

DAVINCI

Modeling the Big Plunge: DAVINCI Entry, Descent, and Landing

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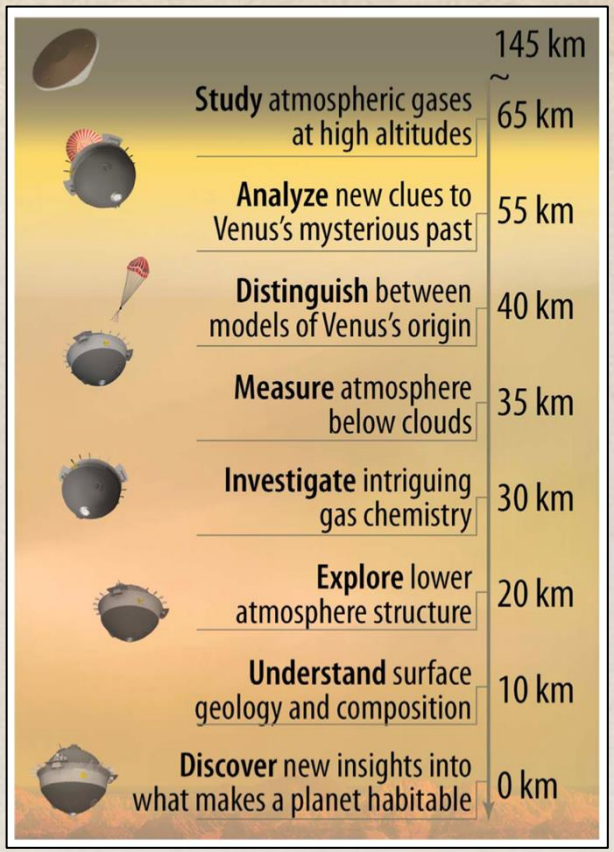
International Planetary Probe Workshop 2026
Washington, DC
June 22-26, 2026

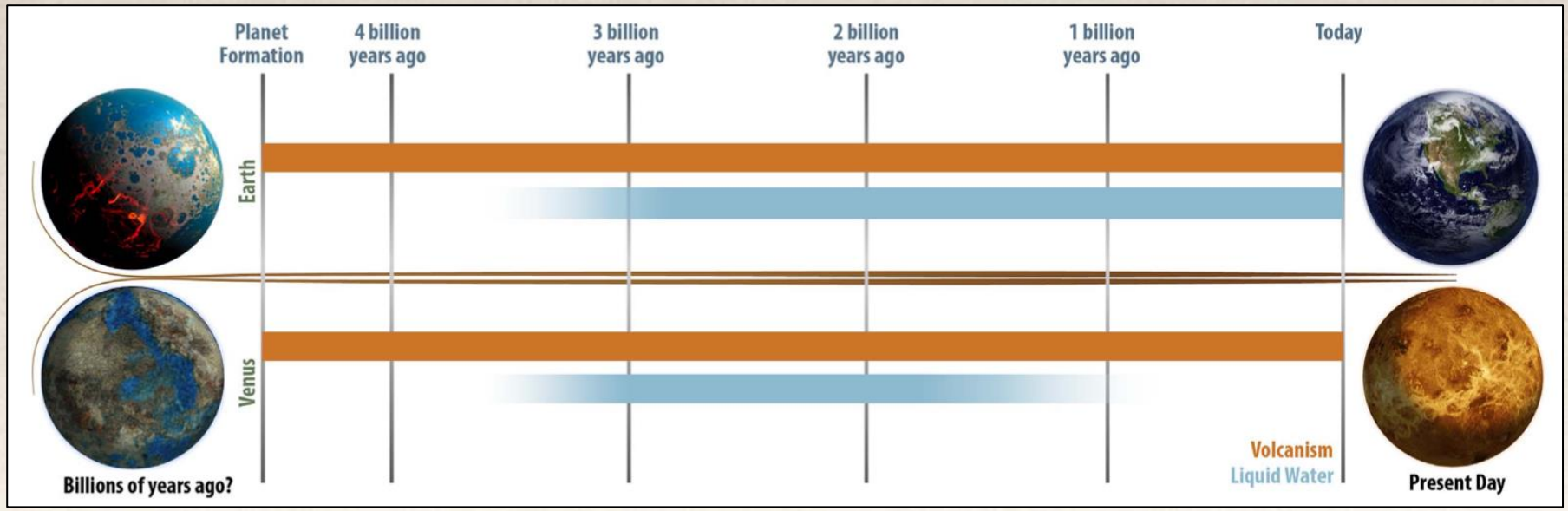
*Analytical Mechanics Associates

DAVINCI and Venus

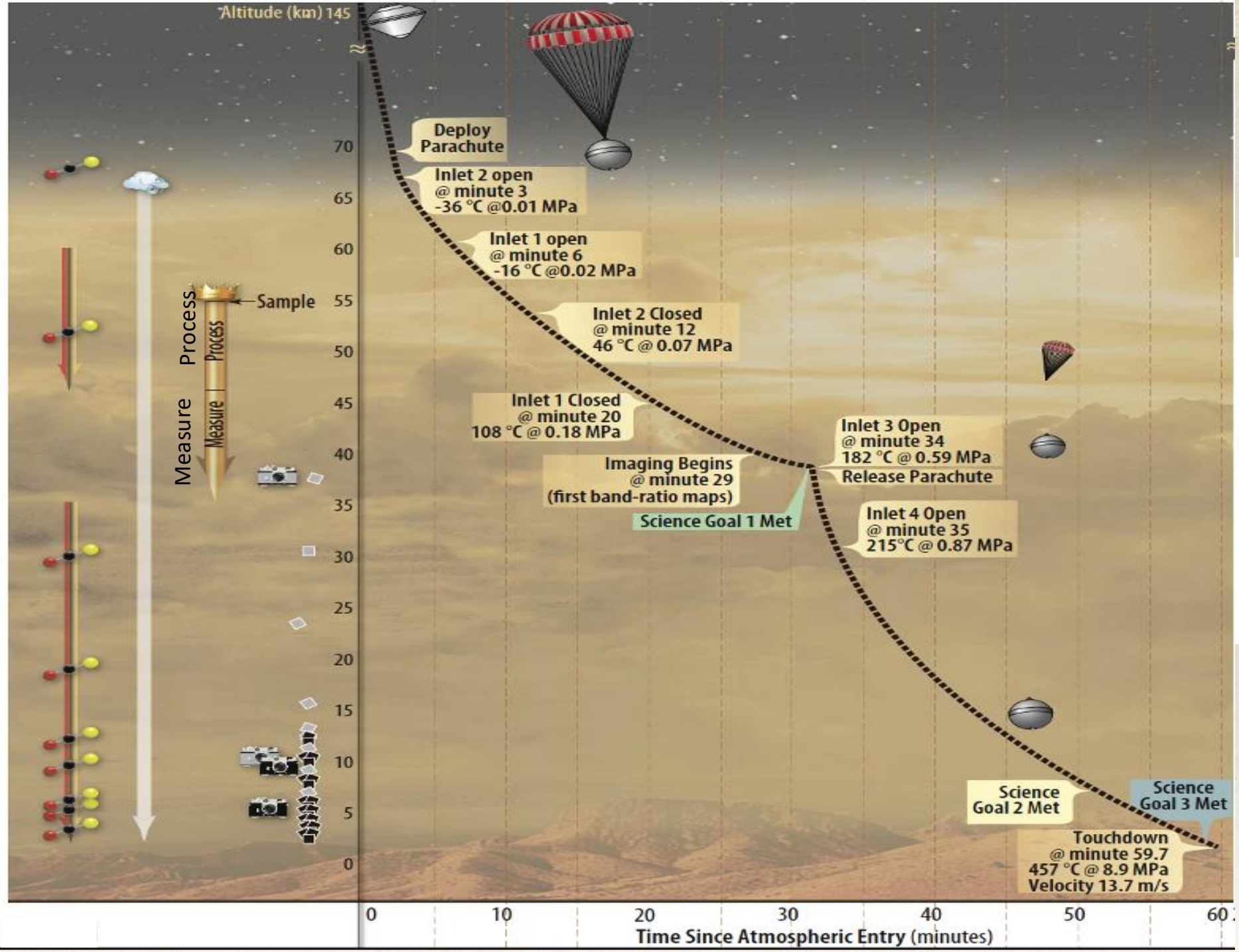
See Garvin et al. (Monday)

- Deep Atmosphere Venus Investigation of Noble gases, Chemistry and Imaging (DAVINCI)
- First in-situ probe since Soviet missions (last in 1980's) and Pioneer Venus (last in 1970's)
- New understanding of atmosphere, surface, and evolutionary path of Venus as a possibly once-habitable planet and analog to hot terrestrial exo-planets
- Yield 60 Gbits (compressed) data about atmosphere and near surface





Credit: Garvin 2022
(Planetary Science Journal)



Credit: Garvin 2022 (Planetary Science Journal)

Legend

- Temperature, Pressure & Winds
- Targeted Trace Gases
- Trace Gases Every 50 - 200 m
- Noble Gases & Isotopes
- 1 μm Narrowband Imaging
- Broadband Imaging

Triggering of key events during DAVINCI based on a priori determined timeline informed by modeling and simulation

Outline

- DAVINCI and EDL modeling motivation
- Modeling and simulation overview
- Model-by-model update
- Sample results
- Summary

Modeling and Simulation via POST2

Program to Optimize Simulated Trajectories II (POST2)

CRIS = Carrier-Relay-Imaging Spacecraft
PFS = Probe Flight System

Atmosphere

Flight Software

Aerodynamics

See Cheatwood et al. (Wednesday)

Orbital Determination/ Navigation (CRIS and PFS)

See Andreini et al. (Wednesday)



Credit: NASA

Sensors

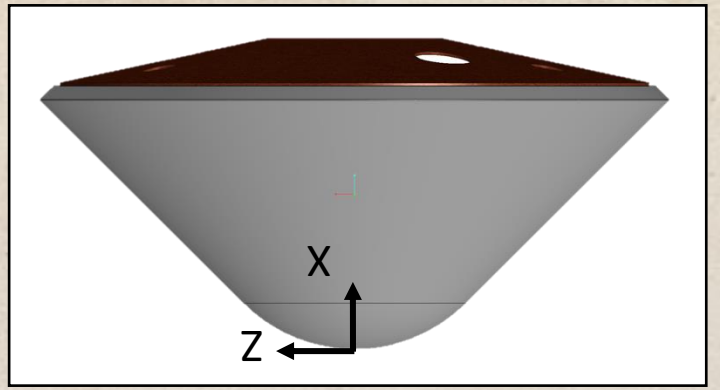
Terrain Model

Science Instrumentation Model

Telecommunications

Multi-Body Dynamics

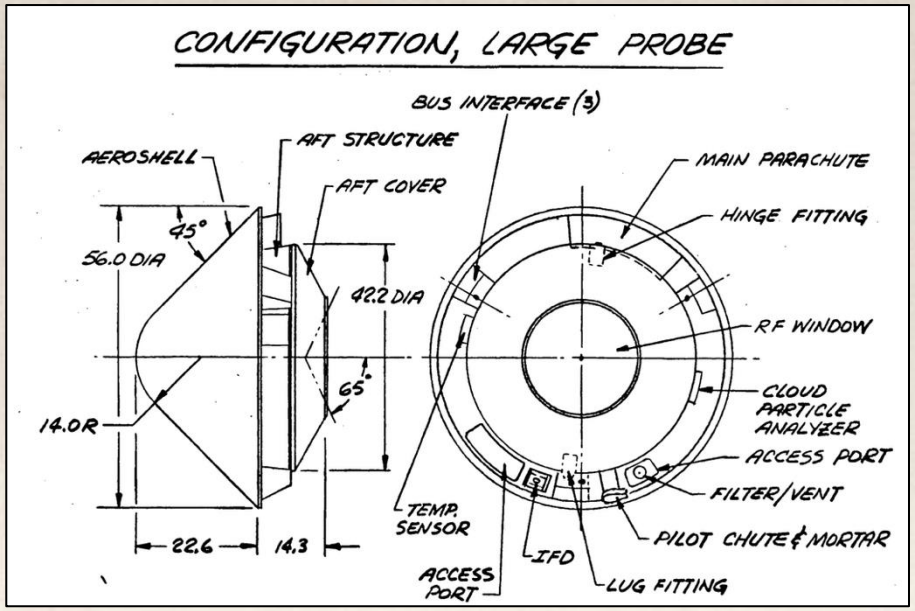
Aerodynamics: Entry Body



Credit: NASA, Units in inches

Geometric Parameter	DAVINCI
Sphere-Cone Angle	45 deg
Aeroshell Diameter (D)	2.54 m*
X_{cg}/D	0.24*
$Radius_{nose}/D$	0.25*

* Approximate (some internal iterations occurring)

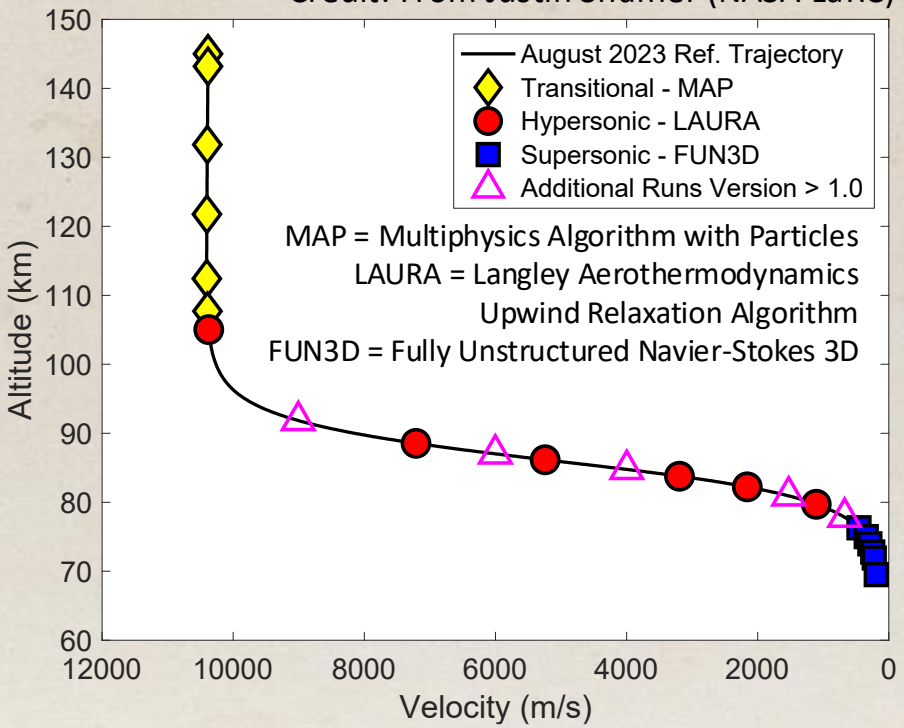


Pioneer Venus (PV) Large Probe



Credit: Smithsonian

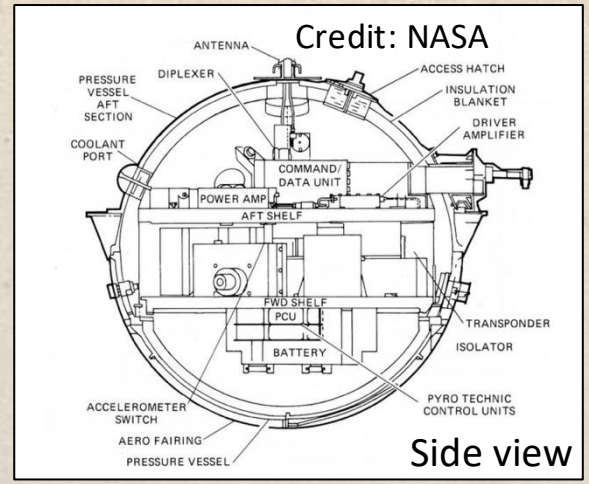
Credit: From Justin Shafner (NASA LaRC)



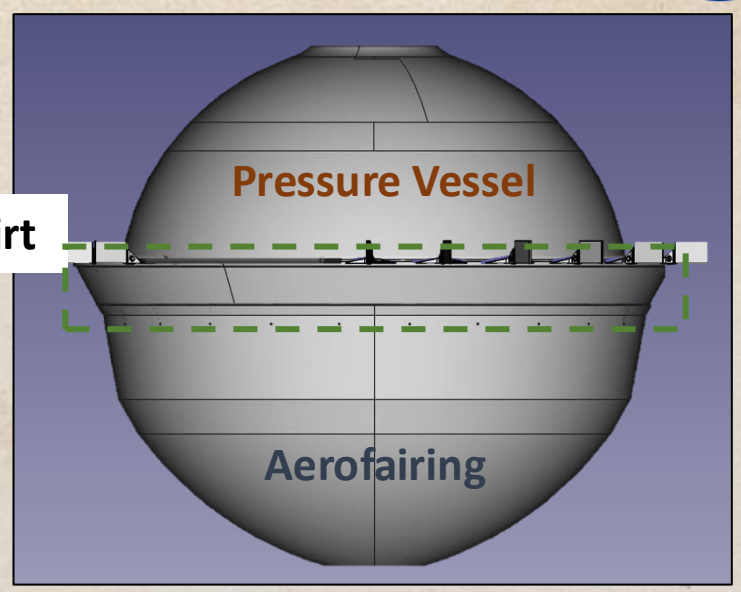
Aerodynamics: Descent Sphere/Zephyr

Aerodynamic Surfaces

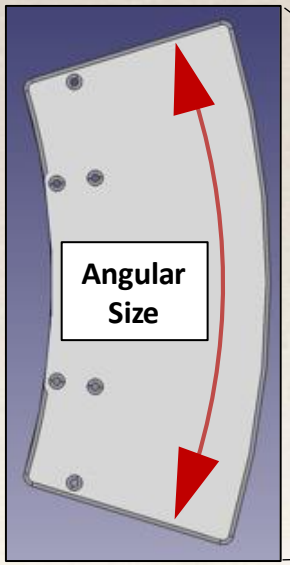
- Drag plates: Passive descent time control
- Spin vanes: Passive roll rate control
- Drag skirt: Forces flow separation

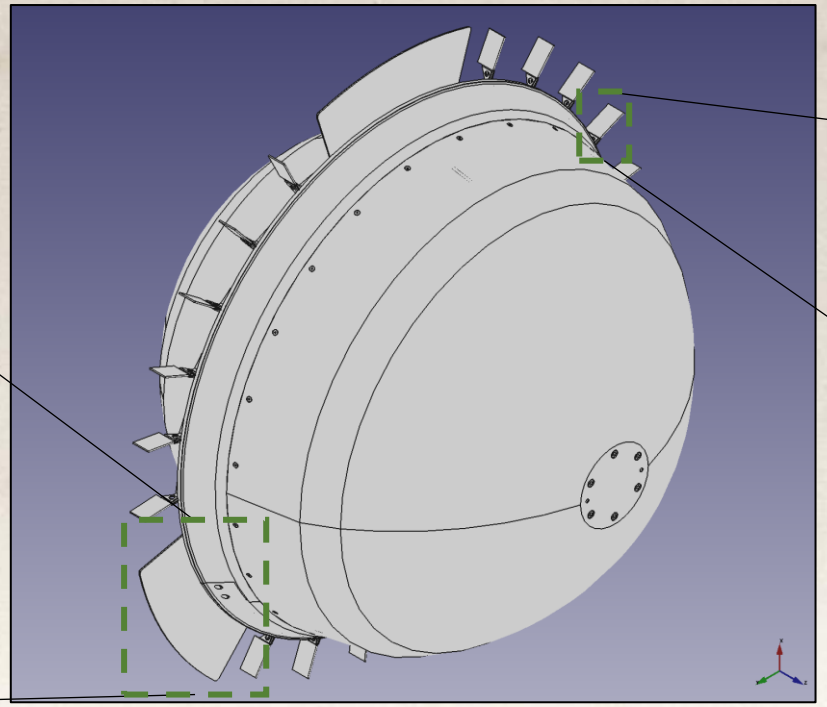


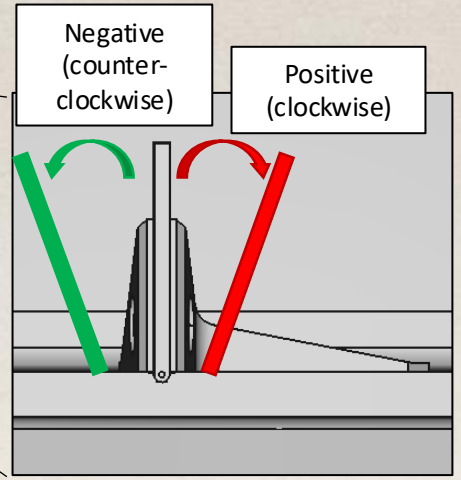
Pioneer Venus Large Probe



Enlarged Drag Plate





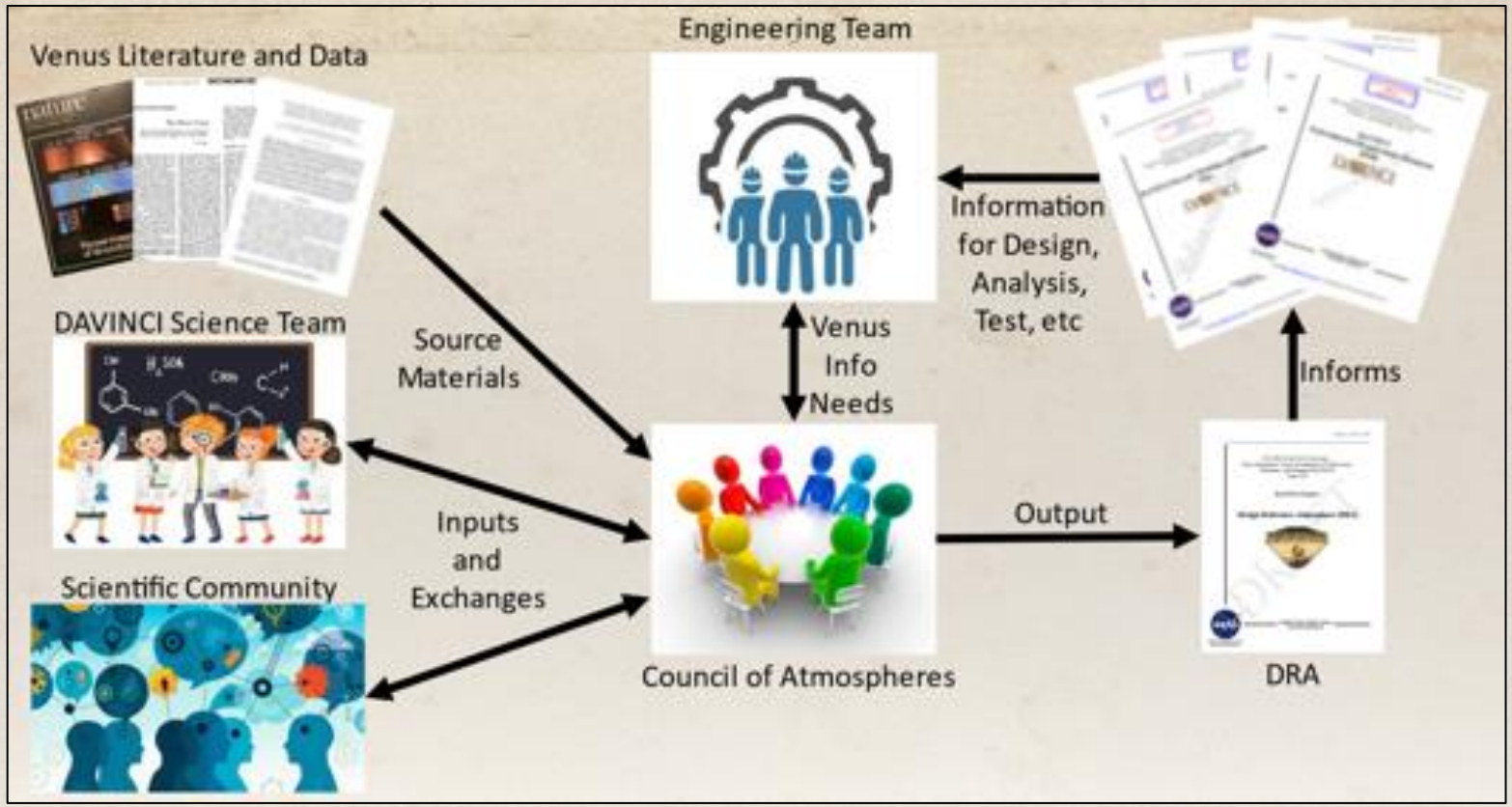


Enlarged Spin Vane

Credit: From Giovanny Guecha (NASA LaRC)

Atmosphere

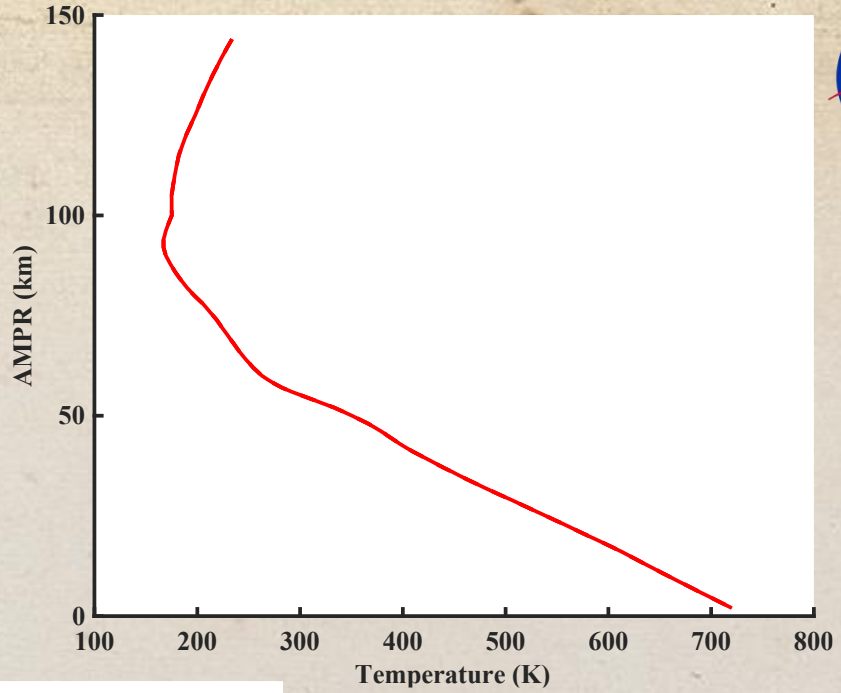
- DAVINCI Council of Atmosphere (CoA): scientists and engineers working Venus projects
- Use current best estimates for Venus atmosphere
- Engineering models listed in a Design Reference Atmosphere
  - Base pressure, temperature, and density from Venus International Reference Atmosphere (VIRA) within Venus Global Reference Atmosphere (Venus GRAM)
  - Winds from re-analysis of past probe, balloon, cloud tracking
  - Sulfuric acid concentration from past observations
  - Scintillation of S-Band signals from past mission data, atmospheric composition

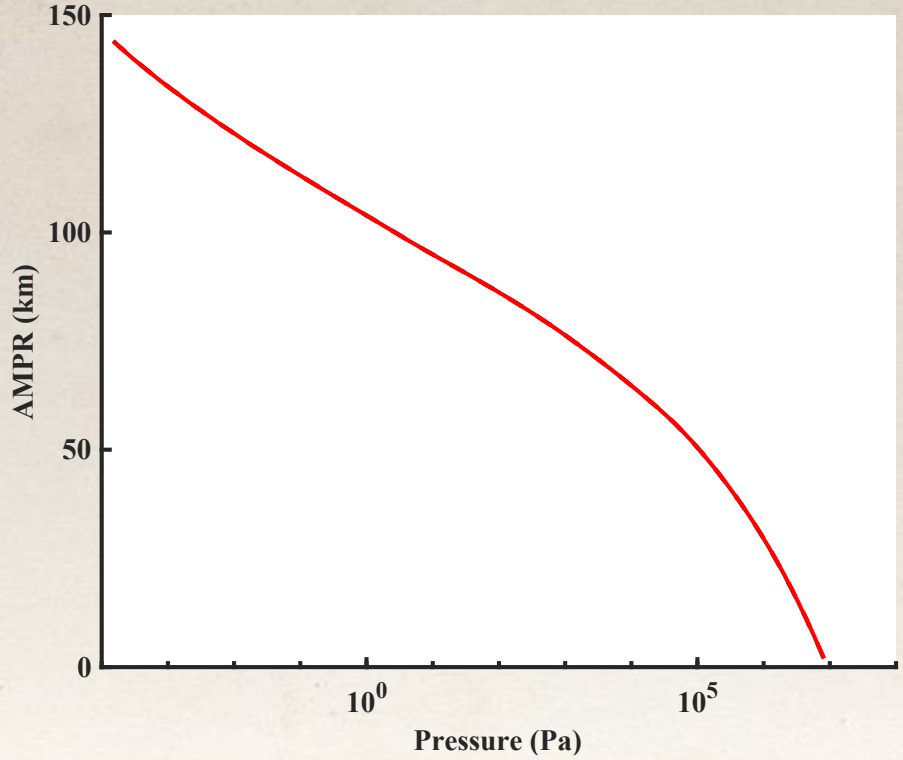


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AMPR = Altitude above mean planetary radius

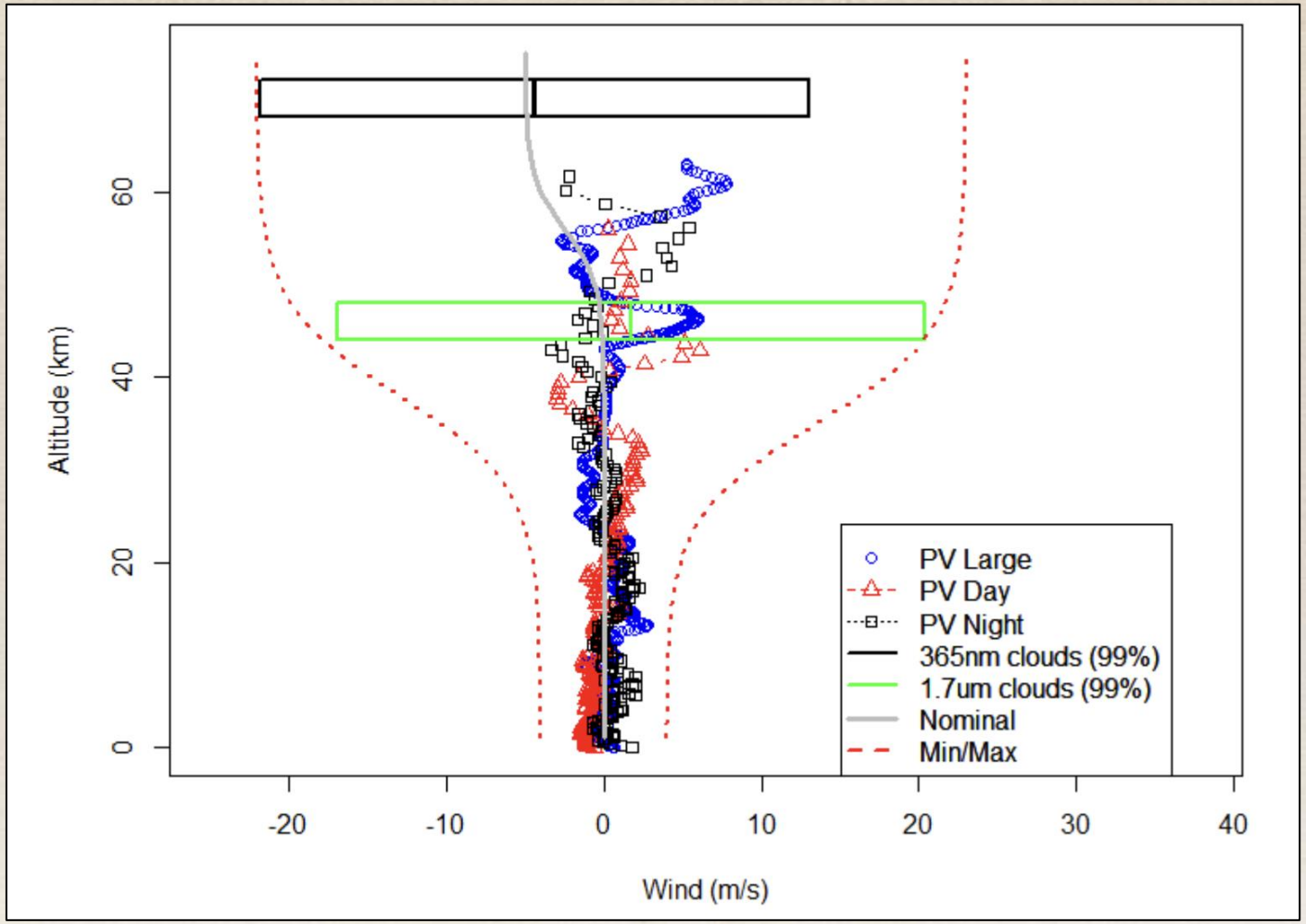




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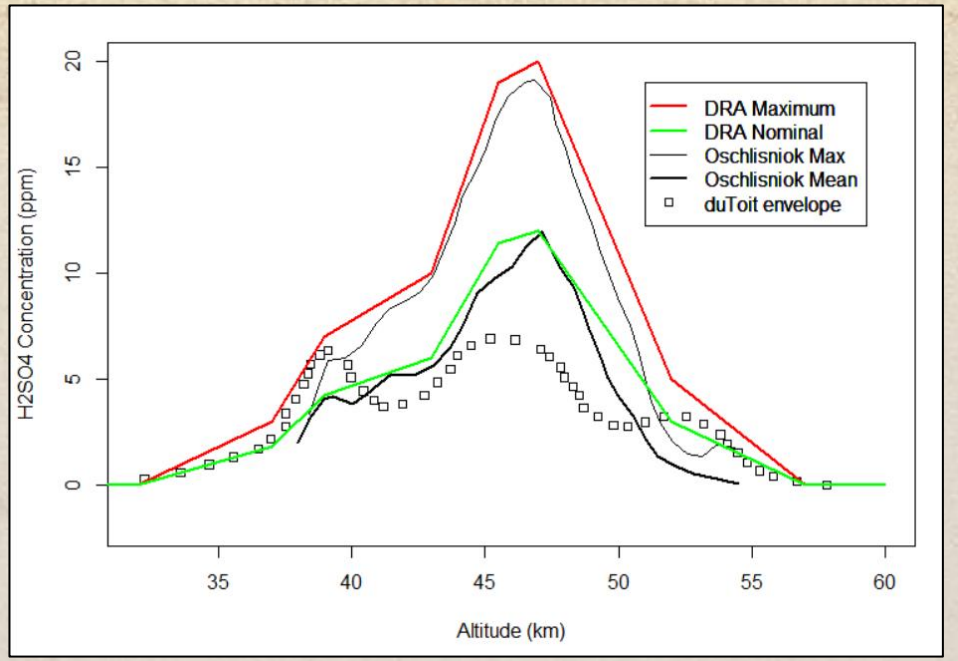
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Meridional Winds

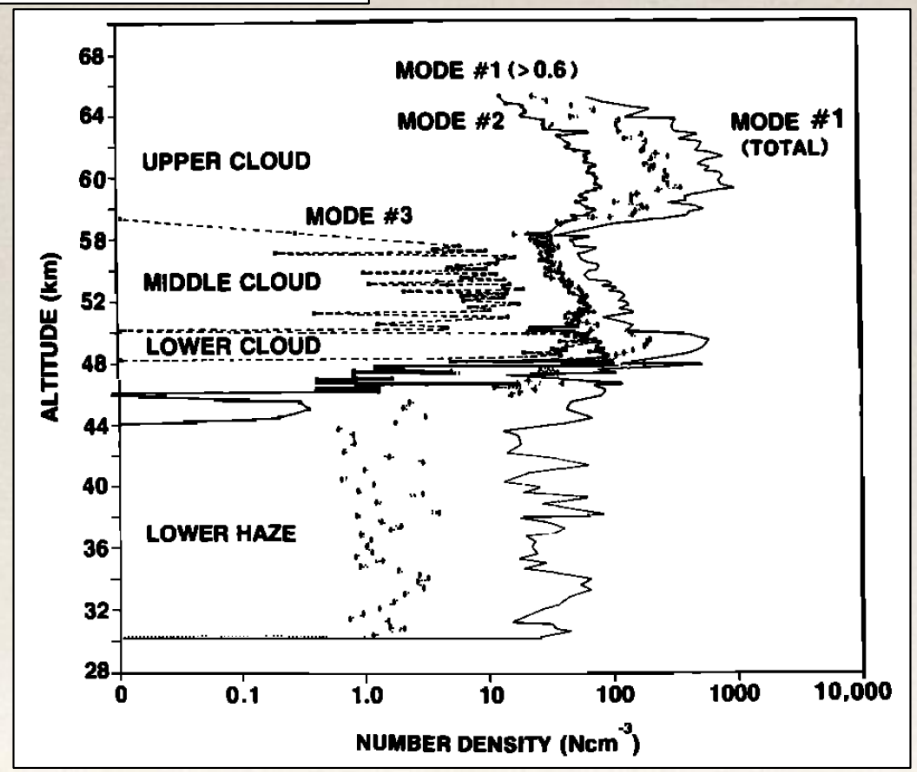


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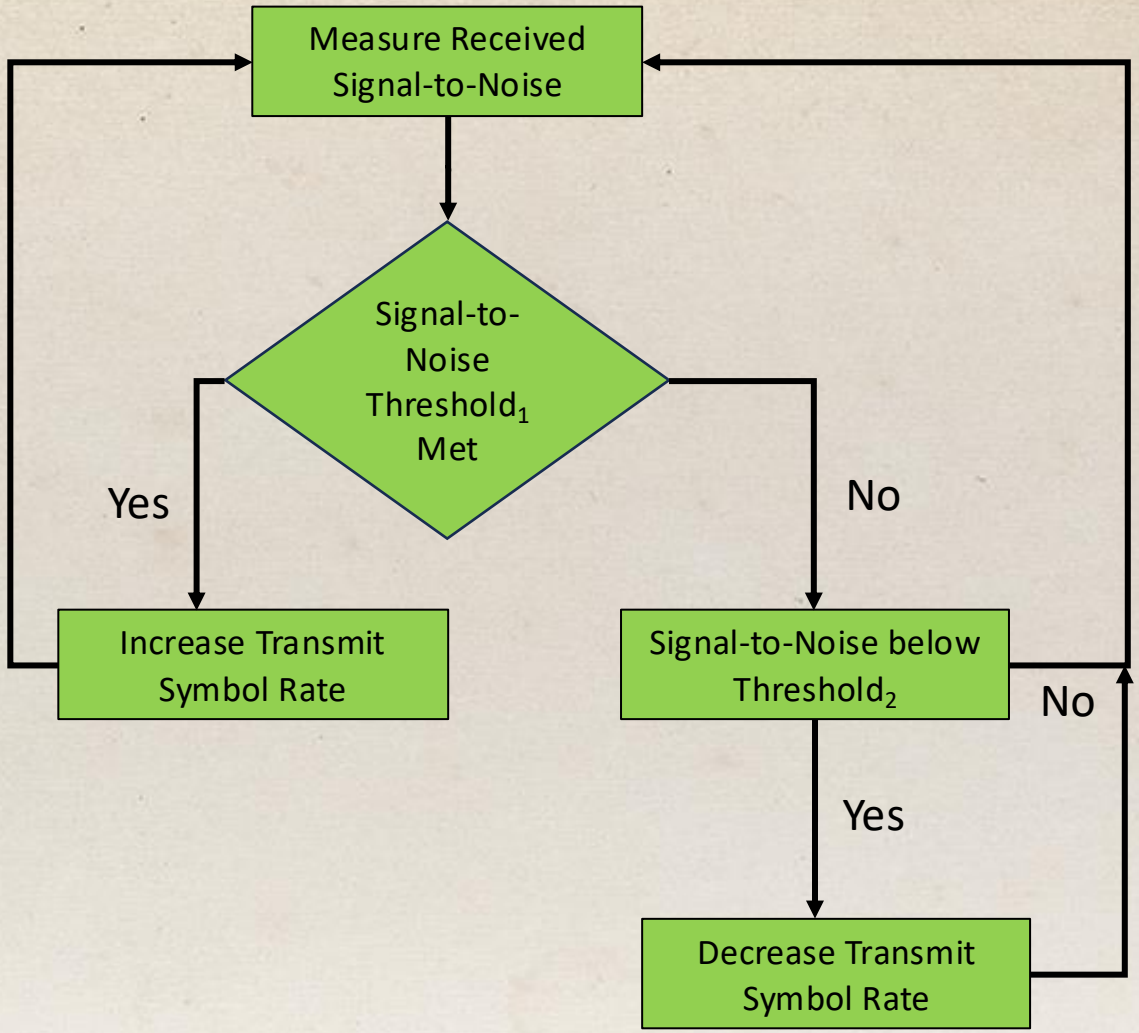
Sulfuric Acid Concentration by Altitude



Number Density of the Cloud Particle by Altitude

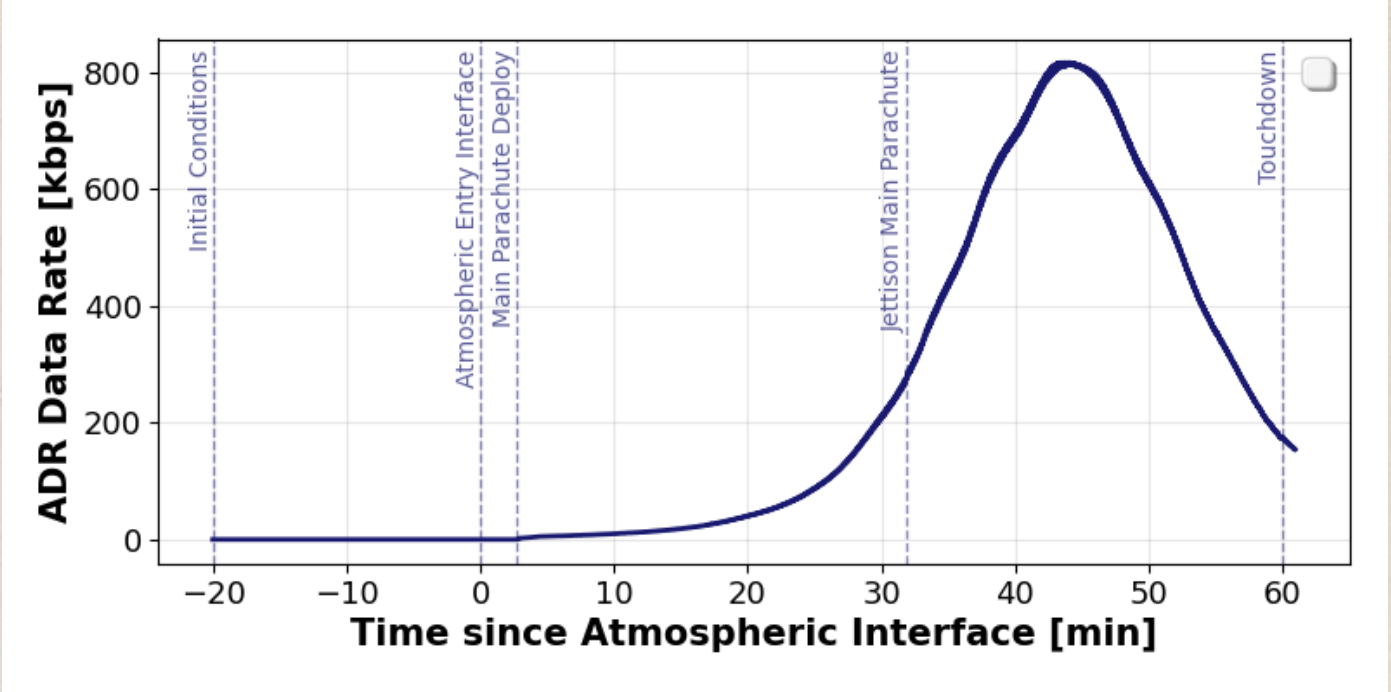
Telecommunications and Relay

- Probe does not need to survive impact
- Essential to relay in-situ measurements and images during 1-hour descent
- More important science data taken closer to the surface (imaging of the last 3-5 km altitude when not distorted by clouds)
- Adaptive data rate (ADR) system that updates uplink rate based on link quality – modeling in simulation important to optimize science return



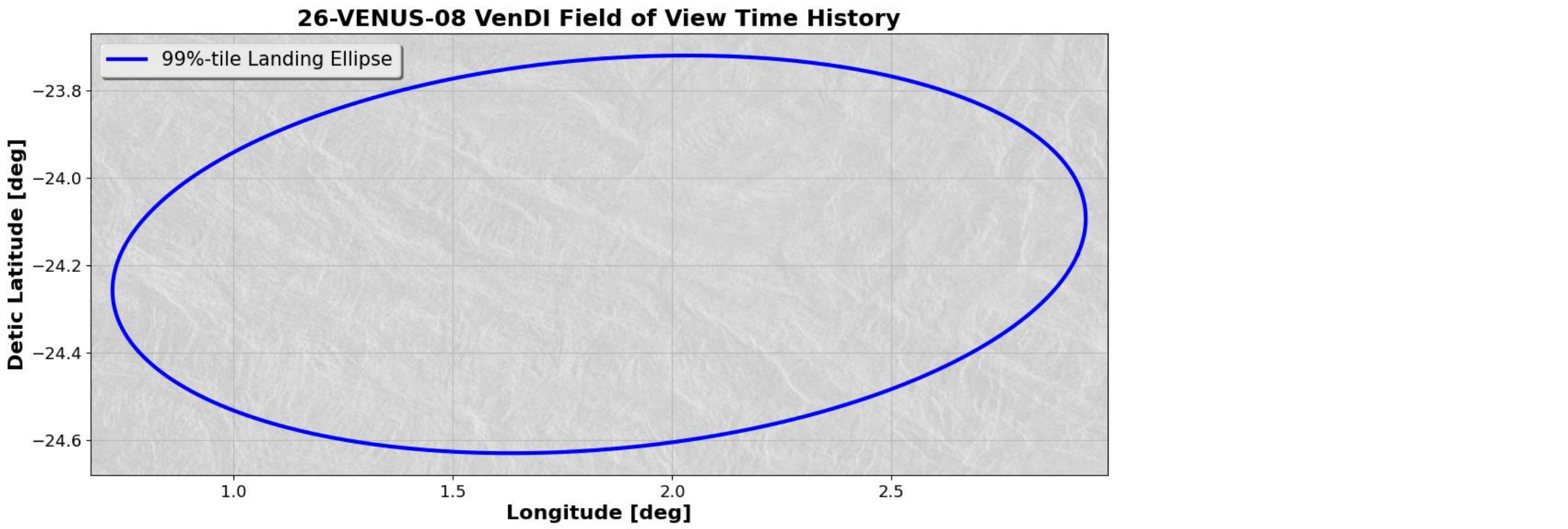
Telecommunications and Relay

- Probe does not need to survive impact/touchdown
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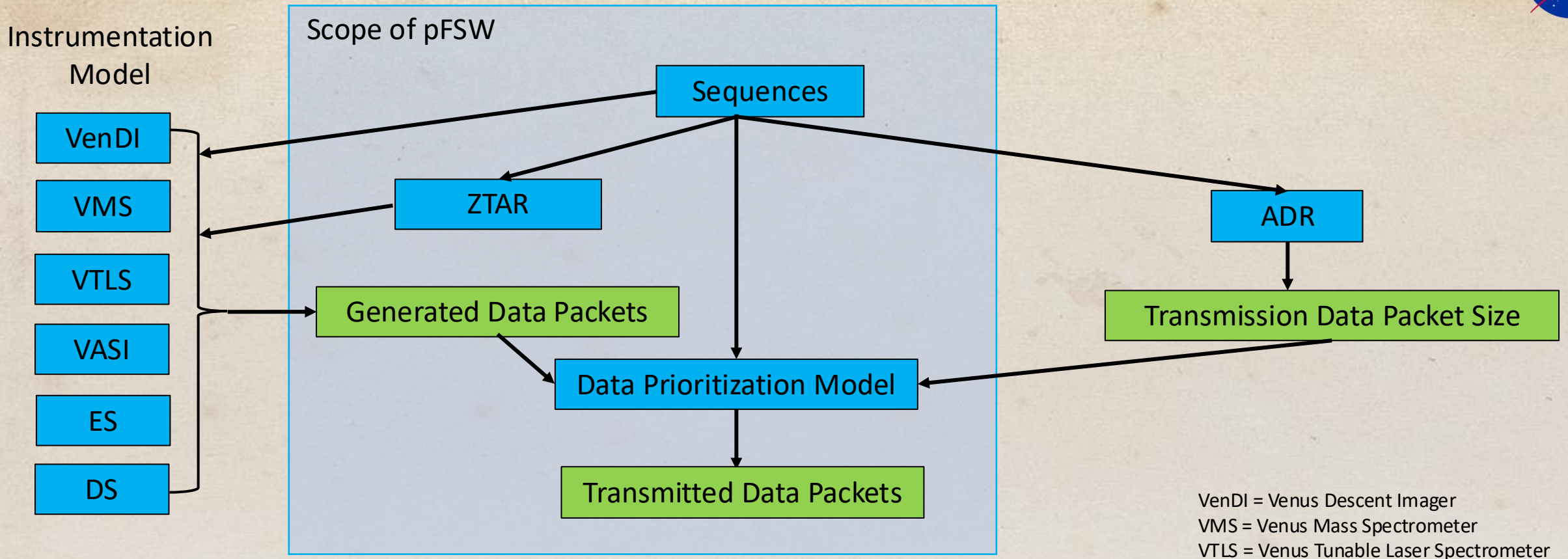


Science Instrumentation Data

- DAVINCI has several instruments collecting data during EDL; the type and size of the data changes with different phase/time of flight
- Part of EDL modeling and simulation is processing the sequence of EDL events, tracking generated data, and understanding if science requirements are met



Software-in-the-loop Simulation: eFSW vs. pFSW



VenDI = Venus Descent Imager
VMS = Venus Mass Spectrometer
VTLS = Venus Tunable Laser Spectrometer
VASI = Venus Atmospheric Structure Investigation
ES = Entry Systems
DS = Descent Sphere

- Currently, emulated flight software (eFSW) is a function of:
  - Sequences
  - Zephyr Technical Allocation Requirement (ZTAR)
  - Data Prioritization
- Other models interacting with the FSW include the adaptive data rate (ADR) model
- Cross-check data generated, queued, and transmitted with the prototype flight software (pFSW)
- Final plan is to implement pFSW

Sample Results

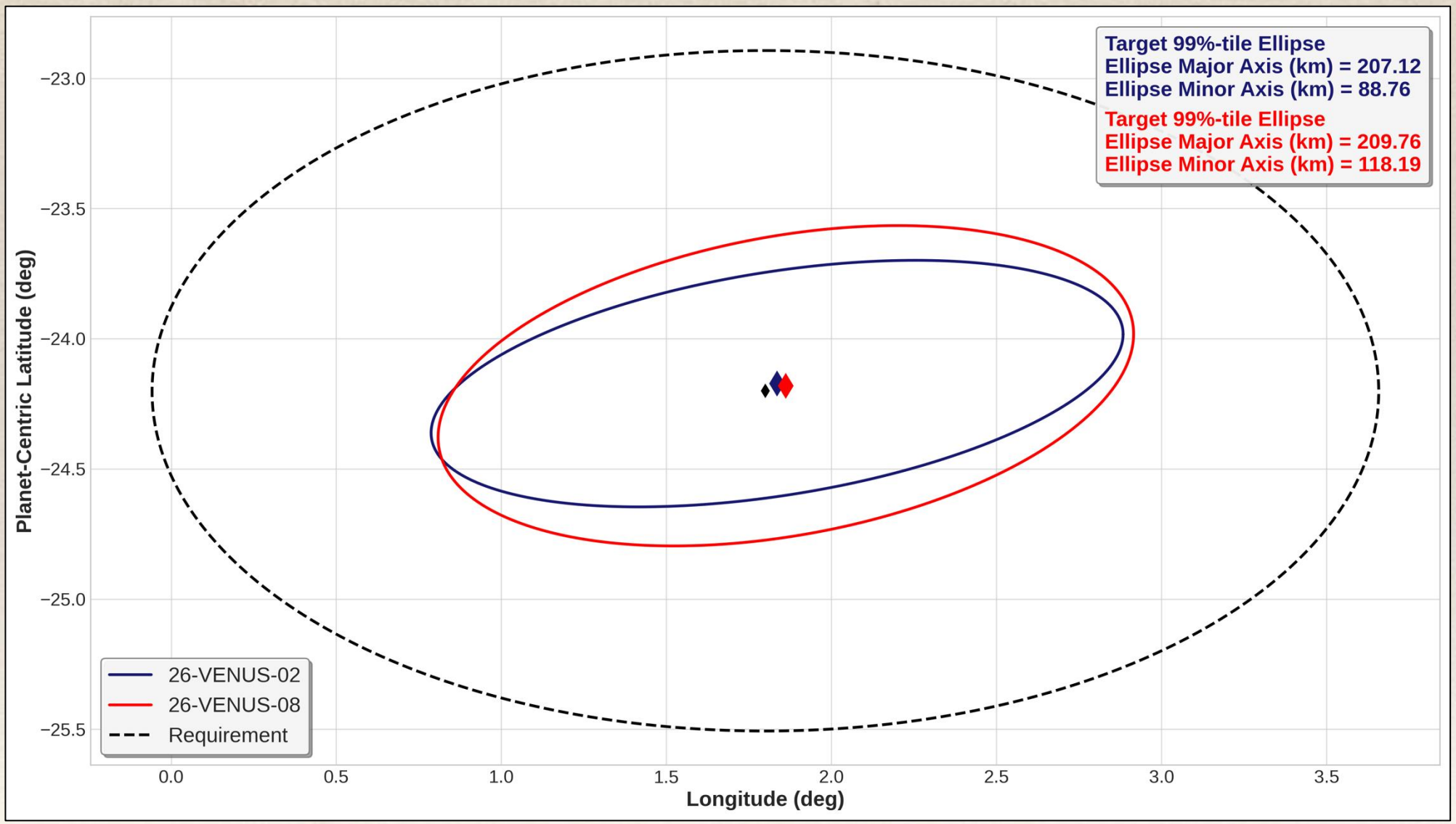
- Track critical requirements and provide statistical information about off-nominal behavior

ID	Requirement Metric	Limit	Red Limit	Units	Type	26-VENUS-08
MRD-062	VMS Noble Gas Measurements <110km uplinked	>=	1		1%-tile	1
MRD-047 and MRD-044	VMS High Altitude Scan >55km AMPR uplinked	>=	1		1%-tile	27
MRD-020 and MRD-061	Start of VMS low-altitude scans AMPR	>	30	km	1%-tile	29.60
MRD-048	VTLS high altitude scans >55km AMPR uplinked	>=	1		1%-tile	1
MRD-049	VTLS low altitude scans <35km AMPR uplinked	>=	5		1%-tile	5
MRD-049	VTLS low altitude scans <15km AMPR uplinked	>=	3		1%-tile	3
MRD-034	VenDI BB images >20km AGL uplinked	>=	2		1%-tile	42
MRD-033	VenDI BB images 20-10km AGL uplinked	>=	6		1%-tile	57
MRD-028	VenDI BB images 10-5km AGL uplinked	>=	7		1%-tile	36
MRD-029	VenDI BB images 5-1.5km AGL uplinked	>=	6		1%-tile	39
MRD-031	VenDI BB images <1.5km AGL uplinked	>=	3		1%-tile	12
MRD-083	VenDI NB+BB pairs 23-18km AGL uplinked	>=	2		1%-tile	23
MRD-084	VenDI NB+BB pairs 11-6km AGL uplinked	>=	2		1%-tile	35
MRD-085	VenDI NB+BB pairs 6-3km AGL uplinked	>=	2		1%-tile	3
MRD-146	Total transmitted data during descent	>	154	Mbits	1%-tile	639.94
TAR 2.3.3.1.1	Total transmitted data during descent	<	2200	Mbits	99%-tile	700.35
MRD-355	Uplink rate at touchdown	>=	36	kbps	1%-tile	123.296

92.6% of cases meet req.

Sample Results

- Track critical requirements and provide statistical information about off-nominal behavior
- Typical EDL metrics, like landing location within requirement (e.g. 99%-tile confidence ellipse)



Forward Work

- Schedule
  - Descent Sphere Preliminary Design Review (PDR) is in early 2027
  - Entry Systems PDR is in early 2028
  - Project is also considering a 1-year accelerated timeline for launch from the current baseline of Dec. 2031
- Modeling updates
  - Expect updates to descent aerodynamics with updated wind tunnel tests (summer 2026 and beyond) and updated computational fluid dynamics (CFD)
  - Parachute design is being finalized, procurement with vendors
    - Modeling will leverage past higher-fidelity models from Mars Science Laboratory, Mars 2020, and Dragonfly (Titan) – “Multi-body” model
    - Properties for aerodynamics, lines properties will need to be updated for Venus
  - Incorporation of the prototype flight software (in-the-loop for all analysis or limited in scope for testing emulated flight software)

Summary

- DAVINCI is approaching PDR for its various subsystems
- Modeling and simulation of the EDL phase critical for minimum science return from the mission
- Updated models for aerodynamics, atmosphere, science instrumentation, data link, and emulated flight software has improved understanding of the current EDL design
- Modeling and simulation development continues based on forthcoming updates of critical aerodynamic and parachute models

Acknowledgement

- DAVINCI is a Discovery-class project chosen by the NASA Science Mission Directorate
- Modeling and simulation of the entry, descent, and landing phase of flight is possible due to contributions of team members from NASA Langley, NASA Goddard, Lockheed Martin, NASA Ames, KinetX/Intuitive Machines, APL, and Dscosys

Questions



Credit: NASA

Backup