EXPLORING COMETS, ASTEROIDS, AND RELATED BODIES: A REPORT FROM THE CAMPAIGN STRATEGY WORKING GROUP ON BUILDING BLOCKS AND CHEMICAL ORIGINS OF THE SSES.

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Introduction: The Campaign Strategy Working Group on Building Blocks and Chemical Origins (CSWG/BBCO) of the SSES was set up to help chart a comprehensive program for the study and exploration of asteroids, comets, and related small bodies in the solar system. An important goal of such studies is to provide further understanding of the chemical and physical processes that were at work when the solar system formed 4.5 billion years ago. Essential steps in achieving this goal include (1) extending the survey of the diversity of small bodies; (2) improving the chemical/physical chracterization of materials preserved in key objects through detailed in-situ analyses, and especially through detailed analyses of returned samples; (3) developing techniques for investigating the structures and compositions of the "deep" interiors of comets and asteroids.

During the past year, the CSWG/BBCO has (1) reviewed ongoing and planned comet/asteroid missions, including DS-1, DS-4/Champollion, Stardust, CONTOUR, Rosetta, NEAR, and MUSES-C; (2) surveyed the technology needs of future missions to explore and study small bodies; and (4) initiated studies in collaboration with JPL of a post-Champollion sample return mission to a comet.

Comet Exploration: The CSWG/BBCO believes that while many important questions concerning comets, and especially the assessment of diversity among these bodies, can be addressed adequately through the DISCOVERY program, more elaborate missions are also needed to address key objectives. In particular, the CSWG believes that a sample return mission to a comet, one which will take the next step beyond STARDUST and return a sample of material from a comet's nucleus, is a prime objectives. Note that it is no longer planned for the DS-4/Champollion mission to include a sample return demonstration.

Studies at JPL during the past year have shown that a very attractive sample return mission to a comet nucleus can be designed at moderate cost. The objectives and requirements of such a mission are outlined in Table 1. Note that the word "pristine" as used is a euphemism for material that has been altered as little as possible by radiation, thermal, and impact processes that affect the surface layers of comet nuclei. Whether such materials can really be found is a key exploration goal of such a mission.

Table 1: Comet Nucleus Sample Return (CNSR)

Objective: Return "pristine" samples of comet nucleus material for analysis on Earth

Key Requirements:

Obtain three samples (10 gm each) from coring device (top of regolith, 10 cm and 1 m) at one location.

Attempt to obtain one sample (10 gm) at a depth of 10 meters.

Obtain samples (10 gm each) from at least three widely spaced sites on the comet.

Preserve samples at < 150°K

Characteristics:

2007 launch/SEP

7-year mission

In order to achieve the ambitious goals listed in Table 1 at moderate cost, extensive use of new technology is required. Much of this new technology will be demonstrated by the DS-4/Champollion mission. Included are demonstrations of the following: (1) Low-thrust propulsion with a multi-engine, throttleable SEP; (2) inflatable solar arrays; (3) autonomous guidance/navigation; (4) autonomous landing/anchoring; and (5) improved sample acquisition and sample transfer mechanisms. Additional technological developments needed by CNRS concern primarily the ability to visit multiple sites and to effect sampling down to 10 meters.

Asteroid Exploration: The CSWG/BBCO believes that the current approach to the exploration of asteroids which includes flyby studies by spacecraft such as Galileo and dedicated investigation by DISCOVERY-class missions such as NEAR must be augmented by a suite of more complex endeavors which includes: (1) multi-asteroid missions; (2) access to distant objects such as Trojans, Centaurs, etc., and (3) comprehensive orbiter/lander/sample return missions to selected large mainbelt asteroids. In conjunction with the CNSR studies described above, JPL has also shown that a mission to a large mainbelt asteroid, with objectives broadly similar to those outlines for a comet nucleus in Table 1, is feasible at modest cost. For example, such a mission could be launched in 2007, and using a multi-engine SEP, be completed in seven years.

Additional Recommendations: The CSWG/ BBCO believes that in the future more emphasis needs to be placed on missions which eludidate the internal physical and chemical makeup of small bodies. In particular, techniques for "sounding" the interiors of such objects should be refined, and practical methods of acquiring samples (including cores which preserve stratigraphy) down to depths of at least 10 meters need to be developed.

Conclusion: A vigorous program of small-body exploration must include a mix of small missions which are ideal for exploring the wide diversity of comets, asteroids, and related bodies, and more comprehensive missions which provide more detailed information, much of which can best be obtained through the study of samples returned to Earth. While many easily and moderately accessible comet and asteroid targets can be identified, it is increasingly evident that a complete understanding of the chemical and physical processes in the early solar system will not be obtained until techniques are developed to investigate in detail the many fascinating distant small bodies: Trojans, Centaurs, and Kuiper Belt objects.