

VEXAG Steering Committee updated as of 12/2/19

Darby Dyar (PSI, Mount Holyoke College), Chair
Noam Izenberg (Applied Physics Laboratory), Deputy
Giada Arney (NASA GSFC)
Lynn Carter (University of Arizona)
Natasha Johnson (NASA GSFC)
Candace Gray (NM State University)
Jeff Balcerski (Ohio Aerospace Institute)
Gary Hunter (NASA GRC), Technology Focus Group Lead
Kevin McGouldrick (University of Colorado)
Pat McGovern (Lunar & Planetary Institute)
Joseph O'Rourke (ASU)
Emilie Royer (University of Colorado)
Jennifer Whitten (Tulane)
Colin Wilson (University of Oxford)
Tommy Thompson (JPL), Scribe
Adriana Ocampo (NASA HQ) ex officio

Bold indicates new
Committee members



VEXAG Near-Term Goals

- Provide **support for the Decadal Survey**
 - 3 documents nearly in press, paper in *Space Science Reviews*
- Build a **Venus program!**
 - **Engage the community** to come together with a common vision
 - **Improve communication** within Venus community and among the general public: **listserve** has >500 members, **media outreach**
 - Open meetings and **public forums**
 - Expand **visibility of Venus science** at conferences and at NASA: 67 Venus papers at DPS/EPSC, AGU session, Exoplanets in Our Backyard

VENUS GOALS, OBJECTIVES, AND INVESTIGATIONS



Image credit: John D. Wbanek

Goal #1. Understand Venus' early evolution and potential habitability to constrain the evolution of Venus-sized (exo)planets

- A. Did Venus have temperate surface conditions and liquid water at early times?
- B. How does Venus elucidate possible pathways for planetary evolution in general?

Goal #2. Understand atmospheric composition and dynamics on Venus

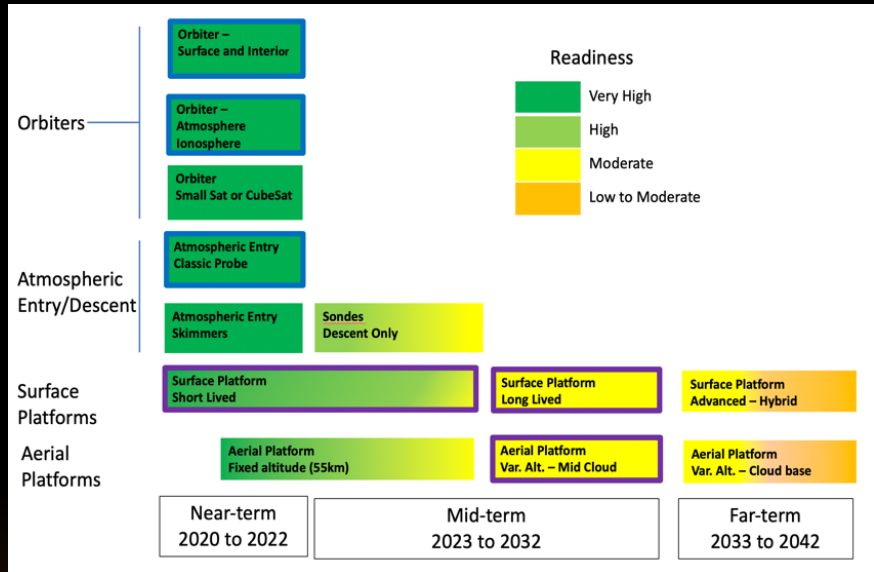
- A. What processes drive the global atmospheric dynamics of Venus?
- B. What processes determine the baseline and variations in Venus atmospheric composition and global and local radiative balance?

Goal #3. Understand the geologic history preserved on the surface of Venus and the present-day couplings between the surface and atmosphere.

- A. What geologic processes have shaped the surface of Venus?
- B. How do the atmosphere and surface of Venus interact?

ROADMAP FOR VENUS EXPLORATION

VENUS EXPLORATION
VEXAG
ANALYSIS GROUP
2019



VEXAG GOI			Roadmap Mission Modalities											
Goal	Objective	Investigation	Orbiter	Orbiter	Orbiter	Atmospheric Entry			Surface Platform			Aerial Platform		
			Surface/Interior	Atmosphere	SmallSat	Skimmer	Probe	Sonde	Short-lived	Long-lived (Pathfinder)	Long-lived (Advanced)	Fixed Altitude	Variable Altitude	Variable+Altitude
			Near-term	Near-term	Near-term	Near-term	Near-term	Mid-term	Near-term	Mid-term	Far-term	Near-term	Mid-term	Far-term
I. Early evolution and potential habitability	Did Venus have liquid water?	I.A.HO. (1)												
		I.A.RE. (1)												
		I.A.AL. (2)												
	How does Venus inform pathways for planets?	I.A.MA. (3)												
		I.B.IS. (1)												
		I.B.LI. (1)												
II. Atmospheric dynamics and composition	What drives global dynamics?	I.B.HF. (2)												
		I.B.CO. (2)												
		II.A.DD. (1)												
	What governs composition and radiative balance?	II.A.UD. (1)												
		II.A.MP. (2)												
		II.B.RS. (1)												
III. Geologic history and processes	What geologic processes shape the surface?	II.B.IN. (1)												
		II.B.AE. (2)												
		II.B.UA. (2)												
	Atmosphere and surface interactions?	II.B.UG. (3)												
		III.A.GH. (1)												
		III.A.GC. (1)												
Color Code		Meaning												
		Vital: Mission modality enables measurements that are vital (either alone or in combination) to completing the investigation.												
		Supporting: Mission modality enables measurements that substantially contribute to completing the investigation.												

Image credit: John D. Wirbanek



Table 1. Major Needs Arising from This Study

Area	Needs
Entry Technology	Funding to ensure the entry technology capability does not atrophy Development of high temperature electronics, sensors, and high-density power sources for the Venus environment with increasing capability
Subsystems	A competitive program to determine which Variable Altitude balloons approach is most viable
Aerial Platforms	Adaptation of flight-demonstrated technology and development of new instrument systems uniquely designed for the Venus environment
In situ Instruments	Study of the feasibility of and methods for establishing a Venus communications and navigation infrastructure
Communications and Infrastructure	Investments in highly efficient mechanical thermal conversion and cooling devices
Advanced Cooling	New concepts for adapting precision descent and landing hazard avoidance technologies to operate in Venus' dense atmosphere
Descent and Landing	Transitioning of automation and autonomous technologies to Venus-specific applications
Autonomy	Development of small platform concepts in addition to larger missions, as well as a new mission type designed around small platforms
Small Platforms	Support of laboratory facilities and capabilities for instrument and flight systems, including critical technologies to avoid atrophy of capabilities
Facilities and Infrastructure	Establishment of a system science approach to Venus modeling
Modeling and Simulations	Continued and expanded support for programs such as HOTTech, and other technology development
Unique Venus Technology	

17th Meeting of the Venus Exploration and Analysis Group (VEXAG) November 6–8, 2019, at the LASP

- HQ presentation (thank you, Lori!)
- Mission summaries: Parker Solar Probe, Akatsuki, Bepi Columbo, ISRO
- New format: technique tutorials, science as posters, field trip
- Tutorials for 2019:
 - Melissa Trainer: *Noble Gases on Venus*
 - Gary Hunter: *High Temperature Capabilities*
 - Kevin McGouldrick: *Orbit to In-Situ Atmospheric Spectroscopy*
 - Scott Hensley: *Venus Radar*
 - Bob Grimm: *Orbit to Surface Geophysics*



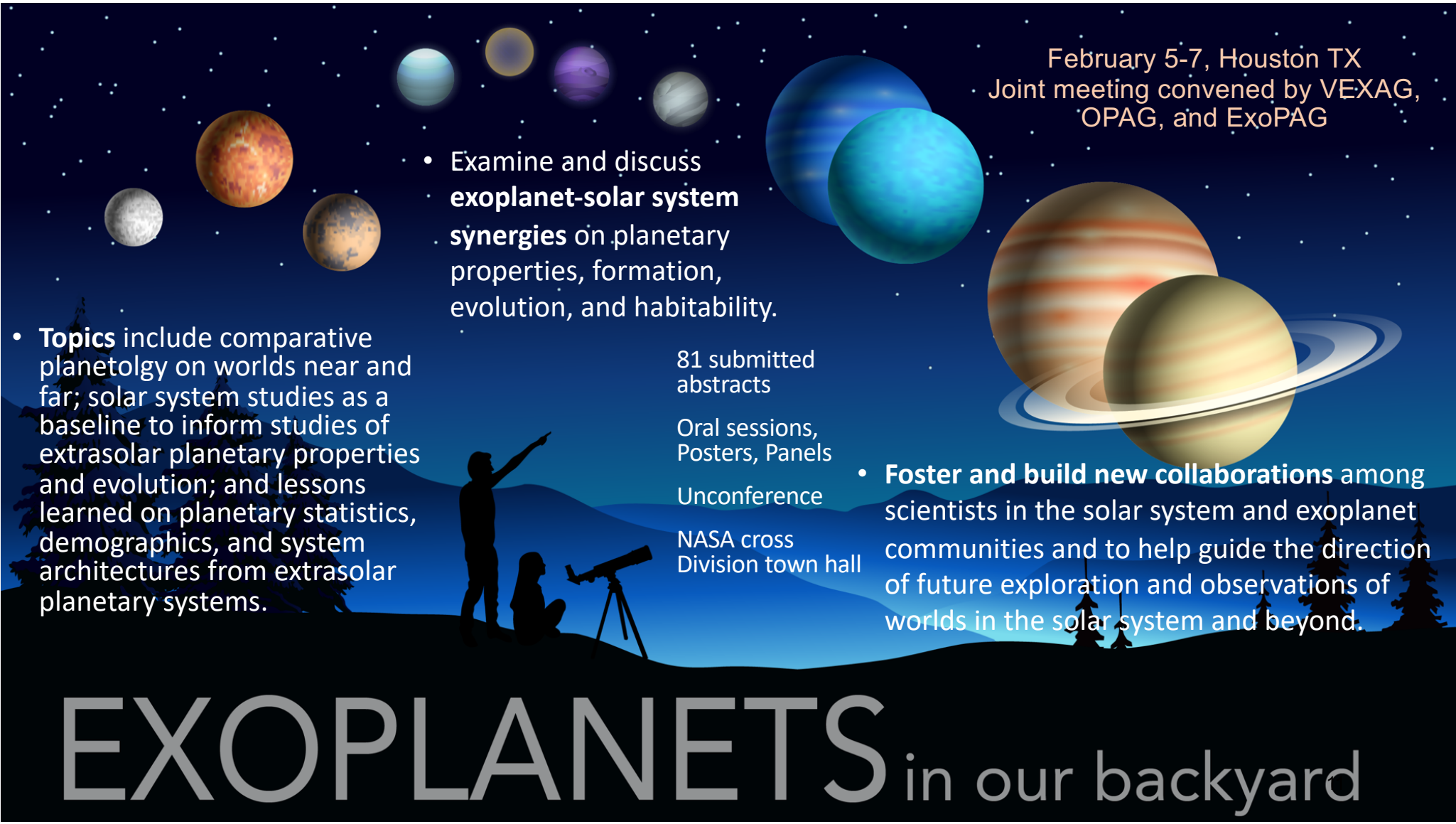




VEXAG White Papers

Drafts discussed at
VEXAG meeting in
November. Current total
being tracked is now 35.

1. Noam Izenberg: EMPIRE Strikes Back: Venus Exploration in the New Human Spaceflight Age
2. Stephen Kane: Venus as a Nearby Exoplanetary Laboratory
3. Marty Gilmore: Venus Flagship report (only if not funded)
4. Tibor Kremic/Gary Hunter: LISSEe, VBOS, etc. small platforms for long-lived surface missions
5. Gary Hunter: High temperature electronics, recent advancements
6. Raj Venkatapathy: HEEET
7. Jim Cutts: Aerial platform update to prior report, with ore emphasis on exploring the habitable zone
8. Joe O'Rourke: Searching for crustal remanent magnetism...
9. Kevin McGouldrick: Venus atmosphere/weather
10. Emilie Royer: Airglow as a tracer of Venus' upper atmosphere dynamics
11. Sue Smrekar: Venus tectonics and geodynamics
12. Joern Helbert: Orbital spectroscopy of Venus
13. Amanda Brecht: Coupling of 3D Venus models and innovative observations
14. Jenny Whitten: Venus tessera as a unique record of extinct conditions
15. Sanjay Limaye: Venus as an astrobiological target
16. Attila Komjathy: Investigating dynamical processes on Venus with infrasound observations from balloon and orbit
17. Pat McGovern: Venus as a natural volcanological laboratory
18. Helen Hwang: Thermal Protection System Technologies for Enabling Future Venus Exploration
19. Alison: Venus facilities and applications for them for technology development and science investigations
20. Allan Treiman/Molly McCanta: Experimental work for understanding Venus
21. Frank Mills: Carbon, oxygen, and sulfur cycles in Venus' atmospheric chemistry
22. Eliot Young: Ground-based observations of Venus in support of future missions
23. Glyn Collinson: Space plasma science questions and technologies
24. Colin/Sanjay: Coordination and strategy for international partners and collaborations for Venus: future fly-bys and international missions?



February 5-7, Houston TX
Joint meeting convened by VEXAG,
OPAG, and ExoPAG

- **Topics** include comparative planetology on worlds near and far; solar system studies as a baseline to inform studies of extrasolar planetary properties and evolution; and lessons learned on planetary statistics, demographics, and system architectures from extrasolar planetary systems.
- Examine and discuss **exoplanet-solar system synergies** on planetary properties, formation, evolution, and habitability.

81 submitted
abstracts

Oral sessions,
Posters, Panels

Unconference

NASA cross
Division town hall

- **Foster and build new collaborations** among scientists in the solar system and exoplanet communities and to help guide the direction of future exploration and observations of worlds in the solar system and beyond.

EXOPLANETS in our backyard



Venus small-mission opportunities and VeGASO



- Both *Dragonfly* and *Europa Clipper* baseline launch scenarios include Venus gravity assist/flybys.
- Pending final confirmation of launch vehicle and trajectories:
 - ~~Both~~ missions' launches represent perfect opportunities to deliver payloads of opportunity to Venus. (Clipper may be out)
 - Multiple, high science return, low cost cubesat to smallsat Venus missions have been studied and deemed feasible via PSDS3, Venus Bridge*, and other efforts. (*Venus Bridge study targeted a higher cost point, but resulted in multiple elements within SIMPLEX or SALMON range).
 - Small Venus missions would ride along on launch and separate as early as initial boost to Venus trajectory.
- **SIMPLEX or SALMON calls for these planetary missions should be dedicated to Venus opportunities.**
- **Venus Gravity Assists Science Opportunity document needs updating**
- PSDS3, HOTTech, Venus Bridge concepts: CUVE, Cupid's Arrow, VAMOS, LLISSE, SAEVe, V-BOSS, VB-IRO, -SMO, -RSOC, -UVO, -PFO, -Skim, -Probe, -Balloon.

VEXAG Preliminary Findings to be finalized at January SC meeting

1. Careful evaluation of U.S. funding commitments to international missions, and prioritization of U.S.-led missions.
2. VEXAG and the entire Venus community ask to be kept informed as commitments to international partners are considered and selected.
3. Support of ride-along opportunities for Venus missions.
4. Support programmatic balance among mission selections.
5. Continue to support HOTTech, high energy entry capabilities, and long duration surface power systems.
6. New support for suborbital observations of Venus.

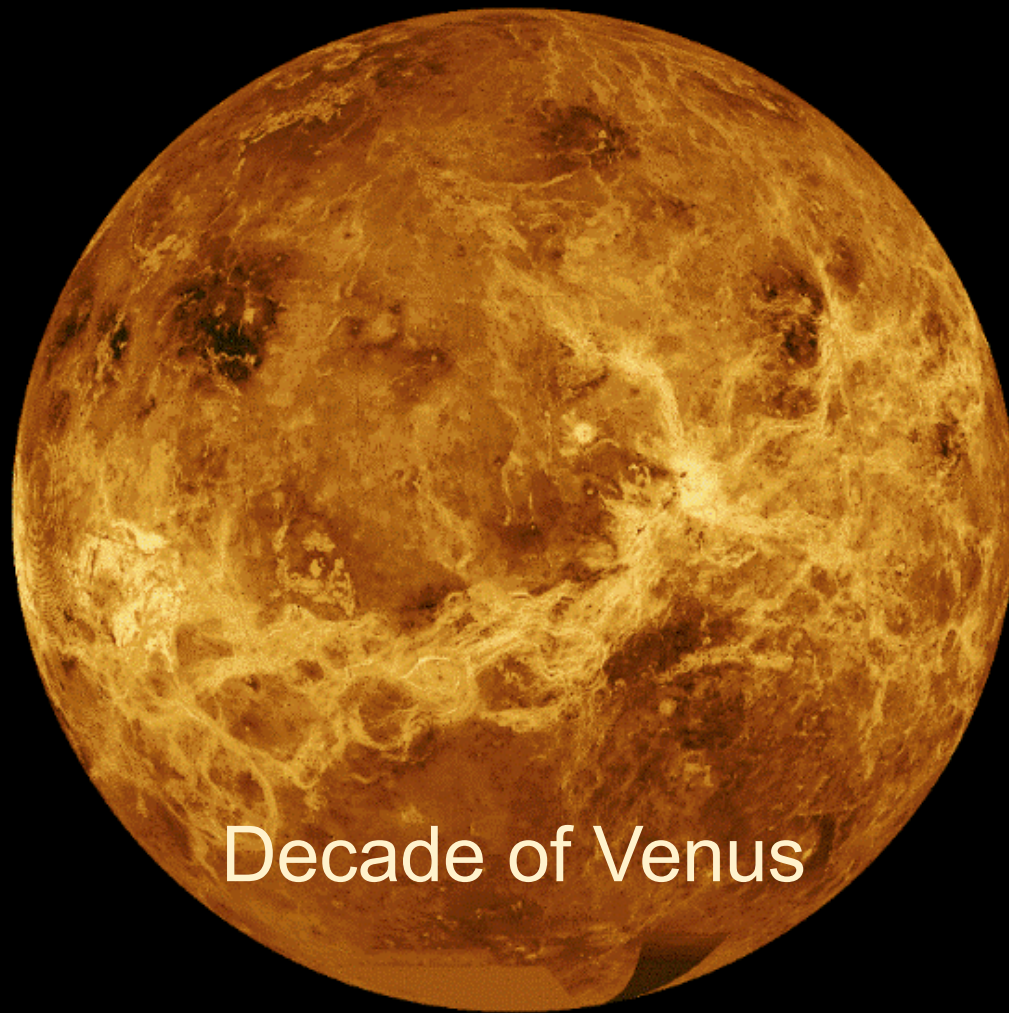
VEXAG Findings, continued

7. VEXAG asks for an open reporting of all AG budgets and establishment of equity across them.

Attendance and participation at AG meetings are critically important in fostering a cohesive and collegial Venus research community and building collaborative research across institutions. However, the **lack of a current Venus mission and relatively small numbers of Venus R&A PIs mean that only a subset of the community is financially able to attend.**

VEXAG functions are significantly limited by an opaque budget and lack of support for critical functions, such as support for on-site meeting, editorial and printing of important documents, and travel funding for mid-career and older scientists to attend AG meetings.

VEXAG requests **transparency and fairness in funding of AGs and their activities.**



Decade of Venus