Summary of the 2009 October 28 to 30 Meeting of the Primitive Bodies Panel of the 2010 Planetary Science Decadal Survey

Irvine, California

Michael Busch

Introduction

The Primitive Bodies Panel of the Planetary Science Decadal Survey met from 2009 October 28 to 2009 October 29, one of the series of meetings organized for the Survey by the Space Studies Board of the National Research Council (NRC). The panel met to assemble a list of mission planning requests for the steering committee and to begin preparing its report, and heard presentations on the status of the PanSTARRS and LSST projects, research on solar system ices, and a proposed flyby mission to Neptune, Triton, and a KBO and summaries of white papers related to primitive bodies not covered at the previous meeting.

This report was prepared by a graduate student observer and captures the topics discussed, but does not represent the specific views of any individual. It reflects the status of the panel's work as of the end of the meeting, and does not include any later decisions. The open and closed sessions have been reported separately. A list of acronyms is provided as an appendix.

Open Sessions

Wednesday, October 28, 12:00 PM – 4:00 PM

The open sessions of the meeting were accessible to the public via webcast and teleconference, and archives of the webcasts are available through the Planetary Science Decadal Survey website.

The meeting opened with introductions for the visitors and for the record. The only difference in the panelists between the two meetings was that Larry Soderbloom represented the Steering Committee, rather than Steven Squyres. In addition, the panel received instructions to select a final list of mission design studies by the end of the meeting and to begin writing its draft report as quickly as possible. New Frontiers missions currently under review will not be considered for design studies or costing until after the downselect. The panel was also encouraged to provide material for the Town Hall meetings at the AGU and LPSC, to continue the precedent set at the DPS.

Solar System Science With LSST
Zeljko Ivezic, University of Washington

The Large Synoptic Survey Telescope (LSST) aims to cover the entire span of primitive objects. 90% of the observing time will be assigned to the "deep-wide-fast" survey, covering the whole visible sky every three nights with two visits per night to any given point. The telescope will be located at Cerro Pachon in Chile. The project has started construction (casting and polishing of the mirrors) due to private funding, and has been allocated sufficient money from the NSF and DOE to complete construction. Operating costs are not currently covered.

The design of the telescope has been set to reach the Congressional near-Earth-object mandate by 2025. LSST will survey to magnitude 25 with 15 s integration time and a 10 square degree field of view. The primary diameter is 8.4 m and the data volume will be 30 TB/night. Based on detailed simulations of the survey; in the process of discovering 90% of near-Earth objects larger than 140 m, LSST will also reach 90% completeness on 300 m main-belt asteroids (5 million objects), 1 km Jupiter Trojans (300,000 objects), and 100 km Kuiper Belt objects closer than 40 AU (40,000 objects). At extreme distance, it will locate all Sedna-sized objects closer than 150 AU. While the majority of the objects will be discovered within the first two years of the survey, over ten years, each object will be observed an average of 200 times in six filters. In addition to 50 mas astrometry and fitted orbits, the standard solar system data product will include lightcurves and colors. LSST will use the Moving Object Processing System developed for Pan-STARRS, although extensively modified to the telescope's requirements. The data will be processed and released in real time.

Astro2010 is also interested in LSST. Solar System Science is one of four teams on the project. The others are Dark Energy and Dark Matter, Astrophysical Transients, and Mapping the Milky Way. All four projects require the same sort of survey; trimming any one does not greatly decrease the overall cost.

LSST currently has a team of 200 collaborators from the US, Europe, and Chile; the solar system collaborations has 30 members and is chaired by Steven Chesley. The 455 million USD construction cost is being covered by 50 million in private donations, and ~135 million from the US Department of Energy and ~265 million from the NSF. Construction at the site in Chile is to start in 2011, with first light in 2015 and full data in 2017. The main survey will run for 10 years, and funding the observatory and staff and Chile and operations and science center in the US will is estimated at 37 million USD/year.

The team suggests that NSF and NASA each contribute 1/3 of the operations cost, with some additional DOE funding and international and private partners to cover the remainder. Their rationale for NASA involvement is that 15% of the survey time must be particularly targeted to the northern ecliptic plane to meet the 90% completeness limit on near-Earth objects, so ~15% of the total cost of the project represents a proportional investment.

The Pan-STARRS Project (Pan-STARRS4)
James Heasley, University of Hawaii

The Pan-STARRS project has an alternate approach to wide-field imaging. Rather than one large telescope, they propose to use four 1.8 m telescopes, each with a 7 square degree field of view. They plan to survey 7000 square degrees to magnitude 24 each night. Pan-STARRS1 has been built and the second unit is in fabrication, so the cost and final design of the project is known. Pan-STARRS1 is located at Haleakala on Maui. They want to put the multiple-telescope version (two, three, or four) in place of the 88-inch on Mauna Kea. This must be approved under the use permits for the mountaintop.

Pan-STARRS has the same science goals and data products as LSST, and a somewhat earlier start time. The discovery rate is not quite as fast as the larger project, and its reachs 90% completeness only on 300 m objects, since it does not go quite as deep. It does cover the northern hemisphere rather than southern.

The main software pipeline for the project is MOPS: the Moving Object Processing System. It automatically searches all images for moving sources, computes and fits the orbits, giving a list of detections and automatically flags new discoveries that require follow up as soon as possible. This is done by fitting tracklets from one night to those from three and six nights away. Discovery takes a week from first detection. It automatically searches for precovery data on the entire archive of saved images. The pipeline is currently running on two clusters operated by the project and duplicated by LSST, the Palomar Transient Factory, and WISE, among others. In addition to testing on simulated objects, runtime testing includes synthetic objects added into the real data.

Pan-STARRS1 is currently taking a small amount of data and MOPS can track the objects in it in much better than real time, with fit residuals of ~140 mas. The optics in the telescope are out of alignment, but are currently being fixed, as are problems with fitting the focal plane. The current survey plan is to search at both opposition and at small solar elongations to find near-Earth objects along the Earth's orbit. Pan-STARRS1 is currently planned to go into full survey mode by mid 2010. Pan-STARRS2 optics are complete and the camera is in production. If funding is available quickly, observing with Pan-STARRS4 is scheduled for 2015. The cost of removing the 88-inch and replacing it with Pan-STARRS is uncertain but the additional cost of the project is estimated at 80 million, with 10 million/year in operating costs. Unlike LSST, there will be a proprietary period before data release – targets requiring rapid follow-up will still be made public within a matter of days.

The funding sources for Pan-STARRS4 will both complete the telescope and define the survey strategy – it is not quite a do-everything project and federal money would ensure relevant planetary time. The team requests the survey endorsement for funding, and suggests NSF takes the facility budget and NASA operations.

Planetary Ices
William Grundy, Lowell Observatory

First he gives a definition of ice: a mineral that is thermally unstable and room temperature and made of abundant elements. Organics and ices are considered at the same time, since they fall on a continuum of volatility. Ice can be studied petrographically, as meteorites are. "Cryopetrology" can give information on low temperature events in the history of the solar system, and uses familiar techniques, but applied to cryogenic samples in vacuum. Any sample return will require a special lab.

For cryogenic sample return (presumably from a comet), the temperature of the sample determines the vapor pressure and sublimation rate at zero pressure – as witnessed by the seasonal ice motion on Triton and Pluto. For example, at 145 K water sublimates at 1 mm/year at zero pressure and even a sealed sample will change in microstructure. The temperature used to store a sample is determined by the science goal and how long the sample must be held there.

While ices are more difficult to transport than silicate materials, they have an advantage for remote sensing, since their near-infrared spectra generally have narrow spectral lines. Several chemical species have been mapped on KBOs, and even the phase of the ice (e.g. methane in a nitrogen mixture) can be determined from line shifts. Since grain size is also reflected in spectra, infrared remote sensing can provide the microstratigraphy of the upper few microns of an icy surface. Here additional laboratory work is essential, to determine the phase diagrams and spectra of many species and mixtures of them.

As an example of the capabilities and limitations of remote sensing: amorphous and crystalline water ice can be distinguished by their IR spectra. Chemical kinetics says that ice should be amorphous in the Kuiper Belt, and the amorphous-to-crystalline transition is invoked to explain the outgassing from Centaurs, but no amorphous ice has been observed. Here laboratory work is required, to establish if large KBOs are resurfacing or if micrometeorites, sputter, and cosmic rays can remove or crystallize the amorphous ice as fast as it forms. New Horizons will be informative when it does reach Pluto.

There is a continuum from the organic ices to carbonaceous materials, e.g. methane to graphite. The more complex organics have broader absorption bands, hampering remote sensing, but are easier to transport for sample return. Their formation requires different conditions than the ices, so sampling them provides different science. For sample return, and given the lack of a reliable definition for ‘primitive’ composition, he suggests that a comet sourced from the cold classical KBO population would have a sample that is as close as possible chemically to its composition immediately after formation. Planning any cryogenic sample return from a comet must include the pending results from ROSETTA.

Murthy Gudipati, Jet Propulsion Laboratory

While focusing on laboratory and chemical studies of ice, he strongly recommends in situ observations: funding instrument development to eventually take the lab to the samples through landers and rovers, perhaps through some dedicated NASA program.

Comets are porous masses of hydrocarbons, carbon dioxide, and water ices, but we do not know the physical structure of that material – if the interior is amorphous or crystalline, if solar heating and cosmic rays compact the interior, what the density of a representative comet is. The last can be obtained by studying a large number of objects, but the prior two require microscopic analysis of material >1 m below the surface, either in situ or returned samples. To keep the individual crystals that were present when a sample was grabbed intact, he suggests holding them at temperatures as low as 30 K; while accepting that the gravity load on re-entry will destroy the macrostructure of the sample.

To understand the distribution of amorphous and crystalline water ice, he recommends extensive laboratory studies on thick samples – to capture cosmic ray and photochemical alteration. These can both anneal and disrupt the ice crystals, as well as producing a wide range of chemicals.

As a brief note on asteroids, he cites the main belt comets. Since a sample return from one of them is prohibitively expense, he recommends standoff Raman spectroscopy to obtain high-resolution chemical information. This would be equally useful for rocky objects.

Cryogenic Nucleus Sample Return
Harold A. Weaver, Johns Hopkins University

Cryogenic nucleus sample return is a long-term priority for the cometary science community, as a flagship mission. This survey is only going to recommend further study and technology development. The science goals are the inventory of water and organics; particularly trace volatiles (especially noble gases), isotopic ratios (particularly deuterium to hydrogen), and physical properties; to chart the thermal history of the comet material originating in the outer solar system.

Weaver recommends maintaining the same at temperatures below the temperature at the nucleus, to preserve its physical structure, but the colder the better. Maintaining a sample at <263 K ensures that water does not vaporize, <135 K ensures that amphorous ice will not transition to cubic assuming that the cruise phase is not greatly prolonged. The technology development for keeping the ice cold during extraction and cruise is a primary concern. If the ice cannot be kept cold enough, the evolved gases should be collected. Regardless of the temperature of the sample container, the physical structure of the ice will not be preserved during landing, so there must be some in situ petrographic and structural analysis as well.

The diversity of comet nuclei may pose a problem for choosing targets, both in terms of the depth to pristine ice and the structure of the surface. The depth to which the mission must dig is likely to be a meter or more to get below the diurnal thermal layer and the annual lag deposits. The options on drilling technologies are the second area for technology development. Regional composition changes in the nucleus may make multiple sample sites attractive.

For reliable isotopic ratio and noble gas measurements, the returned sample mass should be at least 500 grams and preferably significantly higher. More than a few liters in volume appears problematic for the re-entry vehicle, setting an upper bound.

Thursday, October 29, 3:00 PM to 4:00 PM

The Argo Mission to Neptune
Candice Hansen, JPL

This is a mission concept for New Frontiers 4, assuming that there is a suitable supply of plutonium for an ASRG. The Giant Planets and Satellites panels have both expressed interest in Argo, as a precursor to a flagship mission in the distant future, but the Kuiper Belt object flyby portion of the mission is of the most interest to this panel.

The mission trajectory is for launch from Earth in 2019, a flyby of Jupiter in 2020, a flyby of Saturn in 2022, and a flyby of Neptune and Triton in either 2028 or 2029. The range in flyby date at Neptune is determined by the target KBO: currently, there are 32 known potential targets, with possible flybys from 2032 to 2034. There is a trajectory allowing a flyby of Eris, but that would occur in 2044, which runs into limits on the lifespan of an ASRG. Onboard propellant and ASRG lifetime are such that a flyby of a second KBO cannot be promised, particularly given the large uncertainties in KBO positions. The mission must launch by 2020 or wait 12 years for Jupiter to move into line again.

The science goals of the Triton and KBO flybys are to provide much better data on Triton and to double the sample size of visited KBOs from New Horizons. Basic science returns: mass; volume; composition; presence and properties of satellites; global maps of colors, terrains, ice distribution, and surface thermal properties; gravity and magnetic field measurements for the internal density distribution and inductive response to the interplanetary magnetic field (to check for subsurface liquid).

In many respects this mission is similar to Voyager, but the technical advantages are obvious: CCD and near-IR cameras, UV imaging spectrometer, and much larger data volume. The current instrument suite is: radio science, magnetometer, visible camera, UV and IR spectrometers, thermal imaging radiometer, charged particle spectrometer. Telecommunications requires the 70 m DSN antennas or an equally sensitive replacement.

The mission's cost estimate is rough, and they request a Team X study. An RMA has been requested by Giant Planets and Satellites for possible New Frontiers missions to Neptune, and may choose a flyby. The Argo team notes that a Uranus gravity assist would be almost equally effective in bending a spacecraft's trajectory to reach a target KBO with a suitably short flight time.

Appendix: Acronym Definitions

AGU	American Geophysical Union
ALMA	Atacama Large Millimeter Array
APL	Applied Physics Laboratory at Johns Hopkins University
Astro2010	Astronomy and Astrophysics 2010 Decadal Survey
ASRG	Advanced Space Radioisotope Generator
DPS	Division for Planetary Sciences of the American Astronomical Society
EPO	Education and Public Outreach
GSFC	Goddard Space Flight Center
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
KBO	Kuiper Belt Object
LCROSS	Lunar Crater Observation and Sensing Satellite
LPSC	Lunar and Planetary Science Conference
LSST	Large Synoptic Survey Telescope
MOPS	Moving Object Processing System used in astronomical surveys
MSL	Mars Science Laboratory
NEO	Near-Earth Object
NASA	National Aeronautics and Space Administration
NRC	National Research Council
NSF	National Science Foundation
Pan-STARRS	Panoramic Survey Telescope And Rapid Response System
R&A	Research and Analysis programs, distinct from missions or observatory funding.
RMA	Rapid Mission Architecture study
RTG	Radioisotope Thermal Generator
WISE	Wide-Field Infrared Survey Explorer