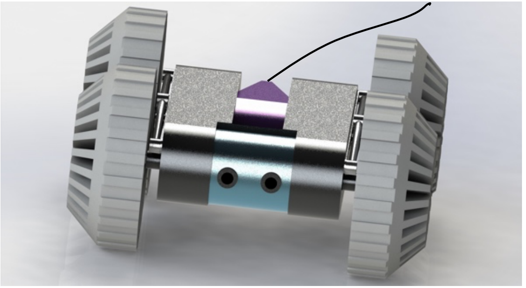
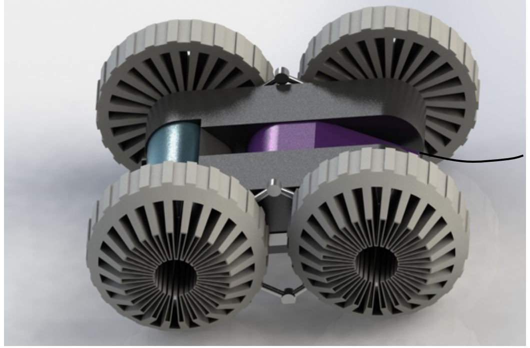
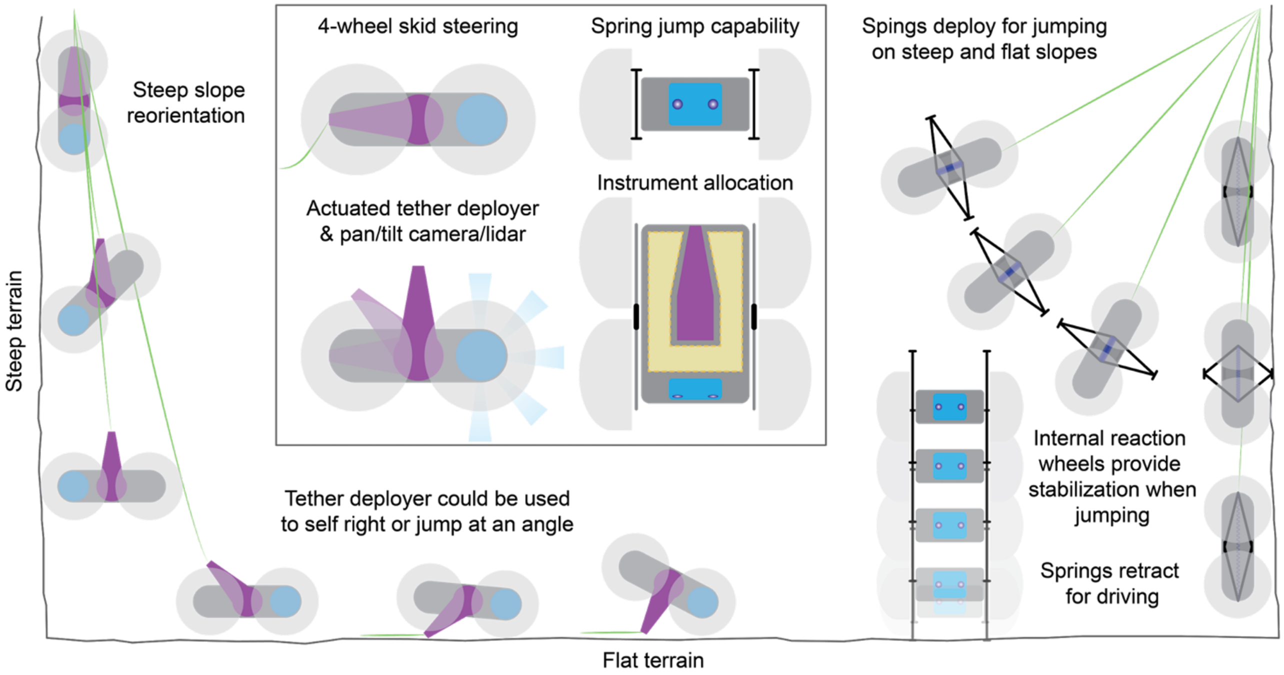






Virtual Research Presentation Conference

A concept study for ASTRA: Autonomous Steep Terrain Robotic Abseiler

Principal Investigator: Patrick McGarey (347F)
Co-Is: William Reid (347F), Benjamin Hockman (347F)

Program: Spontaneous Concept

Assigned Presentation # 256

Jet Propulsion Laboratory
California Institute of Technology

Introduction

source: www.rapjumping.com, https://www.youtube.com/watch?v=6PqXjAhBXA0

source: https://www.youtube.com/watch?v=k825hJ9vrHg

Inspired by rapid rappelers on Earth, the **Autonomous Steep-Terrain Robotic Abseiler (ASTRA)** is a new concept for a tethered hopping rover whose mobility is decoupled from the terrain by virtue of an ability to rapidly jump (abseil) up/down steep areas. The purpose of the rover is to explore extremely harsh terrains across the solar system, especially the Moon, Mars, and Icy Moons of Jupiter and Saturn

ASTRA Team: Patrick McGarey, William Reid, Benjamin Hockman (347)

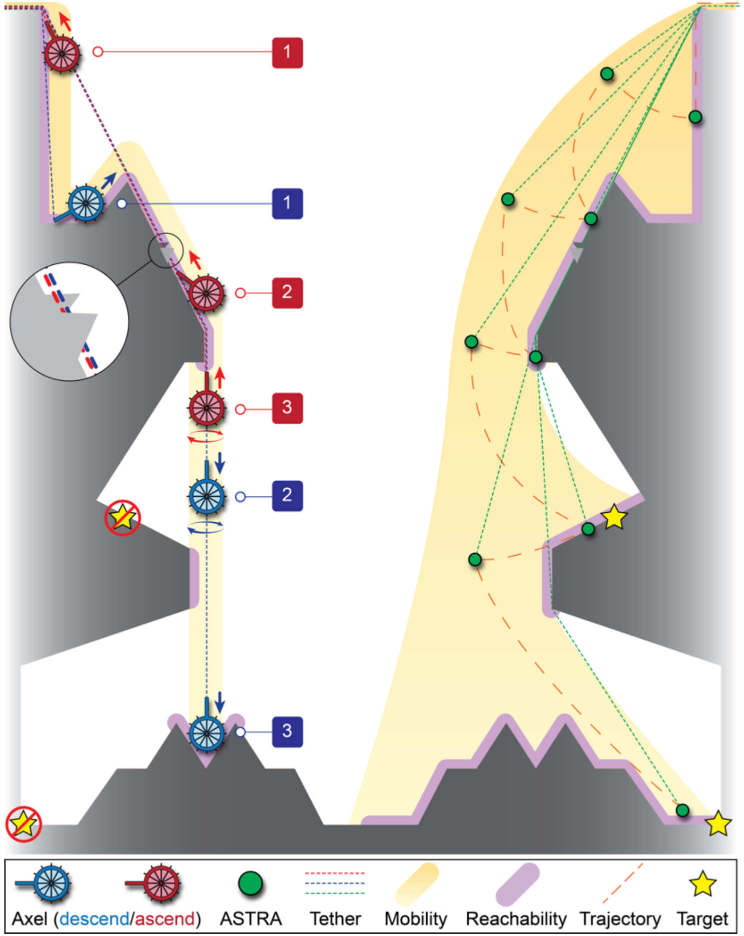
Problem Description

a) State-of-the-art platforms like JPL tethered Axel rover are designed to explore extremely steep terrains. Due to terrain uncertainty in these areas, **local upslopes and obstacles present significant hazards for exploration**. In this study we focus on the ability to bypass hazards aided by jumping over/around them.

b) **ASTRA is a tethered rover with jumping capabilities**, which makes its mobility less reliant on the terrain than existing approaches. The overall mobility workspace and thus reachability are increased, opening **new possibilities for exploration of steep features** such as craters, pits, crevasses, vents, etc.

c) An ASRTA rover enables future exploration missions to exciting targets of strategic interest to both JPL and NASA including.

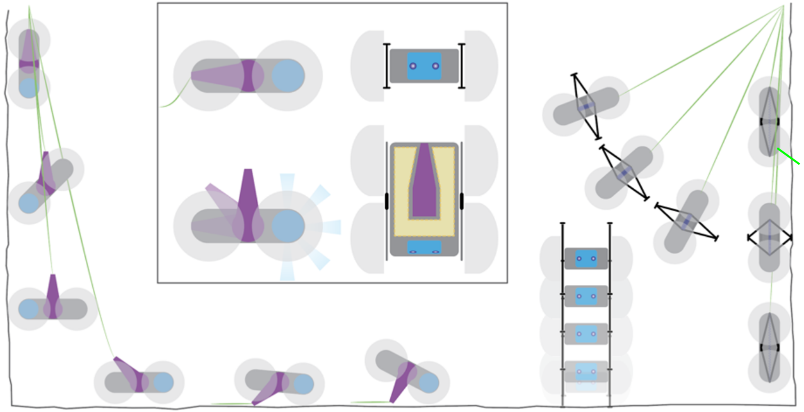
- Lunar Pits and Caves
- Crevasses on Icy Moons of Jupiter and Saturn
- Martian ice deposits on slopes, caves, and RSL features
- Low-gravity bodies

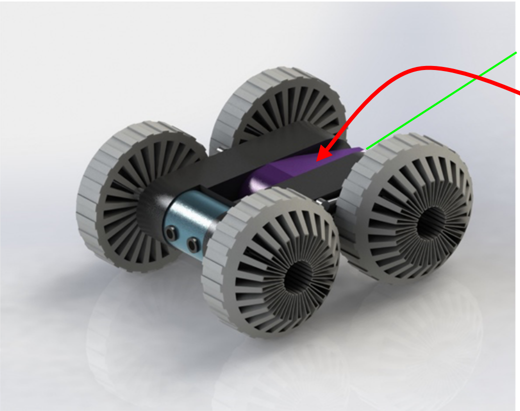


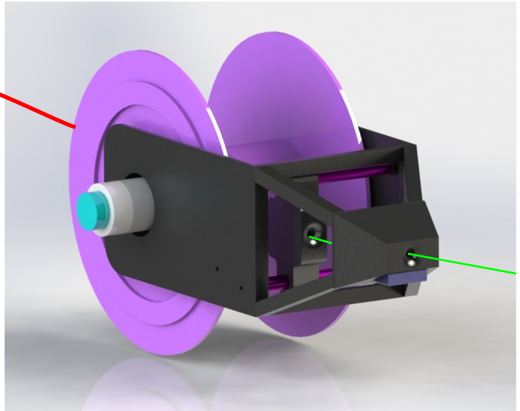
Methodology

This trade study involves a first order investigation of the following objectives.

1. Abstract unique mobility cases from natural terrain
2. Perform wheeled mobility study for sloped, obstacle-ridden terrain
3. Conduct Jumping study looking at capabilities and mechanisms
4. Design Tether control and management design to enable driving and jumping up/down slopes
5. Establish first-order point design







Results

Mobily Study

- A cross platform analysis (in 2D) was performed, looking at mobility over obstacles and up slopes (assumes constant and simple wheel)
- While mobility is best for articulated limbed vehicles, the nature of the ASTRA rover is dynamic and requires robustness for impacts when landing from a jump
- Overall, a simplistic 4-wheel skid steer vehicle was favored for it general mobility and simplicity, which provides robustness
- Large compliant wheels closely spaced are selected to provide additional advantages for skid steering, obstacle clearance, and impact absorption

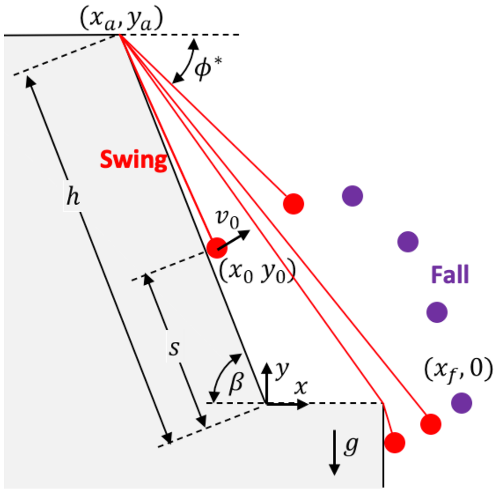
	Terrain Type					Mobility Score
Rover Type	1	2	3	4	5	
A	Infeasible (R < 0)	N/A	Infeasible (R<0)	Infeasible (R<0)	N/A	3
B	5.00	N/A	0.70	Infeasible (R < 0)	N/A	3
C	0.83	1.25	0.70	0.83	5.44	2
D	0.18	0.31	0.70	0.78	0.79	1
E	2.70	5.25	0.70	4.2	4.50	3

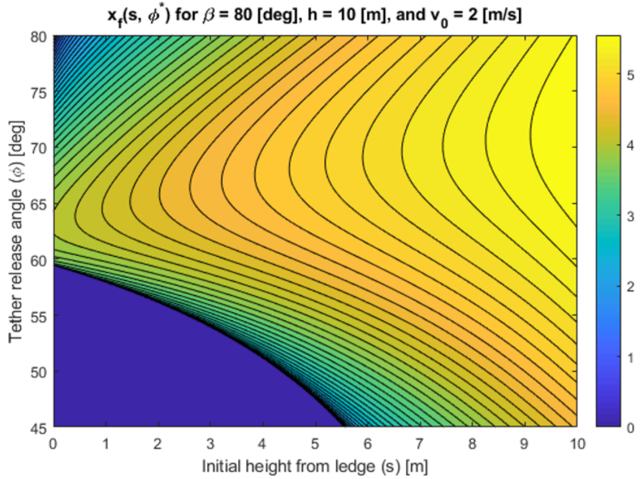
	Performance Metric		Weighted Sum (Mobility*0.5 + Num_Actuators*0.25 + Complexity*0.25)
Rover Type	Number of Mobility Actuators	Control Complexity (1:Quasi-Static Simple, 2: Quasi-Static Complex, 3: Dynamic)	
A	3	1	3(0.5)+1(0.25)+1(0.25) = 2
B	6	3	3(0.5)+2(0.25)+3(0.25) = 2.75
C	2-4	1	2(0.5)+1(0.25)+1(0.25) = 1.5
D	12-16	2	1(0.5)+3(0.25)+2(0.25) = 1.75
E	8-12	2	3(0.5)+3(0.25)+2(0.25) = 2.75

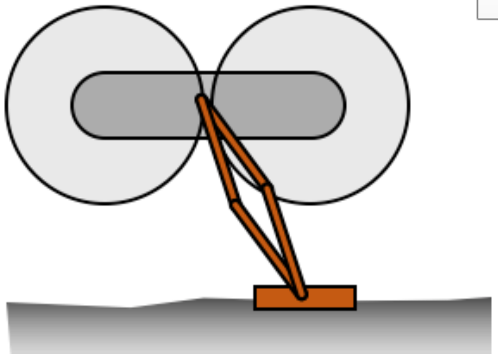
Results

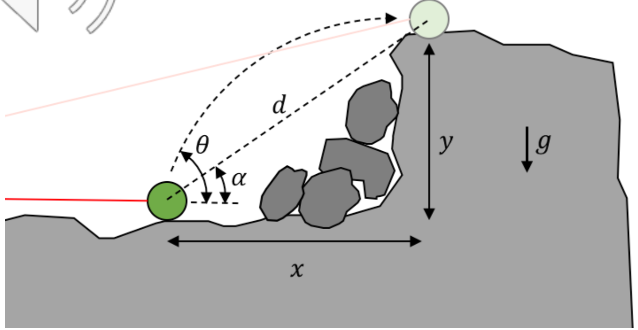
Jumping Study

- We developed a model to determine the expected clearance distance of a rover related to the jump off point, length of tether, and assuming a constant initial velocity of 2 m/s.
- The results suggest that a jumping rover has an optimal release angle, ϕ, that allows for best jumping performance
- In order to achieve jumping capability, we performed a trade looking at options ranging mechanical to chemical (propulsion) solutions
- We have determined that a linear push stroke actuated by a light-weight spring system allows for repeatable jumping and repeatable reloading





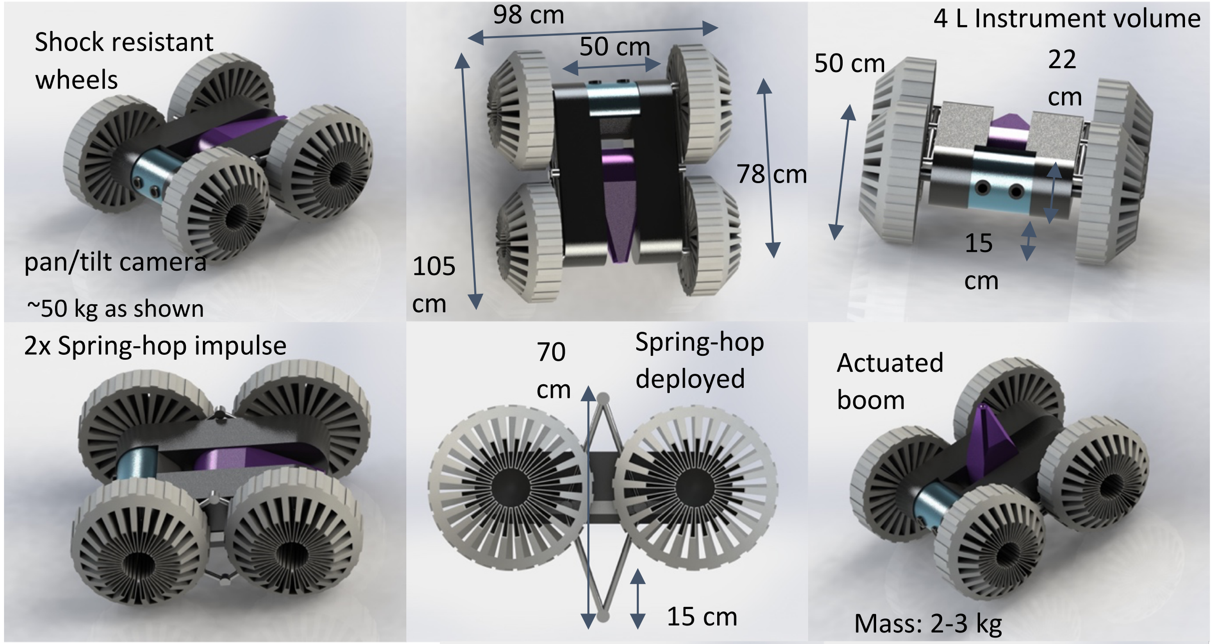


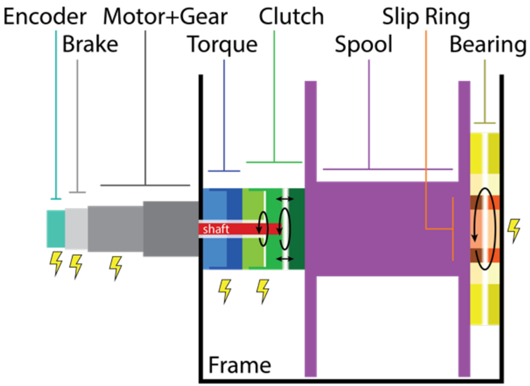


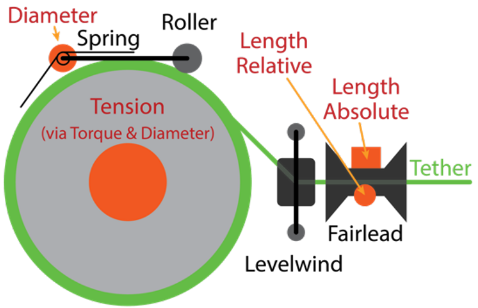
Results

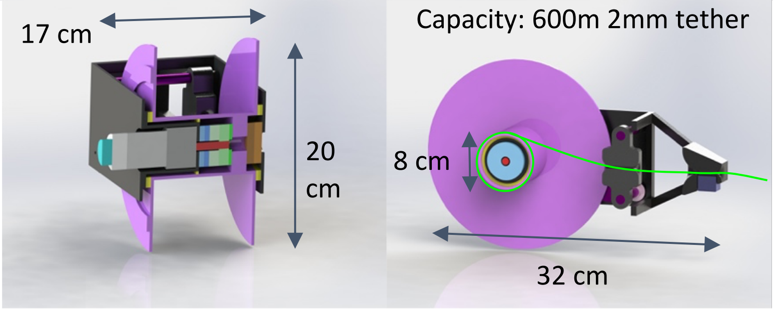
Rover Design

- Skid-steered rover with compliant wheels and spring-hop system
- Actuated tether arm/boom for self-righting and orientation
- Clutch-release tether management system with electrical pass through and tether state sensing









Publications and References

Our comparison study primarily focused on state-of-the-art systems referenced below.

[1] Nesnas, Issa AD, Jaret B. Matthews, Pablo Abad-Manterola, Joel W. Burdick, Jeffrey A. Edlund, Jack C. Morrison, Robert D. Peters et al. "Axel and DuAxel rovers for the sustainable exploration of extreme terrains." *Journal of Field Robotics* 29, no. 4 (2012): 663-685.

[2] Parness, Aaron, Neil Abcouwer, Christine Fuller, Nicholas Wiltsie, Jeremy Nash, and Brett Kennedy. "Lemur 3: A limbed climbing robot for extreme terrain mobility in space." In *2017 IEEE international conference on robotics and automation (ICRA)*, pp. 5467-5473. IEEE, 2017.

[3] Sandflea Rover, Boston Dynamics

[4] McGarey, Patrick, François Pomerleau, and Timothy D. Barfoot. "System design of a tethered robotic explorer (TReX) for 3D mapping of steep terrain and harsh environments." In *Field and Service Robotics*, pp. 267-281. Springer, Cham, 2016.

This work is protected by provisional patent filed 9/8/20