Report to Planetary Science Decadal Survey Primitive Bodies Panel

Perspectives from the Previous PBP Experience, 2001-2002

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Dale Cruikshank
NASA Ames Research Center

Primitive Body Panel Members

- Cruikshank -- Chair
- A'Hearn
- Veverka
- Zolensky
- Stern
- Dermott

The Report

- I. Introduction
- II. Underlying and unifying scientific themes
- III. Themes and key science questions
- IV. Key measurement objectives
- V. Suggested missions
- VI. Priorities and recommendations

Two Themes Identified

- I. Primitive Bodies: Building Blocks of the Solar System
  - Science questions identified
- II. Primitive Bodies as Reservoirs of Organic Matter in the Solar System – The Raw Materials for the Origin of Life
  - Science questions identified

Evaluation of three categories of science questions against missions

Class of Question	Theme 1. BUILDING BLOCKS	Current missions	KBP	First CNSR	Trojan/ Centaur Flyby	Primitive NEO return	Survey and Follow-Up Telescopes
Paradigm altering	1. What is the population structure of the Solar System?		xxx		x		xxx
	2. What is the nature of KBOs?		xxx	x	xx		xx
	3. What is the formation history of the trans-Neptunian region?	x	xxx	xx	x		xx
	4. Where in the Solar System did building blocks form; which were transported, and which were not?	xx	xx	xx	xx	x(?)	xx
Pivotal	1. How do compositional differences between the Oort Cloud and the Kuiper Belt bodies relate to their sites of origin?	x	x	x	x		x
	2. Are small, distant bodies like KBOs, Pluto and Charon geologically active today?		xxx		x		x
	3. What is the nature of binary objects in the Solar System? What do they tell us about formation history?		xx				xx
	4. What processes modify the surfaces of all categories of building blocks?	xx	xx	xxx	xx	xxx	
Foundation building	1. How do colors and albedos of small bodies relate to their compositions and histories of alteration by various processes since their origin?	x	xx	xx	xx	xx	xx
	2. What roles did various dynamical processes play in the origin and evolution of the primitive bodies in the solar System, and what were the time-scales?		xx		xx	x	xx
	3. What are the orbital distributions of long-period and new comets, and how have these distributions evolved over the age of the Solar System?		x				x

Key Recommendations

- Explore Pluto-Charon and Kuiper Belt
- Initiate a first sample return from a comet
- Survey primitive body reservoirs
- Exploit the sample, *in situ*, and remote sensing datasets from missions in progress or in development
- Select additional competed medium-size missions, such as NEO sample return and/or Trojan+Centaur dual flyby

Suggested Missions

- Discovery-Plus Category (*New Frontiers*)
  - Kuiper Belt – Pluto flyby
  - Comet Nucleus Sample Return
  - Trojan Asteroid/Centaur flyby
  - NEO lander/rover/sample return
  - Triton/Neptune flyby
- Large Category
  - Comet Nucleus, cold samples from depth

Lessons Learned

- Conflicts of interest (or appearance of such) may ruin a very good idea
- Theme and related key science question identification is good
- *Paradigm-changing*, *pivotal*, and *foundation-building* categories very useful
- Use a truth table for 3-dimensional evaluation of missions, science questions, and importance of the themes/questions.

Major Advances in PB Solar System Studies Since 2002

- Cassini Huygens Results
  - Phoebe is likely a captured KBO
  - Activity in Enceladus
  - Titan surface and atmosphere
  - Saturn ring structures and colors
  - Organic solids on Iapetus, Phoebe, Hyperion

Major Advances in PB Solar System Studies Since 2002

- KBOs and Centaurs
  - Sizes (Pluto-class)
  - Compositions
  - Satellites
  - Densities
  - Collisional family

Major Advances in PB Solar System Studies Since 2002

- Comets
  - *Stardust* sample return/analysis
  - *Deep Impact*
  - Discovery of Main-Belt comets

Major Advances in PB Solar System Studies Since 2002

- Asteroids
  - Trojan satellites and densities
  - Trojan thermal emission spectra (*Spitzer*)
  - Nice model predictions for Trojans
  - Itokawa images from *Hayabusa* (possible sample return)
  - Measurement of Yarkovsky effect
  - Further exploration of asteroid-meteorite connections

Major Advances in PB Solar System Studies Since 2002

- Measured changes in Pluto's atmosphere
- Changes on surface of Triton
- Extension of spectral studies to longer wavelengths

Work to be Done - I

- Outer Solar System Surveys
  - Pan STARRS is not yet going, and the CFA group is said to intend to keep the outer Solar System data private for 3+ years.
  - LSST is not funded—NASA should be taking the initiative on this
  - NASA should fund a 8-10m telescope dedicated to defining contents of Solar System to enable better targets for missions
  - NOTE: NASA's strong aversion to support of ground-based telescopes
  - Ensure that *WISE* asteroid results are made available

Work to be Done - II

- Explore ice in asteroids to establish their zone of formation and help understand their role in delivery of volatiles to terrestrial planets
- Find the source(s) of the carbonaceous meteorites
- Fly a mission to the Trojan asteroids (but note Cruikshank's conflict)

Work to be Done - III

- Comet sample from depth and cryogenic return
- Return of selected samples from NEO(s)