VEXAG Goals, Objectives, Investigations and Priorities: 2006

Steve Mackwell

Kevin Baines

Ellen Stofan

SRM 3: The Solar System Exploration Strategic Roadmap

NASA Goal relevant to Solar System Exploration

"Conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore the moons of Jupiter, asteroids, and other bodies to search for evidence of life, to understand the history of the solar system and to search for resources"

SRM 3: Scientific Objectives*

1. Learn how the Sun's family of planets and minor bodies originated
2. Determine how the solar system evolved to its current diverse state including the origin and evolution of the Earth's biosphere
3. Explore the space environment to discover potential hazards and search for resources that could enable permanent human presence
4. Understand the processes that determine the fate of the solar system and life within it
5. Determine if there is or ever has been life elsewhere in the solar system

- * currently under revision

NASA Science Mission Directorate *Directions**

A. How the universe began, how it became the way it is today, and its final destiny
B. How the planets and their moons form, and how they evolved over the lifetime of the solar system
C. What conditions allowed life to arise on Earth, and whether there are similar conditions elsewhere
D. Whether life, and possibly intelligent life, exists elsewhere
E. How the Sun affects conditions and life on Earth
F. How to predict the Sun's behavior well enough to protect human space travelers
G. How to predict the changes in the Earth's system of land, oceans, atmosphere, and life
H. How human activity is affecting conditions and life on Earth

** From the President's 2007 NASA budget*

Why are we here?

VEXAG White Paper preparation:

(targeting NASA Advisory Groups, Program Management; providing support for mission concepts)

Review GOALS and OBJECTIVES, then define MEASUREMENTS

Timeframes: Input from Focus Groups over next 2 days, assimilation and draft posting on web site by Summer 06, with opportunity for further community input

VEXAG Goals

I. Investigate how Venus originated and evolved, including the potential for an early biosphere (maps to Solar System Roadmap Objectives 1,2,5)

II. Characterize the processes that shape Venus (maps to Solar System Roadmap objectives 1,2,4)

III. Determine what Venus can tell us about the fate of Earth’s environment (maps to Solar System Roadmap objective 4)

**based largely on Crisp et al. (2002) in The Future of Solar System Exploration 2003-2013*

I. Investigate how Venus originated and evolved, including the potential for an early biosphere.

The surface of Venus mostly reveals the history of that planet over the past 1 by. Clues to Venus' origin and earlier history may lie in a more complete characterization of the surface than possible previously, a deeper understanding of the nature and evolution of the interior dynamics, and in the detailed chemical composition of the atmosphere (in particular, the noble gases and their isotopes). Early periods in the planet's history, with possible sustained surface oceans, and a climate more amenable to the development and evolution of living organisms are not excluded based on the present knowledge of the planet. This Goal aims to search for evidence of the past history of Venus before the present epoch (around 1 by) including evidence in the rock record of earlier wetter and cooler periods, chemical tracers in the atmosphere that provide timing on degassing and the development of runaway greenhouse, and biological markers or organisms in the atmosphere.

I: Investigate how Venus originated and evolved, including the potential for an early biosphere.

Objective 1: Measure atmospheric composition to seek chemical signatures (notably noble and trace gases, such as H2O, and their isotopes) of earlier epochs of Venus' history, and clues to Venus' origin/formation.

Objective 2: Map rock mineralogy on a planetary scale to search for the presence of more silica-rich lithologies that may provide evidence for an earlier, cooler and wetter Venus.

Objective 3: Seek evidence for sedimentary rock structures and/or fossil evidence of earlier development of biological organisms.

Objective 4: Search for biomarkers in the Venusian atmosphere.

Objective 5: Quantify the history of volatiles in the interior, surface and atmosphere of Venus, particularly water, carbon dioxide and sulfur dioxide, including degassing and atmospheric escape, to better understand the planet's geologic and atmospheric evolution.

Objective 6: Determine the ages of the various structural units on the surface of Venus, using absolute and relative dating techniques.

Objective 7: Seek parallel examples of Venus-like planets in the suite of extra-solar planets.

II. Characterize the processes that shape Venus

The surface of Venus appears to have been mostly resurfaced within the past 1 by, largely covering over or obliterating signatures of earlier tectonic activity. The nature and duration of the resurfacing event remains enigmatic. Subsequent to this resurfacing, styles of tectonism and volcanism evolved as the near-surface of the planet cooled, so that the thermal/dynamic regime of the planet now resides in a stagnant or sluggish lid configuration. While the general sequence of events is known in general terms, considerable debate on the evolution of tectonic and volcanic processes remains. Although some atmospheric data suggest that Venus is still volcanically active, we have no direct evidence of current volcanic or tectonic activity.

II. Characterize the processes that shape Venus

Earth's sister world is truly alien, with mind-boggling extremes in temperature, acidity, and wind, to name just a few outstanding atmospheric properties. As such, it has much to teach the Earth. As one example, the winds of Venus blow virtually everywhere and constantly with hurricane force (as measured by ram-air pressure) – from the equator to very close to the poles and from just above the surface to over 100 km altitude. Just how such a sluggishly rotating planet – which revolves more slowly than a normal walking speed of 6 km/hr – can whip up winds globally to speeds in excess of 60 times the planetary rotation speed is an enigma that is very poorly understood. Exploring and characterizing processes on Venus – whose thick, CO_2-laden, hot, reactive atmosphere may actually be the typical environment of rocky inner planets everywhere - can help us understand dynamical, chemical, and geologic processes on alien worlds throughout the universe.

II. Characterize the processes that shape Venus

Objective 1: Constrain the thermochemical, photochemical and dynamical state of the Venusian atmosphere to understand radiative balance, climate, dynamics and chemical cycles.

Objective 2: Determine the nature of the ionosphere and its effect on volatile loss.

Objective 3: Characterize atmospheric super-rotation by measuring and modeling the steady and transient components of the wind field at all atmospheric levels.

Objective 4: Characterize the Venus Greenhouse effect, including the interplay of chemistry and physics of the atmosphere, and especially the clouds.

Objective 5: Determine whether Venus is currently tectonically or volcanically active.

Objective 6: Constrain the resurfacing history of Venus.

Objective 7: Determine the internal physical, chemical, thermal and magnetic structure of Venus.

III. Determine what Venus can tell us about the fate of Earth's environment

The terrestrial planets all formed at about the same time within the inner solar system, presumably from largely similar chemical and isotopic reservoirs. Despite these similarities, the terrestrial planets appear to have followed very different evolutionary paths. In particular, Venus and Earth formed at similar distances from the Sun, and have very similar masses and densities, yet their atmospheres and current tectonic styles are vastly different. It has been suggested that Venus may have more Earth-like earlier in its history but evolved to its current state, and that Earth may ultimately follow a similar evolutionary line as Venus. Thus, understanding the interior dynamics and atmospheric evolution of Venus may provide insight into the ultimate fate of Earth.

III. Determine what Venus can tell us about the fate of Earth's environment

Objective 1: Map rock mineralogy on a planetary scale to search for the presence of more silica-rich lithologies that may provide evidence for an earlier, cooler and wetter Venus, more parallel to present-day Earth.

Objective 2: Quantify the history of volatiles in the interior, surface and atmosphere of Venus, particularly water, carbon dioxide and sulfur dioxide, including degassing and atmospheric escape. Such a history of volatile escape may provide constraints on the evolution from plate tectonics to stagnant lid tectonics on terrestrial planets.

Objective 3: Characterize the Venus Greenhouse effect, including the interplay of chemistry and physics of the atmosphere, and especially the clouds, allowing a comparison to atmospheric evolution on Earth.

For this meeting:

Break into groups in order to:

- Review and revise Goals
- Review, modify, delete and add Objectives
- Prepare text for each Objective
- Prepare a list of Investigations: things needed to satisfy each objective (leads to instruments/ missions)
- Think about priorities: what needs to happen first (do not prioritize mission scenarios).