

## Summary

### Venus Exploration Analysis Group (VEXAG) Meeting #13 Tuesday-Thursday, October 27-29, 2015 James Webb Auditorium, NASA Headquarters

75 members of the Venus community participated in the VEXAG Meeting #13, held at NASA Headquarters, Washington, DC on October 27-29, 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 (about items that are germane to Venus research and exploration); status reports on the European Venus Express, Japanese Akatsuki, Russian Venera-D, and European Envision as well as on future Venus Discovery missions; recent and upcoming Venus workshops and conferences; and (most importantly) thinking about the year ahead and what's next for Venus.



Group Photo – Thursday, October 29, 2105

Current important VEXAG and Venus related events include:

- Two Venus Discovery mission proposals are accepted for Phase-A studies. These are VERITAS (Sue Smrekar, JPL, PI), an orbiting mission to produce high-resolution topography and imaging as well as global surface composition; and DAVINCI (Lori Glaze, Goddard, PI), an atmospheric probe mission to study the origin, evolution, and chemical processes of the atmosphere,
- A Venus III Book based on Venus Express results, is in preparation. It will be a Special Issue of Space Science Reviews as well as a hard-copy book,
- Venus Exploration Targets Workshop, May 2014 (LPI, Houston, Texas) – Report being finalized,
- Venus Science Priorities for Laboratory Measurements and Instrument Definition Workshop held in Hampton, Virginia in April,
- Comparative Tectonics and Geodynamics of Venus, Earth, and Exoplanets Conference, Caltech, Pasadena, May, 2015

- The CCTP2 conference ("Comparative Climates of Terrestrial Planets II: Understanding How Climate Systems Work") held at NASA Ames, September 2015, and
- An International Venus Science Conference 2016, to be held in Oxford, England, April 2016.

A key activity for this meeting was the preparation of Science Nuggets with a Tutorial from Jim Green on Tuesday, October 27th and presentations by attendees on Thursday, October 29th.

### NASA Reports

**Jim Green (NASA Headquarters)** provided a well-received status report on activities associated with NASA's Planetary Science Division (PSD), by discussing recent and near-term NASA mission events, the Discovery and New Frontiers Programs, the Europa Mission status, the new Communication Policy, as well as the NASA PSD Response to VEXAG findings. For recent and near-term mission events, Jim noted that:

- DAWN results were highlighted with images of craters that have central pits instead of central peaks,
- Pluto results were highlighted with images of hazes as well as of nitrogen, methane and CO<sub>2</sub> snows,
- For the new NASA Planetary Homesteader Program, had 84 proposals with 8 selections, each for \$1M. One selection, a Venus Entry Probe Prototype by Lori Gaze, NASA Goddard, is important to future in situ exploration of Venus
- There will be CubeSat call in FY16 – InSight mission will have two CubeSat flybys, fly-bys to observe InSight Entry, Descent and Landing, and
- An Icy Giants Study for next Decadal Survey has been started with a kick-off workshop at DPS.

For the Discovery and New Frontiers missions, Jim noted that there were 27-28 Discovery proposals, all good. Five were selected, four with female leads. The PSD Budget will support a 3-year cadence. Foreign contributions were not considered in the selection. And collaborations with STMD were used for technology enhancements. For New Frontiers, the expectation is the New Frontiers-4 AO will be in late FY16 for the five missions proscribed by the Decadal Survey. The follow-on New Frontiers-5 AO will be at the end of the Decadal Survey timeframe, 2023, for the seven missions proscribed by the Decadal Survey. In parallel with this, Europa is now in a Phase-A study with five instruments selected for inclusion. Following this VEXAG meeting, NASA announced that the New Frontiers-4 AO would be addressing the following mission themes (listed without priority):

- Comet Surface Sample Return,
- Lunar South Pole-Aitken Basin Sample Return,
- Ocean Worlds (Titan and Enceladus),
- Saturn Probe,
- Trojan Tour and Rendezvous, and
- Venus In Situ Explorer.

A National Council Study has been requested to examine the program elements of the PSD R&A programs, as they currently exist following restructuring, for their consistency with past NRC advice. This study will address two questions: (1) are the PSD R&A program elements appropriately linked to, and do they encompass the range and scope of activities needed to support the NASA Strategic Objective for Planetary Science and the PSD Science Goals, as articulated in the 2014 NASA Science Plan, and (2) are the PSD R&A program elements appropriately structured to develop the broad base of knowledge and broad range of activities needed both to enable new

spaceflight missions and to interpret and maximize the scientific return from existing missions? Also, NASA's Communications Policy is evolving. In particular, traditional news and social media, multimedia and public outreach and engagement were consolidated. Activities and funding were restructured along science disciplines, not missions, for integrated education strategies within SMD.

There have been a number of developments on the international front. There was a NASA-ESA Bilateral Meeting with ESA a couple of weeks ago, where the Europeans expressed an interest in participating in the Europa mission. There is an ongoing NASA-ISRO collaboration for India's Mars missions. And a joint NASA-Russian Venera Science Definition Team is getting underway again with a recent meeting in Moscow.

Jim Green continued with a presentation on Planetary Science Nuggets. Each week Planetary Science Division provides one science discovery/story for distribution through NASA's upper management and the Administration. Some SMD science nuggets have even attracted the attention of the President. These Science Nuggets also help PSD create their annual reports, as required by the U.S. Government Performance and Results Modernization Act (GPRMA), and as stipulated by the Congress, and the Strategic Objective Annual Review (SOAR), required by the Administration. These Science Nuggets should address current event-based activities, results, or science papers, where there is a compelling result for a "general" audience. An image or simple graphic (artist concept) is required. Accompanying text should give background information and explain the impact of the results or activity to the field at about a Grade 8 level. Reference to a paper in scientific journals are important. Previous Planetary Science Nuggets are posted at <http://www.lpi.usra.edu/nuggets/>

**Keivan Stassun (Vanderbilt University)** gave a presentation on an Astronomy and Astrophysics Advisory Committee (AAAC) Proposal Study – Applicability to R&A. This report had been given to Planetary Science Subcommittee in early October. Keivan noted that success rates for competed research proposals in the Astronomical sciences (Heliophysics, Astronomy and Astrophysics, Planetary Science) have fallen dramatically over the last decade at both NASA and NSF. The key questions are:

- What is the cause of the change?
- What are the impacts of the change?
- Are there optimum and catastrophic thresholds for success rate?

Proposal pressure in NASA's Planetary Science has resulted for a reduction of budgets that have fallen from \$1,731M (2004) to \$1,380M (2015). A proposal success rate of 40% in 2004 has fallen to 20% in 2014. The number of awards of 493 has fallen to 263. In parallel, the merit category of VG (Very Good) has been virtually dropped as proposals with this rating are not being funded.

These lower proposal success rates stress the agencies, reviewers, the community, as success rates greater than 30% are healthy, and success rates of 15% are not sustainable. People are leaving, panels are more risk averse, and new researchers are not entering the field. The solutions are not clear. Options include more funding, and rebalancing the program.

### **Past, Present and Future Missions**

**Håkan Svedhem (ESA/ESTEC)** provided a report on the recently completed Venus Express mission, which had the objectives of conducting a comprehensive study of the atmosphere of Venus and to study to some detail the plasma environment and number of aspects of the surface of the planet via systematic use of the spectral windows in the near IR. Håkan noted that the operation of the spacecraft has been extraordinary smooth. Over 5000 Gbit of science data has been downloaded to ground from the six scientific instruments. 16 Earth occultation seasons have taken place,

yielding more than 700 density/thermal atmospheric profiles. 13 atmospheric drag campaigns have been performed yielding over 100 atmospheric density measurements down to an altitude of 165km. ESA's first aerobraking campaign resulted in 27 deep atmospheric profiles, down to 129 km altitude. Significant improvements in understanding were:

- Understanding of atmospheric dynamics in four dimensions,
- Mapping of atmospheric structure (T and density),
- Characterizing of the dynamic plasma environment and magnetosphere,
- Mapping of the dynamic distribution of H<sub>2</sub>O, CO, NO, O<sub>3</sub>, OCS, SO<sub>2</sub>, HF, HCl,
- Obtaining observations of C and O isotopes in CO<sub>2</sub>,
- Characterizing airglow of several species,
- Characterizing the clouds and hazes: droplet size distribution and refractive index, and
- Improving of general circulation models and cloud formation models.

Håkan concluded by noting that Venus Express has clearly driven the understanding of Venus forward in many fields. A key finding is that there is a significant variability in many measured atmospheric parameters, both spatial and temporal (on long and short term scales). Questions related to the interior, the surface and the surface-atmosphere interaction need to be studied further, preferably with a lander/rover, but important results can be achieved by using a high-resolution (interferometric) SAR. As information on the atmosphere below the clouds is still very sparse, atmospheric probes are needed. As questions about on Venus' evolution remain, measurements of selected stable isotopes and noble gasses are needed (balloon). Imaging of the surface below the clouds is still not done, except for at radar wavelength (probes, plane).

**Takeshi Imamura (JAXA)** provided an update on the Akatsuki mission noting that Akatsuki (a Venus' meteorological satellite) has the objective of understanding the atmospheric dynamics and cloud physics of Venus. Akatsuki, which was launched in 2010, was designed for remote sensing from an equatorial, elliptical orbit. Its science instruments include three infrared cameras, an Ultraviolet Imager, a Lightning and Airglow Camera, and an Ultra-stable oscillator.

The first attempt at a Venus orbit insertion (VOI) failed on December 7, 2010 due to a malfunction of the propulsion system that destroyed the main engine. An orbit control maneuver was conducted in November 2011. RCS thrusters enabled a Venus encounter in 2015. The total power of 4 RCS (23 N) thrusters is approximately 20% of the main thruster (500N). A second attempt of VOI is scheduled for December 7, 2015. Trajectory maneuvers required before VOI have been successfully conducted using RCS instead of the broken main engine. The conditions of three cameras (LIR, UVI, and IR1) seem to be normal. The new orbit around Venus is a long elliptical one with the orbital period of 9-15 days. Onboard software, which extracts a portion of the image area containing Venus for observations from far distances, has been installed and verified. Coordination with ground-based observations is ongoing. NASA Deep Space Network support for orbital determination is conducted almost every day. Some characteristics of the post-VOI operations will be as follows:

- The bitrate will be relatively low in 2016 and relatively high in 2017,
- The local time of apoapsis varies with a period of ~220 days,
- The first 4 months after VOI will be suitable for night-side imaging,
- The length of umbra will be typically 30 minutes,
- The opportunities of radio occultation observations and observations with Lightning and Airglow Camera will overlap with each other until August 2016, and
- The periapsis height will be varying periodically from about 1000 km to 9000 km with a period of ~110 days.

After this VEXAG meeting, Akatsuki successfully executed a Venus Orbit Insertion on December 7th. Takeshi in a report to The Venus Express Science Working Team on December 10th noted:

- Orbit insertion maneuver went almost as planned. Akatsuki has become a Venus orbiter,
- Observations of the dayside atmosphere of Venus were conducted just after VOI using IR1, UVI and LIR. Other instruments (IR2, LAC and USO) will be tested later. (IR2 cooler was turned on today.) Checkout of HGA is ongoing, and
- Nominal operation will start by next spring.

**Sue Smrekar** and **Lori Glaze** provided reports on the two Venus Discovery Mission proposals accepted for Phase-A studies. These are VERITAS (Sue Smrekar, JPL, PI), an orbiting mission to produce high-resolution topography and imaging as well as global surface composition; and DAVINCI (Lori Glaze, Goddard, PI), an atmospheric probe mission to study the origin, evolution, and chemical processes of the atmosphere.

**Dave Senske** described another potential future Venus mission, Russia's Venera-D mission. Building on the highly successful Venera and VEGA missions of the 1970s and 1980s, IKI/Roscosmos has proposed an ambitious mission to return to Venus. NASA and IKI/Roscosmos have agreed to establish a Science Definition Team (SDT) to study a potential future Venera-D mission composed of a lander and orbiter. Goals of the SDT are:

- Identify, prioritize and develop science goals, investigations, and measurements consistent with the current Venera-D concept,
- Assess the Venera-D mission architecture including possible modular options (i.e., subsystems, etc.) for collaboration opportunities and required instrumentation capabilities,
- Identify mission components (mission elements/subsystems/instruments) that best lend themselves to a joint collaboration,
- Assess the precursor observations and instrumentation validation experiments needed to enable or enhance the Venera-D mission (e.g., instrument testing in a chamber that emulates the pressures and temperatures found in the atmosphere or at the surface of Venus), and
- Evaluate how Venera-D would advance the scientific understanding of Venus and feed forward to future missions.

The current status of the Venera-D concept is that Venera-D was initially identified as a core mission as part of the Russian Federal Space Program. Changes in the Russian Federal Space Program have placed Venera-D in a category where it will need to be proposed. IKI is interested in moving forward with Venera-D as a potential joint mission with NASA.

The baseline concept for Venera-D is an orbiter with a polar 24-hour orbit with a lifetime greater than 3 years, and an updated VEGA lander with 2-plus hours on the surface. Other Components studied (which could be possible contributions) include: a long-lived station that could survive up to 24 hours on the surface, a sub-satellite, and one or two balloons, in the clouds and below the clouds, with possible mini-probes dropped from the lower balloon. Science goals for the orbiter include:

- Studying of the dynamics and nature of super-rotation, radiative balance and nature of the greenhouse effect,
- Characterizing the thermal structure of the atmosphere, winds, thermal tides and solar locked structures,
- Studying the clouds, their structure, composition, microphysics, and chemistry, and
- Investigating the upper atmosphere, ionosphere, electrical activity, magnetosphere, and the escape rate.

Science goals for the lander include:

- Performing chemical analysis of the surface material and studying the elemental composition of the surface, including radiogenic isotopes,
- Studying of interaction between the surface and atmosphere, and
- Investigating the structure and chemical composition of the atmosphere, including abundances and isotopic ratios of the light and noble gases.

Follow-up activities include face-to-face meetings in Moscow, Russia, next spring and summer as well as interim reports to IKI and NASA in the spring and fall.

**Richard Ghail** described EnVision, a Venus mission to be proposed as ESA M-class mission with the goal of understanding what made Earth's closest neighbor so different. It will carry a subsurface sounder, emissivity mapper and spectrometer, and its primary instrument, a synthetic aperture radar, based upon the United Kingdom's NovaSAR, which will be implemented via four small low cost SAR satellites that provide continuous global environmental management and disaster monitoring. The first NovaSAR is scheduled for launch in 2016. The proposed EnVision launch date is October 2029. There are number of synergies with VERITAS and DAVINCI, the two Venus Discovery missions that were accepted for Phase-A studies:.

EnVision has the potential of advancing our knowledge of Venus to that of Mars today. High-resolution imagery, topography and compositional data will determine the nature of geological activity on Venus. Measurements of surface, tropospheric and mesospheric volatiles will characterize geochemical cycles. Calibrated polarimetric and high resolution contextual imagery of the Venera landing sites will provide an understanding of what the landers imaged.

### Venus III Book and International Venus Conference

**Sue Smrekar** described the current status on the Venus III Book. This will be similar to the previous publications, the Venus Book I in 1983 based on Pioneer-Venus results and the Venus II book in 1997 based on Magellan and Vega results. Springer will publish the Venus-III book as special issue of Space Science Reviews with each chapter electronically accessible as a Space Science Review paper. The complete volume can also be purchased as a hardcover book. The original book schedule was established at a Venus Express Science Working Team Meeting in December 2014. At that time, detailed outlines of chapters were established with draft chapters to be submitted in February 2015 and final manuscripts to be submitted in April 2015. However, at the time of this VEXAG Meeting, only 8 of 11 draft chapters have been received. Non-delivering authors have been given an ultimatum.

**Colin Wilson** described the International Venus Conference, which will be held in Oxford, England on April 4-8, 2016. Presentations are invited for all aspects of Venus science, from the interior to the exosphere. Presentations on Comparative planetology, Future missions and supporting lab investigations are welcome. Thematic sessions will address the Surface and Interior, Dynamics and Thermal Structure, Chemistry and Clouds, Lab-based Supporting Investigations, Plasma and Induced Magnetosphere, as well as Future Missions, Observations, and Measurements. Splinter meetings will include a Venus Express legacy session addressing science archive and outstanding remaining questions as well as opportunities for future missions. Expected attendance is 100. Some 10 to 20 early career scientists will be supported. Abstract and registration deadlines are January 22, 2016 and February 26, 2016, respectively. After the conference, there will be a call for papers for special issue of *Planetary and Space Sciences*.

## Open Microphone and Student Paper Presentations

There were six Open Microphone presentations, covering a diverse set of topics. These were:

- Venus Colonization, by Eric Boyd,
- Best Tesserae to Measure Tessera Composition?, by Martha Gilmore,
- LASMA for VEXAG, by G. Managadze, and his colleagues,
- Radar-bright Highlands at Ovda Regio and Maxwell Montes: Different Patterns, Different Processes, by Allan Treiman, Elise Harrington, Simon Fraser
- Coordinated Ground-based/Akatsuki Observations and Observing Venus from the Earth's Stratosphere, by Eliot and his colleagues,
- Planetary Science from Balloon-Borne Platforms: the Case for Venus Observations, by Eliot and his colleagues.

VEXAG sponsored travel for three students. Their presentations were:

- Lab Measurements Supporting mm-Wavelength Observations of the Venus Atmosphere" by Amadeo Belotti (Georgia Tech)
- Refining the Design of Proposed Venus Sample Delivery Systems, by Siddharth Pandey (University of New South Wales, Australia)
- Detailed Structural Mapping of a Specific Region in Aphrodite Terra, by David Tovar (University of Minnesota)

## Science Reports

There were 10 Science Reports covering a diverse set of "hot topics", including:

- Gateway to Understanding Rocky Planet Evolution - Mark Bullock,
- Noble Gases and Isotopes in Venus' atmosphere - Kevin Zahnle,
- Hubble UV Observations of Venus - Kandi Jessup,
- ALMA Observations of Venus - Arielle Moullet,
- Ground-based observations of Atmosphere below the Clouds - Giada Arney,
- Venus IR Emissivity Observations - Martha Gilmore,
- Venus in a Box – High-temperature NIR Emissivity Measurements of Venus Analogs – Joern Helbert,
- Geochemical and Mineralogical Measurements on Venus's Surface - Darby Dyar,
- Why Venus Lacks Plate Tectonics: Insights from Possible Subduction Zones – Sue Smrekar, and
- Heat Loss and Geology of a Young Venus – Bob Grimm

## VEXAG/Venus Conferences

There were five reports on science conferences involving Venus related topics.

**Kevin McGouldrick** provided a report on the Venus Exploration Targets Workshop that was held on May 19-21, 2014 at the Lunar and Planetary Institute. Workshop goals were to (1) identify and evaluate key locations, transects, and regions for future exploration of Venus, either on the surface or within the atmosphere, and (2) provide guidance to future mission planning. The workshop established that the top surface targets were the tessera, plains, young lava flows, and volcanoes. The complex matrix of 'domains' varying across geographic locations, height, time, duration, challenged the Atmosphere Group. Long-term, high spatial and temporal measurement of

meteorological parameters is ideal but likely unrealistic. The Orbit Group noted that technological advances (such as SAR interferometry, stereogrammetry, IR emissivity) offer vast improvements over current surface observations. Proposed platforms were:

- Surface Platforms targeting and landing technologies in a dense atmosphere are key for future exploration from Venus surface,
- Atmospheric Platforms, providing widest range of investigable possibilities, and
- Orbital Platforms that could provide broadest repeatable coverage of the planetary surface.

Multimodal observations were also noted as they provide a great advantage to synchronous observations from different platforms due to dynamic atmosphere of Venus. A preliminary of a Venus Targets Workshop Final Report was available as a hand-out at the meeting. Also, a Venus Exploration Targets Workshop Traceability Matrix was presented during Tuesday's poster session.

**Tibor Kremic**, and **Jeff Belcerski** provided a report on the Venus Science Priorities Workshop for Laboratory Measurements and Instrument Definition that was held in conjunction with VEXCAG Meeting #12 in Hampton, Virginia on April 7-8, 2015. Workshop objectives were to: present, discuss, and document the status of the instrument technologies and the definition of new instruments, as well as the needs of laboratory experiments in support of fundamental science AND as mission preparation. In all areas; surface, atmosphere, and orbit laboratory experiments are needed. Basic fundamental research is needed for:

- Thermal and spectral properties of atmosphere constituents,
- NIR emissivity of materials,
- Physical properties of supercritical phase, and
- Effects of trace species.

Also, application and interpretation of instruments/measurements need to account for pressure and temperature effects on instruments, measurements, and their interpretation. Modeling work is needed for instrument use in particular physical environments. A draft report for this Workshop has just been distributed to the Organizing Committee. In parallel, draft is being made available on VEXAG website for larger community review. After report is complete (at the time of LPSC) there will be an effort to make the report that can be referenced.

**Bob Grimm** provided a report on the Comparative Tectonics and Geodynamics of Venus, Earth, and Exoplanets that was held at the Keck Center, Caltech, Pasadena on May 4-6, 2015, This workshop brought together scientists studying Earth, Venus, and rocky exoplanets in order 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. A key topic of discussion was why Venus and Earth display dramatically different geodynamical and tectonic regimes despite having nearly the same size and bulk composition. As Venus lacks evidence of recent plate tectonics analogies with early Earth tectonics was emphasized. This in turn was extrapolated to rocky exoplanets as they likely have a broader range of geodynamic outcomes.

**Tim Titus** provided a report on the International Dunes Workshop that was held in Boise Idaho, on May 19-22, 2016. Workshop goals were to (1) Increase the collaboration between terrestrial and planetary aeolian scientists across multiple disciplines, (2) facilitate the fusion of remote sensing data, analog research, laboratory experiments (including wind tunnels, and computer modeling, and (3) prepare the next generation of scientists (graduate and undergraduates students). Previous workshops were held in New Mexico (2008), Colorado (2010), and in Arizona (2010). EOS articles and special issues of *Aeolian Research* have documented these



workshops. Abstracts for all of the meetings are posted on-line. The next workshop will be held in St. George, Utah in 2017.

Tim noted that aeolian bed forms (dune-like structures) are observed throughout the Solar System with similar morphologies. Different processes in a range of environments and sizes have formed these dunes. Key questions address transverse aeolian ridges, the importance of megadunes, and the identification of the sand sources. Venus has only 2 dune areas - Al-Uzza Undae with a diameter of 150 km and Menat Undae with a diameter of 100 km, although microdunes may be present. Possible causes for the lack of Venusian dunes could be low wind speeds, a lack of sediment, or a lack of higher spatial resolution data to resolve smaller dune fields. A possible Venusian dunes analog is the dunes seen on terrestrial ocean floors.

**Jeff Hollingsworth** provided a report on the Comparative Climatology of Terrestrial Planets II Conference that was held at NASA Ames Research Center on September 8-11, 2015. This was a follow-up to the first highly successful Comparative Climatology of Terrestrial Planets Conference in Boulder, CO, June 2012. These conferences, which are supported by all four divisions (Astrophysics, Earth, Heliophysics and Planetary) cover a wide range of terrestrial atmospheres and climate processes and are interdisciplinary by design with emphasis on the Sun and other stars on the climates of Earth and other planets. The focus for this conference was to “Understanding How Climate Systems Work” by:

- Continuing to work across discipline boundaries on understanding how planetary climate systems work in the context of their host star,
- Sharing expertise to improve the understanding of climate atmospheric problems from a wide variety of perspectives,
- Improving the understanding of any single planet by placing it inside the context of other worlds and, where data exist, and
- Strengthening existing collaborations.

Reports on this this conference include an *AGU/Eos* Meeting Report and an official NASA Conference Proceedings (CP) Report. The complete oral program is archived and available for streaming at [cctp2.arc.nasa.gov](http://cctp2.arc.nasa.gov). Items of interest from this conference were:

- Pursuing a new ROSES element on Comparative Climatology,
- Formulating a cross-disciplinary working group for roadmap development, and
- Pursuing climate models inter-comparisons of climate models via benchmarking and assessment of climate model biases.
- A third conference in this series is being planned for July 2017.

NASA announced after this VEXAG meeting that a ROSES element for Comparative Climatology as an “Emerging Topic” would be pursued in the next ROSES call.

**Lynnae Quick** provided a status report on VEXAG’s Young Scholars Focus Group noting that they have a significant web presence. This includes:

- Maintaining a regular updates to the Early Career Scholars page on the VEXAG website,
- Hosting a VEXAG Early Career Scholars Facebook group that has 117 members and is growing,
- Cross-posting with Venus Exploration (262 members) and Young Scientists for Planetary Exploration (1606 members) Facebook groups has resulted in increased awareness of VEXAG-sponsored and Venus-related events.

In addition, a new Venus Science and Technology Interview Series that posts interviews twice each month been initiated. The first interviewees are Constantine (Con) Tsang and Candace Gray, who address questions such as:

- What do you find most intriguing about the planet Venus?
- What are your current research activities and how are they linked to Venus science
- What is the webpage link to your research?
- Anything else you'd like to add?

Interviewees are asked to provide the names of two individuals engaged in Venus research, who would be ideal candidates to be interviewed.

**Sanjay Limaye** provided a report on current challenges of understanding the Current Venus Atmosphere. Current questions are:

- Is lower atmosphere of Venus well mixed?
- What is the altitude dependence of the Adiabatic Lapse Rate in the Lower Atmosphere?
- What causes the near surface unstable and stable layers?
- Are there haze/dust layers in the lower atmosphere?
- What causes the Venus atmosphere become supercritical?
- What is the impact of Venus atmosphere being supercritical - What is the supercritical point of the Venus atmosphere? And do supercritical fluids mix well?
- Why are Venus clouds different from morning to evening?
- What is the ultraviolet absorber?

With respect to ultraviolet absorber, they could be inorganic species such as  $\text{FeCl}_2$ ,  $\text{S}_8$ ,  $\text{S}_{12}$ , with some spatial and temporal variation inferred from Venus Express' Venus Mapping Camera (VMC) or organic species such as acidophilus. Ferro-oxidans bacteria have physical and optical/spectral properties that are similar to Venus cloud/haze particles. Further questions are what are the sources and sinks, and what are the processes that control their abundances?

**Sanjay Limaye** continued with a report on the prospects for international collaboration on future Venus missions. Recent collaborations have included NASA Participating Scientists and Guest Investigators participation in ESA's Venus Express mission and NASA Participating Scientists being re-instated for JAXA's Akatsuki mission. Current collaborations include the NASA-IKI/Roscosmos Venera-D Joint Science Definition Team, and an informal ISRO-NASA Joint Working Group that have been considering a Venus mission. Collaborations in the immediate future include ESA's Cosmic Vision M-5 with a call for proposals by end of the year. Also, many US scientists may collaborate on the EnVision mission proposal being developed as well as ISRO's internal effort to consider Venus mission ideas. For collaborations in the next decade, it is inevitable that the next large mission to Venus will be an international effort.

Sanjay concluded by noting that the Venus international scientific and engineering communities were active a decade ago in a Venus Flagship Design Reference Mission study. This was followed by planetary Decadal Survey studies for a Venus Climate Mission, a Venus Intrepid Tessera Lander, and a Venus Mobile Explorer. Currently, COSPAR's International Venus Exploration Working Group provides a forum for discussing international collaboration and coordination opportunities.

### Wrap-Up

**Lori Glaze** led a discussion of what directions VEXAG should be taking over the next few years. This was discussed further during a VEXAG Executive Committee meeting immediately after this meeting. This led to the Deliberations of the 13th VEXAG Meeting given in the sections of this Summary. These Deliberations were called Findings and Resolutions in previous meetings.

## Deliberations of the 13th VEXAG Meeting

27 – 29 October 2015 Webb Auditorium, NASA Headquarters, Washington, DC

1. VEXAG has been greatly served by having Dr. Adriana Ocampo as our NASA HQ Point of Contact (POC). Through her, the Venus community has been informed of relevant NASA activities and directions and she has helped our community navigate the NASA policies and procedures. We have also benefited from her representation of Venus interests in the day-to-day NASA HQ interactions and decisions. In short, her support to the Venus community has been invaluable and her absence in recent months has been felt. We sincerely desire her quick and full recovery and look forward to her continued support of the VEXAG when she returns to a full-time schedule. In the meantime, the VEXAG needs an interim person at NASA HQ who can actively serve as our backup POC. Therefore, **VEXAG encourages the PSD to identify a HQ POC who is available to engage in our activities and represent our needs as a backup until Dr. Ocampo resumes her role on a full-time basis.**

This was accomplished after this VEXAG Meeting, when Adriana Ocampo returned to full-time duties at the end of 2015.

2. **VEXAG appreciates recent support from the Planetary Science Division, and strongly encourages continued support, of international opportunities for science participation and investigation.** The VEXAG community is enthusiastic about the imminent return of Akatsuki to Venus, and looks forward to the science results from the mission and NASA's Participating Scientists. VEXAG is excited about re-activation of the Venera-D Joint Science Definition Team and additional possible international cooperative possibilities of the upcoming European Space Agency's M-5 opportunity. VEXAG continues to encourage NASA participation in future international partnerships including mission collaboration and participating scientist programs. NASA support of the International Venus Exploration Working Group (COSPAR), and collaborating communities in IKI and ISRO will facilitate the needed dialogue towards the exploration programs. The Venus science community is energized by the Phase A Discovery selections of DAVINCI and VERITAS and hopeful about the prospect of one, or even two imminent, high value NASA/US missions to Venus.
3. In order for NASA to receive maximum scientific value from the community's investment in New Frontiers mission proposals, VEXAG encourages the Planetary Science Division to provide adequate, additional time for New Frontiers proposers to complete their proposals after the 2016 Discovery selection(s) are announced. This will best position the proposed New Frontiers missions to address Decadal Survey science objectives in the context of the newly selected Discovery missions(s).
4. VEXAG reaffirms the importance of a balanced program of Discovery, New Frontiers and Flagship missions to further the exploration of Venus. The Planetary Science Division is conducting further studies in FY16 and FY17 of the Ice Giants and Enceladus Flagship missions that were identified and prioritized by the 2011 Planetary Science Decadal Survey (PSDS). **VEXAG finds that reassessment of the Venus Climate Mission (VCM), which was also identified by the PSDS as a Flagship priority, is also needed.** Conducting further studies of the Venus Flagship mission

immediately following the completion of the Enceladus study should allow sufficient time for an in depth study in time to be evaluated by the next PSDS.

5. VEXAG encourages PSD support for upcoming opportunities and initiatives:
- Continued efforts to initiate the Extreme Environments Challenge,
  - A workshop focused on science results based on laboratory, theoretical modeling, and simulation studies of a broad range of Venus topics,
  - 14th VEXAG meeting, November 2016, Location TBD, and
  - Comparative Climatology of the Terrestrial Planets – 3 (CCTP-3), in FY2017.

### **Agenda - VEXAG Meeting #13**

Tuesday-Thursday, October 27–29, 2015, James Webb Auditorium, NASA Headquarters

Meeting Theme - Increasing our Momentum

#### **Tuesday, October 27, 2015 - 8:00 AM – 6:30 PM – NASA and Mission Reports**

8:00 Sign-In, Pick up Handouts, Coffee

8:15 Welcome and Objectives of 13th VEXAG meeting - Lori Glaze

- Venus Exploration Slogans
- Community Comments on Next Decadal Survey

#### **8:45 NASA Reports**

8:40 Update on NASA Planetary Science Division - Jim Green

- Response to our previous VEXAG findings and recommendations
- Update on NASA Planetary Science Division

10:00 COFFEE BREAK

10:30 Science Nuggets – Jim Green

11:00 NASA Headquarters Q & A

11:30 Student/Young Career Meet and Greet / Luncheon

11:30 LUNCH

#### **1:00 Mission Reports**

1:00 Venus Express Report – Håkan Svedhem

– What we've learned from Venus Express/ What's left unanswered

1:30 Akatsuki Report – Takeshi Imamura

2:00 Venera-D Science Definition Team – Dave Senske (Web-Ex)

2:30 COFFEE BREAK

3:00 AAAC Proposal Study – Applicability to R&A - Keivan Stassun

- 3:45 Technology Posters Overviews – Pat Beauchamp, Moderator
- 4:30 POSTER/SOCIAL EVENT—Residence Inn Washington DC/Capitol Hotel
- 6:30 ADJOURN

**Wednesday, October 28, 2015 - 8:00 AM - 5:00 PM - Technology Reports**

- 8:00 Sign-In, Pick up Handouts, Coffee
- 8:15 Venus Mission Plans in Europe - Richard Ghail (Web-Ex)
- 8:45 Venus III Book and 2016 International Venus Conference  
– Colin Wilson (Web-Ex)
- 9:00 Venus Discovery Missions
- 9:00 VERITAS (Sue Smrekar, PI), an orbiting mission to produce high-resolution topography and imaging as well as global surface composition; and
- 9:30 DAVINCI (Lori Glaze, PI), an atmospheric probe mission to study the origin, evolution, and chemical processes of the atmosphere.
- 10:00 Discussion
- 10:20 COFFEE BREAK
- 10:45 Open Microphone Presentations (5 minutes/2 view-graphs each)
- 11:15 Student/Young Scholar Invited talks
- 11:15 "Lab measurements supporting mm-wavelength Observations of the Venus atmosphere"- Amadeo Bellotti (Georgia Tech.)
- 11:25 Refining the Design of Proposed Venus Sample Delivery Systems  
- Siddharth Pandey (University of New South Wales)
- 11:35 Detailed Structural Mapping of a specific region in Aphrodite Terra  
- David Tovar (University of Minnesota)
- 11:45 LUNCH BREAK

**Wednesday, October 28, 2015 - 1:00 PM - 5:00 PM - Science Reports**

- 1:00 Gateway to Understanding Rocky Planet Evolution - Mark Bullock
- 1:20 Noble Gases and Isotopes in Venus' atmosphere - Kevin Zahnle
- 1:40 Hubble UV Observations of Venus - Kandi Jessup
- 2:00 ALMA Observations of Venus - Arielle Moullet
- 2:20 Ground based observations of atmosphere below the clouds - Giada Arney
- 2:50 COFFEE BREAK

- 3:10 Venus IR Emissivity Observations - Martha Gilmore
- 3:30 Venus in a Box - High temperature NIR emissivity measurements of Venus analogs - Joern Helbert
- 3:50 Geochemical and Mineralogical Measurements on Venus's Surface Darby Dyar
- 4:10 Why Venus Lacks Plate Tectonics: Insights from Possible Subduction Zones - Sue Smrekar
- 4:30 Heat Loss and Geology of a Young Venus - Bob Grimm
- 4:50 Preview of Thursday Agenda Topics – Lori Glaze
- 5:00 ADJOURN

**Thursday, October 29, 2015 - 8:00 AM - 1:00 PM - VEXAG Activities**

- 8:00 Sign-In, Pick up Handouts, Coffee
- 8:15 Discussion – Lori Glaze
- 9:00 Science Nugget Presentations
- 9:30 Venus Exploration Targets Workshop Recap – Kevin McGouldrick
- 9:45 Venus Science Priorities Workshop for Laboratory Measurements and Instrument Definition Recap - Tibor Kremic, Jeff Belcerski
- 10:00 COFFEE BREAK
- 10:30 Comparative Tectonics and Geodynamics of Venus, Earth, and Exoplanets - Bob Grimm
- 10:45 International Dunes Workshop #4 – Tim Titus (Web-Ex)
- 11:00 Comparative Climatology of Terrestrial Planets II Conference Recap  
Jeff Hollingsworth
- 11:15 Young Scholars Focus Group Report - Lynnae Quick
- 12:00 VIRA Update and Current Venus Atmosphere Challenges – Sanjay Limaye
- 12:15 Prospects for International Cooperation on Future Missions - Sanjay Limaye
- 12:30 Proposed Findings and Resolutions / VEXAG Goals & Plans for 2016  
Community Survey for Next Decadal Survey - Lori Glaze
- 1:00 ADJOURN
- 1:30 VEXAG Executive Committee Meeting

**VEXAG Meeting #13 Technology Posters**  
**POSTER/SOCIAL EVENT - Monday October 27, 2015, 4:30PM**

### **Residence Inn, Washington DC/Capitol Hotel**

1. High-temperature, Radiation-tolerant Ultra-violet Photodetector Arrays for Space Exploration. Ruth Miller and Debbie Senesky, Stanford Univ.
2. Gallium Nitride High Electron Mobility Pressure Sensors for Venus Exploration. Caitlin Chapin and Debbie Senesky, Stanford University.
3. Venus Heat Flux Sensor Instrument Development. Michael Pauken, Suzanne Smrekar, Jean-Pierre Fleurial and Kevin Smith, JPL
4. GaN (Gallium Nitride) Electronics for Extreme Environments (high temperature, high radiation). Robert Frampton and Leora Peltz, Boeing Corp.
5. Silicon Carbide (SiC) Electronics Development for High Temperature Venus Applications. G. W. Hunter, P. G. Neudeck, D. J. Spry, G. E. Ponchak, G. M. Beheim, M. C. Scardelletti, R. D. Meredith, M. J. Krasowski, NASA GRC, Liangyu Chen, Ohio Aerospace Institute, D. Lukco, Vantage Partners.
6. Current Laboratory Research and Venus In-Situ Chamber Investigations. E. Kohler and N. M. Johnson (GSFC)
7. A progress report on Heat shield for Extreme Entry Environment Technology (HEEET) Development for New Frontier Missions. Ethiraj Venkatapathy, Don Ellerby, Peter Gage, Mairead Stackpole, Keith Peterson, Zion Young, Matt Gasch and Milad Mahzari. (ARC)
8. Conformal TPS for New Frontier Missions – What is it? Why should Venus Mission Proposals need to consider it? Ethiraj Venkatapathy, Robin Beck, Matt Gasch and Mairead Stackpole (ARC)
9. Adaptable, Deployable Entry and Placement Technology (ADEPT) – Overview of FY15 Accomplishments. P. Wercinski, C. Brivkalns, A. Cassell, Y-K Chen<sup>1</sup>, T. Boghozian, R. Chinnapongse, M. Gasch, S. Gorbunov, C. Kruger, A. Makino, F. Milos<sup>1</sup>, O. Nishioka<sup>1</sup>, D. Prabhu, B. Smith, T. Squire, G. Swanson, E. Venkatapathy, B. Yount, and K. Zarchi
10. VAMP Science Instrument Accommodations and Performance Capabilities. Floyd Ross, Gregory Lee, Ronald Polidan, Daniel Sokol, Linden Bolisay, (Northrop Grumman) Sanjay Limaye (U. Wisconsin) and Thomas Widemann (Paris Observatory/LESIA).
11. Auto-Inflatable Sojourner Balloon Concepts for Venus. Michael Pauken (JPL-Caltech), Paul Voss (Smith College), James Cutts (JPL-Caltech), and Julian Nott (World-Renowned Balloon Designer)
12. Simulating Venus with GEER, Tibor Kremic, Dan Vento, GRC.
13. Thermal Control of a Venus Lander: Evaporation of Ammonia. Eric Golliher, GRC and Michael Pauken, JPL
14. Investigating the Origin and Evolution of Venus with In Situ Mass Spectrometry. Melissa Trainer, Paul Mahaffy, Will Brinckerhoff, Natasha Johnson, Lori Glaze, GSFC
15. Venus Exploration Targets Workshop Traceability Matrix. Buck Sharpton, Lori Glaze, Larry Esposito, Kevin McGouldrick, Stephanie Johnston, Chris Lee, Christophe Sotin, Marty Gilmore, Robbie Herrick

### Attendees VEXAG Meeting 13, October 27–29, 2015

Arnold, Steven	Johns Hopkins University Applied Physics Laboratory
Arney, Giada	University of Washington
Aye, Michael	University of California Los Angeles
Baines, Kevin	University of Wisconsin-Madison & Jet Propulsion Laboratory
Balcerski, Jeff	NASA Glenn Research Center
Beauchamp, Pat	Jet Propulsion Laboratory
Bellotti, Amadeo	Georgia Institute of Technology
Berger, Gilles	IRAP – Université Paul Sabatier, Toulouse
Boll, Nathan	NASA Headquarters
Boyd, Eric	The Venus Society
Brinckerhoff, William	NASA Goddard Space Flight Center
Bullock, Mark	Southwest Research Institute
Campbell, Bruce	Smithsonian Institution
Cathala, Annick	Université Paul Sabatier, Toulouse
Chapin, Caitlin	Stanford University
Cottini, Valeria	NASA Goddard Space Flight Center
Cutts, James (Jim)	Jet Propulsion Laboratory
Deepak, Adarsh	Science and Technology Corp.
Dwyer Cianciolo, Alicia	NASA Langley Research Center
Dyar, Darby	Mount Holyoke College
Economou, Thanasis	University of Chicago
Esposito, Larry	LASP, University of Colorado
Ghail, Richard	Imperial College London
Gilmore, Martha	Wesleyan University
Glaze, Lori	NASA Goddard Space Flight Center
Gorog, Jan	Consultant
Grimm, Robert	Southwest Research Institute
Grinspoon, David	Planetary Science Institute
Grossman, Jeff	NASA Headquarters
Guzewich, Scott	USRA/ NASA Goddard Space Flight Center



Helbert, Jorn	Deutsche Zentrum für Luft- und Raumfahrt
Herrick, Robert	University of Alaska Fairbanks
Hollingsworth, Jeffery	NASA Ames Research Center
Hunter, Gary	NASA Glenn Research Center
Imamura, Takeshi	Japan Aerospace Exploration Agency
Izenberg, Noam	Johns Hopkins University Applied Physics Laboratory
Jessup, Kandi	Southwest Research Institute
Johnson, Natasha	NASA Goddard Space Flight Center
Johnston, Stephanie	NASA Goddard Space Flight Center / CRESSI
Katucki, Tommy	National Academies of Sciences, Engineering, and Medicine
Kohler, Erika	NASA Goddard Space Flight Center
Kremic, Tibor	NASA Glenn Research Center
Landis, Rob	NASA Headquarters
Lee, Greg	Northrop Grumman Aerospace Systems,
Limaye, Sanjay	U. of Wisconsin/Space Science & Engineering Center
Lorenz, Ralph	Johns Hopkins University Applied Physics Laboratory
Lundquist, Ray	NASA Goddard Space Flight Center
Paul Mafferty	NASA Goddard Space Flight Center
Managadze, Georgy	Russian Space Research Institute (IKI)
Martin, Emily	Smithsonian Institution
McGouldrick, Kevin	LASP, University of Colorado
Miller, Ruth	Stanford University
Moulet, Arielle	National Radio Astronomy Observatory
Mueller, Nils	Jet Propulsion Laboratory
Ocampo, Adriana	NASA Headquarters
Pandey, Siddharth	University of New South Wales, Australia
Parsons, Ann	NASA Goddard Space Flight Center
Polidan, Ronald	Northrop Grumman Aerospace Systems
Quick, Lynnae	NASA Goddard Space Flight Center /UMBC
Rall, Jonathan	NASA Headquarters
Richey, Christina	NASA Research and Education Support Services
Sherwood, Brent	Jet Propulsion Laboratory

Smith, David H.	National Research Council
Smrekar, Sue	Jet Propulsion Laboratory
Stassun, Keivan	Vanderbilt University
Steffes, Paul	Georgia Institute of Technology
Svedhem, Håkan	ESA/ European Space Research and Technology Centre
Thomas, Chantz	Aerospace Industries Association
Thompson, Tommy	Jet Propulsion Laboratory
Titus, Tim	United States Geological Survey
Tovar, David	University of Minnesota
Trainer, Melissa	NASA Goddard Space Flight Center
Treiman, Allan	Lunar and Planetary Institute
Tsang, Constantine	Southwest Research Institute
Venkatapathy, Ethiraz	NASA Ames Research Center
Whitten, Jennifer	Smithsonian Institution
Widemann, Thomas	Paris Observatory
Wilson, Colin	Oxford University
Young, Eliot	Southwest Research Institute
Zahnle, Kevin	NASA Ames Research Center



**Pioneer Venus (atmosphere) and Magellan (surface) views of Venus.**