

## VIPRE: A TOOL FOR VISUALIZATION OF THE IMPACT OF PROBE ENTRY CONDITIONS

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**Brief Presenter Biography:** Dr. Damon Landau is a systems engineer at JPL, where his primary interests are mission formulation and trajectory optimization. He routinely leads the systems engineering development for proposals to NASA's EVM, MIDEX, SIMPLEX, Discovery, and New Frontiers programs. Damon has developed award-winning techniques to rapidly tailor concepts of operations and mission designs that support unique scientific requirements.

**Introduction:** Atmospheric probes provide a critical method for understanding the Ice Giants, offering unique insight into atmospheric composition, structure, and dynamics [1]. Such in situ measurements are vital to understanding the formation and evolution of these bodies and our solar system. To pursue these scientific opportunities space agencies are now turning their attention to the development of atmospheric probes to the Ice Giants and other bodies. The newly released Decadal Survey prioritized Uranus and Saturn probes as well as a Venus in situ explorer [2]. Few such missions have flown and it is not likely that there will be other atmospheric entry probes until the DAVINCI+ Venus probe mission in the early 2030's. Entry probe concepts such as these require a delicate balance between science objectives, orbital mechanics, atmospheres, and signal processing. The development of future entry probe missions will rely on tools which allow mission teams to concurrently filter and compare trajectories to optimize science return.

**A New Approach to Mission Design:** To aid science planning for future entry probe missions we have developed a tool for Visualization of the Impact of Probe Entry (VIPRE) conditions on science, mission and spacecraft design [3]. VIPRE provides concurrent design capabilities for entry probe and lander missions by combining a precomputed database of optimized interplanetary trajectories with analytical models for entry point targeting, atmospheric descent and data-return rates. The user is able to explore the science tradespace using a GUI to constrain a variety of entry, trajectory,

and data sufficiency parameters. Constraint-based interaction allows for direct, easy evaluation of scientific value and mission feasibility in real time. VIPRE is flexible to a variety of mission architectures allowing direct comparison of mission value between combinations of orbiters, entry vehicles and landers.

Users primarily interact with VIPRE through a GUI. Figure 1 provides an illustration of some of the available mission design, science parameter and constraint interactions within the VIPRE GUI. On its left edge, the GUI allows for the selection of a target body, Saturn in this case, and a range of filtering parameters. Based on these inputs, the GUI displays the top row of plots which indicate the filtered interplanetary trajectory parameters. Once a trajectory of interest is selected the "Overview" parameters are populated and the bottom row plots are generated to illustrate reachable probe entry locations, colored based on parameters of interest. Reachability, in this case, is defined by the selected filtering parameters as well as target specific constraints, i.e. avoiding Saturn's rings. The GUI also allows for user customization of figures and filter parameters.

**Applications:** We present the motivation and models used for the development of VIPRE, with specific application to Uranus and Saturn probe missions. Of particular interest is the accessibility of high and low latitudes for probe entry, how this is influenced by mission architecture (flyby versus orbiting probe release), and data constraints due to probe communications geometry.

**References:** [1] Hofstadter, M. et al., Uranus and Neptune missions: A study in advance of the next planetary science decadal survey, *Planetary and Space Science* 177 (2019) 104680. [2] National Academies of Sciences, Engineering, and Medicine. "Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032." (2022). [3] Probst, A. et al, VIPRE: A Tool Aiding the Design for Entry Probe Missions, *The Planetary Science Journal* 3.4 (2022) 98.

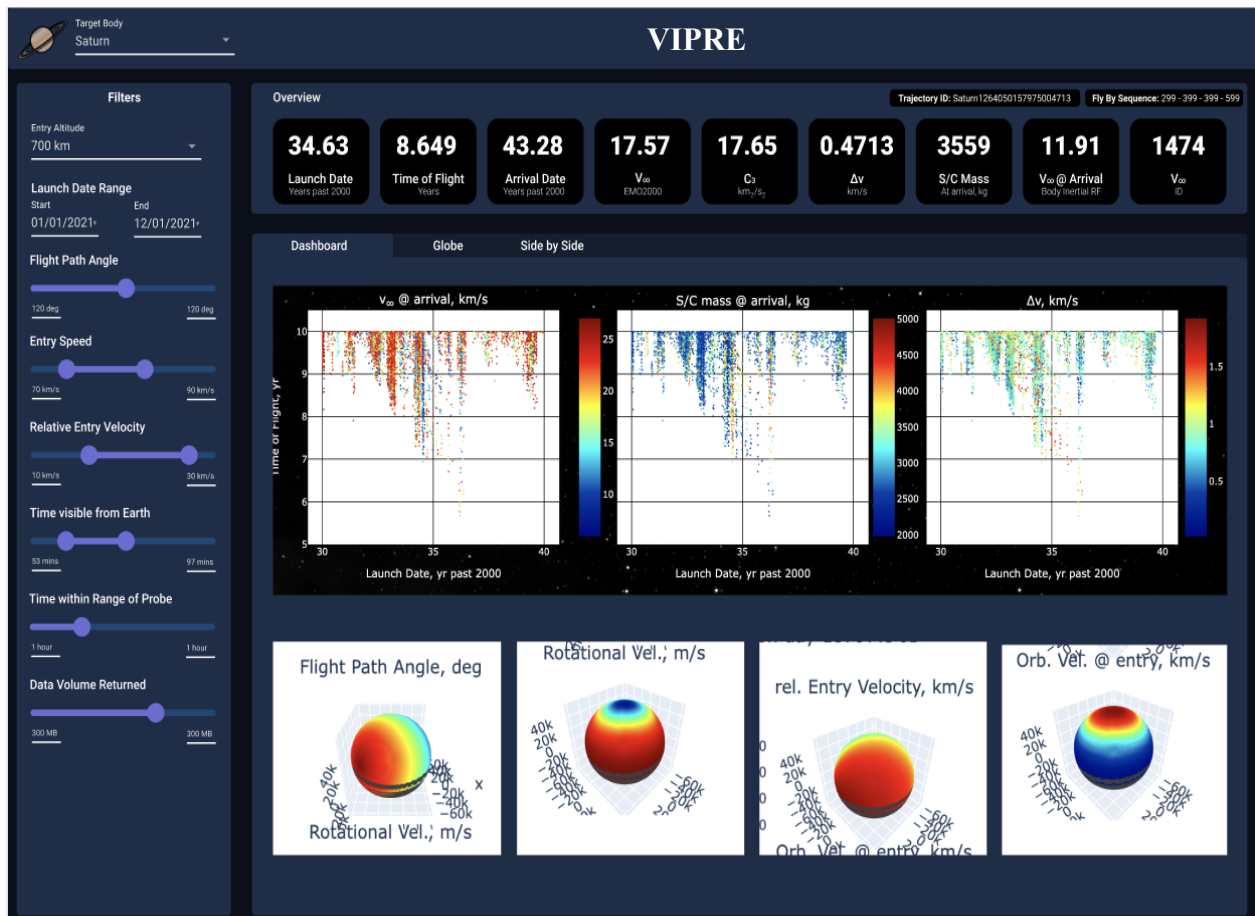


Figure 1. Example of VIPRE trajectory selection for a Saturn probe mission. Left panel provides sliders to constrain science and engineering parameters. Middle row displays trade space of interplanetary cruise options, where each dot represents a different trajectory. The bottom row displays the trade space of entry conditions for a single selected interplanetary arrival.