W. W. Hansen Experimental Physics Laboratory
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Gravity Probe B Relativity Mission

EPS ADP Review – Final Issue Close Out

(Power Distribution Unit, Standard Power Regulation Unit, Batteries, Solar Arrays)

S0858, Rev. -

April 4, 2003

Close Out Certification

The EPS data package* has been reviewed by Stanford University. MSFC and the IRT have been requested to identify any flight risks from any review to the Stanford University review chairman. The chairman, having assessed all inputs received as of the review date of 4 April 2003, finds the EPS components reviewed acceptable for the GP-B flight mission contingent on the acceptable closure of the action items and acceptable system level testing.

* the following items were reviewed: Power Distribution Unit, Standard Power Regulation Unit, Batteries, Solar Arrays

ADP Review Chairman:

18 APR 03

Bill Bencze **Date**

GP-B Program Manager:

Gaylord Green 24 Apr 2003

Gaylord Green **Date**

Concurrence:

4/24/2003

Systems Engineering **Date**

Concurrence:

Apr. 21, 03

Quality Assurance **Date**

ITAR Assessment Performed

Tom Langenstein

4.25.03

ITAR Control Req'd? ☐ Yes ☒ No

EPS ADP Data Review (telecon) and Issues Resolution Meeting Minutes:

Location: Lockheed Martin, Building 255 Room OA235, 1 pm, April 4, 2003
Minutes prepared by: Steve Young

References:

LM EM SYS 277, Response to MSFC issues for SPRU, PDU, Battery and SSR, Rich Whelan, March 27, 2003
[note: references are ITAR / U.S. Export Controlled documents]

Attendees:

MSFC: ..... Charlie Dischinger, Ted Edge, Bill Feltner, Eric Folk
SU: ..... Bill Bencze, Dorrene Ross, Steve Young
LM: ..... Rich Whelan, Lim Mar, Shawky Shehata, Mike Sisley, Mike Miranda, Dave Steele

Background:

Acceptance Data Packages for all Spacecraft and Space Vehicle components were sent to Marshall Space Flight Center for review. MSFC responded with questions and issues raised by the ADPs. A series of Issue Resolution Meetings were scheduled to address those questions and achieve issue closure based on appropriate discussions, clarifications, or actions. The issue closure process began when several ATC component issues were addressed in January 2003. Meetings scheduled for March and April (2003) will address other subsystems and their components.

The April 4, 2003 meeting focused on the Electrical Power Subsystem (EPS), including the Power Distribution Unit (PDU), Standard Power Regulation Unit (SPRU), Batteries, and Solar Arrays.

Overview / Summary:

Review of the MSFC questions regarding the EPS ADP was divided into two sections. First, those issues not included in EM SYS 277 were discussed and brought to closure pending appropriate clarifications and/or provisions. All issues reviewed and further discussion regarding these items are included below. Next, the EPS component questions included in EM SYS 277 were discussed, all of which referenced the "Standard Questions" listed in the referenced document. No further discussion of these items is included in this document, as all issues contained in EM SYS 277 were closed as stated. Following closure of these items, there was a discussion of questions regarding the solar array component ADP which were not included in the original MSFC response. It was agreed that MSFC would send these questions to LM for review, issue resolutions would be drafted and returned to MSFC, and further discussion of these items would be scheduled if deemed necessary by the reviewers. Initial discussion and closure of these solar array questions is included below.

EPS Questions / Issues from MSFC:

ADP	Sybsystem	MSFC Reviewer	Findings/issues	Finding resolution
EPS	Power Distrib Unit	Feltner	Verify that a Certificate of Conformance/Compliance (C of C) is present and is signed.	See EM SYS 277
			Verify that all Mandatory Inspection Points (MIP's) have been performed/stamped.	See EM SYS 277
			Verify the presence of an as-built configuration list and audit it to the as design documentation.	See EM SYS 277
			Verify that all contractually required drawings are contained.	See EM SYS 277
			Verify that all drawings are approved and released.	See EM SYS 277
			Verify that all Acceptance Test Procedures (ATP) are performed, complete, approved, and accepted.	See EM SYS 277
			Audit ATPs for compliance of test results to ATP requirements/tolerances.	See EM SYS 277
			Verify that all redlines or test departures have been approved.	See EM SYS 277
			Verify that all required Inspection Reports are approved.	See EM SYS 277
			Verify that all Nonconformance Reports/MRBs are approved and closed.	See EM SYS 277
			Verify that all Deviation/Waiver's are approved and closed.	See EM SYS 277
			Verify that all Open Work/Deferred Work is documented.	See EM SYS 277
			Verify that all contractually required Historical Records/Log Books are contained.	See EM SYS 277
			Verify the presence of a Limited Life Items List.	See EM SYS 277
			Verify the presence of a Cleanliness Certificate	See EM SYS 277
			Verify that all Temporary Installed Items are listed.	See EM SYS 277
			Verify that all Loose Delivered Items are listed.	See EM SYS 277
			Verify that all Loose Delivered Items are listed.	See EM SYS 277
			PDU Specification Section 3.2.3.2.3 SPRU Input and Spacecraft Bus. his paragraph contains three requirements that are stated as "shalls". There is no attempt in the PDU test procedure to address the verification of the first requirement, that is, "shall be rugged in design". However, this "rugged design" is mentioned as mitigation for the Spacecraft power bus being a single point failure to the GP-B mission. The verification of the remaining two requirements are addressed in the test procedure and appear to be appropriate.	Ref: S. Shehata This issue was addressed by EM EPS 244 (see detailed description of "rugged design" verification below (1)) and EM EPS 249. CLOSED

	PDU		PDU Specification Section 3.2.1.5.1.1 Noise and Ripple. One additional requirement is discussed, noise and ripple on the PDU output. This is not an EPS flow down requirement as mapped out in the traceability section below in Problem 5, however it can affect the ability to make the small scale measurements necessary for the science of GP-B. The requirement states that the noise and ripple "shall not exceed 0.020V peak-to-peak". However the test limit called out in the test procedure is 0.050 Vp-p. In all cases the measured value is less than 50 mVp-p, but in several cases the measured value is above the 20 mVp-p. No explanation is given for why the ripple is tested to a value that is relaxed for the specified requirement. This verification can not be certified. While this requirement is not one the 33 flow down requirements to the PDU from the SCSE-12, it can have an impact on the error of the science measurements.	PDU Specification Rev. D states that the (correct) noise and ripple test limit is 0.050 Vp-p. Rev. E of this document incorrectly lists the limit as 0.020 Vp-p. A CCB has been issued to correct the specification document – Rev. F will reflect this correction. CLOSED
			There is a specification traceability problem. The PDU specification contains 33 paragraphs that contain one or more requirements that are flow-down EPS requirements from SCSE-12. This represents 33% of the known EPS Spacecraft requirements that flow down to the Spacecraft component (box) level. SCIT-01, Part 2 maps the PDU requirements to SCSE-12 Section 3.7.3 requirements. SCIT-01, Part 1 maps the SCSE-12 Section 3.7.3 EPS requirements to 802SE-12, Section 28, Design Practices. The 802SE Design Practices section contains no requirements. Further Discussion: Table 4.2.1-1 in the PDU specification and Table D-1 in the PDU test procedure contain the verification matrix and test verification matrix, respectfully. Only those EPS flow down requirements that are mapped by SCIT-01, Parts 1 and 2 and that are tested are discussed.	R. Whelan The process followed by the Spacecraft team was to flow down the requirements from higher level documents to the lower level component, then include all the 'derived' requirements that reflect normal or best aerospace practice. No additional document was written to capture the fact that derived requirements, as well as the directly flowed down requirements are contained in the specification. For system level requirements, LM either completed the verification, or assisted the vendor in completing the verification. CLOSED
			PDU Specification Section 3.2.1.1.1 Spacecraft Bus. This requirement calls for the distribution of the Spacecraft Bus within the PDU. It specifies test parameters and limits to be tested. The actual test called out in the Test Procedure uses different values than are listed in specification.	Ref: S. Shehata These test values are listed in the original PDU Acceptance Data Test Procedure (1079-ET-E07466) See Para. 3.5 and Table 3-4. -- testing was done to a higher level than spec. CLOSED
			PDU Specification Section 3.2.1.7 Power Consumption. This requirement specifies that the power consumption of PDU monitoring circuits will not exceed 7 W. The test called out in the Test Procedure (A.1) does not test this. The test performed compares the output of the monitoring circuits against an expected value. No power consumption measurements are taken. This requirement is not verified by this test.	Ref: S. Shehata PDU data package (Original / Supplement) Section A.1, Table A-1 measure the current drawn from the PDU instrumentation power supplies. CLOSED

	PDU		PDU Specification (LMMS P086883E) Paragraph 3.2.1.5.1.3; Scale Factor {CHANGE} is by each table. What does this mean?	Ref: S. Shehata The current sensor scale range was changed from (-40 to +20) amps to (-40 to +40) amps. (See PDU spec, Table 3.2.2.5-3) CLOSED
			Paragraph 3.2.1.2 Power Switching Functions are neither analyzed, tested, nor inspected. Why are they not tested?	Ref: S. Shehata Test results are shown in table A-1 & A-3 in the PDU Test Procedures (Original and Supplemental) CLOSED
			Paragraph 3.2.1.5 Analog Monitor is inspected only. Why is this not tested?	Ref: S. Shehata It is tested in original data package (Table 3-5). (See also Tables A-2, A-3, 3-3). (Table 3-3, in original data package). This question refers to a review of only the Supplemental Data Package CLOSED
			Paragraph 3.2.6.1.2 Relative Humidity is inspected only. Why is this not tested?	Ref S. Shehata By analysis only (material control / analysis). CLOSED
			Paragraph 3.3.2.3 Grounding are neither analyzed, tested, nor inspected. Why is this not at least inspected?	Ref S. Shehata Continuity measurements and Hi-pot testing is shown in Para. 3.2 of original data package. See Table 3-3 for results. CLOSED
			Spectrum Astro Data Package (1162-ED-E24760:P. 186 and succeeding pages: GSU shutdown testing was deemed as "Not Applicable". We noticed that in the original of this document, released in 1997 that this requirement was lined out. Why is that?	Dashes signify that there is no requirement. This is a command with no reading available; it configures the GSU (now GSS) enable / disable for the measurements that follow (Appendix A, Abbreviated Functional Testing). -- function was verified CLOSED
			Spectrum Astro Data Package (1162-ED-E24760: Paragraph 3.16 We noticed that during verification and validation versus the original document that Thermal Vacuum Testing was done, but was not done in the succeeding document: only thermal cycling was done. What was the reasoning behind that?	Ref S. Shehata Minimal rework was done. No TVAC was required for penalty test. CLOSED
			Spectrum Astro Data Package (1162-ED-E24760: Paragraph 3.19 No Burn-In was done. Why is that?	Ref: S. Shehata Burn-ins were performed after the first rework in May 1998 and the second rework in Apr 2001. EM EPS 226 describes how the burn-ins were performed. EM 226 (1st rework May 1989, Burn-in; 2nd rework: April 2001, Burn-in for FET circuits) CLOSED

	PDU		Spectrum Astro Data Package (1162-ED-E247605: P. 270 There was a Facility Power Loss, but we do not see any documented explanation as to how that effort was recovered.	Ref: S. Shehata No concerns since power was lost when chamber was going cold and the PDU is powered off. CLOSED
			Data package does not demonstrate compliance to requirements: 3.2.1.5.1.1 Noise and Ripple; 3.2.1.7 Power Consumption; 3.2.3.2.3 SPRU Input and Spacecraft Bus	Ref: S. Shehata This data is listed in the original ADP (Par. 3.4 Table 3-6, Table A-1, Table 3-1) CLOSED
EPS	Std. Pow. Regulation U.	Feltner	Verify that a Certificate of Conformance/Compliance (C of C) is present and is signed.	See EM SYS 277
			Verify that all Mandatory Inspection Points (MIP's) have been performed/stamped; some found, but no way to determine whether complete list.	See EM SYS 277
			Verify the presence of an as-built configuration list and audit it to the as design documentation.	See EM SYS 277
			Verify that all contractually required drawings are contained.	See EM SYS 277
			Verify that all drawings are approved and released.	See EM SYS 277
			Verify that all redlines or test departures have been approved.	See EM SYS 277
			Verify that all Nonconformance Reports/MRBs are approved and closed; some found, but no way to determine whether complete list.	See EM SYS 277
			Verify that all Deviations/Wavier's are approved and closed; some found, but no way to determine whether complete list.	See EM SYS 277
			Verify that all Open Work/Deferred Work is documented.	See EM SYS 277
			Verify that all contractually required Historical Records/Log Books are contained.	See EM SYS 277
			Verify the presence of a Limited Life Items List if required.	See EM SYS 277
			Verify the presence of a Cleanliness Certificate.	See EM SYS 277
			Verify that all Temporary Installed Items are listed. (If applicable)	See EM SYS 277
			Verify that all Loose Delivered Items are listed. (If applicable)	See EM SYS 277
			Verify the presence of an as-built EEE Parts List	See EM SYS 277
EPS	Batteries	Feltner	Verify that a Certificate of Conformance/Compliance (C of C) is present and is signed.	See EM SYS 277
			Verify that all Mandatory Inspection Points (MIP's) have been performed/stamped; some found, but no way to determine whether complete list.	See EM SYS 277
			Verify that all drawings are approved and released.	See EM SYS 277
			Audit ATPs for compliance of test results to ATP requirements/tolerances.	See EM SYS 277
			Verify that all required Inspection Reports are approved.	See EM SYS 277

	Batteries		Verify that all Deviations/Wavier's are approved and closed	See EM SYS 277
			Verify that all Open Work/Deferred Work is documented (Someopen from battery buyoff (Some open from battery buyoff)	See EM SYS 277
			Verify that all contractually required Historical Records/Log Books are contained.	See EM SYS 277
			Verify the presence of a Cleanliness Certificate	See EM SYS 277
			Verify that all Temporary Installed Items are listed. (If applicable)	See EM SYS 277
			Verify that all Loose Delivered Items are listed. (If applicable)	See EM SYS 277
			Outstanding open items from the Battery Buyoff Review at Eagle-Picher:Check EPT drawing mounting holes against LMMS battery pallet drawing. There was an Action Item sheet but no entry into the Action Item response block. This remains unverified.	Ref: S. Shehata All Action Items have been closed. The flight batteries have been mounted to the flight pallet. CLOSED
			Outstanding open items from the Battery Buyoff Review at Eagle-Picher:Research reliability prediction minimum 0.97 source. There was an Action Item sheet but no entry into the Action Item response block. LMMS responded with EM SYS 256 which did not give a clear answer. We were unable to link the raw reliability data and the final battery reliability number. We are now using in-house S&MA support to verify the battery reliability number.	Ref: S. Shehata All Action Items have been closed. Eagle-pilcher did not issue a reliability number for the batteries. EM SYS 256 was the only source. -- MSFC will conduct further review of battery reliability CLOSED
EPS	Solar Arrays	Feltner	No Certificate of Conformance/Compliance found	R. Whelan: Page 5 of 388 in file "GPB Data Package.PDF" contains certificate. CLOSED
			Verify the presence of an as-built configuration list and audit it to the as design documentation.	R. Whelan: Not required from Solar Array Center. Top Level As-Built in ADP. CLOSED
			Drawings not included in the data package; release status & completeness indeterminate.	R. Whelan: Substrate drawing 8A01310 has been delivered. Process of building up to final product is covered in build records. Top Assy drawing has proprietary process data . This drawing has been requested from the Solar Array Center and will be forwarded to MSFC. Solar Array Center has stated that page 2 of the drawing contains significant proprietary process information and will not be provided electronically. This page can be viewed in Sunnyvale by any MSFC GP-B visitor. CLOSED

	Solar Arrays		Illumination (flash) and isolation tests procedures and data are in the data package but are not identified as Acceptance Test Data; define ATPs	R. Whelan: Data in Data Package is Acceptance Data. CLOSED
			Discrepancy Report List is in Package; completeness and status of deviations & waivers is indeterminate.	R. Whelan: No Deviations or Waivers for Solar Arrays. CLOSED
			Measurements of the Center of Gravity of the Solar Array Panels are found. However, there is no evidence of this being used as input to the Spacecraft Spin-Balance Procedure. Define how this is documented.	R. Whelan: Component package could not have this data, by definition. As-measured mass properties will be reconciled with final vehicle mass properties and ballasting following the complete on/off list analysis – process to be covered in the Spin Balance Review scheduled for 22 April 2003. CLOSED
			A significant piece of data that is included in this data package is the final illumination "flash" test electrical performance data for each solar cell string on each panel. This data can now be incorporated into the GP-B MATLAB Solar Array (SA) Power Generation Model. This will provide the model with measured solar cell string performance data (cell grade measured efficiency as placed on the panel) rather than earlier analysis which used an average cell grade efficiency across the panel as a basis for predicting the on-orbit (BOL) begin-of-life and (EOL) end-of-life power generation capability of the solar array. Where is this analysis documented?	R. Whelan: The data has been reviewed to assure that the original analysis was conservative. EM EPS 247 will document these findings. CLOSED

Additional Notes:

(1) Description of PDU "rugged design" verification, Shawky Shehata

EPS 244: 1. Compact and robust design, 2. All components are mounted to the baseplate, 3. The lead lengths from components to the I/P power connectors and power distribution backplane are minimized by the compact layout of the design, 4. the baseplate is located 4 inches below the Power Conversion board providing ample spacing and physical separation for the baseplate components, 5. Separation between bus ground plane and shunts is approximately 0.43 inches, 6. Separation between the solder-side of the backplane to the inside wall that is adjacent to it is approximately 0.2 inches. The 50 amp Hartman relays, shunts, power bus and other high current components are mounted on the baseplate. These parts are interconnected with 12 AWG wires. This compact design minimizes power dissipation, insuring robust PDU design, 7. There is a minimum of one a tenth of an inch between the cable from J5 to its termination point inside the box and is staked with Uralane. Also, the shunts are conformal coated with approximately 5 to 11 mils thick coating.