Robust Verification Tools for Precision Entry Guidance

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Team Members:

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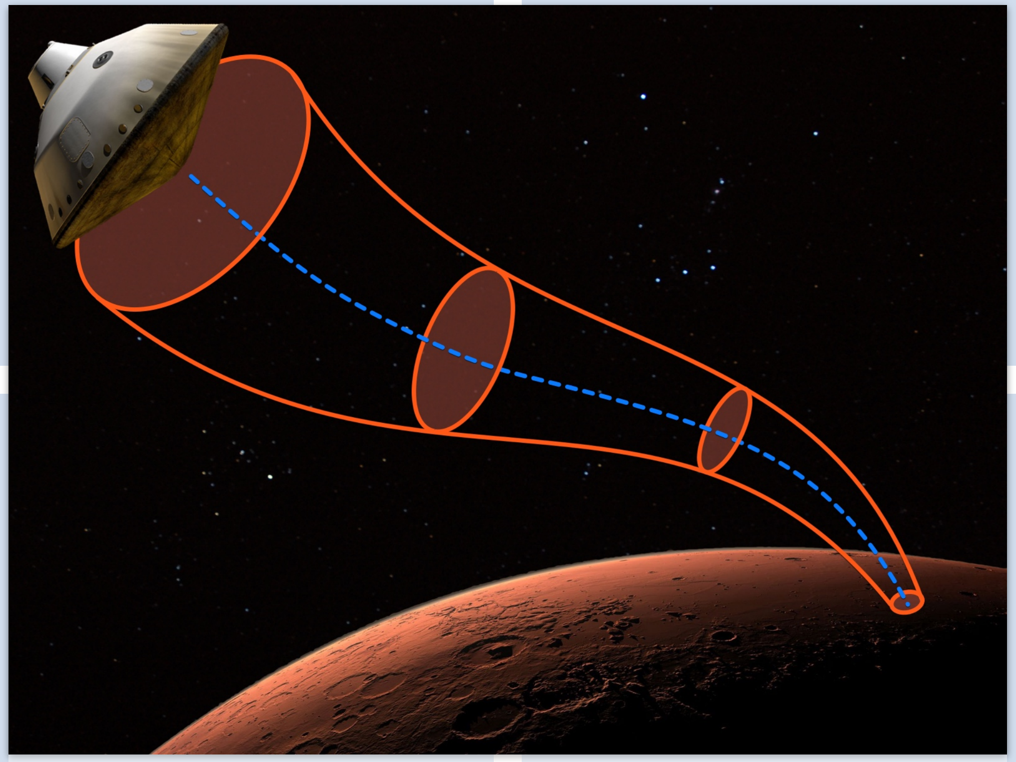
Research Objectives

This work will improve upon current state-of-the-art entry guidance methods by developing algorithms that can:

- Reason about **full 6-DOF flight dynamics**
- Generalize to **any entry vehicle** configuration
- Rigorously **account for uncertainties** and disturbances
- Provide closed-loop **performance guarantees**
- Have **minimal online computational requirements**

Start TRL: 1-2 **End TRL: 3**

The underlying mathematical theory and optimization techniques behind the proposed method are well understood. We will build practical algorithms for entry guidance and demonstrate them in simulation.



Conceptual drawing of an entry vehicle tracking a reference trajectory (shown in blue). The vehicle is guaranteed to remain in the pre-computed funnel that encloses the reference trajectory.

Approach

We will leverage recent advances in sum-of-squares optimization and motion planning for underactuated robotic systems and apply them to entry vehicle guidance.

Sum-of-squares (SOS) optimization enables computation of a robust invariant funnel around a reference trajectory. This funnel bounds the state of the closed-loop system in the presence of model errors and disturbances.

We will combine SOS verification with trajectory optimization and simple feedback control laws like LQR to create feedback policies that offer high performance and guaranteed robustness to bounded uncertainties and disturbances.

Potential Impact

Current entry guidance methods have limited precision and many are not able to handle future entry vehicle capabilities like angle-of-attack modulation and supersonic retropropulsion.

The proposed research will help enable autonomous high-precision landing on Mars and other solar system bodies with a high degree of robustness and safety. This capability is crucial to many future robotic and human-crewed NASA missions.

The new algorithms may also be applicable to other challenging guidance and control problems with a high level of uncertainty and strict safety and robustness requirements.