FEASIBILITY AND MASS-BENEFIT ANALYSIS OF AEROCAPTURE FOR SMALLSAT MISSIONS TO VENUS

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Aerocapture Control Methods

Lift Modulation

MSL-like low L/D aeroshell, HEEET TPS

Drag Modulation

ADEPT-like system with $\beta_2/\beta_1 > 10$
1. Dedicated Mission to Venus

Orbit Insertion options
- Propulsive
  - Bi-prop. (320 Isp)
- Aerocapture (MSL-like aeroshell)
- Propulsive + Aerobraking

Not to Scale
2. Rideshare with mission flying to/by Venus

Orbit Insertion options

- Propulsive
  - Mono prop. (230 Isp)
- Aerocapture (ADEPT-like aeroshell)
- Propulsive + Aerobraking
3. Rideshare with lunar mission

Orbit Insertion options
- Propulsive
  - Mono prop.
  - SEP
- Aerocapture (ADEPT)
- Propulsive + Aerobraking
1. Dedicated Mission to Venus: Capture options comparison

- Propulsive (400 x 400 km)
- Propulsive + Aerobraking (400 x 60,000 km)
- Aerocapture (400 x 400 km)

Delivered Mass Fraction:
- Propulsive: 0.7
- Aerocapture: 2.3x propulsive
- Propulsive + Aerobraking: 2.8x propulsive
2. Rideshare with mission flying to/ by Venus

\[ V_\infty = 5 \text{ km/s} \]

- Propulsive (400 x 400 km): 3x
- Aerocapture (400 x 400 km): 4.8x
- Propulsive + Aerobraking (400 x 60,000 km): 2.7x
2. Rideshare with mission flying to/by Venus

\[ V_\infty = 10 \text{ km/s} \]
3. Rideshare with lunar mission

- Propulsive (400 x 400 km)
- Aerocapture (400 x 400 km)
- Propulsive + Aerobraking (400 x 60,000 km)
- SEP [6] (bound large orbit)
Summary

1. Aerocapture at Venus is feasible using existing low L/D aeroshells, or using drag modulation systems in development. No new technology is required.

2. Propulsive capture + aerobraking to lower orbit allows most mass delivered, if the time (several months) for aerobraking is acceptable.

3. Aerocapture offers mass benefit over aerobraking if,
   - entry system payload mass fraction > 0.7
   - or, for getting into orbit from high $V_\infty$ flyby mission

4. If low Venus orbit is desired immediately upon arrival, then compared to propulsive alone option, aerocapture offers:
   - 2.3x mass for dedicated large orbiter
   - 3.6x mass for SmallSat ride-along with Venus mission
   - 2.3x mass for SmallSat orbiter ride-along from lunar mission
Acknowledgements

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V-BOSS: Venus Bridge Orbiter and Surface System (S. Oleson et al.) study preliminary report was used for rideshare from lunar mission calculations.
References

Backup Slides
Venus Exploration Domains

- CubeSat (5 kg)
- SmallSat (100 kg)
- Aerial platforms (weeks)
- Comm. relay
- Sample return orbiter
- Ascent vehicle
- Descent probe
- Short lived lander (hours)
- Long lived lander (days)
Aerocapture

- Periapsis Raise Maneuver (PRM)
- Science Orbit
- Coast phase
- Too steep
- Too shallow
- Approach navigation
- Interplanetary cruise, Arrival $V_\infty$
Aerocapture at Venus is feasible using existing low L/D aeroshells like MSL (L/D=0.24) and HEEET TPS material (7000 W/cm²).
Aerocapture at Venus is feasible using ADEPT-like drag modulation systems in development, with a $\beta_{2}/\beta_{1}$ of $\sim 10$, and carbon cloth TPS.

The entry corridor for drag modulation aerocapture is smaller than that for lift modulation.

Navigation studies will need to be done to assess if entry flight path angle errors can be reduced to a level required for it to fit within the drag modulation corridor.
### Venus Aerocapture Payload Mass Fraction

<table>
<thead>
<tr>
<th>Payload Mass Frac.</th>
<th>Rigid lifting aeroshell</th>
<th>ADEPT</th>
<th>Nano-ADEPT</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>57% *</td>
<td>50%</td>
<td>50%#</td>
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* Estimated for using an MSL-like aeroshell for Venus aerocapture

# Estimated to be the same as full-scale ADEPT
Dedicated Launch to Venus – Trajectory Data

Delivered Mass to 400 km x 400 km Orbit, 1000 kg Launch Mass

- Propulsive Capture + Aerobraking
- Aerocapture
- Propulsive Capture

Launch Date
Rideshare with mission flying to/by Venus

Delivered Mass to 400 km x 400 km Orbit, 180 kg Mass Allocation.

- Propulsive Capture + Aerobraking
- Aerocapture
- Propulsive Capture

Launch Date

Delivered Mass into Orbit, after VOI (kg)
Venus Mission Implementation Pathways

- **Dedicated Launch**
  - **Rideshare Options**
    - Missions to/flyby Venus
      - GTO/Lunar
      - Low-thrust
      - Chemical
  - Transfer Option
    - Propulsive
    - Propulsive + AB
    - Aerocapture

- **Capture Option**