**THE CAMPAIGN STRATEGY WORKING GROUP FOR THE FORMATION AND DYNAMICS OF EARTH-LIKE PLANETS: SEEKING TO DETERMINE HOW EARTH-LIKE PLANETS FORM AND EVOLVE.**

E.R. Stofan[1], W.B. Banerdt[1], D.D. Bogard[2], B.A. Campbell[3], D. Grinspoon[4], R.M. Haberle[5], P.G. Lucey[6], C. Peterson[1], R.J. Phillips[7], C.M. Pieters[8], R.S. Saunders[1], S.E. Smrekar[1] and P.D. Spudis[9], [1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 ellen.r.stofan@jpl.nasa.gov, [2] NASA/JSC, Houston, TX 77058; [3] NASM, Washinton, DC 20560; [4] University of Colorado, LASP, Boulder, CO 80309; [5] NASA/ARC, Moffett Field CA 94035; [6] HIGP, University of Hawaii at Manoa, Honolulu, HI 96822; [7] Washington University, St. Louis, MO 63130; [8] Brown University, Providence RI 02906; [9] LPI, Houston, TX 77058.

The Campaign Strategy Working Group (CSWG) for the Formation and Dynamics of Earth-like Planets is one of five working groups that report to the Solar System Exploration Subcommittee (SSES) chaired by Dr. Christopher Chyba. The SSES is in the process of formulating recommendations to NASA regarding mission priorities for Solar System exploration beyond 2005. Official CSWG tasks include: examining missions to be flown between now and 2005, and assessing the extent to which they meet the most important science objectives in that group's area of responsibility; examining the missions beyond 2005 that are in the current strategic plan, and defining their science objectives in detail; identifying other potentially attractive post-2005 missions, both from the Solar System Exploration Roadmap (http://eis.jpl.nasa.gov/roadmap) and from the scientific community, and refining their science objectives; identifying key technologies that enable or enhance science for all these missions; and identifying any science-based or technology-based rationale for establishing the sequence in which the missions should be conducted.

The Formation and Dynamics of Earth-like Planets CSWG focuses on the fact that many aspects of the formation and evolution of Earth are best illuminated by the study of our planetary neighbors, thus this mission planning activity concentrates on Mercury, Venus, Moon and geophysical networks on Mars. Fundamentally, this CSWG seeks to put the Earth in context. In order to understand the differences among our neighboring planets, we must address the following questions: to what extent do initial composition and evolution of distance from a star govern how a planet turns out?; how are changes in the atmosphere and geology of planets linked?; how large a role do chance events play in determining the fates of planets?; can we predict which evolutionary paths lead to habitable worlds?; and why is Earth so unique? To predict and recognize the properties of Earth-like planets around other stars, we need to understand how and why our neighboring planets formed and changed through time.

Each body in the inner solar system provides unique data to address how Earth-like planets form and evolve. At Mercury, we seek to understand what this iron rich body close to the Sun reveals about planetary formation and the role of giant impacts. On Venus, Earth's mass twin, the lack of both present-day plate tectonics and a hospitable climate can help us determine why a planet becomes habitable. The lunar cratering record and compositional structure can reveal much about the evolution of Earth, including its biosphere. In order to fully understand how terrestrial planets evolve, we need to determine how and when (and if) Mars became geologically inactive, and how this is related to the evolution of the martian climate.

One of the key areas of focus of this CSWG is the linkage between the evolution of atmosphere and geology/geophysics of a planet. We seek to determine how both climate and interior evolution have been affected by the interaction between the atmosphere and the solid planet; the nature of the chemical processes taking place between the surface and the atmosphere, the history and role of water and other volatiles on the planet; the climate history and what factors have influenced it; the state and dynamics of the current atmosphere; and the biological and nonbiological sources of disequilibria in atmospheres. To address these issues, we need to make specific measurements. In the atmosphere, we need to measure noble gas compositions, isotopic ratios, and the general dynamical nature of the atmospheric circulation. To understand how the surface and atmosphere have evolved, we need measurements of the mineralogy and chemistry of the surface (including weathering processes and products), as well as the identification and quantification of present escape processes. At Venus, current rates of volcanic and seismic activity, the oxidation state and composition of the lower atmosphere and the workings of the sulfur cycle which intimately connects the atmosphere with the interior, the nature of high reflectivity material, and the identity of the unknown ultraviolet absorber are particularly important. At Mercury and the Moon, we need to understand the nature of the polar deposits, and the sources, sinks, exchange processes and timescales for the polar deposits and the metallic exospheres. At Mercury, we also need to understand the basic geometry of the core, mantle and crust; the shape of the planet; surface composition and age distribution; and the interaction of the planet with the solar environment. We also need sample from diverse lunar terrains as well as from depth in the crust and upper mantle of the Moon. At Mars, we need to quantify the current atmosphere and interior state, the fundamental volatile cycles (CO2 and water) that involve the atmosphere, surface and subsurface; and we need more precise measurements of the isotopes of carbon and oxygen.

Measurements of the age of a planet's surface will help quantify the evolutionary path it has taken. These data will help us to determine when their heat engines started, peaked, and ultimately shut down (if they have). It is also critical to assess impact rates and how they have varied over time. While age dating accuracies of ±10 my can be determined in the lab, much coarser accuracies are acceptable for the in situ dating of many planetary surfaces, and for providing context for sample return missions. Age dating accuracy requirements to address these fundamental questions vary for each planet. At Mercury, we would like to determine the surface age to within ±200 my, while an age resolution of ±100 my is needed at Venus. For lunar surfaces, an accuracy of ±500 my is acceptable for dating the youngest volcanics, while ±100 my would be required to address the existence of a terminal lunar (and presumably terrestrial) impact cataclysm. At Mars, resolutions of ±200-500 my would be adequate for dating of various units which have been mapped on the surface. We see the development of in situ age dating capabilities as one of the highest technology priorities for this CSWG.

Ultimately, to understand the dynamics of Earth-like planets, it is necessary to characterize their interior structure. This includes the determination of planetary composition, interior layering, and how the planet has cooled over time. Is the planet still active? To answer these questions, we need to measure crustal composition and structure, the moment of inertia, obtain seismic data for mantle structure and core size, measure the gravity field and surface topography, and measure the heat flow. For the Moon, we need farside gravity data, heat flow, seismic data (especially for the deep interior and farside), and a lower crust/mantle sample returned to Earth. For Venus, seismic data, surface composition, heat flow, and the moment of inertia need to be measured. Gravity, topography, composition, heat flow, and seismic data are required for Mercury, while seismic data and heat flow are the priorities at Mars.

To address these scientific questions and associated measurements, the Formation and Dynamics of Earth-like Planets CSWG is in the process of assessing an integrated set of missions through 2016. This mission list currently includes: a Mercury Orbiter which would complete the photographic survey of this planet and map its surface composition; a Venus Atmospheric Sample Return, to provide clues to the origin, loss, and sources of the venusian atmosphere and answer questions about Venus' turbulent geologic past; a Lunar Interior Sampler to analyze the unsampled character of the lower crust and mantle of the Moon and further our understanding of the evolution of differentiated bodies and the Earth-Moon link; a Venus Geoscience and Atmospheric Aerobot Explorer, to measure compositions of the surface and near-surface atmosphere and address how the intimately coupled Venus atmosphere and geology have evolved differently from those of Earth; a Mars Geophysical Network, with a network of seismometers and other geophysical and meteorological instruments to understand the life and death of Mars; a Venus In Situ Explorer, to acquire geophysical and compositional data to determine the recent history of the surface and the interior structure (which may include sample return/in situ age dating); and a Mercury In Situ Explorer, which would acquire geophysical and compositional data to determine the very early history of the surface and the interior structure (which may include sample return/in situ age dating). Technology priorities for this CSWG include in situ age dating capability with accuracies on the order of 100 my, systems that can operate for extended periods at high temperature including aerobots, highly capable and affordable networks to obtain geophysical and meteorological data, long-lived power sources, and atmospheric and surface sample return capabilities.