DEVELOPMENT OF THE VENERA-D MISSION CONCEPT, FROM SCIENCE OBJECTIVES TO MISSION ARCITECTURE. D. Senske[1], L. Zasova[2], A. Burdanov[3], T. Economou[4], N. Eismont[2], M. Gerasimov[2], D. Gorinov[2], J. Hall[1], N. Ignatiev[2], M. Ivanov[5], K. Lea Jessup[6], I. Khatuntsev[7], O. Korablev[2], T. Kremic[8], S. Limaye[9], I. Lomakin[7], M. Martynov[7], A. Ocampo[10], S. Teselkin[7], O. Vaisberg[2], V. Voronstsov[7], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [2]Space Research Institute RAS, Profsoyuznaya 84/32, Moscow 117997, Russia, [3]TSNIIMASH, 4 Pionerskaya Street 141070 Korolev, Russia, [4]Enrico Fermi Institute, University of Chicago 933 East 56th Street, Chicago, IL 60637, [5]Vernadsky Inst. RAS, Kosygin St., 19 Moscow, Russia, [6]Southwest Research Institute 1050 Walnut, Suite 300 Boulder CO 80302, [7]Lavochkin Assoc. 24, Leningradskaya Str. 141400 Khimki, Russia, [8]Glenn Research Center, 21000 Brookpark Rd, Cleveland, OH 44135, [9]Univ. of Wisconsin, 1225 W Dayton St Madison, WI 53706, [10]NASA Headquarters, Washington, DC.

Background: The highly successful Soviet Venera and VEGA missions [1,2] of the 1970s and 1980s along with the US Pioneer and Magellan [3] missions have provided the foundation for the basic understanding of the atmosphere and surface of Venus. Subsequent exploration in the current era by the Venus Express and Akatsuki missions [4,5] have provided additional understanding into the properties of the surface and the structure and dynamics of the atmosphere, allowing new scientific questions to be formulated. Building on the results of these missions and with the overarching goal of understanding why Venus and the Earth took divergent evolutionary paths, a joint NASA-IKI/Roscosmos Science Definition Team (JSDT) was established in 2015 with the task of defining the science and architecture of a comprehensive mission to Venus composed of an orbiter and lander, Venera-D (Venera-Dolgozhivuschaya (long-lasting)) envisioned to be launched in the post-2025 timeframe. In January of 2017, the JSDT completed the first phase of its work and generated a report of its findings [6]. The second phase of the JSDT activities is currently underway with a focus on refining the science investigations through community modeling workshops, undertaking a compressive development of the core orbiter and lander mission architecture, and a detailed examination of the types of aerial platforms that could address key Venus science [7, 8].

Science goals of the Venera-D mission concept: Specific Venera-D investigations would address questions focused on the dynamics of the atmosphere with emphasis on atmospheric superrotation, the origin and evolution of the atmosphere, and the geological processes that have formed and modified the surface with emphasis on the mineralogical and elemental composition of surface materials, and the chemical processes related to the interaction of the surface and the atmosphere. For each Venera-D baseline mission component, the following goals would be addressed:

***Orbiter Goals*:**

- Study of the dynamics and nature of super-rotation, radiative balance and nature of the greenhouse effect;
- Characterize the thermal structure of the atmosphere, winds, thermal tides and solar locked structures;
- Measure composition of the atmosphere; study the clouds, their structure, composition, microphysics, and chemistry;
- Investigate the upper atmosphere, ionosphere, electrical activity, magnetosphere, and the escape rate

***Lander Goals*:**

- Perform chemical analysis of the surface material and study the elemental composition of the surface, including radiogenic elements;
- Study the interaction between the surface and the atmosphere;
- Investigate the structure and chemical composition of the atmosphere down to the surface, including abundances and isotopic ratios of the trace and noble gases
- Perform direct chemical analysis of the cloud aerosols;
- Characterize the geology of local landforms at different scales.

To aid in the refinement of the Venera-D science objectives, two community modeling workshops were held in 2017. The first took place at the Glenn Research Center with the goals of evaluating (1) the status of modeling of Venus' exosphere, atmosphere, surface, and interior and (2) the factors that are currently limiting the ability of investigators to advance models and how modeling efforts can benefit from and guide experimental studies and future mission activities. The second workshop took place in Moscow with the objectives to understand the limitations and needs of current models (*e.g*. General Circulation Models, interior structure, and the plasma environment), potential landing sites, and the types of measurements needed to more adequately constrain parameters in models and experiments. This would in-turn form a basis to better identify the types of instruments needed to achieve the science of Venera-D. The results of these workshops are being incorporated into the proceedings of the JSDT and it is anticipated that additional workshops will be held as the mission concept develops.

Development of the Venera-D mission concept architecture: The members of the JSDT from the Lavochkin Association are leading the effort in the development of the mission concept architecture [6]. Key aspects of this assessment include the following: (1) Development of the general configuration for both the orbiter and the lander, along with how they are assembled into a single flight system; (2) Accommodation of systems and subsystems within the orbiter and lander; (3) Assessment of orbit options along with the strategy for descent and landing; (4) Evaluation of telecommunication options from the spacecraft to the earth and from the lander to the orbiter and; (5) Accommodation of an aerial vehicle in its own delivery system to be released upon arrival at Venus. In assessing the delivery of the flight system to Venus, launch dates between 2026 and 2031 have been evaluated for both Angara-5 and Proton launch vehicles. From the standpoint of total mass delivered to Venus, the best launch opportunities occur in 2026 and 2031. Development of the architecture is ongoing with detailed focus on the core orbiter and lander elements.

Venus Aerial Platforms: The JSDT concluded that *in situ* atmospheric measurements made aloft over an extended period of time (many hours to months) would be scientifically enabling, especially for understanding the processes that drive the atmosphere. Mobility within the atmosphere was also deemed to be of high priority in terms of understanding the location of the UV absorber and identifying its composition. Thus, a high priority augmentation to the core concept would be an aerial platform to address science focused on atmospheric superrotation (UV–absorber), chemistry, and trace species in the middle cloud layer.

To better understand the science needs, capability, and technology readiness of potential aerial platforms that might be incorporated into the Venera-D payload, a NASA study is currently underway led by the Jet Propulsion Laboratory [8]. A key aspect of this evaluation is to understand the cost and risk of each platform type relative to the science that could be achieved. The three types of platforms under examination include, super pressure balloons, altitude controlled balloons, the Venus Atmospheric Maneuverable Platform (VAMP)[9], and solar powered aircraft. The final report from this study is anticipated in February of 2018 and it will be incorporated into the deliberations of the JSDT.

Ongoing activities of the Venera-D JSDT: The current phase of activity of the Venera-D JSDT will result in a report to be delivered to NASA-IKI/Roscosmos in late January of 2019. Over the next year, the tasks of the group will concentrate on (1) science refinement and completion of the evaluation of payload elements, specifically notional instruments; (2) continued development and refinement of the mission concept architecture including concepts of mission operations and risk assessment; (3) evaluation of potential landing sites within the context of the evolving lander engineering concept; and (4) incorporation of the results from the aerial platform study in the evaluation of a potential contributed element(s).

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