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To: Distribution

From: J. Kinnison

Subject: Summary of SPP PDR Actions and Advisories

The Solar Probe Plus (SPP) Mission Preliminary Design Review (PDR) was held 13-16 January 2016 in 200-E100. With fifty presentations over 3½ days, the review covered all aspects of the mission from science, through payload and spacecraft design, to ground and launch systems. The purpose of this memo is to summarize the technical findings, requests for action, and advisories from the PDR review team. While financial and schedule findings are not reported here, in general these were consistent with the technical findings.

Given the high visibility of SPP, NASA established a Standing Review Board (SRB) early in the mission with the intention that the SRB members would continue through the life of the mission, giving continuity in reviews; this was largely accomplished for the PDR, with many SRB members returning. Table 1 gives the makeup of the SRB for the PDR.

The PDR was structured as a non-consensus board, meaning that the SRB Chair develops a report of the review and provides these findings to NASA as the confirmation process proceeds. The report is based on input and findings by the SRB as a whole, however, the Chair makes the final recommendations from the SRB. The SRB report includes an assessment of the project strengths and issues. SRB members that disagree with findings by the Chair may issue a minority report, however, for the SPP PDR, no minority reports were submitted.

During the review, the SRB Chair collected input from the members in the form of Requests for Action (RFAs), which could be in the form of requests or advisories, and from these the issues reported in the SRB report are generally developed. Some 30 RFAs were submitted, of which a few were withdrawn or combined with others. After some work with the SRB Chair, the result was a total of 25 Actions Items (AIs) and 11 Advisories. Table 2 gives the AIs, with agreed-upon assignments and due dates for completion. Table 3 gives a summary of advisories.

Major technical findings reported by the SRB Chair include:

- The review was conducted in accordance with Agency policy (NPR 7120.5E and 7123.1A).
- The project made significant progress during Phase B in advancing the technology readiness levels of key technologies required for the mission. Key technologies have been demonstrated to be at TRL 6.
- Level 1 science objectives are clearly defined and well understood.
- Many lessons learned from previous APL projects such as Radiation Belt Storm Probes, STEREO and Messenger have been incorporated into the plan.

In addition, the SRB recognizes that the SPP team is highly capable and is composed of experienced engineers with the technical skills necessary for this type of challenging mission. They believe that the project is at or beyond the desired state for PDR.

Technical issues reported by the SRB are documented in RFAs and advisories, and include:

- A question on the analysis remaining to be completed for the 2019 backup mission and how that could impact the possibility of a launch delay until 2019.
- A concern on the procurement of reaction wheels given no standard product meets the project needs.
- Questions on the appropriate level of sparing for some avionics components.
- Recognition of a resource risk associated with the possible impact on instruments of the late tailoring of the TPS to control Cp-Cg offset.

- A concern over the ability to fully meet Level 1 measurement requirements if negative charging of the TPS should take place.
- Questions concerning the timing of the Upper Stage development if the Star-48 GXV continues to be the baseline and potential thermal effects of the Upper Stage on the spacecraft.

Given the technical strengths notes and the issues raised, the SRB Chair reports that SPP has satisfied the requirements for PDR and recommends that the project proceed into Phase C. We believe that the issues documented in the SRB report and in the PDR RFAs represent a good review of the project and are resolvable through the process leading to the mission Critical Design Review in March 2015.

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SPP Team
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Table 1. SPP Standing Review Board Members

Name	Affiliation	Expertise
Chris Jones	JPL	SRB Chair, Programmatics
Robin Land	NASA HQ	Review Manager
Arthur Amador	JPL	Mission Operations/Ground
Steve Battel	CTS	Avionics
Heidimarie Borchardt	NASA HQ	Schedule Analyst/Programmatics
Keith Bowman	USAF/AFRL	Thermal
Dennis Byrnes	CTS	Mission Design
Tom Kerslake	NASA/GRC	Power
Neil Murphy	JPL	Science/Instruments
Susanna Petro	NASA/GSFC	Systems Engineering/Instruments
Steve Scott	NASA/GSFC	Systems Engineering
David Steinfeld	NASA/GSFC	Thermal
Chris Stevens	JPL	Programmatics
Consultants to the Board		
Jan Chodas	JPL	Programmatic/Flight Software
Kim Clark	TMG	Cost Analyst
Jonathan Drexler	NASA/GRC	Schedule Analyst
Scott Glubke	NASA/GSFC	Systems Engineering
Steve Harvison	NASA/MSFC	LV/Upper Stage
Ken Hinkle	CTS	Mechanical
Nopachi Iamsakuldacha	TMG	Cost Analyst
Gary Kinsella	JPL	Thermal
Andrew Prince	NASA/MSFC	LV/Upper Stage

Table 1. PDR Action Item Summary

AI	Title	Action	Reviewer	Assignee	Due Date
1	Minimum Perihelion Requirements	Identify the actual perihelion requirement. Provide a decision making process for operations whenever some flexibility remains in targeting the final post-Venus7 perihelion. Include criteria for deciding if a particular maneuver will be performed or not.	Dennis Byrnes	J. Kinnison	28 Mar 2014
2	Requirements Documentation	Charts 6-12/13 show the completion status of the SPP requirements at PDR. Several documents are designated as "In Work". Please explain why it is acceptable for these documents to be late. Identify what risk, if any, the project has accepted as a result and the expected date of completion for each document.	Chris Jones	D. Kelly	28 Mar 2014
3	Mission Design and Navigation - Requirements	For Mission Design Driving Requirement No. 5 - Clarify the requirement for at least one perihelion pass be visible from Earth for simultaneous Earth-based observations of the sun (i.e. the simultaneous view angle of the S/C relative to the view angle from Earth).	Ken Hinkle	N. Fox	28 Mar 2014
4	Possible Science Requirements Inconsistency	Either a) correct the inconsistency on operations durations (mission success criteria vs. threshold science requirements) or b) explain or the inconsistency between the two including how the mission success criteria will satisfy the threshold science requirements	Gary Kinsella	N. Fox	28 Mar 2014
5	Third Stage PDR - 1	Identify what, if any risk, the project has accepted or may encounter as a result of delaying this PDR to mid-November 2014.	Steve Harvison	C. Engelbrecht	30 Apr 2014
6	Third Stage PDR - 2	The project has done considerable work on the spacecraft TPS. The project should consider the thermal effects on the spacecraft due to radiant heating from the upper stage motor during operation. Has heating been considered, analyzed and is there any issue on the spacecraft?	Steve Harvison	C. Engelbrecht	28 Mar 2014
7	Dust Damage Margin and Alternative Flight Trajectory	Explain how accumulative dust damage affects reliability with respect to time? Is final mission reliability an effective measure of mission margin? Does backup mission trajectory also have sufficient margin?	Andrew Prince	D. Mehoke	28 Mar 2014
8	TPS and Structure Load Case	Explain the difference between +/-5150 lb truss testing load and 6.0g testing load applied to TPS for Z direction. 20g load applied with paper reams addresses max third stage thrust at burnout. The aforementioned loads appear to address launch loads. Are they equivalent? If not why is one held to a higher requirement given equivalent environments.	Andrew Prince	T. Hartka	28 Mar 2014
9	Venus 7 Maneuvers	Identify if any maneuvers leading to Venus7 may meet the criteria of Critical Events.	Dennis Byrnes	J. Kinnison	28 Mar 2014

10	Impact of Negative Charging on Meeting Science Requirements	As shown on presentation slide 10-12, published results indicate significant negative charging (~10-40 V negative) near perihelion; dependent on assumptions made about secondary electron emission yield. There wasn't a satisfactory response on what could be done to resolve this concern. It was stated that due to the very high temperatures of the involved materials very little data on secondary electrons emissions are available. If there is a science impact, please explain: 1. How this concern can be resolved if those measurements are not available and if they are, as the project stated, difficult to be made. 2. Once the Leidos spacecraft charging analysis is completed and reconciled with the science simulations please provide a summary of the science impacts, if any, for meeting mission L1 and L2 requirements.	Steve Battel	N. Fox	7 Feb 2014
11	RWA Procurement Plan	1. Please provide a detailed assessment of the technical options with cost and schedule for the RWA procurement including the risk and possible mitigation for each option. This includes configuration changes that include existing wheel options. 2. Please provide an assessment of the qualification for each option including any work that would be required to achieve qualification. 3. Related to item 1, please provide any options for incentivizing the vendor to achieve on-time and/or early delivery. 4. Please explain the work-around options for late delivery to ensure that the 2018 launch date is maintained.	Steve Battel	R. Vaughan	28 Mar 2014
12	Adequacy of Avionics Hardware Complement	Review several scenarios to assess whether or not the project has the appropriate complement of flight/EM/BB RPM and REM hardware. Include in the scenarios late deliveries of the flight units to System Test, the need to rework a flight unit, the need to rework some of the flight cards, a problem with an EM, etc. Keep in mind that there is only 1 test set per box to support any test/retest needs, and the need for some units to support various testbeds. Also consider populating and testing some of the flight spare boards to help mitigate a shortage of hardware assets.	Jan Chodas	E. Reynolds	28 Mar 2014

13	PDU EM	Reassess the decision to not develop a PDU EM due to the likelihood of an impact on System Test. Strongly consider building an EM, or populating and testing some of the flight spare boards, or build a full flight spare	Jan Chodas	E. Reynolds	28 Mar 2014
14	Backup Mission	More detailed analysis of the backup mission needs to be performed very soon to bring it to the same level of readiness as the primary mission.	Dennis Byrnes	Y. Guo	28 Mar 2014
15	Test-as-You-Fly, End-to-End Thermal Design Verification	In light of no plan to conduct end-to-end thermal verification testing at the system level, recommend that the project systems engineering team develop and execute a plan to continuously evaluate their test/analysis/modeling approach, as results are obtained and the models are validated, to identify and ensure that all practical actions have been taken to minimize the risk of undetected anomalies.	Chris Stevens	MK Lockwood	30 Apr 2014
16	Solar Array Cell/Substrate Qualification	Assess the effects of ground environmental test and predicted flight thermal and mechanical cyclic loads on the solar array panels and the ability of the panels to meet all mission performance requirements with required margins..	Ken Hinkle	E. Gaddy	30 Apr 2014
17	ACS thruster propellant and pyro contamination	Please provide contamination assessment results for these contamination sources.	Tom Kerslake	J. Nichols	30 Jun 2014
18	Risk for Changes due to CP-CG off-set Measurement	Create a resource risk (schedule and cost) due to the late final measurement of the CP-CG offset and the potential impact in the instrument mounting and/or FOV.	Scott Glubke	MK Lockwood	28 Mar 2014
19	Upper Stage Flow Induced Performance Factors - 1	Account for throat erosion variability in motor performance predictions. Bound all possible performance 3-sigma or show other justification for lower variability.	Andrew Prince	C. Englebrecht	30 Apr 2014
20	Upper Stage Flow Induced Performance Factors - 2	Show that grain design features do not induce increased performance variations that could affect spacecraft requirements. Typical methods used are two-phase flow CFD, or additional DM testing.	Andrew Prince	C. Engelbrecht	30 Apr 2014
21	Spacecraft Bus Thermal Workforce	Reassess spacecraft thermal workforce level and consider augmenting it to address all spacecraft thermal problems in sufficient detail.	Gary Kinsella	D. Mehoke	28 Mar 2014
22	Rapid MLI Build for C-P Analysis	Spacecraft thermal lead should work with c-p engineer to determine what tolerance will suffice for the c-p analysis. Since the blankets probably don't have a big impact due to their small and distributed mass, the blanket mass uncertainty could be large enough such that a hand calculation suffices rather than expediting the blanket fabrication schedule in order to weigh the actual flight blankets.	Gary Kinsella	J. Troll	28 Mar 2014
23	MAG Boom Design	Further develop the mag boom concept to be consistent with the requirements of the FIELDS E-field measurements.	Neil Murphy	E. Adams	28 Mar 2014

24	RWA Procurement Plan	Employ JPL or a similar expert organization to independently verify the CP analysis to ensure that the final analysis and adjustments are within acceptable tolerance for proper operation during each phase of the mission.	Steve Battel	MK Lockwood	30 Apr 2014
25	Star 48GXV Combustion Instability Testing and Analysis	The project should track this as an upper stage risk and continue with the mitigation steps presented at the PDR splinter session. The project is to report on the final acceleration data collected during the POC test and determine if T-burner data is necessary prior to testing DM-1.	Steve Harvison	C. Engelbrecht	30 Apr 2014

Table 3. PDR Advisory Summary

Advisory	Title	Action	Reviewer
1	Radiation Design Margin	Suggest that the project adopt a requirement for EEE parts radiation design margin (RDM).	Chris Jones
2	Requirements and Verification Engineering	Identify a process to ensure requirements verification compliance if verification methods (e.g., test vs. analysis) change after CDR. Consider if a verification compliance review for all subsystems late in phase D might be warranted to ensure that nothing falls between the cracks.	Gary Kinsella
3	SPIS Benchmark Cases	If analysts are novices on the European SPIS software, consider running benchmark cases in SPIS to ensure proper modeling of the problem the project is actually trying to solve.	Gary Kinsella
4	Materials Identification and Usage List	Consider if Carl reviewing a materials interface usage list (or equivalent) is time well spent in the quest to identify potential downstream issues early.	Gary Kinsella
5	EMI / EMC testing at the box/unit level for all the instruments	I recommend that EMI/EMC testing be added at the box/unit level for all the instruments to reduce the risk of finding problems late in the development schedule where they are much more costly. I suggest doing only conducted testing where you would not have to go to an EMI/EMC facility to run your tests. In particular, I suggest to all the instruments teams to do common mode measurements that would help identify problems for radiated testing. For common mode the test should be run on all harnesses.	Susanna Petro
6	Use of G10 on Spacecraft	Consider whether SPP is allowed to use G10 as a thermal isolator. G10 is an electrical isolator, and in your charging environment, most satellites require something more electrically dissipative for thermal isolators. Consider using Ultem 1200UC for these surfaces.	David Steinfeld
7	Thermal Protection System (TPS) TRL-6 Qualification	Prior to claiming a design meets the definition of TRL 6, complete additional TPS structural and materials testing which correlate with structural analysis predictions that demonstrate positive margins of safety.	Ken Hinkle
8	Additional Launch Date Study	Mission Design should do additional study on the August 20 launch date (and perhaps a few more days later) to determine if launching with a C3 constrained to 154 and a concomitant nominally non-zero TCM1 is preferable to delaying to the backup mission.	Dennis Byrnes

9	Gates Model Navigation Analysis	Navigation analysis should be done with a different Gates model for TCM using execution errors consistent with the data presented by G&C which shows slightly higher errors for very small maneuvers, but much, much, smaller errors for larger maneuvers.	Dennis Byrnes
10	Verification of actuators in circuits	As there are pyros in the cooling system, I recommend that the NASA Standard Initiator Guide from Johnson Space Center be considered before finalizing the circuit and related resistors in order to avoid any unwanted activation. It is very helpful also to perform a preliminary analysis by PSPICE.	Susanna Petro
11	Dust Impact on FIELDS	Create a risk item for FIELDS that addresses the risk of failure or damage caused by a dust impact on the boom cables leading to the FIELDS magnetometer and search coil sensors.	Neil Murphy