A New Form of Planetary Surface Mobility: Hoppers

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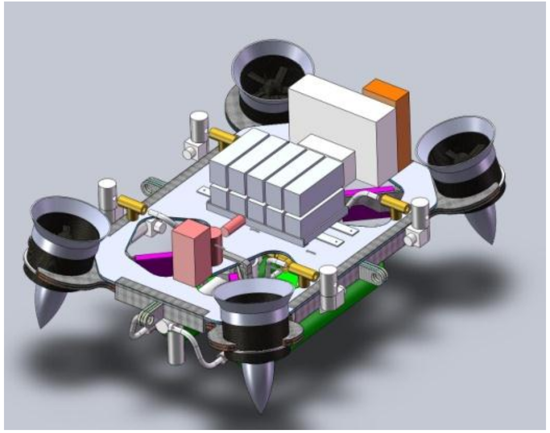
Overview

- The origins of hopping
- The basics of hopping
- TALARIS

- Current Research
  - Hopper Modeling
  - Navigation
  - Titan Hopper
  - Fractionated Mobility Systems

- Questions

Planetary Hopping



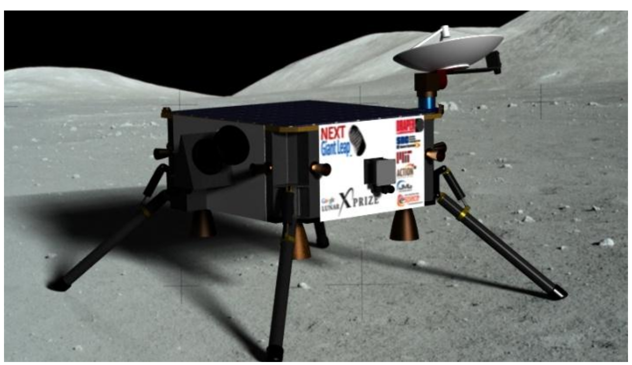
Google Lunar X-Prize

First commercial team to land on the moon, traverse 500 meters, and return imagery wins grand prize of $20M, with bonus prizes up to $5M. At least 90% of the funding must be raised privately.

Teams

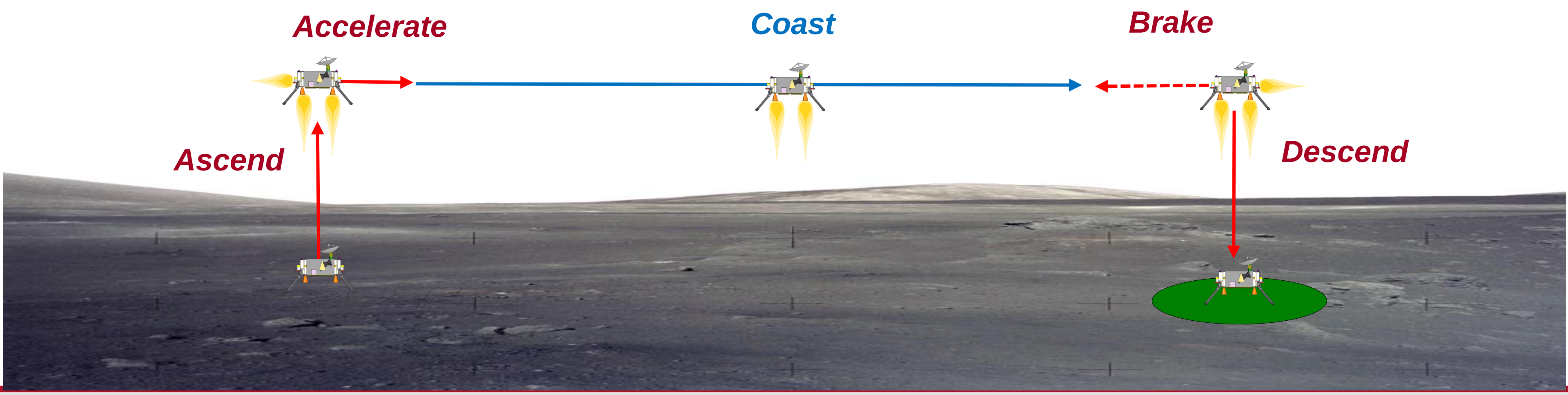
Next Giant Leap: SNC, Draper, MIT, LL

RCSP: Dynetics, Draper, Andrews, UAH



WHAT IS HOPPING?

- Most vehicles that have landed on other planets have either:
  - Orbited from up-high
  - Landed and sat still in one place
  - Landed and slowly rolled along the surface
- Hopping takes the platform that "sat still in one place" and blasts it off the surface to go land somewhere new



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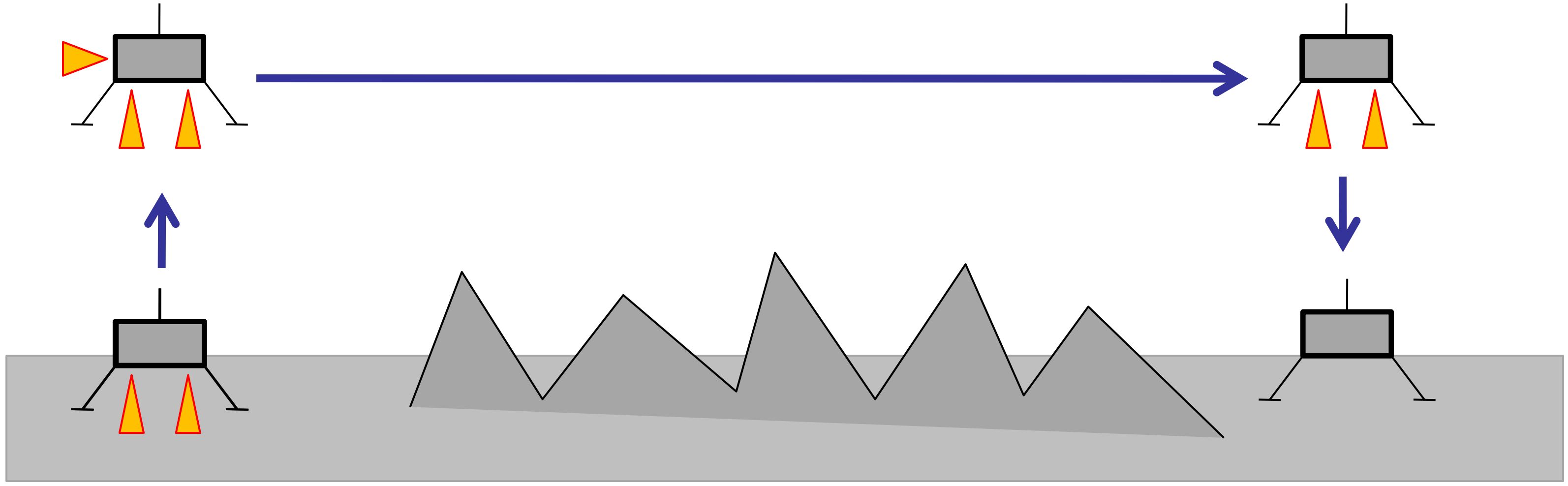
Hopper Trajectories: Hover Hop

Smaller peak Thrust to Weight ratio required, side thrusters needed

Fixed attitude, fixed altitude provides stable platform for science instruments and surface observation

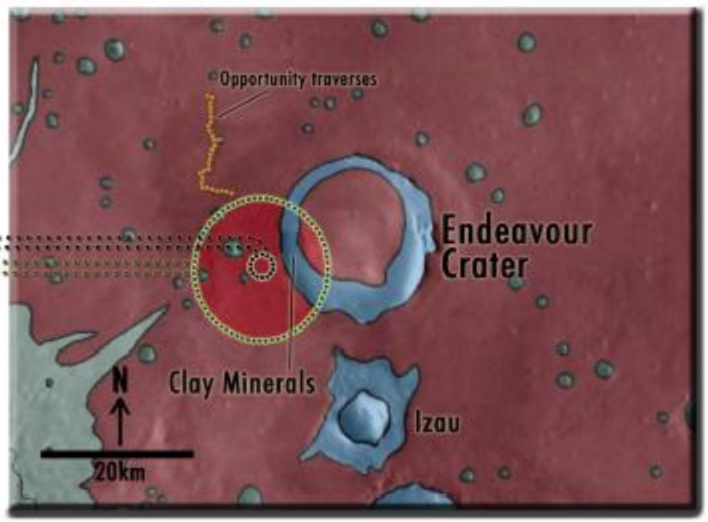
Gentler, controlled landing



TERRAIN FREEDOM

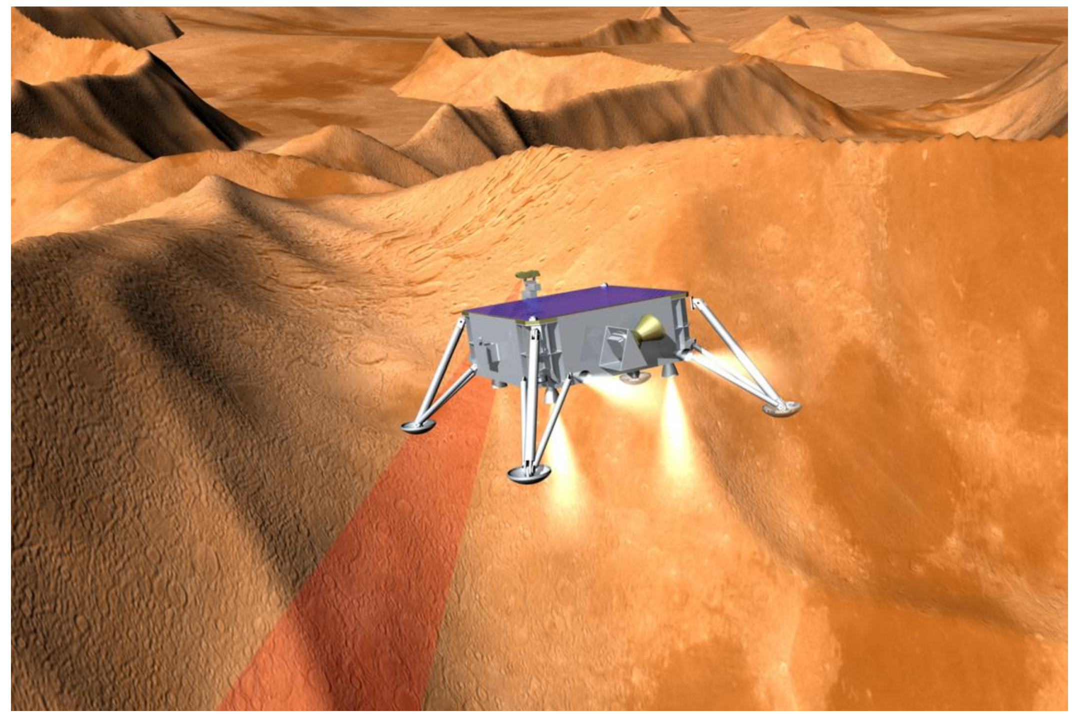
Rapid Regional Access

Mars Rovers
20 km
Several Years



Hopper
Hundreds of km
Several Hours

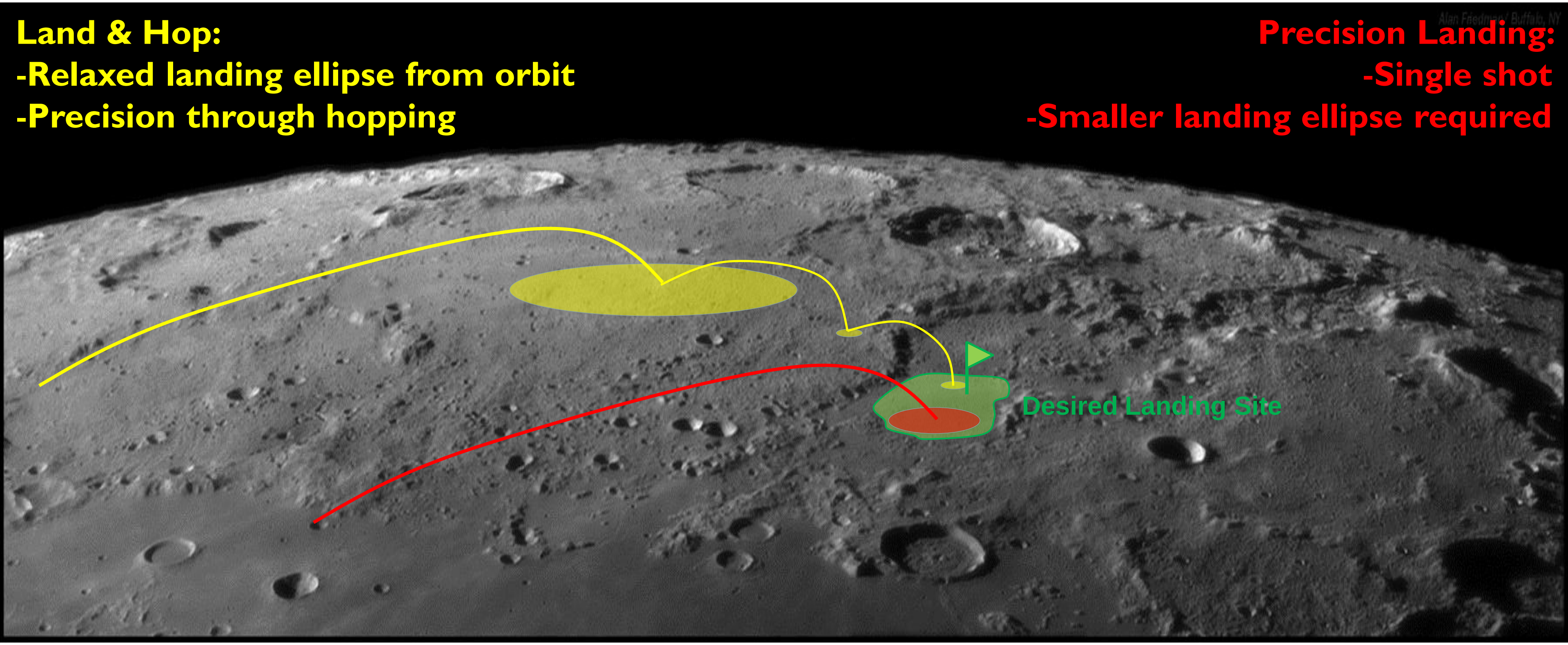
Ability to Scale Cliffs and Access Hazardous Terrain



“Ultra-Precise” Landings

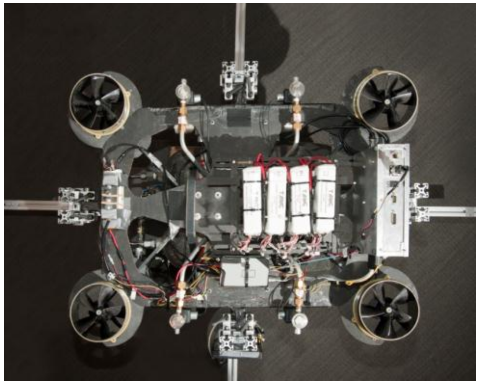
Hopper golf analogy: Achieve precision placement through several hops instead of a single landing

- “Hit the big fairway, approach, and chip in, instead of going for the hole in one”
- Land safely, determine location, then start hopping to the desired landing location



HOPPER PARTNERSHIP: DRAPER & MIT

Terrestrial **A**rtificial **L**unar **A**nd **R**educed Grav**I**ty **S**imulator

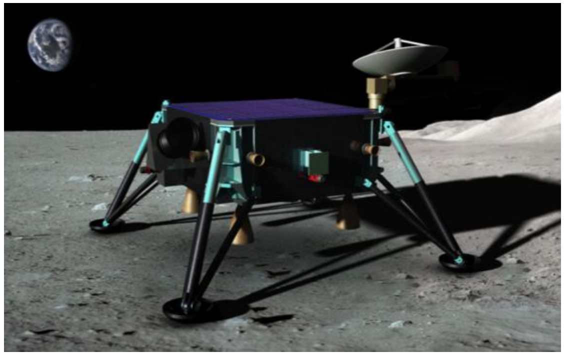


What is TALARIS?

Terrestrial hopper platform consisting of dual propulsion systems, capable of mimicking the gravity environment of other planetary bodies

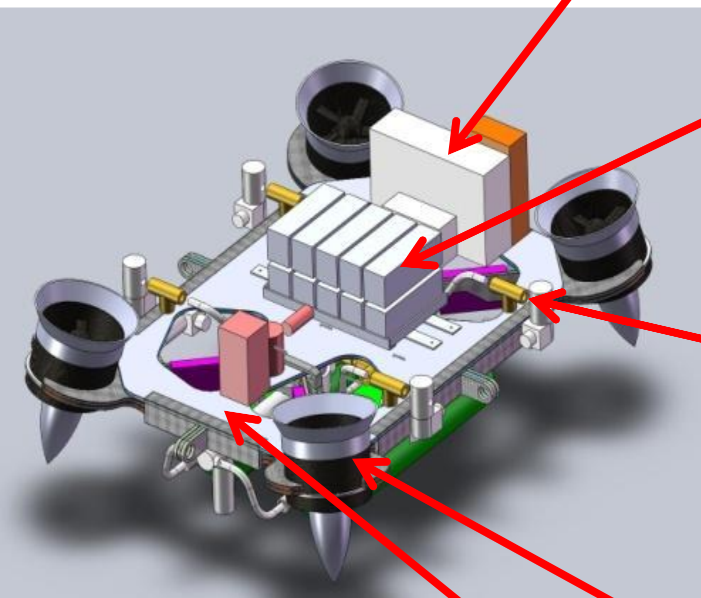
Why Draper and MIT?

- This is a very tough Systems & GNC problem
- Together, we create a unique capability to develop new technologies by bringing together bright and motivated staff and students
- Hoppers build on Draper's heritage of landing GNC



The TALARIS team began development of hoppers in 2009

TALARIS: VEHICLE CONFIGURATION



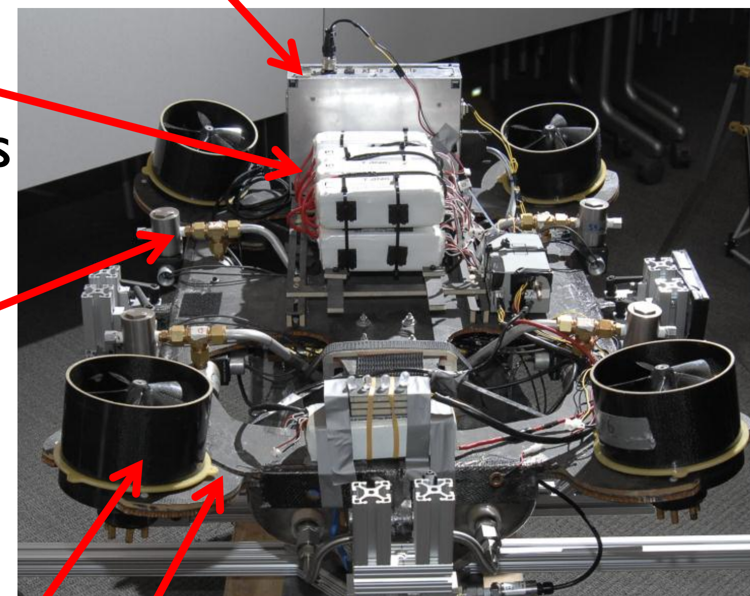
On-board computer

12 Lithium polymer batteries

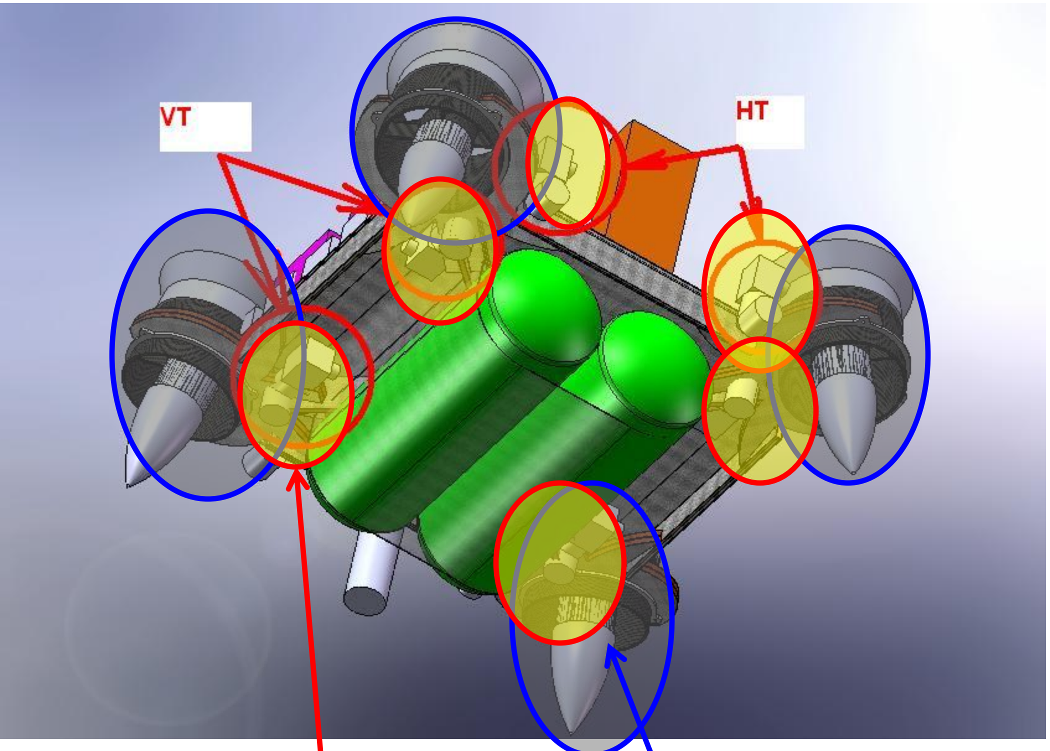
8 Cold gas thrusters

Electric Ducted Fans (EDFs) x 4

Carbon fiber structure



PROPULSION SYSTEM



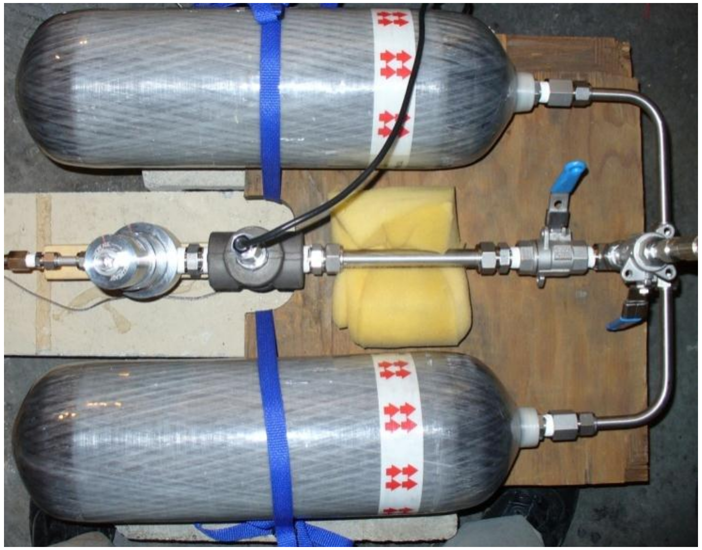
Compressed Gas Thrusters x 8 (4 horiz., 4 vert.)

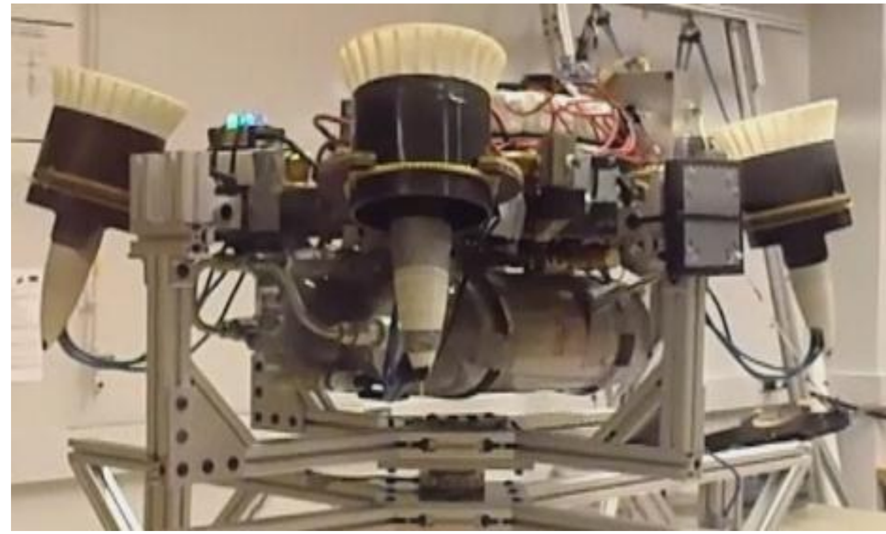
Electric Ducted Fans x 4

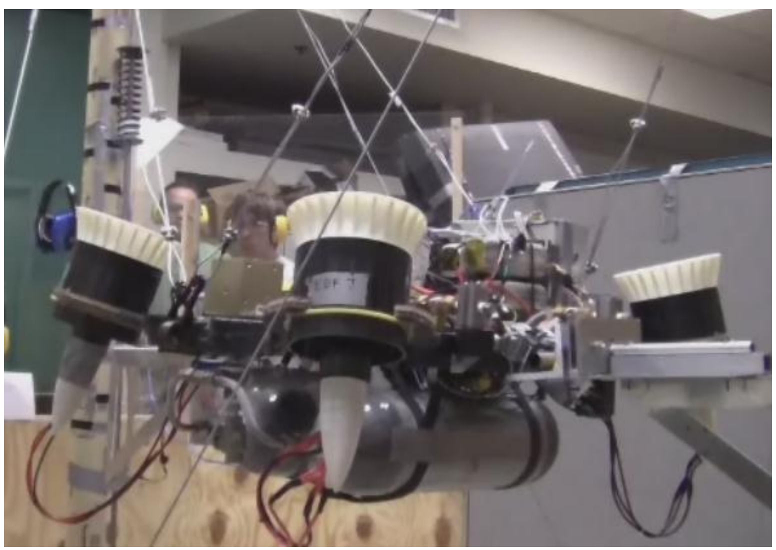
Hybrid Propulsion System

- **Electric Ducted Fan (EDF) System**
  - Provides constant vertical thrust equal to 5/6 of vehicle weight
- **Cold Gas (CG) System**
  - Controls attitude and all maneuvering
  - "Sees" 1/6 of the vehicle's weight: simulates flight in lunar g

Building and Testing







Concept development

Subsystem design

Component tests

Characterization tests

Integrated system tests

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VIDEO: TESTING PROGRAM

Video: Masten Xombie (using GENIE)

Areas of Current Research

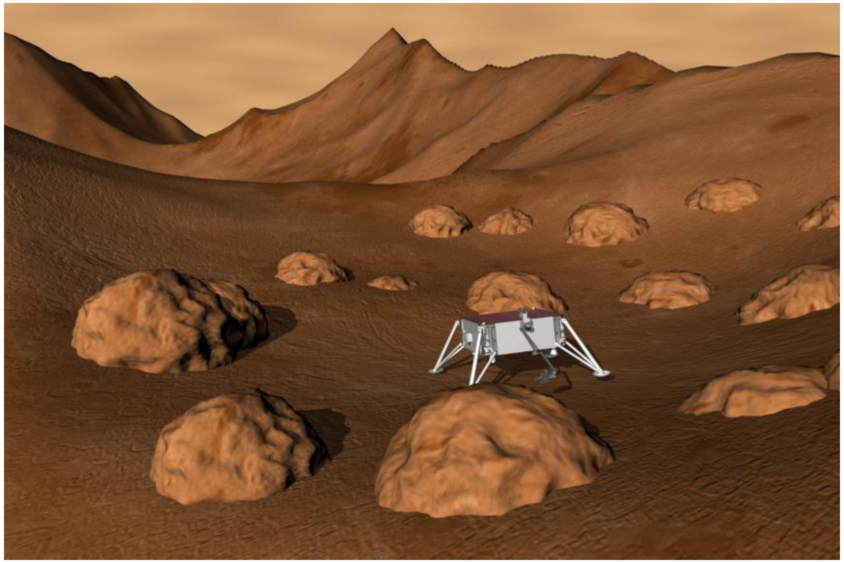
The TALARIS group currently consists of:

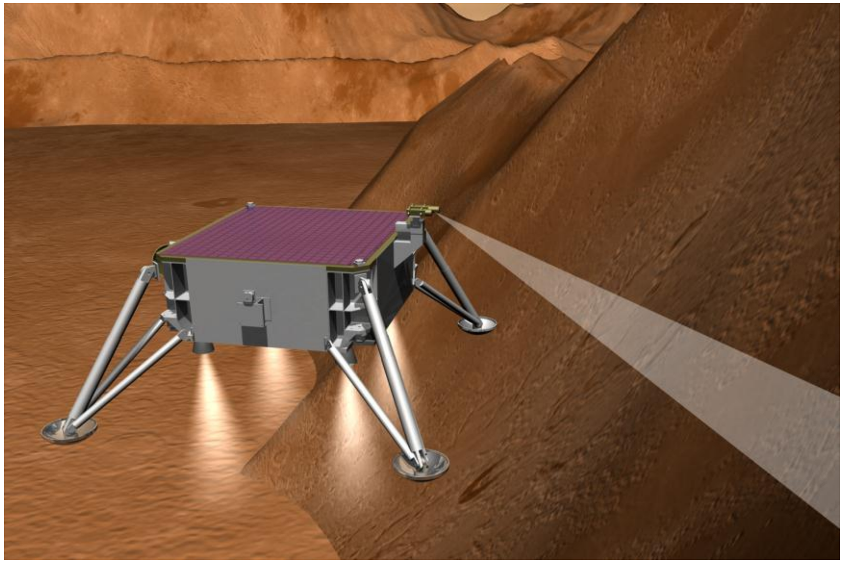
- 3 PhD Students
- 3 Masters Students
- Several undergraduate students

These are part of 100+ students who have worked on TALARIS over the years.

Ongoing research within the group includes:

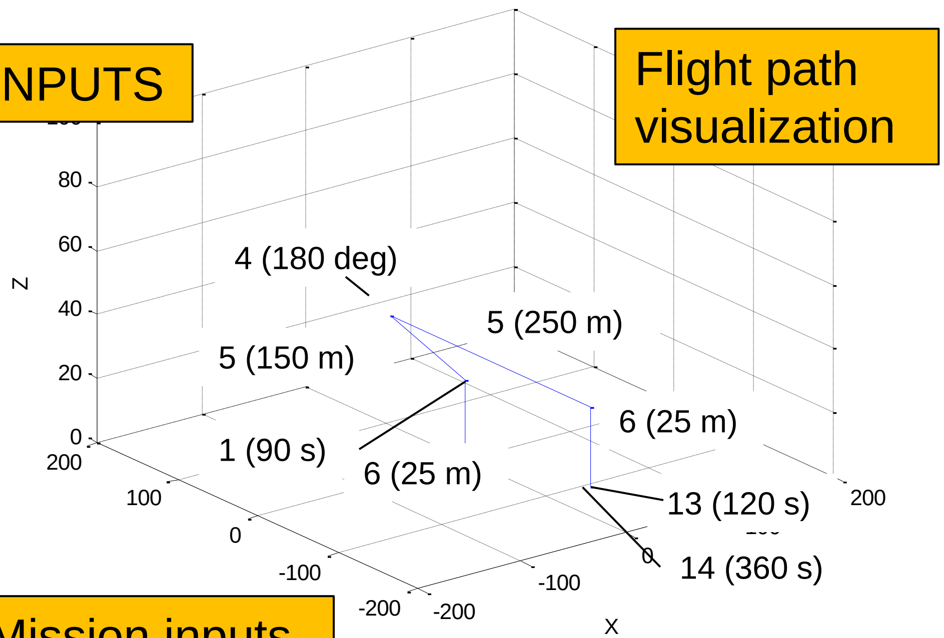
- Hopper Vehicle Modeling
- Landing Navigation
- Titan Hopper Concepts
- Fractionated Robotic Architectures
- NASA Microgravity University flight in June 2012





HOPPER MODELING

INPUTS



Flight path visualization

Mission inputs

Planetary body/region

Mars

Payload

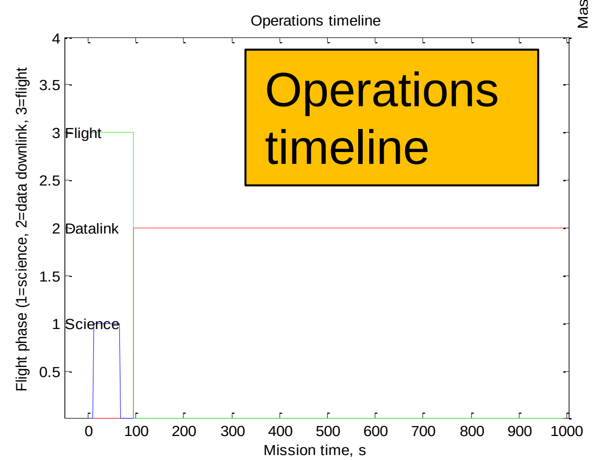
1. Biological Analysis Bay
2. Sample collection arm
3. Magnetometer
4. X-ray spectrometer

HOPPER SYSTEM

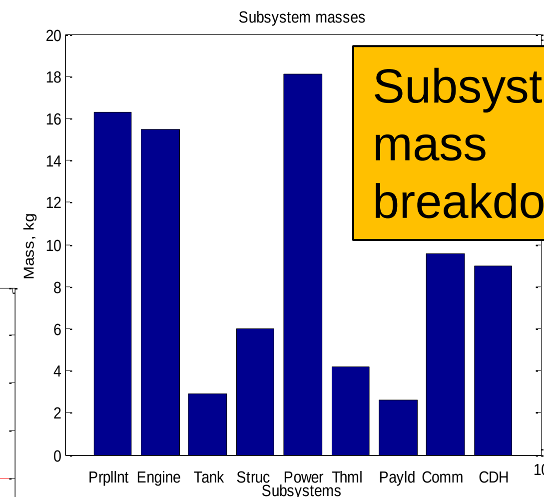
Mass: 567 kg
Power: 86 W average, 114 W pk
Dev Cost: $328.8 M
Build Cost: $25.7 M
Ops Cost: $25.7 M

Engine TRL: 4

Additional design insight



Operations timeline



Subsystem mass breakdown

OUTPUTS

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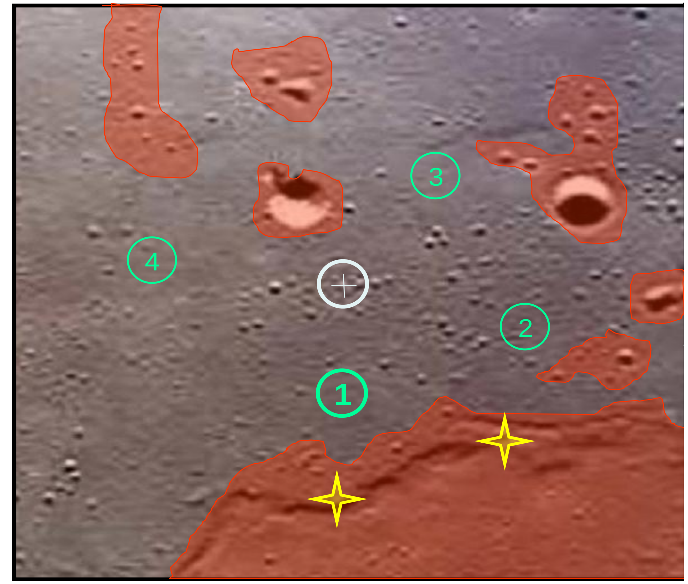
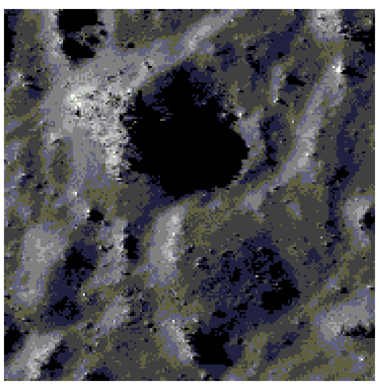
PRECISE AND SAFE LANDING

Heritage from NASA ALHAT Program (Autonomous Landing and Hazard Avoidance Technology).

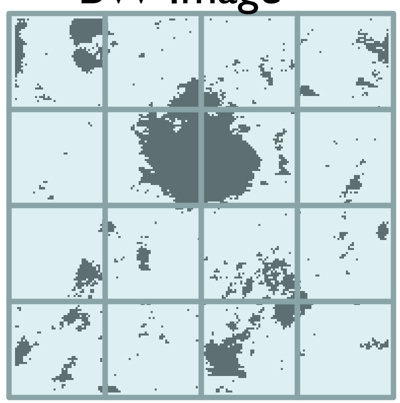
- Autonomous, human interactive, descent and landing GNC
- Terrain relative navigation
- Hazard detection & avoidance
- Sensors: 3D imaging LIDAR, Ground relative velocimeter, altimeter, IMU, StarCamera



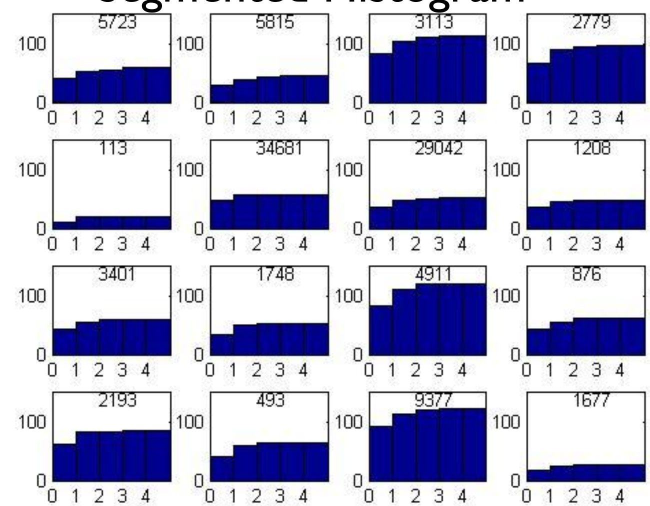
Image



Segmented BW Image



Segmented Histogram



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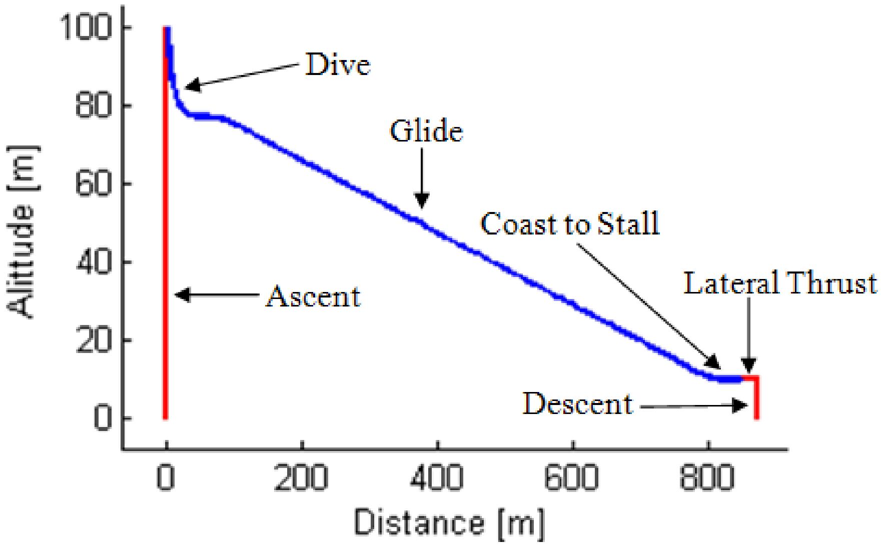
Modified Hopper for Titan

- **Gliding Hop Trajectory:** Flight path takes advantage of dense atmosphere
- **In Situ Cold Gas Propulsion:** Enables repeated, short-range hops
- **Electric Ducted Fans:** Effectively reduce weight of vehicle during vertical flight modes



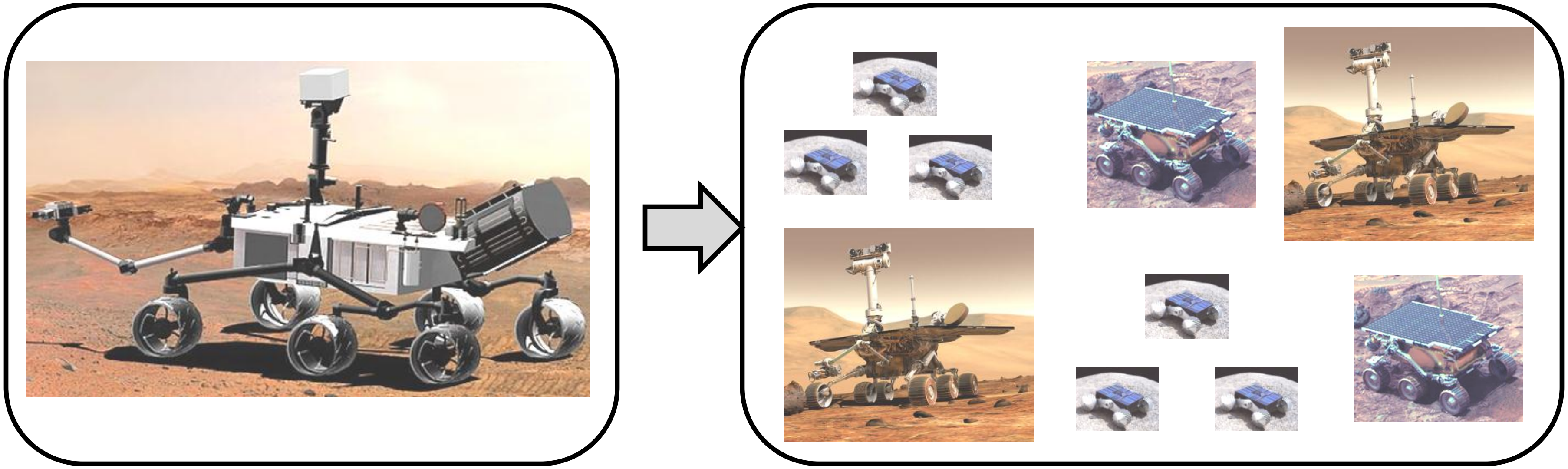
Fractionated Mobility System Architectures

Fractionation

A system composed of *physically independent* (i.e., structurally separate) constituents that can, but do not have to, *collaborate to provide benefit/value* to the beneficiaries and beneficiary stakeholders of that respective system

Fractionation offers an **opportunity** to:

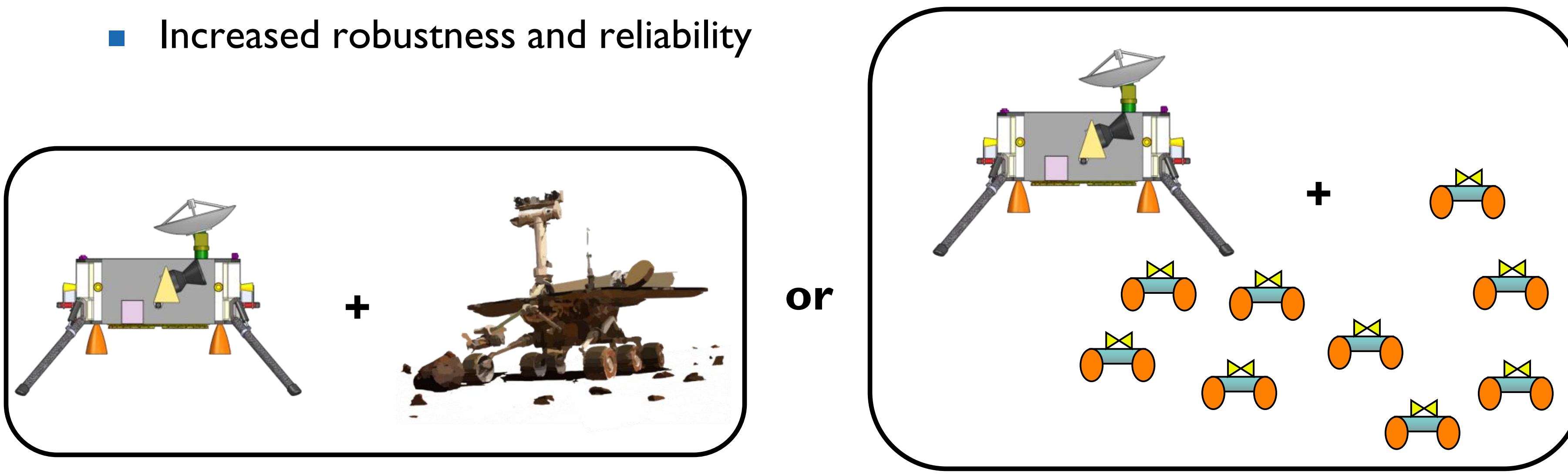
- Increase return for a given mass
- Increase robustness
- Address complexity



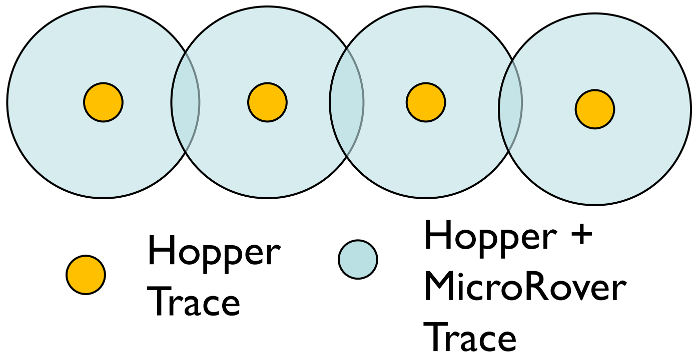
Heterogeneous Fractionated Architectures

- **Takes advantages of the strengths of several types of mobility systems**
  - Hoppers can travel large distances quickly
  - Rovers can visit very precise locations and have significant heritage
  - Walkers, wheeled vehicles and hybrids also have their advantages

- **Functionality is spread across several vehicles**
  - Science performed simultaneously at different sites
  - Goals achieved more quickly
  - Increased robustness and reliability



Example of a Hopper and MicroRover System



Assumptions:
- 250kg baseline hopper, 4 hops
- 15 microrovers @ 3kg each, 0.5 m/s
- 20 kg infrastructure

→**adds 90 kg to the system**

A 35% increase in system mass leads to an accessible area which is 3 orders of magnitude greater

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Summary

Hoppers offer unique & exciting opportunities in planetary surface exploration

- Rapid regional access
- Cliff Scaling
- Travel across hazardous terrain
- Precision landing
- Adaptable for several planetary bodies
- Fractionated heterogeneous architectures