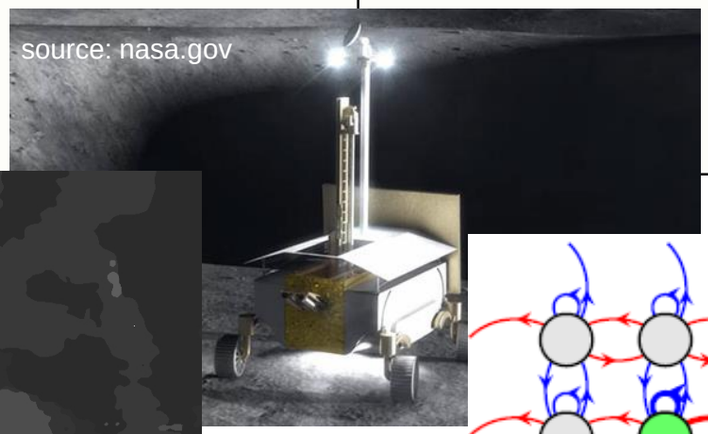
Safety-Constrained and Efficient Learning for Resilient Autonomous Space Systems

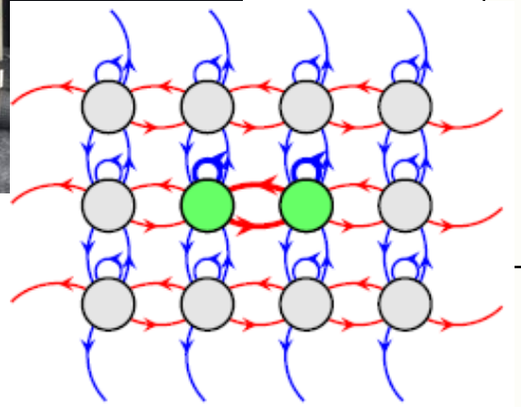
Principal Investigator: Melkior Ornik

University of Illinois at Urbana-Champaign

Co-Investigator: Ufuk Topcu,
University of Texas at Austin

Project personnel:
Two graduate students
(one at UIUC, one at UT Austin)





Theory and algorithms for safe and efficient learning, with resilience necessary for continued autonomous operations in space

Research Objectives — Innovation

- Formal guarantees for safety of IPS operating and learning in unknown environments
- Efficient active learning that exploits knowledge of previous and parallel missions
- Proactive design of intelligent systems provably adaptable to component degradation

Initial TRL: 1 (preliminary theory)
Final TRL: 3 (analytical studies + proofs of concept)

Approach

Integration of formal methods, learning, and adversarial game theory

Thrust I — Formal safety

Thrust II — Efficient learning

Thrust III — Guaranteed resilience

Demonstration and yearly assessment with concrete metrics: case study on lunar rover operations with representative models, specifications, objectives, component degradation scenarios

Potential Impact

Fundamental shift in the learning and planning:

- Systematic, composable safety specifications
- Learning about an unknown environment with no risk to system safety
- Maximal use of previously obtained knowledge
- Planning naturally suitable for integration with complementary missions
- Inbuilt adaptation to system degradation
- If mission is unviable, automatic synthesis of related viable missions