

Summary

Venus Exploration Analysis Group (VEXAG) Meeting #12 National Institute of Aerospace, Hampton, Virginia Thursday, April 9, 2015

62 members of the Venus community participated in the VEXAG Meeting #12 at the National Institute of Aerospace, Hampton, Virginia on April 9, 2015. Lori Glaze, VEXAG Chair, welcomed the attendees and noted that the primary goal for this meeting was to keep the Venus momentum going. Key items for this meeting were learning about what's happening at NASA Headquarters (items that are germane to Venus research and exploration); status reports on Venus Express, Akatsuki, and potential future Venus missions; the upcoming New Frontiers mission opportunity, recent and upcoming Venus workshops and conferences; and (most importantly) thinking about the year ahead and what's next for Venus?

Current important VEXAG and Venus related events include:

- Venus Exploration Targets Workshop, May 2014 (LPI, Houston, Texas) – Report coming soon!
- Venus Express: Successful aerobraking campaign in summer of 2014; fuel depleted in November 2014; end of mission in January 2015 after nine successful years in orbit
- Discovery mission proposals were submitted to NASA on February 16th. As best we know, there were 28 proposals submitted. The four Venus-specific proposals illustrate that now is the time for NASA to return to Venus
- Venus Town Hall and Early Career Mixer at LPSC in March
- The Glenn Extreme Environments Chamber (GEER) is operational as of March 30th. This facility can simulate full Venus atmosphere chemistry at near surface temperatures and pressures. It is large enough to test instruments and hardware. To use this facility, propose through ROSES.
- Akatsuki is planning on orbit insertion in November 2015. NASA has selected 2 Scientists in Residence and 4 Participating Scientists
- A Venus III Book is in preparation (chapter drafts were due in April)
- NASA R&A Restructuring has settled down, although acceptance rates are ~20-30 %
- VEXAG's documents - Venus Exploration, Goals, Objectives, and Investigations (GOI), Venus Exploration Roadmap and Technology Plans - were updated in the last couple of years are now in final form and posted on the VEXAG Web-Site (<http://www.lpi.usra.edu/vexag/>)

Venus relevant items discussed at the March Planetary Science Subcommittee Meeting were assessment of Restructured R&A, radioisotope power sources, value of NASA Analysis/Assessment Groups (AGs), an increased launch cadence of Discovery missions to 24 months; long-term enabling technology development efforts, and international collaborations.

Lori concluded by noting that there is a need to think about what's next for VEXAG. For the last couple years VEXAG has focused on laying out the Venus Science Objectives, as well as developing an Exploration Roadmap and Technology Plan. In addition, there is an improved Venus community understanding of Venus explorations targets, technologies and instruments. A key item is to think about what VEXAG should do in the coming year. There is an opportunity to participate directly in these VEXAG activities, as there will soon be an announcement of opportunities to be a VEXAG Executive Committee and/or Focus Group member.

Jim Green (NASA Headquarters) provided a well-received status report on activities associated with NASA's Planetary Science Division (PSD), by discussing the current NASA planetary missions events, the NASA Planetary Budget, upcoming Discovery and New Frontiers events, the status of NASA's Advisory Groups (the AGs). Jim noted that it's important to "tell the public what they're getting in return for their investment". For the current NASA planetary missions events, Jim discussed a number of events including DAWN's approach to the dwarf planet Ceres, the upcoming end of the successful MESSENGER mission, and New Horizons' mid-July encounter with Pluto. MESSENGER is beginning to detect Mercury's magnetic field.

For NASA's Planetary Budget, Jim noted that "Congress has been good to us". The good news is that there is a "healthy budget" for Discovery, that the Mars2020 Rover is healthy, and there would be a New Frontiers AO in late FY16 (bolstered by new ROSES element to develop New Frontiers technology developments). A Europa mission is in now in Pre-Formulation. Unfortunately, the budget for NASA R&A is stressed. Instrument development continues in the MATISSE and PICASSO programs. A new SIMPLEx call for Cubesats would close on April 10th, the day after this meeting. In closing, Jim noted that he is working with NASA lawyers to rectify the current situation where the NASA Advisory/Assessment Groups (the AGs) were not included in a recent update to how NASA Advisory Committee/Planetary Science Committee operates. How the AGs will continue is an open item at this point in time. The primary impact of this change is that all the AG meetings will be considered "conferences" for the foreseeable future.

Håkan Svedhem (Venus Express Project Scientist) provided an update on Venus Express noting that there was a successful aerobraking campaign last summer, that propellant was exhausted in late November, and Venus Express disintegrated in the Venus' atmosphere last January. The aerobraking campaign was conducted in mid-May through early July 2014. Periapsis was lowered to 130km (well down into the Venus atmosphere), and the orbital period was subsequently decreased to 22:15 hours. Venus Express, like Magellan, experienced large day-to-day variations in atmospheric densities at the 130km altitude. This aerobraking campaign provided a means of collecting atmospheric data of Venus in a region not accessible by other methods, including the preliminary discovery of atmospheric gravity waves at higher than expected altitudes. This also set a new record for lowest altitude for aerobraking at Venus as well as highest dynamic pressure experienced by a spacecraft at any planet. Håkan concluded by noting that the efficiency of aerobraking was clearly demonstrated, thanks to a robust spacecraft design.

Takeshi Imamura provided an update on Akatsuki noting that Akatsuki was launched in 2010 with the objective of understanding the atmospheric dynamics and cloud physics of Venus by remote sensing from an equatorial, elliptical orbit. Its scientific payload of 35 kg has two Infrared Cameras, an Ultraviolet Imager, a Lightning and Airglow Camera, and an Ultra-stable Oscillator (for radio science occultation experiments). The spacecraft has now passed through the perihelion 8 times, with the final perihelion passage coming up on August 29th. A VOI plan, in which the attitude control thrusters will be used instead of the main thruster, has been developed. VOI is set for December 7, 2015. The new orbit around Venus will be a highly elliptical one, with the orbital period of 8 to 16 days. Although all of the science instruments have been turned off for more than three years to satisfy thermal constraints, some of them will be turned on before VOI.

Sanjay Limaye described prospects for international cooperation on future missions noting that it has been an interesting and exciting year. International successes include the ESA-NASA collaboration on Venus Express via U.S. Participating Scientists and on Akatsuki (Venus Climate Orbiter) via Participating Scientists and Scientists in Residence. A Roscosmos-NASA Collaboration on Russia's Venera-D mission was underway in February 2014 when a Joint Science Definition Team was solicited and selected. Unfortunately all dialog halted due to diplomatic tensions following the Ukraine conflict. Sanjay noted that VEXAG should request NASA to consider re-opening the VENERA dialogue. ISRO, the Indian Space Agency, is seriously contemplating a Venus Mission by hosting Venus Exploration Workshops in July 2012, May 2013, June and October 2014. A NASA-ISRO Joint Working Group for Venus, modeled on the existing NASA-ISRO Joint Working Group for Mars would be timely. Sanjay also discussed the status of Venus Data from past NASA and international missions. Venus Express data is archived at ESA's Planetary Science Archive and mirrored to NASA's Planetary Data System (PDS). However valuable Venera data has never been archived. Although raw data from the Pioneer Probe and Orbiter mission still exist, they are not in NASA's National Space Science Data Center or in the PDS.

There were reports on past and future Venus Science Conferences. Lori Glaze filling in for Virgil (Buck) Sharpton provided a report on the Venus Exploration Targets Workshop that was held last May at the Lunar and Planetary Institute. The workshop goal was to identify and evaluate key locations, transects, and regions for future exploration of Venus. The workshop considered targets on the surface and in the atmosphere. Appropriate candidate targets included those requiring landers, orbital missions, as well as atmospheric probes, gliders, or balloons. For the surface, significant science could be achieved from low-risk areas such as plains, while a tessera lander site would be more scientifically fruitful but more risky (although landing risks could be mitigated by autonomous hazard avoidance landing technologies implemented via high-resolution imaging and topography). For the atmosphere, there was a large number of domains to consider, as no single static target would be adequate. It was noted that remote surface observations from low altitude and coincident orbital observations would be beneficial. Lori concluded by noting that a report is being compiled. The community would be given

the opportunity to comment on this report. When completed, this report will be posted on the VEXAG website.

Tibor Kremic provided an overview of the Workshop on Venus Science Priorities for Laboratory Measurements and Instrument Definition that was also held at the National Institute of Aerospace on April 7-8, 2015 (the 2 days before this VEXAG Meeting). The workshop objectives were to (1) Present, discuss, and document the status of the instrument technologies and the definition of new instruments, and (2) Present, discuss, and document the status and needs of laboratory experiments in support of fundamental science as well as mission preparation. Background for these objectives were provided by the recently released VEXAG Goals and Objectives, Pathways and Technology Plan documents as well as by the findings from the Venus Explorations Targets Workshop held at LPI in May 2014. Tibor noted that 70 attendees participated, and two public lectures were held at Virginia Air and Space Museum. There were 1.5 days of breakouts focused on instruments and laboratory measurements needed for Venus exploration. The surface, atmosphere, and orbital experiments needed for basic fundamental research include:

- Thermal and spectral properties of atmosphere constituents
- Near-IR emissivity of materials
- Physical properties of supercritical phase
- Effects of trace species

Also, modeling of pressure and temperature effects on instruments, measurements, and their interpretation is needed. A draft workshop report will be available for review by Venus community in August.

Sue Smrekar provided a preview of the Workshop on the Comparative Tectonics and Geodynamics of Venus, Earth, and Exoplanets, to be held May 4-6 and Caltech. One motivation for this workshop is the realization that Venus and Earth have dramatically different geodynamics and tectonics even though they have basically the same size and bulk composition. This workshop will bring together scientists studying Earth, Venus, and rocky exoplanets to explore the role of key variables such as mass, composition, temperature, atmospheric interaction, and volatiles on tectonic and geodynamic processes, and to compare planetary evolutionary paths within our solar system and beyond. Workshop discussion topics would include Volcanism, Crustal Formation and Planetary Structure Evolution.

Lori Glaze provided a preview the Comparative Climatology of Terrestrial Planets II Conference that will be held at NASA Ames, Moffett Field California on September 8-11, 2015. This is a follow-on to the highly successful Comparative Climatology of Terrestrial Planets conference held in Boulder, Colorado, June 2012. This conference, which has support from all four NASA Science Divisions, has an overall theme of how climate systems work. A key point here is that Venus is an important example for comparative climatology and for understanding exoplanet climates. The conference format will include invited speakers, contributed talks and posters, as well as panel discussions.

Tibor Kremic provided an overview of NASA's Extreme Environments Centennial Challenge. From the NASA perspective, the ultimate goal is to mature technical capabilities to implement a future missions to destinations with extreme conditions like those of Venus (100 bar, 500C, duration of 10 hours). Based on the applicability to terrestrial applications and a large available electronics base, the electronics phase of the challenge was chosen to be first. An Industry Day was held last October at the Ohio Aerospace Institute. There were over 40 participants from companies including General Electric, Boeing, and some smaller high temperature electronics and thermal management companies. An RFI is now being prepared with the basic message that NASA is considering a challenge aimed at extreme environment technologies. For this RFI, NASA needs an idea of the level of interest and feedback on prizes, structure, etc. This RFI should be released soon.

Sanjay Limaye provided a progress report on recent study of Venus Gravity Assist Science Opportunities (VeGASO) for Venus fly-bys by the Solar Probe Plus, Solar Orbiter and BepiColombo missions. A VeGASO Panel was underway last October with the goal of determining opportunistic science that could be carried out during Venus fly-bys for missions headed toward Mercury and the Sun. These opportunities would have to be carried with no impact on missions and no changes to instruments. The number of gravity assists for the 3 missions are:

- BepiColombo – 2 Venus Gravity Assists
- Solar Probe Plus – 7 Venus Gravity Assists
- Solar Orbiter – 6 Venus Gravity Assists

These fly-bys provide a unique opportunity to observe Venus in its interplanetary environment, as this would be the first opportunity to observe a planet in its extended interplanetary environment, far beyond 10 R_v . Specific scientific opportunities include:

Surface and Interior:

- Refinement of the oblateness (C2 coefficient)
- A high accuracy, independent estimate of the gravitational parameter (GM)

Ionosphere/Magnetosphere:

- Venus bow shock and magnetotail as well as Venus ion escape
- Ion cyclotron waves and other waves observed around Venus

Atmosphere:

- Vertical structure of the atmosphere – clouds, thermal structure, hazes
- Airglow and lightning/electrical activity

The final VeGASO Report, which was presented to NASA Headquarters on April 10th, the day after this meeting, is now posted on the VEXAG web-site

<http://www.lpi.usra.edu/vexag/>.

Tibor Kremic discussed the use of stratospheric balloons for planetary science noting that balloons have advantages in that they:

- Enable long baseline observations at mid IR, and near UV wavelengths not possible from the ground or aircraft
- Provide a rapid response potential, not feasible for space missions
- Generate high-value observing time at low cost

- Engage the science community via frequent new missions and broad science targets, especially good for early career scientists
- Provide for rapid maturity of technologies in near space environments
- Provide for rapid improved, modified science payloads as are science payloads are generally recovered

Also, the Decadal Survey noted, “Balloon- and rocket-borne telescopes offer a cost-effective means of studying planetary bodies at wavelengths inaccessible from the ground. Because of their modest costs and development times, they also provide training opportunities for would-be developers of future spacecraft instruments.” Tibor concluded by noting that uses of balloons for Venus could include:

- Searching for lightning on Venus,
- Observing of surface emissivity (extending Venus Express VIRTIS observations), and
- Measuring the wind fields of associated with the lower/middle/upper cloud decks.

Lynnae Quick provided a report on activities associated with VEXAG’s Early Career Scholars Focus Group. The Early Career Venus Scholars Facebook group now has 106 members. Posted topics include Venus-related meetings, student opportunities, and new Venus science results. Lynnae concluded by noting that there would be student activities such a mixer or a luncheon at the upcoming Comparative Climatology of Terrestrial Planets II and VEXAG Meeting #13. Suggestions for further opportunities for student involvement would be welcome.

During open microphone session at the end of this meeting, there were four presentations:

- New developments in Venus Aeronomy,
- Status of Heat-shields for Extreme Entry Environment Technology (HEEET),
- Use of Combined Remote Raman Spectroscopy and,
- Elastic Lidar for exploring the atmosphere and surface mineralogy of Venus, and the use of stand-Off LIBS and Raman Spectroscopy for addressing key Venus science questions.

Lori Glaze closed the meeting by thanking those who participated and previewed a number of items that would be addressed in Findings and Resolutions. In general, “Findings” request some form of action by the Planetary Science Division. “Resolutions” are internally focused actions to be taken by VEXAG over the coming year. The Findings and Resolutions for this VEXAG Meeting follow.

Findings and Resolutions of the 12th VEXAG Meeting
National Institute of Aerospace, Hampton, Virginia
Thursday, April 9, 2015

Findings

1. VEXAG is enthusiastic about the science observations of the dynamic environment of Venus that can be made during the more than two dozen gravity-assist fly-bys that will occur through 2024 from ESA and NASA missions - Solar Orbiter, BepiColombo and Solar Probe Plus. These would be particularly valuable to maintain continuity of Venus observations until the next mission(s) to Venus. VEXAG appreciates the role that PSD played in identifying these opportunities and in supporting the assessment of possible science observations. VEXAG encourages PSD to identify future opportunities to include Venus science with missions that have other primary applications/targets. Many mission trajectories include one or more Venus flybys and these opportunities may enable new low cost mission data. VEXAG also encourages PSD to consider secondary payloads for Venus observations that can take advantage of missions that may have excess launch mass capacity.

2. VEXAG encourages PSD to create a sustained mechanism for the development/maturation of specialized spacecraft systems that will enable PSD to explore all the solar system, including the challenging yet scientifically significant atmosphere and surface of Venus. Future Venus missions can be enhanced or enabled by advanced technology. Some of these technologies are of a specialized nature with limited applications outside of planetary science and therefore unlikely to be developed or matured by others. Examples of technologies that are critical for future Venus exploration include high temperature electronics, high temperature power generation and storage systems, and high temperature mechanisms. Currently there is no mechanism for these technologies to get proposed or funded within PSD or elsewhere.

3. VEXAG encourages PSD to explore the feasibility of STMD supporting technologies applicable to Venus missions. Some technologies could benefit from space demonstrations and could be prime candidates for consideration in the Technology Demonstration Mission program.

4. VEXAG encourages PSD to support the further development of a new stratospheric observing asset that would be made available to the science community. The recent assessments and demonstrations of stratospheric balloon borne telescopes offer promise and could benefit the Venus community by providing science data such as day and night time winds, cloud properties, emissivity mapping, and more. A facility balloon asset would provide frequent and much needed opportunities to engage in missions and science measurements. Competing the science and observing time through ROSES is encouraged to maximize community access and engagement, as well as the science returned.

5. VEXAG continues to encourage NASA participation in future international partnerships including mission collaboration and participating scientist programs (e.g., Akatsuki and Venus Express). NASA support of the International Venus Exploration Working Group (COSPAR) will facilitate the needed dialog towards the exploration programs.

6. VEXAG encourages PSD support for several upcoming opportunities and initiatives:

- a) Comparative Climatology of the Terrestrial Planets -2 (CCTP2), 8-11 September 2015, Ames Research Center, Moffett Field, CA.
- b) VEXAG is encouraged by the broad support for this meeting from all four NASA science divisions
- c) Participation from students and early-career scientists whose research spans all four NASA HQ science divisions is expected. VEXAG anticipates travel support for these early career scientists to present the results of their research at this meeting.
- d) 13th VEXAG Meeting, October 27 – 29, 2015, Washington, DC area
- e) Continued efforts to initiate the Extreme Environments Centennial Challenge
- f) A workshop focused on science results based on laboratory, theoretical modeling, and simulation studies of a broad range of Venus topics
- g) A future workshop to cross-fertilize technologies of interest to Venus exploration as well as other applications

Resolutions

1. VEXAG resolves to identify all data sets, including calibration and standardization data, from the Russian missions to Venus. This list will identify which data are contained in the PDS, which data are held by NSSDC but not in the PDS (e.g., microfiche on file), and which data may only be held by the original investigators in Russia. Many analog data sets from past Venus missions (such as Venera) may be disappearing as individuals who have the data retire. As a result, some unique measurements (e.g., surface geochemistry) may be lost forever. It is very important to make sure that all existing Venus data are preserved, and permanently archived in the PDS. Once all data are identified, VEXAG will encourage PSD to officially request missing data from the Russian space agency and to support the permanent archival of all Venera data in the PDS.

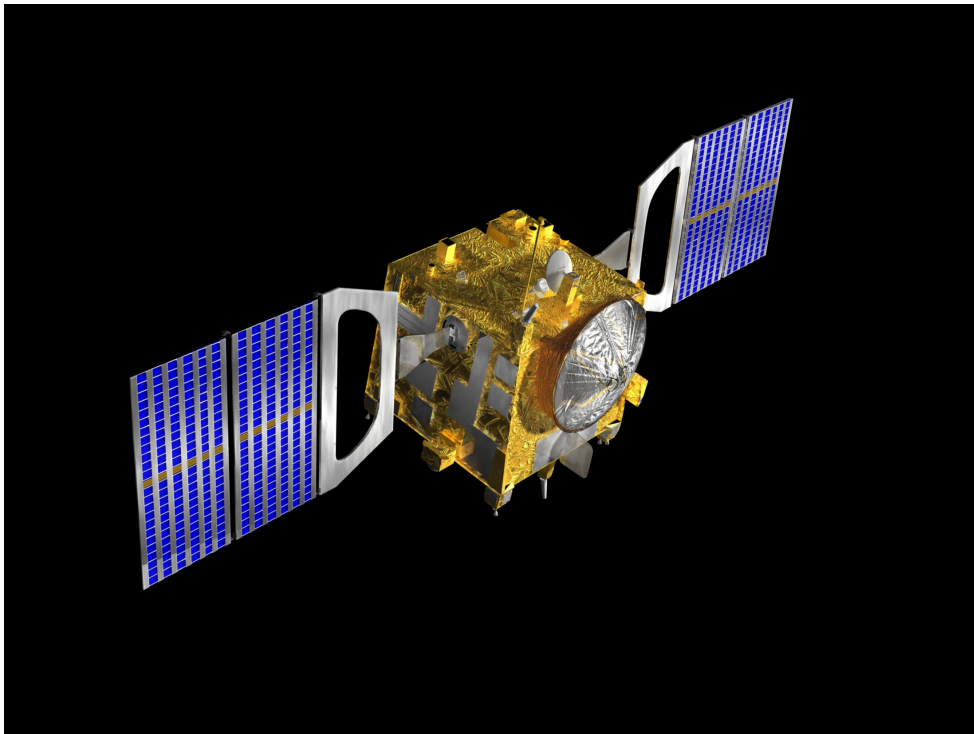
2. VEXAG appreciates the support PSD provided for the “Venus Science Priorities for Instruments and Laboratory Measurements” workshop held at the National Institute for Aerospace near NASA LaRC on April 7-8, 2015. VEXAG also sincerely thanks all the participants and organizers of this workshop. The community engagement and the discussions support Venus exploration objectives and, based on the quick results, the workshop achieved its objectives and helped raise community awareness and understanding of the status and needs for Venus focused laboratory experiments and instruments. VEXAG resolves to increase awareness of needed work identified by the workshop. Needed work includes laboratory experiments in fundamental sciences, such as physical properties of supercritical elements and emissivity of materials as well as better

understanding of the temperature and pressure effects on instruments and interpretation of the data. Better measurements of atmospheric species and aerosols including the upper atmosphere, and modeling are also needed. VEXAG is looking forward to the detailed meeting report and other documents that will be developed and will plan for a presentation of final results at a future VEXAG meeting.

3. VEXAG resolves to consider the utility of updating the Venus International Reference Atmosphere (VIRA) model based on new data from Venus Express, including new data on atmospheric density from the aerobraking campaign. VIRA is the standard used by mission designers to plan Venus atmospheric entry scenarios. However, the information contained in the VIRA is based on data from the handful Pioneer Venus and Vega entries.

4. VEXAG resolves to continue encouragement for the use of existing ground and suborbital (balloon, airplane, and sounding rocket) observing assets to acquire new and unique Venus science data. These assets should continue to be made available to Venus scientists through the appropriate Planetary Science ROSES elements.

5. VEXAG endorses the Comparative Tectonics and Geodynamics of Venus, Earth, and Rocky Exoplanets meeting planned for May 4 – 6, 2015, in Pasadena, California.



Venus Express – Launched on November 9, 2005, arrived at Venus on April 11, 2006, achieved its science orbit on May 7, 2006, exhausted its propellant in late November 2014 and subsequently disintegrated in Venus' atmosphere in late January 2015.

Agenda - VEXAG Meeting #12

National Institute of Aerospace, Thursday, April 9, 2015

- 8:00 Sign-In, Pick up Handouts
- 8:15 Welcome and Objectives of 11th VEXAG meeting - Lori Glaze
- 8:30 Update on NASA Planetary Science Division - Jim Green
- 9:30 Venus Express Report - Håkan Svedhem
- 9:45 Akatsuki Report - Takeshi Imamura
- 10:00 Comparative Tectonics and Geodynamics of Venus, Earth, and Exoplanets
- Sue Smrekar, Bob Grimm
- 10:15 Comparative Climatology of Terrestrial Planets II Conference Preview
- Jeff Hollingsworth, Lori Glaze, Shawn Domagal-Goldman,

- 10:30 BREAK + Venus Technology Poster Session

- 10:45 Prospects for International Cooperation on Future Missions- Sanjay Limaye
- 11:00 Extreme Environments Centennial Challenge - Tibor Kremic
- 11:20 Venus Exploration Targets Workshop Recap - Buck Sharpton
- 11:40 Venus Gravity Assist Science Opportunities (VeGASO)
- Marcello Coradini, Sanjay Limaye

- 12:00 LUNCH + Venus Technology Poster Session

- 1:30 Venus Science Priorities Workshop for Laboratory Measurements and
Instrument Definition Recap - Tibor Kremic
- 2:00 Stratospheric Balloons for Venus Exploration - Tibor Kremic

- 2 20 BREAK + Venus Technology Poster Session

- 2:40 Young Scholars Report - Lynnae Quick
- 3:00 Open Microphone Presentations (5 minutes/2 view-graphs each)
- 3:30 Proposed Findings and Resolutions / VEXAG Goals & Plans for 2015 and 2016,
Lori Glaze

- 4:00 ADJOURN / VEXAG Executive Committee Meeting

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