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THE NATURE OF COMETARY MATERIALS, James Stephens, Jet Propulsion Laboratory, Pasadena, CA

Because cometary surfaces are likely to be far colder and of a different composition than other planetary surfaces with which we have experience, there are some new considerations that must be examined in regards to placing instrumented packages or sample return devices on their surfaces. The qualitative analysis of the problem of attaching hardware to a comet and not being ejected back into space can be divided into two parts.

The first problem is to pierce the mantle and obtain access to the icy core. Drilling through the mantle requires that the drilling forces be reacted. Reacting such forces probably requires attachment to the icy core below. Therefore, some kinetic impact piercing device is likely to be required as the first act of attachment. This piercing device may ricochet off of the mantle if it cannot be directed approximately perpendicular to the impact surface. The local surface may be closer to vertical than to horizontal because solar heat focusing, fluid dynamic channeling and electrostatic filament forming forces will likely prevail over the low comet gravity to form very grotesque surface topography. Furthermore, if the mantle that covers the icy core has mineral particles that are bonded together by a tar-like substance and if the surface tension forces of this "tar" prevail then the mantle may shrivel to form an "asphalt" like , brittle, high density, high strength material. In addition, new cometary mantles may be formed from the thermally stress-fractured remnants of earlier mantles.

The second problem for a piercing device to overcome is the force produced by the impact kinetic energy that tries to eject the piercing device back into space. The mantle and icy core can absorb some of the impact kinetic energy in the form of fracture formation and friction energy. The energy that is not absorbed in these two ways is stored by the core as elastic deformation of the mantle and icy core. This elastic deformation energy is returned to the piercing device and the fragmented mantle and core material that surrounds it after the piercing device comes to zero velocity. The elastic deformation rebound force is assisted by the pressure force of the gas that is formed by the previously mentioned fracture formation and friction energy. Much of the fracture formation and friction energy is converted into heat that is ultimately converted into gas because the icy core is in thermodynamic equilibrium with its under-mantle environment. An additional source of gas is supplied by the new equilibrium that the core must achieve when the conductance through the mantle is increased by the additional venting of the mantle by the piercing device.

The drill or penetrator must develop hold-down forces that can overcome the elastic deformation rebound force and the pressure force of the gas. Hold-down forces that depend upon friction between the piercing device and the icy core may be insignificant because a gas bearing may form at the contact between the piercing device and the icy core. Hold-down forces that depend upon cohesion between the piercing device and the icy core are likely to be insignificant because there are no liquids that are likely to form at the interface and bond the piercing device to the core. Even if the icy core can rebound and clamp the piercing device in the crater, the friction forces and the cohesive forces remain small. Hold-down forces that depend upon fixed or deployed barbs are insignificant because they will shatter the core material during entry as does the piercing device and it is unlikely that the material that they engage will still be attached to the core. Even if anchoring devices could be deployed horizontally below the surface of the unfractured icy core, the hold-down force might be as little as the gravity force of the pieces of the core that may be fractured by the deployment forces of the barbs. Subsurface wedging forces may be very large in low porosity and brittle substances and the resulting cracks may extend to the surface.

It is concluded that because the cometary materials are almost certainly brittle and the icy core is likely to be self lubricating, the elastic rebound and gas pressure expulsion forces must be counteracted by forces greater than those that may be provided by a piercing device or its capture devices (barbs).