AEROBRAKING STRATEGY FOR MARS EXPLORATION MISSIONS

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In the context of Mars exploration missions, the aerobraking strategy has been brought to the fore as an alternative to a fully propulsive scenario for the insertion into the target science orbit.

The purpose of the aerobraking technique is to reduce the energy of a highly elliptical orbit, transforming it into a low-eccentricity, low-altitude orbit by successive atmospheric passes. In each pass, a small part of the S/C energy is dissipated into heat by aerodynamic friction mainly on the S/C solar panels, thus enabling progressive orbit apoapsis lowering and orbit period reduction.

While **technically more complicated, longer and operationally more demanding** than a fully chemical orbit insertion, the aerobraking strategy is implemented in Mars missions because it allows for **large ΔV savings**, so as to reduce the propellant budget for the science orbit acquisition.

The definition of the **heat flux / dynamic pressure corridor** width to guarantee S/C integrity during aerobraking has a key impact on the aerobraking duration and on the number of periapsis control manoeuvres to be performed. Thermal and lifetime limits (which generally require higher altitudes to increase margin) are traded with aerobraking duration and number of drag passes (which require lower altitudes for minimisation). The primary means to deal with these margins is the **apoapsis manoeuvre strategy that raises or lowers the periapsis altitude** to adjust the drag achieved on each pass, taking into account the changing Mars atmospheric conditions.

A typical aerobraking scenario covers the following operational phases:

- In the initial **"walk-in" phase**, the periapsis altitude is progressively decreased from its initial value until the nominal heat flux level is reached.
- During the **main phase**, the key criterion for periapsis altitude control is the limitation in terms of heat flux / dynamic pressure.
- In the **"walk-out" phase**, the periapsis altitude is progressively increased and orbit lifetime is the major driver to ensure that the apoapsis remains above a safety altitude limit (~300 km) for few days without control.
- Finally, science orbit acquisition manoeuvres are performed (**termination**).

This paper provides an overview of the approach for the analysis of the aerobraking scenario of a Mars mission, streamlining the aerobraking phases and highlighting the key issues and drivers. To assess the impact and the effectiveness of the aerobraking strategy, two ESA missions are addressed as representative study cases, namely ExoMars (under development) and MarsGen (mission concept), since both envisage the use of the aerobraking technique to achieve the target Mars orbit. The results obtained encompass aerobraking ΔV budget, duration and operational implications, and they are intended to draw the roadmap for an exhaustive assessment of the aerobraking scenario for future Mars exploration missions.