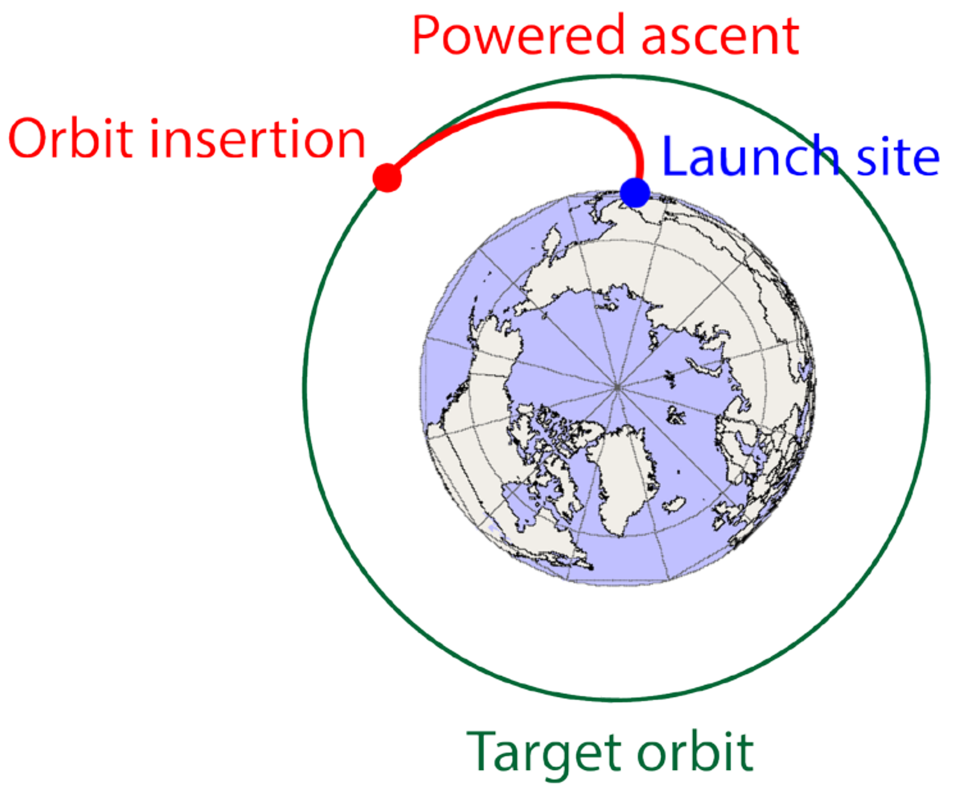
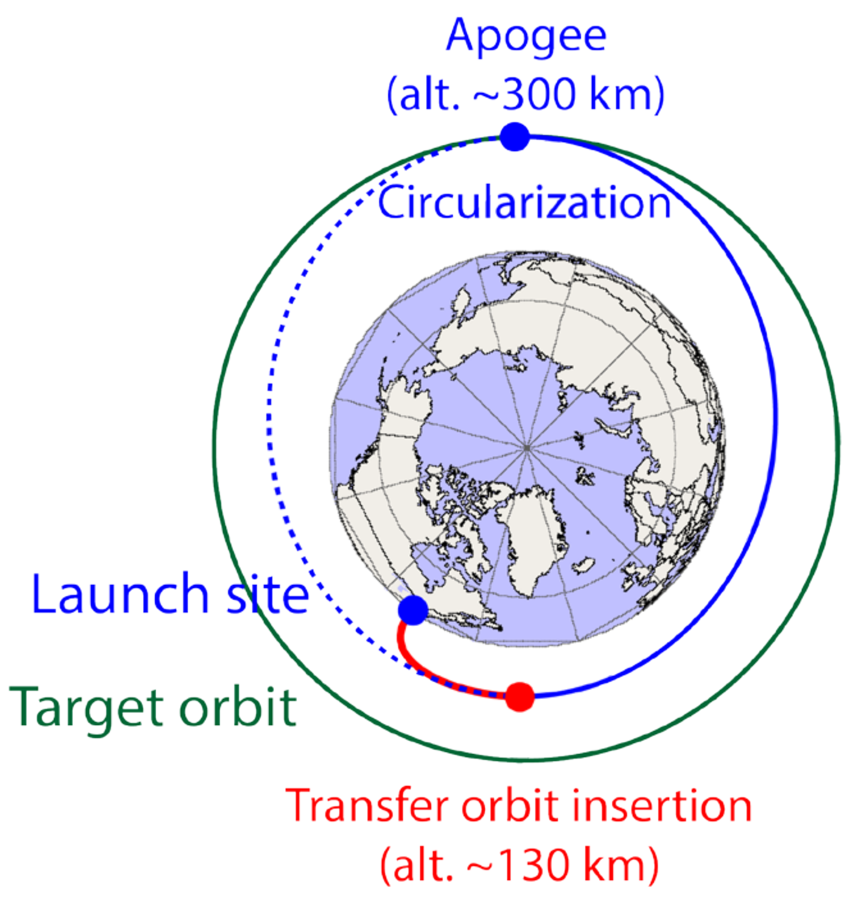




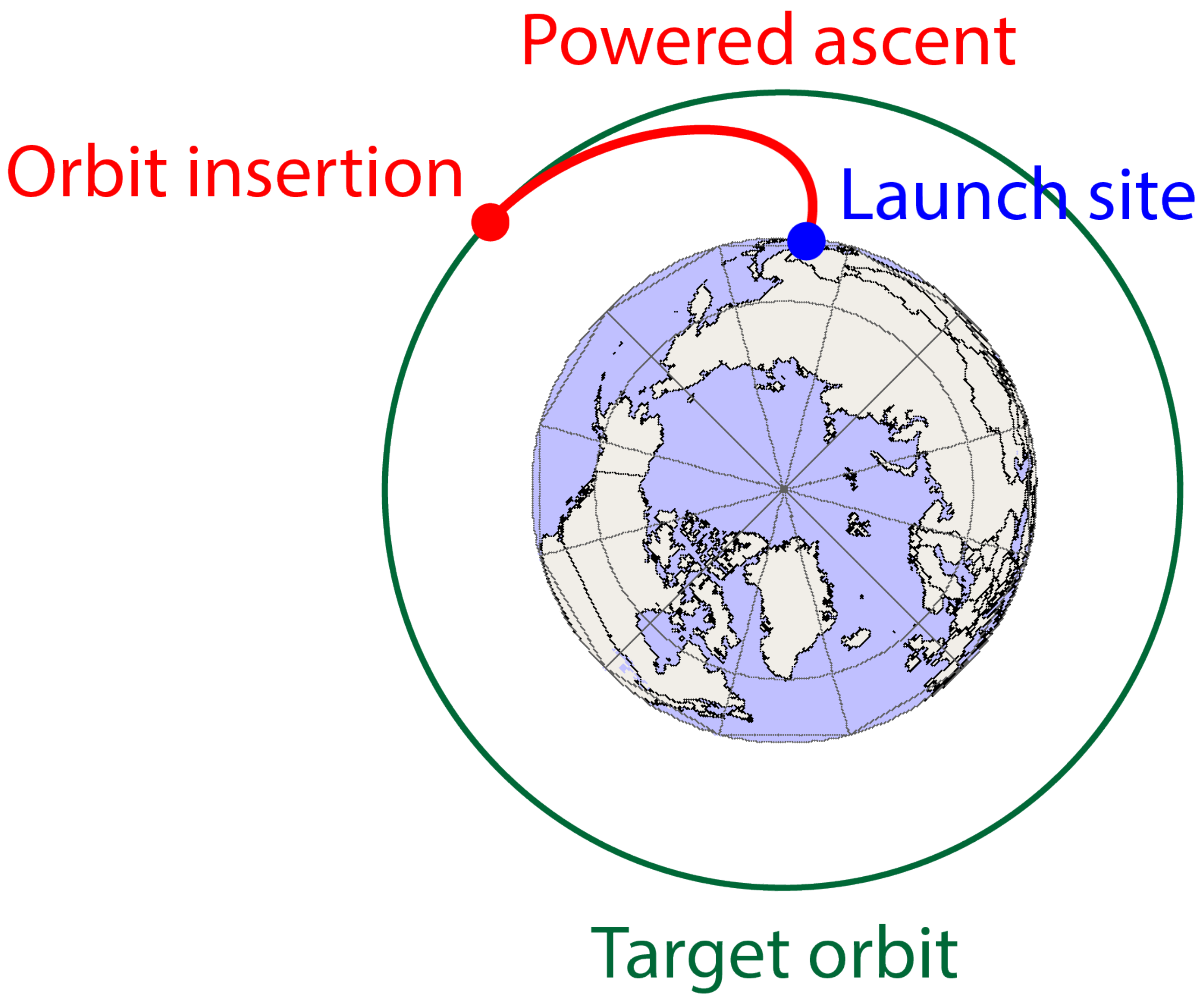
4.5.1 Ascent to space and re-entry

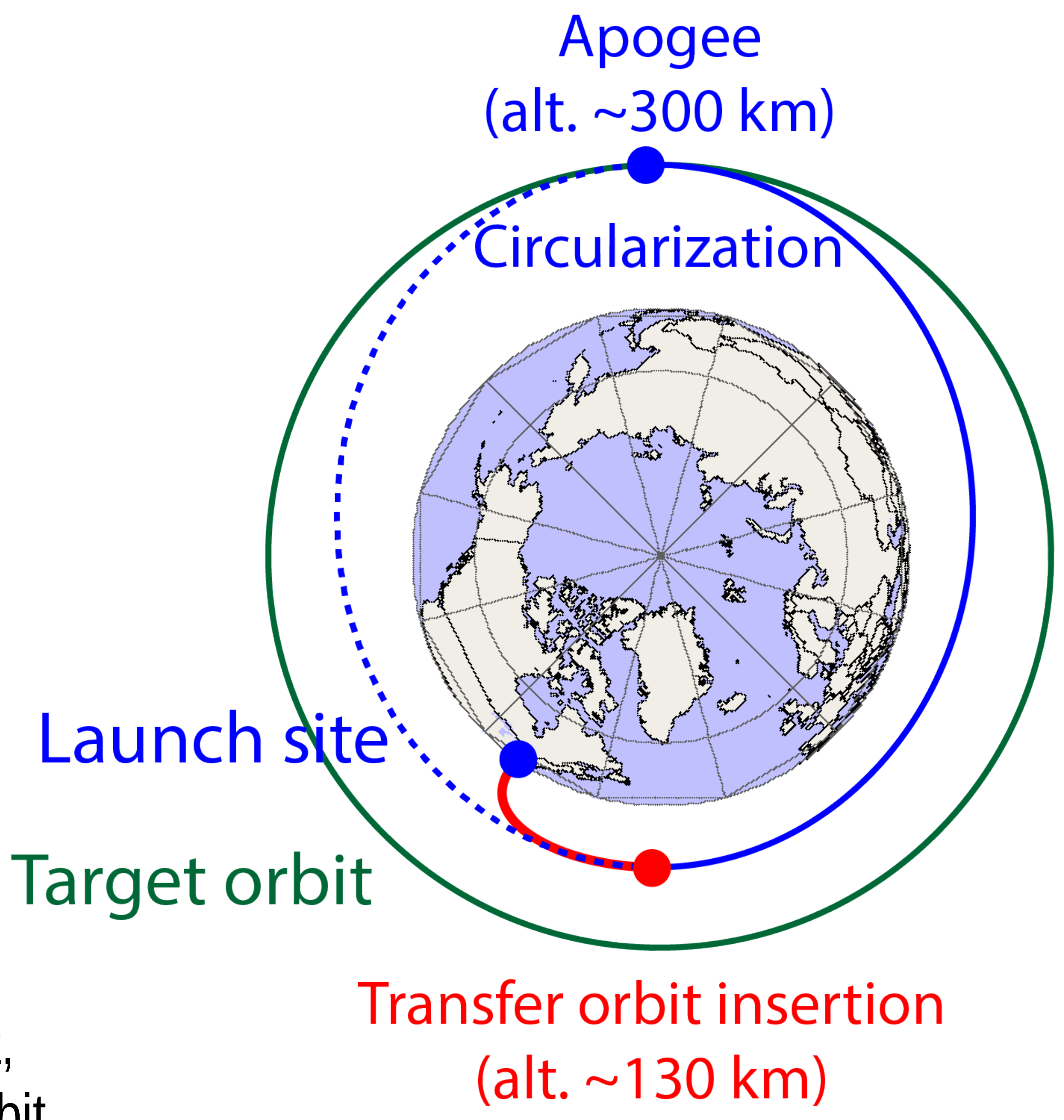
Space Mission Design and Operations

Prof. Claude Nicollier

Orbit insertion

Orbit insertion consists in bringing a spacecraft to a desired stable orbit after a launch from the Earth surface.

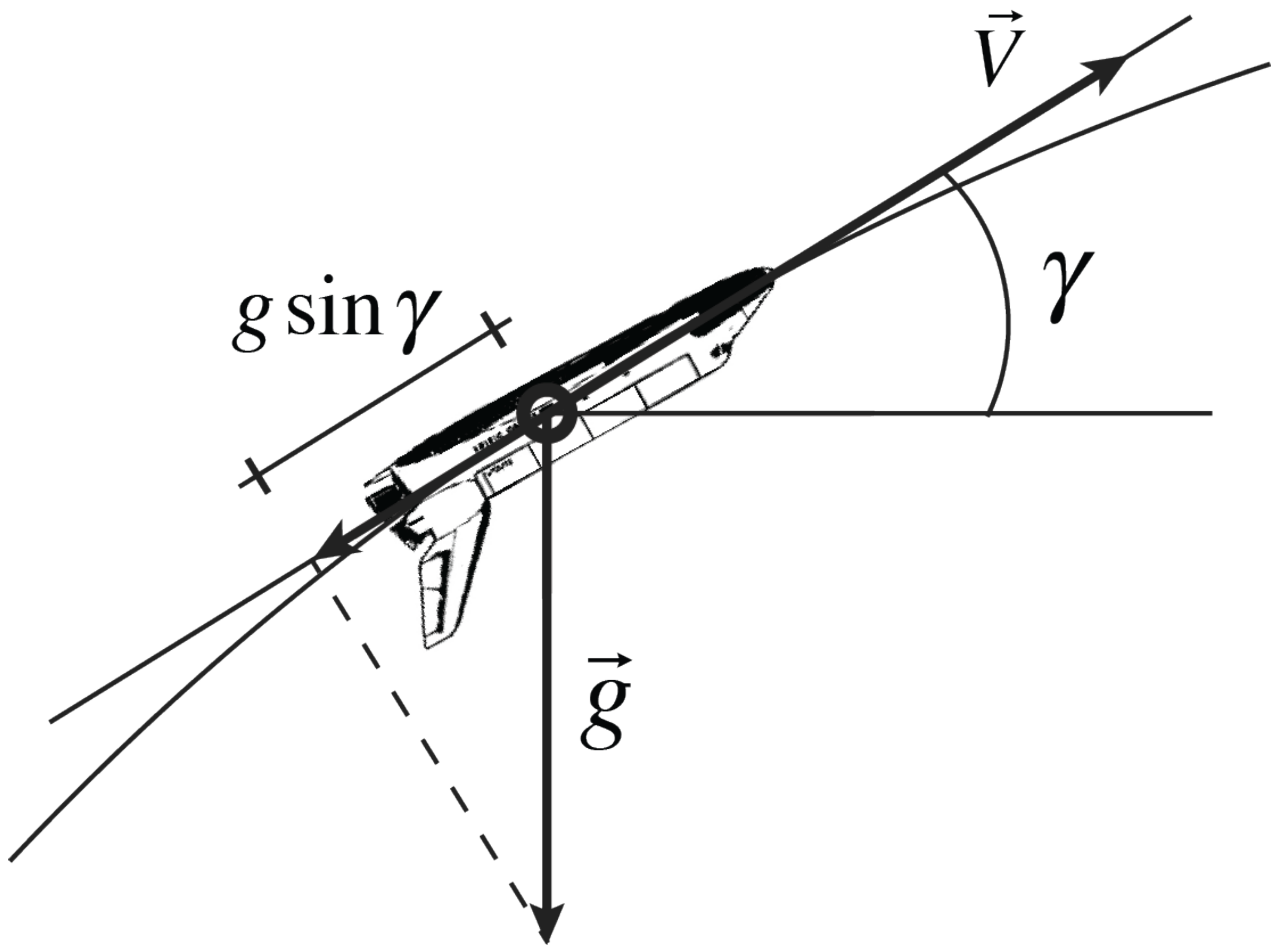




Direct insertion into orbit: initial launch at the vertical, powered ascent, using the propulsion system of either one, two or three stages until orbit insertion.

Losses during ascent to orbit

$$\Delta V = g I_{sp} \log_e \left(\frac{m_i}{m_f} \right) - \left(\int_{t_0}^{t_f} g \sin \gamma dt + \int_{t_0}^{t_f} \frac{D}{m} dt \right)$$

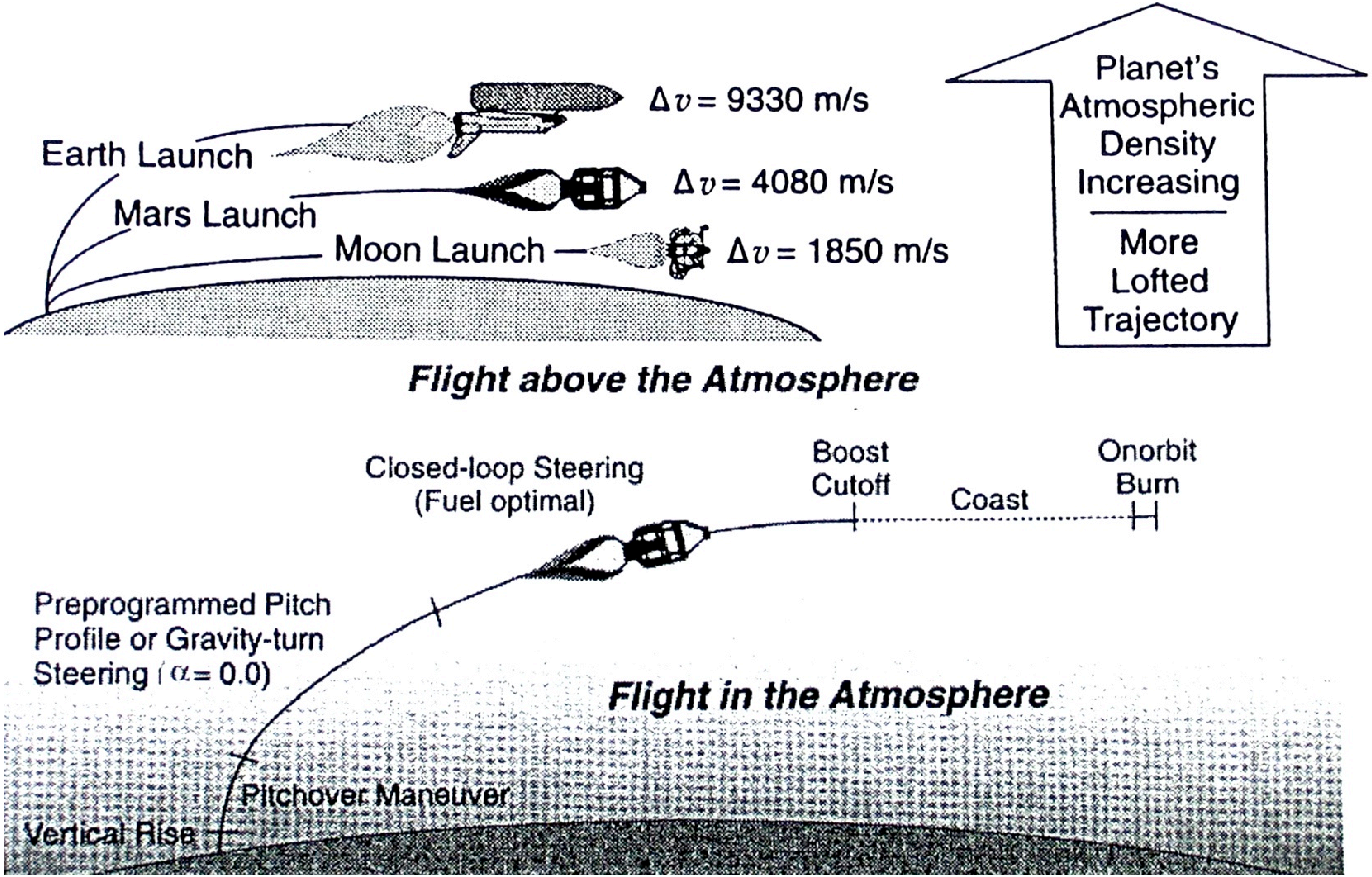


Losses during ascent to orbit: gravity loss and drag loss
The idea is to shape the ascent trajectory to minimize these losses.

- D: drag force in Newton
- ϒ: flight path angle

Different cases of orbit insertion

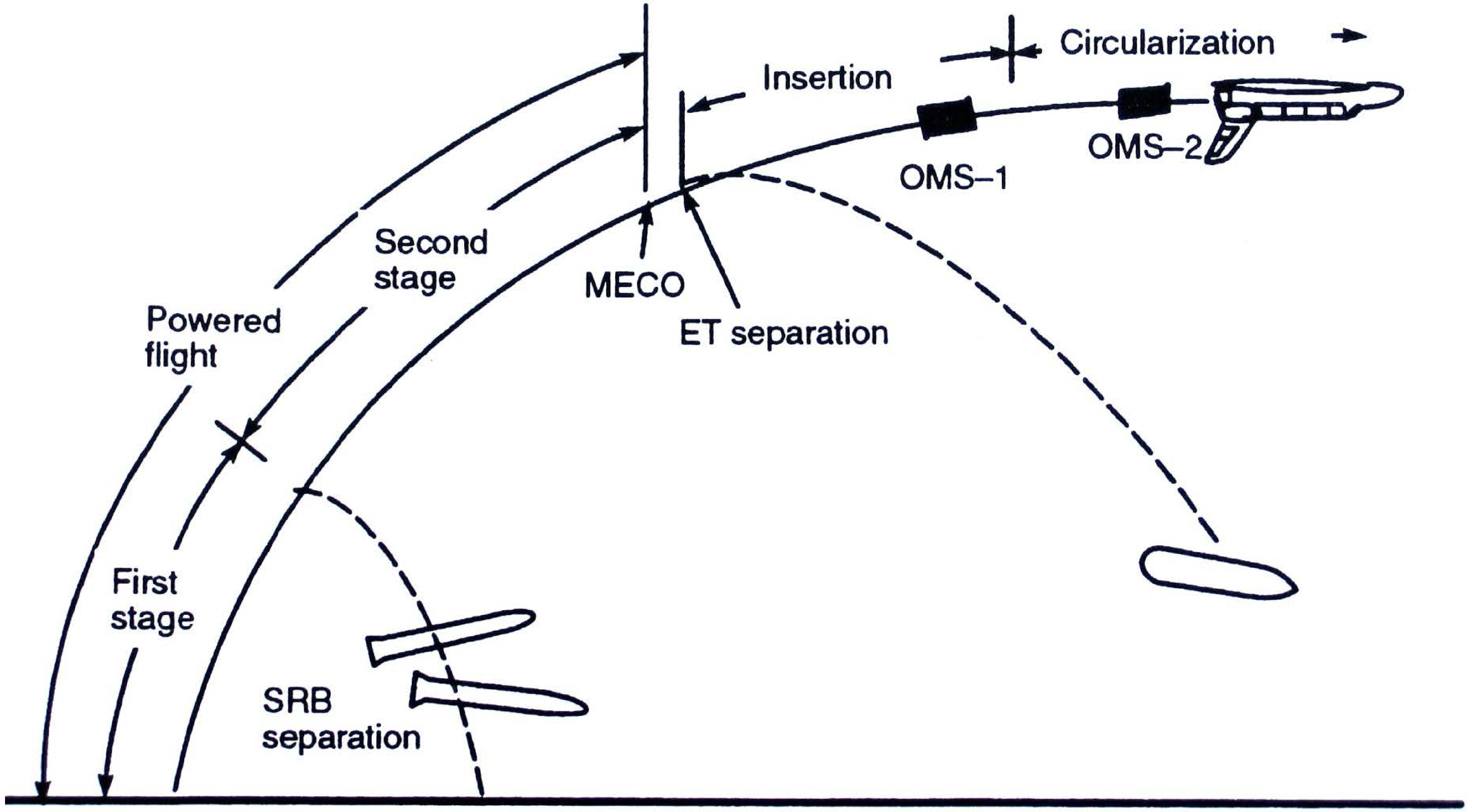
For Earth launch, the ascent trajectory shall be lofted because of the atmosphere. On a planet with thinner atmosphere like Mars, loft is less necessary.
Moon case: no atmosphere, only gravity loss if the trajectory is too lofted, so after very short period of vertical launch to reduce the gravity loss the spacecraft goes toward the desired direction.



Credits: Documention of the training division for NASA astronauts in the 90's.

Shuttle ascent to orbit

Shuttle mission STS 41G, 1984

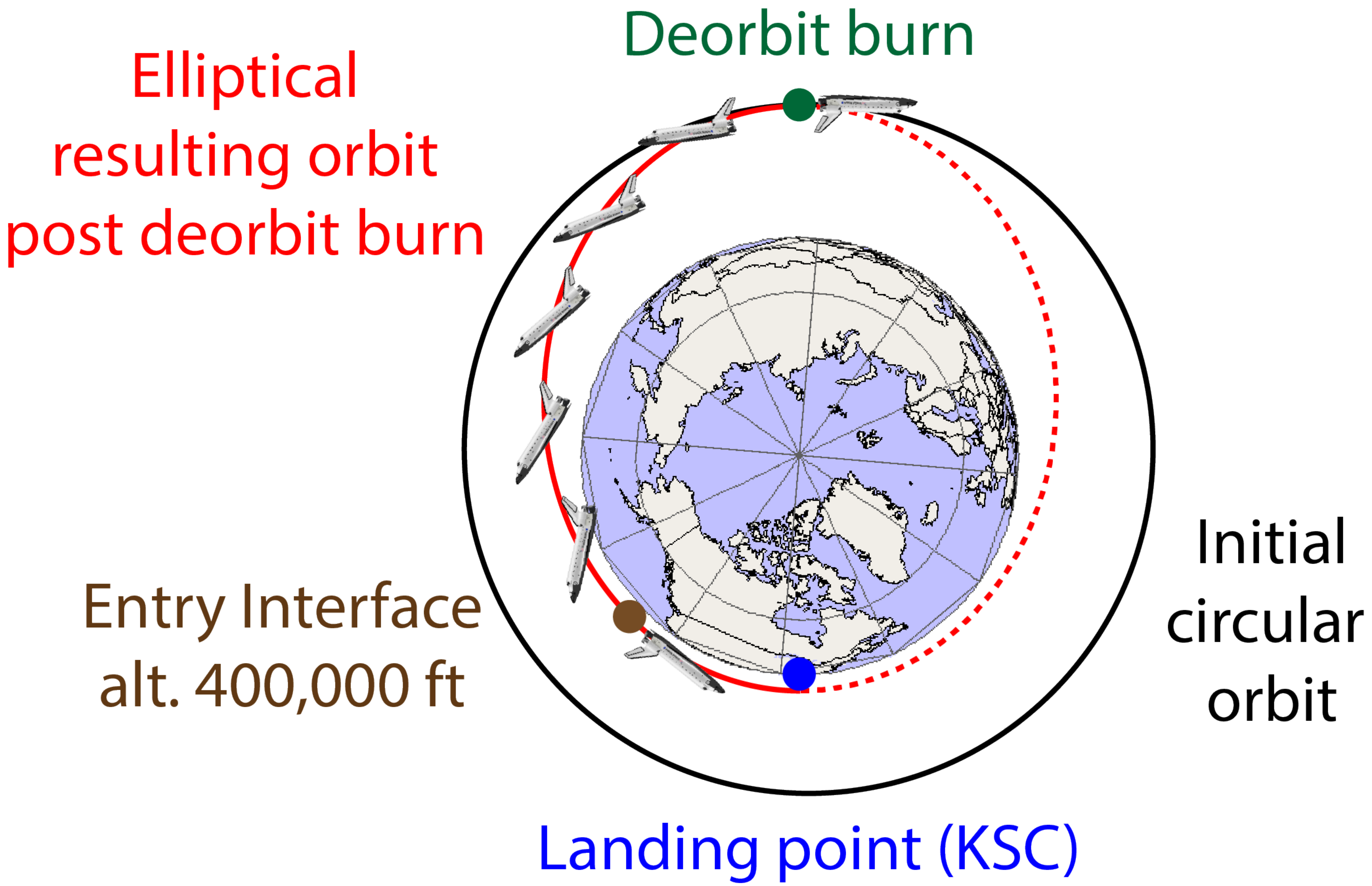


SRB: Solid Rocket Booster   MECO: main engine cut off   ET: external tank
OMS-1, OMS-2: Posigrade burns at the apogee of transfer orbit to circularize the trajectory

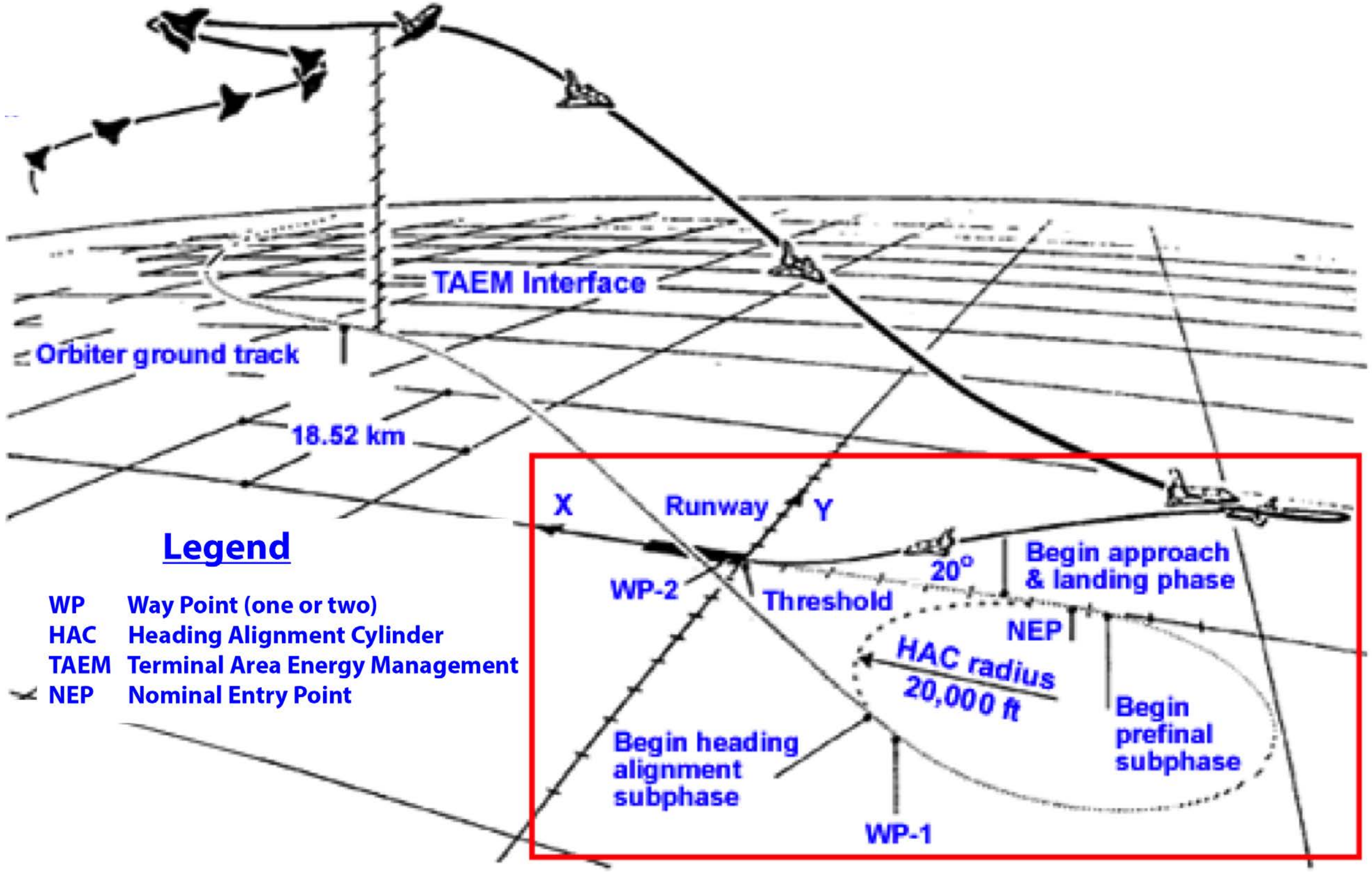
Credits: Documention of the training division for NASA astronauts in the 90's.

Shuttle re-entry

The deorbit burn is a braking maneuver, realized by using the OMS engine to reduce the velocity and modify to the orbit which perigee is above the landing point.
Angle of attack: 40º



Shuttle final approach to landing



TAEM interface: Terminal Area Energy Management interface.
HAC: Heading Alignment Cylinder

Re-entry through the atmosphere

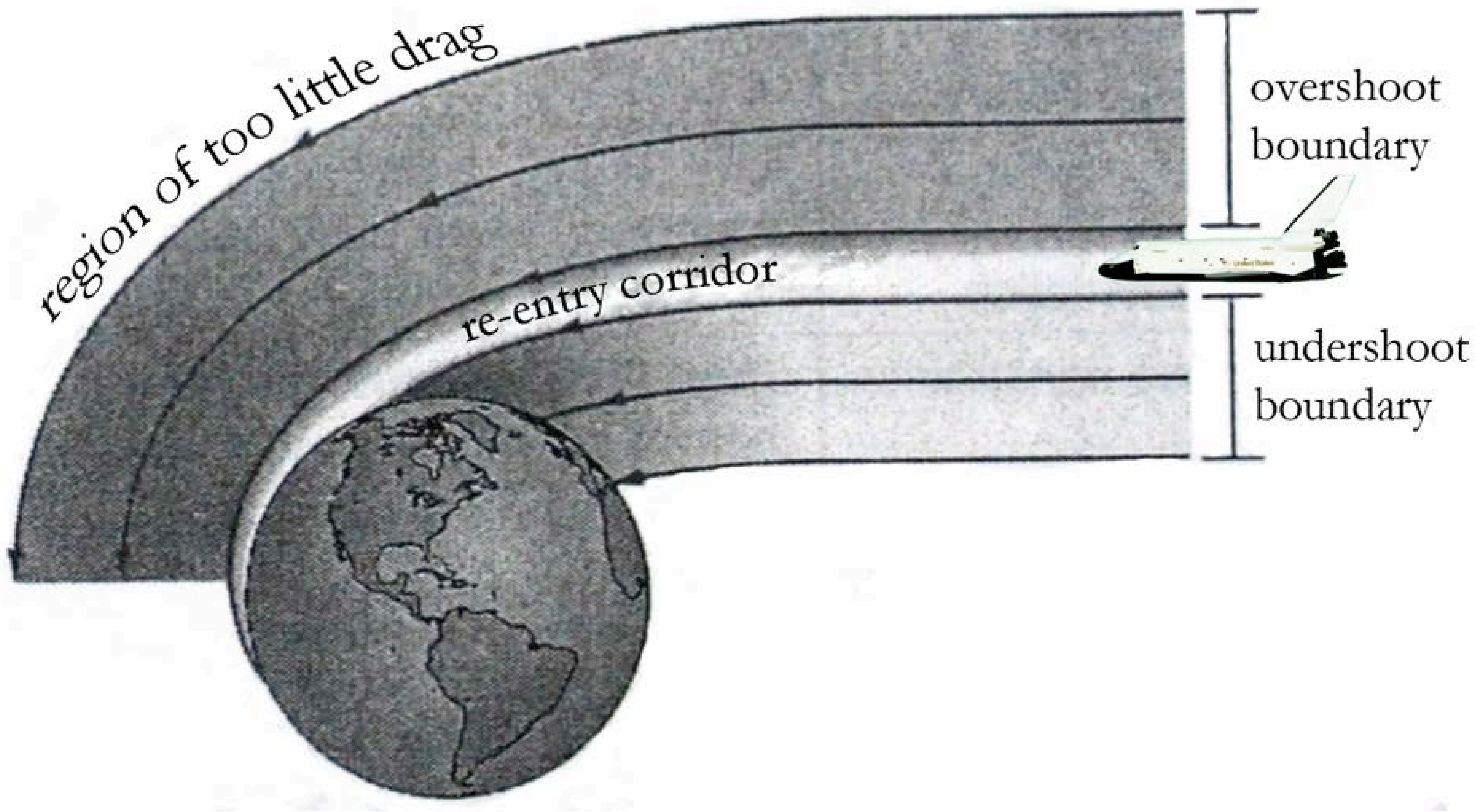
- Entry requirements and constraints:

  - Deceleration: Human limit is about 12g's for short duration.

  - Heating: Must withstand both total heat load and peak heating rate.

  - Accuracy of landing or impact: Function primarily of trajectory and vehicle design.

  - Size of the entry corridor: The size of the corridor depends on three constraints (deceleration, heating and accuracy).



Entry requirements and constraints applicable for any re-entry vehicle, which does not have a destructive re-entry

Credits: Documention of the training division for NASA astronauts in the 90's.