DEEP SPACE 2: NASA'S FIRST PLANETARY PENETRATOR. S.A. Gavit, Jet Propulsion Laboratory, California Institute of Technology, MS 264-840, 4800 Oak Grove Dr., Pasadena, CA 91109, sarah.a.gavit@jpl.nasa.gov

Introduction: In January 1999, two basketball-sized aeroshells containing a 2.2 kg (4 lbs.) **microprobe** each will be launched to **Mars**. They ride piggyback aboard another spacecraft destined for the Red Planet, the Mars **Polar Lander**. At their destination eleven months later, the two aeroshells are released from the larger spacecraft's cruise ring and plunge through the Martian atmosphere. See Figure 1. Unlike any spacecraft before, the aeroshells crash into the planet at approximately 200 meters per second (400 miles per hour) where they shatter on impact. The probes contained inside must survive the impact, and when they hit Martian soil they separate into two parts. The forebody, containing a miniature laboratory of instruments, penetrates as far as 1 meter (about 3 feet) below the surface. The aftbody remains on the surface to relay data back to Earth via the Mars Global Surveyor spacecraft, which has been orbiting Mars since September 1997. The forebody and aftbody communicate with each other via a flexible cable.

Figure 1: Deep Space 2's aeroshells will plunge through the Martian atmosphere and shatter upon impacting the surface at speeds up to 200 m/s (400 mph).

Microprobe System: Deep Space 2 is the National Aeronautics and Space Administration's (NASA's) first mission to penetrate the surface of a planet. It is the second in a series of technology demonstration flights sponsored by the New Millennium Program. The main purpose of the mission is to test technologies that are needed by future "network science" missions, in which multiple probes or landers will be dispersed across a heavenly body to gather data from different locations at the same time. To accomplish its goal, DS2 was challenged to develop a stand alone system that is both very small and lightweight.

The DS2 atmospheric entry system, the aeroshell, is the first of its kind in several respects. See Figure 2. First, unlike most entry systems, the DS2 aeroshells are not required to be "pointed" or spin-stabilized when they enter Mars's atmosphere. Rather, their design ensures that the heatshield is aligned properly prior to peak heating, even if the system is tumbling upon atmospheric entry. Second, the DS2 entry system is single-stage from atmospheric entry until impact---there are no parachutes, retro rockets, or airbags to slow the system down prior to impact. In fact, the entry systems are not even jettisoned by the probes but accompany them to the surface of the planet where they shatter on impact, releasing the probes. This very simple, technically elegant system greatly reduces the number of tests required to demonstrate that the design works, and thus greatly reduces the costs to the mission.

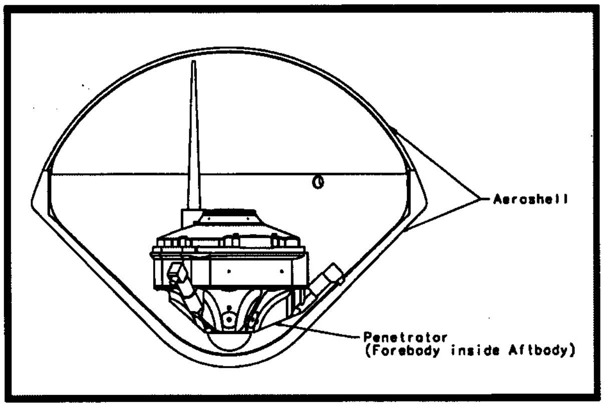

Figure 2: During atmospheric entry, each microprobe is protected from the extreme heat by a protective aeroshell. The probe is mounted close to the nose of the aeroshell to ensure the system always enters the right side up.

Each probe is approximately the size of a large grapefruit, and contains a suite of miniature electrical and mechanical systems. The systems must withstand extreme environments, as well as be able to crash into the planet's surface at speeds of up to 200 m/sec (400 miles per hour). These requirements are met through a combination of using advanced materials, mechanical designs, and microelectronic packaging techniques, which have been developed as a result of extensive testing. The probe's forebody and aftbody must also operate at temperatures as low as -120 degrees C (-184 degrees Fahrenheit) and -80 degrees C (-112 degrees Fahrenheit) respectively.

Penetration below the Martian surface provides the probe's forebody with some unique opportunities for studying the soil. First, scientists measure the conductivity of the soil by measuring the rate at which the probe cools down after impact. For this purpose, two temperature sensors are mounted on the structure of the forebody. See Figure 3. Second, scientists search for the presence of subsurface water ice. The forebody carries out this task by driving a micro-drill out to collect a sample of the surrounding soil. Tailings from the drill fall into a heater cup, which is then sealed and heated to vaporize any water that may be present in the soil. If water is present, it will be detected by the drop in intensity of a laser signal which will be passed through the vapor.

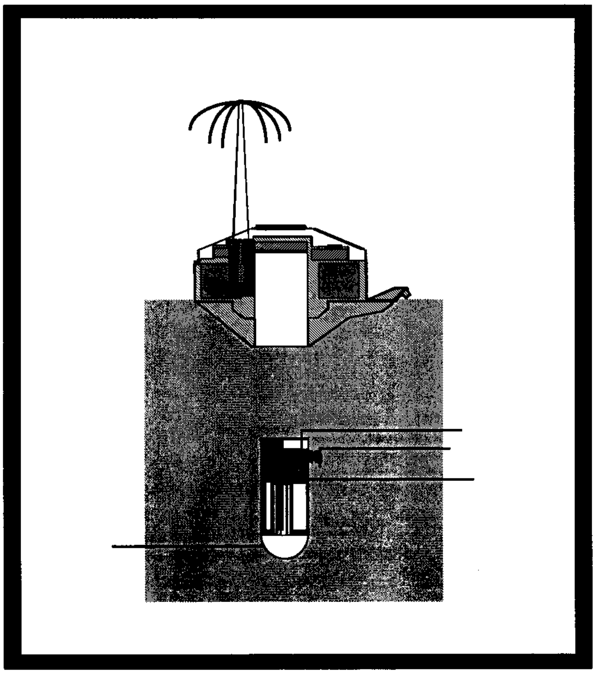

Figure 3: Mars Microprobe in Deployed Configuration

The part of the probe which remains above the surface, the aftbody, hosts a descent accelerometer for characterizing atmospheric entry conditions, and a sun detector to determine the sun location relative to the aftbody axes. The aftbody also includes the telecommunications subsystem which relays data back to Earth via the Mars Global Surveyor (MGS) spacecraft. The receiver and transmitter operate in the Ultra High Frequency (UHF) Range and transmit data to MGS at a rate of approximately 7 Kbits/second.

Future micromissions: The technologies developed by DS2 will enable future micromissions which can deploy multiple small landers for network science. The system's low ballistic coefficient allows the probes to reach any latitude on Mars at any opportunity. They are also capable of landing at elevations up to 6 km. The design is robust with respect to the type of terrain. The current probe is intended to survive impact into solid ice and penetrate up to 20 cm. It is also capable of surviving an impact with an angle-of-incidence up to 30 degrees and angle-of-attack of up to 9 degrees.

The probe system is both extremely small (the probe is the size of a large grapefruit and the aeroshell the size of a basketball), and lightweight (the probe weighs 2.4 kg (5.3 lbs) and the aeroshell weighs 1.2 kg (2.6 lbs)), enabling future missions to deploy 5 to 10 such probes from a single spacecraft. Additionally, the capability of the electronics to operate at extremely cold temperatures (down to -120 degrees C (-184 degrees Fahrenheit)) allows a wide range of operating environments for future missions.

The forebody/aftbody design provides access to both the surface and subsurface of a heavenly body for science data collection. Changing the DS2 instrument package would result in redesign of the electronics, and probably the telecom system depending on relay options. Packaging techniques developed for surviving high g-loads, however, permit a wide range of future instruments. Many innovative instrument concepts based on the DS2 design have been studied which include oxidants, organics, the depth to the water or ice interface, and mineralogy or geochemistry. If desired, the mission duration could be increased by adding solar power and rechargeable batteries, or increasing the battery mass.

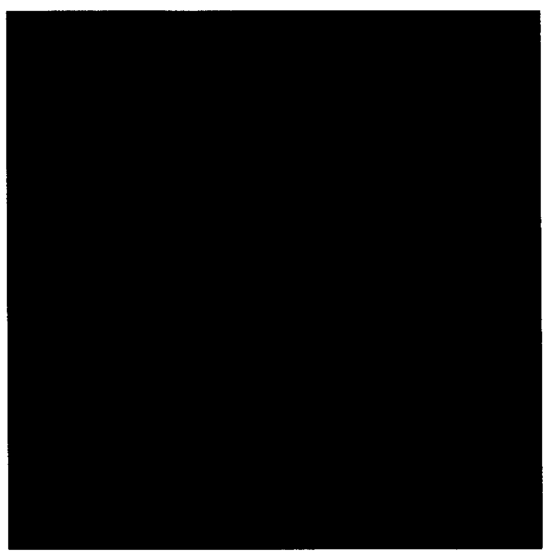

Figure 4: Mars Microprobe Flight Unit