Pioneer Mars 1979 Mission Options

John C. Niehoff* and Alan L. Friedlander†
Science Applications, Inc., Rolling Meadows, Ill.

Theme

THE present concern for fiscal budgetary restraint combined with NASA's commitments to develop the Space Shuttle Transportation system promises further belt-tightening decisions in the Agency's programs between now and the early 1980's. In particular, the Planetary Programs Division of OSS/NASA may face the difficult task of limiting its exciting and expanding program of planetary exploration. This paper presents several low cost (<$100M) alternatives as candidate 1979 Mars missions which, although limited in capability, address viable science questions of our most interesting neighbor planet. These mission concepts are relevant to a "balanced" plan of exploration of the solar system. It is understood that, should the 1975 Viking missions discover life on Mars, a very different plan of "Mars-emphasis" may be preferred.

Contents

Two low-cost 1979 Mars mission concepts, based on the 1978 Pioneer Venus Orbiter (PVO '78) design, are proposed for consideration. These are: 1) an Aeronomy/Geology Orbiter; and 2) and orbiter with multiple surface penetrators. The Aeronomy/Geology Orbiter uses a low periapse altitude orbit for atmospheric sampling, remote surface sensing, and gravity determination. The Orbiter/Penetrator mission carries a number of surface penetrators which it can sequentially deploy from orbit to investigate subsurface characteristics over a broad region of the planet. Both missions rely on a high degree of hardware inheritance from PVO '78, a spacecraft planned for launch to Venus in May, 1978. For each mission concept a single launch is suggested using the Atlas/Centaur launch vehicle.

Motivation for a Mars aeronomy orbiter stems from the need for long-term diurnal measurements of the planet's neutral and positive-ion ionospheric composition and upper atmospheric heat balance to resolve uncertainties in present theoretical models for the basic nature and subsequent evolution of the Mars atmosphere. The necessary low-periapse altitude requirement for atmospheric sampling also suggests several interesting remote sensing instruments, i.e., a γ-ray spectrometer and a radar altimeter. The global surface geology questions these instruments could address significantly enhance the science value of the mission. It must be cautioned, however, that the γ-ray spectrometer and a suitable radar altimeter are not yet developed to the same advanced state already enjoyed by the aeronomy instruments.

The Aeronomy/Geology Orbiter mission is characterized in Table 1. The spacecraft is a slightly modified PVO '78 drum which is spin-stabilized. Minimum power and bit rate at Mars are 150 w and 32 bps, respectively. A periapse altitude not lower than 100 km is recommended based on atmospheric drag and spacecraft heating. An initial orbit of 24 hr is consistent with the baseline PVO '78 retro propulsion performance. Selection of the orbit inclination, as well as periapse altitude and initial period, has a strong effect on the quantity and value of scientific data the orbiter can return. Analysis of the combined perturbation effects of oblateness, solar gravity, and atmospheric drag showed that 45° inclination provides an acceptable compromise of diurnal and latitude coverage for an extended period of time.

The baseline orbit of the Aeronomy/Geology Orbiter will continue to decay because of the low periapse altitude ultimately culminating the mission with atmospheric entry of the spacecraft. Hence, the orbiter must be sterilized to satisfy Mars quarantine requirements. A total operational lifetime of 1000 days permits up to one Mars year of sampling in orbit. The projected useful orbit mass is 335 kg of which 60 kg is budgeted for the science instruments. Adding the loaded mass of the SVM-2 baseline PVO' 78 retro motor brings the total launched payload to 495 kg. This Aeronomy/Geology Orbiter mission, assuming a large degree of inherited PVO '78 hardware and instruments, is estimated to cost 40-50M FY '75 dollars, exclusive of the launch vehicle.

The motivation of a Mars penetrator mission stems from the interest in continued surface exploration of the planet, initiated by the 1975 Viking missions. A mission cost ceiling of $100M will greatly restrain the science capability compared to Viking, but the penetrator concept adds a new dimension of subsurface investigation not performed by Viking. Such basic objectives as planet heat flow, indigenous soil chemistry, surface structure, and soil volatiles inventory are all favored by subsurface measurements. Seismic measurements can be interpreted much better if the seismometers are firmly implanted in the soil instead of resting on the surface. At least twice as many sites (four) can be sampled with one penetrator

Table 1 Pioneer Mars mission summaries

Item	Mission: Aeronomy/ Geology	Mission: Penetrators
Mission characteristics		
remote measurement domain	surface	atmos/surface
in situ measurement domain	ionos/atmos	subsurface
spacecraft type	PVO '78	PVO' 78
orbit period	24 hr(w/decay)	24.6hr (stable)
periapse altitude	100 km	1000 km
operational lifetime (orbiter)	1000 days	1000 days
(penetrator)	...	7 days
sterilization	orbiter	penetrators
estimated cost (FY '75)[a]	$40-50M	$70-80M
Mass summary		
orbiter science	60 kg	40 kg
orbiter	275	278
racks/launchers	...	78
penetrators (4)	...	124
orbited payload	335	520
orbit retro motor	160	250
total injected mass	495 kg	770 kg

[a] Atlas/Centaur launch vehicles cost excluded.

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Index categories: Spacecraft Mission Studies and Economics; Lunar and Interplanetary Spacecraft systems, Unmanned.

*Senior Engineer. Member AIAA.
†Senior Analyst. Member AIAA.

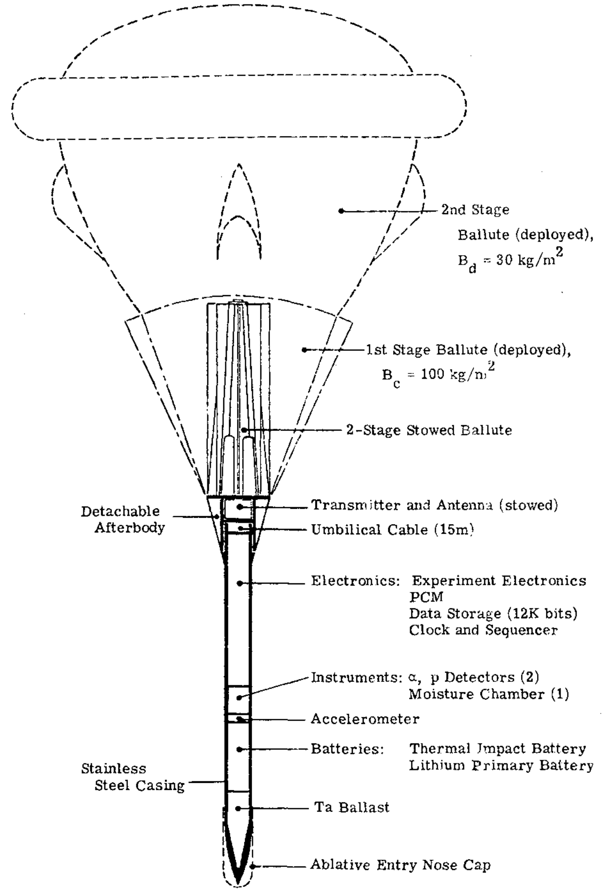

Fig. 1 Mars penetrator schematic.

mission as with the two 1975 Viking missions. Such simple surface measurements as atmospheric pressure become very meaningful with an array of four sites. From the sum of these features of the penetrator an exciting low-cost mission concept emerges for continued Mars surface exploration.

A schematic diagram of the Mars penetrator is presented in Fig. 1. It consists of three basic parts: 1) the forebody, which penetrates to depth upon impact; 2) the afterbody, which detaches from the forebody and remains at the surface upon impact for data transmission; 3) an aerodecelerator for atmospheric braking upon entry from orbit, in this case a two-stage ballute. The penetrator concept, developed principally by Sandia Laboratories,[1] has been subjected to literally thousands of tests. It has been applied as an exploration device in deserts, lava flows, ice packs and other environments relevant to Mars. The design chosen for Mars has an impact velocity of about 150 m/sec resulting in penetrations of 1-15 m depending upon soil conditions.

The forebody of the penetrator houses the instrument package. For this conceptual analysis the instruments were limited to a decelerometer, two α-proton detectors, a H_2O/CO_2 inventory chamber, and a pair of hygrometer/temperature sensors. This package was selected based on a battery-only power source. Further study of a RTG-power source was required to permit the important addition of seismometers which require higher power consumption. The design shown in Fig. 1 weighs 31 kg, the forebody diameter is 8 cm (3″) and the overall length with the ballutes stowed is 1.7 m (66″).

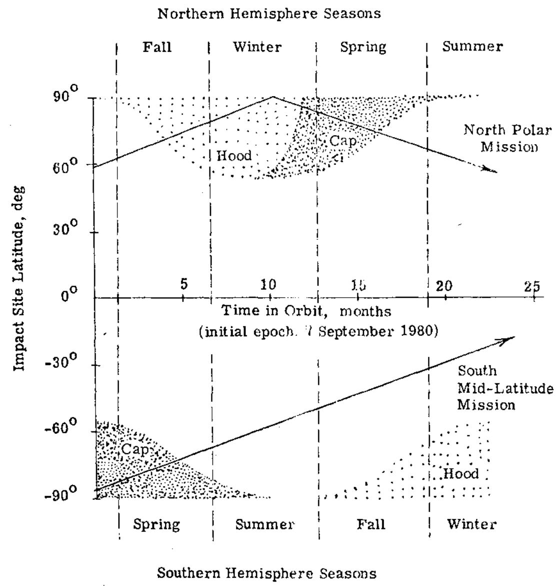

Fig. 2 1979 Mars penetrator mission impact site accessibility.

The salient characteristics of the Penetrator mission are summarized in Table 1. A modified PVO '78 spacecraft carries four penetrators into a Mars synchronous elliptical polar orbit. The periapse altitude is 1000 km. The penetrators can be sequentially deployed to preselected impact sites over a period of one Martian year, the operational lifetime of the orbiter. Traces of impact latitudes available as a function of time in orbit are shown in Fig. 2 for North Polar and South Polar orbit options. Impact longitude flexibility is achieved by small orbit period adjustments between penetrator deployments. Upon impact, each penetrator begins a sequence of preprogramed measurements. Once a day it transmits up to 12K bits of data to the orbiter as it passes overhead. It continues to operate until its battery power is used up, a period of 7-8 days.

The total useful mass in Mars orbit is 520 kg of which 40 kg are budgeted for orbiter science. The TEM-616 back-up PVO '78 retro motor, about 67% loaded at 250 kg, can deliver its payload into the appropriate orbit. The total Atlas/Centaur launched payload is 770 kg. The penetrators are sterilized and kept in bioshells while mounted onboard the orbiter. This Mars Penetrator mission, assuming a modified PVO '78 Orbiter bus, is estimated to cost 70-80M FY '75 dollars, exclusive of the launch vehicle.

On the basis of this conceptual analysis, Phase-A systems studies have recently been completed by Hughes Aircraft Co.[2,3] and Sandia Labs.[4] for NASA Ames Research Center. These studies confirmed the feasibility of both mission options and have added considerable detail to the mission definitions outlined here.

References

[1] Young, C. W., "Empirical Equations for Predicting Penetration Performance in Layered Earth Materials for Complex Penetrator Configurations," Rept. SC-DR-72-0523, Dec. 1972, Sandia Labs., Albuquerque, N. Mex.

[2] "Pioneer Mars Aeronomy/Geology Mission," Doc. D2546. SCR 40275R, Aug. 1974, Hughes Aircraft Company, Culver City, Calif.

[3] "Pioneer Mars Surface Penetrometer Mission," Doc. D2546. SCG40274R, Aug. 1974, Hughes Aircraft Co., Culver City, Calif.

[4] "Mars Penetrometer: Subsurface Science Mission," Doc. SAND-74-0130, Aug. 1974, Sandia Labs., Albuquerque, N. Mex.