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VERITAS Aerobraking and Engineering Science Investigation

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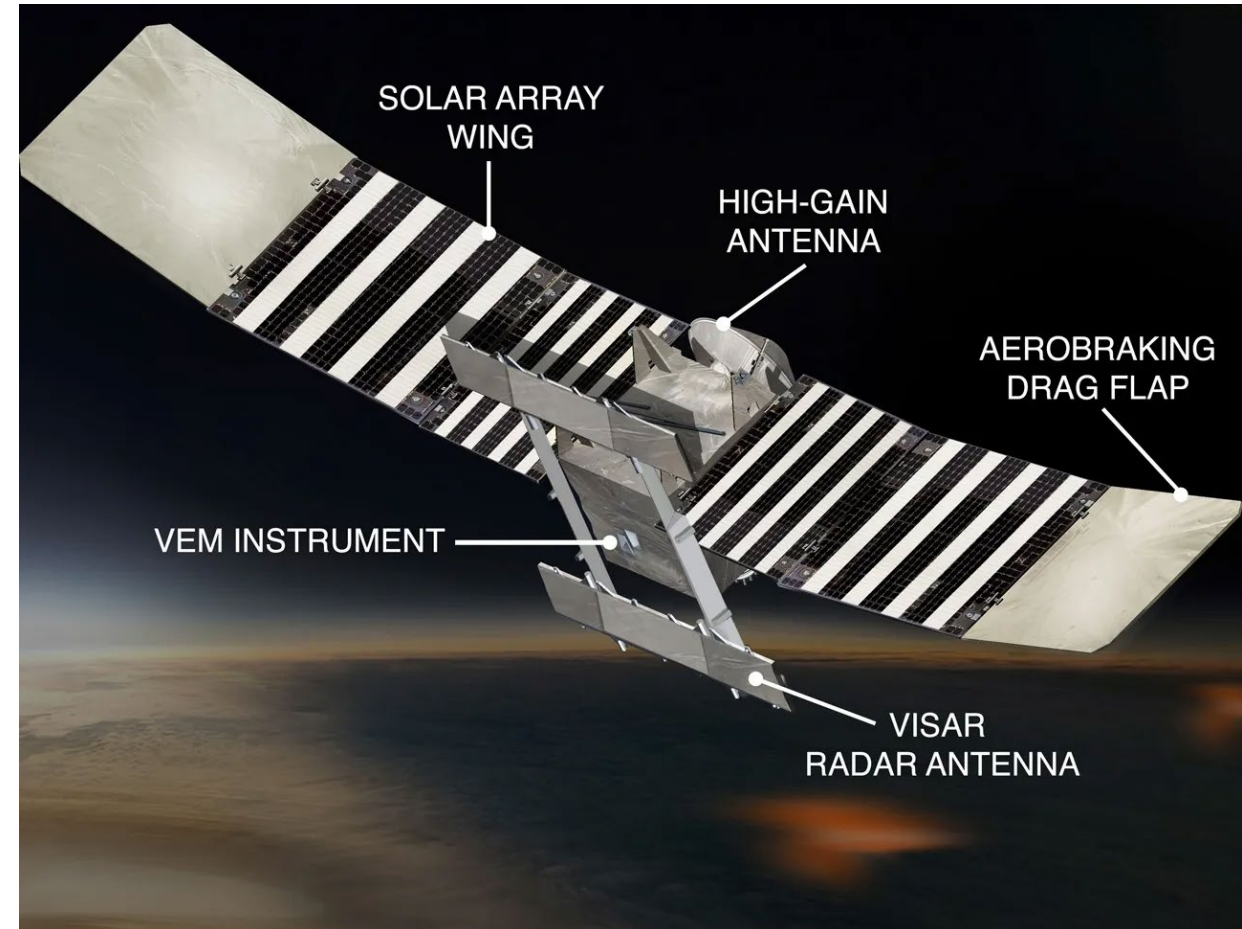


Outline

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- Motivation
- VERITAS Mission Concept
- Aerobraking Objective and Goals
- Engineering Science Investigation
- Future Work



Motivation

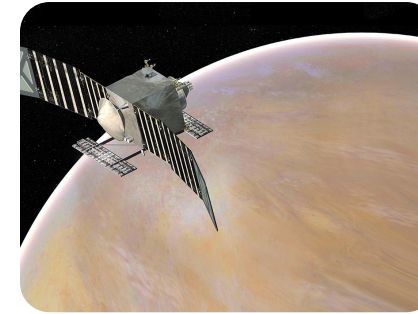
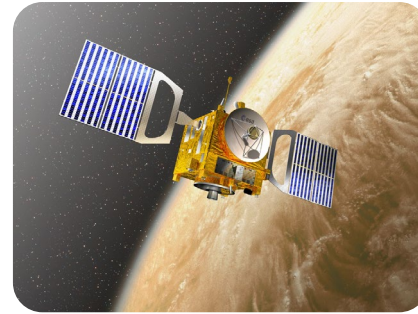
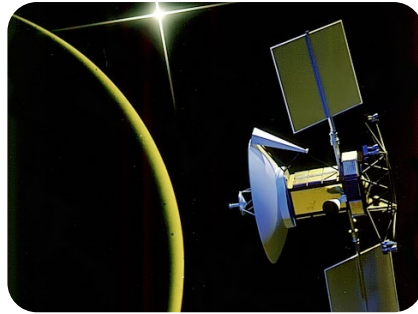
- ❖ **Venus Emissivity, Radio science, InSAR, Topography, and Spectroscopy (VERITAS) orbiter mission aims to examine Venus for past and present water, volcanic activity, and geologic evolution of Venus**
- ❖ **Aerobraking is utilized as the orbit period reduction technique to transition from Phase 1 to Phase 2 science orbit**
- ❖ **During the prolonged aerobraking campaign, a plethora of flight data can be obtained that can be utilized to understand the upper Venusian atmosphere**
- ❖ **This talk will present the current plan for VERITAS aerobraking and engineering science investigation**



How Does VERITAS Compare To Existing Venus Missions?



Note: Not shown
here is EnVision
2031 launch (TBD)
16-month AB Duration
220 – 540 km AB Orbit End



	Magellan (MGS)	Venus Express (VEX)	VERITAS
AB Years	1993	2014	2033 (TBD)
# AB Phases	1	1	2
AB Orbit Start	170 x 8,500 (3.2 hr)	127 x 66,000 (24 hr)	131 x 40,000 (120 hr)
AB Orbit End	250 x 700 (1.5 hr)	250 x 66,000 (24 hr)	219 x 400 (1.6 hr)
AB ΔV -savings	1200	N/A	3000
# of AB Passes	730	25	2635
AB Duration	70 days	25 days	300 days
Corridor Control	Dynamic Pressure	Dynamic Pressure	Heat Rate



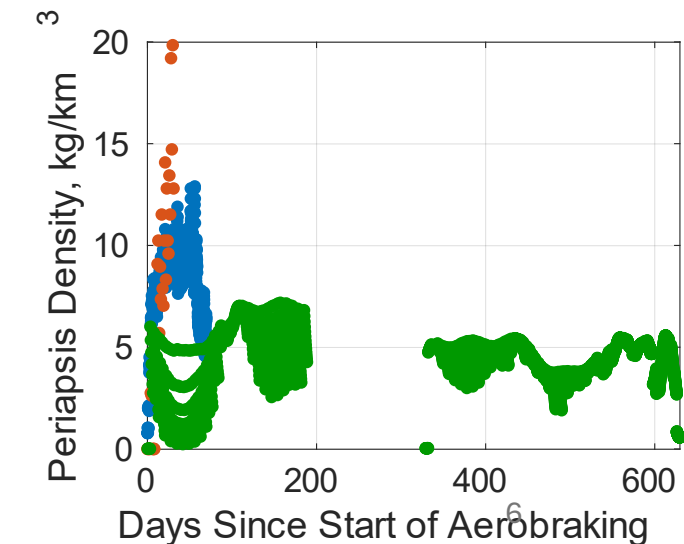
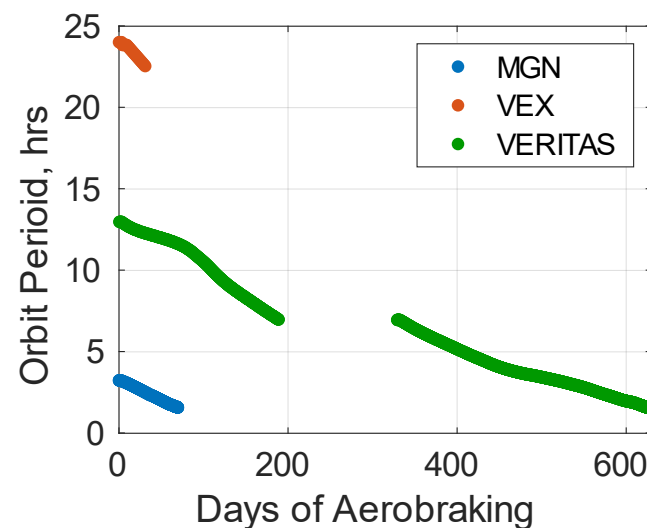
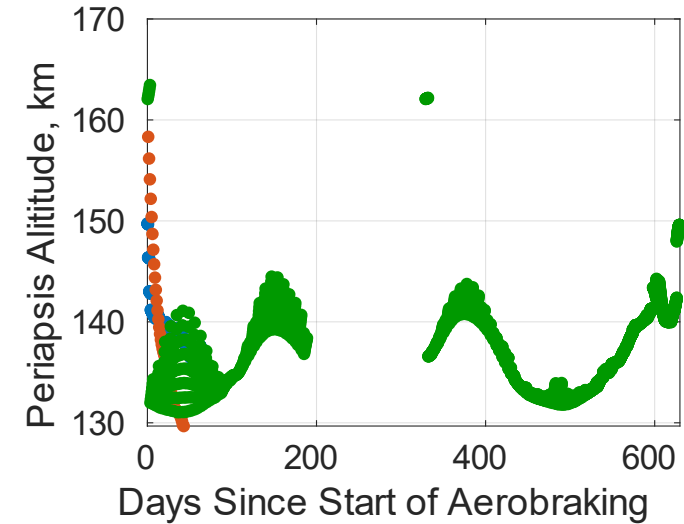
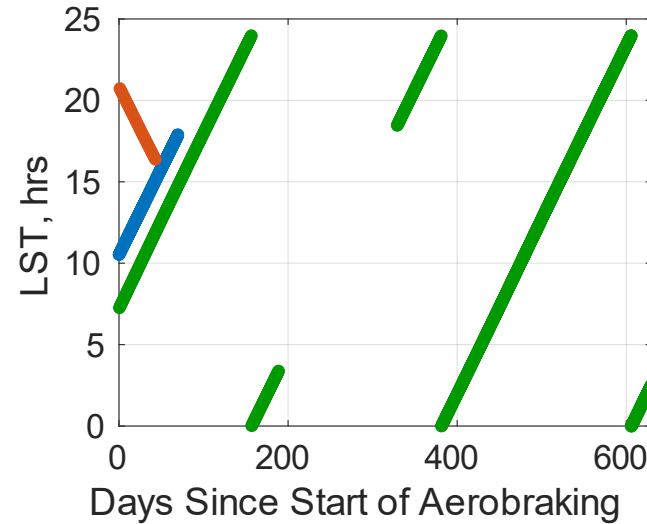
How Does VERITAS Compare To Existing Venus Missions?

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➤ Two previous aerobraking missions at Venus: Magellan (MGN) and Venus Express (VEX)

- At minimum, VERITAS captures range of data measured by both missions
- Data improvements
 - Multiple passes over terminator (LST)
 - Longer AB campaign -> more drag pass opportunities
 - Increased orbit period reduction





VERITAS Engineering Science Investigation (ESI)

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➤ From Discovery Announcement of Opportunity

“Discovery Program investigations involving aerobraking or EDL into the atmosphere of a Solar System objects shall include an Engineering Science Investigation, to be funded outside of the AO Cost Cap, to obtain diagnostic and technical data about vehicle performance and entry environments.”



VERITAS ESI Goals

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- Adds no burden to the spacecraft or mission
- Uses existing sensors and measurements to obtain diagnostic and technical data that will
 - **Verify models** - aerodynamic, aerothermal, thermal, atmosphere
 - **Perform science** - evaluate atmosphere variability at the terminator
 - **Benefit existing mission** - using atmosphere density measured each drag pass to build an offline atmosphere model that can potentially **aid in maneuver burn size selection**
 - **Benefit future missions** - advance autonomous aerobraking capabilities, more efficient corridors



VERITAS ESI Sensors

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➤ IMU (20 Hz)

- Density can be derived from IMU accelerometer measurement
- Quality of density data depends on aerodynamic model
- Similar to MAVEN, an aerodynamic model will be developed for flight at Venus and validated during aerobraking

➤ Temperature Sensors (1 Hz)

- Thermal modeling will predict hot spots on solar arrays and recommend placement
- Monitor and predict thermal load during aerobraking
- Flight data will be used to validate thermal model



VERITAS ESI Benefits

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- Thermal Modeling, especially at Venus, can enable efficient aerobraking by
 - Eliminating the need for surrogate corridors (heat rate, density) and use actual vehicle response to inform corridor – fly a temperature corridor based on solar array thermal limits (accounts for eclipses and shadowing, or lack of, prior to drag pass)
 - Allowing efficient maneuver burn sizes (save propulsion or reduce uncertainty on estimates) and more efficient overall aerobraking mission

- Atmosphere Modeling
 - Reduces atmosphere uncertainty
 - Improves global models
 - Improves science understanding of the atmosphere effect near the terminator



Forward Plan

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VERITAS aerobraking will provide increased opportunities to measure and understand the Venusian Upper Atmosphere

- Resume Mission Design and Aerobraking Working Group Development in FY26

- Continue Aerobraking Simulation Development and Analysis
 - Aerodatabase + Aerothermal Model
 - Atmosphere Model updates (Venus Climate Database; VenusGRAM)
 - Monte Carlo Performance Assessment

Questions?



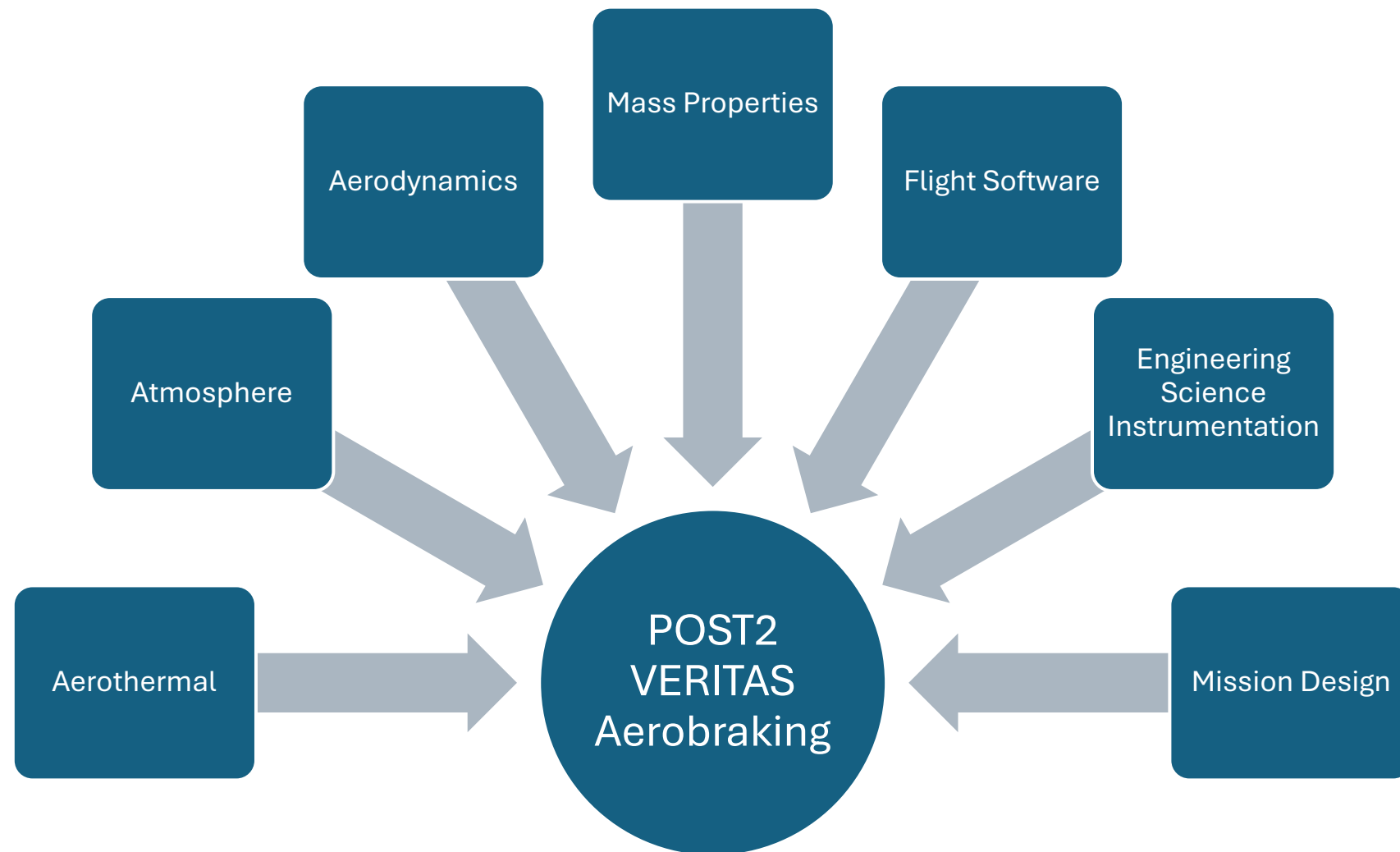


Aerobraking Flight Mechanics Simulation Modeling

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- High-level flow diagram showing model inputs
 - Many inputs are still work-in-progress



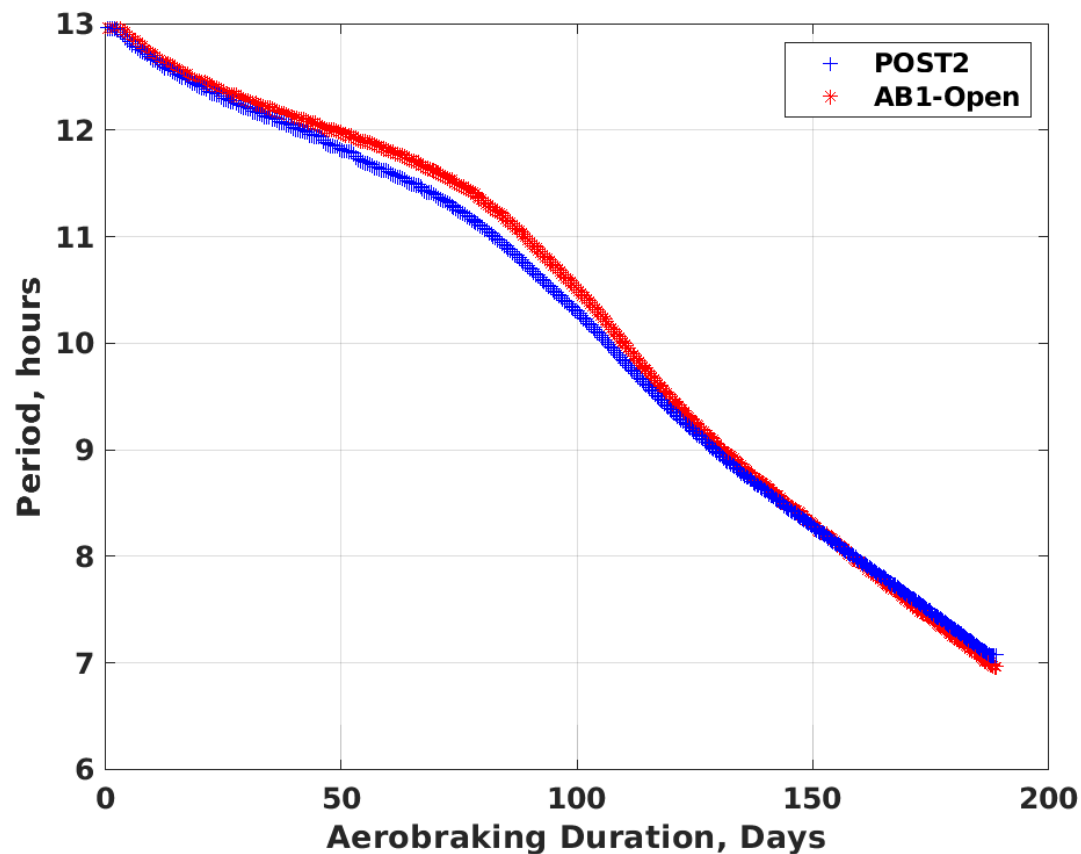


VERITAS Aerobraking Glide Slope

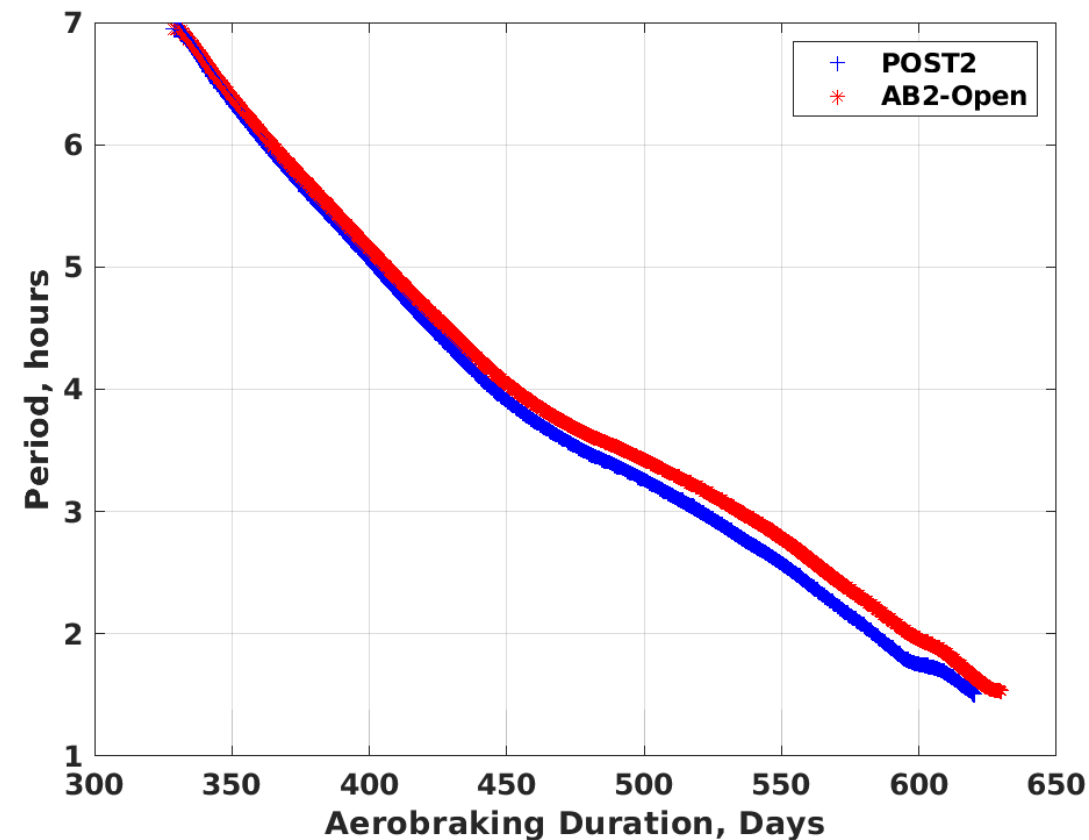
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Phase 1



Phase 2



- Starting comparison between aerobraking simulations; still work-to-go
- Glide Slope: Phase 1 shorter aerobraking duration than Phase 2

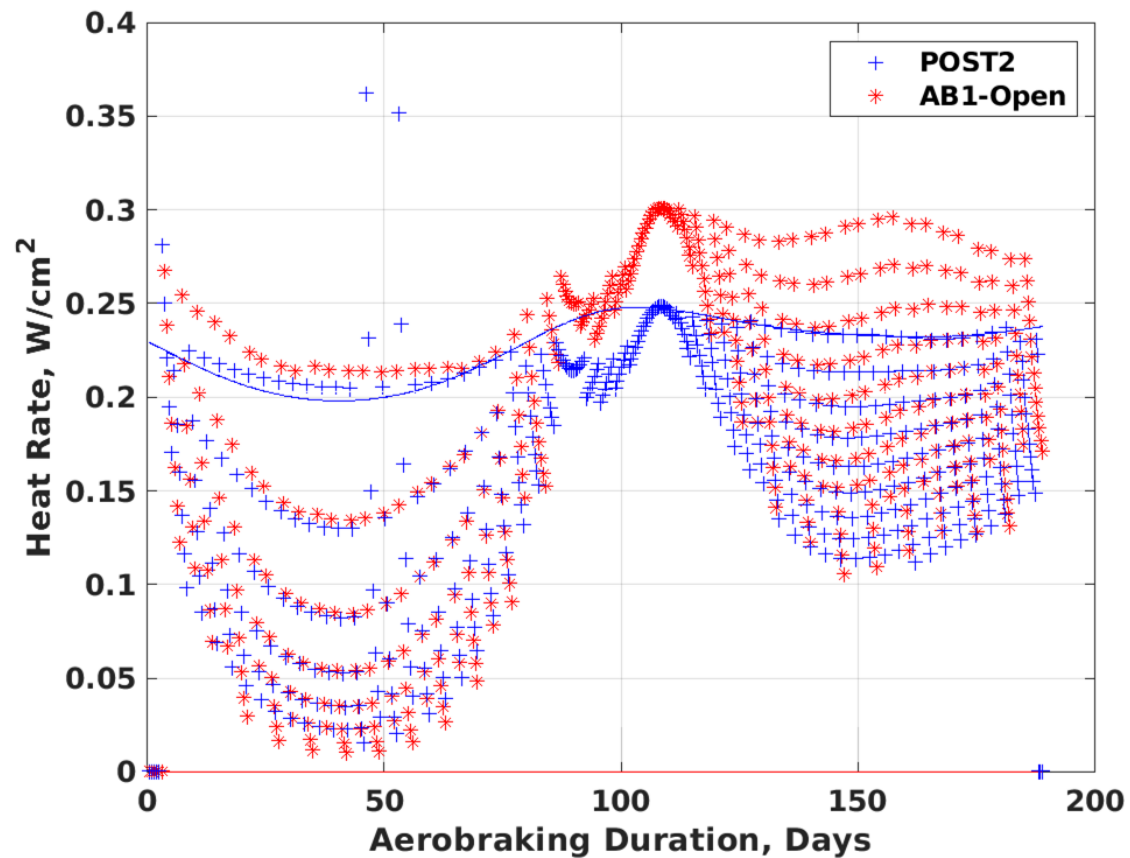


VERITAS Aerobraking Corridor

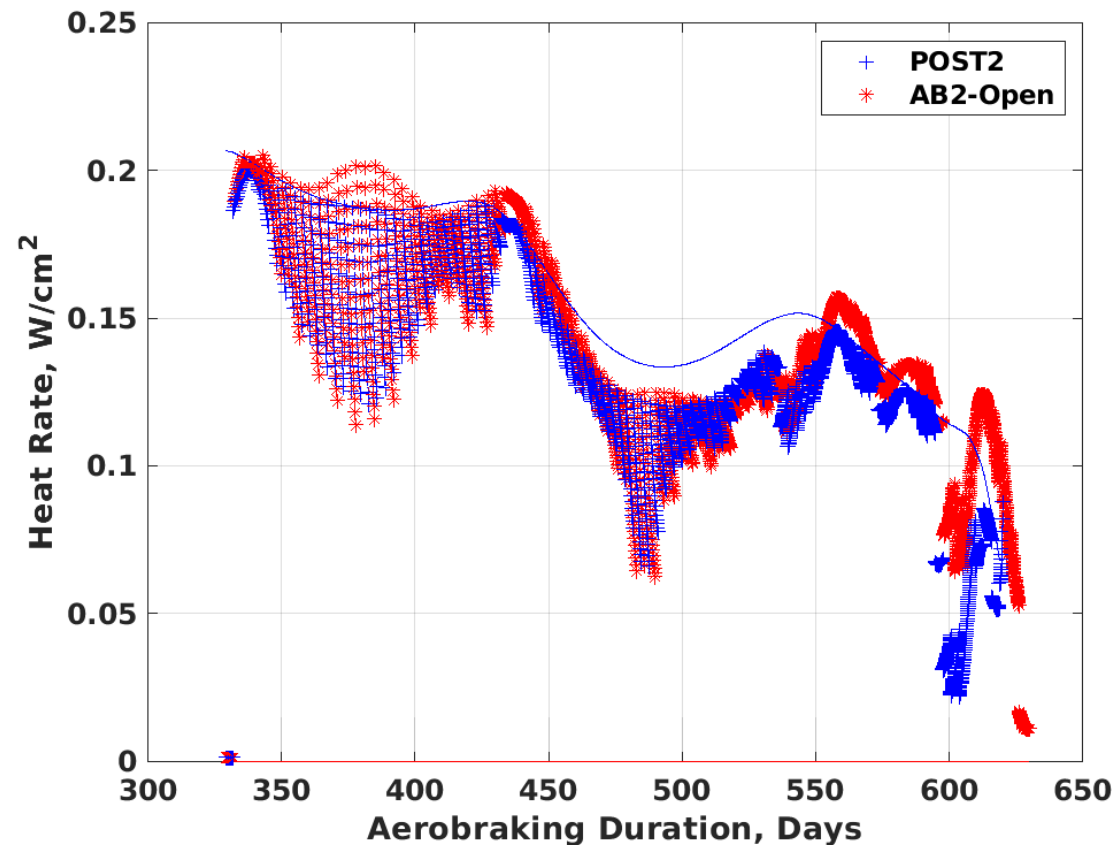
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Phase 1



Phase 2



- Corridor bounds (solid line) vary with orbit energy and sun flux angle
- Periapsis heat flux (+) for each drag pass stay below corridor bounds



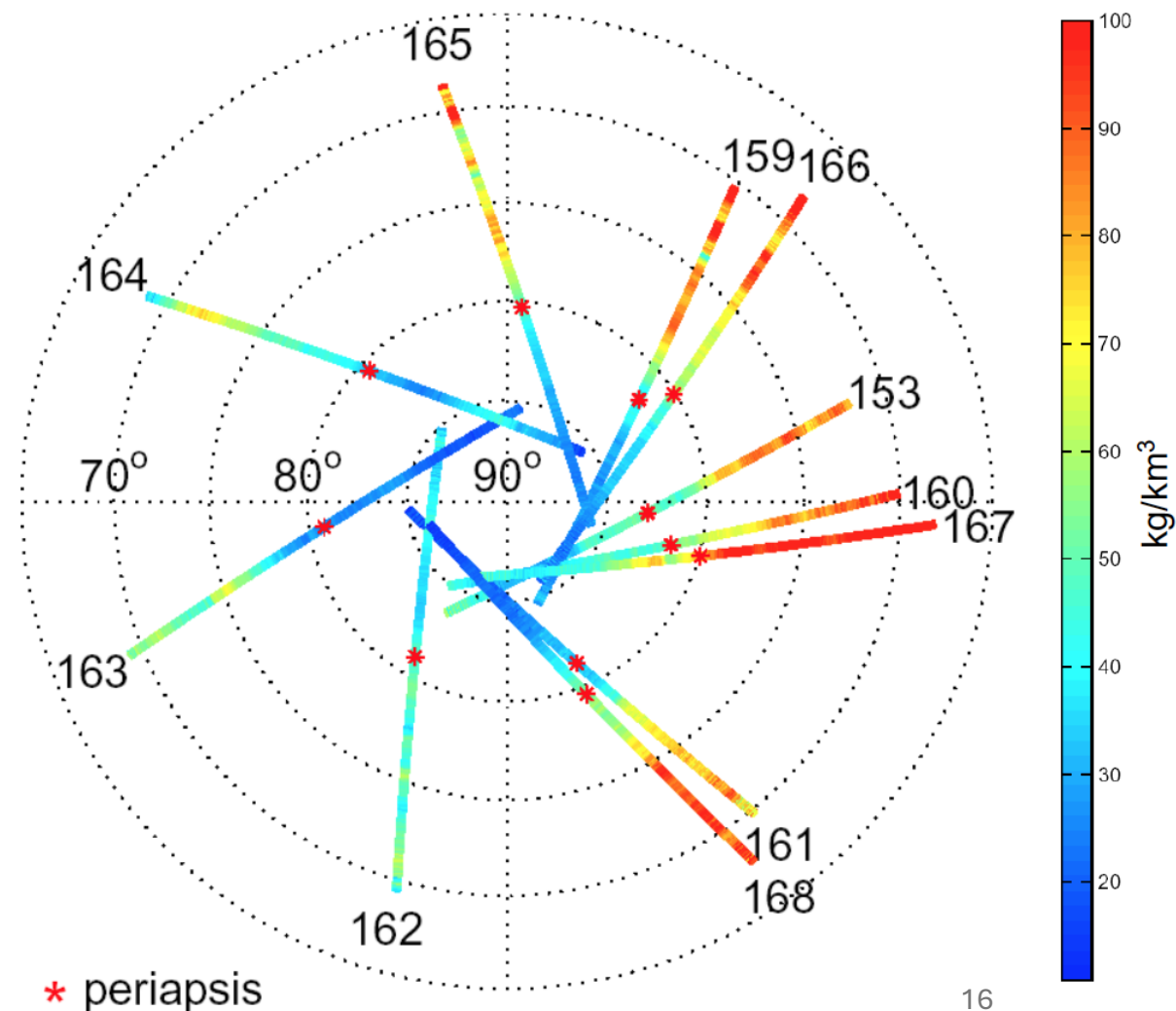
VERITAS ESI Potential Science

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➤ Sample: Understanding Polar Vortex at Mars

- Plot of density profiles over the Mars North Pole (90°) mapped to 100 km altitude for Odyssey aerobraking
- Density is truncated at 100 kg/km³ to enhance variability.
- The transition from red to blue near 80° latitude characterizes the location of the Mars Polar Vortex.
- The information, used to anticipate Odyssey periapsis conditions and mission planning,





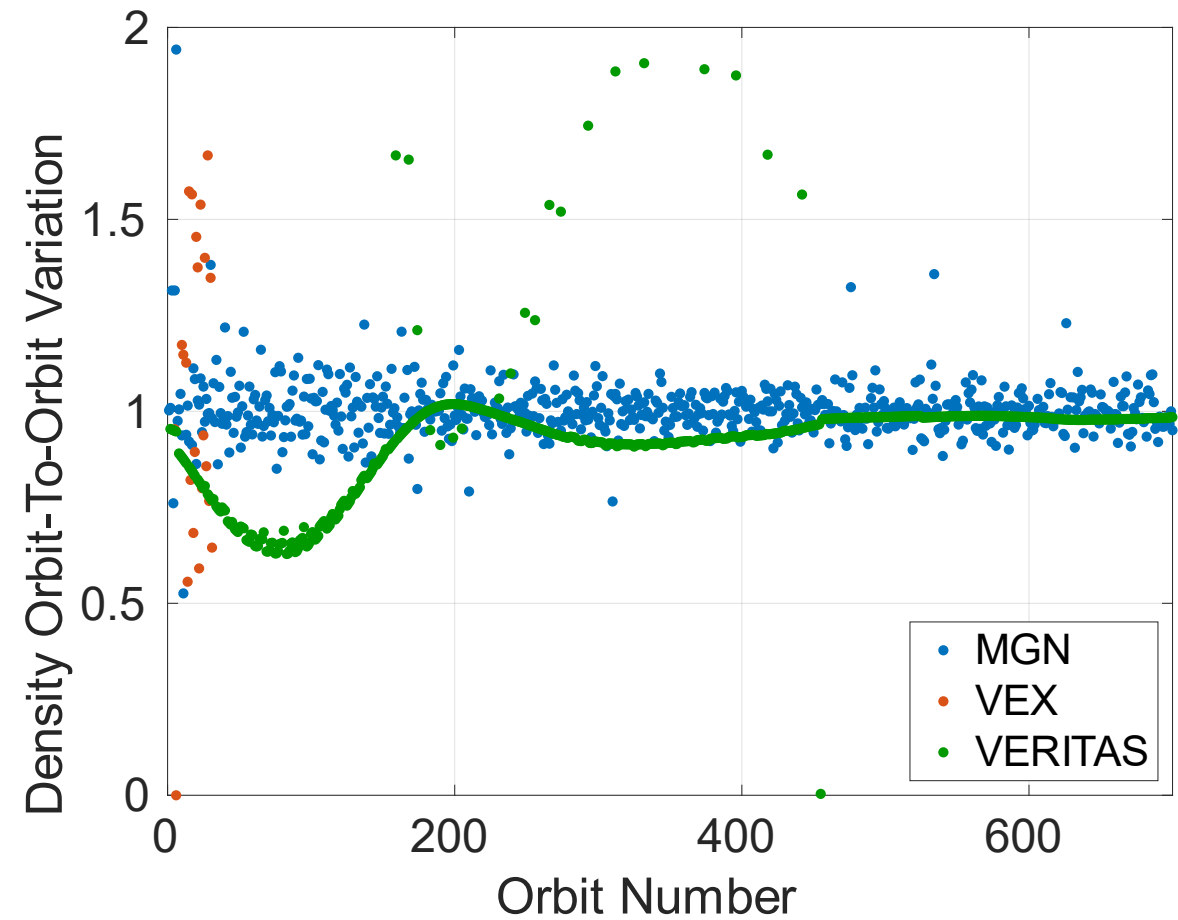
How Does VERITAS Compare To Existing Venus Missions?

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➤ Two previous aerobraking missions at Venus: Magellan (MGN) and Venus Express (VEX)

- Anticipate similar orbit-to-orbit density variation
- Model higher variability near the terminator that was observed in Pioneer Venus Orbiter and Magellan missions
- Future work to assess Aerobraking performance with latest Venus atmosphere models



*VERITAS density values come from simulated VenusGRAM data



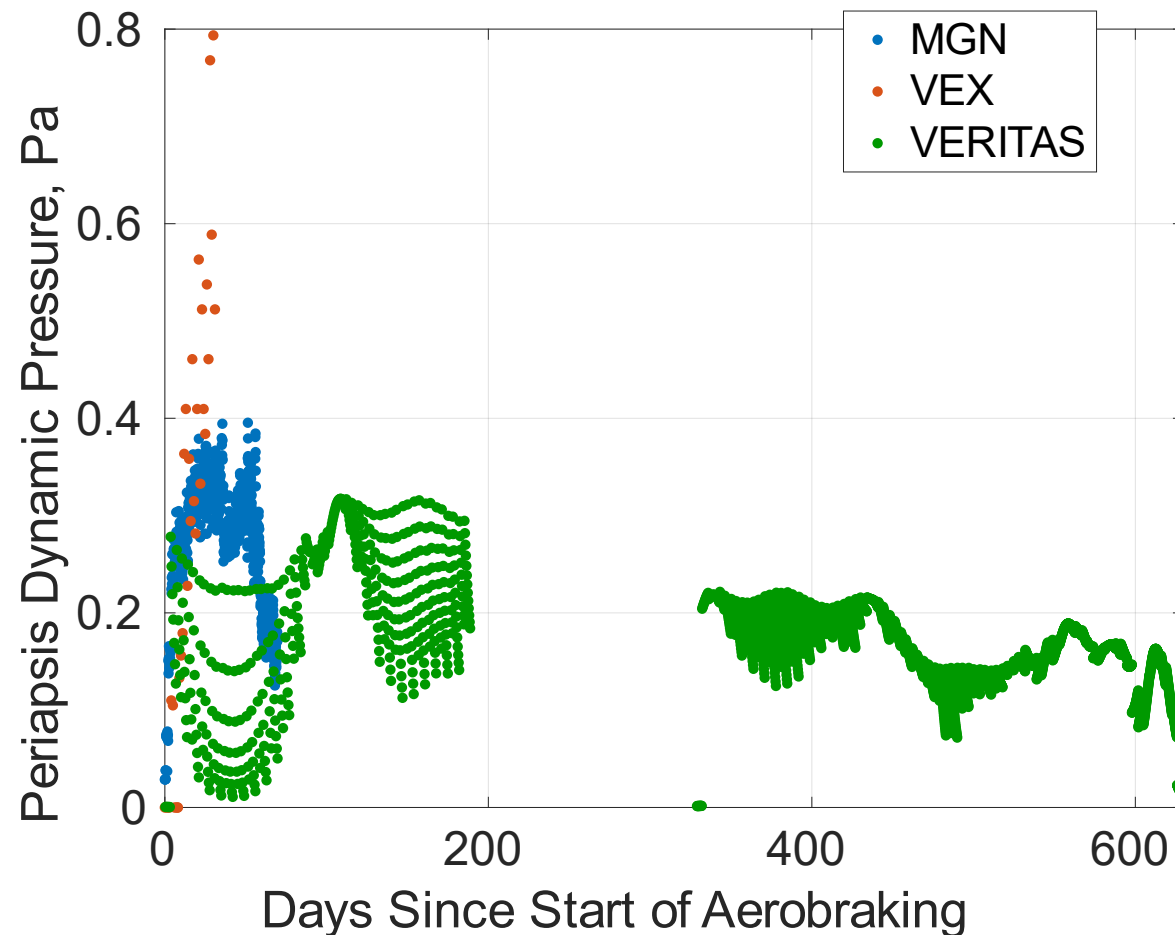
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➤ Two previous aerobraking missions at Venus: Magellan (MGN) and Venus Express (VEX)

- Each AB drag pass stays within a similar corridor
 - Note: MGN [1] and VEX [2] uses dynamic pressure to define corridor
 - VERITAS uses Heat Flux



*VERITAS density values come from simulated VenusGRAM data

[1] Carpenter, A. S., "The Magellan Aerobraking Experiment: Attitude Control Simulation and Preliminary Flight Results", AIAA 1993-3830-CP

[2] Merritt, D.R., "Venus Express: Aerobraking and Post-Aerobraking Science Operations"