

**VENERA-D: VENUS CLOUD HABITABILITY SYSTEM WORKSHOP.** S. T. Port<sup>1</sup>, A. Bhattacharya<sup>2</sup>, S. Dattani<sup>3</sup>, M. Eubanks<sup>4</sup>, T. K. P. Gregg<sup>5</sup>, M. Kriuchkova<sup>6</sup>, J. Mckaig<sup>7</sup>, N. Punt<sup>8</sup>, D. Gorinov<sup>9</sup>, J. A. Cordova<sup>10</sup>, T. Economou<sup>11</sup>, K. L. Jessup<sup>12</sup>, S. S. Limaye<sup>10</sup>, T. Milojevic<sup>13</sup>, A. Ocampo<sup>14</sup>, A. Treiman<sup>15</sup>, M. A. Voytek<sup>14</sup>, L. Zasova<sup>9</sup>, <sup>1</sup>NASA Glenn Research Center, Cleveland, OH, USA ([sara.port@nasa.gov](mailto:sara.port@nasa.gov)), <sup>2</sup>University of Michigan, Ann Arbor, MI, USA, <sup>3</sup>Rutgers University, New Brunswick, NJ, USA, <sup>4</sup>Space Initiatives Inc., USA, <sup>5</sup>University of Buffalo, Buffalo, NY, USA, <sup>6</sup>Pushchino Scientific Center for Biological Research of the Russian Academy of Sciences Moscow, Russia, <sup>7</sup>Georgia Institute of Technology, Atlanta, GA, USA, <sup>8</sup>Fidum Veterinary Services, USA, <sup>9</sup>Space Research Institute (IKI), Moscow, Russia, <sup>10</sup>University of Wisconsin, Madison, WI, USA, <sup>11</sup>University of Chicago, Chicago, IL, USA, <sup>12</sup>Southwest Research Institute, Boulder, CO, USA, <sup>13</sup>University of Vienna, Vienna, Austria, <sup>14</sup>NASA Headquarters, Washington, D.C., USA, <sup>15</sup>Lunar and Planetary Institute, Houston, TX, USA.



**Background:** The Venera-D: Venus Cloud Habitability System Workshop was held virtually from November 29<sup>th</sup> to December 3<sup>rd</sup>, 2021. This workshop featured 54 presentations and 3 panels and was viewed by 264 participants from 36 different countries.

The goals of this workshop were to discuss the formation and stability of Venus clouds over time, past and present habitability, the best measurements and methods needed to address these questions, and how future missions will contribute to understanding the cloud habitability system.

The collected abstracts fell into one of four different categories: 1) cloud layer habitability, 2) inputs (interior, surface, exogenous) to and outputs from the cloud layer over time, 3) measurements and instruments necessary to investigate the Venus cloud region, and 4) open questions or any additional investigations pertaining to the habitability of Venus clouds.

**Venera-D 2019 Workshop:** The Venera-D 2021 Workshop was a continuation of the very successful Venera-D Landing Sites Selection and Cloud Layer Habitability Workshop in 2019. This workshop had two major outcomes. The first was the identification of four plain terrain types that could be viable landing sites because of their lack of recognizable hazards and their scientific merit: 1) the stratigraphically oldest plains; 2) the stratigraphically youngest plains; 3) lobate plains; and 4) canali-fed plains.

The second outcome of the workshop centered around the discussion on the potential for life in the clouds of Venus. The workshop hosted many presentations addressing the possibility of a habitable cloud region and the origins and survivability of life on Venus. Further discussions were held on the necessary lab and modeling studies, as well as measurements

required to tackle these questions. A final report was published and can be found here: [https://www.lpi.usra.edu/vexag/documents/reports/VeneraD\\_2019Wkshp\\_techRp\\_cover\\_21July20\\_v12Final.pdf](https://www.lpi.usra.edu/vexag/documents/reports/VeneraD_2019Wkshp_techRp_cover_21July20_v12Final.pdf)

**Presentations:** Based on the submitted abstracts the workshop organizers created six sessions. The “Present Habitability of Venus” session featured presentations on the past and current challenges that life would need to overcome to survive, and to use the lessons acquired from studying life in the lab and in Earth’s stratosphere to investigate Venus. The “Missions to Venus” session had presentations on the upcoming DAVINCI and EnVision missions, and a summary of suitable and scientifically interesting landing sites. As the title suggests, the “Measurements, instruments and Mission Concepts to Venus” featured numerous presentations on instruments, techniques, mission concepts, and methods to investigate the Venus cloud region and potentially detect life. A representative from the engineering firm NPO Lavochkin gave an update on the prospective Venera-D mission, including its objectives, intended instrumentation, and the next steps toward its realization. The “Putative Origins of Life and Past Habitability of Venus” session had presentations on different chemical, geological, and astrophysical processes that could have had significant effects on the development of life, and if it is possible to detect ancient life on Venus today. The “Biosignatures at Venus” session discussed different potential agnostic biosignatures at Venus, and the importance of understanding an environment and letting that information drive the investigations for life. The final session, “Evolution of the Venusian Atmosphere”, presented talks on the possibility of ancient oceans on Venus and the different geological and physical processes that may have occurred in the past to explain the current atmosphere of Venus.

**Discussion Panels:** The Workshop also hosted three different panels to facilitate discussions on current hot topics in Venus science. The first panel, “A Decade of Venus Exploration — A Multi-Agency Perspective”, centered around current present and future Venus

missions and the possible ways in which science synergy among these missions could maximize their science return. The panelists featured five representatives of International Space Agencies: Lev Zelenyi (IKI), Lori Glaze (NASA), Fabio Favata (ESA), Yoshifumi Saito (JAXA), and Tirtha Das (ISRO).

The next panel discussed phosphine at Venus and heard from Drs. Giada Arney, Matt Pasek, Clara Sousa-Silva, Melissa Trainer, Colin Wilson, Kevin Zahnle while Dr. Kandis-Lea Jessup served as the moderator. They discussed the phosphorus cycle, abiotic sources of phosphine, phosphine as a biosignature, and methods to detect phosphine in the atmosphere.

The last panel deliberated on past and present water availability on Venus, and its importance for the emergence and survivability of life. The panel included Drs. John Hallsworth, Chris McKay, Paul Rimmer, Martin Turbet, Michael Way and Dr. Mark Bullock as the moderator.

**Next Steps:** As was done for the Venera-D 2019 Workshop, the science organizational committee and the scribes will work together to create a comprehensive Final Report that will summarize the talks and sessions, present highlights from the workshop, and list current Workshop's major outcomes and next steps. Once completed, the final report will be made available to the public. There are preliminary plans to organize a future Venera-D Workshop to continue to address the outcomes from this workshop.

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**References:**

[https://www.hou.usra.edu/meetings/venera\\_d2021/](https://www.hou.usra.edu/meetings/venera_d2021/)

Limaye, S. S., Zelenyi, L., Zasova, L. (2021) *Astrobiology*, 21, 10