VEXAG VENUS EXPLORATION DOCUMENTS 2019 UPDATE. N. R. Izenberg[1] and M. D. Dyar[2], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (noam.izenberg@jhuapl.edu), [2]Mount Holyoke College, South Hadley, MA 01075.

Introduction: In preparation for the next Decadal survey that will succeed the Visions and Voyages planning document [1] (2023-2033), the Venus Exploration Analysis Group (VEXAG) is revising its Venus Exploration documents, last updated in 2014. The document set comprises Goals, Objectives and Investigations for Venus Exploration (GOI), Roadmap for Venus Exploration (RVE), Venus Technology Plan (TechPlan), with Venus Exploration Themes (Themes) documenting highlights from past versions. All four of these documents are in the process of revision, which will be completed in the summer of 2019. An executive summary, or Venus Exploration Pathway document, will tie the three major documents together and provide NASA with advice from the community for prioritizing Venus' programmatic resources in pursuit of the major science questions of exploring the Second Planet.

Goals, Objectives and Investigations for Venus Exploration (GOI): Venus is the planet most likely to cast new light on conditions that determine whether or not a planet evolves habitable environments. Current and future efforts to identify planets beyond our solar system (*e.g.,* Transiting Exoplanet Survey Satellite, or TESS) are aimed ultimately at finding Earth-size planets around Sun-size stars. Venus-Earth comparison will be critical in assessing the likelihood that 'Earth-size' means 'Earth-like' for such discoveries.

The current Decadal Survey [1] identified three main goals for inner planets research: understand the origin and diversity of terrestrial planets; understand how the evolution of terrestrial planets enables and limits the origin and evolution of life; and understand the processes that control climate on Earth-like planets.

The Venus community, as represented by VEXAG, believes that a vigorous exploration program to understand the divergence of Venus from Earth plays a key role in addressing these themes. Through an extended period in which community input is being solicited online and through virtual and in-person town hall meetings, we are developing our exploration documents to ensure that they describe the goals, objectives, and investigations that are most important to be addressed by future exploration to Venus. They include three goals of equal priority:

- Understand Venus' early evolution (including possible habitability), and the evolutionary paths of Earth-sized terrestrial (exo)planets.
- Understand atmospheric dynamics, composition and climate history on Venus.
- Understand how physical and chemical processes interact to shape the surface of Venus.

A small number of balanced Objectives within each Goal are stated as scientific questions. A summary table links the Venus exploration objectives back to the relevant themes of Visions and Voyages, though is revision is also intended to provide guidance for the next Decadal Survey. A putative set of investigations are given, designed to provide answers to questions posed by each Objective and tie in with the RVE.

In establishing Venus exploration goals, VEXAG recognizes that different types of investigations, ranging from a potential flagship mission to New Frontiers, Discovery class, and other mission classes, are needed to answer the pressing scientific questions about Venus. In particular, *VEXAG explicitly chooses not to prioritize among orbital, atmospheric probe, aerial platform, flyby, or surface lander missions*, but acknowledges that all these types of missions are desirable and complementary rather than competitive. The science results of the broad palette of Venus missions are needed to fully trace its origins, evolution, and history of habitability.

Roadmap for Venus Exploration (RVE): The Roadmap lays out a framework for future Venus exploration that encompasses observations of atmosphere, surface, and interior using a variety of mission modes: orbiters, probes, aerial platforms, landers, and sample return vehicles. Proposals that address measurement goals expressed in this Roadmap should be recognized by NASA as consistent with VEXAG's recommended Venus exploration strategy. The Roadmap amplifies topics in Visions and Voyages [1] and guides recommendations for the next Decadal Survey.

The Roadmap is based on the GOI document

described above. To facilitate identification of specific mission concepts, the Roadmap is divided into four "exploration domains:" 1) Atmospheric Composition, 2) Surface Composition and Morphology, 3) Atmospheric Structure and Circulation, and 4) Interior Structure and Dynamics. Within each category, measurements and missions are structured in a logical progression of scientific discovery and engineering capability. Relative priority of missions within each domain is based primarily on scientific priorities in the GOI, modulated by assessment of each mission's technical feasibility and compatibility with current budgetary and programmatic realities. Thus, the RVE represents a practical guide to future Venus missions that can achieve the highest priority science objectives in the most expeditious manner, and provides NASA with guidance toward the best application of available resources for Venus exploration.

Venus Technology Plan (TechPlan): A growing number of scientifically important missions can be implemented with existing technology, and engineering development continues to add new capabilities; ambitious missions involving operations for extended periods in the lower atmosphere or the surface of Venus are nearing feasibility due to significant investments in new technology by NASA. A Venus exploration program should continue to include a balance of investments in short term missions as well as technology to enable more ambitious medium- and long-term missions.

Complementing the GOI and RVW documents, the TechPlan provides a basis for enabling the strategic direction for future Venus exploration. It draws information from both documents and performs a more detailed assessment of the technologies that require NASA investment. It builds upon recent advances in Venus technology, including the Venus Bridge study [2], the HOTTech project technology program, the Long-Lived In Situ Solar System Explorer (LLISSE) being developed at NGSC, the heat shield for extreme entry environment technology (HEEET) project at NASA Ames, the Glenn Extreme Environments Rig (GEER), the VEM-CAM being developed at LANL, and the recently completed Aerial Platform Study [3], and in-progress Surface Platform Study.

Venus Exploration Pathway (VEP): This VEXAG document summary is meant to tie the GOI, Roadmap, and TechPlan together in a way that effectively advises and guides NASA in allocating resources to answer the highest priority questions for Venus. The VEP preserves important aspects of past Venus Exploration editions and highlights past missions, mission opportunities, and other aspects and resources for the Venus community. Updated current theme sections will include: 55 years of missions, Venus exploration vignettes, current and future non-US missions, US Venus exploration mission opportunities, Venus laboratory measurements, and an updated "Why Explore Venus Now?" Appendix.

Changes to Decadal: The current recommended list of Medium-Class Missions for the New Frontiers Program [1] includes six science goals. Although the document notes that "achieving all of these objectives represents a flagship-class investment, but achieving a majority is considered feasible in the New Frontiers Program," recent experience suggests that fewer listed goals may improve mission selection success for Venus. Thus, VEXAG is creating a white paper that presents simplified Venus science goals for medium-class missions that can be satisfied by any one of a range of possible mission pathways. These will be incorporated into the new Decadal document.

Timeline: Near-complete drafts of these documents were presented to the planetary science community in January of 2019 on VEXAG web pages (www.lpi.usra.edu/vexag/) to actively solicit comments and revisions from the community. In February 2019, an open community Virtual Townhall provided another venue for community input. A Venus Documentation Workshop, March 17 2019, will provide additional face-to-face community input and discussion, followed by a Venus Town Hall during LPSC 2019 to discuss those revisions. A final virtual town hall or other public discussion is planned for April-May 2019.

VEXAG plans to complete and publish the revised documents in the summer of 2019, and combine the GOI and RVE into a Venus Exploration Roadmap paper for peer reviewed publication by the winter of 2020.

Acknowledgements: VEXAG document working groups, the Venus science community.

References: [1] *NRC (2011) Visions and Voyages,* Natl. Acad. Press; [2] www.lpi.usra.edu/vexag/reports/Venus_Bridge_Summary_Report.pdf; [3] solarsystem.nasa.gov/resources/2197/aerial-platforms-for-the-scientific-exploration-of-venus/.