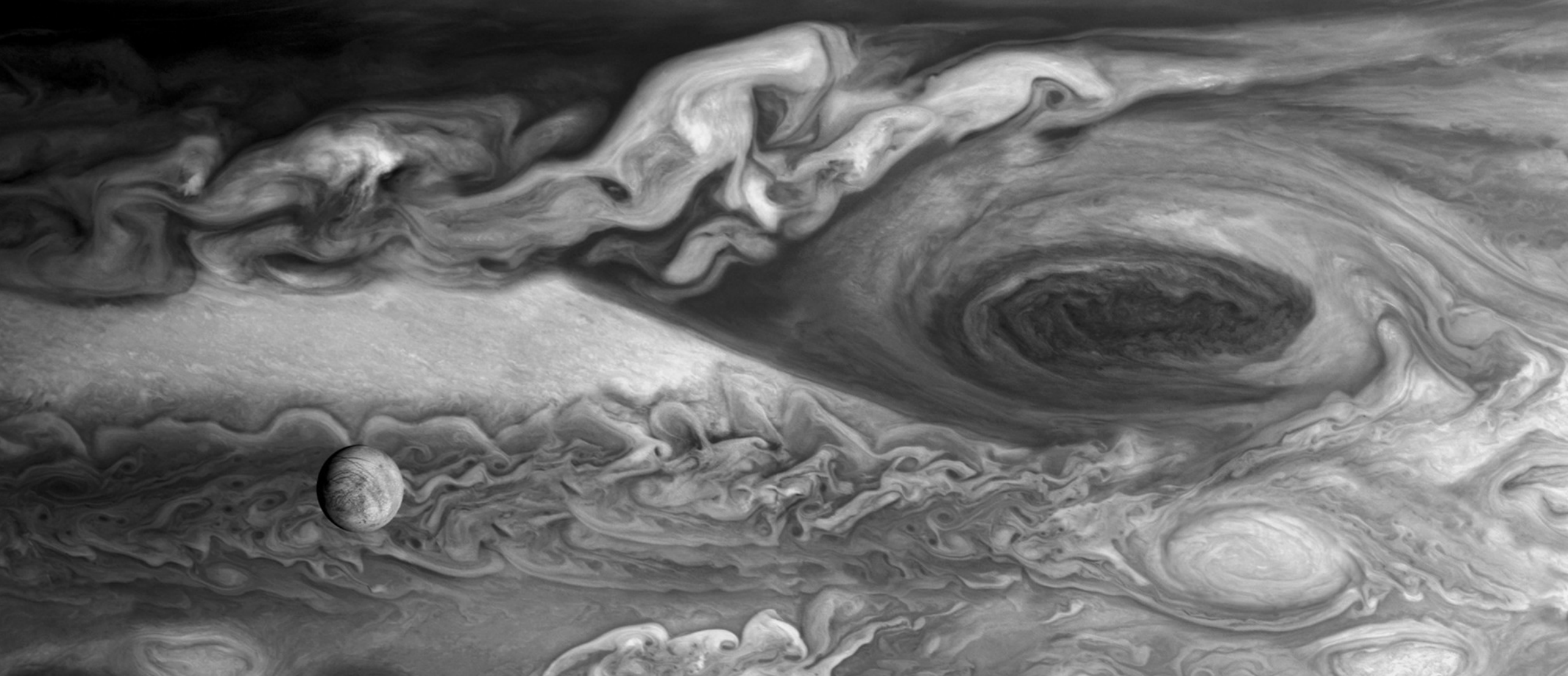


History of Landing on Uncertain Terrain

A. Miguel San Martin
September 10, 2018

Jet Propulsion Laboratory, California Institute of Technology

Pre-Decisional Information – For Planning and Discussion Purposes Only

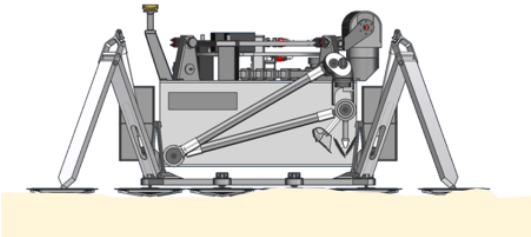
Factors for Judging Landing Success

Factor 0:
Hardware
Integrity/Health

Power Availability

DDL Contamination
& Alteration of Surface

Thermal Safety



Sampling Performance

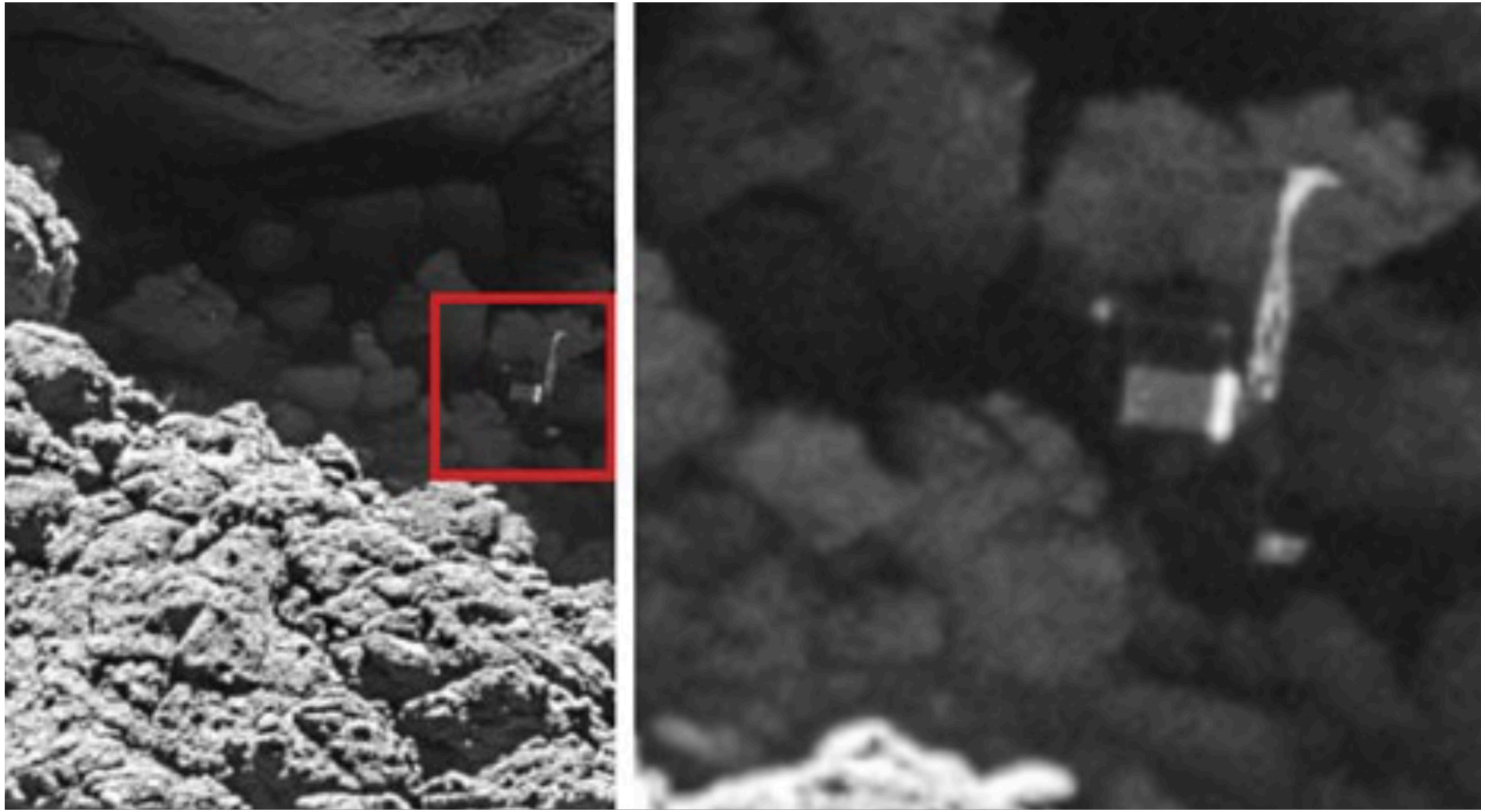
Telecom Performance

Science Relevance

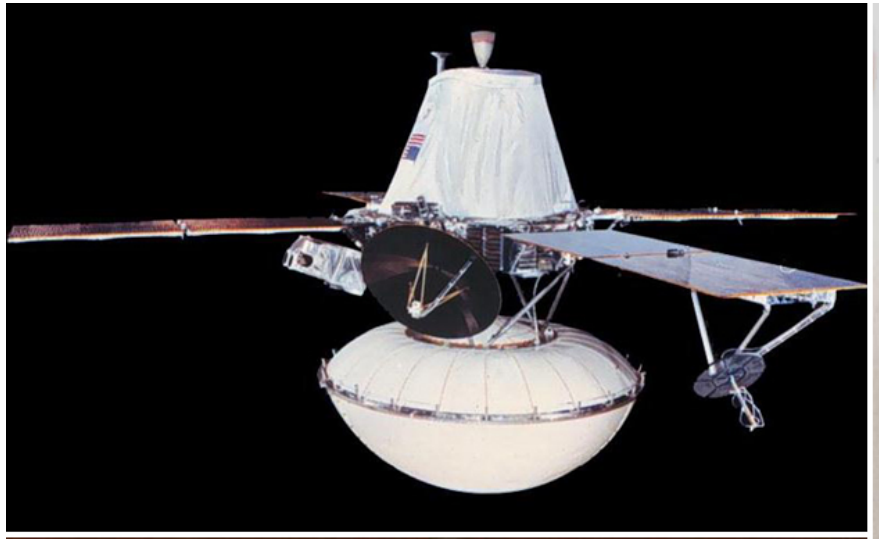
Imaging Performance

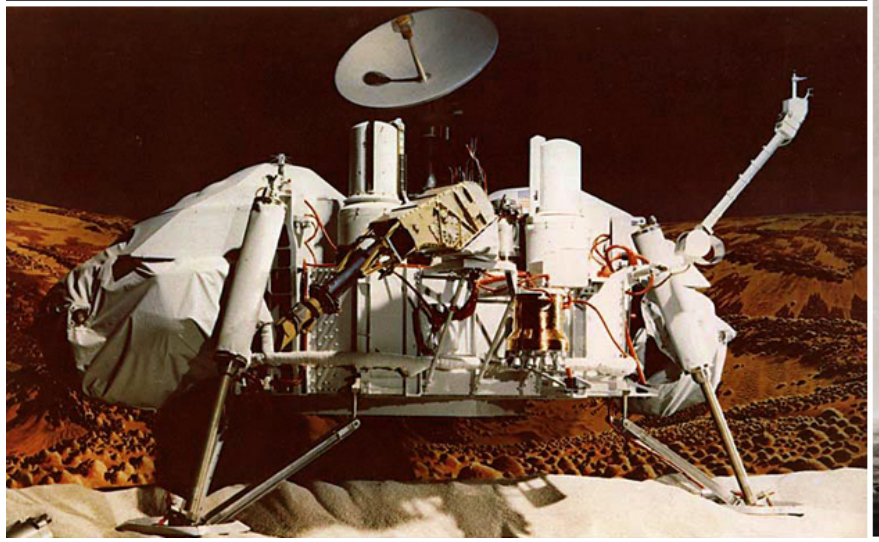
- Note: All of these factors are influenced by terrain in different degrees depending on system design

Philae Lander on Comet CG



Viking I & II (1976)

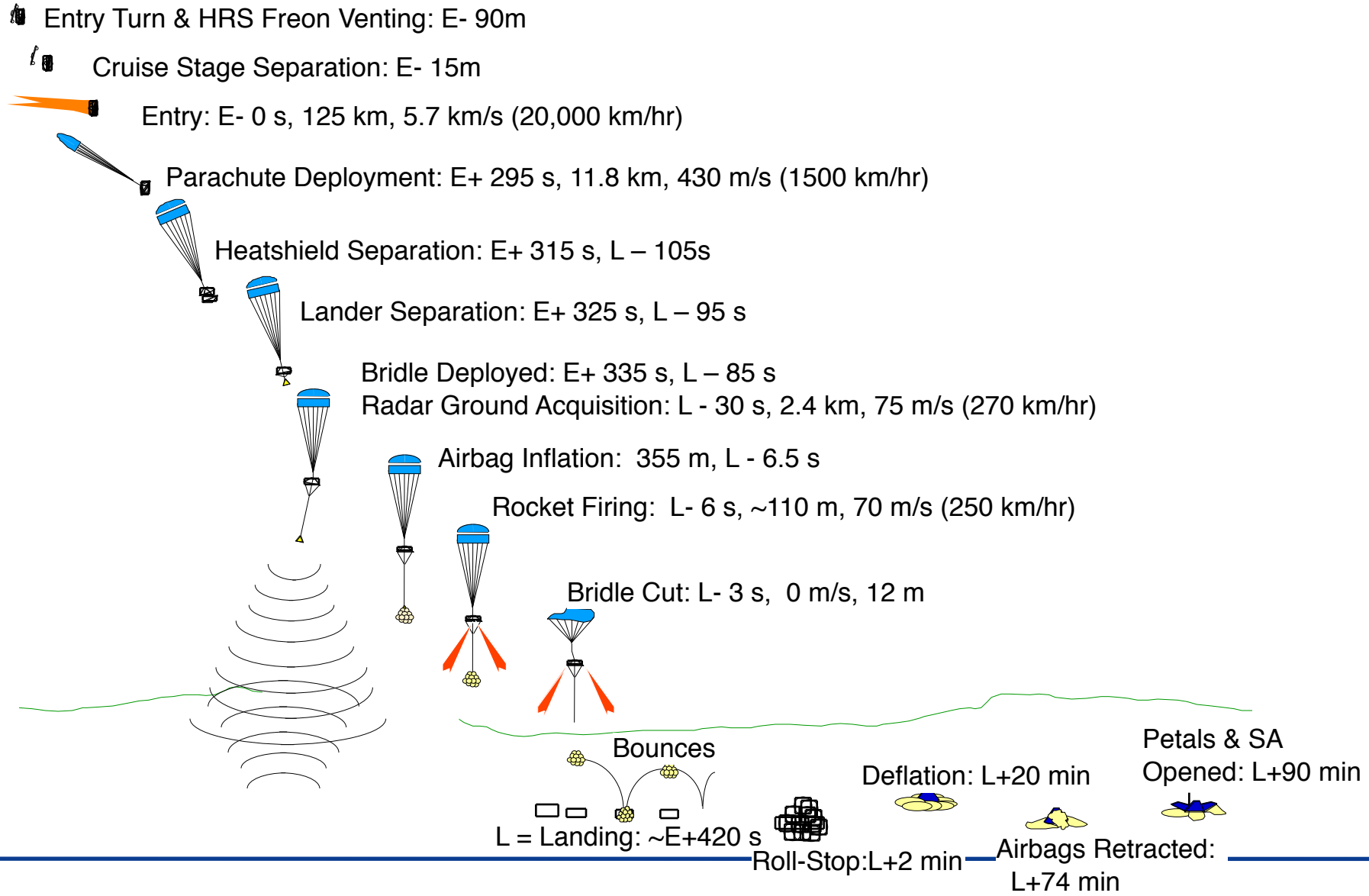




Viking I and Big Joe

Mars Pathfinder (1997)

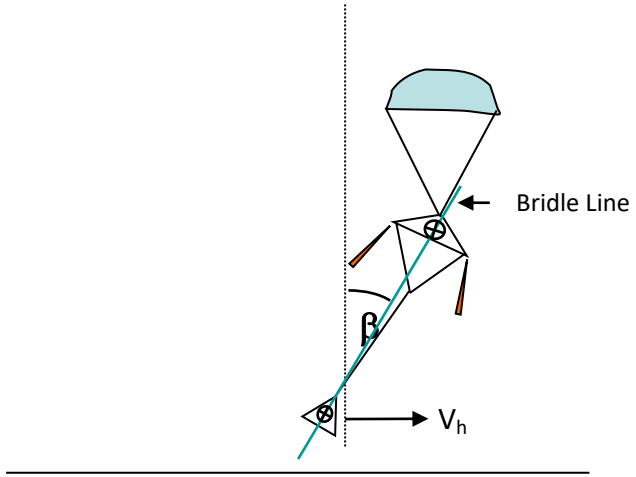
Entry, Descent & Landing Timeline



Wind Induced Horizontal Velocity

Initial Horizontal Velocity — RAD Induced Horizontal Velocity

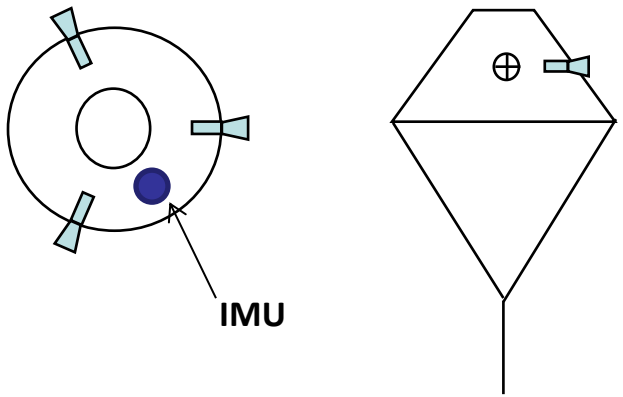
$$V_h(t_{bc}) = V_h(t_{RAD}) + \int F_{RAD}/m * \sin(\beta)\, dt$$

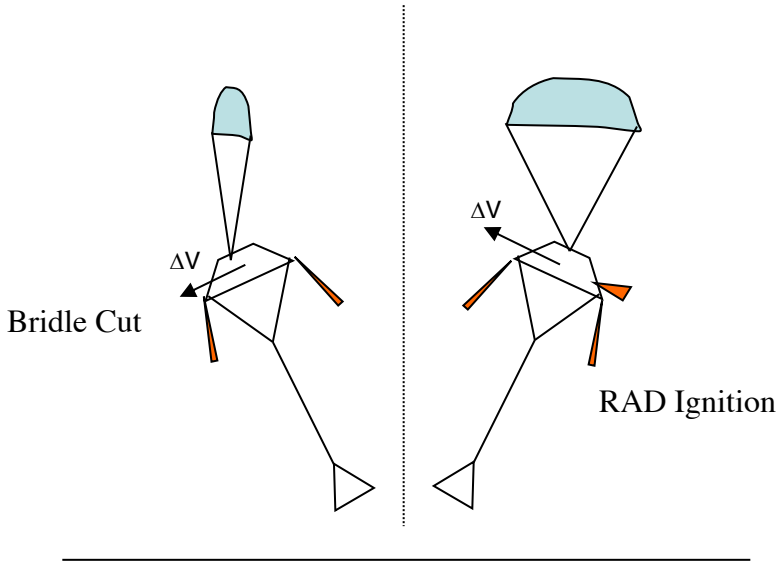


RAD Induced Horizontal Velocity

Transverse Impulse Rocket System

(TIRS)

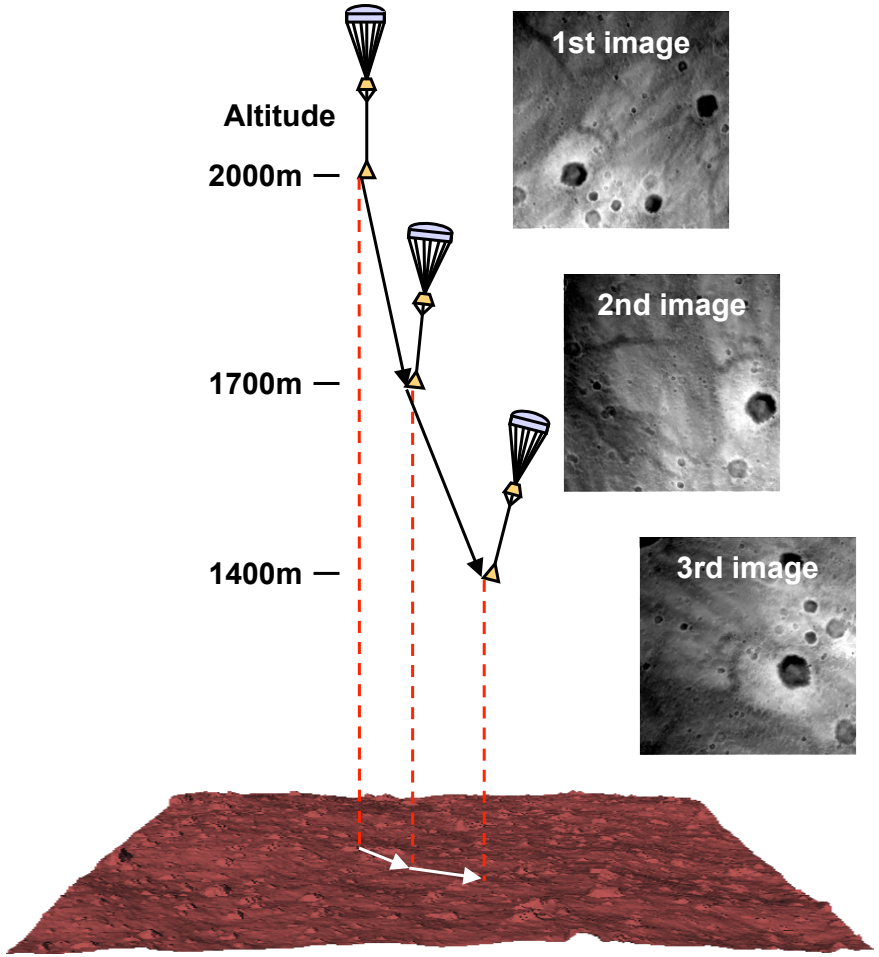


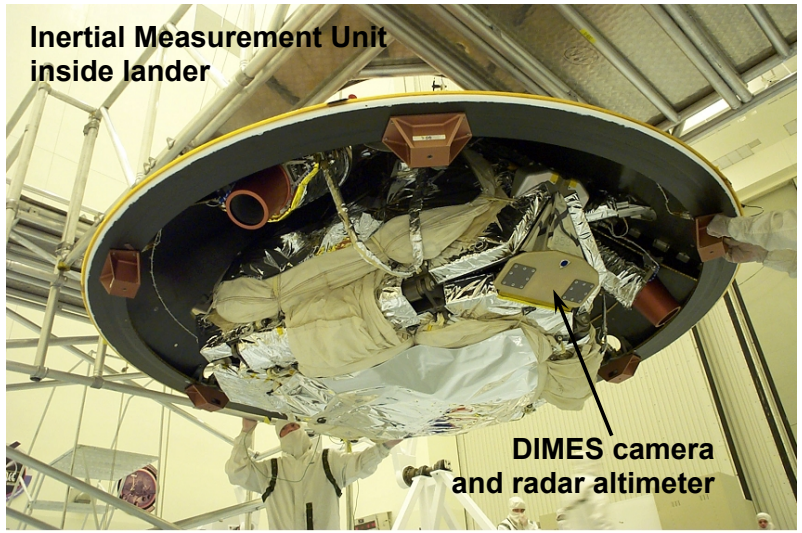


Descent Image Motion Estimation System

(DIMES)

DIMES SCENARIO

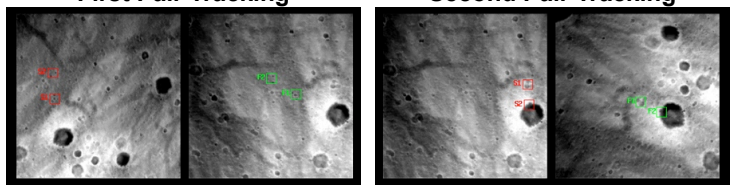




DIMES RESULT

First Pair Tracking

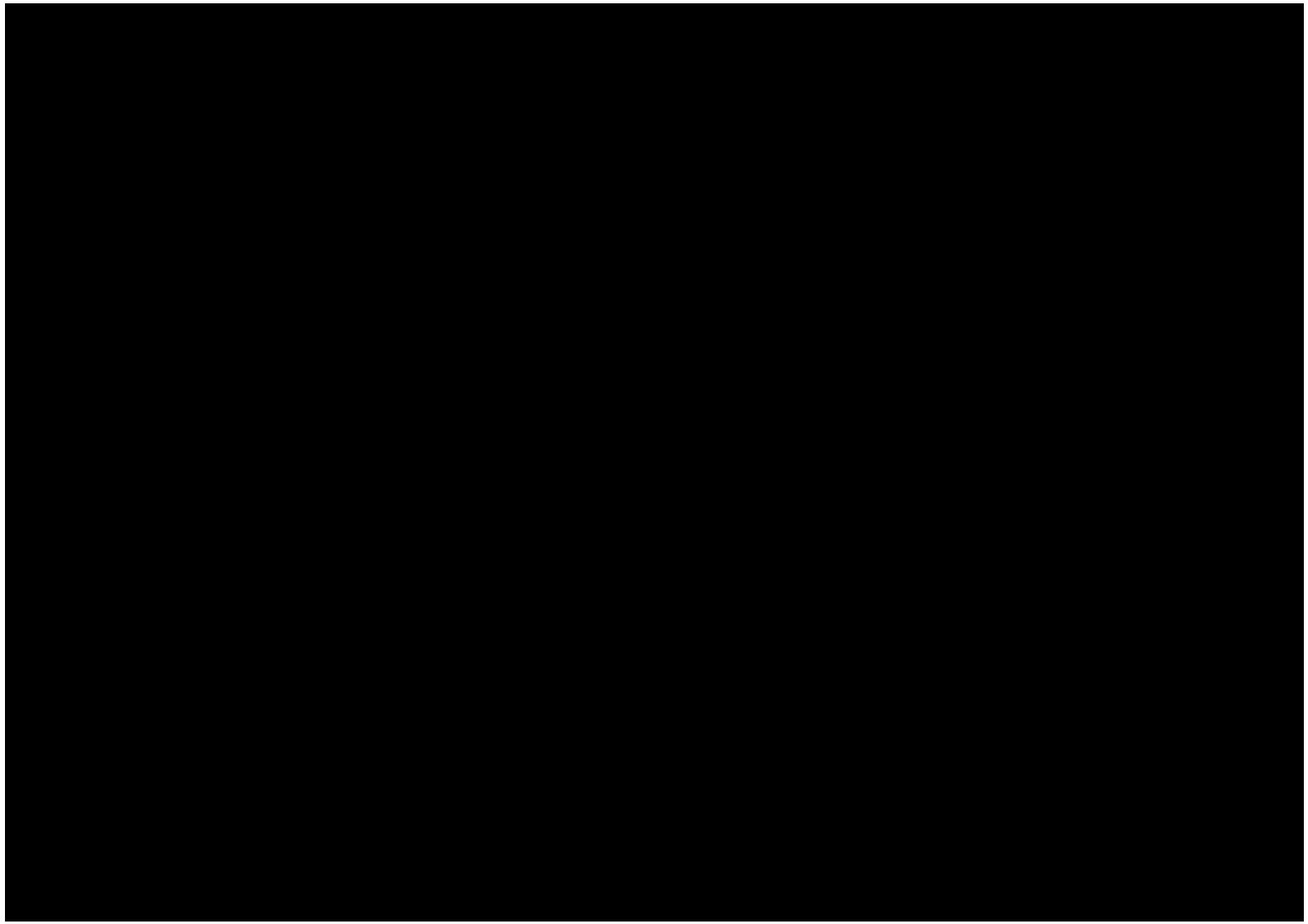
Second Pair Tracking



MER-A/Spirit, Gusev Crater, January 4th, 2004

First use of Terrain Relative Navigation (TRN)

Spirit Landing in January 2004

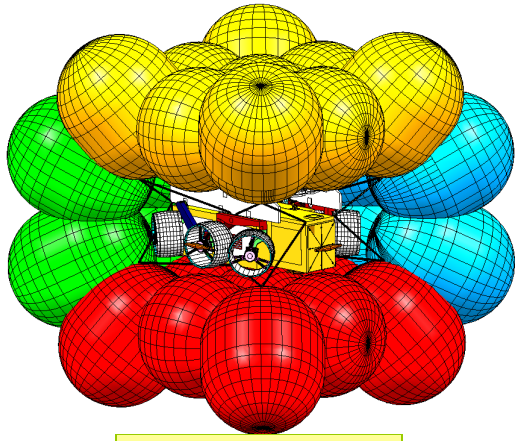


2012 Curiosity Rover

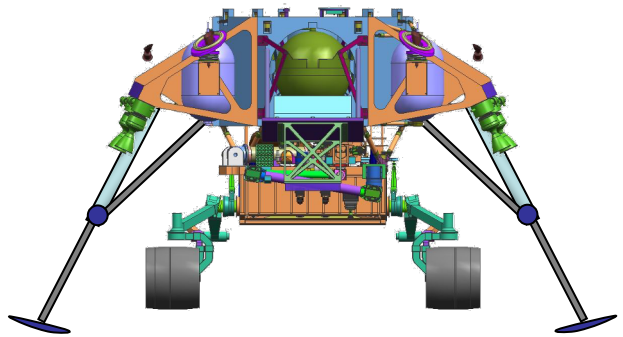
2011 Electric Mini Cooper

Pre-Decisional Information – For Planning and Discussion Purposes Only

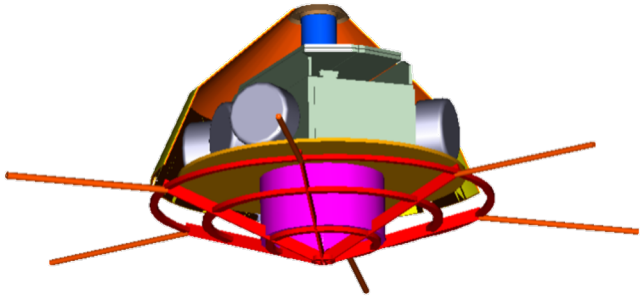
How to land a 1 ton rover on Mars?



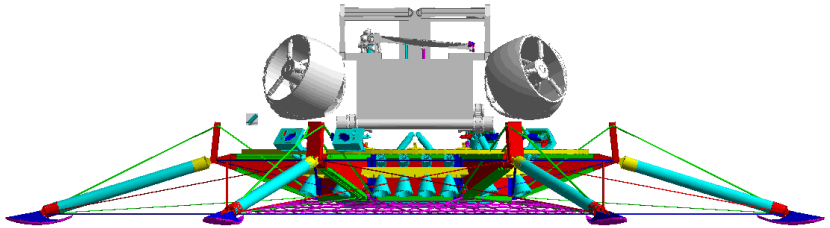
Airbags



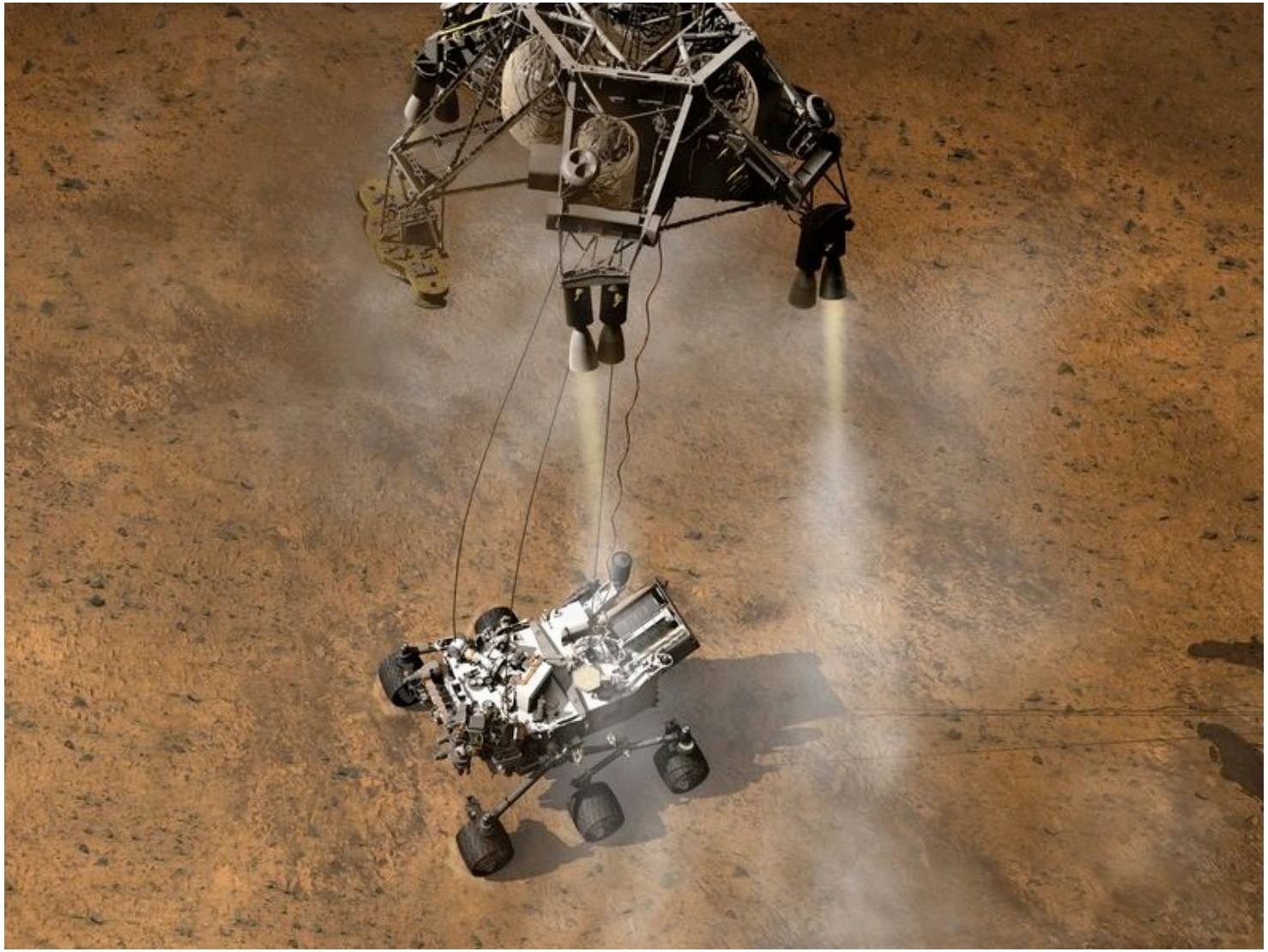
Legs



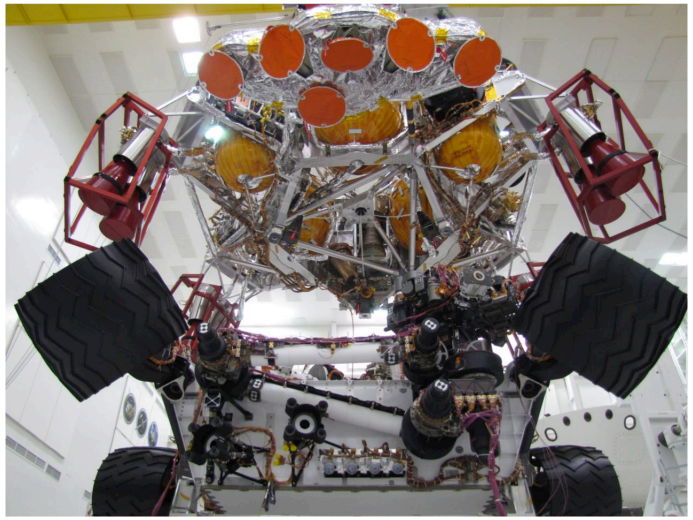
Pallet



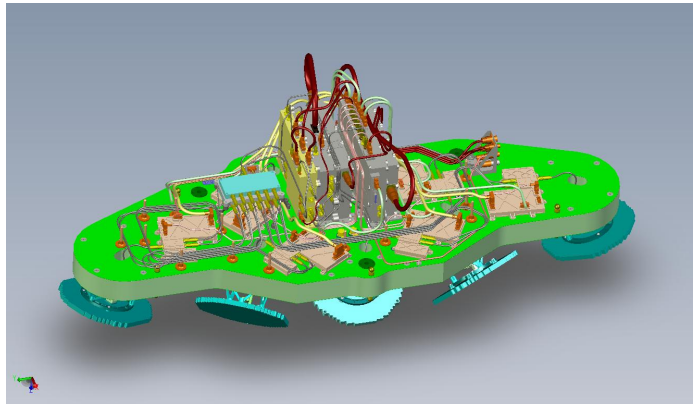
The SkyCrane is Born



SkyCrane Enabling Components

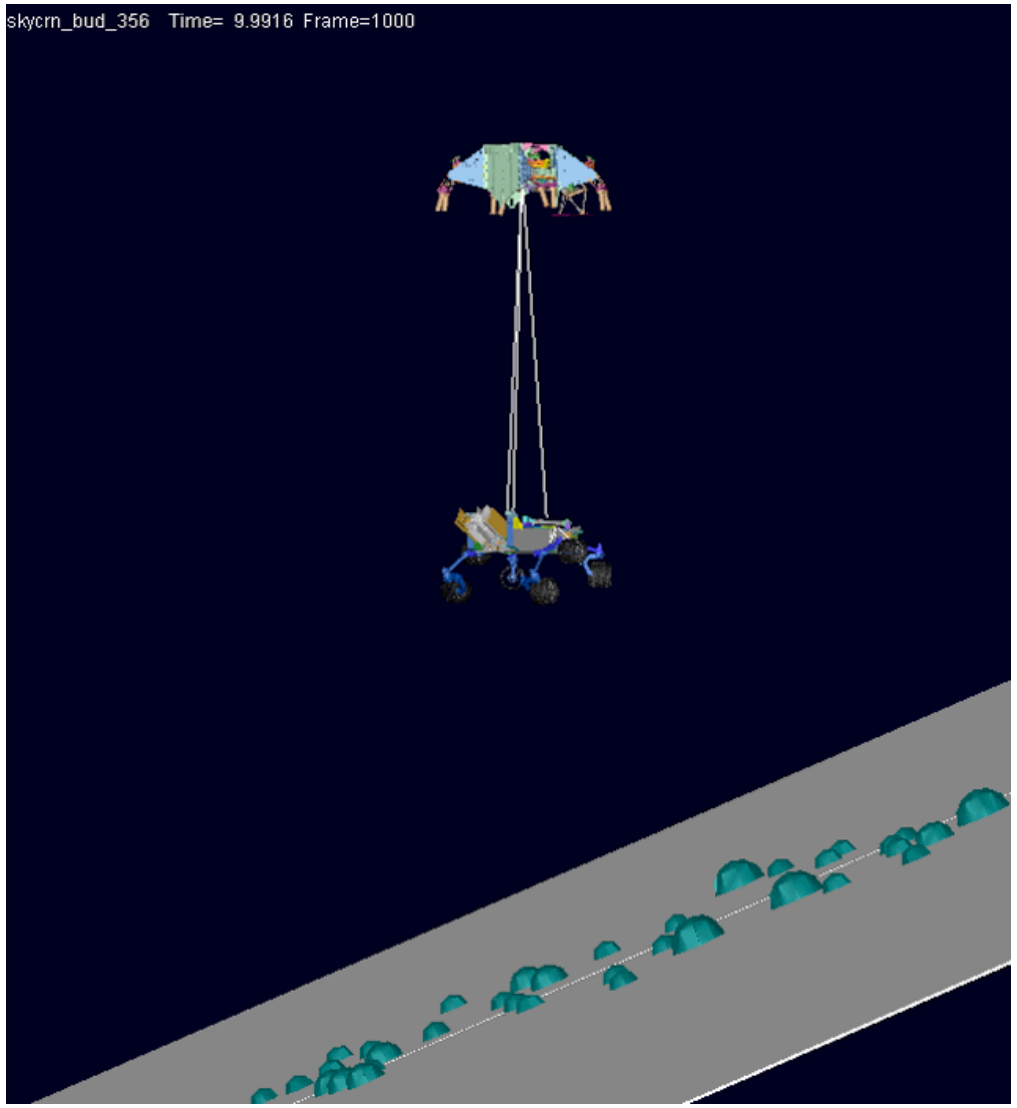


Mars Landing Engine (MLE)

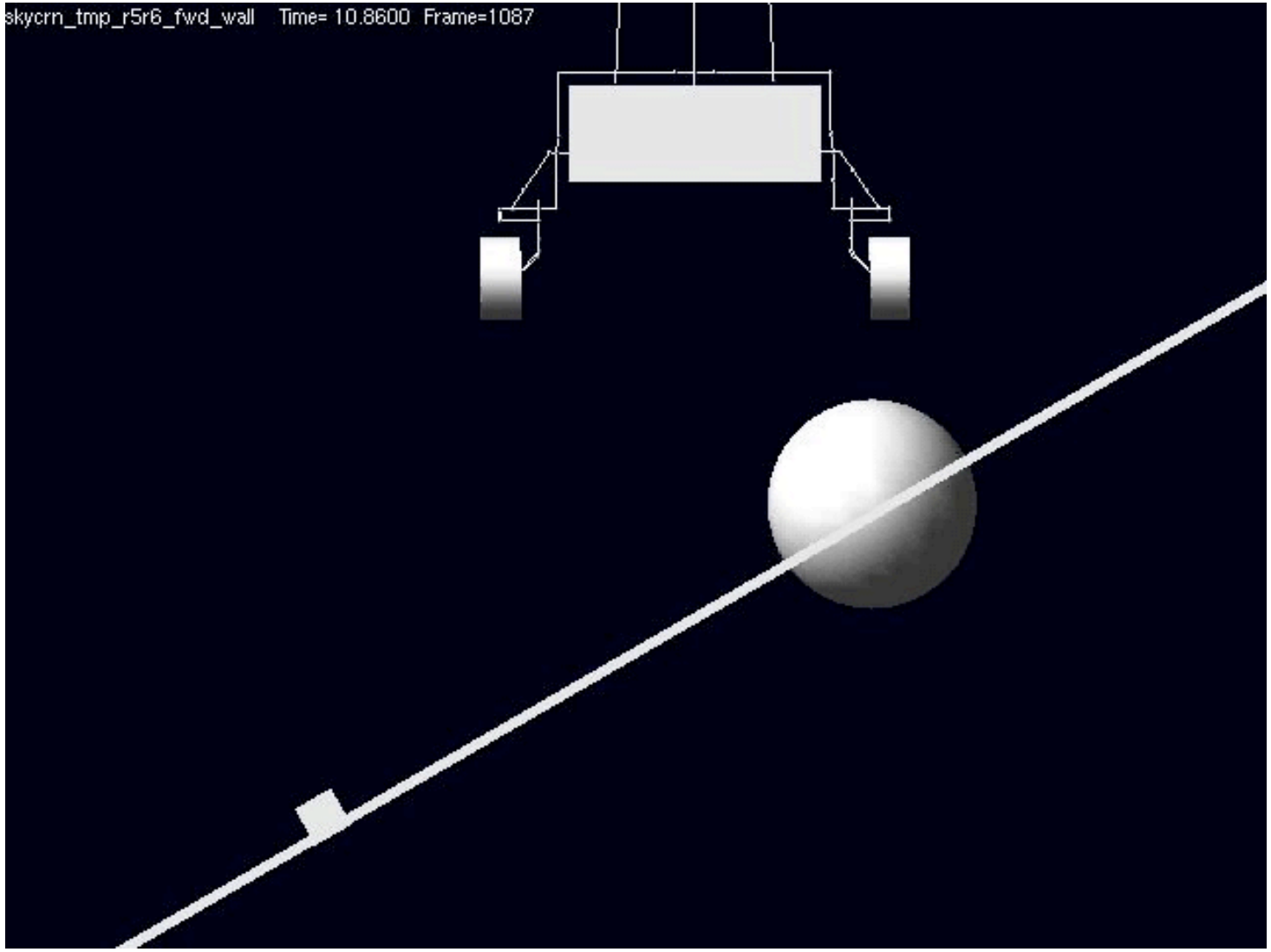


Terminal Descent Landing Sensor (TDS)

Continued Control Through Touchdown

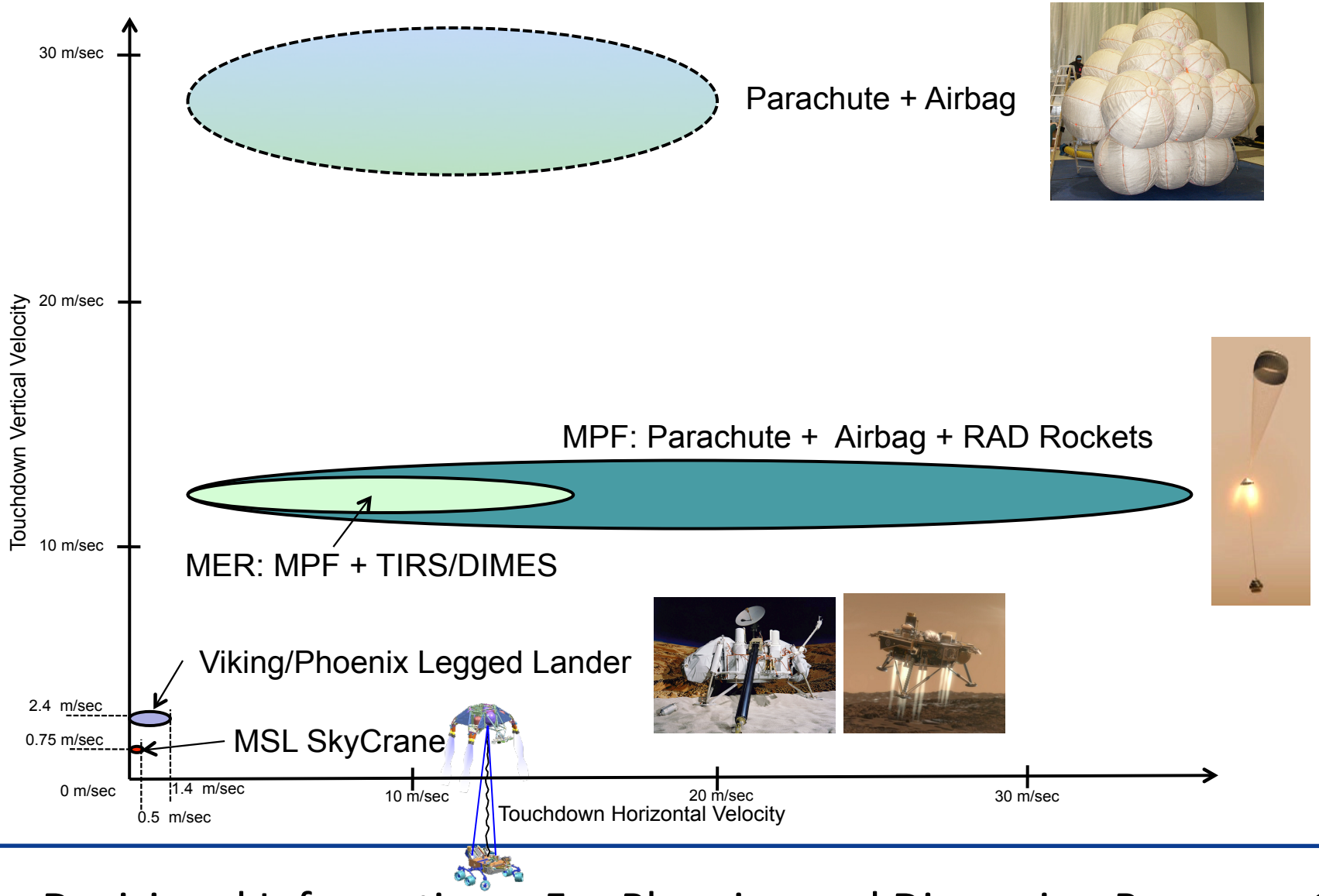


Terrain Adaptable Mobility

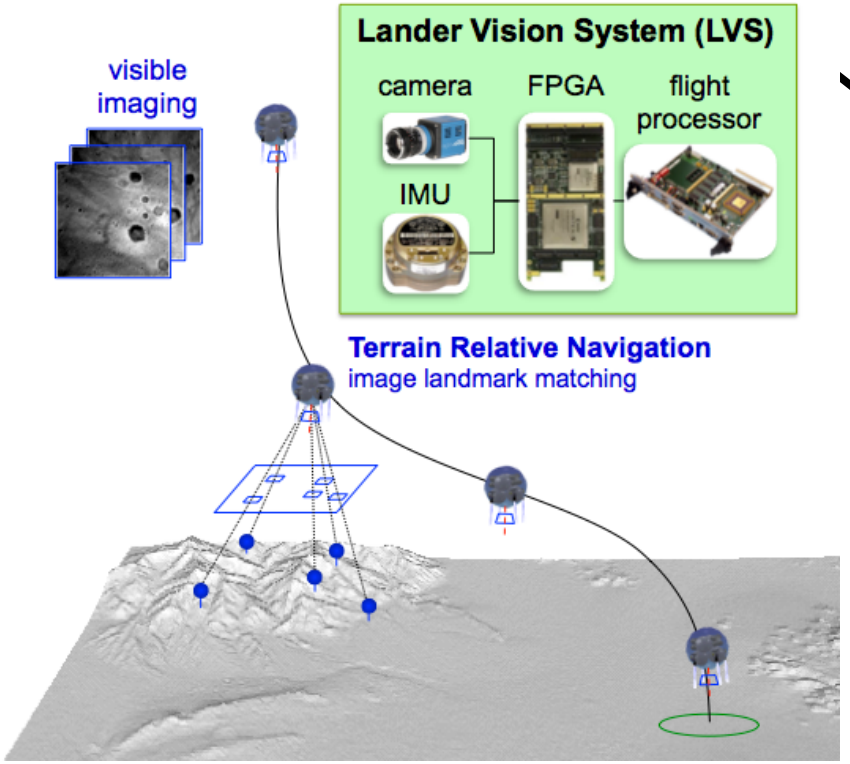


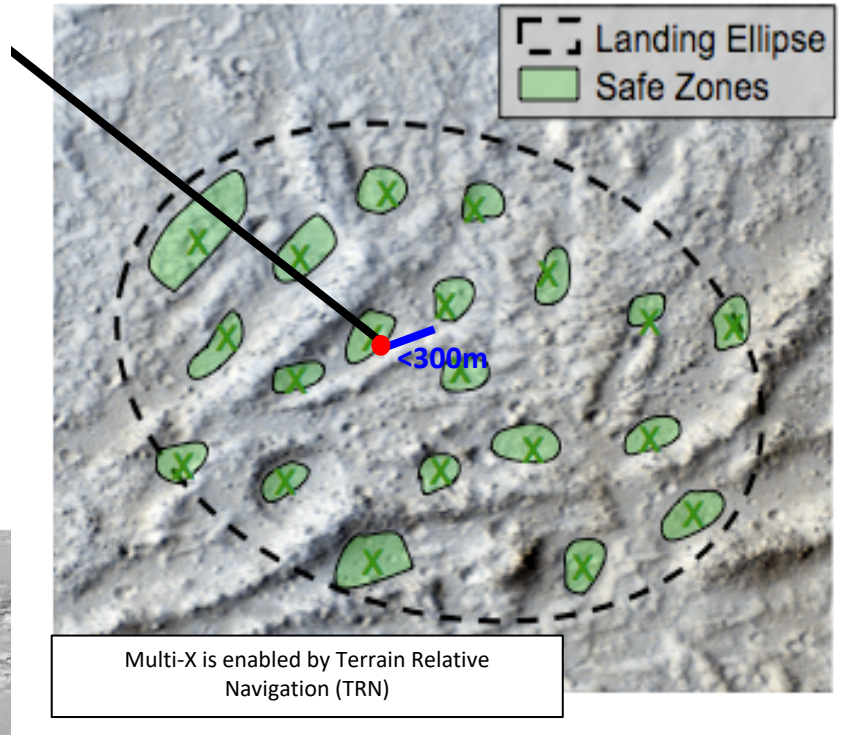
Pre-Decisional Information – For Planning and Discussion Purposes Only

History of Mars Touchdown Velocities

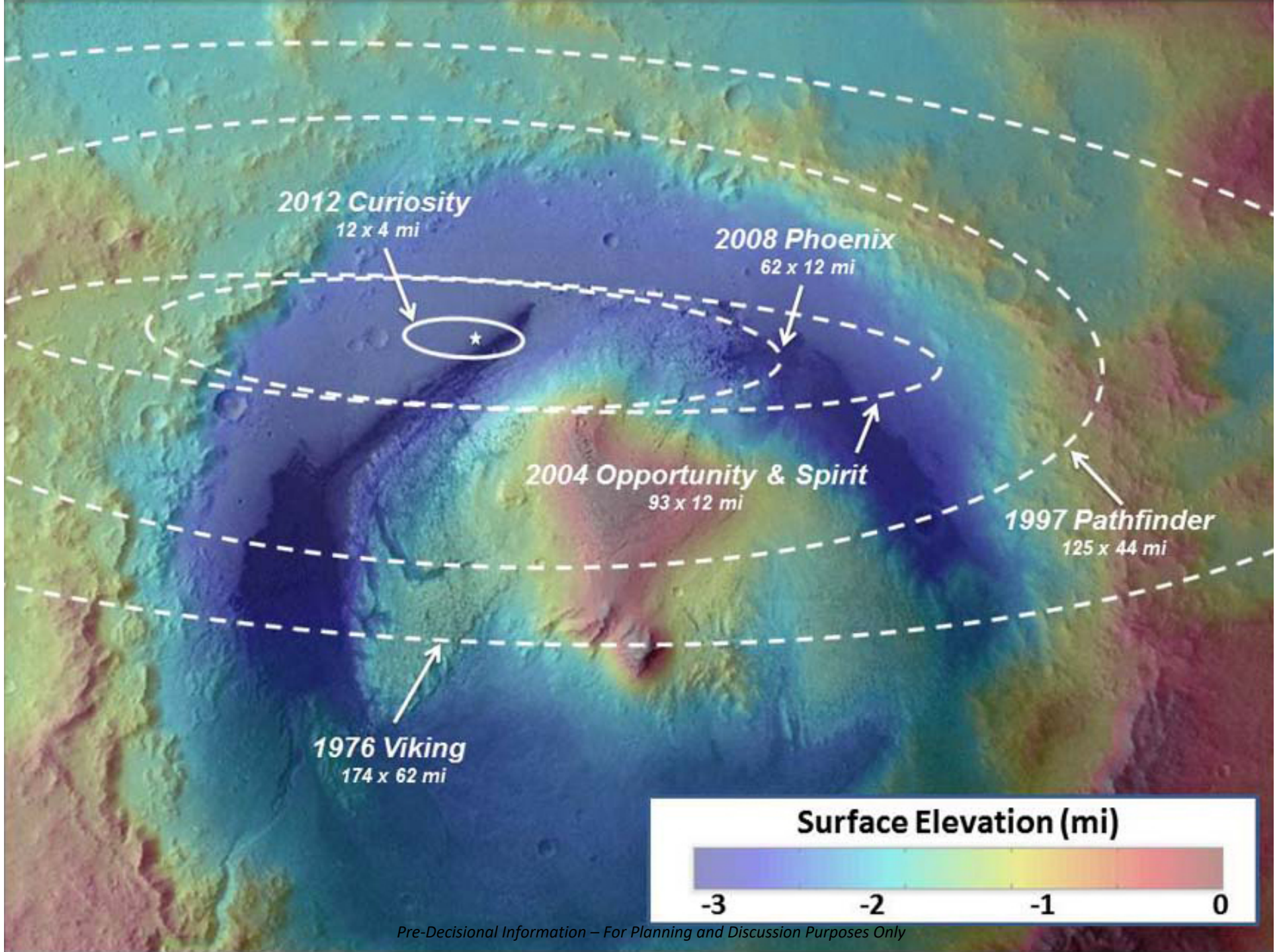


Mars 2020: Terrain Relative Navigation





Multi-X is enabled by Terrain Relative Navigation (TRN)

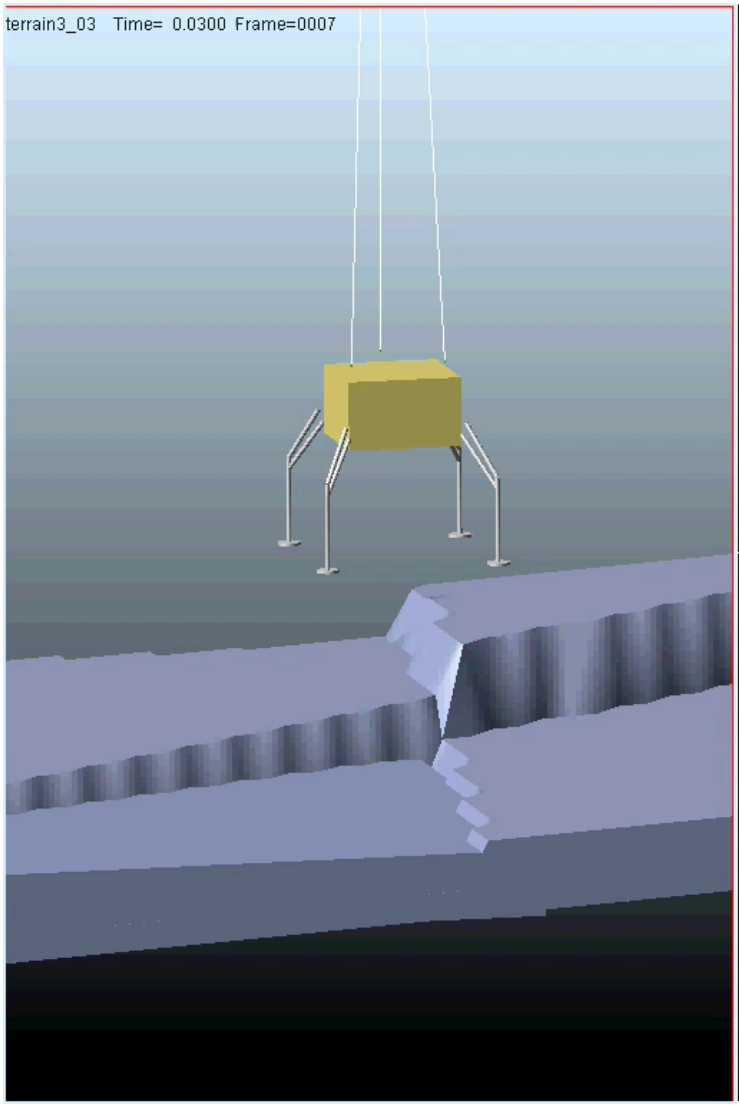


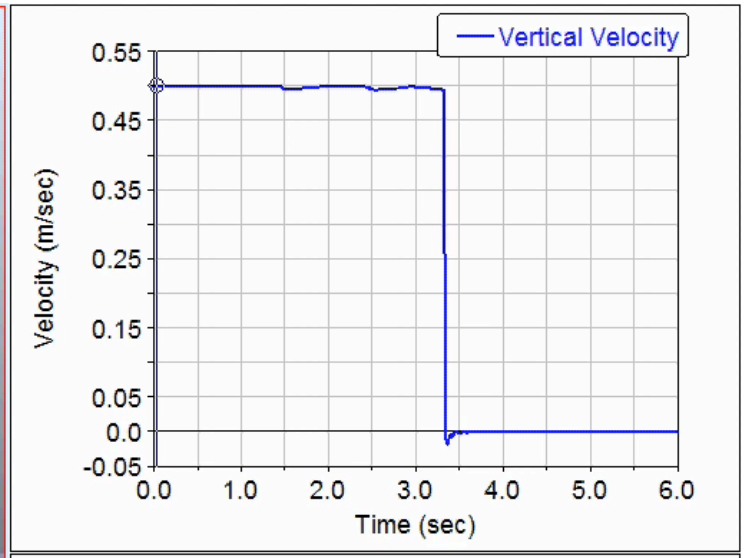
Pre-Decisional Information – For Planning and Discussion Purposes Only

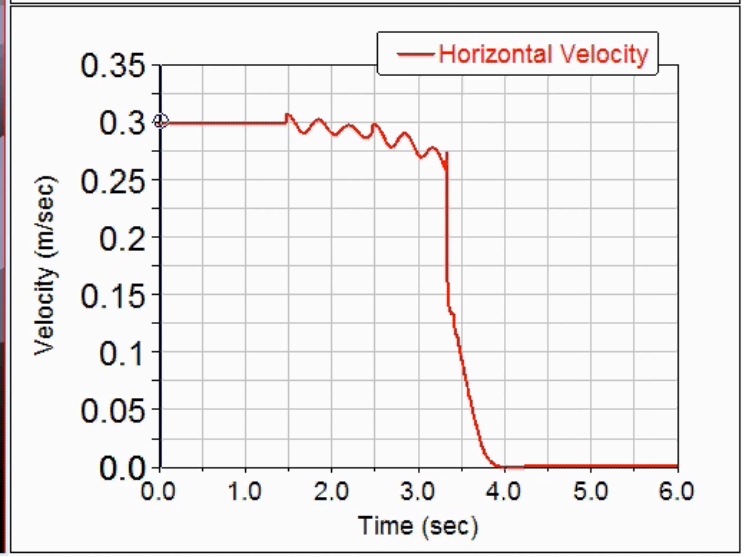
The Five Pillars of DDL for Europa

1. Terrain Relative Navigation (TRN) for reduced landing ellipse size
2. Hazard Detection to avoid lander-scale hazards
3. SkyCrane architecture for soft landing (i.e. Factor 0) and surface alteration avoidance
4. Adaptable Lander Stabilizers to accommodate rough terrain
5. Tolerance of radiation induced resets and failures

Landing Stabilizers







Backup