VEXAG Meeting # 3 Report
Alexandria, Virginia
January11-12, 2007

The Venus Exploration Assessment Group is a NASA-supported forum for scientists, mission architects and technologists to discuss exploration of the planet Venus and to enhance communication between the community and NASA. VEXAG is intended to enhance the communication between the planetary community and NASA Headquarters by regularly evaluating Venus exploration goals, scientific objectives, and investigations including those recommendations in the NRC Decadal Survey and the Solar System Exploration Strategic Roadmap. VEXAG held its third meeting at the Crystal City Marriott in Washington DC and it was attended by 100 participants including George Komar Deputy Associate Administrator for the Science Mission Directorate, Jim Green Acting Director of the Planetary Division and Dave Lavery, Division Technologist for the Planetary Science Division. This report includes highlights of the reports made by Komar, Green and other presenters and a series of findings recommendations that have been formulated by the VEXAG Steering Group as a result of information presented at this meeting and the two earlier meetings.

NASA established the Venus Exploration Analysis Group (VEXAG) in July 2005 as a community-based forum open to all interested scientists, mission architects and technologists to identify scientific priorities and strategy for the NASA's exploration of Venus. NASA recognizes the importance of understanding Venus as a world so similar and so dissimilar to Earth, as a laboratory for understanding the evolution of habitable zones, and as a data point in our ever-growing appreciation for the vast diversity of worlds throughout our solar system and other star systems.) The principal charge of VEXAG is to reassess the current state of Venus science, and identify (a) outstanding science questions, (b) spacecraft missions for achieving them, and (c) enabling technology.

SUMMARY OF PRESENTATIONS AT VEXAG-3

Presentations made at VEXAG-3 that included charts are available on the VEXAG website at http://www.lpi.usra.edu/vexag/jan_2007/presentations.html. The presentations included the following briefings and a series of open mike presentations. The mission culminated in an interactive discussion of the priorities of the science goals that have been developed for inclusion in the VEXAG White Paper which is planned for completion in six weeks.

VEXAG Goals and NASA's Planning Framework

- Planetary Science Division Overview…….Jim Green
- Technology Planning at NASA……..George Komar

- VEXAG Goals and Objectives…….Janet Luhman
- VEXAG-3 Meeting Objectives……Sushil Atreya/Janet Luhman
- VEXAG inputs into Planetary Science Subcommittee…Sean Solomon
- 2006 Solar System Strategic Roadmap…….Ellen Stofan/Jim Cutts
- Education and Public Outreach…….Rosalyn Pertzborn

Missions in Flight and new Science Results

- Status Report: ESA's Venus Express…….Hakan Svedhem?
- Venus Express VIRTIS Science Results……Pierre Drossart / Giuseppe Piccioni
- MESSENGER Flybys of Venus…….Sean Solomon

Missions under Development or in Formulation

- JAXA's Venus Climate Orbiter……Masato Nakamura &Takeshi Imamura
- NASA'S Discovery Candidate VESPER….Gordon Chin

Mission Architectures and Technology

- Architectures for Venus Missions…….Tibor Balint
- Technology Challenges for In-Situ Exploration ….Tibor Balint

Recent Meetings and Workshops Related to Venus

- ESA's Venus Entry Probe Workshop ……Eric Chassefiere (by T. Balint)
- International Planetary Probes Workshops (IPPW4 and 5)……Jim Cutts
- Chapman Conference…….Larry Exposito

Development of VEXAG White Paper

- Overview of White Paper…….Janet Luhman
- Science Goals and Prioritization……..Steve Mackwell

There were 9 open microphone presentations covering a number of topics including:

- A report on the workshop on Surface Ages and Histories that was held in May
- The geology associated with Venus shield fields and associated features
- Development of a Venus environmental chamber at Iowa State University
- Development of SiC-based harsh environment electronics and sensors at NASA Glenn Research Center
- A model for chemical kinetics for the lower atmosphere of Venus
- The possibility that Venus may once have been habitable, like Earth
- Raman spectroscopy for in-situ mineralogy and remote atmospheric sensing.
- A new opportunity to propose revolutionary systems and architectures

A key activity at this meeting was a review and update to the VEXAG Goals, Objectives and Investigations Document led by Steve Mackwell on Friday January 12, 2007, the second day of the meeting. The goal was to understand what our highest priority items are and to document them in order to support NASA's Venus technology and mission developments. Current VEXAG Goals, Objectives and Investigations come from Focus Group discussions at the previous VEXAG meetings in November 2005 and May 2006 as

well as interact web posting after the last VEXAG Meeting. The three overarching VEXAG Goals (with equal priorities) can be paraphrased as:

(1) Search for Evidence of Past Habitability including ancient oceans
(2) Understand Venus as Terrestrial Planet
(3) Understand Venus as a model for future states of the Earth

Within each goal all objectives are important. Discussion during this portion of the meeting established authors for short (a paragraph or two) descriptions of the investigations, the relative priority of the objectives associated with each of the goals, and the relative priority of the investigations associated with each of the investigations.

HIGHLIGHTS OF PRESENTATIONS

Jim Green. Acting Director of the Planetary Science Division announced several recent developments including the publication of the Planetary Science Division (Solar System Exploration) Roadmap and the selection of candidate Discovery and Mars Scout missions including the *VESPR mission to Venus led by Gordon Chin*, which is one of three Discovery missions selected for a nine month Phase A study. Green also described the status of planning for the next Flagship mission he noted that four outer planet Flagship mission candidate missions studies would begin this month and end in the fall and include Science Definition Teams (SDTs) selected from OPAG (the outer planet counterpart of VEXAG). In response to a question indicated that *he would be receptive to carrying out similar studies of a Venus Flagship mission but just as OPAG advocacy had played a key role in the outer planet studies*, VEXAG advocacy would be needed before considering a Venus study. Finally, Green discussed three issues that were identified by the VEXAG Steering Committee as of particular interest to VEXAG

- ***How will NASA cooperate in ESA's Cosmic Vision Plan and how should VEXAG introduce that into its activities?*** Green indicated that VEXAG members are participating in the planning teams and in the Venus Entry Probe workshop to be held in Europa in two weeks.. He noted that participation in Cosmic Vision missions could be through Missions of Opportunity up to 35M. Involvement at a higher level would need to be handled by direct negotiations between NASA and ESA.
- ***What are NASA plans for continuing or additional VEX- related data analysis and for Venus mission related technology development?*** While spacecraft missions are essential, the life-blood of the research community is R&A funding. Therefore, VEXAG urges NASA to take steps for starting a modest V-DAP, especially as data from the Venus Express Mission begin to flow into the PDS.
- ***Status of New Frontiers mission planning*** Jim Green described the Planetary Science Divisions response to two NASA Advisory Council Recommendations concerning New Frontiers. One of these calls for NASA to reconsider the field of New Frontiers candidates and *in response the Science Mission Directorate has enlisted the Committee on Planetary Exploration (COMPLEX) for guidance* (see Green presentation for details). Jim indicated that it would be appropriate for VEXAG to provide an input to COMPLEX concerning selection guidelines the New Frontiers AO mission set.

- ***What are the impacts of NASA's plans for the Vision for Space Exploration (VSE) and management changes in the Science Missions Directorate?*** He indicated that announcements of new management will be made soon but he was not able to discuss them at this time until they had been announced.

Sean Solomon, chair of the **Planetary Science Subcommittee (PSS) of the NASA Advisory Council (NAC)** described the role of the subcommittee. He indicated that VEXAG is one of five Assessment Groups that provide regular reports to the Planetary Science Subcommittee. Janet Luhman, the co-chair of VEXAG is a member of the PSS and makes a report at each PSS meeting. The PSS is the conduit for bringing Venus related issues to the NASA's Advisory Council. Solomon indicated that four issues that PSS is currently dealing with are of potential interest to VEXAG and he would welcome contributions

- Program balance within the Planetary Science Division
- Nature of the Discovery and New Frontiers Programs
- International Cooperation and
- Technology Investments needed

George Komar, Deputy Associate Administrator for Technology for the Science Missions Directorate, described his role in assuring that there is effective investment in technology by SMD. The actual budgets for technology are within the divisions and the Planetary Science Division has investments in Mars Technology, Radioisotope Power, In Space Propulsion and a range of instrument programs. Komar indicated that he is ***endeavoring to build the overall level of investment in technology within SMD to 10%*** - it is currently significantly below that and is seeking to exploit synergies among SMD programs and programs within ESMD (Exploration Systems Mission Directorate). To this end, a ***Science Missions Directorate Technology Plan*** is currently being prepared and it will be a key topic of discussion at the upcoming Technology Federation (TechFed) meeting on Feb 6-7 which will bring together chief technologists from several NASA centers as well as NASA HQ technology management people. He introduced ***Dave Lavery who is the Division Technologist for the Planetary Science Division*** and who is the focal point for dealing with technologies related to Venus exploration.

KEY FINDINGS AND RECOMMENDATIONS

The VEXAG Steering Committee met following the meeting and in subsequent telecom concerning issues related to Venus science, a Venus Flagship mission, New Frontiers mission and technology investments and has developed a set of findings and recommendations to forward to the Planetary Science Subcommittee and to the Planetary Science Division. .

Venus Science:

After a two decade hiatus, the Venus community is now seeing new data on the atmosphere of Venus. In one year of operation at Venus, the ESA Venus Express orbiter has obtained important new observations and VEXAG had a report on the latest results from the VIRTIS (Visible and Infrared Thermal Imaging Spectrometer). On June 5, 2007,

the Discovery Messenger mission will perform a second encounter and will not only acquire unique data with its laser altimeter and X ray spectrometer but will perform coordinate observations with the Venus Express (VIRTIS) using its MDIS and MASCS instruments. These data will be placed in the PDS within 6 months of the encounter.

Finding: Without additional resources, the US Venus science community will further lose leadership in Venus exploration and there will be no opportunity to fully exploit the results of either the VEX or the Messenger mission.

Recommendation: In order to fully exploit the results from both the Venus Express and The Messenger program, funds should be identified for **a**mending the ROSES NRA to include a Venus Science Data analysis program.

Venus Flagship Mission

The Solar System Roadmap has identified a program of Flagship missions to address key scientific questions that were identified in the NRC Decadal Study and that cannot be solved with small and moderate missions. A Venus Flagship mission is included in the three highest priority missions (Europa Explorer, Titan-Enceladus Explorer and Venus Mobile Explorer)**.** The Roadmap also notes that the Venus Flagship will require new technologies and complex flight systems to cope with the Venus surface environment. NASA has recently initiated studies of Flagships to Europa, Titan and Enceladus (as well as the Jupiter System) but not a Venus flagship mission.

Finding:

The completion by VEXAG of scientific goals and priorities now makes it timely to initiate a study of ~~the~~ a Venus Flagship mission in other to define in detail how it can address these science questions and what are the technologies needed to implement that mission. A Venus Flagship mission study should **not** be viewed as part of the competition for the next Flagship mission as a significant and sustained program of technology development is needed to prepare for that mission and a New Frontiers precursor mission to the Venus surface should precede the Flagship mission. Furthermore, this is no reason for delay because the difficulty of the challenge makes it vital to define the pathway to this Venus Flagship mission as early as possible.

Recommendation: *The Planetary Science Division should initiate a study of a Flagship mission to Venus at the earliest opportunity***.** VEXAG urges NASA to take steps for establishing a Science and Technology Definition Team (STDT) at the earliest date to guide the study a Flagship mission to Venus. *The study should assess:*

- *Key scientific questions that can be addressed by a long duration mobile mission to the surface or near surface of Venus.*
- *Alternative missions architectures for addressing these scientific questions.*
- *Precursor scientific measurements and technology validation that might be implemented with prior Discovery and New Frontiers missions.*
- *Technology investments needed to enable the Venus Flagship mission emphasizing the long lead time technologies needing early investment.*

Venus New Frontiers Mission

The NRC Decadal Survey recommended Venus In Situ Explorer (VISE) as one of four New Frontiers mission candidates. The mission candidate proposed by the NRC Decadal Survey acquired a surface sample and raised it with a balloon to the Venus' middle atmosphere for remote analysis. This mission would thus have served as the precursor for a Venus Surface Sample Return that would have also transferred a sample to the middle atmosphere and then launched the sample to space. However, the 2003 New Frontiers AO noted that "*any mission architecture that achieves the majority of the science objectives stated above for a cost within the New Frontiers cost cap will be considered responsive to this AO"*. As a consequence, no proposal for VISE was selected to proceed to Step 2 in 2003.

Finding

VEXAG considers that the Venus In Situ Explorer (VISE) continues to be a vital mission in the exploration of Venus should be included in the FY08 New Frontiers AO. The scientific goals stipulated in the FY03 AO remain valid. The VISE mission also offers a unique opportunity to validate capabilities that would be important to a future Flagship mission. Thus, adding a Technology Demonstration to the VISE payload would reap substantial long-term benefits.

Recommendation: *The Venus In Situ Explorer (VISE) should be included in the New Frontiers AO for 2008 and the scientific goals for this mission should remain unchanged. Consideration should be given to increasing the funding level for New Frontiers to assure the success of the mission. NASA should consider implementing a technology validation element to VISE in particular that would permit demonstration of technologies needed for a long duration mobile mission but not necessary to the success of VISE itself.*

Technology Investments

Just as the solution to many high-priority scientific questions about Mars required landed and mobile in situ exploration of the surface, advances in Venus science will require in situ surface measurements. The impediment has been the technical difficulty of operating at the extreme pressures and in particularly the very high temperatures at the Venus surface. There are opportunities to leverage technologies developed for operation in similar environments encountered in aerospace (jet and rocket engine) and deep drilling application. Nevertheless, the conditions at the surface of Venus are unique with hot supercritical carbon dioxide representing a significant challenge for operations.

Findings: There are credible technical approaches, leveraging from technologies developed in industry to achieving extended operation in the Venus environment. High temperature electronics can enable systems to operate for extended periods. Advanced radioisotope power systems and active thermal control systems could enable conventional components such as microprocessors or imaging sensors to operate for extended periods on the surface of Venus. While further work on mission architectures will be needed to define specific performance goals and focus the technology, work on the technology can

and should begin now. Without NASA direct involvement, it will not be possible to apply the results from industry to the specific needs of in situ exploration.

Recommendations: NASA should initiate a program to develop technologies for operation in the extreme environment of Venus. These should include:

- Passive thermal control technologies for extending the period of operation in the Venus surface and near surface environment from hours to days.
- Active thermal control technologies and power generation systems for extending the period of operation in the Venus environment to many months.
- High temperature electronics and other components capable of extended operation directly exposed to the Venus surface environment
- Mobility systems for operation at the surface and in the lower atmosphere of Venus
- A program of systems analyses to establish performance objectives and evaluate alternative approaches.

If funds were available this could be implemented through an amendment to the ROSS NRA to address technologies for extreme environments.

NEXT VEXAG MEETING

The next VEXAG meeting is scheduled for Friday and Saturday October 5th and 6th .n Orlando Florida directly preceding the Division of Planetary Sciences (DPS) meeting in that same city.

Several VEXAG participants noted the role that the study of Venus greenhouse effect had had in appreciating climate change on the Earth. Jim Hansen of GISS be invited to the next VEXAG meeting to discuss extreme climates and the significance