Contribution to the Mars Sample Return campaign with the Earth Return Orbiter (ERO) is under study by ESA. ERO will launch in 2026 on an Ariane 64 with the objective of bringing Mars samples back to Earth before the end of the 2020’s. For this objective the ERO will be equipped with a sample handling payload (to capture and bio-seal the orbiting sample) and an Earth return capsule (ERC) that will be deployed from the hyperbolic approach to Earth.

Unlike previous ESA missions to Mars, the use of electric propulsion (EP) is being considered for the ERO. ESOC’s Mission Analysis Section is supporting the ERO definition studies by exploring the vast mission design trade space of full-EP and hybrid Mars return missions, using a combination of EP and chemical propulsion (CP) to optimise the mission profile.

ERO’s mission options consist of the following:

- launch and direct escape from Earth
- outbound transfer using EP
- possible Mars orbit injection manoeuvre using chemical engine (if hybrid architecture)
- target orbit acquisition spiraling down to low Mars orbit (LMO) using EP
- rendezvous and retrieval of the orbiting sample
- departure orbit acquisition spiraling up from LMO using EP
- possible Trans-Earth Injection manoeuvre to leave Mars using a chemical engine (if hybrid)
- inbound transfer to Earth using EP
- ERC delivery to the appropriate entry conditions for a landing in the Utah Test and Training Range.

The mission design process involves the generation of a database of optimal EP transfers, both outbound & inbound, for an extensive grid of departure dates and transfer durations. The outbound transfer optimisation is subject to the constraint imposed by the capability of the launcher and the Mars arrival velocity (assumed zero for full-EP missions). The optimal mass delivered to Mars can be represented in a plot (Fig. 1) together with the Earth escape velocity in order to analyse sensitivities with respect to launch date and duration.

Similarly the inbound transfer is optimised considering a fixed mass returned to Earth and for varying the Mars escape velocity. Similar plots for the inbound transfer allow the analysis of the sensitivities of transfer performance and Earth arrival velocity with respect to the departure and arrival dates.

For given launch and Earth arrival dates, the end-to-end mission design is analysed using the results from the transfers database and analytical models for the chemical burns and the phases in EP spiraling. An internal optimisation is performed to obtain the outbound and inbound transfer durations subject to different criteria. A figure of merit that increases mission success probability is the stay time in LMO that can be maximised subject to the feasibility of the mission in terms of mass arriving and departing from LMO.

Different EP technologies and power levels of the platform are being investigated by performing parametric analysis of the main parameters related to the EP system. The resulting information is being used to identify feasible architectures for the ERO.