Hochschule Bremen
City University of Applied Sciences

Atmospheric re-entry

Guided Work (2)

Prof. Dr.-Ing. Uwe Apel

Task (1)

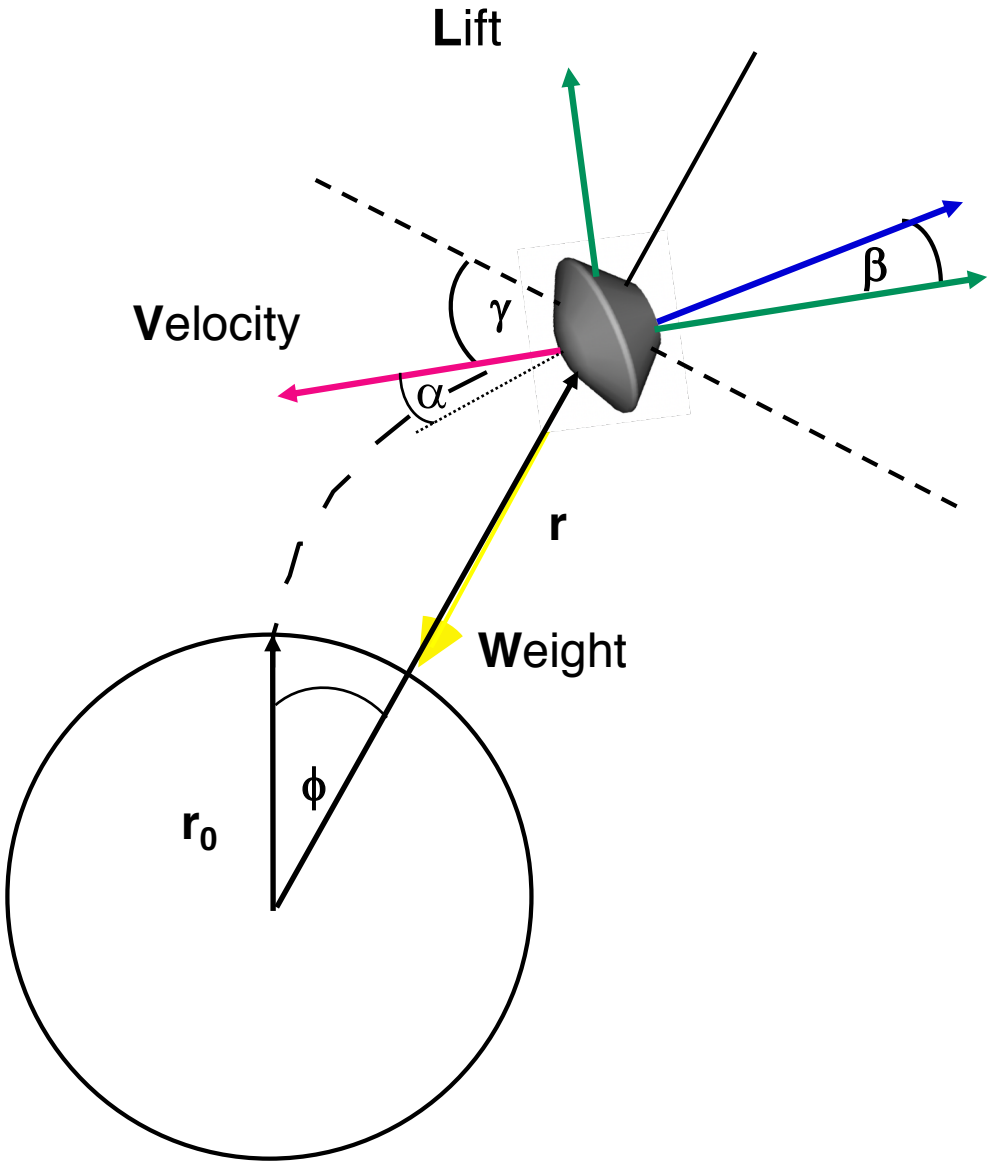
Establish a simulation model for the re-entry trajectory of your selected re-entry mission including the following features:

- Calculate and plot vehicle mass, acceleration, velocity, Mach number, altitude and distance over ground as a function of time
- The simulation shall be two-dimensional (only the motion of the vehicle in the plane of the re-entry trajectory is considered) relative to fixed coordinate system in the centre of the central body
- The central body is considered as a sphere, its gravity field as homogenous and spherical
- The atmosphere of the central body is considered moving with the same angular speed as the central body

Task (2)

- A simplified atmospheric describing pressure, temperature and density over altitude between ground and 120 km altitude shall be used. Above 120 km altitude the atmospheric density and pressure can considered to be 0
- Simulation shall start at the point leaving the orbit (re-entry burn) around the planet and stops when reaching ground
- For the the Lift and Drag coefficients as functions of Mach number M and angle of attack α use the calculation model you have already established during the first group work session
- Use a fixed angle of attack α for a first simulation run. Later, you may vary α with Mach number in order to control acceleration of the vehicle
- As a starting point for your simulation model a simplified ascent trajectory simulation for a sounding rocket is provided as Matlab® code: Sounding_Rocket_2DOF.m (main program)
  Rocket_2DOF.m (functions)

Simplified two-dimensional re-entry trajectory



$$\frac{dV}{dt} = \frac{T \cdot \cos(\beta) - D}{m} + \frac{\mu}{r^2} \cdot \sin(\gamma)$$

$$\frac{d\gamma}{dt} = \frac{T \cdot \sin(\beta) + L}{m} + \left(\frac{\mu}{r^2 \cdot V} - \frac{V}{r}\right) \cdot \cos(\gamma)$$

$$\frac{dr}{dt} = -V \cdot \sin(\gamma)$$

$$\frac{d\phi}{dt} = \frac{V}{r} \cdot \cos(\gamma)$$

$$\frac{dm}{dt} = -\dot{m}$$

Definition of Forces and Parameters

- Thrust Force (if propulsive re-entry, if not T=0) $T = \dot{m} \cdot C$
- Lift Force $L = \frac{\rho}{2} \cdot w^2 \cdot A \cdot C_L$
- Drag Force $D = \frac{\rho}{2} \cdot w^2 \cdot A \cdot C_D$
- Flow velocity depending on vehicle velocity and atmosphere velocity in fixed coordinates $w = f\left(V, V_{rot}(r)\right)$
- Density as function of Altitude according to used atmosphere model $\rho = \rho(r)$
- Lift and Drag coefficients of re-entry vehicle $C_D = f\left(M, \alpha\right)$ $C_L = f\left(M, \alpha\right)$