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Venus Lander Design

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The Mission
The students were tasked to design an Entry, Descent, and Landing (EDL) system for a lander to reach the surface of Venus. The project’s design requirements included specified landing location, maximum acceleration, time of descent, etc. Using a combination of 3D modelling and programming the students designed the EDL within given constraints under specific tolerances.

Inspiration
Lander missions to any planet can provide useful insights. One potential insight that could be gained by studying Venus is a deeper understanding of the runaway greenhouse effect. This understanding could be critical in the mitigation of a similar fate on Earth.

Environmental Challenges
Exploring Venus poses many challenges, such as extremely high pressures (~90 Earth atmospheres at the surface), high temperatures (>450 °C), volcanic activity, sulfuric acid clouds, uneven terrain, etc.

The Plan
The team decided to break the descent into three phases (as seen in the graphic below). In order to understand how the motion through the atmosphere takes place, the lander’s descent through the atmosphere was modeled by a set of six simultaneous differential equations.

The State Variables

The Simulation
Since all state variables (velocity, radius, pitch, yaw, latitude and longitude) are dependent on each other, they must be solved simultaneously at each stage, at each time step. The size of the time step will determine the accuracy of the model. The following plots were obtained to highlight key features of the EDL:

Aeroheating
During the entry stage, the velocity is significant (11.3 km/s). This causes heat generation to the aeroshell due to convective heat and radiative heat.

$$Q_{total} = Q_{convective} + Q_{radiative}$$

Convective and radiative heat both depend on air density, vehicle velocity, and nose radius. When an entry vehicle travels at high speeds air molecules bounce off of the front of the vehicle and collide with oncoming air molecules, resulting in a shockwave. The resulting shockwave impacts further air molecules in front of the vehicle, heating the air around it. This convective heat is the primary source of heat transfer. The shockwave also dissociates atmospheric gas into asymmetric diatomic molecules. The molecules reform into diatomic molecules in the shock layer. These new molecules have a high vibrational temperature that transforms the energy from vibrational to radiative (radiative heat transfer).

Landing Considerations
When landing on the planet, the vehicle is travelling at 4.5 m/s. A cylindrical crush plate is used to minimize the force of impact on the spherical payload. Additionally, to design for steep landing conditions, stabilizing legs were implemented in the design to maintain proper orientation.

Special Thanks
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