SAMPLE RETURN CAPSULE AND SAMPLE PACKAGING DESIGN. K. M. Nebergall, 3137 St Michel Lane, St Charles, IL, 60175, knebergall@gmail.com

Introduction: Objective #15 requests designs for "High-reliability sample return capsules suitable for Earth entry, with special attention on assured containment of returned samples, and preservation of sample integrity." The capsule discussed in this paper was designed as part of Project Rigel Mars Sample Return. It is a passively-decelerated capsule design that contains a 1 kg sample package.

The Rigel sample return capsule packages samples of the atmosphere, dust, soil, rocks, and cores in a nested fashion to maximize the sample diversity within a very small package. This design also covers issues of weight and balance adjustments, integration with the launcher hardware, and robotic sample handling.

Overall Design: This is a passive entry, low density aeroshell with no active parachute, streamer, or related recovery mechanism. This concept was previously proposed in papers by EADS [1] and Robert Zubrin [2], and implemented on the Phobos-Grunt mission. The Rigel design falls exactly halfway between the Zubrin and EADS designs, so mass estimates are scaled accordingly.

The aeroshell would be 30 cm in length with the aft end and 50 cm in diameter. The capsule itself would have an external diameter of 11 cm and 10 cm length, and an internal size of 9 cm diameter and 6 cm length for soil/rock samples. The balance at the front would be for an atmospheric sample chamber.

Atmospheric and Dust Samples: The base of the cylinder contains a thin, disc-shaped atmospheric sample tank. Placing it on the end allows the walls of the tank to aid the structural strength of the overall sample container. The walls of the capsule would contain an air filter material section, which would be removed from the in situ propellant production filter units and placed in the capsule. The third atmospheric sample would be the ambient air around the rock samples themselves. The mission design would allow each sample to be gathered in a different season of the surface stay to capture any variations in dust composition, methane content, and so on.

Rock and Soil Container: The central chamber consists of a simple cylinder to contain the package assembled by the lander. The package consists of a central core sample down the length of the middle of the cylinder. Wrapping that is a pair of tape strips with rock and soil samples placed in chambers along the tape strip (picture bubble wrap chambers containing each sample and wound up around an open spindle). This allows a large number of small samples to be individually gathered, isolated, and labeled. The final element would be for samples too large to fit in the tape strip. This consists of a fabric arrangement similar to a draw-string "bag". This bag is actually a long rectangular arrangement with ten separate chambers. When the draw string is pulled, it wraps into the third short cylinder to place on the spindle/core sample. The sampling, collection, classification, and packaging of these samples is the subject of another submitted abstract.

Crumple Zone and TPS: The cylinder is contained in a 30 cm spherical "crumple zone" of low density shock absorbing material. The outer shell is 1 cm thick composite. The entry aeroshell is a 45 degree angle cone with 3 cm of TPS.

Weight and Balance: The sample cylinder sits on a "plunger" plate 15 cm in diameter and 5 cm above the center point to allow more material between it and the impact point at the bottom of the cone.

One issue with a sample return capsule is weight and balance upon entry, since the mass distribution of the sample cannot be predicted before launch. This impacts not only entry at Earth, but cruise phase spin stabilization dynamics. After the canister is checked for center of gravity prior to loading, this flat disk may be slid by the loading system up to a centimeter in any direction to offset any sample balance issues.

The disk has a fitting for the sample capsule that can be threaded a specific number of turns to make fine adjustments to the longitudinal axis. The fitting is set within a dual-axis slide that allows it to line up with the sample cylinder regardless as to its offset within the crumple zone material.

Sample Sealing Mechanisms:

Sealing the Cap: The sample capsule would initially be threaded with a Teflon tape-filled thread. This would keep dust out of the threads, help seal the threads, and lubricate the threads. Once the sample collection cylinder is screwed together, it is further sealed with a plastic ring that is melted into a grove with an extruder tip by the lander's robotic sample handling system. The grove consists of a raised ridge on the inner plug and outer cylinder. The ridge is angled inward at the top on both sides, providing a completely solid lock. When the sample cylinder is locked in place and balanced, a TPS cover is placed over the back of the aeroshell.

Sealing the Walls: Atmospheric and dust sample valves would be inside the cylinder to allow the entire outside to be stretched from a single sealed ingot of aircraft aluminum or titanium with no exterior holes. To minimize mass, the aluminum is very thin gauge, and a carbon fiber composite structure is built inside by bonding a series of wedges and keys into the interior. Since the shape is a cylinder, the stamping process would be similar to that of forming a cola can.

Masses: This design calls for a 500 to 1000 gram sample mix. The atmospheric entry vehicle mass is estimated as 6.5 kg. For calculation purposes, it is estimated at 10 kg to allow for structural connections and mass creep.

Electronics: A passive transponder, active radio beacon, and strobe light are placed on a timer. The timer is set by the mother ship prior to separation. They are set to go off after the vehicle reaches terminal velocity in the lower atmosphere, and continue for hours after landing. The electronics should be simple enough that they (and the entire capsule) can be autoclaved prior to launch from Earth.

Planetary Protection: Several methods here are borrowed from Viking and my work at Abbott Labs on pharmaceutical sterilization.

Earth to Mars Contamination: Before leaving Earth, the entire capsule is sterilized by autoclave. The entire capsule section is sealed in plastic that was part of the autoclave process. This exterior plastic cover is removed after landing on Mars.

Mars to Earth Contamination: Since the TPS section has a high probability of damage on impact, the core of the structure is filled with foam that is biologically shielded by the capsule's exterior skin from contact with Mars' atmosphere or dust. Since pieces of this foam may be scattered on impact, it is best they have never touched the Martian atmosphere. Filling this space will low density foam not only gives those contaminants nowhere to go but adds to the shock absorption on impact, thermal insulation of the payload, and low overall structural mass. The outer aeroshell would be covered in a second plastic cover that would be left with the Return Cruise Vehicle, or simply allowed to melt away on entry.

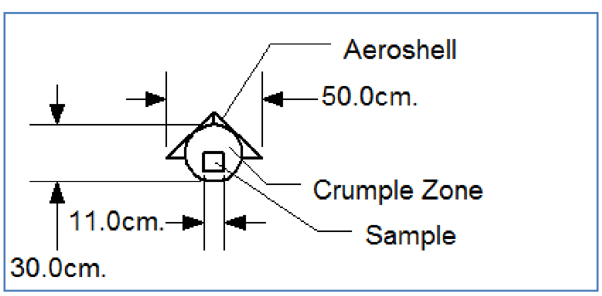

Figure 1: Dimensions of Return Capsule.

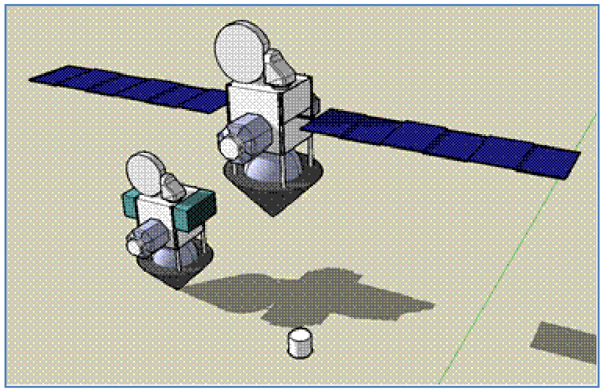

Figure 2: Sample containment Capsule (bottom), folded return vehicle (middle), deployed return vehicle (top).

References: [1] P. Plotard (2005) EADS Space Transportation. Aurora Programme: Delta Qualification Testing of TPS Ablators Summary Report. http://esamultimedia.esa.int/docs/Aurora/execsummaries/Delta_qualification_testing_of_TPS_ablators.pdf.
[2] R.Zubrin, B. Frankie, and T. Kito: Mars In-Situ Resource Utilization Based on the Reverse Water Gas Shift: Experiments and Mission Applications. Pioneer Astronautics, 1997.