A Venus Atmospheric Sample Return Mission Concept: Feasibility and Technology Requirements

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Earth's "Twin" Planet

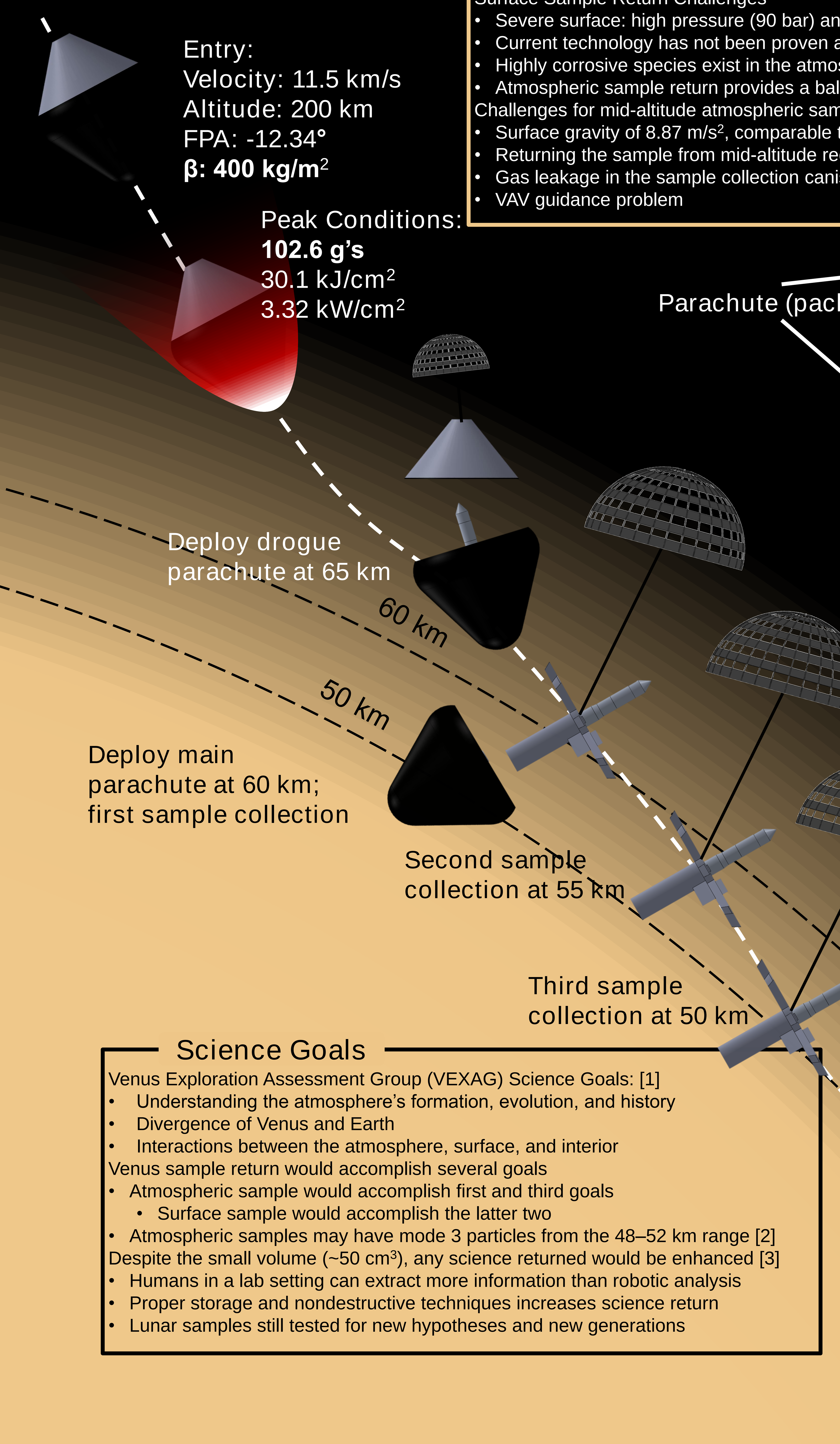
Why Venus?
- Venus and Earth are approximately the same size and same mass, with orbits similar to each other
- However, while Earth is habitable (1 atm, avg. 15°C), Venus is inhospitable (90 bar, 460°C, sulfuric clouds)
- Differences between the evolutionary paths Venus and Earth underwent would provide key insight into planetary evolution

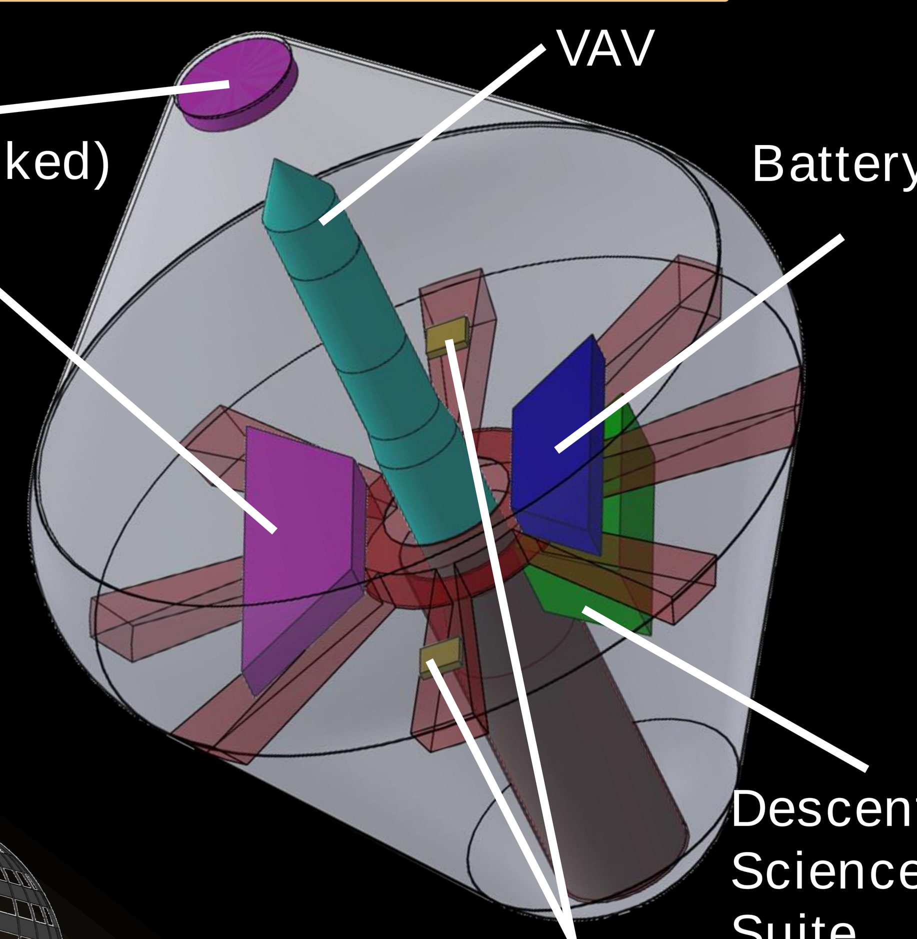
Venus Atmospheric Sample Return:
- Point design, from Venus entry to Venus exit, has been designed, keeping in mind volume and mass constraints
- 9 samples, from three different altitudes, are extracted from the 50 – 60 km range

Price of a Thick Atmosphere

Surface Sample Return Challenges
- Severe surface: high pressure (90 bar) and high temperature (460°C)
- Current technology has not been proven at these conditions
- Highly corrosive species exist in the atmosphere (i.e. sulfuric acid) below 50 km.
- Atmospheric sample return provides a balance between science and risk/cost

Challenges for mid-altitude atmospheric sample return:
- Surface gravity of 8.87 m/s², comparable to Earth's 9.81 m/s²
- Returning the sample from mid-altitude requires a Venus Ascent Vehicle (VAV)
- Gas leakage in the sample collection canister during cruise to Earth
- VAV guidance problem





Trade Studies

Launch Vehicle	Cruise to Venus	Venus Capture	Venus Entry	Terminal Descent
Atlas V 551	Chemical	Direct Entry	Rigid Spherecone	Parachute
Falcon 9	SEP	Aerocapture	ADEPT	Parafoil
		Chemical	Mid L/D	Drag Plate
		Aerobraking		Balloon
				Spherecone

Sampling	Venus Ascent	Cruise to Earth	Earth Capture	Sample Handoff
Single	Solid Rocket	Chemical	Direct Entry	Orbit Handoff
Multiple	Liquid Rocket	SEP	Aerocapture	Surface Handoff
Pumped	Chemical		Chemical	Transfer Canister
Stagnant	Balloon		Aerobraking	Pump Samples
	Plane			

Component	CBE Mass	Cont.	MEV Mass	CBE Power	Cont.	MEV Power
Sample Canister	1.30 kg	50%	1.95 kg	–	–	–
GNC and TTC	4.00 kg	30%	5.20 kg	44.4 W	50%	66.6 W
RCS	5.50 kg	30%	7.15 kg	1.8 W	50%	2.7 W
Battery	1.25 kg	30%	1.63 kg	–	–	–
Propulsion	1137 kg	20%	1365 kg	–	–	–
VAV Total	1149 kg		1381 kg	46.2 W		69.3 W
VAV	1149 kg	17%	1381 kg	–	–	–
Frontshell	406 kg	30%	528 kg	–	–	–
Aftshell	94.7 kg	30%	123 kg	–	–	–
Parachutes	43.2 kg	30%	56.2 kg	–	–	–
Science Suite	15 kg	30%	19.5 kg	37.2 W	50%	55.8 W
Telecomm.	5 kg	50%	7.5 kg	10 W	50%	15 W
Battery	30 kg	30%	39 kg	–	–	–
Structures	546 kg	30%	710 kg	–	–	–
Vehicle Total	2290 kg		2864 kg	47.2 W		70.8 W

Allowable Mass	3181 kg
Margin	317 kg

Science Goals

Venus Exploration Assessment Group (VEXAG) Science Goals: [1]
- Understanding the atmosphere's formation, evolution, and history
- Divergence of Venus and Earth
- Interactions between the atmosphere, surface, and interior

Venus sample return would accomplish several goals
- Atmospheric sample would accomplish first and third goals
  - Surface sample would accomplish the latter two
- Atmospheric samples may have mode 3 particles from the 48–52 km range [2]

Despite the small volume (~50 cm³), any science returned would be enhanced [3]
- Humans in a lab setting can extract more information than robotic analysis
- Proper storage and nondestructive techniques increases science return
- Lunar samples still tested for new hypotheses and new generations

Future Work

- This point design used as many historic and modern technologies as possible
- Future work will look into the trade studies shown above, taking advantage of upcoming and state-of-the-art technology
- Architectures for Venus sample return will be evaluated on a mass, risk, and cost basis, and comparing to previous studies

References

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