Chair of Space Mobility and Propulsion
Department of Aerospace and Geodesy
TUM School of Engineering and Design
Technische Universität München

Bachelor / Master's Thesis

Quantifying the Impact of Advanced Control Strategies on Rocket Propelled Spacecrafts

Background

The space industry is currently undergoing a structural change. Reusable launch systems are becoming central to access to space and will continue to gain importance in the coming years. Increased operational lifetime, more aggressive flight profiles and propulsive landing strategies increase the operational demands on launch vehicles.

At the same time, exploration missions to the Moon and Mars require a very high degree of reliability, especially in the context of crewed missions. Recent events have shown how challenging these systems remain. The crash of Roscosmos's Luna-25 mission, the landing failure of ISRO's Chandrayaan-2, and anomalies during integrated flight tests of SpaceX's Starship vehicle illustrate that propulsion, guidance and control remain mission-critical subsystems.

Future vehicles relying on rocket propulsion (whether for access to space, in-space transportation, or planetary landing) must therefore combine performance, agility and robustness. Achieving this requires dedicated control strategies, including:

- Implementation of fault-tolerant control architectures that maintain stability and performance despite propulsion system anomalies
- Adaptive control strategies that compensate for changing system dynamics due to degradation and aging
- Lifetime-aware control approaches that actively reduce thermal and mechanical loads to extend engine operational life
- Robust control design capable of compensating for manufacturing tolerances and parameter uncertainties
- High-precision nonlinear tracking control under strict state and input constraints

These aspects are often discussed qualitatively. However, their quantitative impact on mission-level metrics such as reliability, availability, propellant consumption and cost has not yet been systematically assessed.

Objective of the Study

The goal of this research project is to quantify the impact of the required control strategies on reusable, autonomous rocket propelled vehicles. The associated research question reads:

"Which control-related technological improvements have the highest impact on mission-critical performance indicators?"

To answer this question, a modular framework is required, including 6-DoF vehicle flight dynamics, representative abstractions of propulsion and engine dynamics and motion planning to facilitate the assessment of various mission scenarios for different vehicles.

Scope and Tasks

This project is designed as a collaborative research effort involving multiple students. Each student will work on a defined subset of the overall framework. Depending on the starting date and thesis level (Bachelor or Master), the scope may include:

- Literature review on nonlinear simulation, modelling and motion planning (for instance via constrained optimization)
- Design and implementation of a modular spacecraft simulation environment in Python
- Implementation of motion planning via constrained optimization
- Analysis of one selected technological lever (e.g. fault tolerance, lifetime-aware control, etc.)
- Quantitative assessment of its impact on mission-critical performance indicators
- Documentation and presentation of results

Candidate Profile

We are looking for highly motivated students who combine a strong interest in space propulsion with analytical thinking and solid programming skills.

Requirements:

- Strong interest in modelling, simulation and control
- Experience with Python
- Experience with software development (version control with git, object-oriented programming)
- Independent and structured working style
- Beneficial: Experience with modelling dynamical systems, numerical simulation, constrained optimization

Our Offer

The Chair of Space Mobility and Propulsion is located at the TUM Campus in Ottobrunn (south of Munich), embedded in a strong aerospace ecosystem.

We offer:

- The opportunity to work on a technically demanding and highly relevant research topic
- Working in a team of students, where you can exchange and learn from each other’s experiences
- The possibility to deepen your expertise in control, optimization and rocket propulsion
- Flexible working arrangements (remote or on-site workspace available)
- And, of course, delicious coffee ;)