

**REPORT  
of the  
Planetary Science Subcommittee  
of the NASA Advisory Council Science Committee**

**Washington, DC  
9 January 2009**

**Introduction**

The Planetary Science Subcommittee (PSS) of the NASA Advisory Council (NAC) Science Committee held its tenth meeting on 9 January 2009 at NASA Headquarters. Seventeen of the 20 members of the subcommittee attended the meeting, and one participated by teleconference.

This meeting was a special one focused primarily on the Mars Science Laboratory (MSL) mission, the recently announced slip in its launch date from 2009 to 2011, and options for how the consequent increase in mission cost would be accommodated within the NASA Planetary Science Division (PSD) budget. At the request of the NAC Science Committee, the PSS also heard an update on planning for the International Lunar Network (ILN).

The agenda (attached) for the morning session was devoted almost entirely to MSL and the accommodation of mission cost increases. PSD Director James Green began with an update on recent division activities. The discussion of MSL, which immediately followed, was divided into five parts. Doug McCuistion, Mars Exploration Program Director, provided a mission overview, and Michael Meyer, Mars Exploration Program Lead Scientist, summarized the scientific promise of the MSL mission. Richard Cook, MSL Project Manager at the Jet Propulsion Laboratory (JPL), provided by teleconference a snapshot of the technical status of the mission as well as a report on the status of mission replanning since the decision had been announced in early December to slip the launch date by 26 months. McCuistion then summarized the status of the current MSL budget and the near-term milestones for approval of the replanned mission.

The presentations on MSL were followed by a discussion by James Green of budgetary and launch options for accommodating the later date for the MSL launch and the increase in total mission cost. Green's presentation stimulated a lengthy discussion within the committee. NASA Science Mission Directorate Associate Administrator (AA) Ed Weiler was present for nearly the entire morning and participated in the discussion as needed.

The afternoon session began with an update on ILN planning, given by PSD Deputy Director James Adams. An opportunity provided on the agenda for public comments yielded no requests for commentary, so the subcommittee continued its discussion of both MSL accommodation and ILN issues. Because the meeting was shorter than a typical PSS meeting, there were no formal reports from Analysis and Assessment Groups. The meeting ended with a formulation of specific subcommittee recommendations to be forwarded to the NAC Science Committee.

**General Assessment of PSD Programs**

Although the meeting was primarily focused on MSL, the subcommittee was pleased to note the achievement of several milestones by the PSD. Operating missions continue to return exciting discoveries. Seven teams have been selected to launch the NASA Lunar Science Institute, and the Stand-Alone Mission of Opportunity Notification (SALMON) was used effectively to select an instrument (Lunar Dust Experiment) for the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission. A draft Announcement of Opportunity (AO) for the next New Frontiers mission was released in November, a workshop on the draft AO was held in

December, and revisions to the AO in response to comments and questions received at the workshop are in progress. The National Research Council (NRC) has begun a study on how best to balance Research and Analysis (R&A) with planned and ongoing missions as well as a study on the detection and mitigation of near-Earth objects; a study on radioisotope power system requirements and plutonium availability is nearing completion; and planning for the next decadal survey for solar system exploration has been started.

### **Mars Science Laboratory**

The MSL spacecraft components are at a generally advanced state of integration, but a number of technical issues remain, and much testing is planned once solutions for those issues are found. Two of the major technical areas still facing challenges are avionics and actuators. The mission is utilizing a new-generation avionics and power electronics subsystem, but hardware maturity has not yet reached the desired level (i.e., the rate of problem/failure reports is still high) as a result of longer than expected design times, requiring considerable rework of flight electronics boxes. Technical problems found in flight actuators (e.g., braking and torque issues) led to delivery delays in flight units that rendered the integration and testing schedule untenable for a 2009 launch. Additional issues are still being worked on the cruise stage (e.g., solar cell rework to fix differential thermal expansion problems), descent stage (e.g., propulsion system rework), aeroshell (assembly ongoing), and rover (e.g., sample processing subsystems), and system-level validation and verification is still ahead. The ten payload instruments appear to be in comparatively good shape, with four delivered, and five expected to be delivered over the next two months.

The PSS reiterates its unanimous support for completing the MSL mission successfully. In the report from our October 2008 meeting, the subcommittee wrote *“The PSS reaffirms its support for the MSL mission, its scientific goals, and the advances in our understanding of the past and present habitability of Mars that will be enabled by the successful completion of the mission.”* The rationale for that recommendation is unchanged from that given in our last report. Moreover, the subcommittee understands the technical and schedule issues that led to recognition that a 2009 launch was not feasible at an acceptable level of mission risk, and we concur with the decision, announced on 4 December, to defer the launch to the next available window in 2011.

The PSS appreciates the thorough briefing given to the subcommittee, but we remain concerned that the technical challenges facing the project team are still numerous and serious. We applaud the project for dedicating the remainder of this fiscal year to the retirement of high-risk development issues and the completion of flight hardware units, where feasible. Because of the importance of near-term milestones to mission risk reduction, **the PSS requests that it be provided reports from the Mars Exploration Program on at least a monthly basis of progress by the MSL project toward meeting its development milestones, particularly in areas where major risks to mission success can be retired.**

### **Options to Accommodate the MSL Launch Slip**

The presentation to the PSS of options to accommodate the cost of completing the MSL mission, given the delay in launch date, demonstrated that PSD management has devoted considerable energy and thoughtfulness to the problem presented by the need to find an amount estimated at the time of our meeting to be approximately \$400M. The PSS was pleased to hear that the PSD was following the “guiding principles” as stated in the report from our October 2008 meeting: *“Consistent with concurrent SMD policy, cost increases incurred by the MSL project should, to the extent possible, be borne by JPL, the implementing organization for the mission. Additional funds should be sought next from within the Mars Exploration Program. Impacts to non-Mars programs, as needed after those two sources of funds are utilized, should be sought through delays rather than cancellation of approved missions now under development.”* It was also clear to the PSS that the options developed by PSD had been

thoroughly discussed, prior to our meeting, within SMD and with the Office of Management of Budget (OMB).

The first decision point presented to the subcommittee was one between immediate cancellation of MSL and locating the approximately \$400M in funds needed to complete the mission through launch, cruise, landing, and all nominal operations on the surface of Mars. For the reasons given above, **the PSS is of the unanimous view that the option to cancel the MSL mission at this time is not warranted on either scientific or technical grounds.**

The principal challenge facing an accommodation of the \$400M increase in MSL mission cost is that most of that cost growth (~\$310M) must be met in fiscal years 2010 and 2011. The remaining ~\$90M will be needed to conduct mission operations in 2013 and 2014, a time after which the nominal mission would have ended had the original launch schedule been met. Consistent with the guiding principles, the needed funds will come from the Mars Exploration Program, but the large fraction of those funds needed in the next two fiscal years presents a budget phasing problem.

The approach recommended by PSD and SMD to accommodate the increased mission cost of MSL involves four actions within the Mars Exploration Program. The first is a deletion of five years of investment in technology for future missions to Mars; those funds in 2010 and 2011 would go directly to MSL, and those funds in 2012-2014 would go to pay back "loans" from other programs. The second action is a reduction in scope of the planned mission to Mars in the 2016 launch window; the reduction would not permit a major mission at this opportunity except through a partnership with the European Space Agency (ESA). The third action is to reduce SMD support for Mars entry, descent, and landing (EDL) technical readiness, on the grounds that the MSL launch slip and the potential to partner with ESA for the 2016 opportunity will maintain PSD's commitment in this key area. The fourth action is a reduction in the budget for operating Mars Exploration Program missions, through reductions in mission carry over, program and mission reserves, and funding for mission extensions.

In addition to the above actions, two further steps within mission lines outside of the Mars Exploration Program would release funds for MSL at no major impact. The first is to rephase the study effort for the next Outer Planet Flagship mission, by reducing expenditures in 2010-2011 and paying those reductions back in 2012, an action that will align NASA's planning efforts for this flagship mission with those of ESA; this action would likely have been taken in any case to permit the OPF mission to go forward as a partnership between the two agencies. The second action is a rephasing of reserves in the Discovery and New Frontiers Programs and the Lunar Reconnaissance Orbiter (LRO) science mission; the rephasing for LRO is enabled by the recent delay in the launch date for that mission.

These six actions, four within the Mars Exploration Program and two low-impact budgetary moves outside of that program, yield approximately \$353M toward the ~\$400M needed to accommodate cost growth in MSL. Given the current estimate that the \$400M figure will be sufficient to accomplish the full MSL mission, an additional ~\$47M must be found.

PSD presented three options for securing such an additional ~\$47M. In order of PSD priority, they are a rephasing of Headquarters-held reserves for the Juno mission, a delay in the next Discovery Program AO and a parallel delay in Advanced Stirling Radioisotope Generator (ASRG) development – possibly an enabling technology for the next Discovery mission – and a delay in ILN and a budgetary rephasing of Lunar Missions of Opportunity.

The PSS was informed that the first of these options would have the least impact on PSD missions. The Headquarters-held reserves for Juno, the second mission in the New Frontiers mission line, were set aside at the time of mission confirmation to meet what was then a new agency requirement that there be a 70% probability of meeting mission success criteria within cost. The reserves were over and above the budget that both the mission principal investigator and the implementing organization feel are needed to complete the mission on schedule and

within budget (including project-held reserves). On the basis of this information, and because the alternative options involve delays in mission opportunities, **the PSS endorses the approach and prioritization set forth by PSD to find the ~\$400M needed to accommodate cost growth in MSL given the delayed mission launch.** Specifically, **if the full \$400M is needed to complete the MSL mission, the PSS endorses utilizing the Headquarters-held reserves for the Juno mission as a contribution toward readying MSL for launch in 2011.**

That said, the PSS wishes to emphasize the importance both to outer planet exploration and to the budget of the New Frontiers Program of the timely launch of the Juno mission in 2011. Notwithstanding that the Juno project does not currently feel the need for the reserves now held at NASA Headquarters for that mission, some unforeseen development issues may arise that would call for the allocation of funds equal to some portion of those reserves. The subcommittee took note of James Green's statement to the PSS that the AO release date for the next New Frontiers mission has been delayed until the budget for the MSL launch slip has been finalized. The final AO release might be set to give the New Frontiers program budget some additional flexibility to respond to unanticipated Juno development issues. Even if such an option is not exercised, **the PSS recommends that PSD take steps to ensure that Juno is completed and launched on schedule in 2011.**

The PSS notes that the cost to complete MSL, given the recency of the launch delay and the ongoing replanning effort, had not yet been developed in detail by the project or JPL as of the time of our meeting, although we were informed that such a cost would be presented to PSD management by the end of the month. We further note that the additional 26 months of development and testing could lead to a desire for technical improvements or "requirement creep" and a consequent increase in mission cost over both current estimates and the cost to complete expected later this month. **We recommend that NASA management strongly discourage any augmentations to the technical requirements for the MSL spacecraft or payload beyond those currently specified.**

Given the history of repeated episodes of cost growth for this project, the subcommittee is not confident that the \$400M figure will bound the final increase in cost requested by MSL's implementing organization to complete the development and launch of this mission as well as all nominal operations of the landed rover on Mars. The subcommittee requests that it be informed of the estimated cost to complete the MSL project, once that estimate is provided by JPL later this month, as well as any subsequent changes to that estimate. **Should growth in the projected MSL mission cost over current budget exceed the Headquarters estimate of \$400M, the PSS recommends that NASA seek additional input from the subcommittee prior to making any further cost accommodations across PSD programs.**

### **Impact of MSL Delay Cost Accommodation on the Mars Exploration Program**

Although the PSS applauds PSD for following the subcommittee's guiding principles in developing a solution to funding the increase in MSL mission cost, we cannot fail to note that this solution will have a large impact on the Mars Exploration Program in the areas of technology and infrastructure development, flight missions in the next decade, and scientific return over that time frame.

In response to an earlier SMD directive to focus the Mars Exploration Program (MEP) on developing a Mars Sample Return (MSR) mission, as well as the redirection of MEP funding to other SMD priorities, considerable effort was expended in developing a program architecture that would lead to the development of the first elements of a sample return capability by the end of the next decade. The broad objectives of that architecture were supported by the PSS. The change in the allocation of MEP funds resulting from the MSL launch delay will substantially alter the pace of Mars exploration after MSL, notably including the postponement by several years or more of an MSR mission.

In the nearer term, the removal of virtually all technology funds essentially eliminates the possibility of a landed mission by NASA that utilizes the 2016 launch window. Such a mission was envisioned to be a precursor to MSR, performing detailed investigation of one of the key surface locations for habitability, and was to have included significant technology development in sample handling and caching in preparation for sample return. NASA's effort toward the 2016 opportunity is now likely to be directed instead toward a joint ESA-NASA effort in support of ESA's ExoMars mission. Although such a partnership would result in a more scientifically ambitious mission than either agency could initiate on its own, such a mission would not involve all of the technological and infrastructure developments of the previous mission concept for the 2016 opportunity. The reduction in EDL infrastructure funding will constrain the development of NASA's EDL capability and may affect future efforts to achieve precision landing both on Mars and on other solar system bodies.

Reductions in funding for currently operating missions may reduce the scientific return from those missions and constrain or limit options for those missions to contribute toward landing site selection for future missions, including sample return. Moreover, the delay in the launch and operation of the MSL mission highlights the need to maintain a reliable communication system at Mars that can support not only that mission but later landed missions as well. Mars Odyssey has been in operation since 2001 and Mars Reconnaissance Orbiter (MRO) since 2005, so these spacecraft presumably have several years of operational capability remaining, particularly MRO. Even with MAVEN scheduled to launch in 2013, PSD should evaluate communication needs at Mars in light of the MSL delay and its implications for later MEP missions.

**In light of all of above issues, the PSS recommends that the Mars Exploration Program Analysis Group (MEPAG), and the Mars community more broadly, reevaluate the MEP architecture to identify the best options currently available, including MSR, to maximize the opportunities for achieving scientific goals of the highest priority.**

### **Juno and MSL Launch Issues**

The PSS understands that both Juno and MSL are each scheduled to be launched on Atlas V launch vehicles in the summer to fall of 2011 and that the United Launch Alliance (ULA) currently requires a minimum turnaround of 90 days when the payload of the second launch contains a nuclear power source (as does MSL). The Juno launch window is three weeks long and occurs during August, when weather-triggered launch delays are common. The MSL launch, given the 26-month slip in launch date, can occur during a three-week interval in October, but that period is too close to the Juno launch window to be permitted by ULA turnaround policy.

The subcommittee was therefore pleased to learn of recent developments that should permit both Juno and MSL to be launched in the second half of 2011. First, discussions are underway among the Air Force, NASA, and ULA regarding a 15-day acceleration of launch pad turnaround by means of increased launch crew staffing. (Such an acceleration is critical to earlier launches for non-NASA payloads, which currently overlap the Juno and MSL launches on the Atlas V manifest.) Second, the MSL project has discovered a December launch option that utilizes a type I interplanetary trajectory that would deliver MSL to Mars earlier than with the October launch window (which uses a type II trajectory) and within specifications for EDL and most landing site constraints. The December window is slightly more than two weeks long, but weather-triggered launch scrubs are far less common in December than during summer months. Finally, the addition of a solid-fuel booster to the MSL launch vehicle (i.e., changing the launch vehicle configuration from an Atlas V 541 to an Atlas V 551) would extend both the October and December launch windows by 13 and 6 days, respectively.

**The PSS recommends that the MSL project consider the use of the Atlas V 551 configuration as its launch vehicle.** The additional booster would be an added cost to a project already under pressure to curtail further cost increases beyond those associated with the launch delay, but the three-week window in December will reduce the risk that a successful launch will

not be achieved because of a last-minute technical difficulty. The longer October window enabled by the more capable launch vehicle, together with an accelerated turnaround of the Atlas V launch pad facility, would also open the possibility that MSL could launch toward the end of its October window if Juno launches at the beginning of its August window. **To keep open the option of the Atlas V 551 configuration for MSL, PSD should ascertain the cost of the additional booster and any associated adaptations to the launch vehicle and payload, and a date should be set by which a final decision on the launch vehicle is made.**

### **MSL Lessons Learned**

As the PSS noted in its October 2008 report, the history of multiple major increases to mission cost for MSL is a poor model for future missions, particularly at the flagship scale, and it is important that the causes of recurring cost growth be understood so that lessons learned can be applied henceforth. We specifically recommended: *“At the earliest appropriate time, NASA should conduct an external review to assess the causes of the MSL cost overruns and to recommend those changes to cost estimation procedures and project management needed to prevent similar situations for future missions.”* The PSS is pleased to hear that PSD will be implementing this recommendation once key personnel from the MSL project have the discretionary time to participate in such a review without jeopardizing the MSL development and testing schedule. The subcommittee hopes that such a review can be completed before the start of the next major mission within PSD so that the lessons learned from the exercise can be fully exploited. Moreover, **the PSS recommends that, on the basis of the MSL experience, procedures be put in place to develop robust estimates of mission cost as early as the mission concept phase, and that those procedures be implemented as part of the upcoming decadal survey for solar system exploration.**

### **Status of ILN Planning**

The PSS was pleased to learn that progress has been made on the planning of an ILN mission, and that the mission is viewed as providing an “anchor node” to a truly international network of geophysical stations that share observations and contribute toward common scientific objectives. The subcommittee is also gratified to understand that the number of stations to be supplied by NASA and the duty cycle and lifetime of individual stations are now envisioned to be considerably larger than in some descriptions of network characteristics given in earlier presentations to the subcommittee. That said, there are significant technology developments needed in the areas of landing systems and power sources, and the PSS has not yet seen the Science Definition Team report, which was only in draft form and still unavailable at the time of our meeting. We look forward to an opportunity to review that report and to hear of progress toward mission concept definition at our next meeting.

During our subcommittee discussion it became clear that such a mission concept definition would benefit from enhanced information on the consequences of network design decisions on scientific return, particularly for the lunar seismology objectives. In designing a seismic network to address a particular scientific problem on Earth, it is traditional to carry out a synthetic resolution test in which hypothetical seismic sources are postulated for a given network configuration and duration, a body of synthetic observations is generated for those sources and that network, and those synthetic observations (with noise added) are inverted to recover information on structure, source locations, or both. Such a synthetic experiment can be repeated as many times as needed to yield a set of trade-off curves of network size, geometry, and lifetime against expected scientific return. **The PSS recommends that PSD solicit proposals to conduct synthetic resolution tests for all ILN scientific objectives so that the number, location, and lifetime of network stations can be optimized for those objectives.**

Shortly before the PSS meeting, the subcommittee was sent six specific questions on ILN by the NAC and its Science Committee. Those questions were as follows:

- (1) Are good heat flow measurements possible at the [lunar] surface by use of the specific methods envisioned for this mission?
- (2) How effective is a seismic network with only two nodes? Why a two-node design? What was the design process that led to two nodes? How is the epicenter location determined?
- (3) Nodes will need to be long-lived.
- (4) Who makes decisions relative to the international interfaces?
- (5) How were the mission cost estimates developed? Is SMD confident in these cost estimates?
- (6) Are there deployment issues associated with the seismometers? Would the ILN seismometer effectiveness (noise) be impacted by putting it under a creaking lander?

Although the agenda for this PSS meeting did not permit an extended discussion of these questions, James Adams did present initial PSD answers to these questions, and the PSS had an opportunity to discuss those responses. In brief, those responses are as follows:

- (1) Completing reliable measurement of heat flow on a robotic mission to the lunar surface requires further study and may be possible only with an investment in new technology.
- (2) The two-node design was presented to the SDT as a Headquarters challenge and is no longer an element of mission design except as a result of mission degradation in the absence of new stations emplaced by international partners. Addressing the hypocenter (not epicenter) location problem requires additional modeling, and a specific recommendation regarding such a modeling effort is given above.
- (3) The current design life for each station is 6 years, in acknowledgement of the need for long-lived stations.
- (4) NASA Headquarters will make all decisions relative to interfaces with international partners.
- (5) No valid cost estimates have yet been developed. NASA will use the formal Planning, Programming, Budgeting, and Execution (PPBE) process to adjust the ILN budget as valid cost estimates become available.
- (6) There are deployment and thermal and mechanical isolation issues associated with the ILN seismometer package. These issues have been factored into the conceptual design to some extent, and they will receive continued attention until operational concerns have been adequately addressed.

### **International Cooperation on Major Missions**

At the end of the morning session, SMD Associate Administrator Ed Weiler asked the PSS whether the subcommittee viewed the internationalization of major missions now under discussion as a good idea. The context for the question was the current plan to develop the next Outer Planet Flagship mission as a joint project of NASA and ESA, the recent proposal that NASA enter into cooperation with ESA on its ExoMars mission for the 2016 launch window, and the widespread recognition that an MSR mission is too expensive to be undertaken by any single space agency.

The PSS is of the general view that international cooperation can be an effective means to accomplish a mission that is more ambitious in its scientific objectives and technical requirements than NASA alone can support. The Cassini-Huygens mission is an example where such a partnership involved shared objectives, cleanly separable technical responsibilities, and the successful accomplishment of an impressive set of mission objectives. Additional examples of international cooperation can be found in other branches of space science. Moreover, the next Outer Planet Flagship mission and ambitious missions to Mars, certainly including MSR, are

mission concepts that benefit by combining the resources and talents of more than one space agency, and in the longer term it can be expected that mission objectives will tend to increase in ambition and cost as easier tasks are accomplished and more challenging ones remain.

Balanced against the greater resources that can be applied toward a joint mission are the additional levels of negotiation required to reach a mutually agreeable partnering arrangement, the need to bring into phase the decision processes of two or more organizations that operate under different constraints and schedules, and the added time that these complexities impose on mission concept definition and development. Moreover, there are key areas of technological expertise for which NASA will always wish to maintain a position of leadership in robotic exploration. For these reasons, **the PSS recommends that international partnerships be sought only for carefully targeted mission opportunities for which the mission objectives are particularly ambitious and the strategic objectives of the partnering organizations can be met in a mutually satisfactory fashion.**

**Planetary Science Subcommittee Meeting**  
**9 January 2009**  
**NASA Headquarters, Room 5H45**

9 January (8:00 AM – 5:00 PM)

8:00	Welcome and Other Administrative Matters	Sean Solomon, Greg Williams
8:15	Planetary Science Division Update	Jim Green
8:45	Mission Overview	Doug McCuistion
9:00	The MSL Science Story	Michael Meyer
9:15	Technical Status	Richard Cook
9:45	Replan Status	Richard Cook
10:10	Budget Status and Approval Path	Doug McCuistion
10:20	Options to Accommodate MSL Launch Slip	Jim Green
10:45	Break	
11:00	Discussion	Sean Solomon
12:00	Lunch	
1:00	Update on International Lunar Network Planning	Jim Adams
1:30	Public Comment Period	Sean Solomon
3:00	Break	
3:15	Discussion and Formulation of Recommendation(s)	Sean Solomon
5:00	Adjourn	Sean Solomon