University of STUTTGART
INSTITUTE OF SPACE SYSTEMS

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Master Thesis Opportunity:

System Requirement Study of an Active Magnetic Shield for High Enthalpy Earth Entry

Motivation:

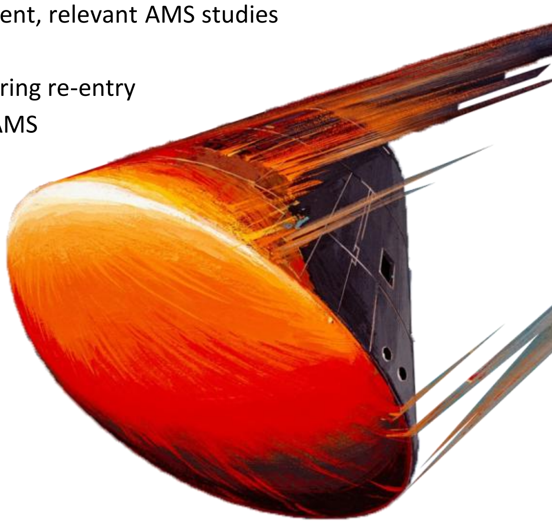
During atmospheric entry from high-energy trajectories, a shock layer forms that dissociates and partially ionizes compressed air, enabling interaction with an applied magnetic field. This MHD interaction induces circumferential electric currents that generate Lorentz forces via Ohm's law, decelerating and repelling the flow behind the shock front and modifying the shock standoff distance. Early experiments in air shock tubes and arc-heated plasma flows have confirmed these effects.

Within the EU Horizon 2020 MEESST initiative, the first experimental campaign using high-temperature superconducting (HTS) technology for magnetic shielding in high-enthalpy conditions was conducted at the Institute of Space Systems. The campaign demonstrated that the applied B-field significantly affects the shock standoff distance, the heat flux distribution, and the stagnation pressure. A key advantage of HTS solenoids is their reduced current and cooling power requirements, which enable scalable high B-fluxes and higher magnetic flux densities compared to conventional solenoids and permanent magnets. Although HTS systems are more complex and costlier, their benefits are critical for active MHD shielding onboard spacecraft.

What remains unknown is the net reduction in thermal protection system (TPS) mass achievable with an active MHD shield (AMS). This thesis will assess the typical mass, volume, and power ratios of re-entry spacecraft systems, using examples such as Orion, Apollo, Hayabusa, Stardust, and Nyx capsules, and estimate the AMS system architecture requirements. In a subsequent phase, a one-dimensional re-entry propagator, adjustable with artificial HF reduction rates, will be developed and validated against flight data. Finally, the TPS mass reduction will be estimated, laying the foundation for future projections of mass, power, and volume budgets for a flight-capable AMS

Task description of the Master thesis work:

- Literature review on spacecraft design, thermal and power management, relevant AMS studies
- Recognition of AMS requirements and boundary conditions
- Development of a simplified model to estimate AMS effectiveness during re-entry
- Estimation of mass, power, and volume budgets for a flight-capable AMS
- Validation of the model against existing literature and MEESST data
- Documentation in English



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