MARS PENETRATOR UMBILICAL

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ABSTRACT

To obtain data on certain geophysical properties of the planet Mars, it is desirable to implant sensors below the Martian surface. The device proposed to gather this sub surface data is a ballistic probe which penetrates the soil after a free fall through the Martian atmosphere. Highlights of the design, development, and testing of several features of the Mars Surface Penetration Probe (MSPP) are outlined in this paper.

INTRODUCTION

A typical mission using the MSPP would commence with a launch from Earth aboard the Shuttle Space Transportation System (STS). The MSPP would be one of several experiments carried by a Mars Orbiter Vehicle. The orbiter would proceed under its own power after separation from the STS. Once in position near Mars, as many as 12 MSPP units could be jettisoned from the orbiter on command for impact on designated target areas.

As the MSPP falls through the Martian atmosphere, heat shields will protect its instruments and aerodynamic braking devices will control the rate of descent to limit the impact velocity to 150 m/s (492 fps) (Fig. 1). Upon impact the tail section separates from the forward body and remains at the surface. The forward body penetrates the Martian crust to a depth of 12m (39 ft.) or less depending upon the local soil properties. The two parts of the MSPP remain connected by a coiled umbilical cable carried in the foreward section and deployed through the penetration shaft.

The instruments in the forward section of the MSPP include accelerometers, seismometers, a thermal conductivity probe and a soil chemical analyzer. Data gathered by these instruments is carried through the umbilical cable to a transmitter in the tail section. In addition to the transmitter, the tail section houses an antenna and various meteorological sensors. Two advantages of this design are that: (1) instruments for measuring soil and crust characteristics are firmly imbedded in the Martian landscape where they are protected from temperature fluctuations and wind loads; (2) instruments for transmitting data and measuring atmospheric properties remain at the surface. Penetration devices similar to the MSPP have been used by the Army and Coast Guard. Umbilical cable breakage during deployment has plagued all previous designs. Development of a reliable cable and cable deployment method has been a major consideration in the testing of the MSPP experimental model.

DESIGN

The umbilical cable must meet severe demands imposed on it by the MSPP mode of operation. It must remain intact while being uncoiled at 150 m/s (492 fps). It must withstand the impact deceleration estimated at 20,000 G's. About 30 conductors are needed to meet the projected requirements of the instruments for data channels. The conductors must be 12m (39ft) long with less than 10 ohms resistance. The entire cable package must be compact and fit within a cylindrical volume approximately 7.62cm(3 in) in diameter and 15.24 cm (6 in) long.

With the foregoing constraints in mind, a model was built for testing design concepts. The important features were fabricated half-size. The four components of the experimental penetration model are the forebody, the umbilical cable, the funnel and the afterbody (Fig. 2). All were designed to enhance the survivability of the umbilical cable.

The forebody provides the fuselage for the experimental penetration model. Its interior features include a mandrel with cylindrical and hemispherical portions, plus sufficient space for housing the umbilical cable and funnel. A blunt nose and several stabilizing fins form the exterior. The umbilical cable is coiled about the cylindrical part of the mandrel until impact separation, then the cable is guided smoothly by the hemispherical section as it unwinds. The mandrel is designed to minimize the friction experienced by the cable during deployment.

Space constraints and performance tests indicate that forming the umbilical cable into a coil provides certain advantages over other configurations. Stress fluctuations in the cable (thought to be a major cause of cable breakage) are minimized by uniformly accelerating the cable as it leaves the mandrel. Photographic data shows that high velocity waves traveling along the cable also contribute to cable failure. Experiments seem to indicate that the dynamics of a cable as it unwinds from a cylindrical mandrel promote uniform acceleration, minimize stress fluctuations and control wave velocity.

A beryllium-copper alloy was found to be the most suitable conductor material. It combines the desirable mechanical properties of high tensile strength and acceptable elongation with good electrical conductivity. The individual wires are insulated with an enamel-like coating of Formvar which is tough and lightweight. The cables used for testing are fabricated by twisting six conductors around a seventh in the center (1-7 construction). The resulting bundle is 0.079 cm in diameter. Seven such bundles are then combined into a cable with 7-7 construction. This forms a 49-conductor umbilical cable which is flexible yet strong because tensile stresses are borne equally among the individual wires.

As the coiled cable unwinds, it acquires a large rotational velocity which causes twisting and torsional failure (Fig. 3). A funnel is incorporated as a cable-guide to reduce the magnitude of the cable spin velocity through friction. As the funnel diameter decreases, the umbilical cable scrubs the funnel wall and yields its rotational energy to friction-produced heat. The geometry and frictional properties of this device have been chosen to optimize the energy exchange without inducing excessive cable tension along the projectile's line-of-flight.

The after body, which serves as the anchor for the umbilical cable, also uses a bell-shaped surface similar in function to the funnel. Cable rotational energy is dissipated through a scrubbing action between the cable and the afterbody surface. The design also reduces stress concentrations in the cable at the attachment point.

TESTING

The testing was conducted in the ballistic ranges at NASA-Ames Research Center. The MSPP experimental models were fired from a 57 mm smooth bore gun, to the target velocity of 150 m/s (492 fps). From the muzzle the model flies through the stripper which is constructed to simulate ground impact and arrests the afterbody at a deceleration level of approximately 20,000 G's (Fig. 4). A hole which exists in the stripper has a profile that allows the forebody, with its fins, to slip through untouched while the afterbody is abruptly arrested. The stripper contains layers of plywood and aluminum which retain the afterbody and prevent bouncing.

Other equipment used during testing includes break wires to measure velocity and trigger shadowgraphs, double exposure shadowgraphs that show detailed deployment at two stations during flight and high speed movie cameras which show the dynamic and after effects (such as continued twisting). At the end of the flight the forebody is stopped by a plywood box filled with layers of Celotex and particle board.

CONCLUSION

The analyses of many tests have yielded these important results: (1) the initial acceleration of 20,000 G's is not a problem if the suspended free length of cable is short; (2) the rotational velocity which induces twisting of the cable must be controlled; and (3) no sharp corners may exist in the mechanism. Two major differences between these tests of the umbilical's motions and the actual MSPP operating conditions are reduced aerodynamic damping resulting from the lower air density in the Martian atmosphere, and greater rotational energy dissipation of the umbilical during deployment through contact with the shaft wall formed by the penetrator. Additional tests are planned to determine the effects of these conditions, although at this time neither appears to present problems. Further testing and minor optimization will complete the design of a reliable umbilical system for the MSPP.

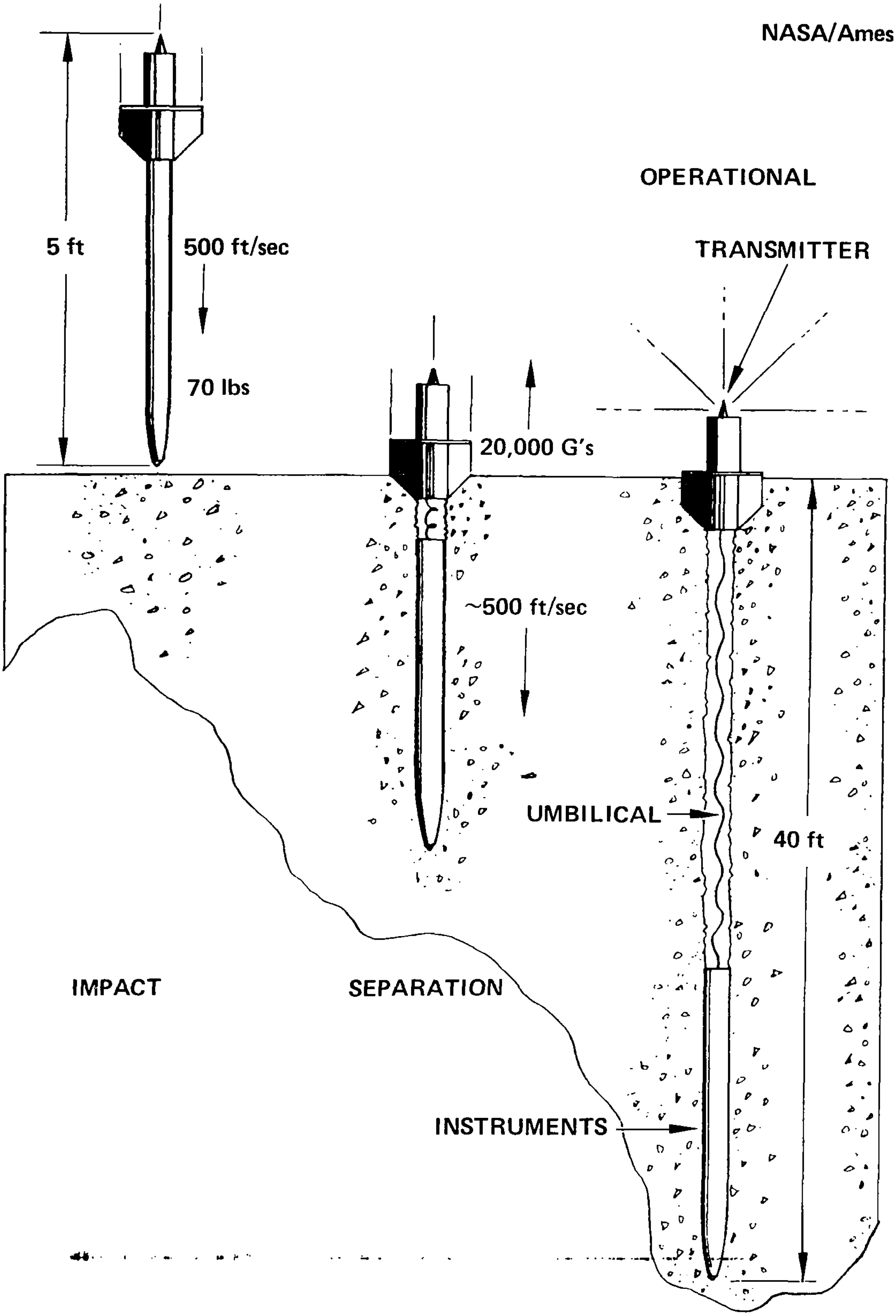

Figure 1   Penetration Sequence

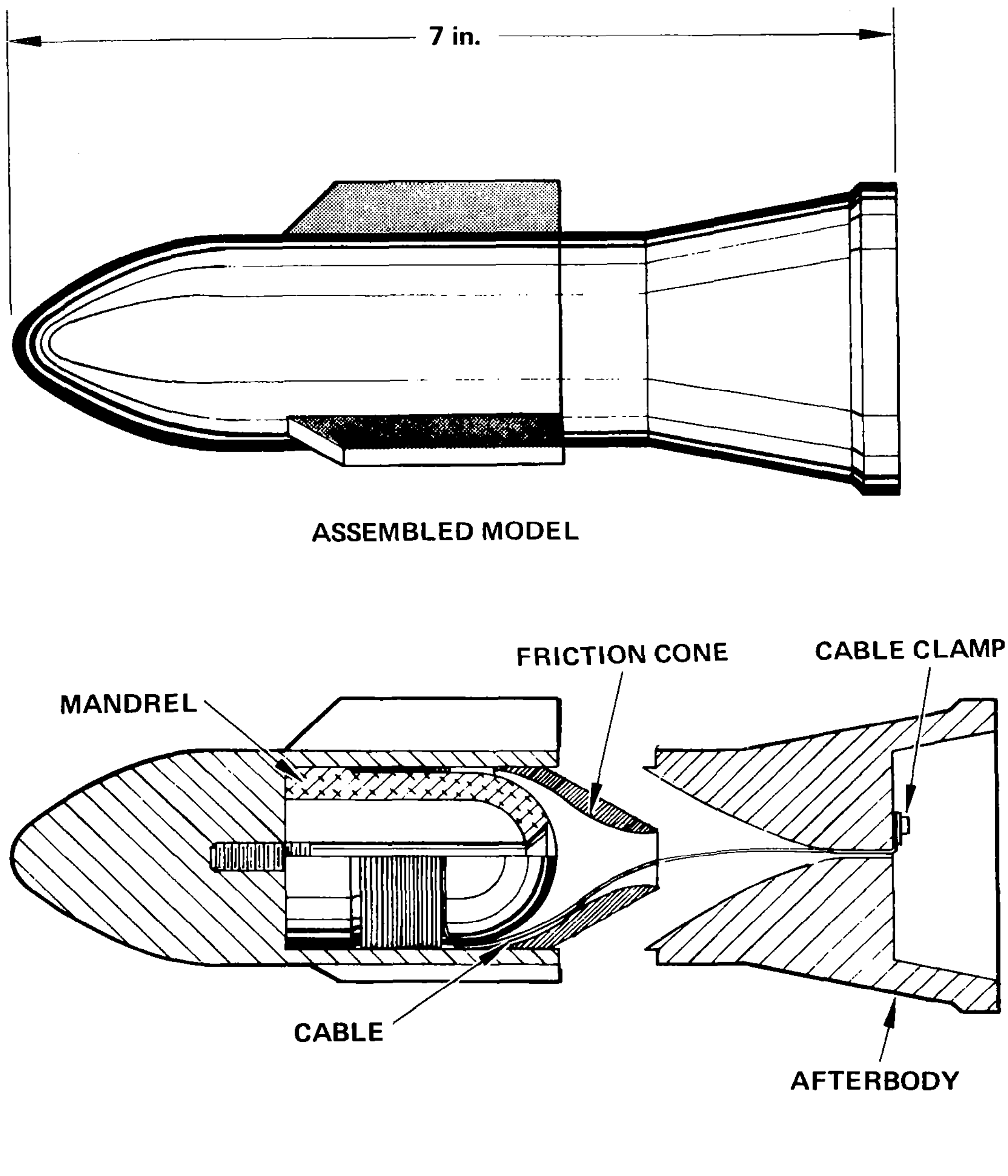

Figure 2 Umbilical Test Model

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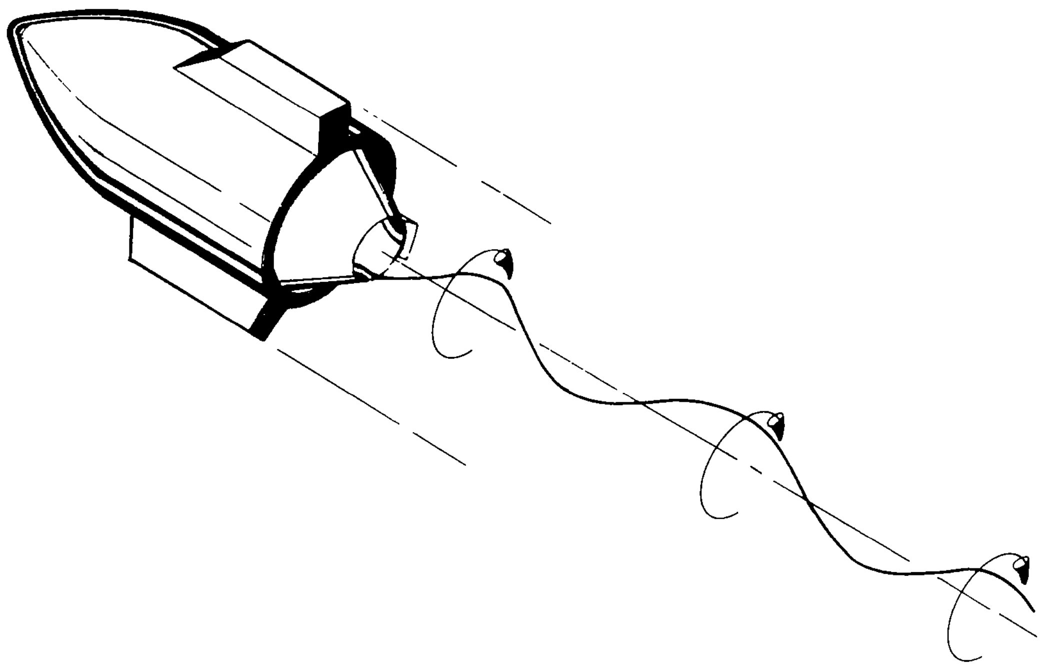

Figure 3 Umbilical Deployment (Note Rotation)

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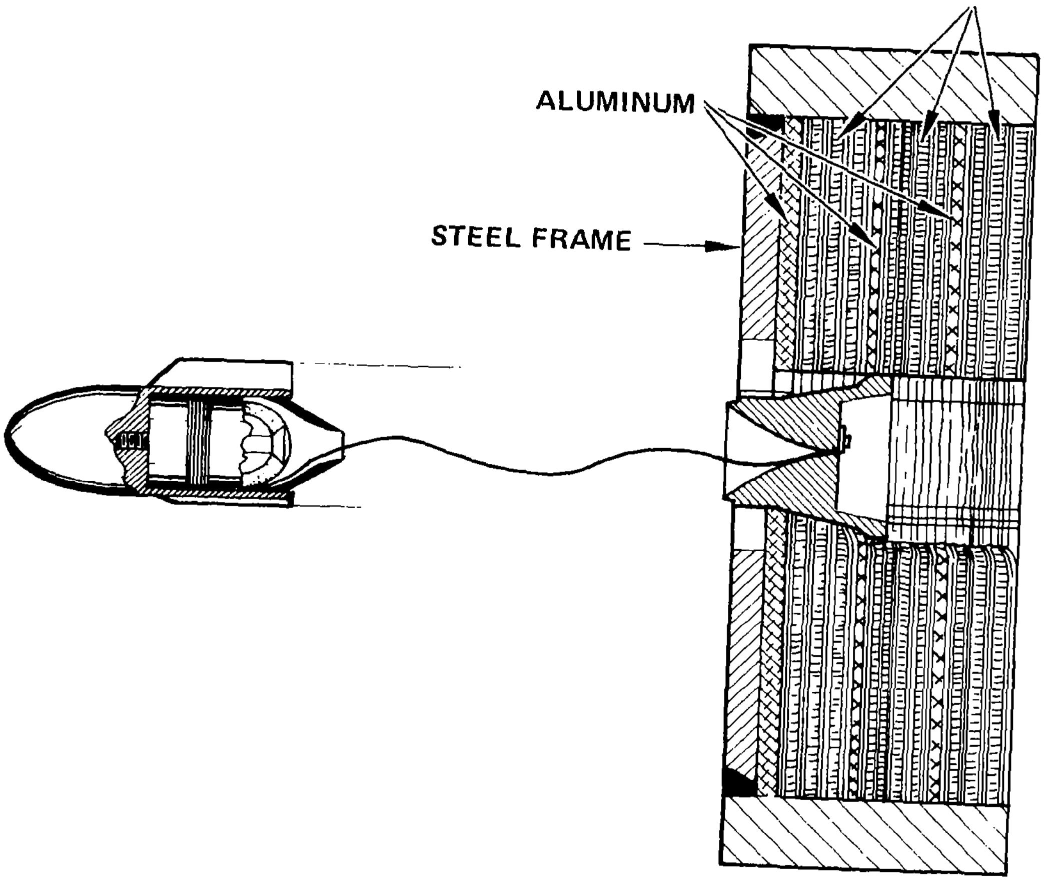

Figure 4 Ballistics Test Rig