Mars Scout 2007 - A Current Status[1,2,3]

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Abstract—The Mars Program institutes the Mars Scout Missions in order to address science goals in the program not otherwise covered in baseline Mars plans. Mars Scout missions will be Principal-Investigator (PI) led science missions. Analogous to the Discovery Program, PI-led investigations optimize the use of limited resources to accomplish focused science and allow the flexibility to quickly respond to discoveries at Mars. Scout missions also require unique investments in technology and reliance upon Mars-based infrastructure such as telecom relay orbiters. Scouts utilize a two-step competitive process for selection. In Dec, 2002, the Step 2 selections by NASA were announced and then approximately five month studies will result in a selection for flight around August, 2003 for a mission to be launched in 2007.

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1. OVERVIEW

The NASA Discovery and Explorer programs are quite successful at using a competitive Announcement of Opportunity (AO) for PI-led missions to accomplish focused science. The Mars Program institutes Scout Missions that use some aspects of the Discovery program as a model. However, several aspects of Scout missions are unique because of the Mars environment. To enable robust missions, the Mars technology program must make investments in key areas. And, since the Scout missions will tend to be smaller and resource-limited, there will most likely be reliance upon infrastructure (both at Mars and at Earth). In this context, Program infrastructure is defined as telecom relay assets in orbit at Mars, common operations infrastructure, and possibly even a "ride" to Mars on another mission such as a Mars lander. Together, focused science, technology, and Mars infrastructure allow a robust structure that enables Scouts to respond quickly to new Mars discoveries.

Also similar to Discovery is the method used to select a Scout mission for flight in 2007. The process takes two steps. Step 1 solicits compact proposals from Principal Investigators that emphasize the science of the proposal. Half of the allotted pages cover science and science implementation. Step 1 proposals are then evaluated by NASA after receipt of proposals. Then, the highest science value concepts that are low risk are asked to prepare Step 2 (or Phase A) studies that are submitted to NASA. NASA then confirms one of the Step 2 Phase A studies to move onward to Phase B and eventual flight to Mars in 2007 to Mars. The Step 2 selections were just announced in December, 2002 and will be described in further detail later in this paper.

2. PROGRAM STRUCTURE

Mars Scout missions are PI-led and use a selection process similar to the current NASA Discovery program as outlined above. The first Scout mission will launch to Mars in 2007. Hopefully, the Scout mode of competitively selected missions will prove fruitful and future Scout opportunities will occur in the next decade.

Pre-AO Definition

Previous work included a Mars Scout workshop in May, 2001 to bring the science, mission, and technology communities together to foster new Scout concepts. It is important at the beginning of a new program to have such a workshop to describe to the community what the vision, requirements, and constraints of the program will be. Also, having scientists, mission architects, and technologists mingle fosters the creation of new ideas and teams. After the workshop, NASA funded ten competitively selected concept studies at approximately $150K a piece. The goal of these studies was to refine the possible science within a mission and technology context while keeping in mind a cost cap of $300M (FY '02). Note that NASA decided to increase the cost cap for the Mars Scout Announcement of Opportunity to $325M (FY '03) partially in response to the ensemble of concept study results. These ten studies did not prejudice the subsequent NASA Announcement of Opportunity (AO) (see IEEEAC paper #384, Updated Nov. 15, 2001 by

1 0-7803-7651-X/03/$17.00 © 2003 IEEE
2 IEEEAC paper #525.
3 The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.
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Matousek for more details on the 2001 Scout concept studies).

AO Process

The Scout AO process is a two-step process very similar to Discovery. The AO was released May 1, 2002. Note that this release date allows sufficient time for the selection process, Phase B, and the design, build, assemble, and test of Phase C/D before launch in 2007 (see Table 1 for a detailed Scout end-to-end schedule). Proposal submittal occurred by August 1, 2002. Then, the NASA HQ evaluation process combs through the proposals in excruciating detail to determine highest science value concepts that can be developed for flight. Panels of science peers and technical experts with no connection to any of the proposals evaluate the submissions. This process culminated in selection of four mission concepts for further study with announcement of selection December 6, 2002. Then, the second step, roughly equivalent to a phase A study in depth and scope, proceeds with selected proposals receiving $600K for a study. Note that the typical $450K of past Discovery Step 2 studies has been increased to enable the study teams to produce an even better product. This five-month Step 2 study period culminates in NASA HQ evaluating these proposals and selecting one for flight sometime in August, 2003.

It should also be noted that the Mars Scout AO solicited Mission of Opportunity (MOO) proposals. Missions of Opportunity are investigations NASA would fund on non-NASA missions. NASA decided not to select any MOOs through this AO since the 2007 CNES Mars Premier orbiter that was the most likely candidate for MOO proposals has an uncertain status due to potential CNES funding shortfalls.

Table 1: Scout End-to-End Schedule for 2007

Event	Date(s)	Comments
Scout Concept Initiated	Summer, 2000	At Mars Synthesis workshop
Initial Scout Proof-of-Concept Studies	Sep., 2000 – Feb., 2001	Studied viability of generic Scout concepts.
Scout Concept Workshop	May, 2001	43 Concepts submitted.
Concept Studies Initiated	June, 2001	10 Concepts selected for 6 month, $150K studies.
Concept Studies Finished	January, 2002	Final reports and briefing to NASA HQ (data is proprietary).
Scout 2007 AO Released	May 1, 2002	Life Cycle Cost Cap is $325M (FY '03)
Scout 2007 AO Proposals Due	August 1, 2002	18 full mission proposals, 5 MOO
Scout 2007 Step 2 Selections	December 6, 2002	NASA selects four concepts for 5 mon, $600K studies.
Scout Step 2 Phase A Reports Due	May 15, 2003	
Selection for Flight	Early August, 2003	One mission selected for launch in 2007
Begin Phase B	~ September, 2003	Allows for ~ 12 month Phase B.
Begin Phase C/D	~ Aug/Sep, 2004	Allows for ~ 36 month Phase C/D.
Launch	~ Aug/Sep, 2007	Must launch by December 31, 2007

3. Selection Process

The Scout 2007 Announcement of Opportunity (AO) was open to all and is available on the NASA Code S Research Opportunities World Wide Web (WWW) site at:

http://research.hq.nasa.gov/code_s/nra/current/AO-02-OSS-02/index.html

or in the future at the NASA Code S research opportunities WWW site at:

http://research.hq.nasa.gov/code_s/archive.cfm

To quote from the AO:

"Investigations proposed as Mars Scouts may include remote observations from Mars-orbiting spacecraft; missions that may deploy aerial or landed systems to study the Martian atmosphere, surface, interior, geopotential fields, and/or deep subsurface; and sample return missions. In all cases, however, Mars Scouts are intended to augment or complement and not duplicate major missions currently being planned as part of NASA's Mars Exploration Program (MEP) or those planned by foreign` space agencies."

Full missions proposed to the AO must be less than $325 million (FY '03), Phase A through science data archival after mission end. In the first step of this process, teams submit proposals to NASA and the proposals are evaluated mostly on science merit. Again, to quote from the AO on the evaluation criteria:

"The evaluation criteria are as follows:

- The scientific merit of the proposed investigation;
- The technical merit and feasibility of the proposed investigation; and
- The feasibility of the proposed approach for mission implementation, including cost risk."

The NASA evaluation leads to the selection of the top science proposals that appear to be within the bounds of the cost cap, the available schedule, and acceptable project risk. Small teams of science and technical peers that are not conflicted evaluate the proposals over several months. Proposers are given the benefit of the doubt if there are uncertainties in any areas of the proposal. This is because page count for information transfer is limited and proposals are judged on material only in the proposal. NASA makes a selection from the top ranked proposals, and these four concepts are looked at in much more detail in the Step 2 Concept Study Reports (CSR's) (equivalent to Phase A studies). In Step 2, ideally science stays fixed and the mission implementation details (technical, cost, and cost risk) are studied further. Then, after the studies are competed and the CSR is turned in to NASA for evaluation from each of the four teams, NASA evaluates the technical feasibility, cost, and cost risk of each CSR. This process culminates in the selection of the mission for flight.

4. The Final Four

Each of the selected four proposals for Step 2 contain outstanding science. These four proposals were among 25 submitted to NASA. Of the 25, two were deemed non-compliant and were returned to the proposers. The remaining 23 consisted of five Mission of Opportunity (MOO) and 18 full mission proposals. NASA does not intend to select any MOO's as the most likely candidate for MOO selection, the CNES Premier orbiter in 2007, has been deferred or cancelled due to the French space agency's current budgetary difficulties. Of the remaining 18 full mission proposals, two were for orbiters, four for landers, two for networks, five for rovers, four for aerial, and one for a dust/gas sample return (see Figure 1 for a graphic of the distribution).

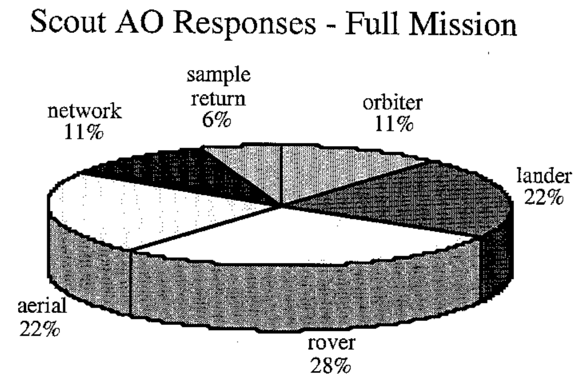

Figure 1 – Breakdown of Scout AO Step 1 Responses.

The selected four Step 2 contenders are (in order of the NASA press release, and quoting liberally from the NASA press release of December 6, 2002):

- SCIM (Sample Collection for Investigation of Mars), with Professor Laurie Leshin, Arizona State University, Tempe as Principal Investigator. This innovative mission would sample atmospheric dust and gas using aerogel and use a "free-return trajectory" to bring the samples back to Earth. Such samples could provide breakthrough understanding of the chemistry of Mars, its surface, atmosphere, interior evolution and potential biological activity.

- ARES (Aerial Regional-scale Environmental Survey), with Dr. Joel Levine, NASA Langley Research Center, Hampton, Va. ARES offers to provide the first in situ measurements of the near-surface atmospheric chemistry within the Mars planetary-boundary layer, thereby providing critical clues to the chemical evolution of the planet, climate history, and potential biological activity.

- Phoenix, with Dr. Peter Smith, University of Arizona, Tucson as Principal Investigator. This mission proposes to conduct a stationary, in situ investigation of volatiles (especially water), organic molecules and modern climate. It aims to "follow the water" and measure indicator molecules at high-latitude sites where the Mars Odyssey orbiter currently in orbit about Mars has discovered evidence of large ice concentrations in the Martian soil.

- MARVEL (Mars Volcanic Emission and Life Scout), Dr. Mark Allen, NASA Jet Propulsion Laboratory, Pasadena, California as Principal Investigator. This mission proposes to conduct a global survey of the Martian atmosphere's photochemistry to search for emissions that could be related to active volcanism or microbial activity, as well as to track the behavior of water in the atmosphere across a full annual cycle.

SCIM utilizes a unique free Earth return trajectory that allows the spacecraft to return with dust and atmospheric samples from as low as ~ 40 km from the surface of Mars. The spacecraft has an aerodynamic shape that minimizes loss of velocity due to drag while in the Martian atmosphere.

ARES utilizes a "rocket" plane to fly for up to 90 minutes close to the surface of Mars. The plane is delivered by a carrier spacecraft and the carrier also functions as a communications relay during the descent of the airplane probe through the upper reaches of the atmosphere. Then, the carrier relays back the science data during the airplane flight.

Phoenix utilizes the cancelled 2001 lander that is currently in storage. It also utilizes "build-to-print" copies of Mars Polar Lander instruments and some flight instruments developed and in storage for the cancelled 2001 lander.

MARVEL utilizes a slight modification of the Mars 2001 Odyssey orbiter to globally observe the atmosphere for at least one Mars year.

These four concepts represent exciting possibilities for the 2007 Mars Scout mission. It will be difficult to pick one winner. But, this will be done sometime in early August, 2007.

5. Scout Program Challenges

The 2007 Mars Scout schedule leading up to launch does not allow much time for new technologies from the Mars Technology Program, and other technology development programs, to be introduced as the schedule is too short. However, it is clear that future Scout opportunities in the next decade from 2010-2020 need new technologies to succeed. Many concepts have been envisioned for which there is no moderate risk way to implement them. This section attempts to outline some of these technologies in order to highlight possibilities that Scout could be in the near future.

Technology for the Future of Scout

Scout technologies identified to date for possible development include:

- Small Entry/Descent/Landing (EDL) systems
- Lightweight propulsion components and tanks
- Lightweight communications equipment
- Lightweight, highly capable science instruments

- Entry, Descent, and Landing (EDL) for small entry probes
    - Precision control of atmospheric interface point
    - Small, low power, low cost inertial measurement sensors
    - Low mass, low power alternative precision guidance techniques
    - Hard landing impact attenuation

- Lightweight propulsion components

- Aerial vehicle technology
    - Robust, lightweight deployment
    - Small, lightweight aerial vehicles
    - Guidance and navigation techniques during the atmospheric flight
    - Post-surface impact data return

- Solar Surface Power Technologies (all aspects, including solar panels and dust mitigation techniques)

- Small, low power (mW-10W), low mass nuclear power systems for long-life small landers and penetrator.

Entry, Descent, and Landing (EDL) for small entry probes:

Scout missions using small entry probes provide several unique challenges. Severe mass, power, and volume constraints generally mean that small probes have less accurate EDL than larger systems currently envisioned in the future MEP. Increasing the EDL capabilities of small probes could lead to future breakthroughs in low cost missions. Several areas are identified below as being of particular interest:

Precision control of atmospheric interface point for probes

Increased precision in controlling the Mars atmosphere interface point leads to increased ability to target surface and near-surface areas. Better targeting increases accessibility and science return.

Small, low power, low cost inertial measurement sensors

Inertial measurement is required in most mission concepts involving entry and descent. Smaller systems enable more payload and/or smaller probes. Examples of systems in this area are gyros and accelerometers.

Low mass, low power alternative precision guidance techniques

Current precision guidance techniques only work on large systems of hundreds to thousands of kilograms. Smaller systems cannot devote the same mass and power to guidance as the larger systems. New methodologies (algorithms, software, sensors, and actuators) that can provide low mass, low power, low cost precision guidance techniques are needed.

Hard landing impact attenuation

Small, low cost surface missions sometimes cannot afford to have mass devoted to lowering surface impact velocities. Low mass, low power impact attenuation technologies can enable a new class of future surface landers.

These technologies, should they be developed, will enable Scouts to provide focused science for low cost.

Utilization of Infrastructure

Scout missions generally benefit greatly from the ability to utilize infrastructure at Mars and Earth. For example, critical event coverage usually can only be achieved with the help of previous, at-Mars orbital assets. Therefore, these mission types rely on telecommunications orbiters already in orbit about Mars to relay data back to Earth. Current plans have at least one orbiter available to relay data from the surface or near surface of Mars. Of course, Scout missions need to share infrastructure resources with other Mars missions. A Mars Program challenge is balancing the data relay and navigation needs of the multiple Mars missions (including a 2007 Scout mission).

6. The Future

Current plans have the first Mars Scout mission launching in 2007. The first mission will be selected around August, 2003 from one of the four exciting candidates discussed earlier in this paper. A second mission is likely to be launched to Mars in 2011, should the first mission development appear to be a success in 2006. 2006 is the year that a competitively selected 2011 Scout mission would need to start the Announcement of Opportunity process. Current advance planning for the next decade of Mars exploration has a Scout mission tentatively launching every four years. Of course, this flight rate is subject to change depending upon the structure of the Mars Program in the next decade. Whatever the flight rate, these competed Scout missions provide focused science able to respond to startling discoveries sure to come. The Mars Program looks with excitement to the first PI-led, competitively selected Mars Scout mission in 2007.

Steve Matousek is currently the Mars Scout Program Manager in the Mars Exploration Program Office at the Jet Propulsion Laboratory. Previously, he was the Deputy Manager of Solar Exploration Advanced Studies and Preprojects at JPL. In that position, he studied and created study teams for advanced concepts for solar-system exploration. His prior work includes supervising the Mars and Microspacecraft Mission Architecture Group as well as numerous NASA Announcement of Opportunity responses to Discovery, MIDEX, and SMEX. He started his career at JPL in 1985 by having the honor of working on the Voyager navigation team as a trajectory engineer for the 1985 Uranus encounter and the 1989 Neptune encounter. Steve's first space job was as a student command controller for the Solar Mesospheric Explorer at the University of Colorado. He also serves AIAA as a member of the Space Systems Technical Committee.