ASTEROID SURFACE SCIENCE WITH PODS. D.J. Scheeres, *U. Michigan, Ann Arbor (scheeres@umich.edu)*, E.I. Asphaug, *U. California-Santa Cruz*, J. Colwell, *U. Colorado-Boulder*, R. Dissly, *Ball Aerospace & Technologies Corp.*, P.E. Geissler, *Lunar and Planetary Laboratory, U. Arizona*, L.A. McFadden, *U. Maryland-College Park*, V. Petr, *Colorado School of Mines*, R. Reinert, *Ball Aerospace & Technologies Corp.*, H. Yano, *ISAS - Japan*.

As one component of its proposed asteroid exploration plan, the Deep Interior Discovery mission will place a number of self-contained science packages on the surface of an asteroid. These packages, called "pods", will make unprecedented measurments and characterizations of the surface environment on an asteroid, and subsequently will be commanded to detonate a load of high explosives, thus creating a crater to allow for sub-surface observations from orbit. This abstract introduces the idea of surface pods, discusses the science that can ideally be done with them, and presents the particular implementation being developed for the Deep Interior Discovery mission.

Basic Pod Concept The pod concept currently being considered was derived from a number of different ideas, but largely inspired by the ISAS Muses-C mission to asteroid 1998-SF36. That mission will place passive navigation aids on the surface of the asteroid and plans on placing a rover on the asteroid which has limited mobility and a small science package. These mechanical elements were combined with ideas from the previous Deep Interior Discovery proposal, which delivered high explosive grenades to the surface of a small body, to create the current pod concept.

A pod is a dynamically passive package with active electronics and measurement devices. It is deployed from an orbiting spacecraft on a ballistic impact trajectory with surface impact speeds on the order of meters per second or less, and then settles on the asteroid surface. While it does not have control over its final resting place, by controlling the deployment conditions and the pod design it will be possible to obtain a reasonable degree of surface delivery accuracy. While the pod will not have active control of its attitude and trajectory during descent, it should have the means to "right" itself on the asteroid surface, in order to bring its instrument suite and high explosives package to bear on the asteroid.

Science possibilities with pods Having a science package on the surface of an asteroid enables a host of possible measurements that would significantly advance our understanding of these bodies. With an appropriately rich instrument suite, a pod would be able to determine the basic mechanical and thermal properties of regolith, characterize the near-surface environment, enable sub-surface characterization, and could contribute to the measurement of bulk properties.

Below, we review some of the basic measurements and instruments that could be placed on a pod, along with the science they would enable. In the following, we assume a pod with uplink/downlink capability, rudimentary processing and storage ability, adequate power, and adequate thermal control. Many of these "ideal" instruments will have high mass, fabrication, and design costs and may have to await future missions. A number of them, however, should be within the reach of a Discovery mission proposal.

Optical instruments: Ideally we would like two cameras on the pods: one with sub-centimeter to decimeter per pixel resolution for the general surface morphology, and a color microscope with several bands in the visible and near-IR for the regolith properties experiment.

Accelerometers or seismometers: Accelerometers can serve a dual role. First they can enable some bulk regolith properties to be estimated during deployment, when the pod is rebounding on the asteroid surface. During later phases they can be used as seismometers to measure pressure waves created by the detonation of other pods.

Electrical probes: Simple Langmuir probes would provide unique data on the near-surface plasma environment, which would have direct ramifications for the loss and transport of dust through charged dust dynamics.

Dust detectors: A major process affecting the upper layers of regolith is micrometeoroid bombardment. PVDF films could be placed on deployed pod panels to record any primary or secondary dust impacts.

Thermal probes: A temperature sensor stuck directly into the regolith could measure thermal inertia and heat flow properties as the solar illumination of the site varies.

Mechanical probes: Mechanical devices to scratch the surface can provide information on the mechanical and stratigraphic properties of the regolith: grain size, grain shape, layering, sorting. These would require associated imaging with 50 micron per pixel resolution. These devices would also provide information on the depth and nature of space weathering, assuming the microscope had some color capability.

If it is possible to image a pod land (and presumably bounce) from another pod, this would provide additional information on bulk regolith properties.

Explosive charges: An exploding pod would produce a crater, exposing the sub-surface for imaging and spectroscopy. The depth and diameter of the crater created by an explosion with known energy would also reveal crucial information about the strength and material properties of the asteroid, and be reproducible in the lab. Imaging of the explosive event and subsequent regolith blanket would provide direct measurements of cratering dynamics on a small body.

APX or γ-ray Spectrometer: A γ-ray spectrometer placed on the asteroid surface would allow for detailed determination of the geochemistry of the regolith. If deployed in conjunction with a mechanical device to sweep aside regolith, it could also measure the properties of the subsurface of an asteroid.

Transponder: Doppler shift measurements between the orbiting S/C and the surface pods will enable the pod locations to be accurately determined within a few days. This information will, in turn, be useful in determining the S/C location relative to the asteroid-fixed frame which could provide very high accuracy determinations of the asteroid rotation state and contribute to asteroid gravity field measurements.

Deep Interior Pod Science As is evident from the above list, there are many exciting measurements that can be performed with science pods on the surface of an asteroid. When budgetary and mass constraints are factored in, however, the feasibility of designing, fabricating, and deploying all of these measurement devices under the Discovery program cost caps is difficult. With this in mind, the Deep Interior science team has developed a prioritized list of science goals for the pods, starting off with a relatively simple goal and progressing to more advanced goals (not as advanced as listed above, however). During the mission proposal and evaluation phase, final decisions will be made concerning the actual pod science package.

Science tasks and priority levels:

1. *Excavate surface crater*
Requires an explosive charge on a timer and a shaped charge in the pod, which must have a specific orientation relative to the surface.

2. *Image cratering experiment*
Requires detonation on command, which in turn requires downlink capability, and requires measurement of the surface location of the pods prior to detonation.

3. *Measure properties of the surface environment*
Requires uplink capability to the S/C and data storage capabilities. Scientific measurements being considered include: imaging the surface at high resolution, measuring the electrostatic properties of the near-surface, measuring the micrometeoroid flux at the surface, measuring the mechanical properties of surface.

4. *Measure pressure waves from explosions*
Requires longer life on the surface (more than a week at least), extremely sensitive seismometers, and the ability to place pods in close proximity to each other.

Current design of Deep Interior Pods Although still in progress, the current Deep Interior pod design has reached a relatively mature state. The current design has a tetrahedral shape with 25 cm edge dimensions and is called a "tetrapod". The shaped charge is oriented relative to the "base" of the tetrapod, with its apex containing three imaging cameras, each with 120° fields of view, and communications equipment housed near the center of the tetrapod.

These pods are self-righting, with the three triangular "petals" of the pod (excluding the "base") slowly opening up with a series of controlled steps (similar to the Mars Pathfinder deployment and self-righting technique). The impulse imparted to the tetrapod by each incremental step of the petals as they open is constrained so that the pod is not lofted into a ballistic trajectory.

The interiors of the deployed petals are covered in reflective material. Thus, following orientation and petal deployment, the pod provides a non-dusty, exposed area of approximately 900 cm^2, which can be seen from orbit. Additionally, if up-link communication is avaible, radiometric tracking from the S/C can constrain the location of the pods to within tens of meters or less.

On the interior of the deployed pod petals, a passive dust detector system can be placed, and from the interior of the pod Langmuir probes can be deployed to measure the relative surface potential. Additionally, simple mechanical devices can be deployed to scratch the surface, followed with imaging by the pod cameras.

The total surface life of the pod experiments will only be a few days, during which all data transfer and measurements must be taken. The pod detonators will be on a separate circuit with their own power, thermal, and down-link capability, and will have a surface life of several weeks. Thus, it is not necessary to locate and detonate the pods within a few-day time period, which would lead to an extremely challenging orbital operations period. Instead, based on the inital data, a fix on the pod locations can be made with precision optical reconnaisance occurring later. Then, once the spacecraft has been placed into its proper imaging orbit, the pods will be detonated on command. Imaging will occur during the explosion, and follow-up imaging and IR measurements of the explosion site will be taken in the days and weeks following the detonation.

Figure 1: A deployed tetrapod.