Jet Propulsion Laboratory
California Institute of Technology

Introduction to

One Shot to Glory:

Designing Adaptive Missions to the Outer Solar System and Beyond

Hiro Ono

Jet Propulsion Laboratory, California Institute of Technology

One-slide summary of everything in this workshop:

Robotic Space Exploration (RSE) 2.0

Current

RSE 3.0

Future

Why do we explore space?

Because we know so little about it

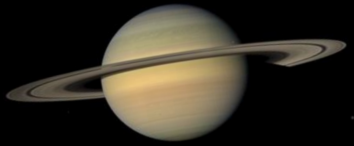
Dr. Morgan Cable (JPL)
Unsolved Mysteries in the Outer Solar System

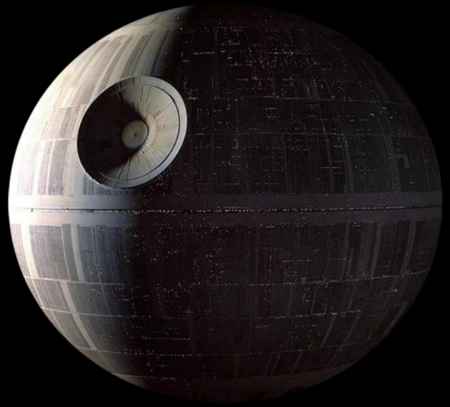
Implications:

- For science: many discoveries waiting to be discovered

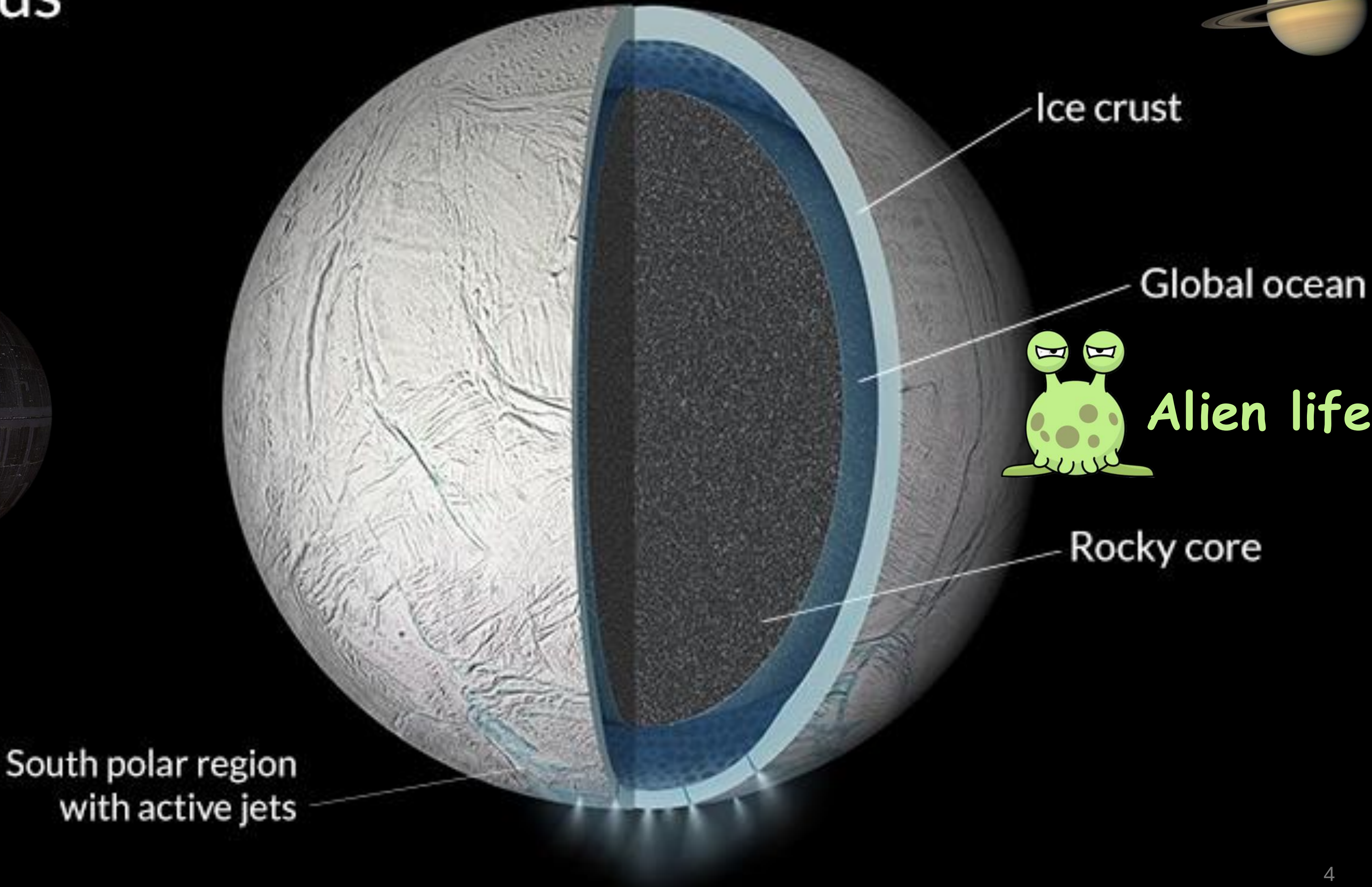
Enceladus

(D = 513 km)





Death Star
(D = 160 km)



Alien life?

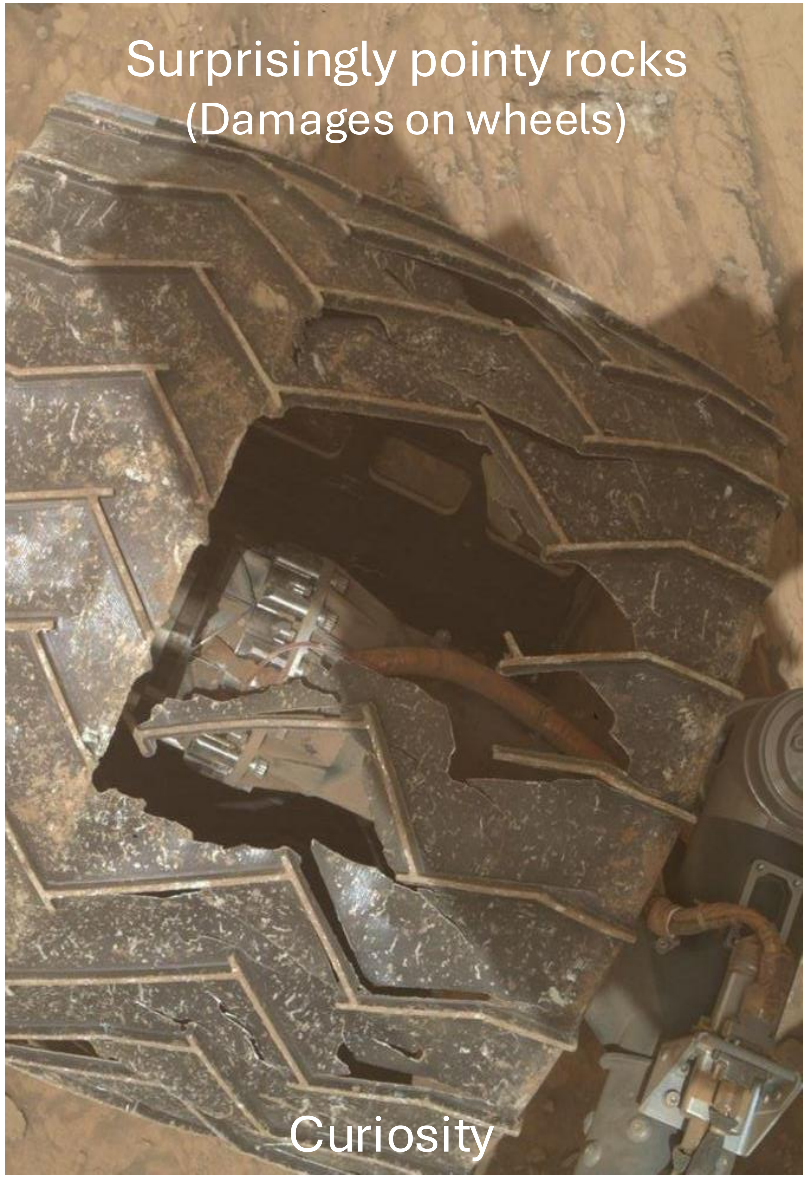
Why do we explore space?

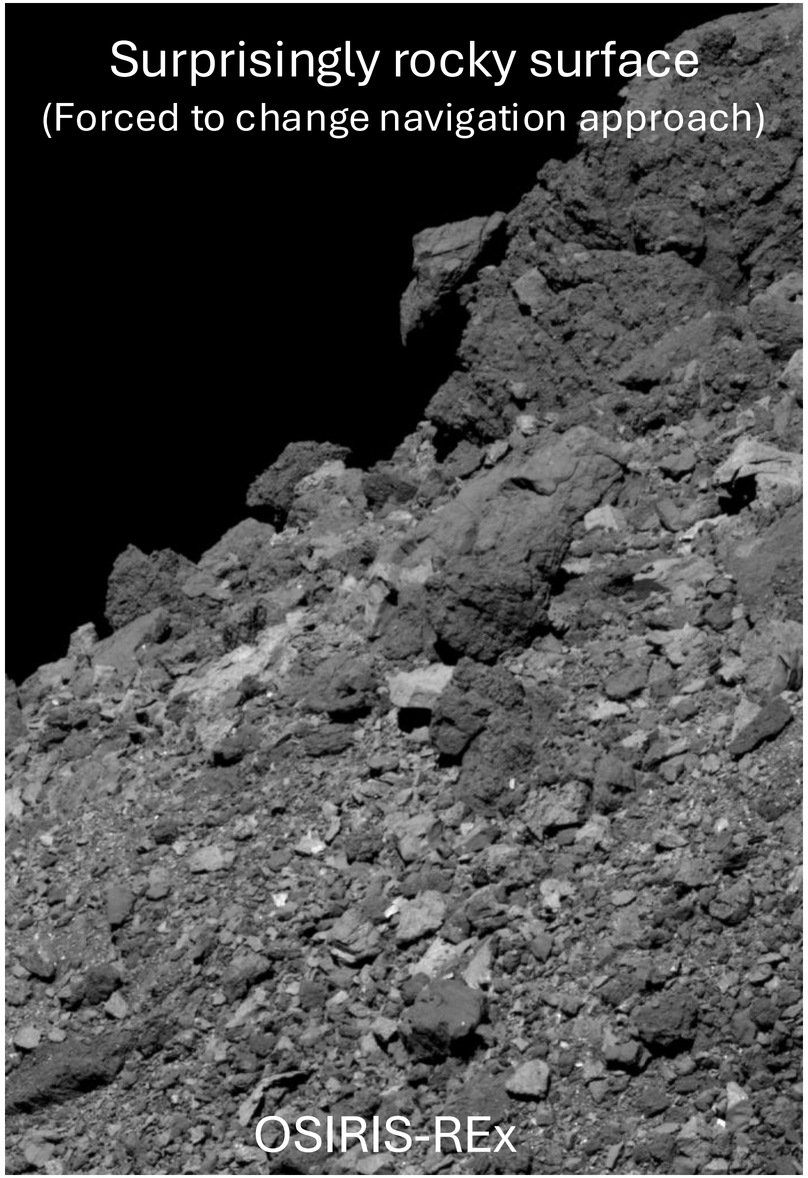
Because we know so little about it

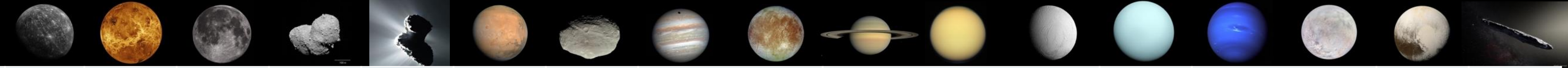
Implications:

- For science: many discoveries waiting to be discovered
- For engineering: many surprises waiting to be encountered

Bad things happen in space







	Mercury	Venus	Moon	NEO (near earth objects)	Short-period comets	Mars	Main belt asteroids	Jovian system		Saturnian system			Uranus	Neptunian system		Centaurs, KBOs	Long-term comets, interstellar objects
								Jupiter	Europa	Saturn	Titan	Enceladus		Neptune	Triton		
Outstanding challenges for robotic exploration	Large delta V to surface; extreme temperature	Extreme temperature (465C) and pressure (92 atm) at surface	Extreme temperature; abrasive regolith; subsurface access	Microgravity; unknown surface property	Microgravity; unknown surface property	More difficult surfaces (RSLs, volcanic terranis) Subsurface access	Relatively large delta V; microgravity; unknown surface property	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Radiation on the surface; access to subsurface ocean	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Exploration of the methane lakes; subsurface ocean access	Access to surface, vent, and subsurface ocean	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Very high delta-V for landing; surface and subsurface access	Extremely high delta-V for rendezvous; extremely long cruise time	Very short time from discovery to flyby (months); extremely high delta-V
Flyby	2	>10	>10	>10	>10	>10	5	7	6	4	3	3	1	1	1	2	
Orbit	1	8	>10	1	1	>10	2	2	*Multi-flyby	1							
Atmospheric		5				1		1			Dragonfly						
Surface		10	>10	2	2	10	1 *impactor				1						
Subsurface			VIPER (cancelled)			Mars Life Explorer											
Sample return			8	3													

Visited >10 times

Visited (at least once)

Future mission exists

Likely a future mission

No plan yet

	Mercury	Venus	Moon	NEO (near earth objects)	Short-period comets	Mars	Main belt asteroids	Jovian system: Jupiter	Jovian system: Europa	Saturnian system: Saturn	Saturnian system: Titan	Saturnian system: Enceladus	Uranus	Neptunian system: Neptune	Neptunian system: Triton	Centaurs, KBOs	Long-term comets, interstellar objects
	La... ex...	Ex... (4600) and pressure (92 atm) at surface	Ex... ab... su...	Mi... su...	Mi... su...	More difficult surfaces (R... Su...	Re... m... su...	Ex... pre... in...	Ra... ac... ocean	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Exploration of the methane lakes; subsurface ocean access	Access to surface, vent, and subsurface ocean	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Extreme temperature, pressure, and wind speed in the deeper atmosphere	Very high delta-V for landing; surface and subsurface access	Extremely high delta-V for rendezvous; extremely long cruise time	Very short time from discovery to flyby (months); extremely high delta-V
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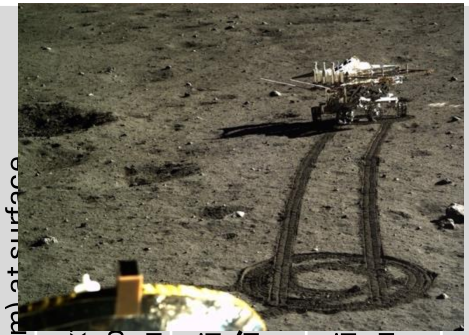


How to enable these missions?

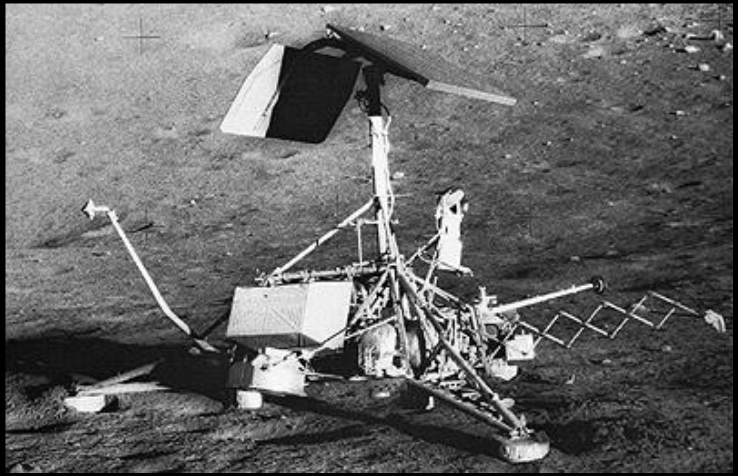
Visited >10 times	Visited (at least once)	Future mission exists	Likely a future mission	No plan yet

A fundamental paradigm change in robotic space exploration (RSE) is needed

1960s

RSE 1.0

Trial and error

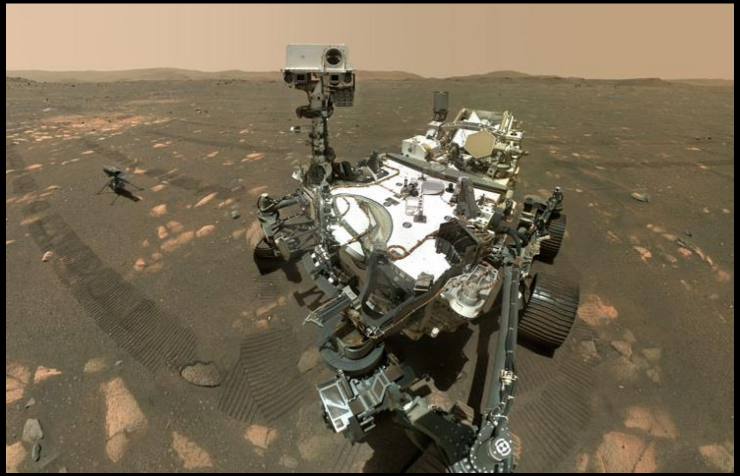


Moon

Current

RSE 2.0

Incremental sophistication

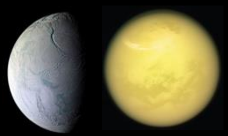


Mars

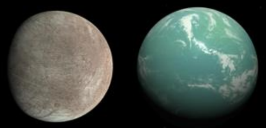
Future

RSE 3.0

Adaptive one-shot exploration



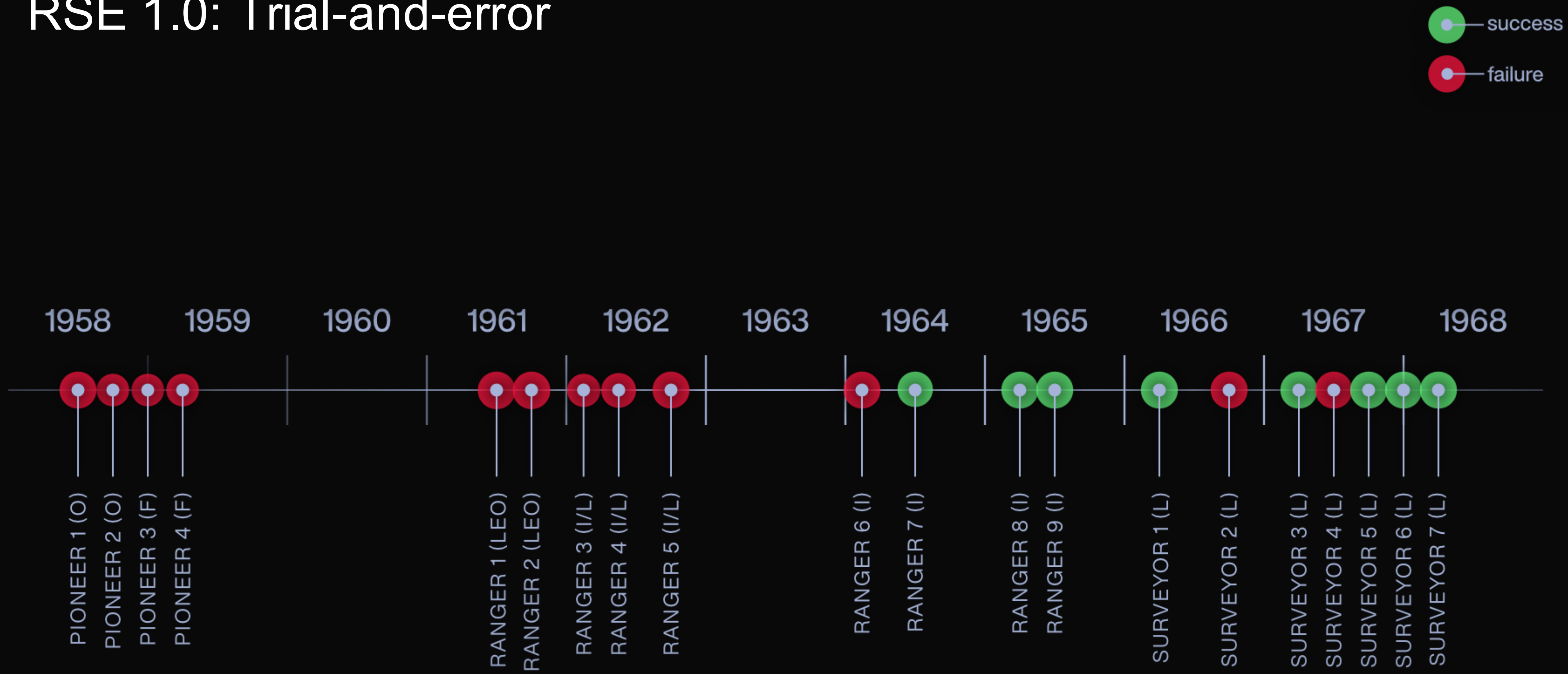
Beyond



RSE 1.0

The Moon (1958 – 1968)

RSE 1.0: Trial-and-error



RSE 2.0

Mars (1992 – Now)

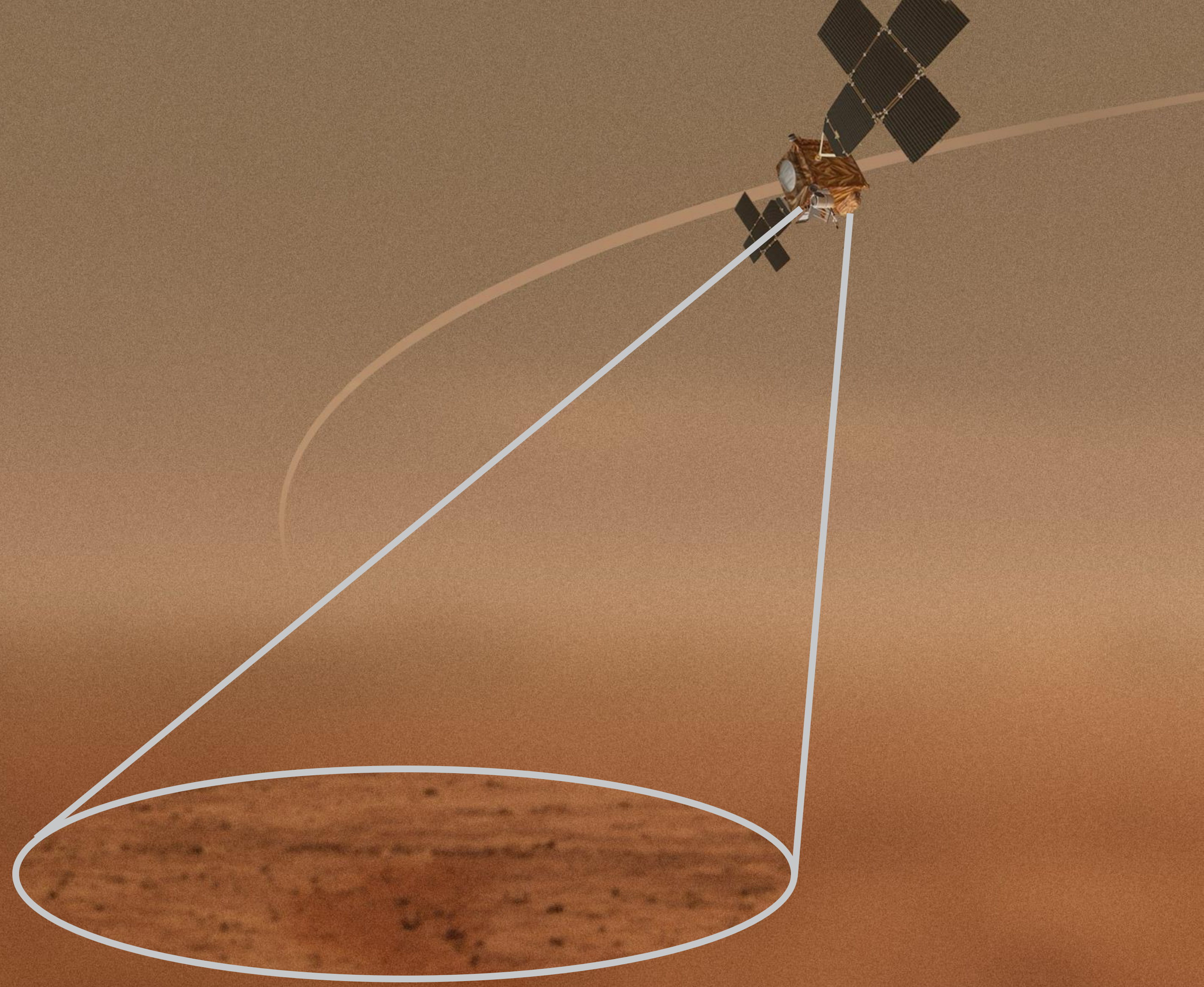
RSE 2.0: Incremental sophistication through a series of missions

Robotic exploration 2.0

Incremental sophistication through a series of missions

Environmental uncertainty

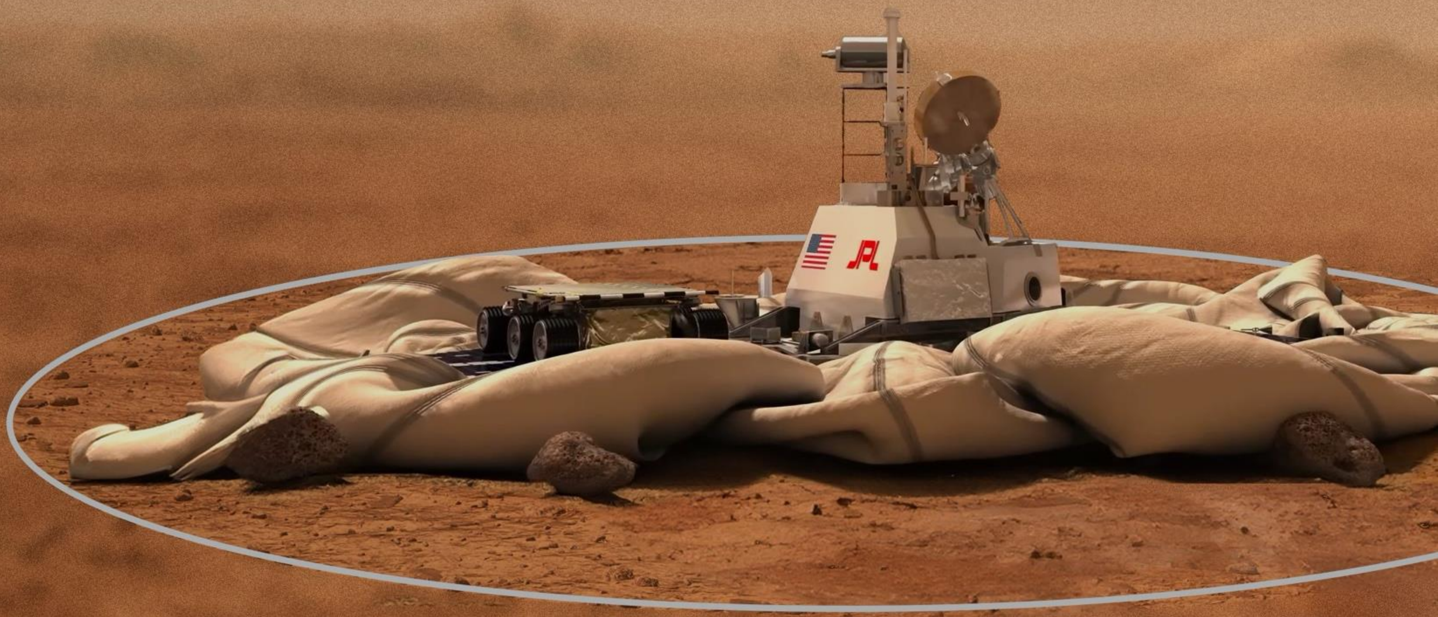
Orbiter



Environmental uncertainty

Task complexity

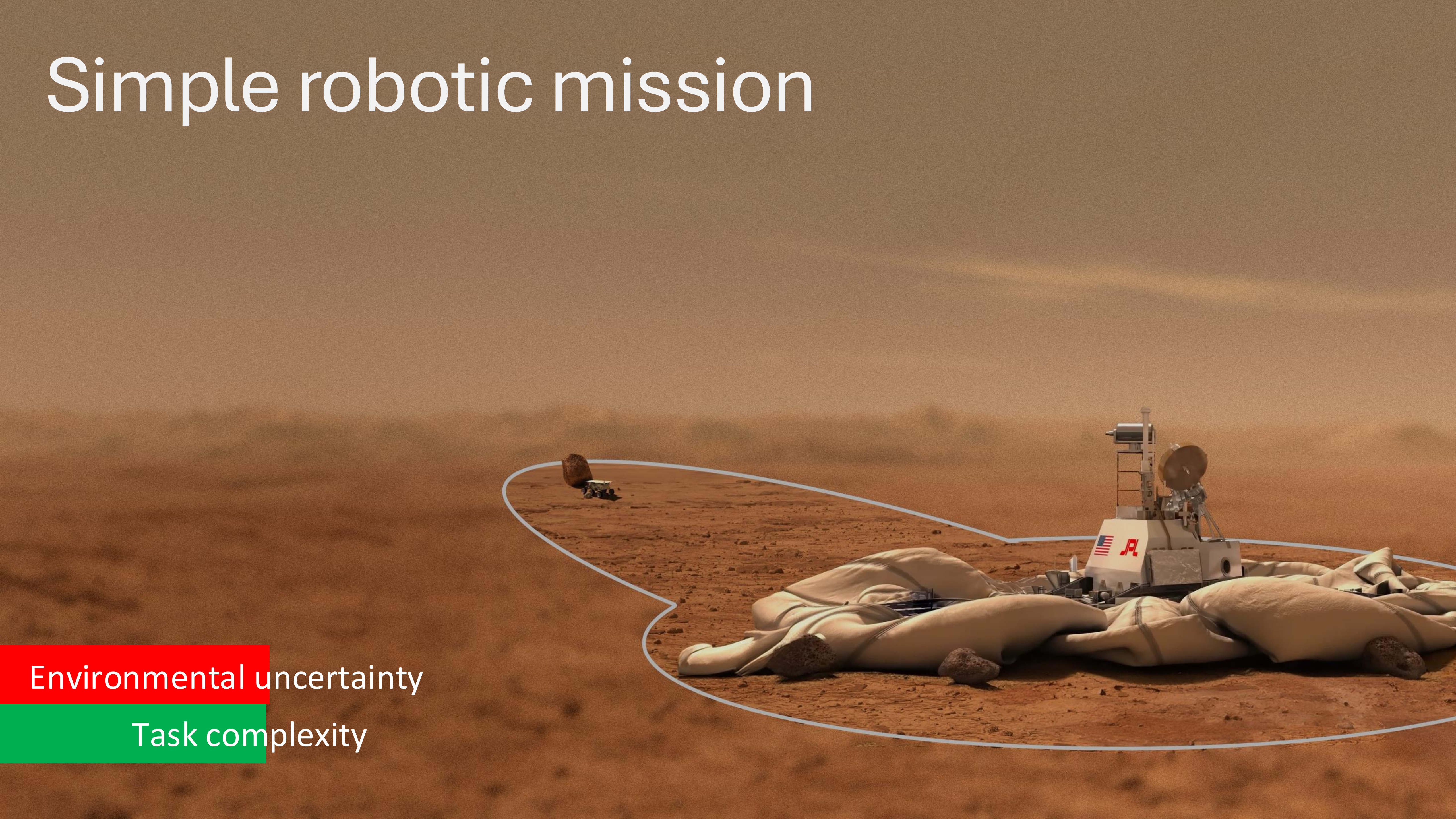
Simple robotic mission



Environmental uncertainty

Task complexity

Simple robotic mission

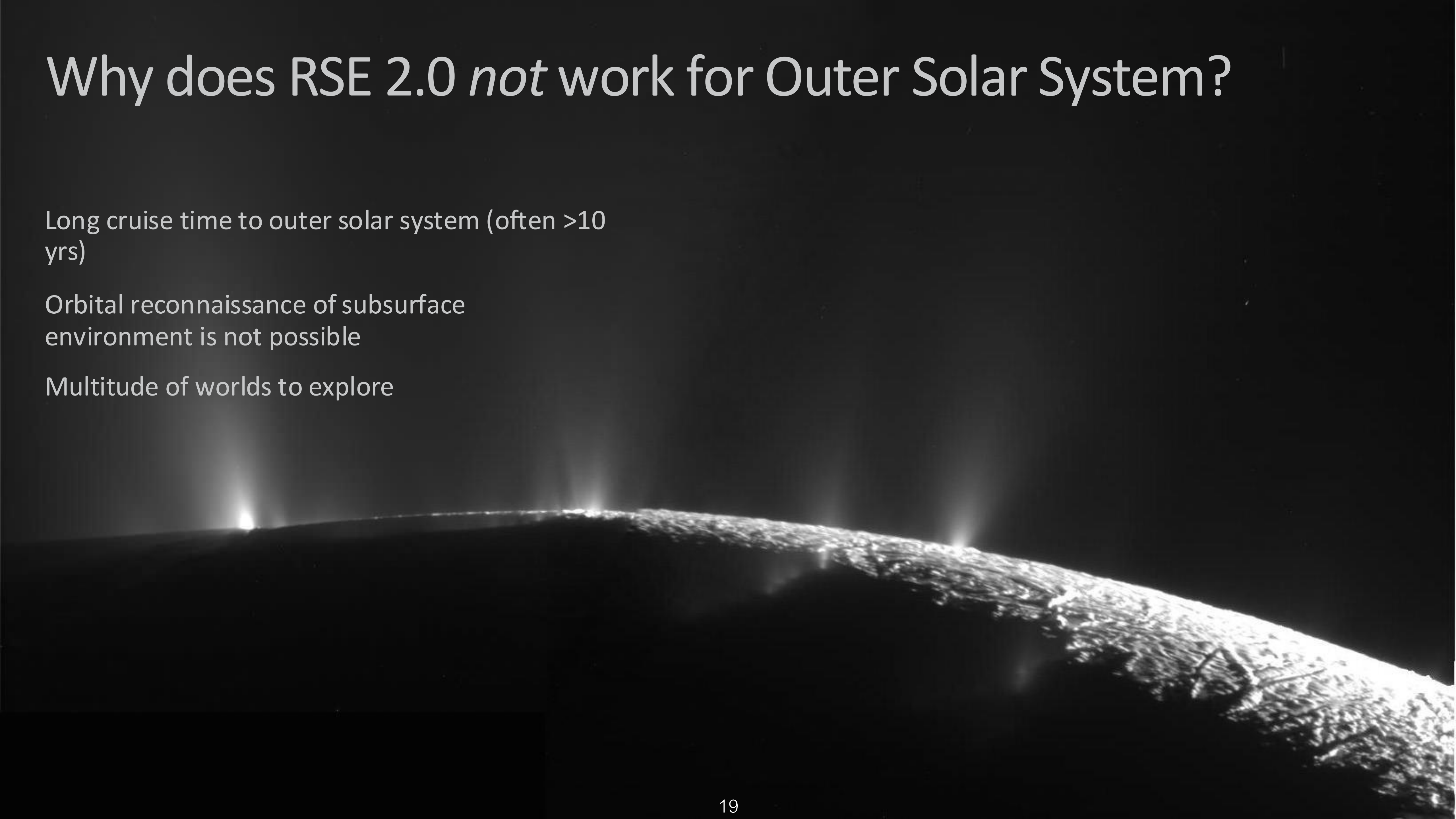


Complex robotic mission

Environmental uncertainty

Task complexity

Why does RSE 2.0 *not* work for Outer Solar System?



Long cruise time to outer solar system (often >10 yrs)

Orbital reconnaissance of subsurface environment is not possible

Multitude of worlds to explore

RSE 3.0

One-shot exploration with *adaptive* space system

Environmental uncertainty

Land and observe

Environmental uncertainty

Task complexity

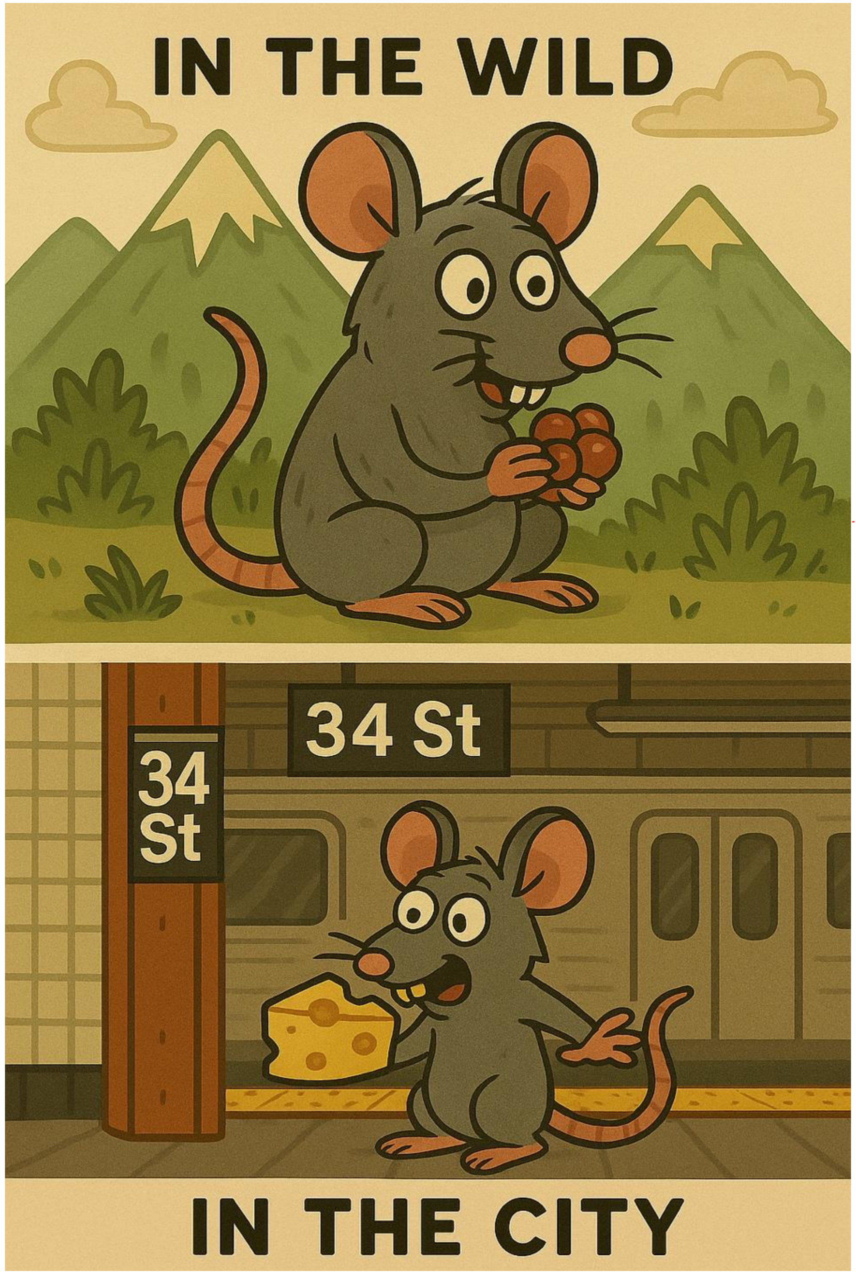
Adapt and perform simple tasks

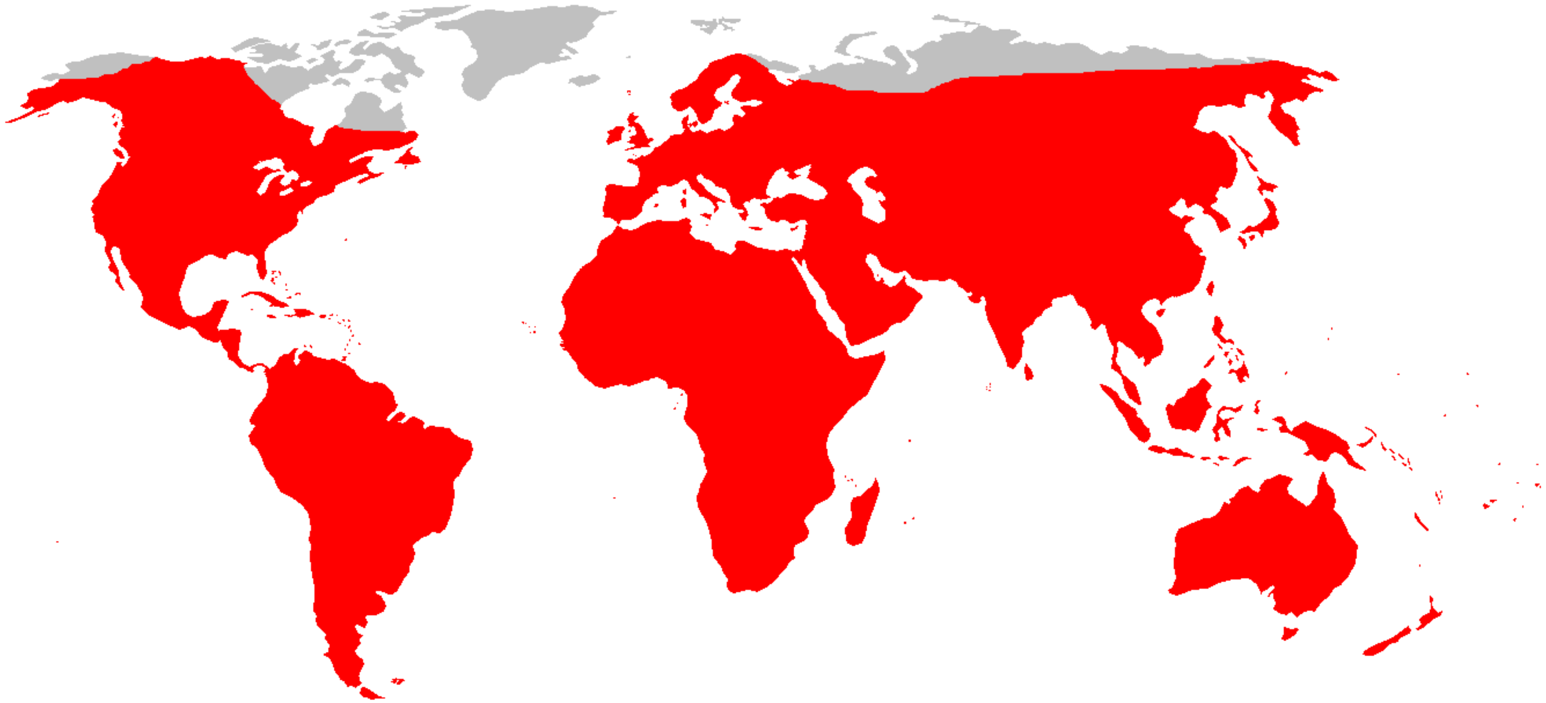
Adapt Complex robotic tasks

RSE 2.0 System: Pandas

- Only eat bamboo
- Only live in bamboo forest at elevations of 2,400 to 3,000 m
    - But not many bamboo species can grow at high elevations

RSE 3.0 System: Rats





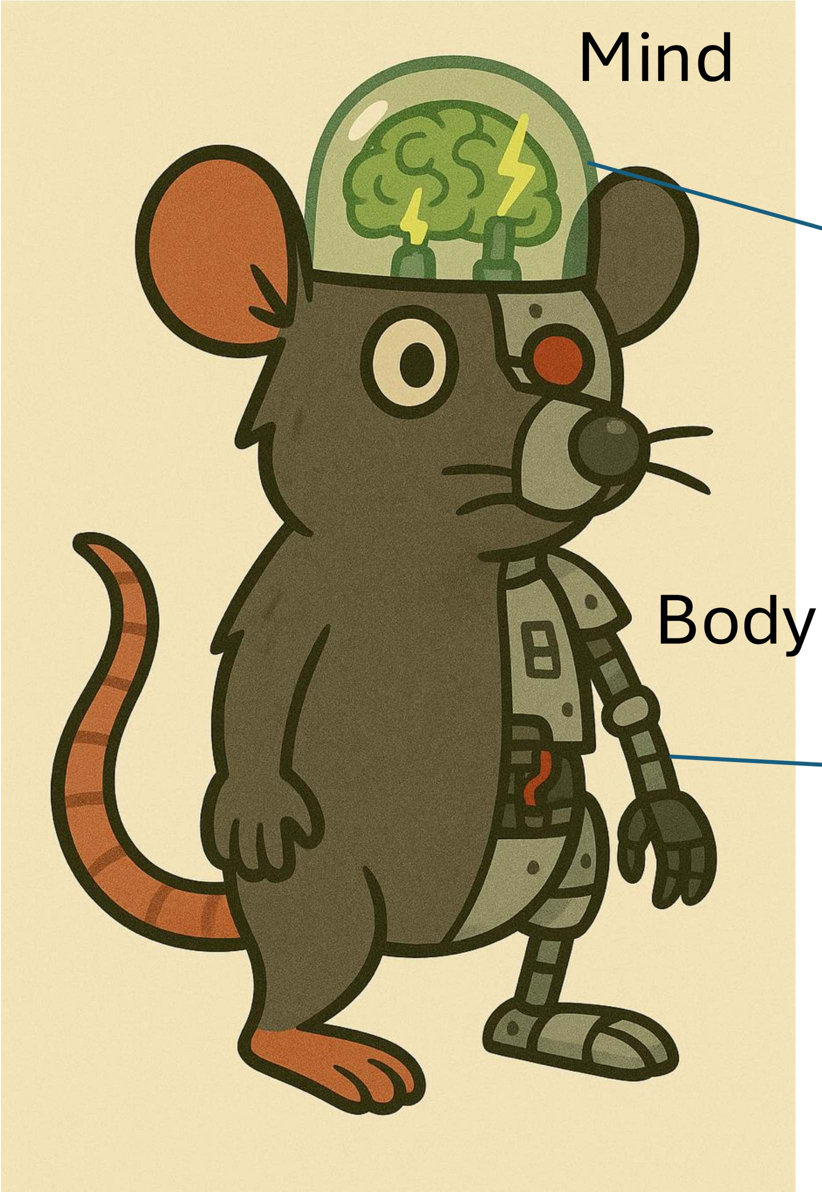
- Can digest almost anything
- Can live almost anywhere
- Can even adapt to urban environments

Prof. Shane Cambell-Staton (Princeton)

System Biological Insights into Space Systems Design

Technologies for RSE 3.0

How to enable a highly adaptive robotic systems?



Prof. Yisong Yue (Caltech)

Adaptive Robotics Technologies 2: Intelligence

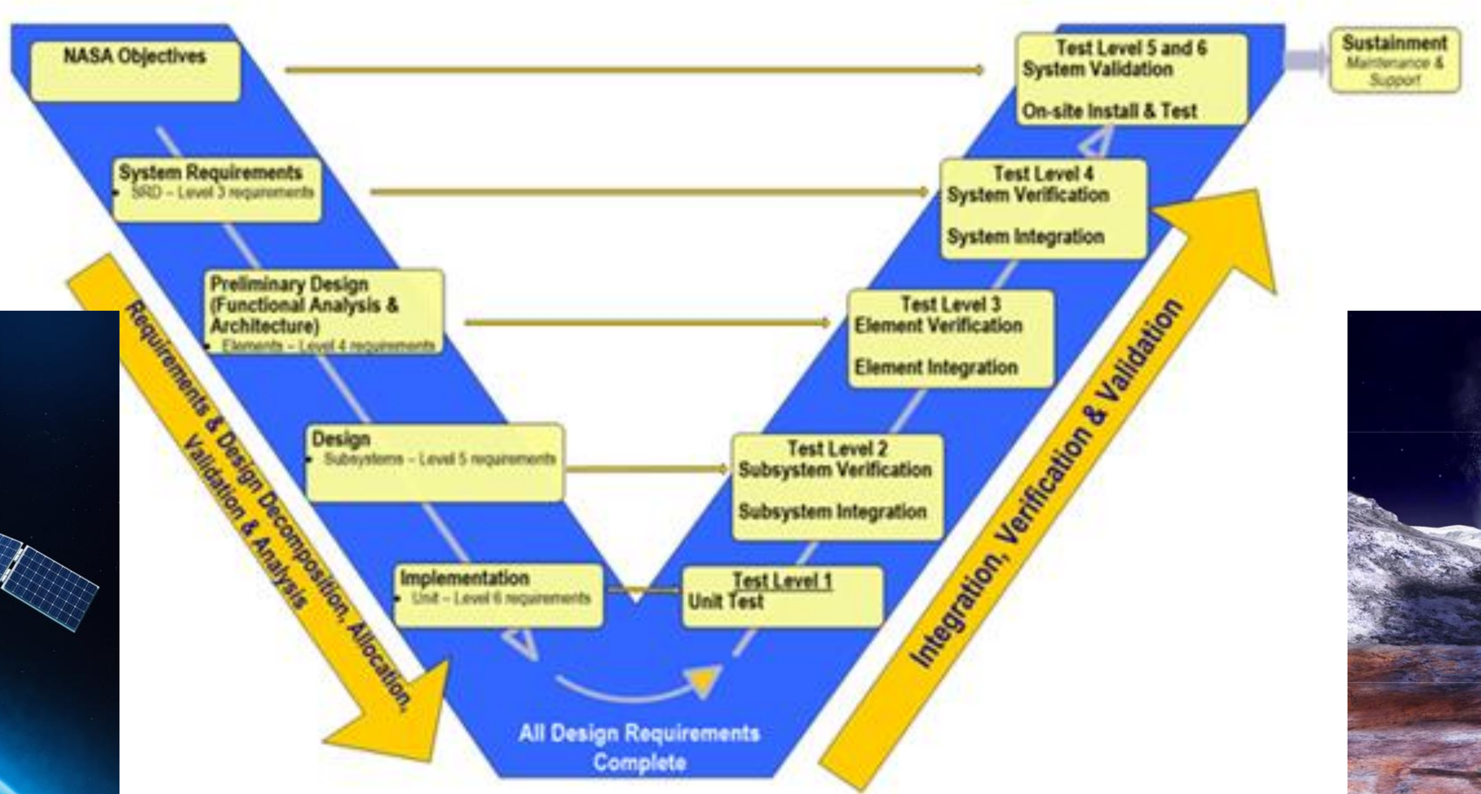
Prof. Maria Sakovsky (Stanford)

Adaptive Robotics Technologies 1: Hardware

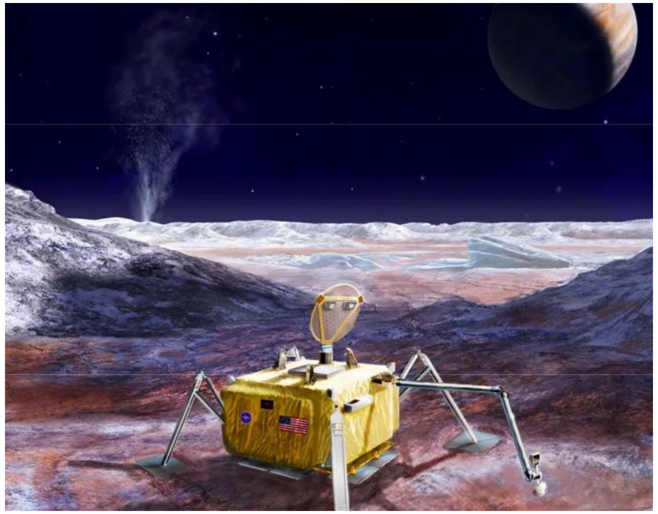
How to design a highly adaptive space system?

Can we use existing systems engineering approaches for RSE 3.0?

Space Systems Engineering



Commercial communication satellites



Planetary missions

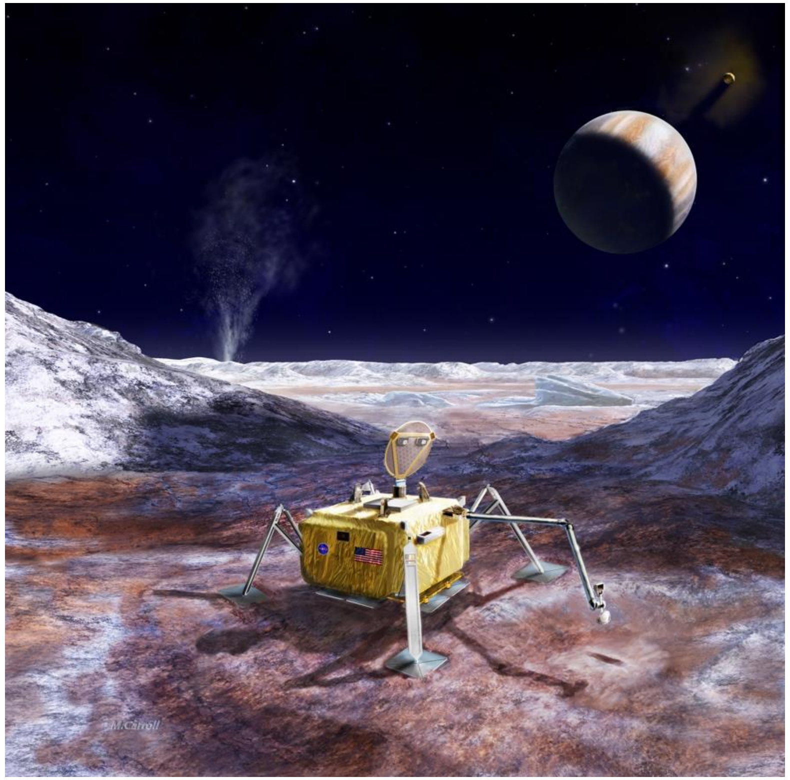
Commercial satellites := Business Trips

You know exactly what you will use them for

	Thursday, November 6, 2025 - Keck Center - Think Tank, Room 155	
	Institute Opens - FREE THINK TIME	
	Coffee and Refreshments at Keck Center	
	Logistics and Team Lead Goals for the Day	Harriet Brettle and Team Leads
	Special Talk: RSE 2.0 Systems Engineering for Space Missions	Rob Manning
	Lightning talks (3) - New systems engineering approaches - Alex Demagall - Marie Ethvignot - Andreas Hein - Dani Selva - Alejandro Salado	Selected participants
10:15 - 10:45	Break	
10:45 - 11:00	Breakout - goals and process	All
11:00 - 12:30	**Breakout Groups (3)** - RSE 3.0 Systems Engineering Approach - Science definition - Designing for dynamic requirements - conceptual design - Designing for dynamic requirements - V&V	All
12:30 - 2:00	Lunch on your own	
2:00 - 2:30	Report outs from breakout groups (10 mins each)	Groups
2:30 - 2:45	Breakout - goal and process	All

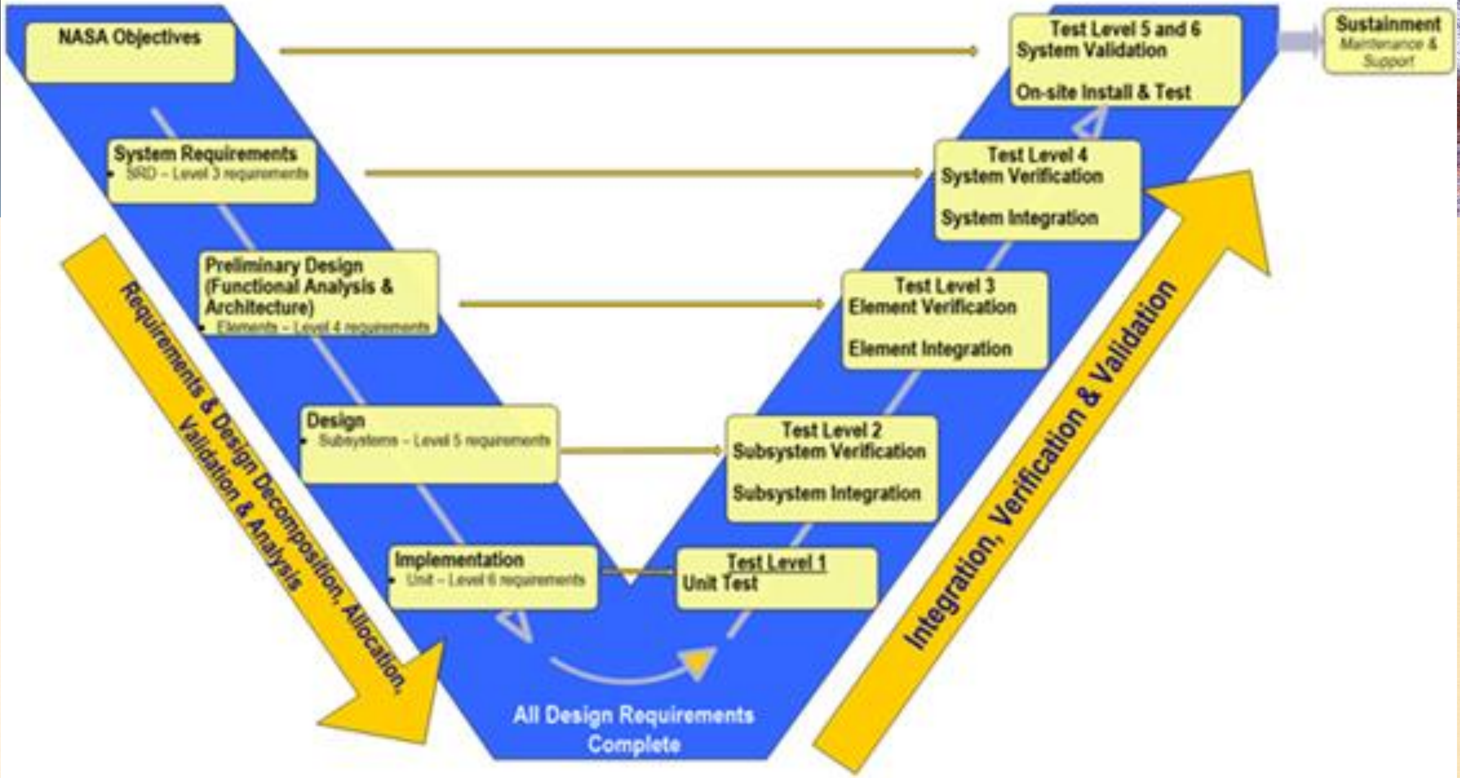
Planetary missions := Backpack Trips

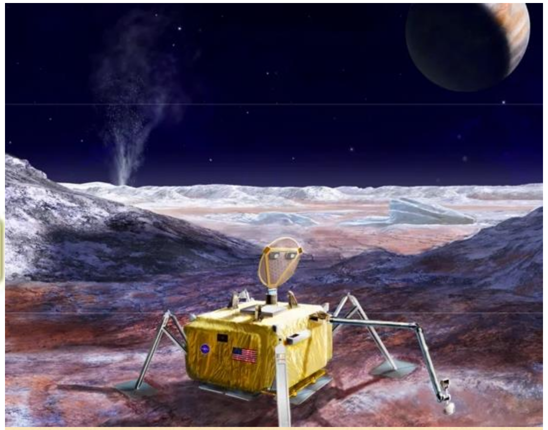
- Don’t know what you will use them for
- But you bring them anyway because they often come in handy in many unexpected ways



How to design RSE 3.0 missions?

Space Systems Engineering





Prof. Alejandro Salado (Univ. of Arizona)

Systems Engineering Challenges for Designing Adaptive One-Shot Missions

Short Course Lineups

9:10		Dr. Morgan Cable (JPL) *Unsolved Mysteries in the Outer Solar System*
9:45		Prof. Alejandro Salado (Univ. of Arizona) *Systems Engineering Challenges for Designing Adaptive One-Shot Missions*
10:50		Prof. Maria Sakovsky (Stanford) *Adaptive Robotics Technologies 1: Hardware*
11:25		Prof. Yisong Yue (Caltech) *Adaptive Robotics Technologies 2: Intelligence*
12:00		Prof. Shane Cambell-Staton (Princeton) *System Biological Insights into Space Systems Design*