



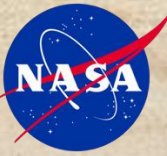
# DAVINCI

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

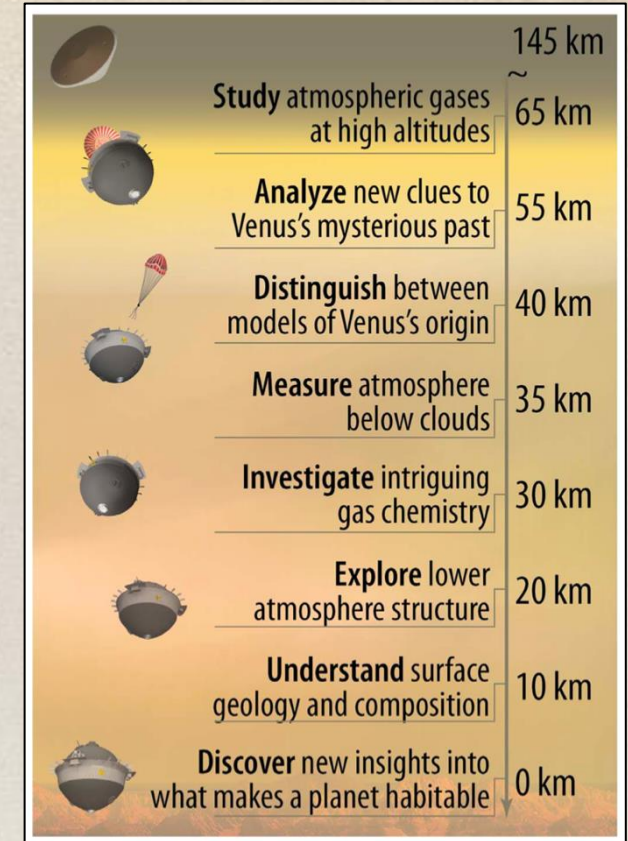
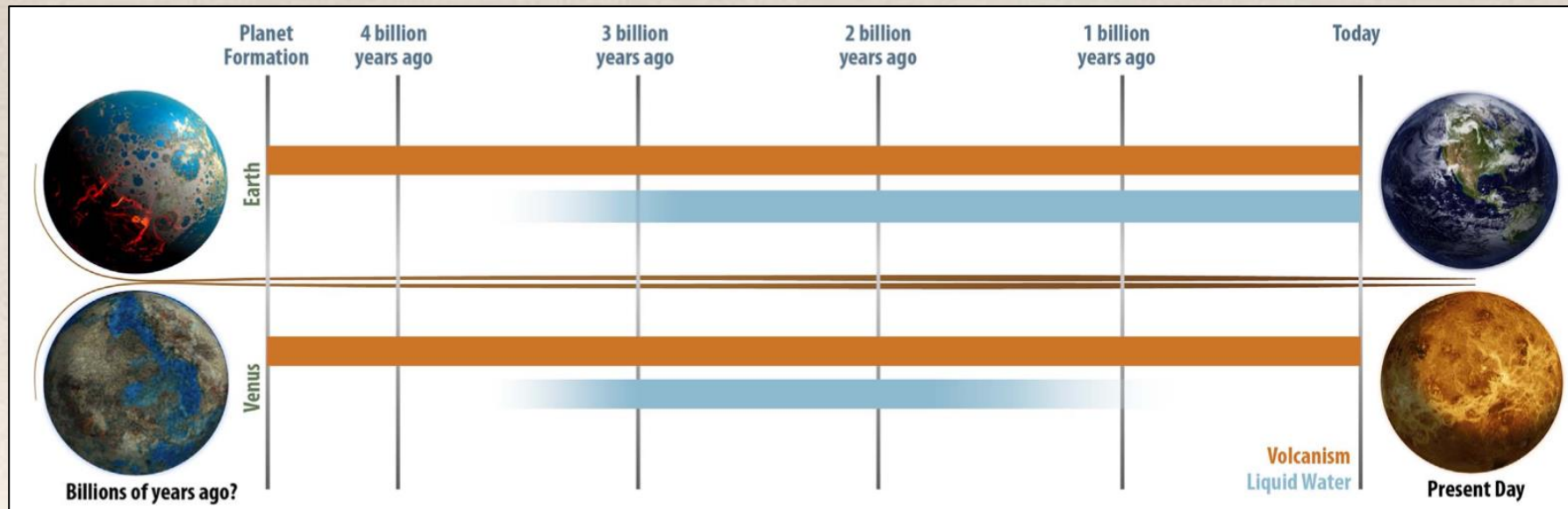
Soumyo Dutta  
NASA Langley Research Center

NASA Langley/Ames Summer Internship Presentation  
June 29, 2026

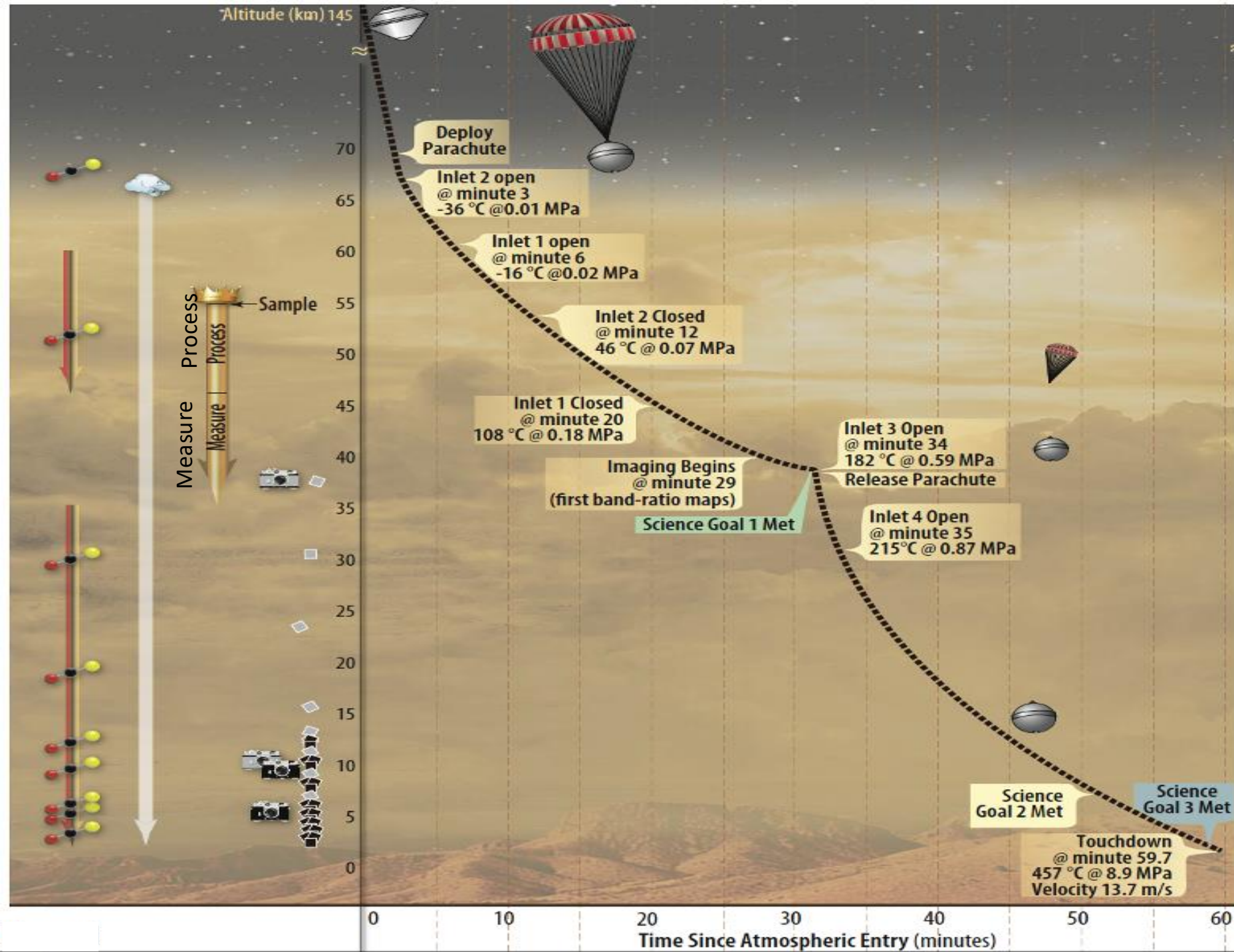
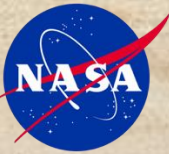
# DAVINCI and Venus



- 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)

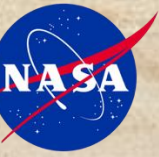


## Legend

	Temperature, Pressure & Winds
	Targeted Trace Gases
	Trace Gases Every 50 - 200 m
	Noble Gases & Isotopes
	1 $\mu\text{m}$ Narrowband Imaging
	Broadband Imaging

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





# Outline

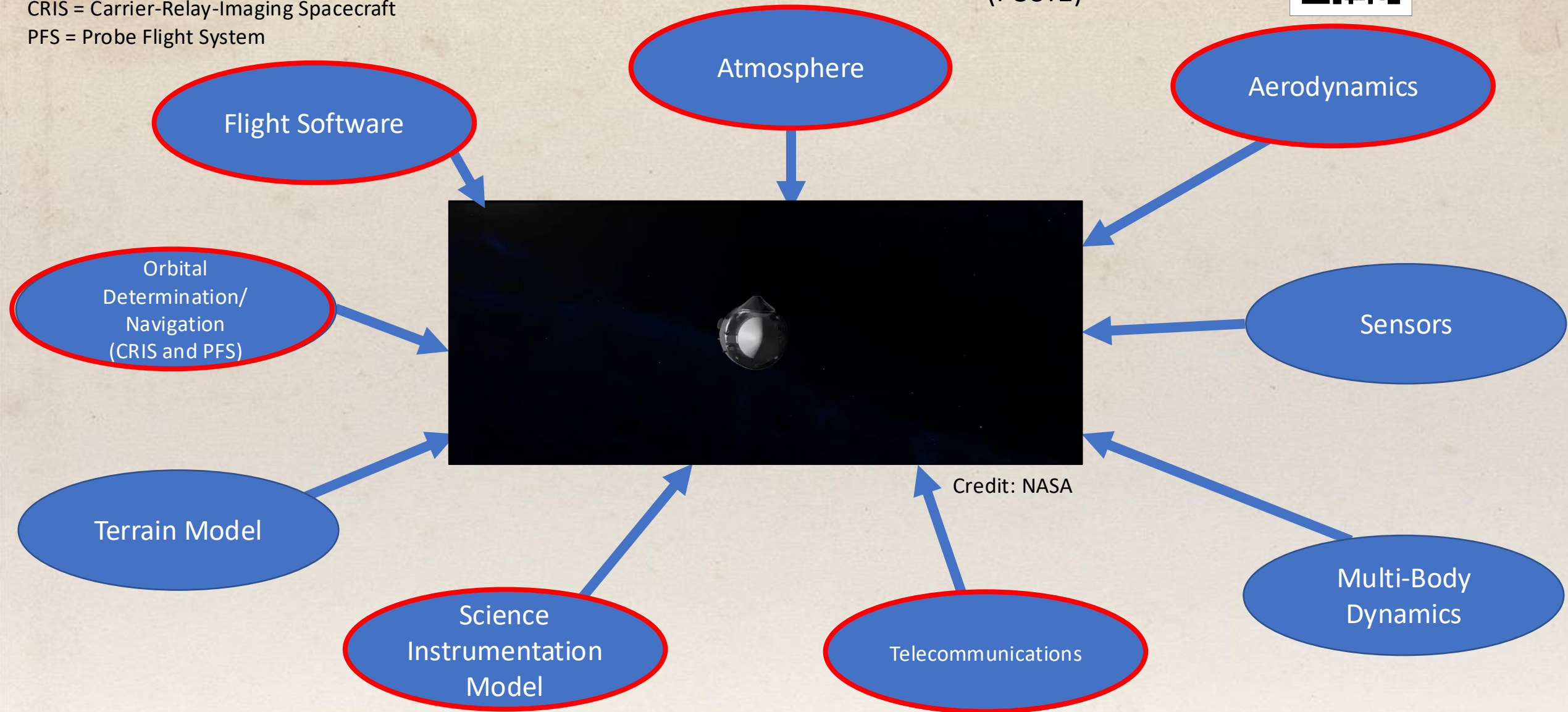
- DAVINCI and EDL modeling motivation
- Modeling and simulation overview
- Model-by-model update
- Sample results
- Summary

# Modeling and Simulation via POST2

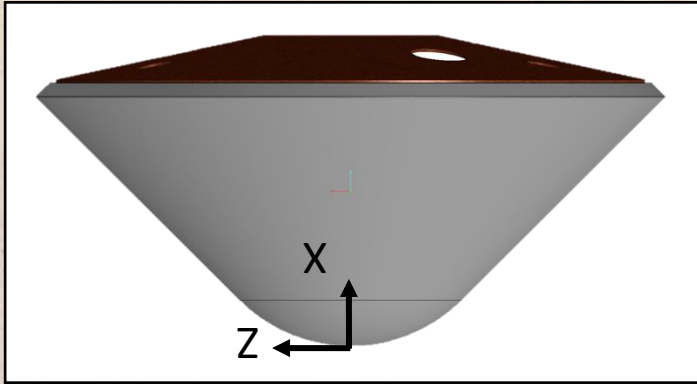
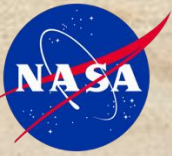
Program to Optimize  
Simulated Trajectories II  
(POST2)



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



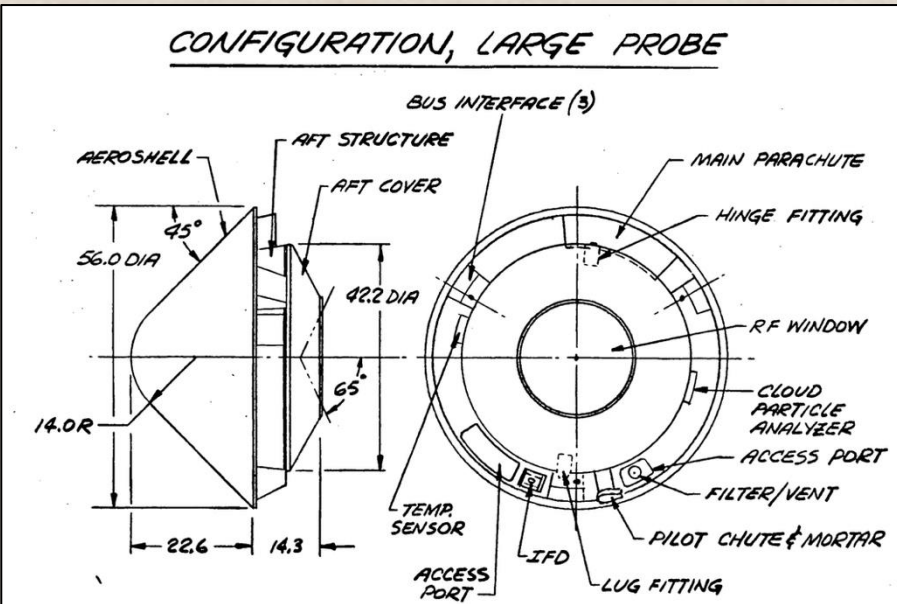
# Aerodynamics: Entry Body



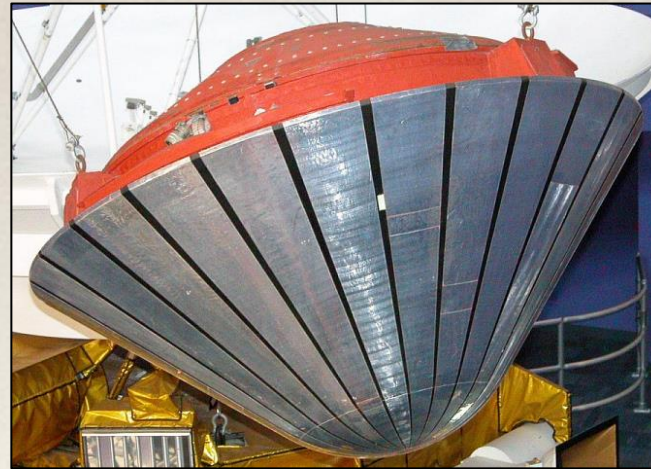
Geometric Parameter	DAVINCI
Sphere-Cone Angle	45 deg
Aeroshell Diameter (D)	2.54 m*
$X_{cg}/D$	0.24*
Radius <sub>nose</sub> /D	0.25*

\* Approximate (some internal iterations occurring)

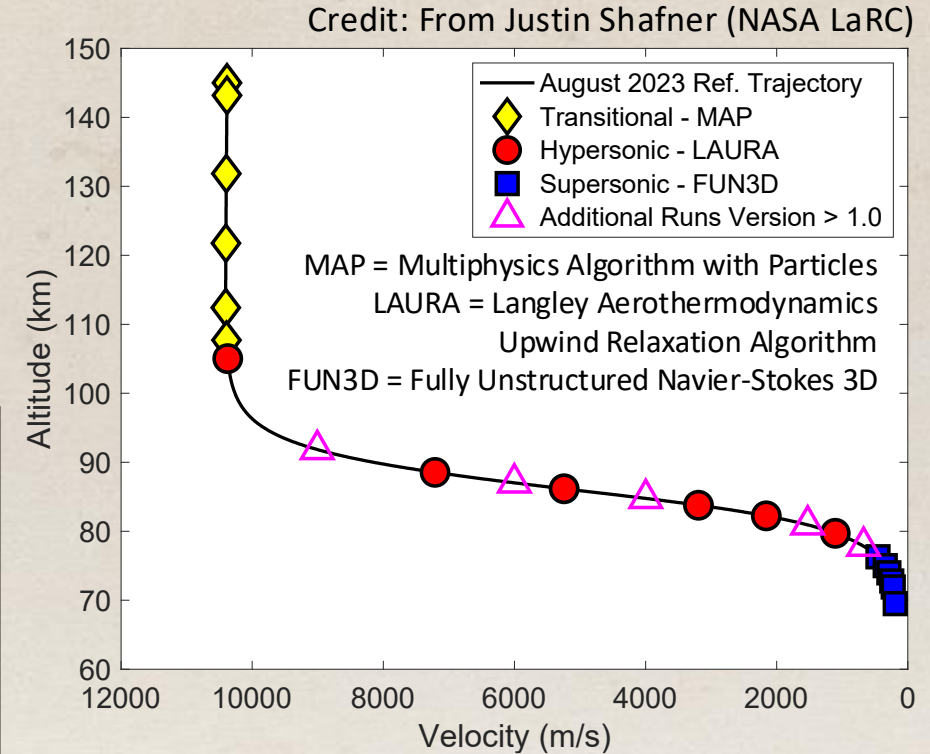
Credit: NASA, Units in inches



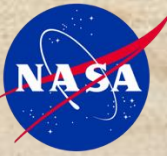
Pioneer Venus (PV) Large Probe



Credit: Smithsonian

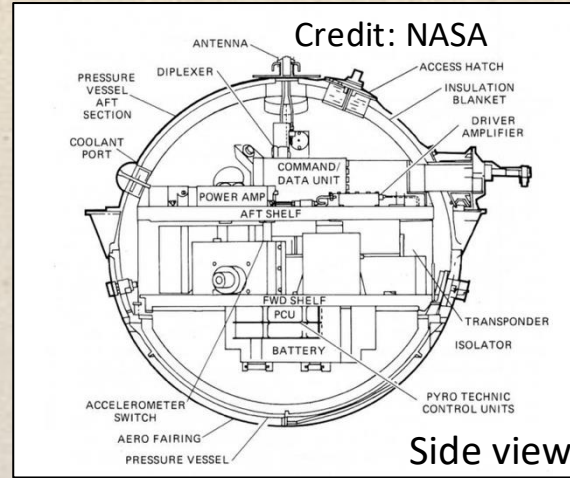


# Aerodynamics: Descent Sphere/Zephyr

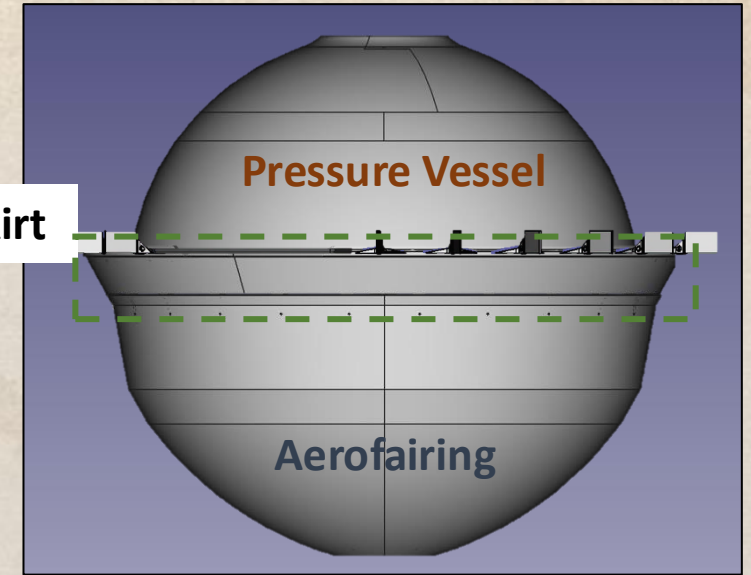


## Aerodynamic Surfaces

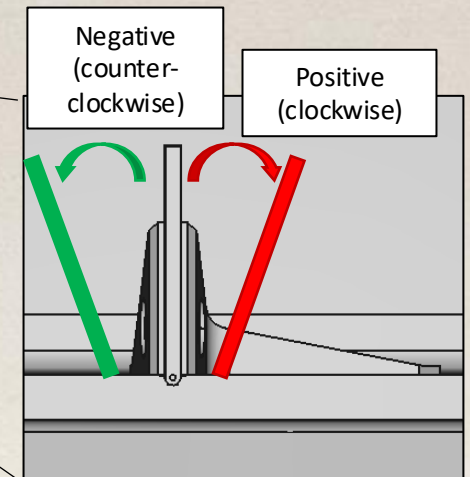
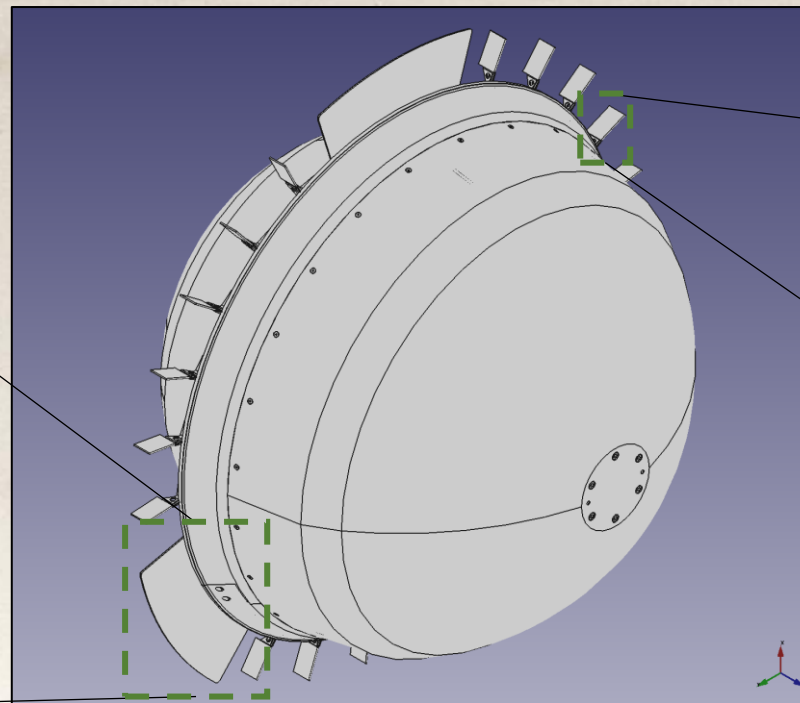
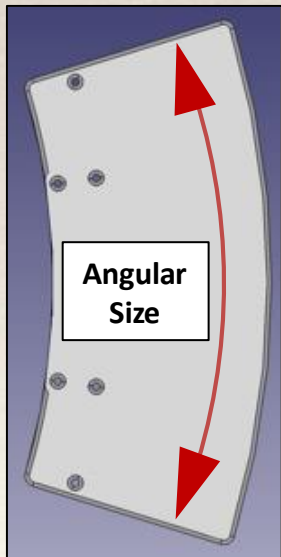
- Drag plates: Passive descent time control
- Spin vanes: Passive roll rate control
- Drag skirt: Forces flow separation



Pioneer Venus Large Probe



## Enlarged Drag Plate

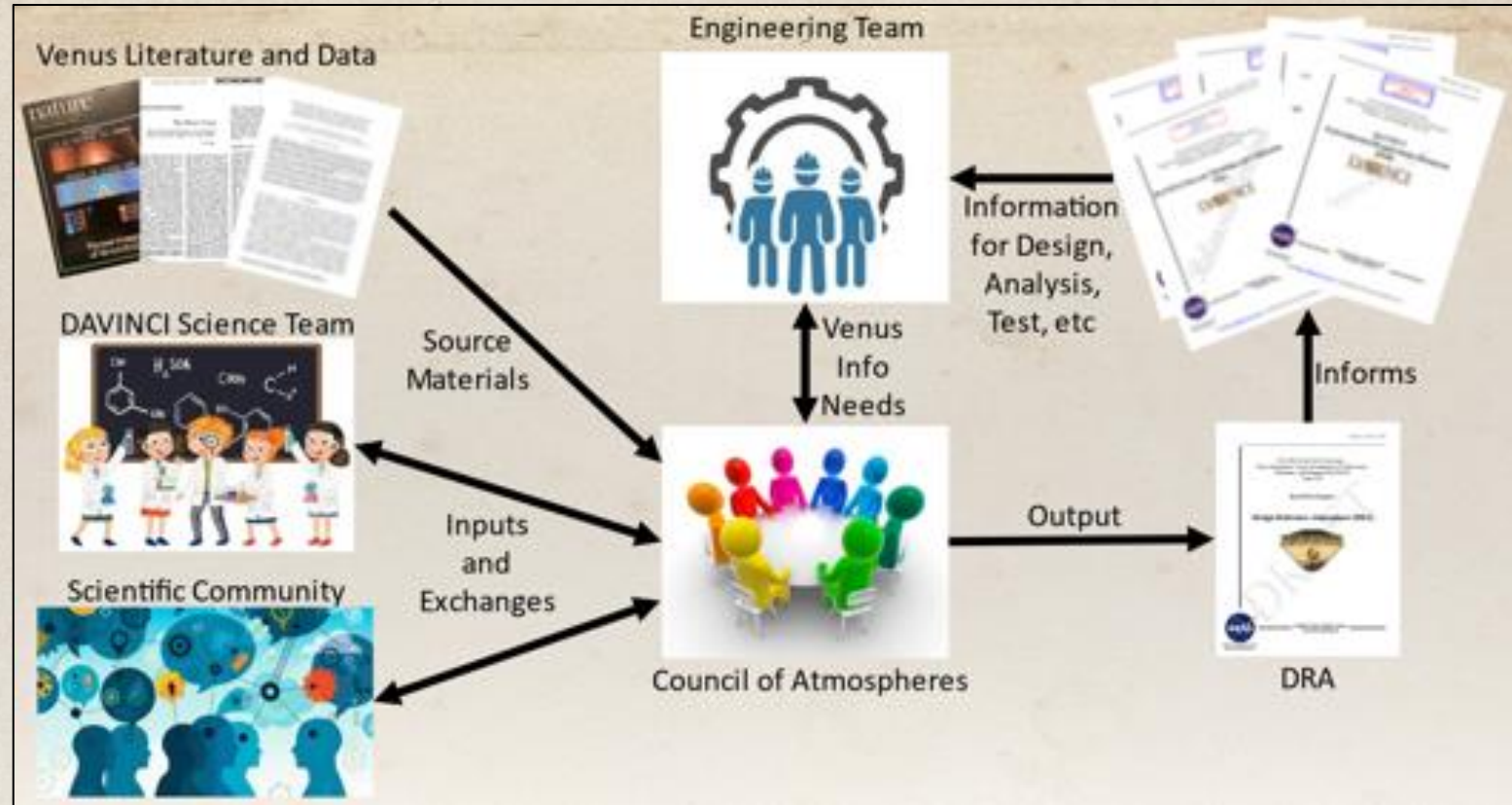


Enlarged Spin Vane

Credit: From Giovanni Guecha (NASA LaRC)

# Atmosphere

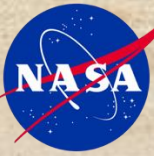
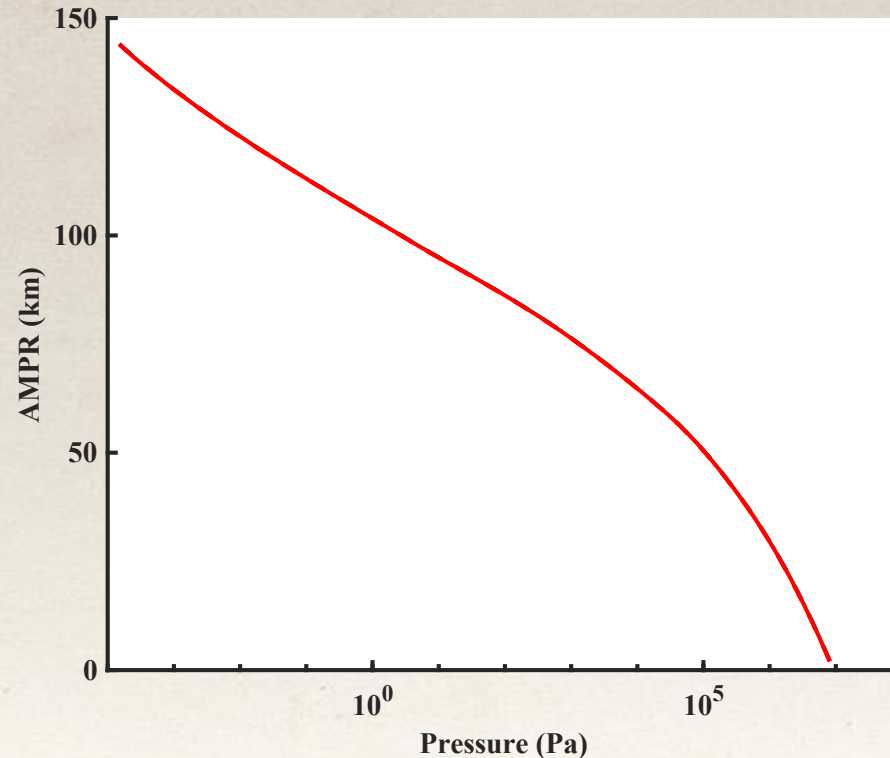
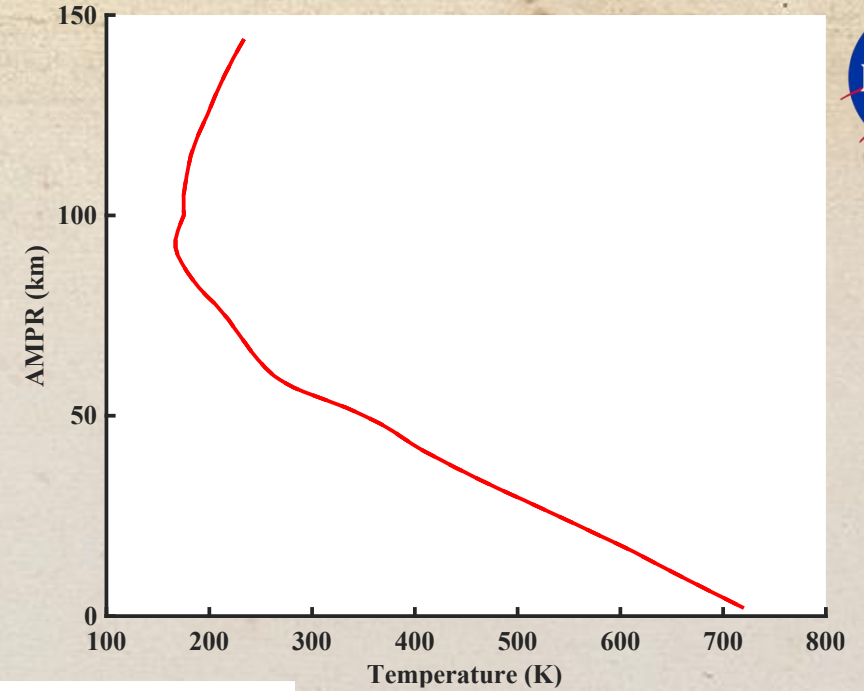
- DAVINCI Council of Atmosphere (CoA): scientists and engineers working Venus projects
- Use current best estimates for Venus atmosphere
- Engineering models listed in a Design Reference Atmosphere
  - Base pressure, temperature, and density from Venus International Reference Atmosphere (VIRA) within 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



# 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

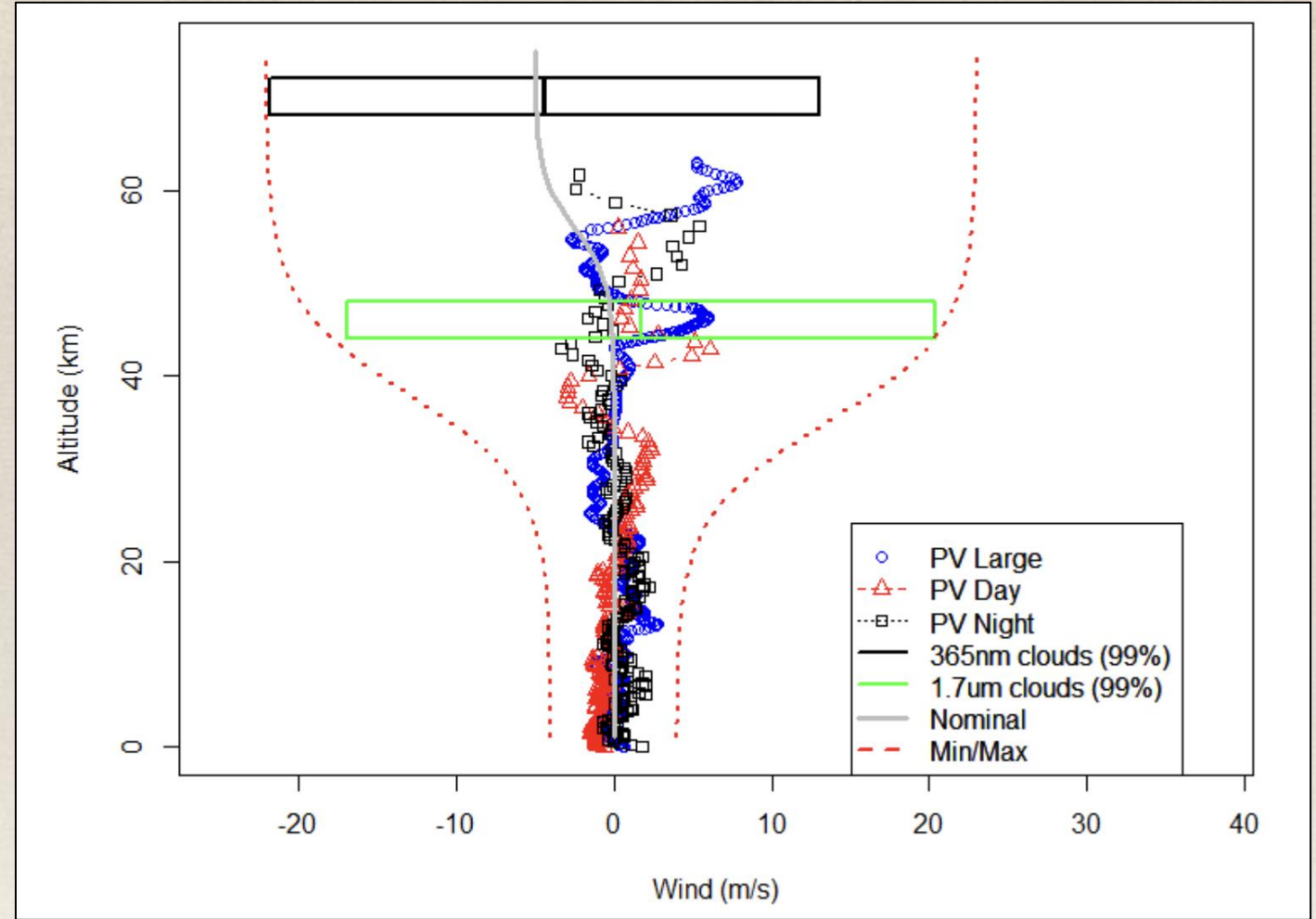
AMPR = Altitude above mean planetary radius



# Atmosphere

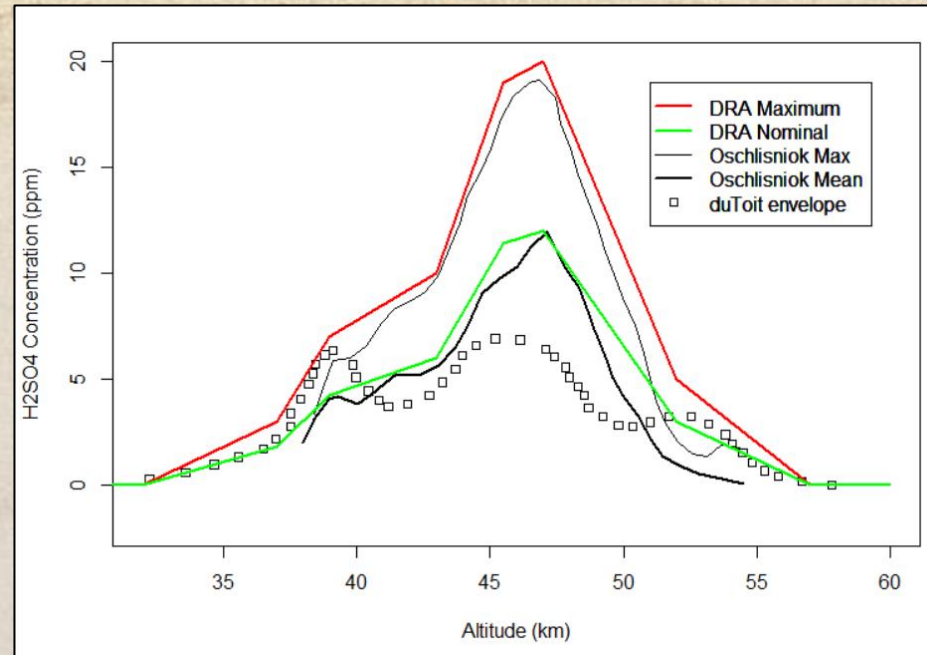
- DAVINCI Council of Atmosphere (CoA): scientists and engineers working Venus projects
- Use current best estimates for Venus atmosphere
- Engineering models listed in a Design Reference Atmosphere
  - Base pressure, temperature, and density from Venus International Reference Atmosphere (VIRA) within 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

Meridional Winds



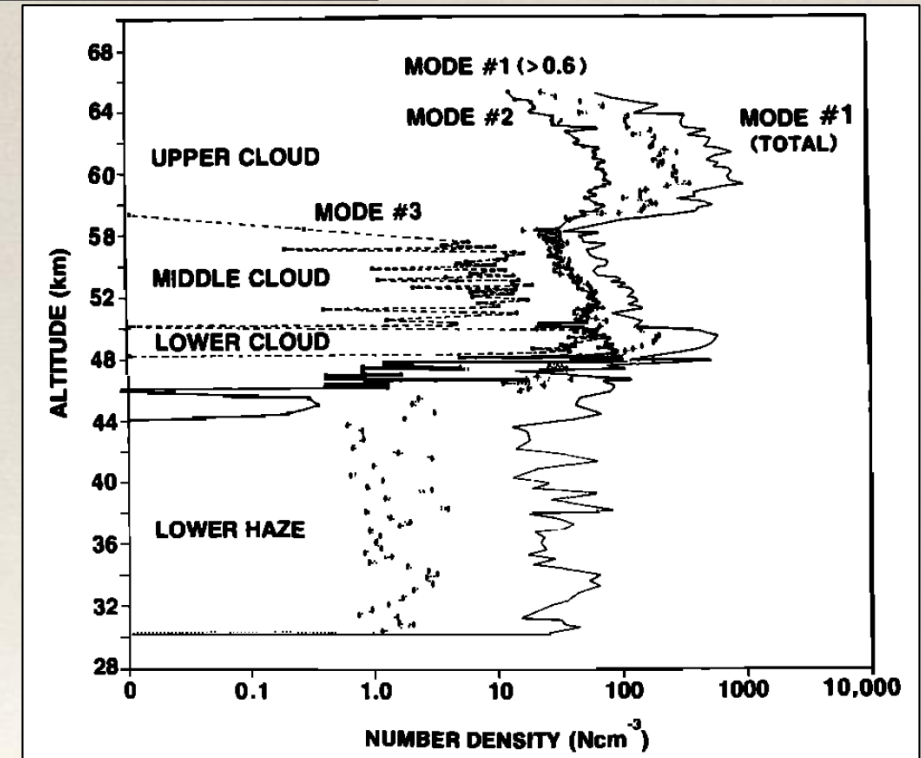
# Atmosphere

- 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

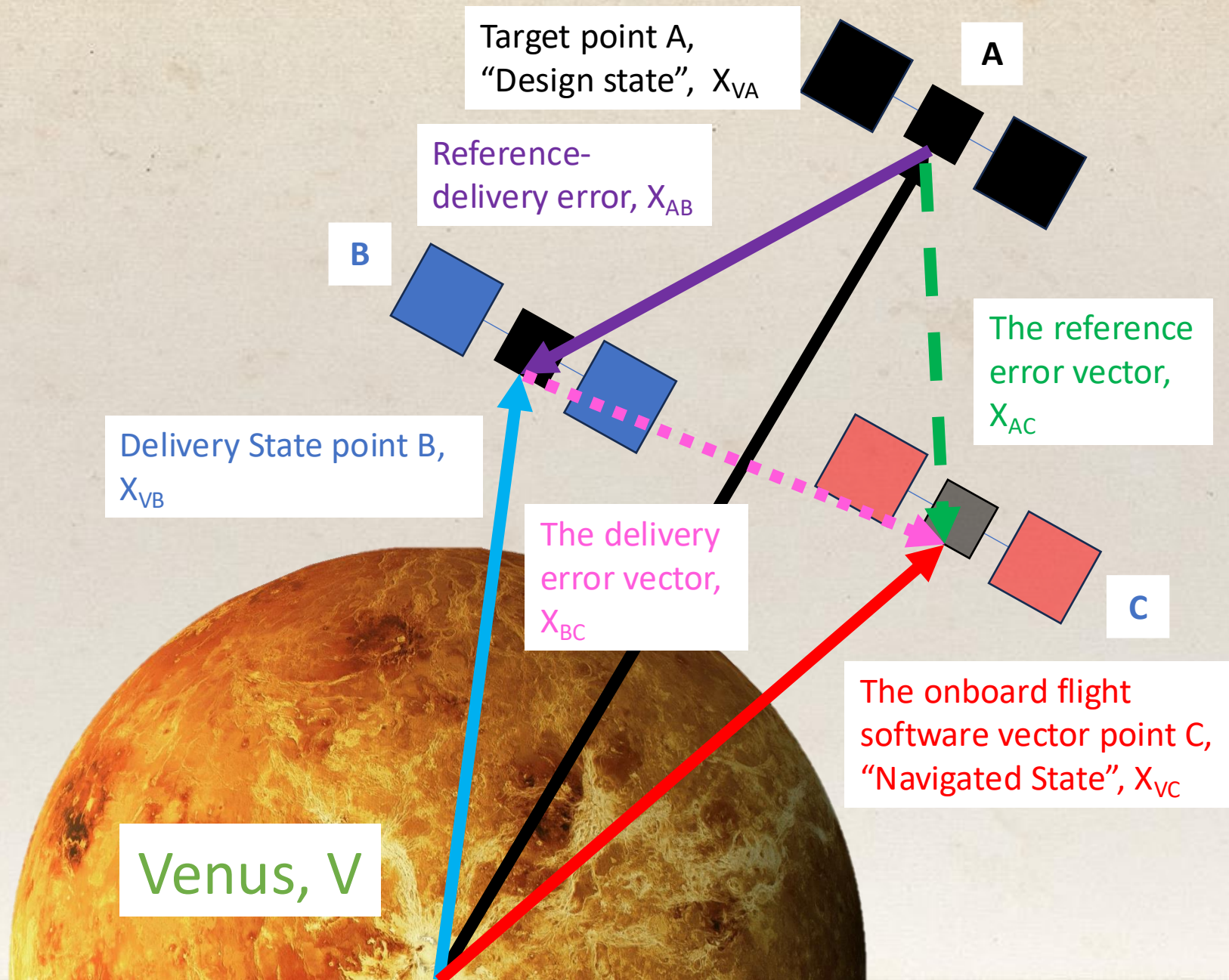
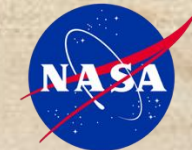


Sulfuric Acid Concentration by Altitude

Number Density of the Cloud Particle by Altitude



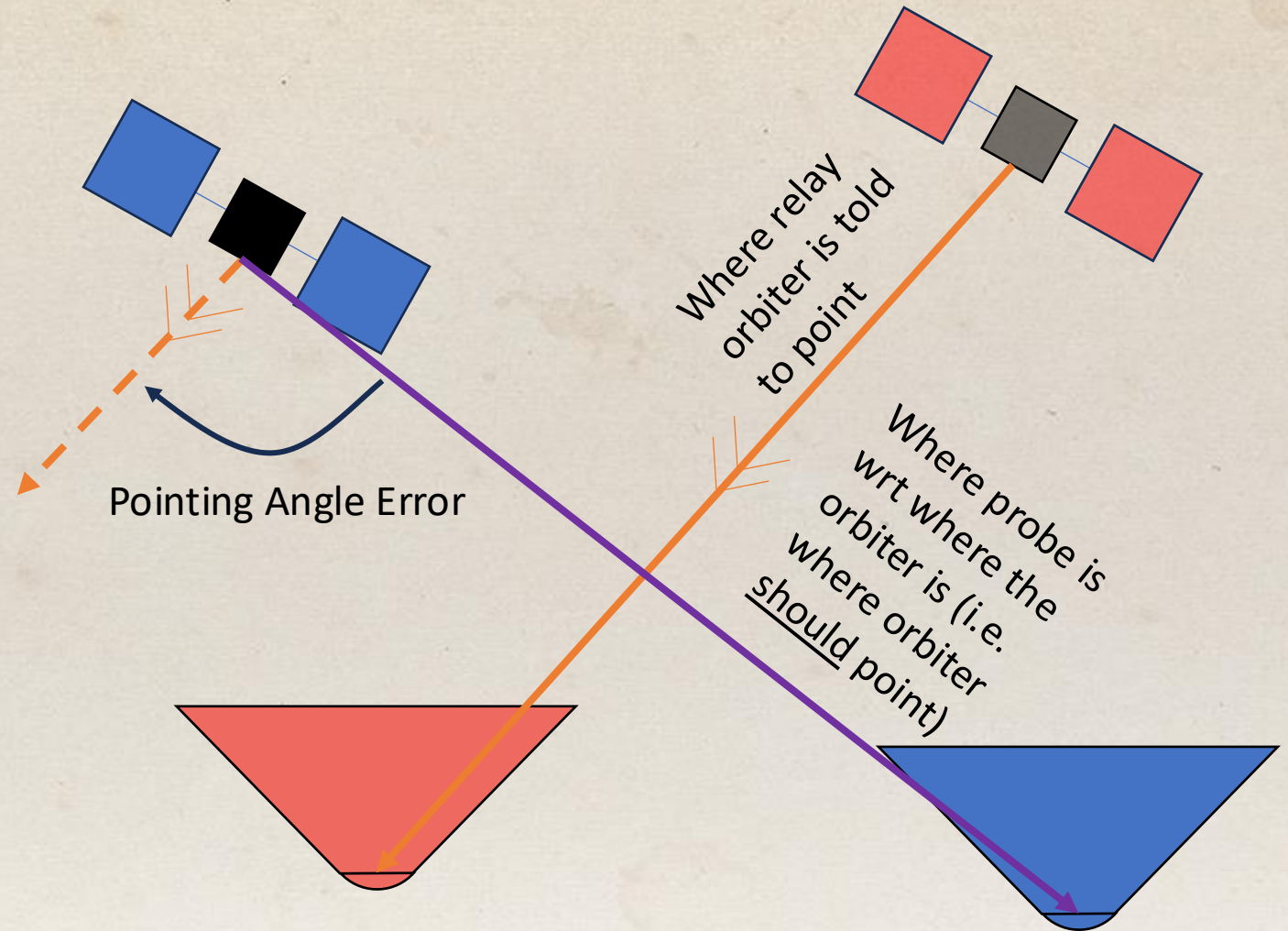
# Initial Conditions



Not to scale

# Pointing angle calculation

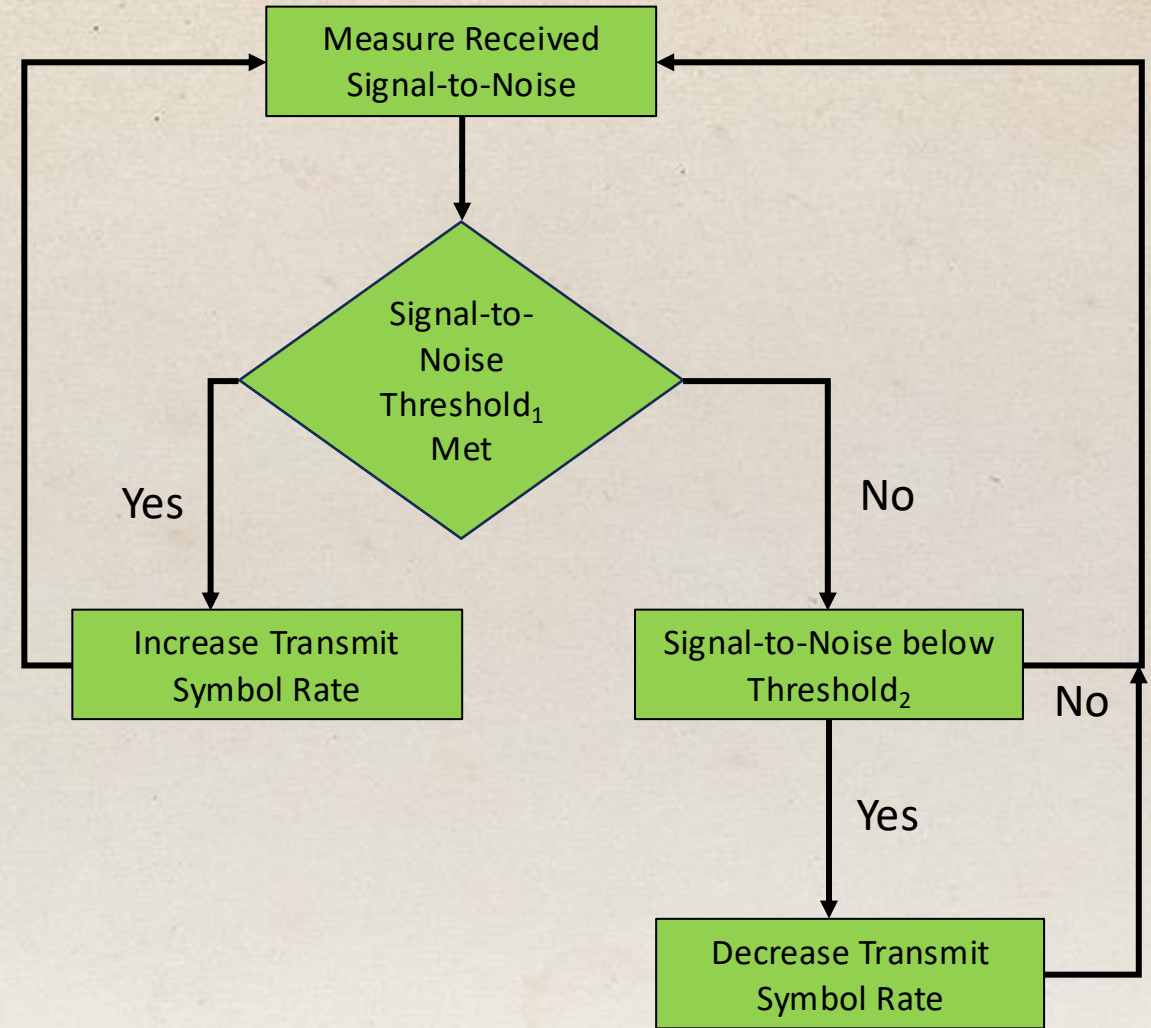
- Requires four separate states:
  - Truth Probe (blue)
  - Reference Probe (red)
  - Truth Orbiter (blue)
  - Reference Orbiter (red)
- Purple is connecting truth states
- Solid orange is connecting reference states
- Dotted orange is the nav state pointing vector originating from the truth state
- To capture true pointing angle error, EDL simulations have to model all of these states
  - This is used to ensure that the vehicles can talk to each other during the EDL phase
- All four sets of states are correlated!



Not to scale

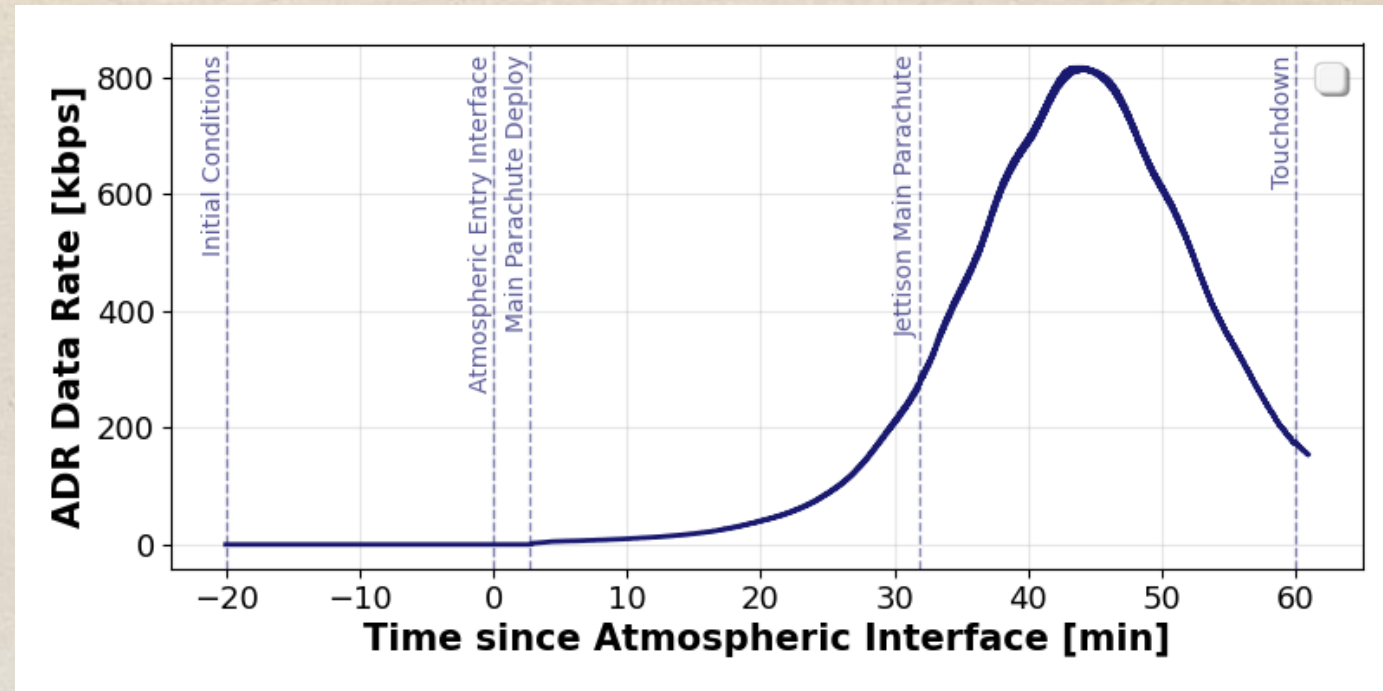
# Telecommunications and Relay

- Probe does not need to survive impact/touchdown
- 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

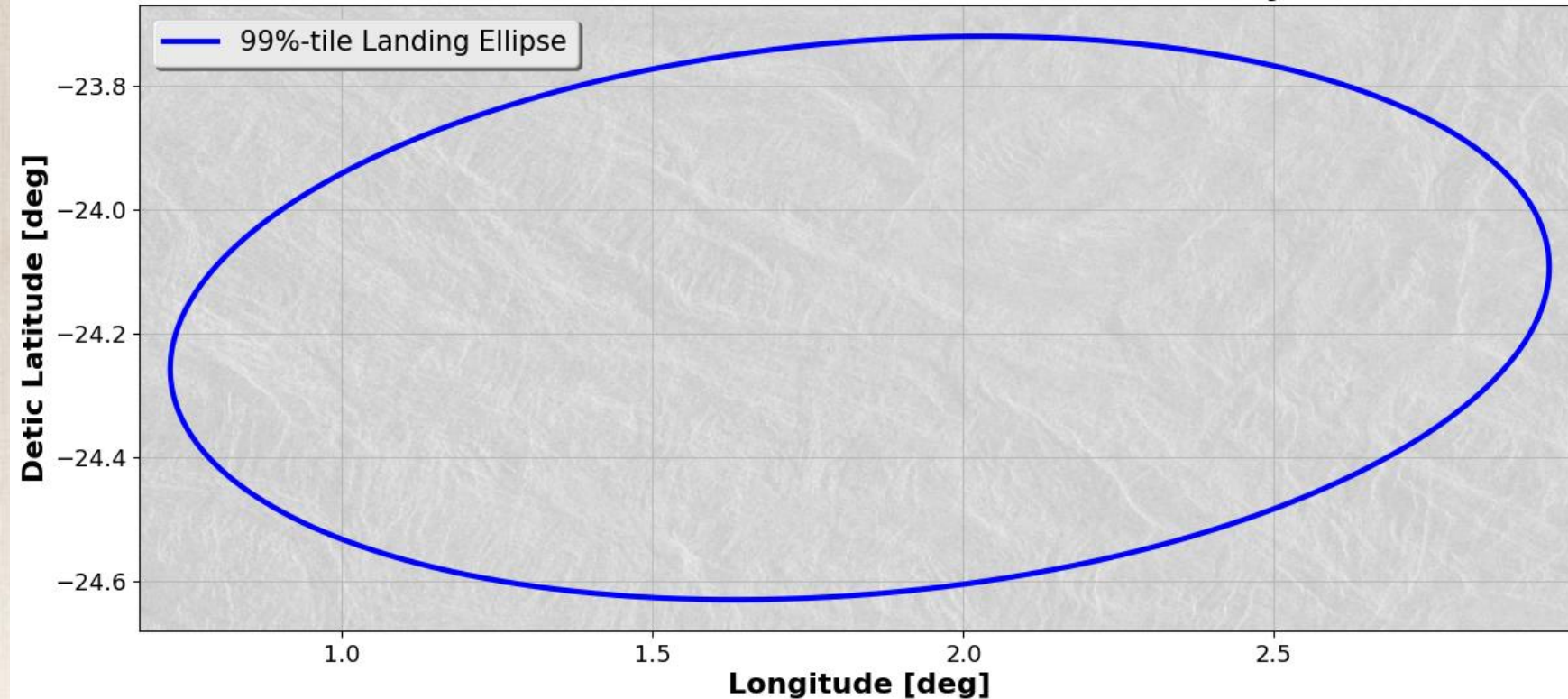
- Probe does not need to survive impact/touchdown
- Essential to relay in-situ measurements and images during 1-hour descent
- More important science data taken closer to the surface (imaging of the last 3-5 km altitude when not distorted by clouds)
- Adaptive data rate (ADR) system that updates uplink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



# 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

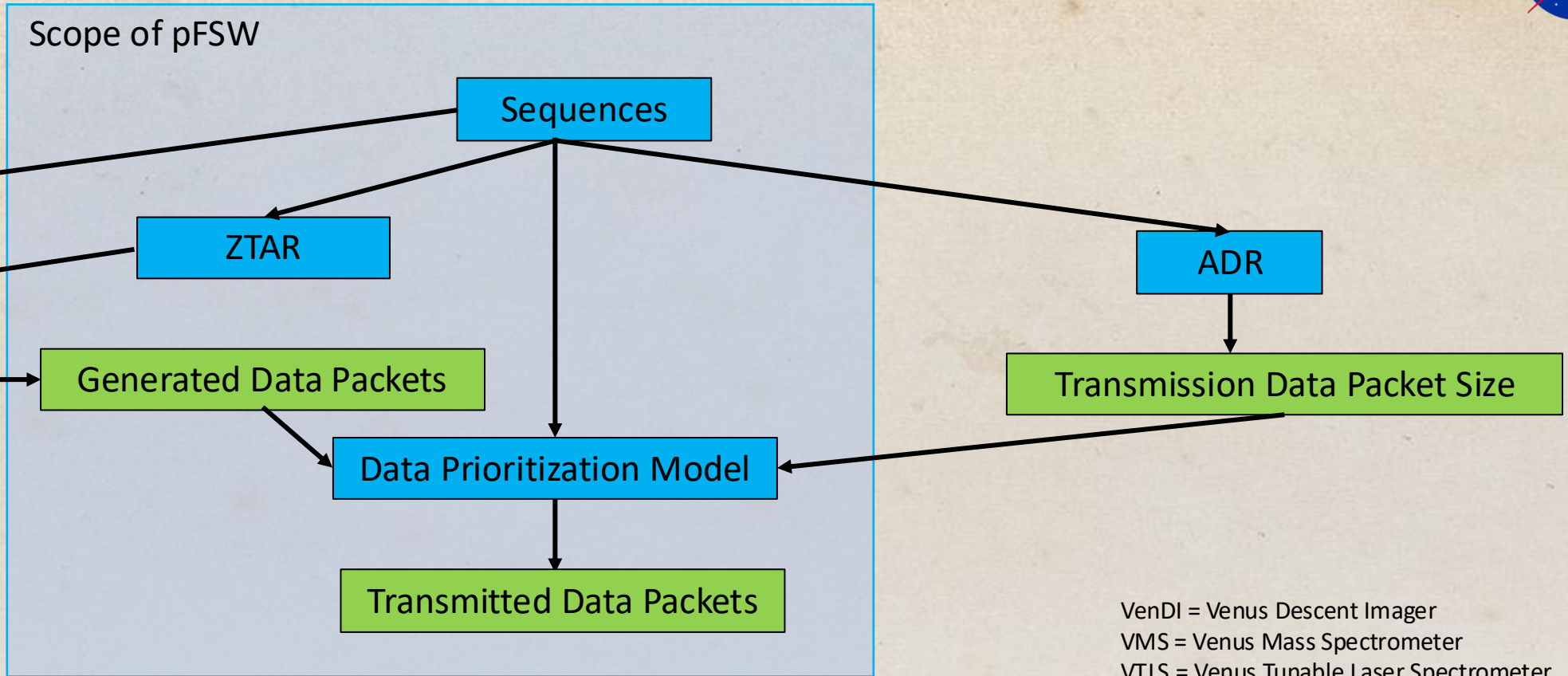
**26-VENUS-08 VenDI Field of View Time History**



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

Instrumentation Model

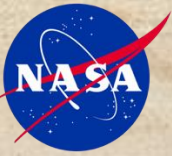
- VenDI
- VMS
- VTLS
- VASI
- ES
- DS



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



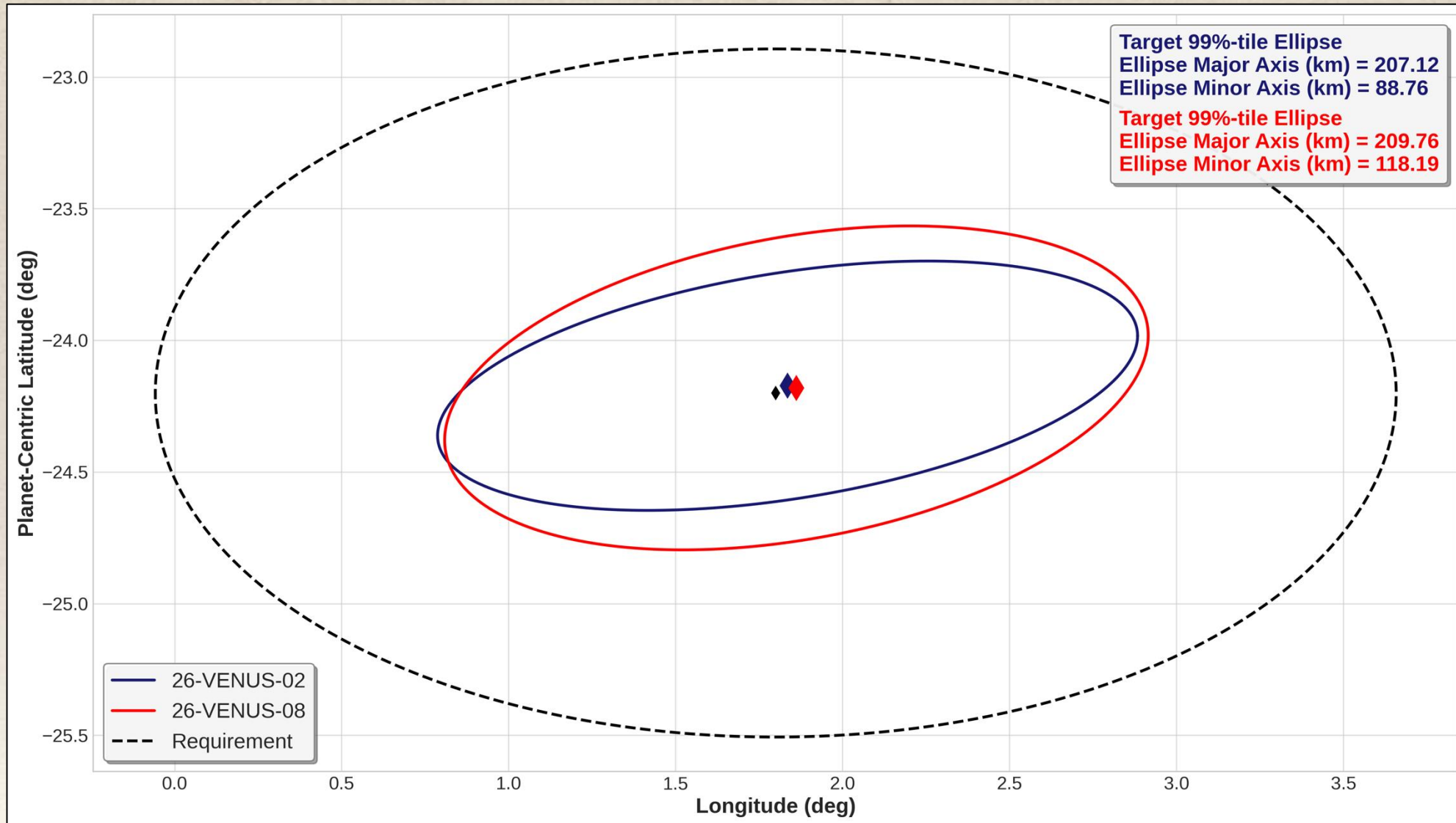
- Track critical requirements and provide statistical information about off-nominal behavior

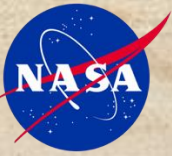
ID	Requirement Metric	Limit	Red Limit	Units	Type	26-VENUS-08
MRD-062	VMS Noble Gas Measurements <110km uplinked	>=	1		1%-tile	1
MRD-047 and MRD-044	VMS High Altitude Scan >55km AMPR uplinked	>=	1		1%-tile	27
MRD-020 and MRD-061	Start of VMS low-altitude scans AMPR	>	30	km	1%-tile	29.60
MRD-048	VTLS high 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)





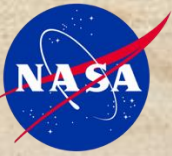
# Forward Work

- **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

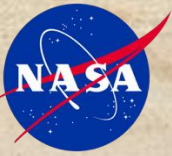
- **Modeling updates**

- 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

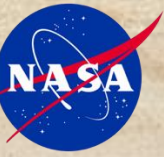
- DAVINCI is approaching PDR for its various subsystems
- Modeling and simulation of the EDL phase critical for minimum science return from the mission
- Updated models for aerodynamics, atmosphere, science instrumentation, data link, and emulated flight software has improved understanding of the current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



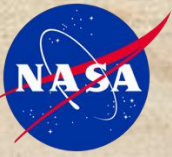
# Acknowledgement

- 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