



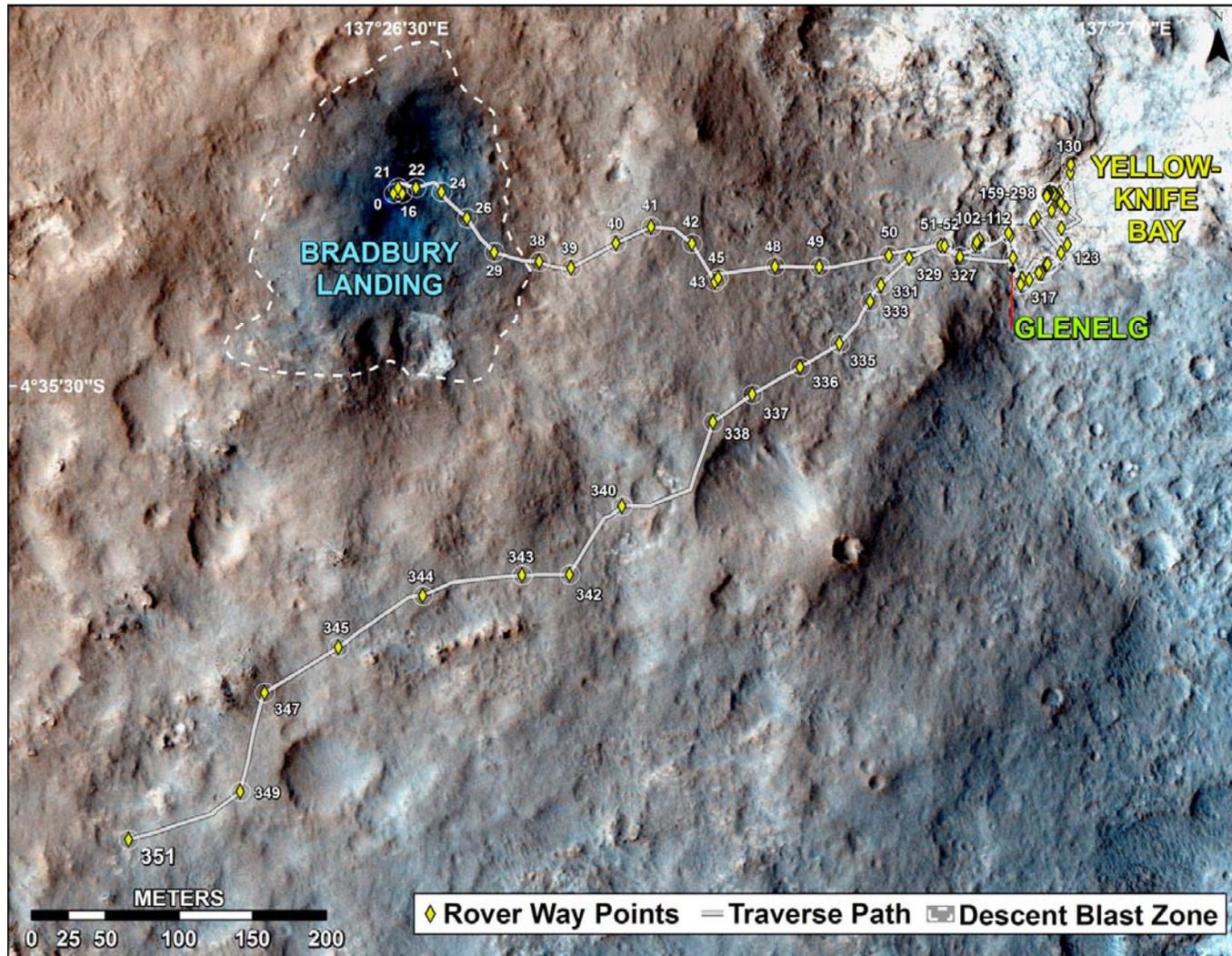
**MSL Lessons Learned  
Presentation  
to  
NASA Advisory Council's  
Planetary Protection Subcommittee**

**May 20, 2014**

# MSL LL Study

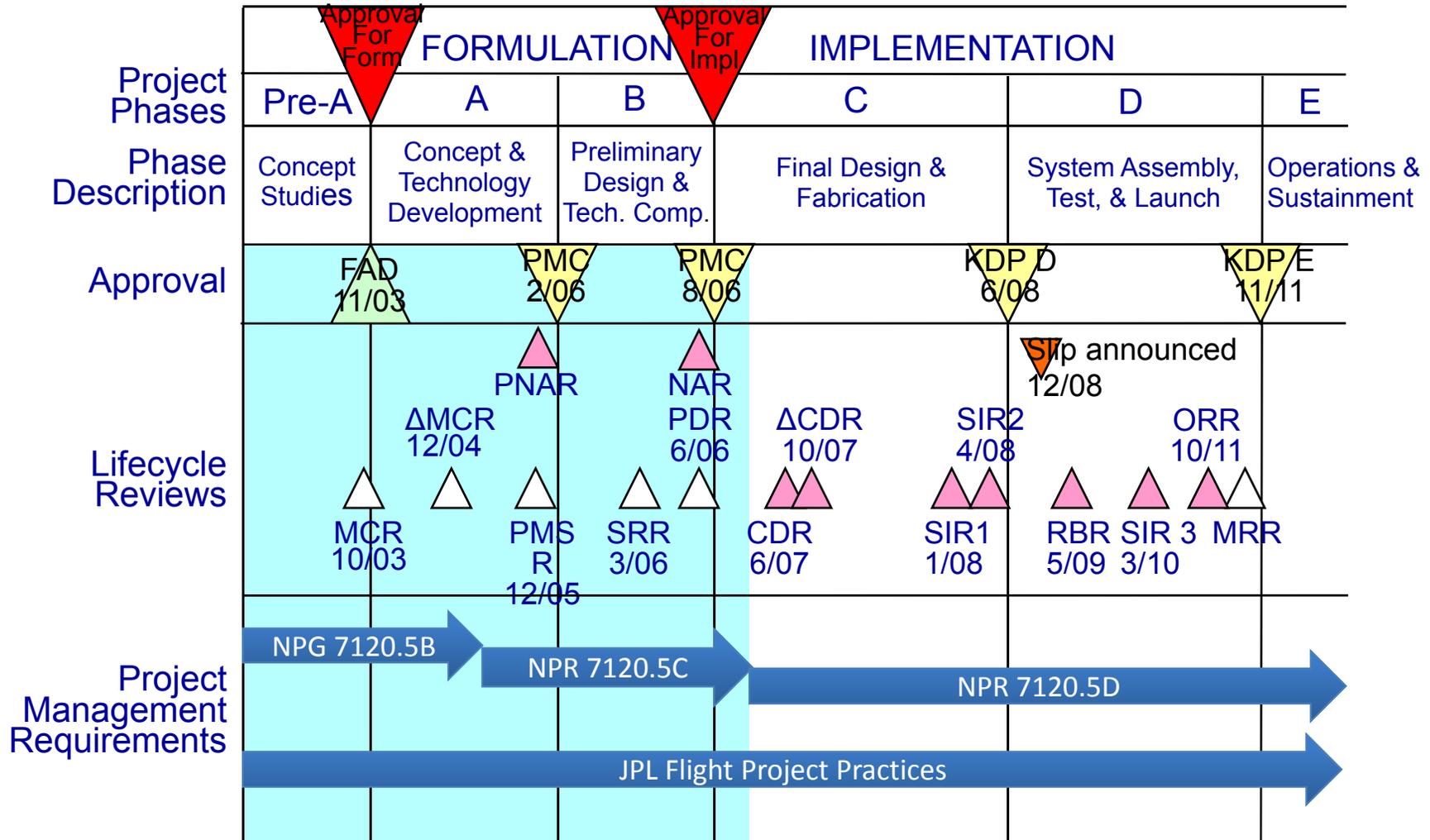
- **Purpose:**
  - Identify why MSL slipped and why we didn't see it coming
  - Identify why MSL failed to satisfy planetary protection requirements for its categorization, IV-c
  - Identify steps to improve performance at all levels in future large complex projects
- **Scope:**
  - Agency, Center and project management, review and decision processes and policies
- **Team Members**
  - Mark Saunders, Chair
  - Noel Hinners
  - Bill Luck
  - Charles Fletcher
  - Scott Hubbard
  - Dolly Perkins
  - Sarah Gavit
  - Jeff Leising
  - Dave Tisdale
- **Team Skills:**
  - Program and project management
  - Instrument development
  - Budgeting
  - Planetary protection
  - Systems engineering
  - Mission development & ops
  - Space science

# MSL has been a great success!



But there are lessons to be learned

# MSL History



-  Center-led Review
-  Independent Review

## ***Why did MSL cost so much and take so long?***

- MSL was “Flagship” mission in every way Flagships generally described
  - 10 instruments, new sample acquisition & handling system, new EDL sys
  - Almost five times bigger than MERs
  - Required similar number of major technical developments to Cassini
- Process of matching scope and resources flawed from beginning
  - Assumptions/analysis never validated by independent non-advocate
    - MSL attempted to reduce scope at  $\Delta$ MCR; management reluctant; design back to similar scope as initially proposed by PDR
    - 14 mos between 1<sup>st</sup> MCR and  $\Delta$ MCR focused on unworkable concept rather than necessary technology and engineering required
- Once payload selected, MSL in reality became \$2B+ mission; 2009 launch undoable
- We believe Agency could have known scope and budget were mismatched
  - Independent non-advocate assessment
  - Historical comparison with previous Flagships or MERs

# ***Why didn't we know it would slip and cost so much until a year before launch?***

- Initial lack of understanding led to estimated life cycle cost and schedule inconsistent with ultimate mission
- MSL constrained Formulation period so final design, AI&T schedule would be sufficient to meet 2009 launch date
  - Phase B only six months long and completely inadequate
  - At PDR, architecture unstable; systems/subsystems not at req'd maturity; only 1 of 6 NAR criteria fully met
- Some MSL mgmt practices inadequate, eg cost, schedule until ~ CDR
- SMD and JPL management oversight insufficient until ~ CDR
- Independent review found most issues but failed to determine MSL was in more trouble than individual findings suggested
  - Prior to slip, MSL never fully met any LCR criteria, yet mgmt authorized transition to next phase
  - Senior mgmt unable to understand full impact to cost and schedule

# MSL LL Findings

**Finding 1:** The Agency has a historical culture of underestimating the resources required to accomplish its work, particularly with strategic/Flagship/directed missions. This happened with MSL.

- Evaluate degree of scope, complexity and risk of every directed mission at MCR.
- Perform independent, non-advocate, CATE-like reviews at MCRs.
- Establish margin in mission scope.

**Finding 2:** The MSL Project did not satisfactorily complete Formulation by Project PDR/KDP-C and arguably did not complete it until after Project CDR.

- Projects ensure they develop Formulation plans to satisfy Formulation criteria and negotiate necessary funding and schedule.
- NASA should improve Program and Project management requirements as proposed by this study.

# MSL LL Findings

**Finding 3:** MSL Project management processes, particularly cost, schedule, staffing and some decision-making, were inadequate.

- Projects should:
  - Ensure complete all work necessary to meet LCR criteria;
  - Have adequate margins to handle inevitable issues;
  - Have management processes adequate to meet challenges.

**Finding 4:** The management and oversight functions of NASA Headquarters and JPL, including the Mars Program at JPL, did not sufficiently assess and control MSL's progress, thus these organizations did not finally accept the slip was inevitable until after System Integration Review (SIR).

- Agency ensure organizations have adequate staff.
- Agency ensure effective periodic reporting.
- JPL should update their policies, requirements and practices.

# MSL LL Findings

**Finding 5:** The independent review process failed to identify the aggregate impact of individual issues on the system-level design, budget and schedule, and did not uncover the likely cost and schedule of the Project.

- The Agency strengthen independent review (IR) process.
- Require IR team and Project to present \$ & t to get to required state.
- Not allow Projects to proceed past a KDP if Project has not satisfied LCR's criteria.

**Finding 7:** MSL Findings 2 through 5 indicate that Agency Lessons Learned and best practices, as documented in our Agency and Center policy and requirements documents, were not fully embraced by MSL, MEP, JPL, SMD and the Agency.

- NASA and its Centers should ensure Programs and Projects follow NASA and Center requirements and best practices.
- NASA should strengthen focus on Lessons Learned.

# MSL LL Findings

**Finding 6:** Planetary Protection (PP), as a discipline, does not follow effective systems engineering and management practices.

- ***Facts:***

- NASA PP policies & req'ts defined in NPD 8020.7 & NPR 8020.12.
- PPO issued PP req'ts and categorization to MSL Project in letter.
- PPO directed MSL's PP staff.
- MSL requested deviation due to possible recontamination of drill bits and wheels.
- PPO responded with SMD letter on November 1, 2011 and re-categorized from mission IV-c to IV-a.

- ***Key Discussion:***

- Although past practice, a letter issuing PP requirements was not in accordance with NASA's standard methods of issuing requirements
  - Thus, standard engineering practices of proper req't definition, flow-down, mission assurance, and V&V were not followed.

# Finding 6 Continued

- **Key Discussion cont**

- PP req'ts not written in clear, concise verifiable manner, further making V&V difficult.
  - Drill bits underwent microbial reduction, but removed from sterilized bit box due in part to determination launching with one bit mounted in drill was, according to the Project "... critical to the success of the mission". This subjected all bits to possible recontamination.
  - Wheels underwent microbial reduction, but during ATLO, protective covers were removed, allowing potential for recontamination.
- MSL struggled with req't for preventing recontamination since req'ts ambiguous in NPR 8020.12, MSL PP Plan and MSL PP Implementation Plan.
  - One example: PP Implementation Plan, p. 4-22, states: "The flight wheels shall be mounted on the rover as late as possible and will be covered as much as possible to prevent recontamination."
  - Many interviewees expressed concern about ambiguities in PP req'ts.

# Finding 6 Continued

- ***Key Discussion cont***

- Interviews revealed lack of understanding of roles and responsibilities of various PP positions and organizations.
  - Responsibilities of SMD AA, PPO and Project described in NPD 8020.7 and NPR 8020.12
  - Responsibilities of other orgs, e.g. JPL's PP group, not covered.
  - No discussion in SMD Handbook on this topic
- Based on comparison of MSL PP staffing with MER PP staffing, MSL Project understaffed to perform their required duties.
- PP Office appears inadequately staffed to accomplish responsibilities and req'ts in NPR 8020.12.
- Although PPO reports to Deputy AA, PPO is in PSD; resources for PP functions provided as part of PSD budget.
  - Places PP function, in some cases, in competition for resources required by PSD Projects. Provides potential for appearance of conflicts of interest.

# Finding 6 Continued

## *Key Recommendation Summary:*

- PP req'ts should be issued to Projects as project-level/Level 1 req'ts
- NASA's should revise NPR 8020.12:
  - To reflect this change.
  - To unambiguously document req'ts for preventing recontamination.
- SMD should revise their Handbook to reflect Planetary Protection Officer's responsibilities and interrelationships between PPO, SMD, Program and Center staff.
- SMD should conduct awareness training to educate Headquarters, Program, and Center personnel on Planetary Protection R&R.
- All PP organizations should be adequately staffed to perform PP work.
- SMD should reconsider current PPO organization location to ensure PP is fully independent of any operational division.
  - PPO role should be re-examined in light of PPO's expanding role, to include human exploration and cross-mission trades for sample return.

# Mars 2020 and Mars Exploration Program (MEP)

Given NASA's severely constrained budget and increased scrutiny by OMB, GAO and Congressional committees, the Mars 2020/MEP recommendations are extremely important to sustaining NASA's Mars Program.

- SMD should:
  - Implement recommendations of this study for Mars 2020.
  - Fill MEP Program Director position immediately.
  - Ensure Mars 2020 meets cost and performance targets.
- Mars 2020 must be accomplished recognizing it is potentially the 1<sup>st</sup> of 3 sample return missions.
  - Understanding linkages to full campaign, including site selection, is essential and requires dedicated engineering staffing.

# MSL LL Takeaway

- NASA needs to **understand scope, complexity and risk of directed/strategic/Flagship missions**, preferably by MCR but no later than PDR.
  - Incorporate independent **non-advocate CATE-like** (Cost and Technical Evaluation) review at MCR for directed missions; ensure scope and resources are matched.
  - **Improve independent review** (IR) to enable greater depth of penetration and improved analysis and reporting.  
*Note: SMD treats competed missions with more rigor in early formulation than directed missions.*
- **Formulation must be adequately funded** if Implementation performance is to be improved.
- Programs/projects **must follow Agency's policies and meet LCR criteria** before being allowed to progress to next phase.
- Centers/mission directorates need to **better oversee their projects**. Independent Review is only a check - not a substitute for oversight.
- **PP needs to be improved** to ensure future missions can meet PP req'ts.
- **Mars 2020** and NASA need to **ensure scope and resources match**. Heritage is key.
- NASA needs to **improve its implementation of lessons learned** through following its processes and conducting training and workshops.