# DAVINCI MISSION TO VENUS' ATMOSPHERE AND SURFACE: SCIENCE UPDATE 2024

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**Introduction:** As of early 2024, the *Deep Atmosphere of Venus Investigation of Noble gases, Chemistry and Imaging* (**DAVINCI**) mission remains on track for a 2029 launch to Venus, with an entry-descent-science campaign in late June 2031 [1,2]. The formal Level-1 requirements have been approved at NASA Headquarters by senior-most officials via a signed PLRA document as of December 2023, with a decision memo for DAVINCI to launch to Venus in 2029. During the past two years of early Phase B project ramp-up , DAVINCI has successfully delivered progress on required gateway reviews and via special engineering-science activities in support of mission risk reduction and performance optimization. This document highlights the current state of DAVINCI as NASA's next mission to Venus, now more than 45 years since Pioneer Venus probes visited the atmosphere and surface in December 1978.

**Background:** DAVINCI was selected for implementation in June 2021, with a 3+ year later launch than proposed, based on funding availability within NASA's *Discovery* program, and with a required 60-day study to present options to NASA leadership for launch options that preserved the peer-reviewed science goals and objectives through the two phases of competition. Options for launches to Venus with scientifically prioritized flybys before the in-situ campaign (entry-descent-science with touchdown) were presented to NASA leadership in Fall 2021 and a signed decision memo for DAVINCI to launch in the available 2029 windows was approved during summer of 2023 (as always, depending on NASA budgets going forward).

**Activities:** Over the past year, key activities included a *Mission Requirements Review* (MRR) in May 2023, and several Systems Requirements Reviews (SRRs) in June, October, and November 2023. These keystone reviews were conducted with members of the DAVINCI Standing Review Board present, as well as the NASA HQ program executive, program scientist, and Planetary Missions Program Office mission manager. Additional engineering trades were conducted, as well as final project level consideration of one science-related trade option that was offered as part of the Phase A concept study in association with new results for Venus (consideration of an additional capability within the *in situ* analytical payload). In addition, an innovative free-fall drop test experiment for aerodynamics was extended to include a demonstration/validation of Structure-from-Motion (SfM) analysis of nested descent images for computation of local scale topography under partially isotropic illumination conditions in October 2023 (led by DAVINCI LaRC engineering team leaders including Dr. S. Dutta). Other activities related to outreach and student engagement (Here2Observe, H2O) as well as instrument performance simulations were also initiated.

**Results/Progress as of Early 2024:**

*Successful MRR Review.* After a two-day review with an independent review board, the DAVINCI mission with flow-down from science Level-1's and mission success criteria to project Level-2's and below (via a Mission Reqt's Document [MRD]) was successfully passed in May 2023, with only 3 RFA's. A complete PLRA document was submitted to NASA HQ and has now been signed. A plan for a push to mission PDR and confirmation was developed, with a goal of late 2025 (HQ Decision Memo, July 2023).

*Successful SRR for VMS.* After a multi-day review, the Venus Mass Spectrometer (one of 5 instruments in the Descent Sphere or DS) was successfully reviewed with no critical issues, with approval to push to PDR [3].

*Successful SRR for Descent Sphere (Zephyr).* A multi-day technical and programmatic review of the GSFC-developed DS was conducted in Oct. 2023, with no major issues, and a plan forward for PDR in 2025.

*Successful Drop Test Experiment at UTTR.* An aerodynamic drop test of a DS "test unit" configured with a descent camera (GoPro Hero-10) and GPS/IMU's was conducted at UTTR in October with a total freefall trajectory of ~ 1.4 km over ~ 30 seconds, with a touchdown in a playa surface adjacent to a cluster of ~18 m tall dunes and other features, all under cloudy (isotropic illumination) conditions analogous to the conditions at Venus. DEM's were computed from descent images via SfM and compared to independent topographic ground-truth from Stereo Maxar WV-3 imaging (1 m GSD) with an $R^2$ correlation of 0.88 over relevant FOV areas, with differences all at sub-meter vertical levels. This confirmed the utilization of SfM methods to meet L-1 DEM requirements at more severe conditions (e.g., higher free-fall velocities) than we expect at Venus for DAVINCI.

*Successful SRR for VTLS (at JPL).* In November of 2023, a SRR review at JPL was conducted with a successful outcome, let by JPL PEL (C. Webster) and deputy PEL (A. Hofmann), with a clear plan forward for PDR.

*Successfully signed PLRA (at NASA HQ):* As of 13 December 2023, a formally approved set of Level-1 objectives with Mission Success Criteria was approved at the SMD Associate Administrator level for DAVINCI, thanks to efforts by the Science and Systems engineering teams [**Fig. 1**]. There are 17 Level-1 requirements traceable to mission goals and objectives, which

themselves trace to five NASEM Decadal Survey priority questions.

**Discussion:** The successful set of FY23 activities (into early FY24) even in a time of restricted budgets showcases the DAVINCI Project progress toward a 2029 launch [**Fig. 2**]. Highlights of the past years' effort related to science include:

*(A) DAVINCI in situ analytical capability trade study.* The DAVINCI science leadership team openly engaged the Venus atmospheric science community on scientific inputs to a trade study at the DAVINCI project level, planned as an early Phase B activity at the time of selection. With science priorities bounded by analytical instrument capabilities, emerging science priorities, and alignment with the DAVINCI mission, the trade study was conducted by the DAVINCI science, programmatic, and technical teams, with final determination to maintain the baseline payload by the mission PI. Further details are described in work now in preparation.

*(B) Free-fall drop test DEMs.* Validation of SfM methods for computing multi-scale DEM's from nested descent images acquired during a ~ 1.4 km free-fall drop test over a geologically relevant target (for Venus) will influence the progress forward on descent timeline optimization for imaging as part of the DAVINCI In Situ Campaign in June 2031 at Venus over Alpha Regio. The minimally required number of VenDI images under worst case conditions (sub-nominal descent timeline) will ensure delivery of new DEM's using SfM at scales required (L-1), with options for additional experimental DEM's at finer scales (< 15 m x,y) but with less certain vertical precisions.

*C) Band-Ratio for Surface Composition.* We have simulated DAVINCI's ability to discriminate end-member mafic (volcanic) and felsic (possibly indicative of past water-rock interactions) rock types at Venus using a spectral retrieval model [4]. Our results indicate that the Venus Descent Imager (VenDI) nadir-oriented camera on the descent sphere should be able to discriminate felsic rocks at high (> 5 σ) confidence over the Alpha Regio tessera region using a band ratio technique. The Venus Imaging System for Observational Reconnaissance (VISOR) camera suite on the spacecraft will measure a diverse set of surface features during two Venus gravity assist flybys prior to probe descent. Results indicate VISOR will discriminate felsic surfaces with at least 3 σ confidence, providing a global context in which to understanding the local measurements from *Alpha Regio*.

Other activities including the H2O Program where DAVINCI has been paired with New Mexico State University to provide mission observation and engagement opportunities to historically marginalized groups [5]. We have successfully engaged student observers in activities including a career panel and meeting in person at the joint VEXAG and Venus as a System workshops in Nov. 2023. Spring 2024 will see a one-on-one mentorship component with students and DAVINCI team members.

**Conclusions:** DAVINCI remains on track for a 2029 launch to Venus thanks to the progress by the Project team (including science) and support of NASA HQ, PMPO (NASA MSFC), and the science community. The Project expects to engage with the wider community in 2024-2025 via conferences, workshops, and publications. See our science-facing web-site for more information: https://ssed.gsfc.nasa.gov/davinci/mission

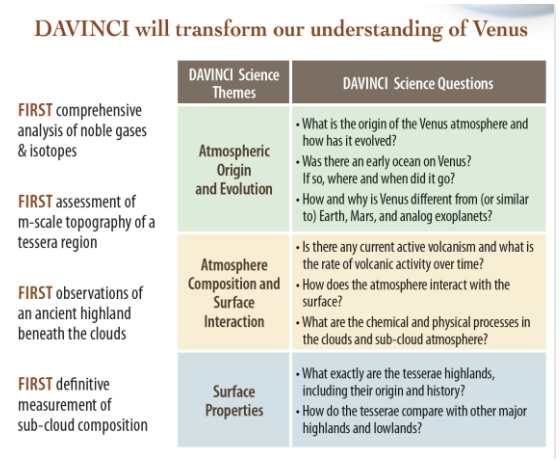


**Figure 1:** Key goals and objectives for DAVINCI from the Project fact sheet, all traceable to 2022 Planetary Decadal Survey priorities (5 key questions), and PLRA Level-1 (L-1) requirements.


**Figure 2:** Planned mission events for DAVINCI with 2029 launch. The In-situ Campaign occurs in late June 2031, with all acquired data back to Earth by July 2031, and end of primary mission by Dec. 2031.

**References:** [1] Garvin, J. *et al.* (2022) *Planet. Sci. J.* ***3*** *117.* [2] Widemann T. *et al.* (2023) *Space Science Reviews 219:56.* [3] Trainer M. *et al.* (2024) *LPSC 55* (this meeting, submitted Jan. 2024). [4] Lustig-Yaeger *et al.* (2022) *AJ*, 293, 140. [5] Smith D.J. *et al.* (2024), *LPSC 55* (this meeting, submitted Jan. 2024). *Special thanks to the NASA Discovery Program within the Science Mission Directorate for their continued support and to our primary partners at Lockheed Martin.*