1 Capacity/Energy for EVA Mode

The battery shall deliver a minimum capacity of 26.6 Ah to the EMU in seven continuous hours within the output voltage range indicated in 3.2.2.1 and in a temperature range of 3.2.3.8 throughout its service life as indicated in Section 3.3.8.1.

3.2.1.1.2 Capacity/Energy for BTA Mode

As per ICD-4-0012-0C-1, to support the Bends Treatment Adapter (BTA) mode, the LLB shall deliver a minimum capacity of 1.8 Ah at a rate of 7.5A continuous and within a voltage range of 21.0 to 16.0V and while in the airlock environment.

3.2.2.3 Continuity

The redundant leads of the PLSS connector shall have a designed resistance of less than 0.03 ohms to be verified at Cert and shall be checked at PDA and PIA to be less than 0.5 ohms.

3.2.2.4 Insulation Resistance

3.2.2.4.1 Electrical Isolation

The electrical isolation test shall be conducted at a voltage of 500 Vdc or at the maximum connector voltage, whichever is lower. The measured resistance shall not be lower than 10 Mega Ohms.

3.2.2.4.2 Dielectric Withstanding Voltage

The electrical isolation of internal cable assemblies and wire harness subassemblies shall be verified with a DWV (Dielectric Withstanding Voltage) test at a setting of 1.5K Vdc or highest voltage that the connectors can withstand. The maximum allowable current shall not be greater than 1.0 mA.

3.2.2.5 Peak Current

During its 7-hour EVA discharge, the LLB shall be capable of delivering transient power pulses specified in ICD-4-0012-0C-1, which are expected to occur upon start-up and once an hour thereafter during the 7 hour EVA while staying within the voltage range of 3.2.2.1. This pulse applies to both types of LLB connectors.

3.2.2.6 Storage State of Charge/Discharge

The LLB shall be supplied with a recommended depth-of-discharge that is compatible with its service life for storage during non-operational periods.

3.2.2.7 Charge Retention

The fully charged LLB shall be capable of retaining its charge and meeting its mission requirements for a period of at least 50 days without the need for additional top-off charging.

3.2.2.8 Charge Interruption

The LLB shall tolerate any user interruption in the charging process for up to two weeks total without incurring any permanent capacity loss over that expected with nominal storage and cycling capacity fade and nominal self-discharge.

3.2.2.9 Rest Time

a. The LLB shall not require a rest time between the end-of-charge and the beginning of discharge in order to meet the requirements herein.
b. After a discharge or an EVA, the LLB shall not require a rest time longer than that required for the temperature to comply within the range of 10 ºC to 35 ºC, before initiating a charge or a discharge.

3.2.2.10 Maximum Charge Rate

3.2.2.10.1 J1 Connector

The LLB shall be capable of achieving full charge within 24 hours when charged through the PLSS J1 connector.

3.2.2.10.2 J2 Connector

The LLB shall be capable of achieving full charge within 8 hours when charged through the J2 connector.

3.2.2.11 Thermal Sensing Capability

a. The LLB shall have the capability for internal thermal sensing with an accuracy of ± 3 ºC within the 10 to 50 ºC temperature range.

b. This sensor shall be used for the LIB Charger and GSE charge/discharge control and be terminated at the J2 connector using two or fewer pins.

3.2.2.12 Venting

The Battery Assembly shall have two credible failure tolerance to cell venting. Credible failures exclude internal shorts due to crushing and thermal runaway conditions due to external heating above 100 ºC.

3.2.2.13 Power Consumption

Not applicable.

3.2.2.14 Existing Charger Compatibility

The LLB shall be capable of being recharged with the ALPS charger on the Shuttle while still meeting all other requirements herein.

3.2.3 ENVIRONMENTAL REQUIREMENTS

All environmental test tolerances shall comply with SSP 41172. Test criteria not defined herein or SSP 41172 are up to the Contractor to establish. In case of conflict between criteria defined herein and that defined in SSP 41172, the criteria defined herein shall take precedence.

3.2.3.1 Humidity

3.2.3.1.1 Ground Handling & Transportation

The LLB, packaged for shipping, shall be capable of operating after exposure to the humidity environment of MIL-STD-810E, Method 507.3 Procedure I, with relative humidity range of 0 to 100%, dry bulb temperature range of 21 to 38 ºC and ten 24-hour temperature cycles.

3.2.3.1.2 Ground Storage & Test

The LLB shall be stored and tested in a controlled environment with humidity within the following range: 22 % relative humidity at 26.7 ºC dry bulb; 85% relative humidity at 18.3 ºC dry bulb.

3.2.3.1.3 Flight Vehicle Storage

The LLB shall be capable of operating during and after exposure to the vehicle humidity levels, which are controlled within the following limits: Maximum: 85% relative humidity at 17 ºC dry bulb; Minimum: 17% relative humidity at 32 ºC dry bulb.

3.2.3.2 Random Vibration

3.2.3.2.1 Qualification Vibration for Flight Vehicle Storage (EMU and Locker Stowed Items)

The LLB shall be capable of operating, after exposure to the following qualification vibration requirement. The input shall be applied to a rigid vibration fixture that shall hard mount the LLB using its interface mounting points to simulate the PLSS interface.

20 to 150 Hz	Increase + 6 db/oct
150 to 1000 Hz	Constant 0.03 g^2/Hz
1,000 to 2,000 Hz	Decrease - 6 db/oct.

Duration: 7.5 + 10%/-0% minutes/axis (15 Launches)

3.2.3.2.2 Acceptance Vibration for Flight Vehicle Storage (EMU and Locker Stowed Items)

The LLB shall be capable of operating after exposure to the following acceptance vibration requirement. The input shall be applied to a rigid vibration fixture that shall hard mount the LLB using its interface mounting points to simulate the PLSS interface..

For EMU and locker storage, the locker shall be subjected to an acceptance vibration input of:

20 to 80 Hz	Increase +3 db/oct.

80 to 350 Hz	Constant 0.04 g^2/Hz
350 to 2000 Hz	Decrease - 3 db/oct

Duration: 1 + 10%/-0% minutes/axis

3.2.3.2.3 Qualification Acceptance Vibration.

To qualify the vibration acceptance level, a qualification LLB shall be capable of operating after exposure to the following:

20 to 80 Hz	Increase + 3 db/oct.
80 to 1000 Hz	Constant 0.113 g^2/Hz
1000 to 2000 Hz	Decrease - 3 db/oct

Duration: 5 + 10%/-0% minutes/axis.

The LLB does not have to be fastened to a vibration fixture by its PLSS interface mounting points for this environment.

3.2.3.3 Sinusoidal Vibration

3.2.3.3.1 Flight Vehicle Storage

The LLB shall be capable of satisfying performance requirements after exposure to a sinusoidal vibration environment imposed in three (3) orthogonal axes in the frequency range of 5 to 35 Hertz at an acceleration amplitude of ± 0.25g peak. Duration is controlled by a one octave per minute sweep rate. The LLB shall not be required to operate during this environment. The LLB shall be tested at the component level the following vibration requirements shall be 0.25g peak from 5 to 10 Hz, 0.40 g @ 15 Hz, and 0.50g, @ 35 Hz.

3.2.3.4 Acoustics

The LLB shall comply with the Acoustic Noise Criteria in JPG 8080.5, Standard G-41 and JSC 28322, Standard NC40.

3.2.3.5 Acceleration

The LLB shall be capable of satisfying its performance requirements while operating in a zero-g environment.

3.2.3.6 Shock

3.2.3.6.1 Ground Transportation

The LLB packaged and not operating shall be unaffected by exposure to the shock environment of FED-STD-101C, Method 5019 and Method 5007.

3.2.3.6.2 Ground Handling & Test

The LLB unpackaged and non-operating shall not be affected by the Bench Shock environment of MIL-STD-810E, Method 516.4, Procedure VI. The LLB may use protective guards that are normally used as ground handling equipment to prevent damage to local protrusions such as controls, latches, etc.

3.2.3.6.3 Flight Vehicle Landing

The LLB shall be capable of satisfying its performance requirements after exposure to the landing shocks specified below. The shock accelerations are rectangular pulses with peaks as indicated below and applied at a rigid vibration fixture that shall hard mount the LLB using its interface mounting points to simulate the PLSS interface. The LLB shall be unpackaged, non-operating during this environment.

Acceleration (g Peak)	Duration (msec)	Application
0.23	170	27
0.28	280	37
0.35	330	32
0.43	360	20
0.56	350	9
0.72	320	4
1.5	260	1
	Total	130

3.2.3.6.4 Design Shock

The LLB shall be capable of operating in accordance with this specification after application of a shock per MIL-STD-810E, Method 516.4, Procedure 1, as modified below has been applied in each direction of each axis:

a) 20.0 ± 2.0g, shock

b) 11 ± 1 millisecond sawtooth pulse,

c) Shock shall be applied to a rigid vibration fixture that shall hard mount the LLB using its interface mounting points to simulate the PLSS interface.

3.2.3.7 Pressure

3.2.3.7.1 Ground Handling & Transportation

The LLB shall be unaffected by exposure to atmosphere pressures ranging from 3.28 to 15.23 psia. The LLB shall be packaged during exposure to this environment.

3.2.3.7.2 Ground Storage and Test

The LLB shall be capable of satisfying its performance requirements after being stored, unpackaged, in a controlled environment with ambient pressure variations of 0.1 to 16.23 psia.

3.2.3.7.3 Flight Vehicle Storage

During flight vehicle storage, the LLB shall be exposed to a controlled environment with ambient pressure variations of 0 to 18.76 psia. For verification purposes vacuum is defined as $< 1 \times 10^{-4}$ torr.

3.2.3.7.4 Operation Within the Flight Vehicle

The LLB shall be capable of operating with ambient pressures of 0 to 18.76 psia. For verification purposes vacuum is defined as $< 1 \times 10^{-4}$ torr.

3.2.3.7.5 Extravehicular Operation

The LLB shall be capable of operating within the requirements of this specification with ambient pressures of $< 1 \times 10^{-4}$ torr.

3.2.3.7.6 Pressurization Rate

The LLB shall be capable of satisfying its performance requirements after undergoing a maximum pressurization rate of 0.76 psia per second and a depressurization rate of –1.94 psia per second.

3.2.3.8 Temperature

3.2.3.8.1 Transportation

The LLB shall be capable of being transported safely and remain operational after exposure to the following conditions while packaged for transportation.

a) Temperature soak at 18 ºC then minus 54 ºC for 2 1/2 hours.
b) Temperature soak at 32 ºC then 65.5 ºC for 6 hours.
c) Temperature soak at 32 ºC then 88 ºC for 1 hour.

The LLB may have its normal charge during this exposure.

3.2.3.8.2 Ground Storage & Test

The LLB shall be capable of being stored and be operational after storage in the temperature range of –20 to 25 ºC.

3.2.3.8.3 Transport to and Return from Orbit

a. The LLB shall be capable of being stored for orbital transfer while fully charged in an environment of 10 to 32 ºC.
b. The LLB shall be capable of being stored for orbital transfer while fully discharged and in an environment of 10 to 45 ºC. This environment will occur for a maximum of 30 days per service life.

3.2.3.8.4 LLB EVA Operation

The LLB shall meet all requirements here-in while exposed to the pre-EVA, EVA, and post-EVA thermal environments specified in paragraph 5.2.3 of ICD-4-0012-0C-1.

3.2.3.8.5 LLB IVA Operation and Storage

The LLB shall be capable of operation and storage per the requirements herein while in a cabin environmental temperature of 10 to 32 ºC and while within the in-cabin pressure range specified in Section 3.2.3.7.

3.2.3.8.6 LLB Maximum Heat Generation

The LLB shall not generate more than 10 W average of heat during discharge or charge operations inside the EMU-PLSS.

3.2.3.9 Micrometeroids and Orbital Debris

3.2.3.9.1 Shuttle-Based EVA (Non-Space Station Support)

The LLB, when integrated in the EMU shall be capable of operating in accordance with this specification after being exposed to the meteoroid environment representative of the meteroid model which encompasses particles of cometary origin in the mass range between 1 and 10^{-12} grams for sporadic meteoroids and 1 to 10^{-6} grams for stream meteoroids.

Average Total Environment:

Particle Density	$0.5 g/cm^3$
Particle Velocity	20 km/sec.

Flux Mass Models

(1) For $10^{-6} < m < 1$, Log Nt = -14.37 - 1.213 log m
(2) For $10^{-12} < m < 10^{-6}$, Log Nt = -14.339 - 1.584 log m -0.063 $(\log m)^2$
Nt = no. of particles/m2/sec. of mass m or greater (m = mass in grams)
Defocusing factor for earth, and if applicable, shielding factor are to be applied.

3.2.3.9.2 Shuttle-Based EVA (Space Station Support) and Space Station EVA

The probability of no penetration of the LLB shall equal or exceed 0.91 cumulative risk while supporting 2700 hours of 2-person EVA over a ten year period in the MMOD environment specified in SSP 30425.

3.2.3.10 Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC)

The LLB, when operating as part of the EMU, shall satisfy the requirements of JSC-SL-E-0002, Book 3 Volume 1, Dated August 10, 2001.

3.2.3.11 Ionizing Radiation

a. The LLB EEE parts shall meet the requirement herein after exposure to ionizing radiation environment as defined in MJ070-0001-1E, Orbiter Vehicle End Item Specification, Revision D (with change notices 1-49, and SCN 01-1003), Paragraph 3.5.20, while using creme96 in place of creme86 as specified in MJ070-0001-1E, paragraph 10.1.7.5.

b. The LLB shall have a Mean Time Between Failure (MTBF) of 5 years or greater, for all SEE effects, other than latches, that can cause an erroneous nominal indication of the battery state of charge when evaluated via the methodology of Section 3.5.20 of MJ070-0001-1E, Orbiter Vehicle End Item Specification for the Space Shuttle System.

c. The battery EEE parts shall exhibit no destructive latches and/or non-destructive latches when exposed to a minimum of 200 MeV (+/- 10 MeV) protons to a fluence of $1E^{10}$ protons/cm^2 or to heavy ions with an effective Linear Energy Transfer (LET) of 14 MeV//mg/cm^2 to a fluence of $1E^6$ ions/cm^2.

3.2.3.12 Orientation Sensitivity

The LLB shall meet all requirements herein while being stored and operated in any orientation on the ground and on orbit during its service life.

3.2.3.13 ESD Susceptibility

The LLB shall be immune to upset or damage by a human-body-model discharge of 4,000 volts at any point (IEC 61000-4-2 level 2). Furthermore, the hardware in its normal installed or shipping configuration shall be immune to upset or damage by a human-body-model discharge less than 15,000 volts at any point (IEC 61000-4-2 level 4).

3.2.3.14 Magnetic Field Susceptibility

The LLB shall operate without degradation or malfunction from nominal performance beyond its operational specification when exposed to static DC magnetic fields and sources with field strength of up to 600 gauss.

3.2.3.15 Conducted Emissions Into Load

The LLB shall not exceed the conducted emission limits of SVHS 7802 (“all other equipment” level given in Figures 4 and 6 of that document) when connected to the EMU or equivalent load. The emissions shall be measured on the output of the battery. This requirement does not apply to any connections inside the battery or to the connection between the LLB and LIB charger.

3.2.4 RELIABILITY

3.2.4.1 Failure Tolerance

The simplicity of the LLB design dictates that it shall be zero-fault tolerant in the event of a short to ground as far as meeting all performance requirements herein are concerned.

3.2.4.2 Failure Propagation

A single failure of the LLB shall not induce any other failures on the LIB charger.

3.2.4.3 Failure Detection, Isolation and Recovery (FDIR)

a. The FDIR requirement, per JSC 29927, is that the GSE shall be able to perform a health check of the battery to determine if any one (or more) cells in the LLB is (are) not contributing capacity.
b. The FDIR requirement also states that project flight hardware and GSE shall be consistent with the Safety Requirements Document, SSP 50021, Section 3.2.4.

3.2.4.4 Cell Acceptance and Lot Certification

All cells fabricated or purchased for assembly into LLBs shall undergo 100% acceptance screening. Accepted cells from the same lot shall be randomly sampled and destructively tested for the purposes of certification.

3.2.5 MAINTAINABILITY

The LLB shall be refurbished at a frequency consistent with its service life as defined in section 3.3.8.

3.2.6 TRANSPORTABILITY

Commercial or government carriers shall be able to transport the LLB with their adherence to the conditions in Section 4 “Preparation for Delivery” and compliance with all DOT regulations for lithium batteries.

3.3 DESIGN AND CONSTRUCTION

3.3.1 MATERIALS, PARTS AND PROCESSES

3.3.1.1 Materials and Processes

a. Materials and processes for flight hardware shall meet the requirements of SSP 30233F, “Space Station Requirements for Materials and Processes,” as implemented by JSC 27301D, “Material Control Plan for JSC Flight Hardware.”

b. The JSC/ES4 Materials and Processes Branch shall review and approve all materials for this hardware and provide a materials certification prior to flight (per ES SOP-007.6 Material and Fracture Control Certification). Materials Usage Agreements (MUAs) will be provided only as needed.

c. The project shall utilize the standard JSC inspection and bonded stores practices for parts handling and control.

d. All Commercial-Off-The-Shelf (COTS) hardware that cannot provide material certifications, traceable parts, or workmanship processes shall be evaluated by further testing that shall be used to supplement the acceptance testing for that hardware.

e. Materials exposed to electrolyte shall be evaluated or tested for compatibility and shall meet the fluid compatibility requirement of NSTS 1700.7B, paragraph 209.1A.

f. All battery spot welds shall comply with PRC-0009, Specification for Resistive Spot Welding of Battery and Electronics Assemblies.

3.3.1.2 Electrical, Electronic and Electromechanical (EEE) Parts

EEE parts are individual electrical, electronic, and electromechanical piece parts (active and passive) such as relays, transistors, resistors, diodes, fuses, connectors, etc.

a. High-reliability electronic parts shall be used where possible and practical.
b. Detailed schematics and parts lists shall be prepared/supplied.
c. EEE parts for flight hardware, except for the lithium ion cells of the battery, shall be selected in accordance with MF0004-400, Electrical, Electronic, and Electromechanical Orbiter Project Parts Requirement (OPPR), Revision F.

3.3.1.2.1 Failure Analysis

a. Piece part level failure analysis shall be performed on the second or subsequent failure of any EEE parts that are in hardware classified with a criticality of 2/2, 1R2, 1R3 (as defined by NSTS 22206) or could cause a scrub/abort of an EVA.
b. The LLB contractor shall perform piece part level failure analysis on every failure to gain a full understanding of the failure mechanisms.

3.3.1.2.2 Destructive Physical Analysis

a. The LLB contractor shall meet the requirements of MIL-STD-1580, Destructive Physical Analysis for Electronic, Electromagnetic and Electromechanical Parts for destructive physical analysis (DPA).
b. A sample from each first production lot date code or first procured lot date code for all part types to be used in flight equipment shall be subjected to DPA to assure that the internal construction and packaging are of high quality. Subsequent lots may require DPA where there is reason to suspect marginal quality or process/design change(s).

3.3.1.2.3 EEE Parts Derating

The LLB EEE part electrical and thermal derating shall be in accordance with Appendix B - EEE Parts Stress Derating Criteria of SSP30312, Electrical, Electronic, and Electromechanical and Mechanical Parts Management and Implementation Plan for Space Station Program, Rev H.

3.3.1.2.4 Wire Selection and Derating

All wires selected for the LLB project hardware shall be procured and inspected per MIL-W-22759. All wire size selection shall comply with the derating process defined by NASA TM 102179, figures 4 and/or 5.

3.3.2 STRUCTURAL DESIGN

3.3.2.1 Fracture Control

The LLB shall comply with the requirements of JSC 26626A section 3.3 and JSC 25863A “Fracture Control Plan for JSC Flight Hardware.” The LLB box shall not be designed to contain the contents of bursting/exploding cells. The LLB shall be designed such that no two credible failures will cause a cell to burst/explode. However, the LLB box shall trap all liquids that could leak from up to 2 cells and allow vapors to escape.

3.3.2.2 Cell Vent/ Burst Ratio

If the cell design includes a vent, the LLB shall possess a Vent/Burst Ratio greater than 1:1.5. If the cell's ratio is greater than 1:2.5, then the rigors of the fracture control process specified in JSC-25863 do not apply.

3.3.2.3 Structural Safety Factor

The LLB shall maintain a minimum structural safety factor of 2.0 and an ultimate strength and 1.5 against yield strength.

3.3.2.4 Point / Kick Load

The LLB shall withstand a push-off load of 125 lbs acting over a 4x4 square-inch area.

3.3.2.5 Collapse Pressure

The LLB shall withstand the collapse pressure of 14.7 psid and meet all safety requirements in 3.3.6.

3.3.3 ELECTRICAL DESIGN

The LLB shall comply with the electrical requirements of JSC 26626A Section 3.4.

3.3.3.1 LLB Electrical Isolation

The LLB shall be designed to electrically isolate the case from all internal electrical circuits.

3.3.3.2 Connectors

3.3.3.2.1 Connector Design

a. Connector designs of the project flight hardware shall comply with standards E-1, E-4, E-5, E-11, E-12, and E-21 in JPG 8080.5.
b. All types of IVA and EVA connectors as per the SSP 50005, shall comply with the following requirement of the space between connectors and adjacent obstructions with a minimum of 25.0 mm (1.0 in.) for IVA and 40.6 mm (1.6 in.) for EVA access.
c. The LLB J2 connector shall be of the “quick-disconnect” design.

3.3.3.2.2 Energized Conductors: PLSS (J1)

The current Increased Capacity Battery (ICB) interfaces with the PLSS with a blind mate connector, which is mated and demated with powered pins. The LLB shall have the same interface with the PLSS (as described in Section 3.1.2.1) and will also mate and demate with the PLSS with powered pins (on the LLB side). Note that in order to comply with JPG 8080.5 requirements to avoid mating and demating high power contacts, the EMU will be verified to be turned off prior to each mate/demate operation.

3.3.3.2.3 Energized Conductors: LLB (J1 and J2)

The LLB design shall prevent inadvertent human contact with energized conductors.

3.3.3.2.4 J2 Connector Shrouding.

The J2 connector shall employ design features that completely enclose or shroud the pins and sockets during making/breaking of electrical contacts.

3.3.3.2.5 J2 Connector contacts

The J2 connector shall use socket contacts.

3.3.3.2.6 J1 Current Limiting

The LLB shall respond t a hard short (< 10 milliohms) by reducing short circuit current in J1 to less than 20A within 0.5 seconds.

3.3.3.2.7 J2 Current Limiting

The LLB shall have a current limiting feature that limits short circuit current in J2 to less than 20 amps within 0.5 seconds.

3.3.3.3 Electromagnetic Interference Free Design

The LLB case shall be designed and fabricated to form an electrically continuous enclosure in accordance with SVHS 7802 Section 3.3.2.2.5.1.

3.3.3.4 Grounding

The LLB shall meet all space station grounding requirements per SSP 30240. When the LLB is being charged by the LIB charger, there shall be a safety ground connection between the charger and the case of the LLB to allow a safe path for any fault currents.

3.3.3.5 Electrical Bonding

The LLB and LIB charger shall meet all space station electrical bonding requirements per SSP 30245.

3.3.4 WORKMANSHIP

The LLB shall comply with the workmanship requirements of JSC 26626A Section 3.2.4.

3.3.4.1 Printed Boards

The LLB shall be assembled to be compliant with PRC-7002 Rev C "Process Specification for the Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies" and PRC-7005 Rev B "Process Specification for the Design of Rigid Printed Circuit Boards" or IPC6012A, "Qualification and Performance Specification for Rigid Printed Boards" and associated IPC standards to Class 3 requirements".

3.3.4.2 Surface Mount Technology

The LLB shall be assembled to be compliant with NASA-STD-8739.2 NASA Workmanship Standard for Surface Mount Technology or IPC J-STD-001C, "Requirements for Soldered Electrical and Electronic Assemblies", Class 3 and associated IPC standards.

3.3.4.3 Soldered Electrical Connections

The LLB shall be assembled to be compliant with PRC-7001 Rev C "Process Specification for Soldering of Electrical Components" or IPC J-STD-001C, "Requirements for Soldered Electrical and Electronic Assemblies", Class 3 and associated IPC standards.

3.3.4.4 Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)

The LLB shall be assembled to be compliant with MIL-STD 1686C "ESD Control Program for Protection of Electrical & Electronic Parts" or ANSI/ESD S20.20-1999 "ESD Control Program for Protection of Electrical & Electronic Parts, Assemblies and Equipment".

3.3.4.5 Electrical Cables, Wiring and Harnesses

The LLB shall be constructed in accordance with PRC-7003 Rev C "Process Specification for the Manufacture of Electrical Cables, Wiring, and Harnesses.

3.3.4.6 Contamination

Contamination control plans developed and implemented for the project hardware shall be per JSC SN-C-0005D.

3.3.4.7 Cleanliness

Prior to delivery to JSC and shipment for Space Shuttle or Space Station integration, the exterior surfaces of project hardware shall be cleaned to the visibly clean sensitivity level as per SSP 30426.

3.3.5 INTERCHANGEABILITY/REPLACEABILITY

The battery shall be replaceable in the EMU by an unassisted crewperson without the use of tools in 5 minutes.

3.3.6 SAFETY

3.3.6.1 Design

The LLB design shall comply with battery safety requirements of JSC 20793, Manned Space Vehicle Battery Safety Handbook.

3.3.6.2 Redundancy

The LLB shall comply with the requirements of SSP-50021, Safety Requirements Document, which requires two-fault tolerance for catastrophic hazard and one-fault tolerance to a critical hazard.

3.3.6.3 Fault Current

The maximum fault current that the LLB shall sustain continuously without tripping its overcurrent protection is 13.0 A.

3.3.7 HUMAN ENGINEERING

The LLB shall comply with the workmanship requirement of SSP 50005.

3.3.7.1 Touch Temperature

The LLB external surfaces shall be designed not to exceed 45°C.

3.3.7.2 Nameplates and Product Marking

The LLB shall use identification and marking containing part number and serial number in accordance with PRC-9002 Process Specification for Part Marking.

3.3.8 LIFETIME

3.3.8.1 LLB Service Life

a. The service life of the LLB shall be 5 years minimum. This means that the LLB must meet all the requirements herein without refurbishment during its entire service life. The beginning of service life is defined as the completion date of the Pre-Delivery Acceptance (PDA) of the LLB.
b. Within the duration of its service life, the LLB shall tolerate storage at 100% SoC (State-of-Charge) at 10°C to 32°C for up to 600 days over five years.
c. During all other storage times, the LLB shall be stored at a vendor-recommended DoD (Depth of Discharge) and at a temperature range of 10°C to 32°C.
d. Calendar life is defined as starting at cell activation and ending at the end of the service life. If cell design configuration control is not implemented, then the service life shall be capable of being interrupted by a storage period of up to 5 years as specified in 3.3.8.3.

3.3.8.2 LLB Cycle Life

a. The cycle life of the LLB shall support the completion of up to 100 EVAs during each service life.
b. LLB charge shall be accomplished by the LIB Charger.
c. Each cycle shall consist of a complete charge on the LIB charger followed by the EVA discharge profile and/or discharged via the battery charger in the event of mission scrub or short EVA.
d. On the 100th EVA mission, the battery shall meet the capacity requirement in Section 3.2.2.2.

3.3.8.3 LLB Storage Life

If cell design configuration control is not implemented, the LLB shall be capable of meeting all service life requirements specified herein following a period of storage of up to 5 years when stored at a vendor specified state of charge and temperature down to but not below –20°C.

3.3.8.4 LLB Refurbished Life

a. The LLB shall be capable of being refurbished up to 4 times before requiring total replacement in order to provide another service life according to 3.3.8.1.
b. At minimum, refurbishment shall replace all cells within the LLB to allow it to provide a subsequent service life according to 3.3.8.1.

3.3.8.5 LLB Service Life with ALPS charging

The service life of the LLB shall be unaffected by using the ALPS charger to recharge the LLBs provided a Charge Adapter Cable (Dongle) is used to terminate the charge at the proper voltage. Alternatively, this requirement can be met by relying on the crew to manually terminate the ALPS charge prematurely.

3.3.8.6 Maximum LLB Usage Scenario

The 5-year LLB service life shall be compatible with a maximum usage scenario, derived from JSC memo DX3-03-02, consisting of 30 charge/rest/discharge cycles evenly spaced throughout the year (the even spacing simulates a worse case condition). As per the maintenance requirement 3.4.1, the worst case also assumes that only one charge per year can be performed with the LIB charger.

3.3.8.7 Most Probable LLB Usage Scenario

The 5-year LLB service life shall be compatible with an average usage scenario consisting of 4 charge/rest/discharge cycles evenly spaced throughout the year. As per the maintenance requirement 3.4.1, the worst case assumes that only one charge per year can be performed with the LIB charger.

3.3.8.8 Lowest LLB Usage Scenario

The 5-year LLB service life shall be compatible with a lowest usage scenario, derived from JSC memo DX3-03-02, consisting of 2 charge/rest/discharge cycles evenly spaced throughout the year. As per the maintenance requirement 3.4.1, the worst case assumes that only one charge per year can be performed with the LIB charger.

3.3.8.9 HST Mission Type Scenario

The LLB shall be capable of meeting HST mission type scenarios in which 5 EVAs are performed in 5 consecutive days using the same batteries on alternating days. This requirement does not add to the cycle life requirement (3.3.8.2) of the battery.

3.3.9 SECURITY

Not applicable.

3.3.10 SOFT GOODS

The design and workmanship of soft goods in the LLB (for example, the Velcro straps) shall comply with the requirements of section 3.5 of JSC 26626A.

3.4 LOGISTICS

3.4.1 MAINTENANCE

3.4.1.1 On-Orbit Maintenance

On-orbit, the LLB will be charged with the LIB charger and ALPS charger while on Shuttle and with only the LIB Charger while on Station. The LLB will be maintained at the proper state-of-charge consistent with the lifetime requirements of Section 3.3.8. This may be achieved with the discharge function of the LIB charger.

a. If the LIB charger provides a cell-balancing feature to the LLB, its use shall not be required more frequently than once a year for the LLB to meet its lifetime requirements.

b. The service life of the LLB shall be compatible with this maintenance frequency.

3.4.1.2 Ground Maintenance

While on the ground and for mission turnaround processes,

a. The LLB shall undergo visual, dimensional, weight, insulation resistance, grounding, and bonding tests.

b. The LLB shall undergo charge and discharge capacity and power performance checks with the GSE.

3.4.2 SUPPLY

Not applicable.

3.4.3 SPARES

There shall not be any spare fabricated units for the LLB project hardware.

4.0 PREPARATION FOR DELIVERY

Cleaning, preservation, packaging, handling, storage, and shipping of the LLB hardware shall be in accordance with NPG 6000.1E, "Requirements for Packaging, Handling, and Transportation for Aeronautical and Space System Equipment and Associated Components." Shipping personnel shall be aware that these requirements must be followed and the hardware must be protected from handling and transportation damage as well as exposure to natural environments that could cause harm.

5.0 VERIFICATION OF REQUIREMENTS MATRIX

The seller's verification program shall satisfy the performance and design verification requirements for the requirements in Section 3.0. As per the Statement of Work, the seller shall propose a suitable approach to requirement verification.

APPENDIX A

ACRONYMS and ABBREVIATIONS

ALPS	Air Lock Power Supply
ANSI	American National Standard Institute
CDR	Critical Design Review
CIL	Critical Items List
COTS	Commercial-Off-The-Shelf
dc	Direct Current
DoT	Department of Transportation
DPA	Destructive Physical Analysis
DWV	Dielectric Withstanding Voltage
EA	Engineering Directorate
EDCPAP	Engineering Directorate Certified Parts Approval Process
EIS	End Item Specification
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EEE	Electrical, Electronic, and Electromechanical
ESD	Electrostatic Discharge
EVA	Extravehicular Activity
FMEA	Failure Modes and Effects Analysis
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
ICB	Increased Capacity Battery
ICD	Interface Control Document
ISS	International Space Station
IVA	Intravehicular Activity
JHB	JSC Handbook
JPG	JSC Support Contractor Procedures and Guidelines
JSC	Johnson Space Center
LIB	Lithium-ion Battery
MIL-STD	Military Standard
MOD	Mission Operations Directorate
MMOD	MicroMeteroids and Orbital Debris
MPLM	Multi-Purpose Logistics Module
MTBF	Mean Time Between Failures
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NPG	NASA Procedures and Guidelines
NSTS	National Space Transportation System
OPPR	Orbiter Project Parts Requirement
PDA	Pre-Delivery Acceptance
PIA	Pre-Installation Acceptance
PLSS	Primary Life Support System
SOC	State-of-charge
SPCE	Service and Performance Checkout Equipment
S&MA	Safety and Mission Assurance

SR&QA	Safety, Reliability, and Quality Assurance
SS	Space Shuttle
SSP	Space Station Program

APPENDIX B

DEFINITION OF TERMS

Adiabatic discharge:	Discharge with no heat exchange with the environment. None of the thermal energy created leaves the unit.
Capacity:	The maximum amount of electrical charge (current integrated over time) that the battery can usefully provide.
Current shunt:	A low value series resistor meant to monitor current flow.
Cycling capacity fade:	Reduction in the maximum charge recoverable from the battery due to repeated cycling. This can be thought of as the battery having been “worn-out” by the cycling.
Derating:	This refers to rating a component at a higher level than that required by the application. For instance, a 100V capacitor might be used in a 25V application.
Internal resistance:	The effective internal resistance of the battery as determined by the magnitude of the change in the battery voltage when the battery current is changed by a certain amount.
Open circuit voltage:	This is the voltage on the battery when there is no significant load on it.
Refurbishment:	Replacing portions of the battery that may have worn out or have limited life.
Self-discharge:	The loss of usable energy from the battery due to internal chemical changes and any internal circuitry in the battery. The loss due to self-discharge is partially recoverable.
State-of-charge:	This is the amount of electrical charge (current integrated over time) that the battery has in its current state. When this term is a percentage, it is the ratio of the amount that the battery has in its present state over the maximum amount that the battery could produce if fully charged.
Temperature soak:	This refers to allowing an item to remain in a constant temperature environment until the item is at a uniform temperature.
Vent/Burst Ratio:	This is the ratio of the pressure at which the cell vents to the pressure at which the cell bursts (in the absence of the vent).
Zero state-of -charge:	The state of the battery when it cannot provide any more useful charge or energy.