

The Mm-s Environmental Survey (MESUR) Network and Pathfinder Missions

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Abstract

The objective of the Mars Environmental Survey (MESUR) Network mission is to establish a global network of small science stations on the surface of Mars to operate concurrently over a minimum of one martian year. MESUR Network is viewed as an evolutionary and affordable step in the scientific characterization of the martian environment following Viking and Mars Observer and preceding sample return and human exploration missions. The full network is envisioned to consist of 10-20 landers providing pole-to-pole coverage of the planet. The broad science objectives of the MESUR Network mission are to characterize the martian environment in terms of atmospheric structure, internal structure, global atmospheric circulation, surface chemistry, and surface morphology. The strawman science payload for the Network mission includes an atmospheric structure package (pressure, temperature, and acceleration measurements during descent), cameras for descent and surface imaging, 3-axis seismometer, meteorology package (surface pressure, temperature, and wind velocity), Alpha/Proton/X-Ray Spectrometer, Thermal Analyzer/Evolved Gas Analyzer, radio science experiments, and others. The MESUR Network project start is targeted for FY 1996 with the first launch anticipated in 1999. A precursor to the MESUR Network mission, designated MESUR Pathfinder, is targeted for an FY 1994 project start. The objective of the Pathfinder mission is to conduct the engineering demonstrations required prior to the full commitment of funds to develop and proceed with the MESUR Network mission. The primary engineering test performed by Pathfinder will be of an entry, descent, and landing approach which employs an aeroshell, parachute, air bags, and a lander petal system; but no propulsion. This passive entry, descent, and landing system is required to decelerate the vehicle from high entry velocity, achieve a semi-hard landing on the martian surface, and establish an upright configuration for the surface operational phase of the mission.

1. Introduction: Evolution of MESUR

In 1978, the National Academy of Science's Committee on Planetary and Lunar Exploration (COMPLEX) provided direction to the post-Viking Mars exploration program in stating:

"The primary objectives in order of scientific priority for the continued exploration of Mars are:

- (1) The intensive study of local areas:
 - (a) To establish the chemical, mineralogical, and petrological character of different components of the surface material, representative of the known diversity of the planet;
 - (b) To establish the nature and chronology of the major surface forming processes;
 - (c) To determine the distribution, abundance, and sources and sinks of volatile materials, including an assessment of the biological potential of the martian environment, now and during past epochs;

- (d) To establish the interaction of the surface material with the atmosphere and its radiation environment;
- (2) To explore the structure and general circulation of the martian atmosphere;
- (3) To explore the structure and dynamics of Mars' interior;
- (4) To establish the nature of the martian magnetic field and the character of the upper atmosphere and its interaction with the solar wind;
- (5) To establish the global chemical and physical characteristics of the martian surface." [1]

in 1983, the Solar System Exploration Committee of the NASA Advisory Council recognized that the degree to which Mars science objectives could be accomplished depended on the establishment and operation of a network of long-lived science stations at diverse locations on the surface of Mars to perform seismic, meteorological, and geoscience observations [2]. Various concepts to establish a global Mars landed network were studied as part of the so-called "90 Day Study" [3]. In 1991, the NASA Ames Research Center developed an innovative concept for a Mars Environmental Survey (MESUR) mission that involved the phased emplacement of a 16 lander network on Mars beginning with the first launch in the 1998/1999 opportunity and ending in 2006 after one Mars year (1.8 Earth years) of full network concurrent operations [4].

Responsibility for the Phase A study of the MESUR Network mission was assigned to the Jet Propulsion Laboratory (JPL) in November of 1991. In early 1992, JPL was directed to study the feasibility of launching a MESUR Network precursor mission under tight schedule and cost constraints to demonstrate engineering systems and technologies key to the Network. The precursor mission, designated MESUR Pathfinder, is slated for a new start as the first Discovery class mission in October 1994 with a launch in late 1996. The MESUR Network start is targeted for 1996 with the first launch targeted for the 1999 opportunity.

11. MESUR Network

The broad science objectives of the Network mission are to characterize the environment of Mars in terms of the internal structure of the planet, the global atmospheric circulation, the structure of the upper atmosphere, surface morphology, geochemistry, and the elemental composition of rocks [4]. The strawman instrument payload designed to accomplish these objectives include:

Three-axis seismometer

The Network seismometer measures ground motion with high sensitivity, large dynamic range, and large bandwidth. The seismometer requires a deployment mechanism to emplace the instrument in direct contact with the soil a few meters from the lander. The data volume associated with the seismology investigation is estimated at 10 megabits per day per lander after event triggering logic and data compression algorithms are employed. The data volume associated with the seismology investigation is a significant mission driver to develop a high capacity direct-to-Earth downlink or to deploy a Mars Relay Satellite (MRS). In addition, the seismology investigation requires instrument operations over a significant period of time (one Mars year baselined) to insure a high probability that Marsquakes are detected.

Meteorology instruments

The meteorology package measures surface pressure, temperature, wind velocity, humidity, and atmospheric opacity. The baseline meteorology investigation requires a pole-to-pole emplacement of landers and instrument operations over a minimum of one Mars year. The latitude and duration requirements preclude the use of solar powered landers and result in a hardware requirement for

radioisotope thermoelectric generators (RTG's) to provide power to high latitude landers over all martian seasons. However, the science cost of limiting the latitude range and/or duration of the meteorology investigation to allow solar power operations currently is being traded against the cost of RTG-powered landers.

Alpha/Proton/X-Ray (APX) Spectrometer

The APX spectrometer measures the elemental composition of surface soil and rocks for most major elements except hydrogen. The spectrometer must be placed in direct contact with the soil and rock samples to obtain a measurement. Thus, a surface rover, mechanized arm, or other deployment mechanism is required.

Thermal Analyzer/Evolved Gas Analyzer (TA/EGA)

The TA/EGA instrument combination determines the mineralogical composition of the martian soil. A soil sample is placed in an oven, heated, and changes in heating and gas releases are monitored. The gas analyzer measures the water, carbon, nitrogen, oxygen, organic, and oxidant content of the released gas. A mechanism is required for obtaining samples.

Descent Imager

The descent imager obtains nested images of the martian surface during the landers parachute descent. These images are used to establish the geologic context of the science measurements taken by the landed station.

Surfacelma ger

The multiband surface imager provides a 360° panorama from the lander edge to the horizon in order to determine the surface characteristics of the landing site.

Atmospheric Structure instrument (ASI)

The ASI obtains pressure and temperature profiles of the martian atmosphere along the entry vehicle trajectory to the surface. In addition, an atmospheric density profile is derived from 3-axis acceleration measurements taken during entry and descent.

Radio Science

Simultaneous 2-way coherent Doppler tracking of three (or more) landers from a single Earth antenna once per week for one Mars year provides information which yields decimeter level determination of Mars rotational parameters.

Satisfaction of the MESUR science objectives requires the concurrent operation of multiple landed stations for an extended period of time (nominally one Mars year). The original scenario for the emplacement of the Network involved a phased deployment over three launch opportunities due to anticipated annual funding rate constraints. Specifically, a single Delta 11 (7925) launch in 1999 would inject four free-flying spacecraft on a trans-Mars trajectory. Two Delta launches in 2001 would deploy four additional spacecraft and a single communications relay orbiter to Mars. Finally, two Delta launches in 2003 would deploy eight spacecraft to complete the 16 lander Network. Operations of the landed stations would continue for a minimum of one Mars year after the arrival of the final complement of eight landers. Thus, a surface lifetime in excess of 6 Earth years is required by the four landers launched in 1999 to satisfy the one Mars year concurrent Network operations requirement.

The current budget climate, as well as technical issues such as the extended surface lifetime requirement of the landed stations, have led to the decision to revisit the MESUR Network design. The MESUR Project Team at JPL, the Mars Science Working Group, the MESUR Science Definition Team, and other groups are studying alternative mission architectures and vehicle designs. The goal of the redesign effort is to define an affordable Network mission in terms of total mission life cycle costs that accomplishes the major science objectives of the Mars exploration program. Trade issues which have major cost and science impacts and are an integral part of the redesign effort have been identified as follows:

Science

Number of landers, latitude dispersion of landers, science instrument suite, instrument deployment scheme

Power

Radioisotope Thermoelectric Generators (RTG's) vs. solar powered landers

Communications

Direct-to-Earth downlink vs. Communications relay orbiter(s)

Thermal Control

RTG vs. Radioisotope Heating Unit (RHU) + solar vs. Phase Change Material (PCM) + solar

Launch Vehicles

Delta, Taurus, Atlas, Titan, Arianc, Proton, etc.

Surface Life

1 month vs. 1 Mars year vs. multiple Mars years

Deployment

Full vs. phased Network emplacement

Cruise carrier vs. Free-flier

Hardware

Common landers vs. landers based on focused surface function

Integrated landers vs. landers based on available hardware

Redundancy vs. single string

The identified trade options have complex interdependencies. For example, the surface lifetime requirements as defined by specific science investigations interact with the latitude dispersion of landers to define acceptable power and communications options. The following matrix depicts the dependence of the power and communications system trades on science objectives and landing site locales.

Table 1. Power and Communications Dependencies

Latitude/Duration	Short Term (Geology & Geochemistry)	Long Term (Meteorology & Seismology)
Low Latitude (Between +/-40°)	Solar/Battery Direct-to-Earth	Solar Direct-to-Earth
Mid-Latitude (+/-40° to +/-60°)	Solar/Battery Communications Orbiter	Solar (marginal) Communications Orbiter
High North Latitude (Above +60°)	RTG/Battery Communications Orbiter	RTG Communications Orbiter
High South Latitude (Below -60°)	RTG/Solar/Battery Communications Orbiter	RTG Communications Orbiter

The RTG/Communications relay orbiter option provides the most flexibility in satisfying mission requirements, but may be an extremely expensive option. As shown in Table 1, RTG's and a communications orbiter are required to perform any long duration investigation at the extreme Northern and Southern latitudes. This requirement evolves because the Sun and Earth are not visible from landed stations at high latitudes for extended periods of time due to the orientation of Mars spin axis and the martian orbit around the Sun.

The schedule for the Network architecture re-definition effort includes a special meeting of the Mars Science Working Group in February, 1993, to present Network alternatives and cost information to the science community. The re-definition task is scheduled for completion in early spring 1993.

III. MESUR Pathfinder

As part of the MESUR program, JPL is studying the feasibility of landing a single vehicle on Mars in 1997 as a demonstration of the enabling systems, technologies, and management approaches for the MESUR Network mission. Because the planned Network mission will have a different, more stressful landing procedure than was used by Viking, it is important to demonstrate critical entry, descent, and safe landing functions prior to the full-up implementation of the MESUR Network fabrication activity. The demonstration mission, designated MESUR Pathfinder, is the first of the Discovery class missions. Discovery missions are defined as fast schedule (3 year development cycle), low cost (\$150 million development cost cap) missions with significant, but focused, science objectives.

The primary objective of MESUR Pathfinder is to demonstrate critical functions, particularly the entry, descent, and landing function, required for the successful development and deployment of the MESUR Network stations. Scientific objectives and a strawman instrument payload for Pathfinder include:

- Acquisition of atmospheric structure data along the Pathfinder entry trajectory from an entry instrument package (pressure, temperature, and vehicle acceleration),
- Characterization of surface morphology and geology at meter scale from a surface imaging camera,
- Determination of the elemental composition of rocks and/or surface materials from alpha/proton/X-ray spectrometer measurements,
- Limited characterization of surface meteorological conditions using the entry instrument package to provide surface pressure and temperature measurements and the seismometer wind sensor to provide wind velocities.

A microrover surface vehicle will be flown on Pathfinder. The microrover will be deployed from the lander to perform instrument deployment functions and to conduct rover technology experiments in the martian environment. The total Pathfinder mass allocation for the science payload and microrover is approximately 20 kg.

A single MESUR Pathfinder aircraft will be launched on a Delta class launch vehicle in November/December 1996. The aircraft consisting of a cruise stage, aeroshell (heat shield and back cover), decelerator systems (parachute and air bags), and a lander will be spin-stabilized and sun-oriented during the cruise to Mars. Pathfinder will enter the martian atmosphere in November 1997 directly from the hyperbolic transfer orbit and descend to the surface using an aeroshell and parachute to slow the descent and an air bag system to attenuate the landing shocks. The

Pathfinder approximate entry conditions (entry velocity 6.5 km/s, entry angle 20°, vehicle ballistic coefficient 40 kg/m²) will result in dynamic loads of 30 g's during the entry phase. The terminal vertical velocity on the parachute of 35 m/s and a horizontal velocity component ranging up to 50 m/s at ground impact will result in loads of up to 50 Earth g's along any vehicle axis. An example Pathfinder entry, descent, and landing scenario is shown in Figure 1.

The Pathfinder landing site will be selected from available low elevation areas large enough to accommodate anticipated targeting dispersions in the 15° South to 15° North latitude band. Landing sites in this equatorial latitude band provide good solar and Earth visibility conditions for the primary solar power and direct-to-Earth communications systems baselined for the Pathfinder flight system. The acquisition and return of scientific data and rover operations will commence immediately following the playback of key engineering data regarding the condition and configuration of the lander and the characteristics of the entry. Figure 2 provides an artists conception of the MESUR Pathfinder lander on the surface of Mars

IV. Acknowledgement

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V. References

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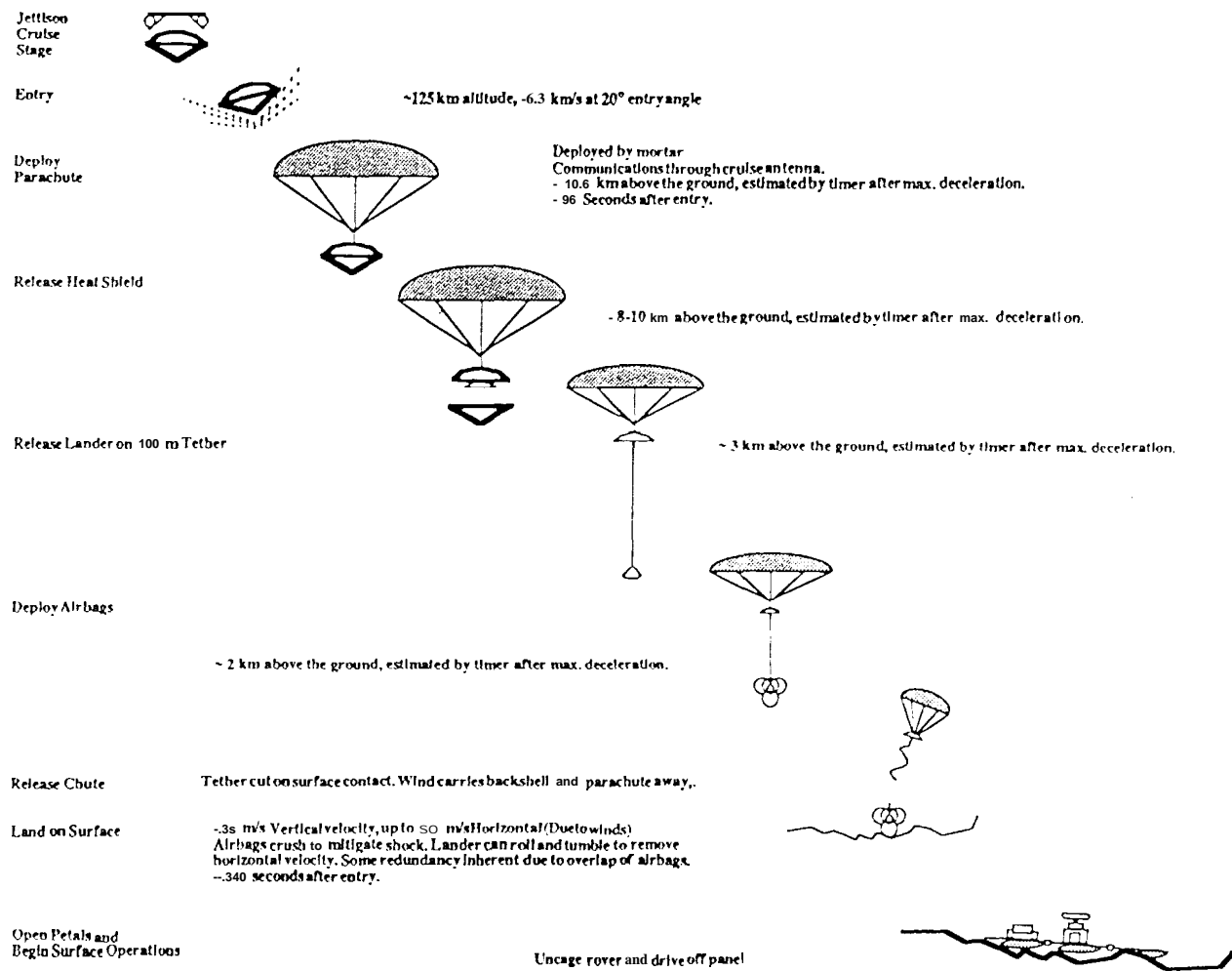


Figure 1. Example Pathfinder Entry, Descent, and Landing Sequence



Figure 2. MESUR Pathfinder Landed Configuration with Microover Deployed