Mars Scouts: An Overview

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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 the baseline Mars plan. 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 the best 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 telecomm relay orbiters.

Overview

The NASA Discovery program is quite successful at using a competitive Announcement of Opportunity (AO) for Principal Investigator (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 to Mars. To enable robust missions, the Mars technology program must make investments in key areas. And, since the missions will tend to be smaller and resource limited, there is reliance upon Mars infrastructure (both at Mars and at Earth). In this context, Program infrastructure is telecom relay assets in orbit at Mars, common operations infrastructure, and possibly even a ride to Mars on another mission like a Mars lander. Taken together, focused science, technology, and Mars infrastructure allow a robust structure that allow Scouts to respond quickly to new Mars discoveries.

Program Structure

Mars Scout missions are PI-led and use a two step selection process similar to the current NASA Discovery program. Current program projections have a Scout mission launching in the 2007 Mars opportunity. Current technologies slated for development in Scout missions include: small Entry/Descent/Landing (EDL) systems, lightweight propulsion components and tanks, lightweight communications equipment, and lightweight, highly capable science instruments. These technologies will enable Scouts to provide focused science for low cost.

Pre-AO Definition

Current work centers on defining the Scout missions in terms of science objectives, possible mission implementation, required technology, cost, risk, and schedule. A current high-level schedule for the Scout program shows that there is sufficient time to allow definition concept studies (see Figure 1, Draft 2007 Mars Scout High Level Schedule). A recently completed Scout workshop had 43 mission concepts submitted for possible selection of a six month, ~$150K study. Of the 43 submissions, ten concepts were selected for further study (see Table 1: Mars Scout Studies Summary). The purpose of these studies is to define the scope of what is possible with Scout missions. Study products include science objectives and required instrumentation, mission concept, required new technology, ROM cost, risk identification, and schedule. Results of the studies will be used as input to the

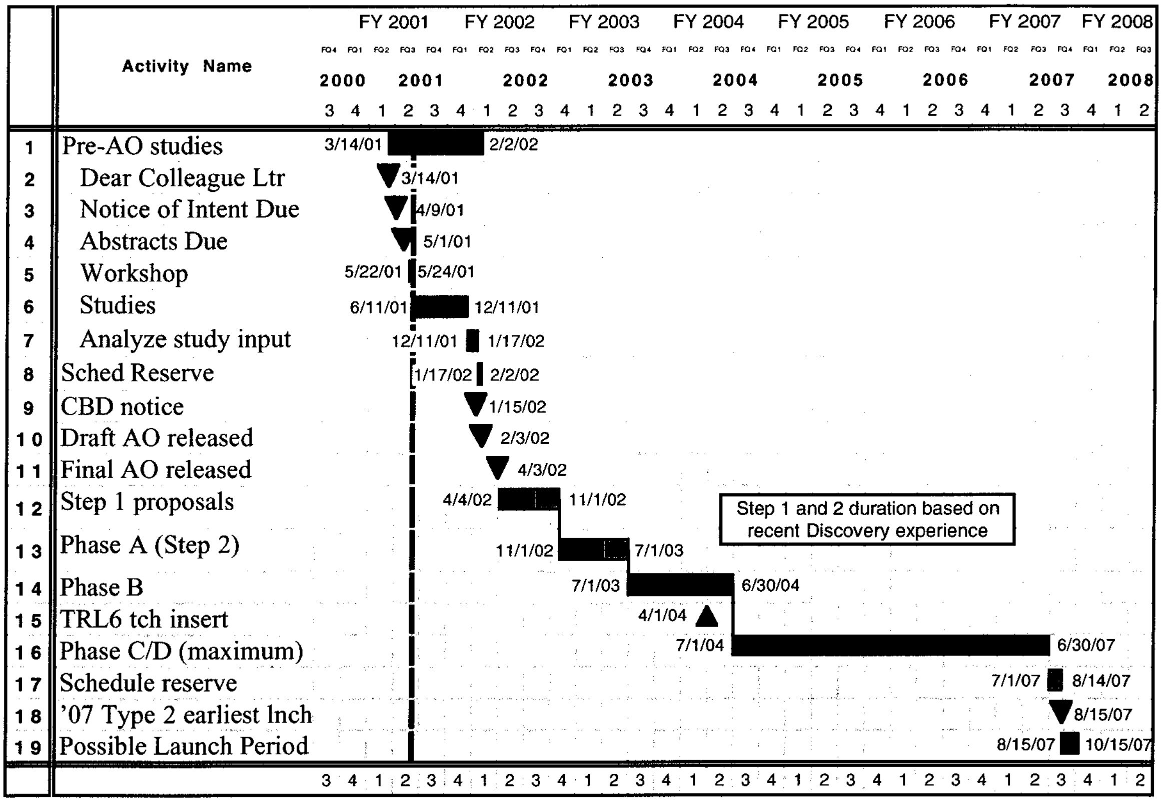

Figure 1: Preliminary high-level 2007 Scout representative schedule shows the pre-AO studies, two-step selection process, maximum phase B, maximum phase C/D, and earliest possible launch date including 8 weeks of schedule reserve above and beyond the normal Discovery-like schedule.

Table 1: Ten Selected Scout Studies (of 43 submitted mission concepts)

AREA	STUDY TITLE	PI (INSTITUTION)	SHORT DESCRIPTION
Landers/Rovers	The Urey Mission	Plescia (USGS)	Rover for age dating
	The NAIADES	Grimm (Blackhawk Geoservices)	Low-frequency EM Sounding for Groundwater
	Artemis	Paige (UCLA)	Multiple polar scouts
	Cryoscout	Carsey (JPL)	Polar probe melts into ice
	PASCAL	Haberle (ARC)	Global meteorology network
Orbiters	Mars SAR	Campbell (Smithsonian)	Global imaging radar from orbit
	Mars Atm Const Obs	Kursinski (U of AZ)	Radio sounding of Mars atm from multiple orbiters
	Mars Env Obs	Janssen (JPL)	Orbital obs of Mars atm
Aerial	KittyHawk	Calvin (U-NV Reno)	Multiple gliders observing Valles Marineris
Other	Sample Collection for Inv of Mars	Leshin (ASU)	High altitude Martian dust collection via atm flyby

AO process. It should also be noted that selection for a study does not prejudice the AO selection process.

AO Process (Preliminary)

The current Scout AO process is a two-step process very similar to Discovery. The initial draft AO will most likely be released around February, 2002. The final AO will then be released about two months later. Proposers will have four months to respond to the AO. Then, a three month NASA HQ evaluation process will culminate in selection of a handful of concepts for further study. This second step, roughly equivalent to a phase A study in depth and scope, will then proceed with selected proposals receiving ~$500K for a Step Two study. A five-month step two study culminates in NASA HQ evaluating the handful of proposals and selecting one for flight.

Possible classes of missions

Scouts focused science objectives appear to fall into one of five categories of missions:

- small science orbiters
- aerial missions
- network missions
- small landers/rovers
- other (combinations of 1-4, or new ideas)

Small Science Orbiters

This Scout category includes polar science orbiters that wish to globally observe Mars surface or atmosphere over at least a Mars year. Characteristics of small science orbiters include the need to return relatively large amounts of data, the need to return data over one or more Mars years, and the desire to observe Mars from as close as possible. These orbiters generally require few, if any, infrastructure elements at Mars. Scout science orbiters minimize the science payload by focusing the science objectives and require few instruments on the orbiter. Some intriguing variations exist such as multiple orbiters observing several hundred radio occultations per day to measure temperature and pressure variations in the martian atmosphere. Currently, the Mars Program requires all orbiters to carry an UHF in-situ relay communications package. While still subject to debate, current requirements have Scout science orbiters carrying a minimal UHF relay package to enable the Scout orbiter to become part of a growing Mars telecommuncations/navigation infrastructure.

Aerial Missions

This class of Scout mission uses the martian atmosphere as a way to provide mobility. Included in this category are balloons (super-pressure and Montgolfierre), gliders, and powered airplanes. Most concepts involve deployment from an aeroshell directly to flight in the atmosphere. Current concepts have not demonstrated deployment at Earth in Mars-live conditions. Mars-live conditions at Earth occur in the atmosphere above 100,000 ft. (density of the atmosphere only, the gravity field of Mars at ~ one-third of Earth s is not simulated). Balloons have the advantage of long duration flight (hours to days or weeks) and the disadvantage of being at the mercy of the prevailing winds. Gliders and airplanes have the advantage of controlling their flight over the terrain, but suffer from having shorter duration flights (minutes to hours). Airplanes have the additional advantage over gliders of longer flights. However, less payload can be carried on an airplane as the engine takes up mass and volume that can be devoted to payload in a glider. Aerial missions require the use of infrastructure elements as they need to relay their data to other mission elements at Mars for transmission to Earth. This is generally accomplished via an orbiter that has line-of-sight to the aerial vehicle for burst radio transmission of data. The communications distance is too great to expect small aerial vehicles to be able to transmit any quantity of data directly to Earth. Advantages of aerial vehicles include closer observation of the martian surface and ability to cover more ground than rovers and landers.

Network Missions

These Scout missions have multiple probes placed over large areas of Mars. The science objectives of this class of missions include global/regional meteorology and global/regional seismic studies. These missions generally require at least one Mars year of operation. The probes rely on in-situ communications/navigation infrastructure as the small, resource-limited payloads can only transmit information at very low power (milliwatts to watts). Technological challenges for these systems include small, lightweight power and telecommunications systems, small, very lightweight sensors, and small, lightweight, high energy density batteries or radioisotope power sources. Surviving a Mars year on the surface at any latitude has particular difficulties as temperature and solar flux vary widely with location and season.

Small Landers/Rovers

This area has many possible combinations. Single, moderate size lander elements, with or without small rovers (ala Mars Pathfinder), are at the large end of surface system possibilities. At the smaller end are multiple landers, possibly with nanorovers (like the recently cancelled MUSES-CN nanorover) that are delivered to one or a few sites. Advantages of this type of mission include more resources devoted to the science payload and to communicating the data back. Most concepts require in-situ communications relay orbiters to send data back to Earth. Since the flight systems are relatively small, direct entry or delivery from Mars orbit are possibilities.

Other Mission Types

Numerous combinations of the previous mission categories are possible. However, Scouts generally need to minimize mission elements to minimize complexity and risk. Focused science objectives drive the mission concept to simplicity. One notable mission from the study list is the Mars dust sample return mission where an atmospheric passage with free Earth return brings back martian dust samples from high in the atmosphere.

Observations

To date, the concepts submitted for study selection and the ten selected studies show innovation. Because of this, Scouts appear to have the potential of filling the gap in the baseline Mars program of focused science objectives. Scouts also have the potential to react to inevitable discoveries.

Scout Program Challenges

Technology

First among the Scout program challenges is preparing technology to support this class of missions. A partial list of identified technology areas include:

- lightweight, low power in-situ telecomm systems
- lightweight, low power science instruments
- small, robust EDL systems
- lightweight, high performance propulsion systems (tanks, valves, filters, small impulse bit/high I_{sp} thrusters)
- long-life, low power, low temperature power systems

In order to meet the schedule for 2007 (see figure 1), any technologies enabling a selected mission must be at Technology Readiness Level (TRL) 6 by Critical Design Review (CDR). This date corresponds to April, 2004. Considering the two step selection process, if technology development waits until the selcction for flight is made, this leaves only a maximum of nine months to develop a technology. Clearly, this is not workable. Consequently, appropriate technologies for Mars Scouts need to be developed starting now. Starting now leaves about 2.5 years to develop technologies to TRL 6. The only prudent way to proceed with this technology development is to make use of all technology development related to the core program missions (2007 lander, Mars Sample Return are two prominent examples). Then, only add Mars Scout specific technology development where necessary. Mars Scout technology development will remain a challenge in the foreseeable future .

Utilization of Infrastructure

Scout missions generally benefit greatly from the ability to utilize infrastructure at Mars and Earth. For example, surface or aerial missions do not have sufficient power or antenna size to transmit data directly back to Earth. Therefore, these mission types need to rely on telecommunications/navigation orbiters already in orbit about Mars to relay data back to Earth (see Table 2). 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).

Table 2: Current Mars Relay Asset Assumptions for 2007 Mars Scouts
(subject to change)

RELAY ASSET	MARS ORBIT	AVAILABLE DATE
MRO	Polar, Near-circular, low altitude	May, 2008
ASI comm orbiter	4450 km alt, circular, inc ~ 130.2…	Sep, 2008
CNES orbiter	Circular, 1000 km alt, inc ~ 94.9¡	Sep, 2008

The Future

Current plans have the first Mars Scout mission launching in 2007. The second mission, probably carried to Mars on a lander or orbiter, occurs in 2011 in the current baseline plan. These competed missions provide focused science able to respond to startling discoveries sure to come.

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† NASA TRL 6 denotes System/subsystem model or prototype demonstration in a relevant environment (Ground or Space). Contrast this with TRL 5 Component and/or breadboard validation in laboratory environment and TRL 7 System prototype demonstration in a space environment.

‡ I note here that Scouts appear to depend much more than Discovery missions on key technologies discussed here. Perhaps this is because Discovery missions to date have not had to land on a planetary surface. Mars EDL provides unique challenges for Scouts where key technologies will enable proposed missions. Scouts will need to rely on enabling technologies while minimizing risk.

§ Further data is available from the Request for Mars Scout Concepts document available at http://spacescience.nasa.gov/an/marsscoutsworkshop/

An excerpt is included here:

Telecommunications/Navigation Relay Orbiters with Relay assets:

¥ 2005 Mars Reconnaissance Orbiter (MRO) Relay support will be available beginning in May 2008, however, this support may be limited due to the continuing MRO primary science mission. Full relay support will be available beginning in January 2009. The MRO orbit will be near-circular at 400 km altitude and 92.9¡ inclination (3pm sunsynchronous). This results in a maximum slant range to the orbiter at minimum elevation (15¡) of about 1030 km. The MRO is assumed to have a UHF antenna with a —0.2dBi gain (nadir pointed — 3 dB) at minimum elevation.

¥ 2007 ASI Telecommunications/Navigation Orbiter (ASI Telesat) Relay support will be available beginning in September 2008. (Support may be available as early as mid-August 2008 depending upon arrival date and duration of spacecraft checkout, etc.)

The ASI Telesat orbit will be circular at 4450 km altitude and 130.2¡ inclination (terminator sun-synchronous). This results in a maximum slant range to the orbiter at minimum elevation (15¡) of about 6250 km. The ASI Telesat is assumed to have a UHF antenna with a 7.4 dBi gain (nadir pointed — 3 dB) at minimum elevation.

¥ CNES Netlander Orbiter Relay support will be available beginning in September 2008 through August 2010 (arrival plus one Martian year) , however, this support may be limited due to the Netlander mission relay requirements. Availability may be increased after a minimum 90 sol Netlander mission. Relay support beyond August 2010 is uncertain due to an undefined extended mission for this orbiter. The orbit will be circular at 1000 km altitude and 94.9¡ inclination. This results in a maximum slant range to the orbiter at minimum elevation (15¡) of about 2050 km. The CNES orbiter is assumed to have a UHF antenna with a 1.6 dBi gain (nadir pointed — 3 dB) at minimum elevation.

DSN Resource Assumptions:

¥ Use only 34 meter assets for nominal operations; 70 meter antennas available only for emergency operations.

¥ For a representative description of mission operations services , refer to NASA s Miss ion Operations and Communications Services document provided for the Pluto-Kuiper Belt Mission Announcement of Opportunity (AO: 01-OSS-01) which can be found at: http://centauri.larc.nasa.gov/pluto/NA SA _Miss _Ops_Comm.pdf

Navigation Performance Assumptions:

Stationary Mars surface elements can assume 30m (3sigma) position determination. This position determination assumes the surface element has two-way UHF Doppler capability to one Mars telecommunication / navigation orbiter and several communications passes over a few days occur.