Assessment of Planned Scientific Content of the LGO, MAO, and NEAR Missions: Letter Report

Committee on Planetary and Lunar Exploration, Space Science Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council

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On May 14, 1986, Committee on Planetary and Lunar Exploration Chair Robert O. Pepin sent the following letter to Dr. Geoffrey Briggs, director of NASA's Solar System Exploration Division.

At its February, 1986 meeting, the Committee on Planetary and Lunar Exploration (COMPLEX) made first assessments of three of the candidate Planetary observer-class missions identified and recommended by NASA's Solar System Exploration Committee (SSEC) in its 1983 report "Planetary Exploration Through Year 2000: A Core Program": the Lunar Geoscience Observer (LGO), the Mars Aeronomy Observer (MAO), and the Near Earth Asteroid Rendezvous (NEAR) observer. These assessments, which include the science objectives, the mission profiles, and engineering considerations, were made with the help of presentations by representatives of the three mission Science Working Groups and engineering study teams.

As you know, it is the practice of COMPLEX to assess the scientific content of a mission as it nears proposal as a new start candidate, in order to measure the response of the Agency, in a mission context, to the Committee's science strategy. The conclusions of the assessment are a measure of the support of the Committee and the Space Science Board for the proposed planetary mission.

ASSESSMENT SUMMARY

The Committee finds that science planning at this stage of mission strategy development for the three observer missions is proceeding within the guidelines established by COMPLEX for inner planet exploration (LGO and MAO) and for asteroidal reconnaissance and initial exploration (NEAR). The Committee plans to make further assessments during the development periods of these missions leading to launch, and at these times will consider the critical matter of measurement capabilities of the selected instrumental packages in the science payloads, as they relate to the measurement requirements specified in the relevant COMPLEX strategy reports.

RECOMMENDATIONS OF THE COMPLEX STRATEGY REPORTS

Mars Aeronomy Observer (MAO) Mission
Lunar Geoscience Observer (LGO) Mission

The COMPLEX report "Strategy for Exploration of the Inner Planets: 1977-1987" defines the measurement of the morphologic, physical, and chemical character of Mars, Venus, Mercury, and the Moon on a global scale as a broad exploration objective of high general scientific importance, and basic to all planetological studies. Within this general objective, COMPLEX recommended that the major thrust of inner solar system exploration in this decade should focus on Earth, Mars, and Venus, with the goal of understanding the present state and evolution of terrestrial planets with atmospheres. Mercury and the moon, both atmosphere-free, were considered to be complementary bodies of high scientific interest; in particular, the relative ease and economy of lunar investigations, and their high scientific return, indicated that the moon must remain an important object of exploration which should receive strong consideration during the decade.

In this context of overall rationale and general goals, COMPLEX defined the primary objectives for the continued exploration of Mars, in order of scientific priority, to be:

1. The intensive study of local areas
   a. to establish the chemical, mineralogical, and petrological character of different components of surface material, representative of the known diversity of the planet;

   b. to establish the nature and chronology of the major surface forming processes;

   c. to determine the distribution, abundance, and sources and sinks of volatile materials,including an assessment of the biological potential of the martian environment, now and during past epochs;

   d. to establish the interaction of the surface material with the atmosphere and its radiation environment;

2. To explore the structure and general circulation of the martian atmosphere;

3. To explore the structure and dynamics of Mars's interior;

4. To establish the nature of the martian magnetic field and the character of

the upper atmosphere and its interactions with the solar wind; and

5. To establish the global chemical and physical characteristics of the martian surface.

Considerations of exploration strategy led the Committee to conclude that global and in situ studies of the planet and the return of martian material are complementary components of an overall program of investigation, each of which is separately necessary; and to recommend that detailed exploration, on both global and local scales, of the diverse environments of Mars for purposes of understanding surface, near-surface, and atmospheric processes is a worthy goal in its own right and should be accomplished within the next decade.

The Committee recognizes, albeit with regret, that it has so far been necessary to restrict the size and cost of proposed Mars missions. Both Mars observer and Mars Aeronomy Observer, which fall in this class, will do excellent science, but do not address the high priority scientific objectives for Mars involving intensive study of local areas of the planet via in situ studies, and detailed planning, at least, for the return of martian material. These will necessarily continue to be the first-order science objectives in the next decadal strategy for martian exploration.

For the Moon, COMPLEX defined the primary scientific objectives for continued exploration by spacecraft in the period 1977-1987, in order of importance, to be:

1. To determine the chemistry of the lunar surface on both global and regional scales;

2. To determine the surface heat flow on both a global and a regional scale; and

3. To determine the nature of any central metallic core in the Moon.

Additional secondary objectives of global lunar exploration were recommended:

1. To map magnetic-field anomalies in the vicinity of the lunar surface, and relate the anomalies to geological structure;

2. To measure gravity and altimetry for studies of isostasy and global asymmetry of crustal structure; and

3. To search for possible volatiles frozen into cold traps at the lunar poles.

Near Earth Asteroid Rendezvous (HEAR) observer Mission

The COMPLEX report "Strategy for the Exploration of Primitive Solar-system Bodies—Asteroids, Comets, and Meteoroids: 1980-1990" presents in detail the science objectives, exploration strategy, and measurement requirements for the first phases of primitive body investigations. To guide the exploration of these bodies over an indefinite period, COMPLEX recommended that the primary goal of their investigation be to determine their composition and structure and to deduce their history in order to increase our knowledge of the chemical and isotopic composition and physical state of the primitive solar nebula, and to further our understanding of the condensation, accretion, and evolutionary processes that occurred in various parts of the solar system before and during planet formation. There were three additional goals: to determine the diversity of composition and structure of primitive bodies; to understand the role played by accretion of these bodies in the evolution of the crustal and atmospheric composition and the crustal structure of the terrestrial planets; and, unique to comets, to understand the dynamical processes responsible for the production, maintenance, and behavior of the gas, dust, and plasma envelopes of active comets. Within the framework of these goals, COMPLEX defined a prioritized set of primary science objectives for asteroids and comets which, in the opinion of the Committee, could be accomplished in a ten-year period of exploration.

Asteroid science objectives, in priority order, are:

1. To determine composition and bulk density;
2. To investigate surface morphology and evidence for operation of endogenic and exogenic processes; and
3. To determine internal properties of selected asteroids of diverse types.

COMPLEX noted that a full response to these science objectives requires rendezvous-type investigations of several selected asteroids.

ASSESSMENT OF THE CANDIDATE OBSERVER MISSIONS

This section comments on the degree to which the recommendations of the relevant COMPLEX strategy reports are followed by the more general elements of the candidate Planetary observer missions—their rationales, science objectives, general strategies, and timeliness. Until the science instrument definition phase for each mission is completed, evaluation of the actual suite of proposed measurements and their likely uncertainties cannot, be carried out with confidence. The Committee intends to make and convey these assessments at appropriate times, after briefings by the selected science teams.

Mars Aeronomy observer (MAO) Mission

The Committee finds that the scientific objectives and straw-man instrumental payload to implement them are fully responsive to priority (4), and in part to (2), in the prioritized list of primary science objectives recommended by COMPLEX for continued exploration of Mars. The approved Mars Observer mission, which focuses on investigation of the global surface composition of mars and aspects of martian climatology, addresses priorities (5) and (2), and those global and regional elements of priority (1) that can be fulfilled by measurements from orbit using current instrumental technology. A timely follow-up of Mars observer with the MAO mission offers the possibility of scientifically synergistic overlap in mission measurements, leading to enhanced understanding of the surface-atmosphere-upper atmosphere relationships.

Among the objectives of MAO, the understanding of the planet's magnetosphere and interactions with the solar wind will fill the remaining gap between mercury and, now, Uranus (including one or two comets) in this area of study. mars may be unique in having, at the same time, a substantial atmosphere and a magnetic field that is barely strong enough to stand off the solar wind. The atmospheric measurements are well-conceived and should bring our understanding to, or beyond, the level we now possess for Venus. Comparison of these two very different $C0_2$ atmospheres should help us to understand their similarities and differences, both with each other and with the Earth.

Lunar Geoscience observer (LGO) Mission

The Committee finds that the candidate LGO mission is in total accord with the COMPLEX decadal strategy for continued lunar exploration. All of the science objectives identified by COMPLEX in the 1977 strategy report-primary, secondary, and at each level of priority—are fully addressed by the proposed suite of multidisciplinary measurements, excepting only those aspects of local chemical and mineralogical measurements (isotopic age determinations, high precision petrochemical analysis, and petrographic study) that inherently require return of material from unsampled areas of the moon, such as the far side.

The LGO science objectives are in general more sharply defined, and address important scientific questions at higher levels of detail, than those set out by COMPLEX ten years ago. The COMPLEX objectives were formulated from consideration of broad and fundamental issues concerning lunar origin, evolution, and present state. They remain valid as general recommendations for exploration of the Moon, and will remain so until the scientific questions they intrinsically address are answered. But the focus has sharpened during an intervening decade of maturation of experimental and theoretical lunar research, and of technological development in the types of measurement capabilities of spacecraft instrumentation. An example is mineralogical mapping of the Moon. The COMPLEX measurement requirement is for 100 km resolution, comparable to the dimensions of major geologic features. For LGO, the spectroscopic and multispectral mapping capabilities of the Visible and Infrared Mapping Spectrometer (VIMS) will probably allow mineral species and the spacial extents of distinct rock and soil types to be identified and mapped at 1/2 km surface resolution. The surface mineralogy objective can thus be implemented not only globally and regionally, but also at a level of local detail—e.g., crater wall rock types—unenvisioned in 1977.

It is likely, judging from performance estimates for instruments in the LGO straw-man manifest, that instruments selected for the science payload will be capable of meeting or significantly exceeding most of the 1977 COMPLEX measurement requirements. Even the most challenging of the primary science objectives, determination of surface heat flow on global and regional scales to an accuracy of 20%, may be possible using a suitably designed and calibrated Microwave Radiometer (MRAD) experiment on LGO. The MRAD concept is promising, but further instrumental development is needed to demonstrate its capabilities. This measurement also requires the existence of a sufficient number of suitable lunar surface regions, relatively smooth and with regolith depths greater than 3-4 meters, for its implementation.

Because of current international interest in and planning for missions to the Moon, the candidate LGO mission provides ample opportunity for international coordination and cooperation. The Committee regards the benefits derivable from such coordination to be mutually complementary and highly positive elements of planetary exploration.

Near Earth Asteroid Rendezvous (NEAR) Observer Mission

Of the three primary science objectives for exploration of asteroids, the Committee finds that the objectives for the NEAR mission address major aspects of priorities (1) and (2) for a single asteroid, with some results possible for (3). The planned long-term maneuvering and orbiting strategy of the mission will give a much better measurement of density than flyby reconnaissance; it will allow detailed mapping at few-meter resolution, with even more detailed imaging of selected areas. This imaging capability is significantly better than the 50 m mapping and 5 m footprint images recommended by COMPLEX. The spectral mapper, gamma-ray, and X-ray instruments will yield good data on composition. Future NEAR science payload studies will define more clearly the limits of accuracy expected on elemental and mineral abundances: the COMPLEX strategy calls for principal asteroidal elements to be measured ultimately to 0.5 atom percent accuracy, and major mineral concentrations to within a factor of 2. A magnetometer, considered at present to be a possible valuable augmentation of the straw-man NEAR payload, would be needed to meet the COMPLEX recommendation of measuring global or local remanence to a level of a few gammas.

The NEAR type observer-class mission fits well into the overall strategy envisioned by COMPLEX for primitive body exploration. Several such missions, or one with multiple rendezvous capabilities, would ultimately be required to implement fully this initial phase of asteroidal science objectives. A single rendezvous such as NEAR would be an important step in clarifying the nature of the many objects that closely approach Earth. This group of several dozen objects almost certainly includes "burnt-out" comets, as well as asteroids ejected from the asteroid belt, and is currently being expanded by several objects per year from present search programs. As more such bodies are discovered, especially those in orbits With low energy requirements for mission exploration, their importance as targets in unmanned and, eventually,manned spaceflight programs is likely to rise. Ground-based observations have grouped asteroids into distinct spectral classes, probably related to the several petrologic classes of meteorites, but the cross-calibration between the two sets of objects remains unknown. A timely asteroid rendezvous mission of the NEAR type to an object of known spectral class would be a major advance in clarifying the nature of one class and allowing a start on connecting meteorite and spectral classes. This additional potential for enhancing and calibrating our gross ground-based understanding is thus important in both scientific and programmatic terms, over and above the general conformance of the NEAR science planning with the recommended COMPLEX strategy and objectives for direct asteroid exploration.

The Committee would like to thank the representatives of the Science Working Groups and engineering study teams for their presentations and discussions with the Committee.

Please feel free to contact me with any questions you may have, or for further discussion.