



Grading NASA's Solar System Exploration Program: A Midterm Report



NASA Briefing January 11, 2008

**Report Released
November 28, 2007**

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Congressionally-mandated study (NASA Authorization Act of 2005)

- **The NRC is to conduct four “performance assessments” of NASA’s response to the decadal surveys.**
- **NASA Astronomy and Astrophysics Performance Assessment (NAPA) submitted to NASA in February.**
- **Contractual due date for solar system exploration program assessment: December 2007.**
- **Will be followed by Heliophysics and then Earth Sciences at approximately one-year intervals.**

Committee Charge

The Space Studies Board shall convene a committee to review the alignment of NASA's Planetary Exploration Division program with previous NRC advice – primarily the reports “New Frontiers in the Solar System: An Integrated Exploration Strategy” and several recent studies concerning Mars, such as “Assessment of Mars Science and Mission Priorities.” More specifically, the committee shall address the following:

- 1) The degree to which NASA's current solar system exploration program addresses the strategies, goals, and priorities outlined in Academy reports;**
- 2) NASA progress toward realizing these strategies, goals and priorities; and**
- 3) Identify any actions that could be taken to optimize the science value of the program in the context of current and forecasted resources available to it.**

Committee Charge

“The review should not revisit or alter the scientific priorities or mission recommendations provided in the cited reports, but may provide guidance about implementing the recommended mission portfolio in preparation for the next decadal survey.”

(next solar system decadal won't start before late 2008/early 2009)

Committee Roster

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Committee Process

Divided into five working groups:

- **Science**
- **R&A, Planetary Astronomy, Data Analysis**
- **Technology Development & Infrastructure**
- **Mars Architecture**
- **Flight Missions**

Assess NASA progress against Decadal and Mars Architecture:

- **Assess against each stated recommendation in the two documents**
- **Determine how well NASA has done in meeting the recommendation**
- **Articulate findings in a few paragraphs**
- **Favor conciseness and clarity over detail**
- **Provide academic style grade (A,B,C,D,F) for current state**
- **Provide trend arrow for past progress and future potential**
- **Be not judgmental on deficiencies**
 - **Provide potential reasons for slow or non-performance**
 - **Provide recommendations for recovery for low grades (C and below)**

Grades and Arrows

Grades:

- **A: achieved or exceeded the Decadal or Architecture goal**
- **B: partially achieved goal or made significant progress**
- **C: some progress towards goal or achieved supporting objective**
- **D: little progress towards goal**
- **F: no progress or regressed**

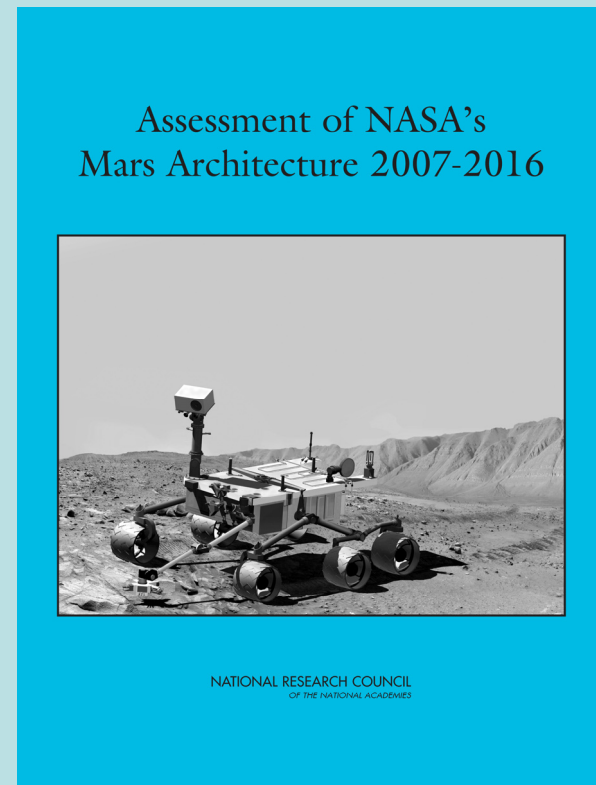
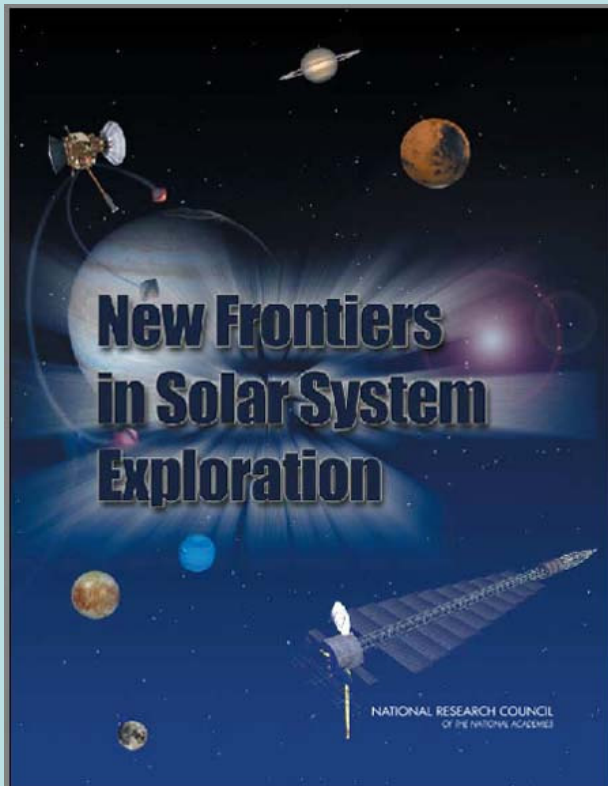
- **Withdrawn: goal dropped**
- **Incomplete: unable to assess**

Trend Arrows:

- **Up Arrow: improving**
- **Right Arrow: no change**
- **Down Arrow: getting worse**

Full Meetings: 22-24 February, 26-28 March, 7-9 May

- Heard from NASA and Congressional Officials, Pls, Decadal Survey leads, COMPLEX, COEL, Cost Estimator, DSN, Technology, and L/V experts.
- Site visits to JPL, APL, GSFC, and ARC.
- Committee compared the Decadal Survey and the NRC report *Assessment of NASA's Mars Architecture 2007-2016* to NASA plans and accomplishments to date.



OVERALL SUMMARY FOR SOLAR SYSTEM EXPLORATION PROGRAM

Grade: B

Trend: Down

Halfway into the 2003-2013 decade covered by the decadal survey *New Frontiers in the Solar System*, NASA has made significant progress toward implementing the recommendations of the decadal survey and the Mars architecture report. The current planetary exploration program is highly productive, carrying out exciting missions and making fundamental discoveries.

However, the committee awarded a downward trend arrow because the committee concluded that this progress is unlikely to continue at the present rate, and that *on its current course NASA will not be able to fulfill the recommendations of the decadal survey.* The reasons for this are reduced investment in research, data analysis, technology development, and smaller mission programs, coupled with increasing mission costs, overruns on approved flight projects, and spiraling launch vehicle costs. The committee weighted these areas more than others and notes that these are all areas that are required for further progress to continue. The trends in these individual areas mean that future progress toward fulfilling the recommendations of the decadal survey is unlikely. NASA has also made insufficient investment in vital infrastructure such as the Deep Space Network. The committee also notes that NASA has failed to start the Europa mission that was the highest-priority mission recommended by the decadal survey. In addition, NASA has neglected work on the Mars Sample Return mission, particularly technology development. Although the agency indicates that this situation may change, the committee notes that only significant progress can erase skepticism about the prospects in this area.

Yesterday's investments have created a momentum that will carry the program for a few more years before the consequences of today's reductions become apparent. *The future of the nation's solar system exploration program as laid out in the decadal survey for 2003-2013 is in jeopardy unless NASA makes an effort to improve the situation.*

Working Group Summary Grades

Science: Grade B, Trend ok

excellent results from current missions

loss of astrobiology funding and future mission-related technology

R&A, Planetary Astro, Data Analysis : Grade C, Trend down

loss of funding, particularly astrobio, support of LSST/JWST/Arecibo

Technology: Grade D, Trend down

loss of funding will lead to major loss of future mission capability

Flight Missions: Grade B, Trend down

current missions performing marvelously

launch rate down, especially Discovery, costs up incl L/Vs, no Europa

Mars Exploration Program: Grade A, Trend ok

only strategic program in portfolio, marvelous performance & plans

lack of progress towards MSR

executive hearing on plans for MSR, needs community input

TABLE ES.1 Science Questions and Progress

| Crosscutting Themes and Key Questions ^a | Grade | Trend |
|---|-------|-------|
| <i>The First Billion Years of Solar System History</i> | | |
| 1. What processes marked the initial stages of planet and satellite formation? | B | ↑ |
| 2. How long did it take the gas giant Jupiter to form, and how was the formation of the ice giants (Uranus and Neptune) different from that of Jupiter and its gas giant sibling, Saturn? | C | ↑ |
| 3. How did the impactor flux decay during the solar system's youth, and in what way(s) did this decline influence the timing of life's emergence on Earth? | B | → |
| <i>Volatiles and Organics: The Stuff of Life</i> | | |
| 4. What is the history of volatile compounds, especially water, across the solar system? | A | ↑ |
| 5. What is the nature of organic material in the solar system and how has this matter evolved? | B | ↑ |
| 6. What global mechanisms affect the evolution of volatiles on planetary bodies? | B | → |
| <i>The Origin and Evolution of Habitable Worlds</i> | | |
| 7. What planetary processes are responsible for generating and sustaining habitable worlds, and where are the habitable zones in the solar system? | A | ↓ |
| 8. Does (or did) life exist beyond Earth? | C | ↓ |
| 9. Why have the terrestrial planets differed so dramatically in their evolutions? | A | ↑ |
| 10. What hazards do solar system objects present to Earth's biosphere? | B | ↑ |
| <i>Processes: How Planetary Systems Work</i> | | |
| 11. How do the processes that shape the contemporary character of planetary bodies operate and interact? | B | ↓ |
| 12. What does the solar system tell us about the development and evolution of extrasolar planetary systems, and vice versa? | B | → |

^aReprinted from National Research Council, *New Frontiers in the Solar System: An Integrated Exploration Strategy*, The National Academies Press, Washington, D.C., 2003, p. 30.

TABLE ES.2 Flight Missions and Implementation

| Flight Missions | Recommendation ^a | Status | Grade | Trend |
|---|---|--|----------|----------|
| “Large” flagship Missions | | | | |
| “Large” flagship missions overall | One per decade | None yet to date. | D | → |
| Europa Explorer | Start Europa mission | Under extensive study, no new start to date | | |
| “Medium” New Frontiers Missions | | | | |
| “Medium” New Frontiers missions overall | 3-4 per decade | One launched, one in development, new AO imminent | B | → |
| Kuiper Belt/Pluto Explorer | Top priority | New Horizons mission launched | A | → |
| Jupiter Polar Orbiter with Probes | Third priority | JUNO orbiter selected w/o probes | A | → |
| South Pole Aitken Basin Sample Return | Second priority | Option for next AO | - | - |
| Comet Surface Sample Return | Fifth priority | Option for next AO | - | - |
| Venus In Situ Explorer | Fourth priority | Option for next AO | - | - |
| “Small” Discovery Missions | | | | |
| “Small” Discovery missions overall | One launch every 18 months | No full mission selected in 5 years; two missions of opportunity selected | D | → |
| Mars Exploration Program | | | | |
| Mars Exploration Program overall | | | A | → |
| Mars Science Laboratory 2009 | Conduct Mars Science Laboratory | In development for 2009 | B | → |
| Mars Science and Telecom Orbiter 2013 | Conduct Mars Science Orbiter | Planned for 2013, science still under definition | A | ↑ |
| Mars Astrobiology Field Laboratory | Option for 2016 | Instrument development required | A | → |
| Mars Mid-rovers | Option for 2016 | Option for 2016 | A | → |
| Mars Long-lived Lander Network | Option for 2016 | Option for 2016 | A | → |
| Mars Scouts | One launch every 52 months | Phoenix launch 2007, selection for 2011 imminent | A | ↑ |
| Mars Sample Return | Start technology development for Mars Sample Return | Progress spotty on enabling technology and no recent systematic mission planning, but recent signs that this will change | C | ↓ |

NOTE: AO, Announcement of Opportunity.

^aRecommendations summarized from National Research Council, *New Frontiers in the Solar System: An Integrated Exploration Strategy*, The National Academies Press.

Chapter 2, Science Recommendations

Recommendation: The next decadal survey should address the objectives and merits of a Neptune/Triton mission.

Recommendation: NASA should return Astrobiology Science and Technology Instrument Development funding and Astrobiology Science and Technology for Exploring Planets funding back to at least their individual Planetary Instrument Definition and Development levels. However, this should not be accomplished to the detriment of the astrobiology research and analysis program, which has already suffered large cutbacks.

Chapter 3, Flight Missions Recommendations

Recommendation: To ensure that flagship mission costs do not negatively impact missions in other cost classes, NASA should apply sufficient resources to obtain good cost estimates in the earliest phases and rigorously review mission costs before selection.

Recommendation: NASA should continue studying possible flagship missions to both the inner and the outer planets as input to the next decadal study.

Recommendation: NASA should select a Europa mission concept and secure a new start for the project before 2011.

Recommendation: NASA should increase the rate of selection and launch of New Frontiers missions.

Recommendation: The New Frontiers missions should follow a two-stage development process, starting with (1) an opportunity to submit a proposal for funding for 1 or 2 years to develop mission concepts. This earlier stage would provide for some endorsement of the best ideas so that they can attract industry and NASA center support. Such support, in turn, would (2) allow more concepts to reach a level of maturity required for considering full-scale proposal development.

Recommendation: NASA should select two of the three Discovery missions currently in phase-A studies (if two are sufficiently meritorious to be selectable) and should seek to achieve an 18-month period between selections for the rest of the decade. These steps can help to restore vitality to this important program.

Recommendation: NASA should return to conducting Senior Reviews once every 2 years to improve efficiency.

Chapter 5, Research and Analysis

Recommendation: NASA should restore an adequate funding level for astrobiology research, based on consultation with the scientific community, that will lead to the achievement of the goals of the *New Frontiers in the Solar System* decadal survey. NASA should provide a stable and sustainable funding environment that is adequate to ensure the vitality and continued scientific productivity of all its research and analysis programs.

Recommendation: NASA should continue to work to more completely integrate astrobiology into all solar system science disciplines.

Recommendation: NASA should improve the visibility of its Fellowships for Early Career Researchers program and advertise it as a postdoctoral program. NASA should also expand the participating research program areas to include origins of solar systems, as well as all appropriate space mission data analysis programs.

Recommendation: NASA should establish formal contacts with the Large Synoptic Survey Telescope project.

Recommendation: NASA should incorporate into the James Webb Space Telescope as quickly as possible the capability to track moving solar system objects.

Recommendation: NASA Announcements of Opportunity should require each space mission proposal to explicitly estimate and budget for archiving activities.

Recommendation: NASA should consider encouraging principal investigators to offer archival data sets in their initial proposal, so that the review panels can assess their desirability.

Chapter 4, Mars Recommendations

Recommendation: NASA should begin actively planning for Mars Sample Return, including precursor missions that identify and cache well-characterized samples of both geological and biological interest.

Recommendation: NASA should begin consulting various groups such as MEPAG and the astrobiology/exobiology research community to assess the current state-of-the-art in laboratory analysis instruments, identify where further development would be beneficial for Mars sample analysis and biosignature detection, and verify that the needed instruments, laboratory facilities, and new researcher training will be made available as part of the sample-handling facility as soon as samples are returned.

Recommendation: NASA should begin robust technology investment aimed at reducing the risk associated with the four major engineering challenges of a successful Mars Sample Return, that is, the definition, design, and development of:

A Mars sample receiving facility that can serve to certify the samples as safe for distribution;

A sample return vehicle that can provide a high probability of successful sample return to Earth consistent with the NASA Planetary Protection Officer's and Committee on Space Research (COSPAR) guidelines;

Autonomous on-orbit rendezvous and docking capability at Mars for sample transfer and return; and

A Mars ascent vehicle that is capable of being transported to Mars, landing, and returning cached samples to Mars orbit.

Chapter 4, Mars Recommendations (cont.)

Recommendation: NASA should take all the scientific, programmatic, and technical information available and make a decision on a mission queue that includes the 2016 and 2018 Mars launch opportunities.

Recommendation: NASA should seek community review to carefully scrutinize the new Mars architecture and its budget implications to ensure that the value of the sample returned is worth the cost to the Mars Exploration Program.

Chapter 6, Enabling Technologies

Recommendation: NASA should develop a strategic plan for technology development and infusion independent of flight programs. In addition, NASA should restore funding to its New Millennium program.

Recommendation: NASA should conduct a study of the trade-offs of the cost versus risk of developing a Ka-band array system to handle the required transmissions (uplink and downlink) and determine whether optical communications are required for data delivery during the 2013-2023 time frame. Prior to the next decadal survey, NASA should present the results of such a study to the science community.

Recommendation: NASA should make an assessment of which technologies will be required for Mars Sample Return and conduct an independent assessment of the analogous technology needs for the Moon, Venus, asteroids, and other targets.

Recommendation: NASA should fund the Small Aperture Receive Array for the Deep Space Network and plan to replace the 70-meter antennas with arrays of small-diameter antennas by 2015.

Major Obstacles to Fulfillment

Uncertain budget and reduced expectations.
Flight mission development cost growth.
Flight mission concept costs underestimated.
Increased infrastructure cost.