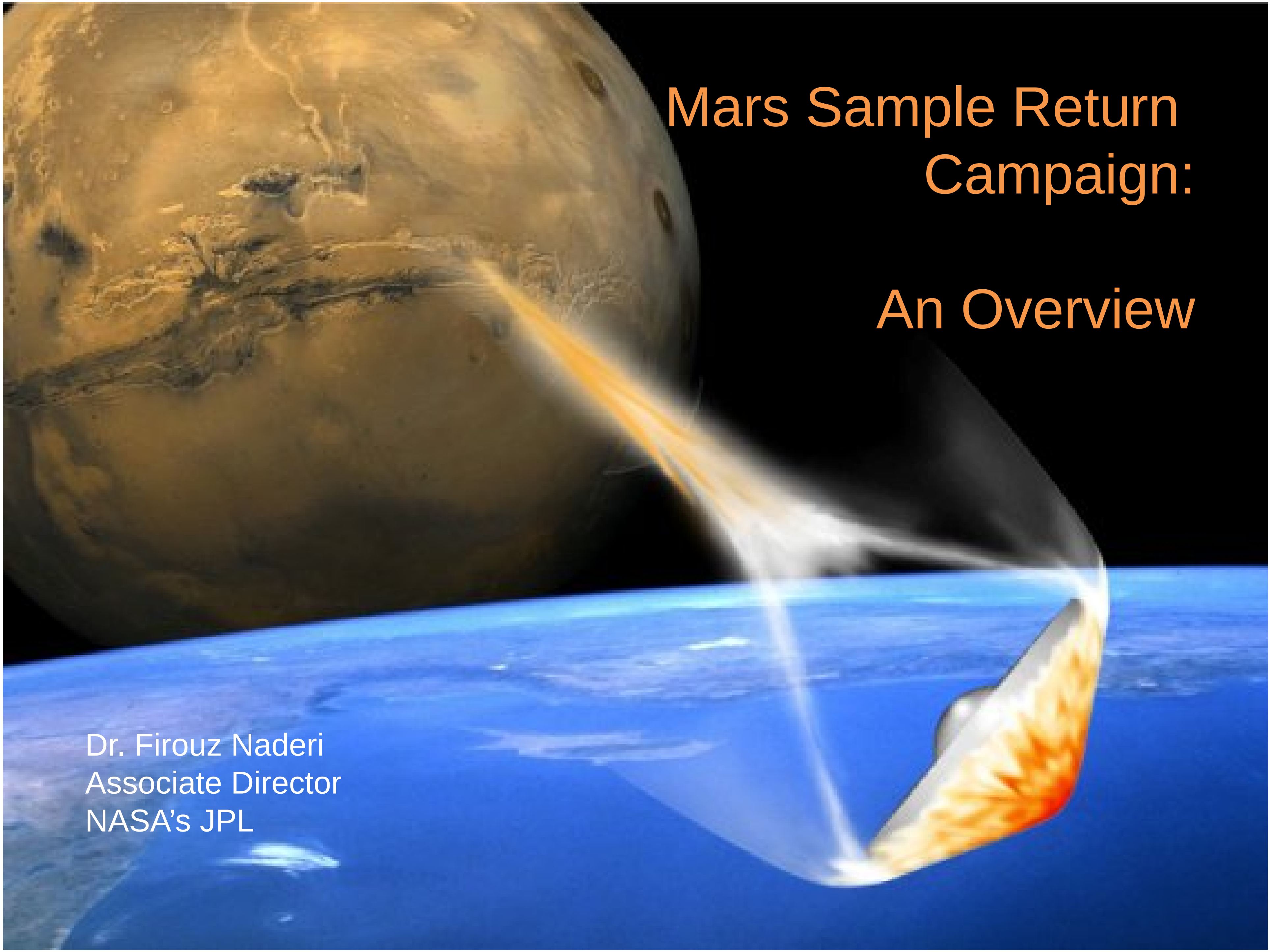
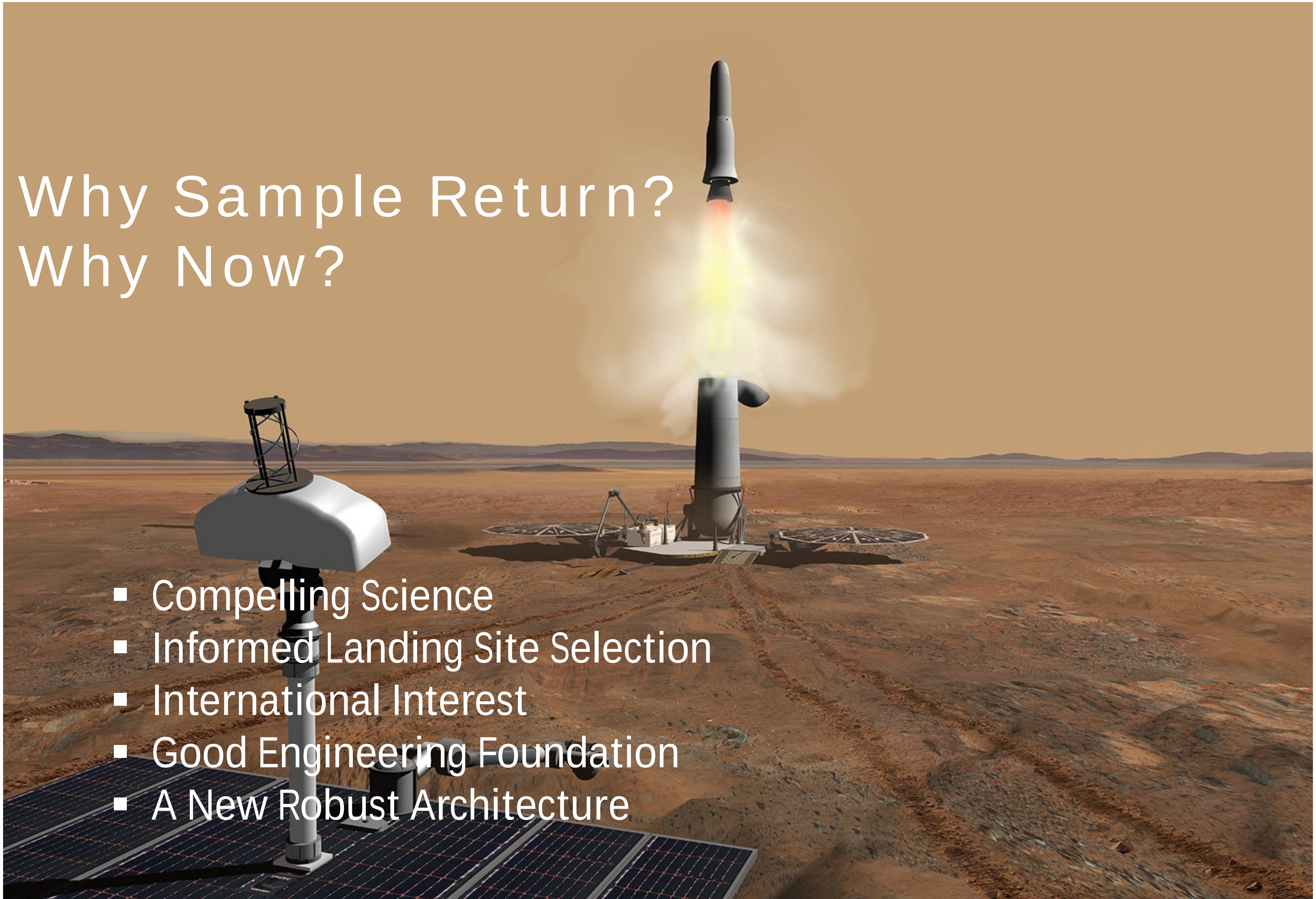


Mars Sample Return Campaign:

An Overview

Dr. Firouz Naderi
Associate Director
NASA's JPL

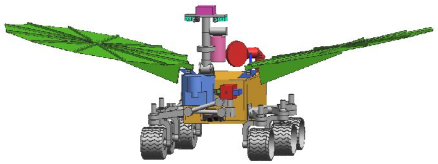
Why Sample Return?
Why Now?

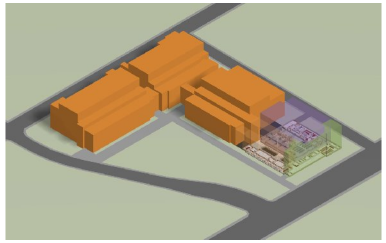


- Compelling Science
- Informed Landing Site Selection
- International Interest
- Good Engineering Foundation
- A New Robust Architecture

Return of Martian Samples in the 2020's Is Achievable

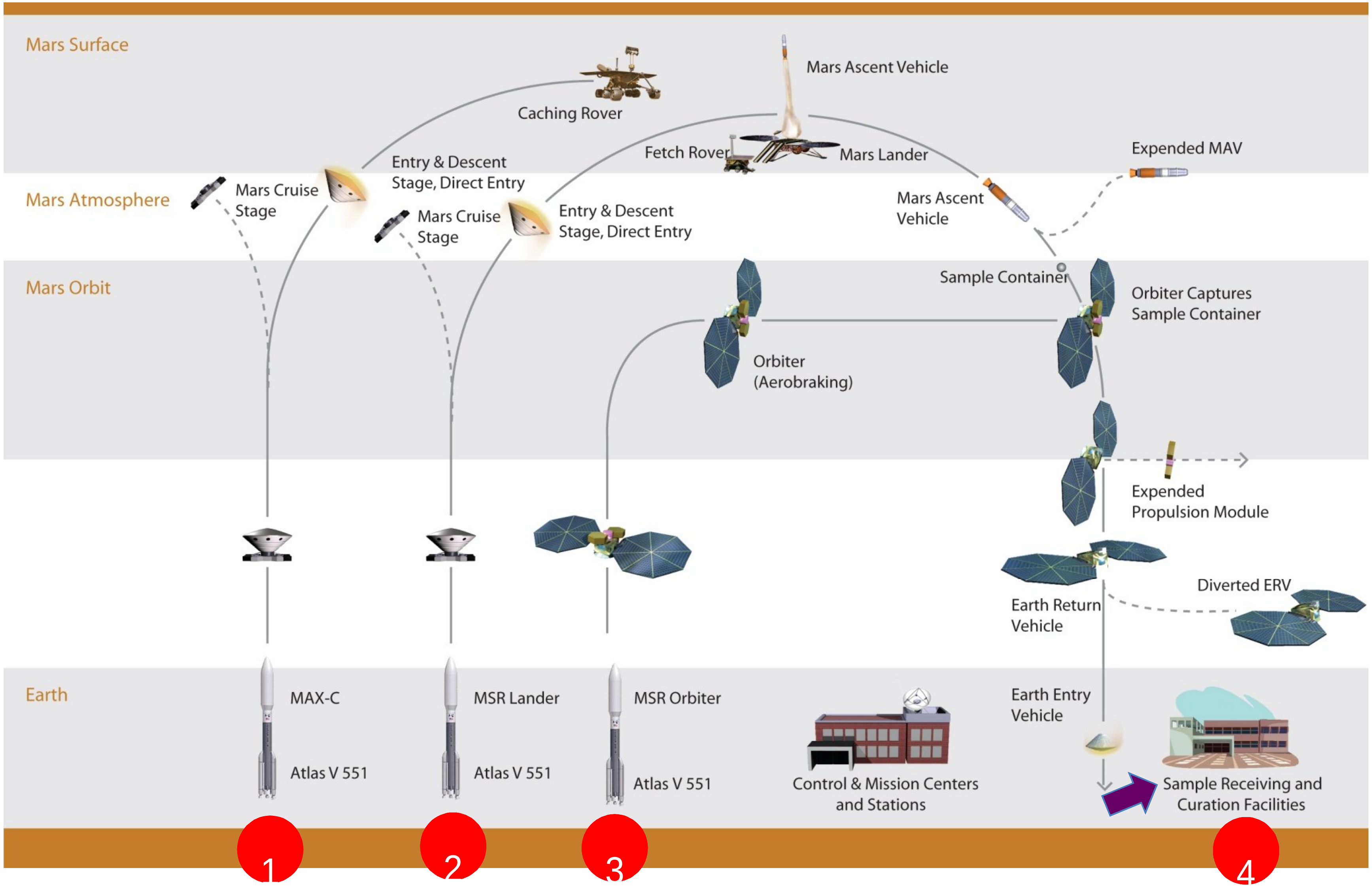
A Campaign Not a Single Mission



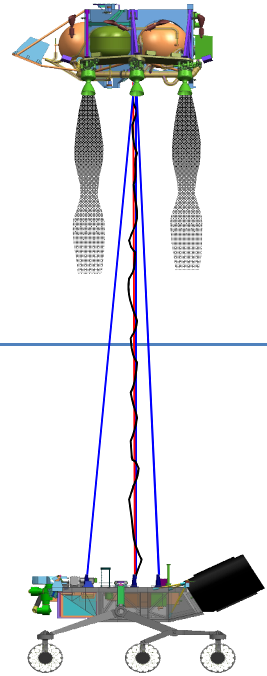


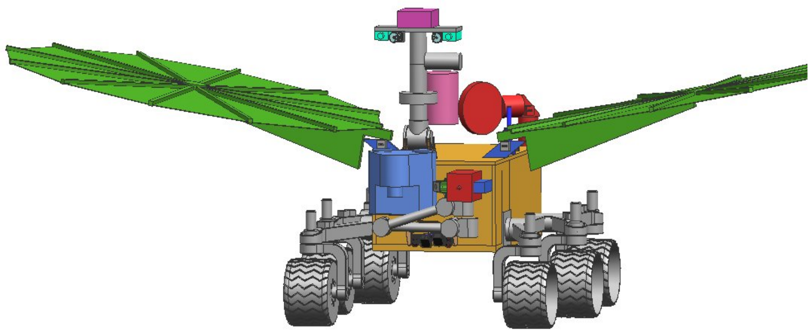
- Reduces the number of technical challenges per element
- Employs flight element concepts that are similar to our existing implementation experience -- allows analogies for scope and cost estimation
- Provides a resilient program and funding flexibility

The Architecture



The Two Landed Elements Will Use the MSL EDL System

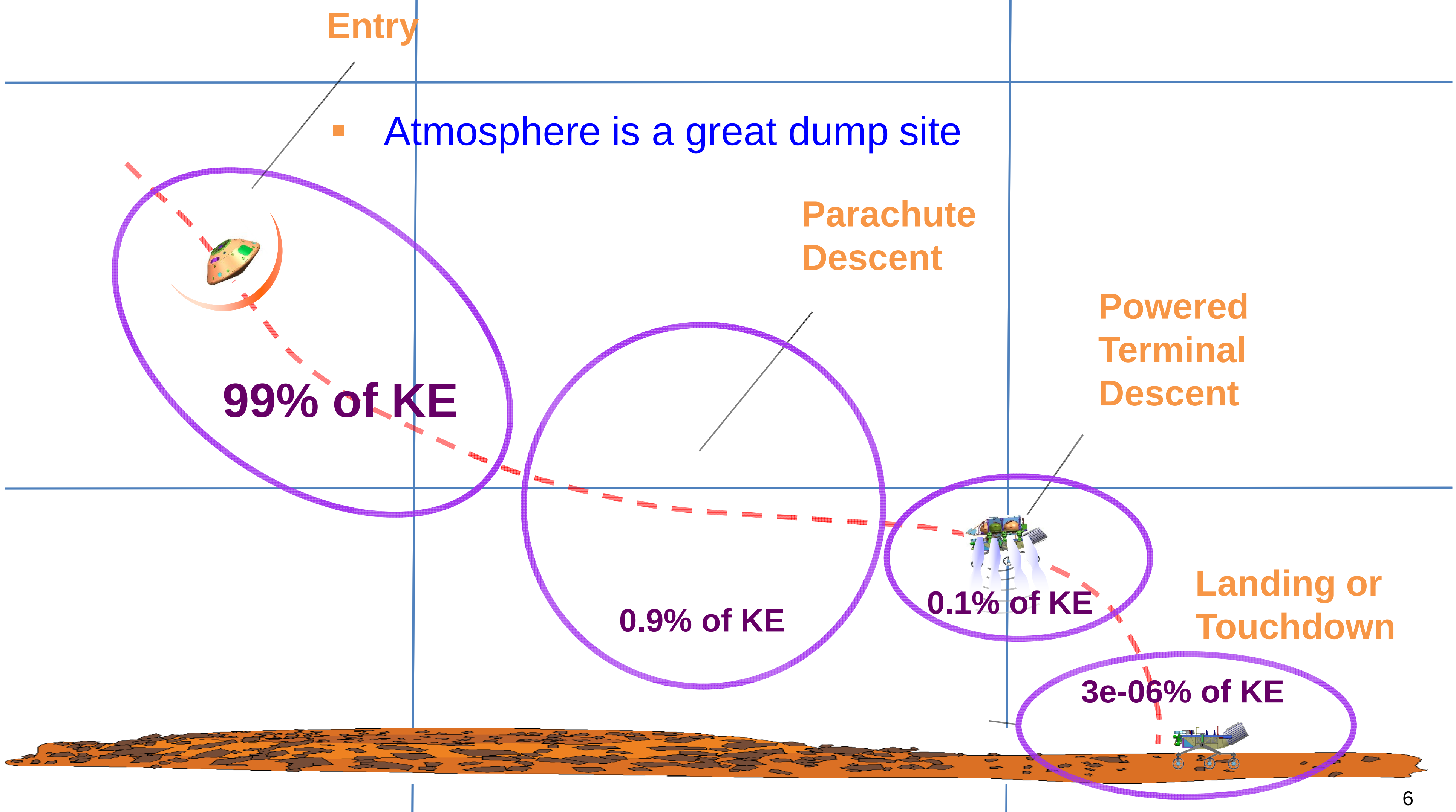




EDL:

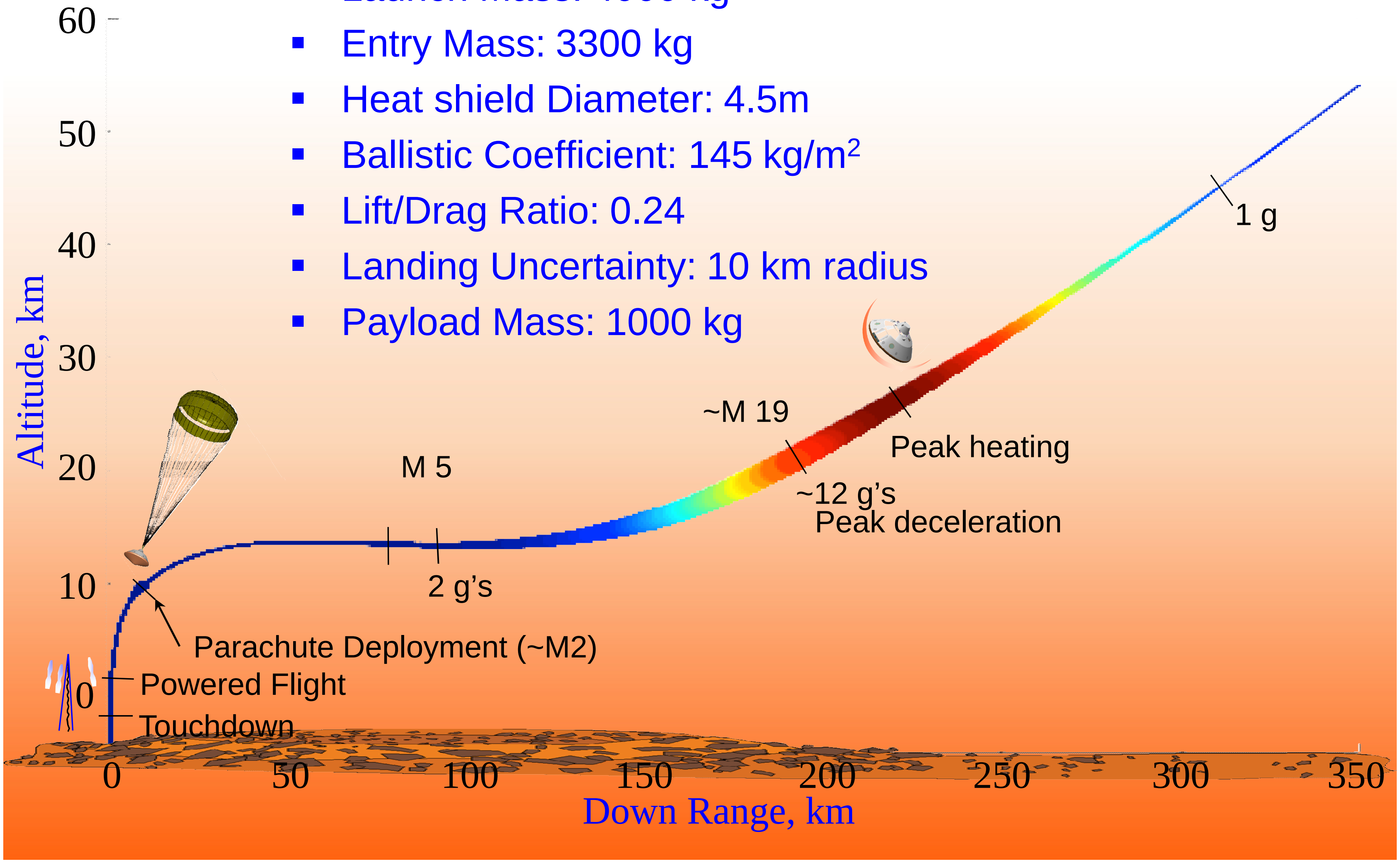
Managed Dissipation of Arrival Kinetic Energy

- Atmosphere is a great dump site



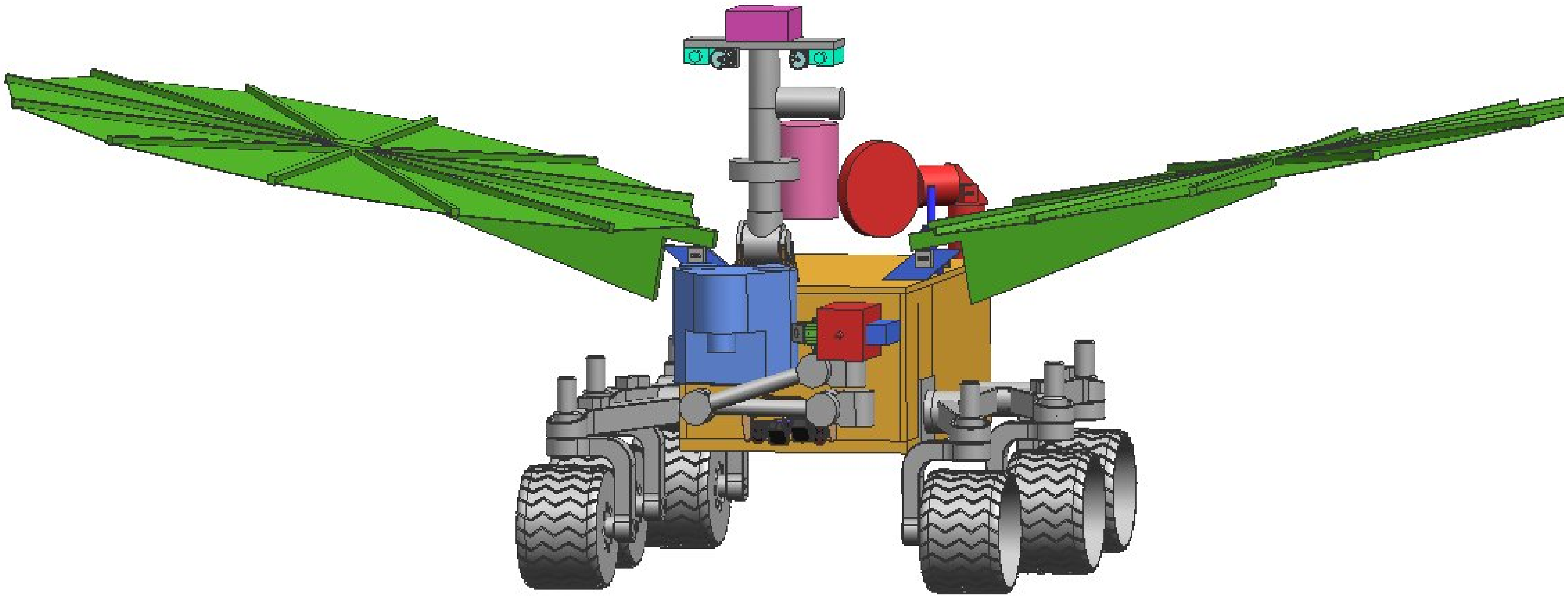
MSL EDL:

- Launch Mass: 4000 kg
- Entry Mass: 3300 kg
- Heat shield Diameter: 4.5m
- Ballistic Coefficient: 145 kg/m^2
- Lift/Drag Ratio: 0.24
- Landing Uncertainty: 10 km radius
- Payload Mass: 1000 kg



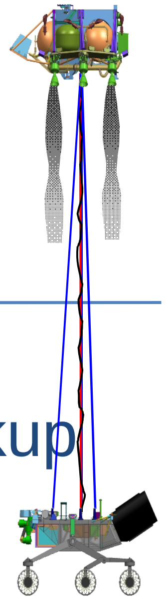
MSR Campaign: Element #1

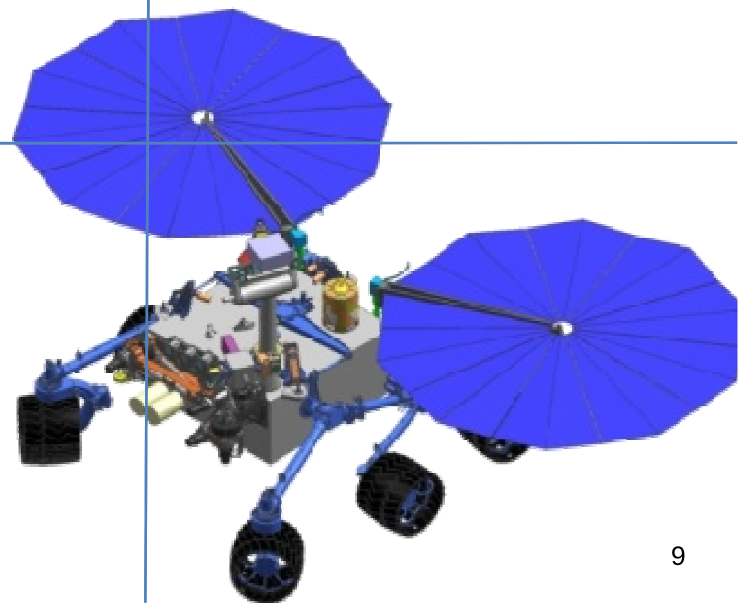
Mars Astrobiological Explorer and Caching Rover (Max-C)



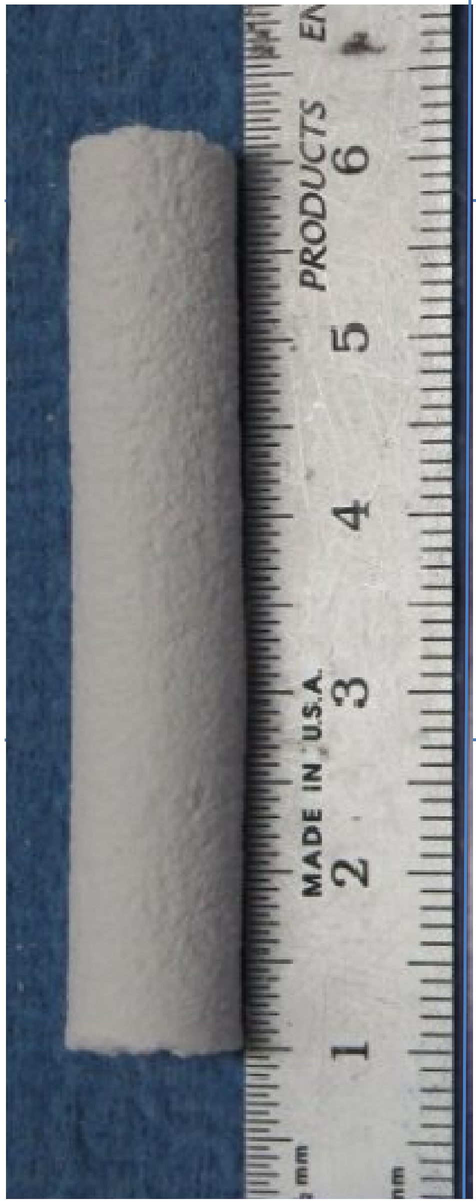
MAX-C

- Function is to select and cache samples for subsequent pickup
- Delivered to the surface via Sky Crane (1000 kg capability)
  - Approximately 300 kg/ea to Max-C, ESA rover, Landing Pallet
- 20 km traverse capability
- 500 sol lifetime





Samples Requirements



Minimum necessary # of samples

- Rock samples*:* *20* (~ 1 cm wide by 5 cm long)
- Regolith samples: 4
- Dust sample: 1
- Gas sample: 1

Sample diversity

- *Diversity is crucial*

Sample preservation needs

- Retain *pristine nature: avoid excess heating, organic and inorganic contamination*
- Packaging to prevent *mixing*
- Link to field context

Need to Detect Composition at Very Small Spatial Scale

- Needed for interpreting the paleo-environmental conditions and alteration history of minerals detected in the rocks
    - cm to sub-mm scale.

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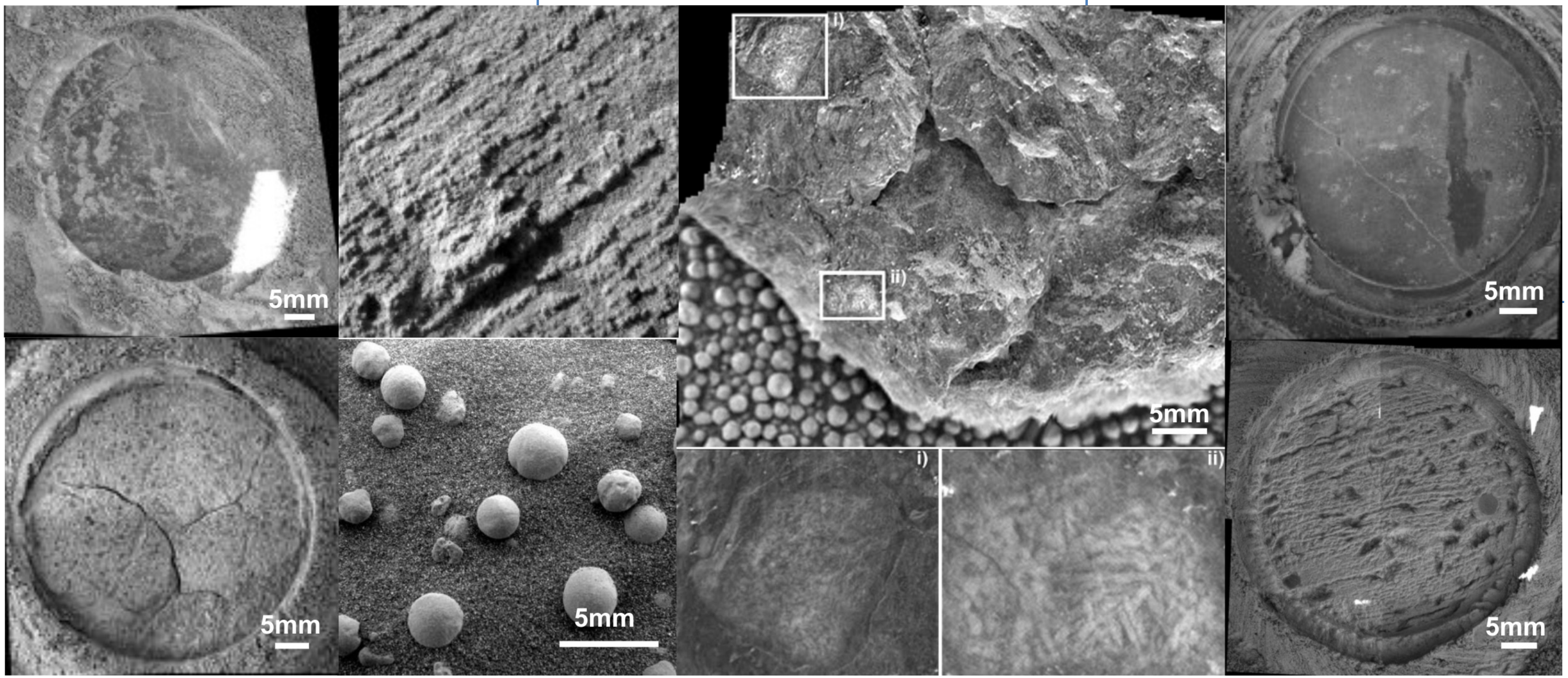
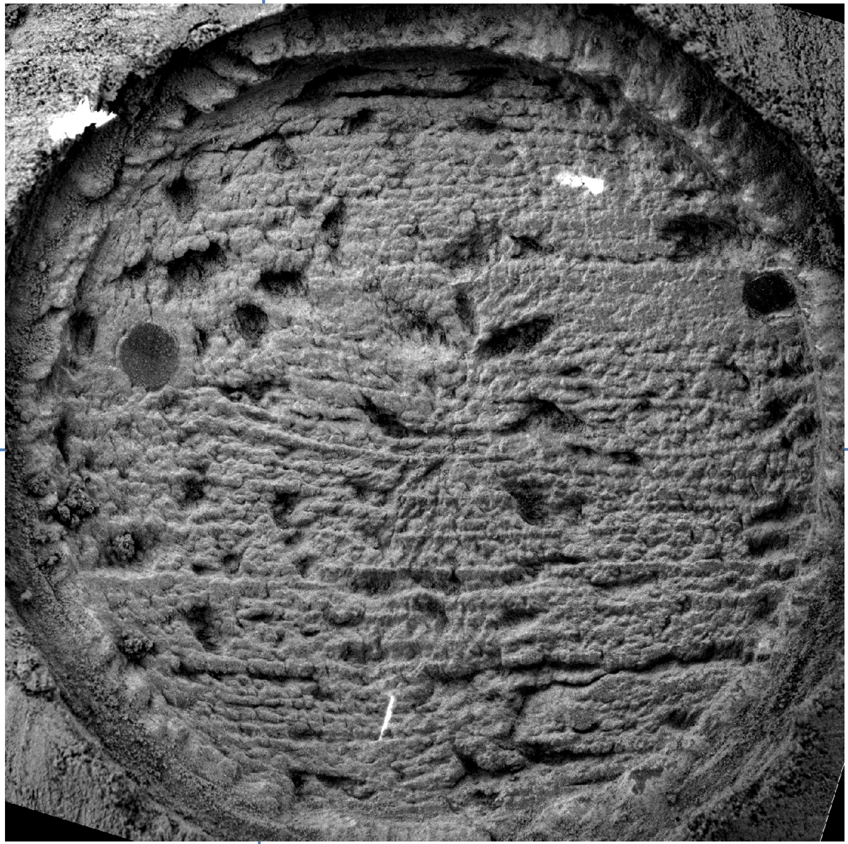


Instrumentation

- *Coring and Caching*
- *Micro-scale imaging*
- *Color stereo imaging*
- *Macro/micro-scale mineralogy*
- *Micro-scale organic detection/characterization*

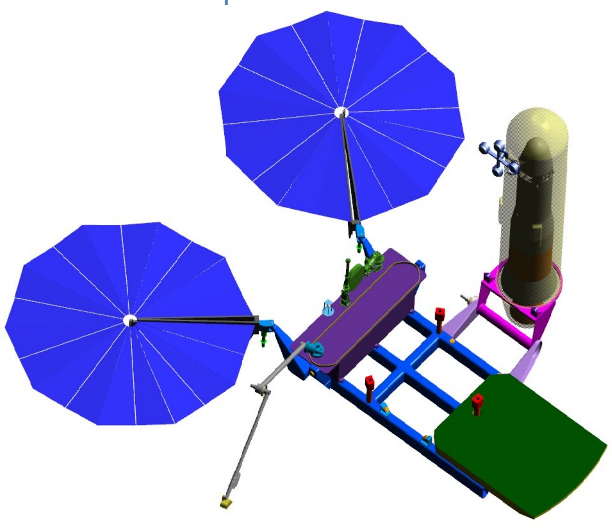
Opportunity "Ratted" Surface



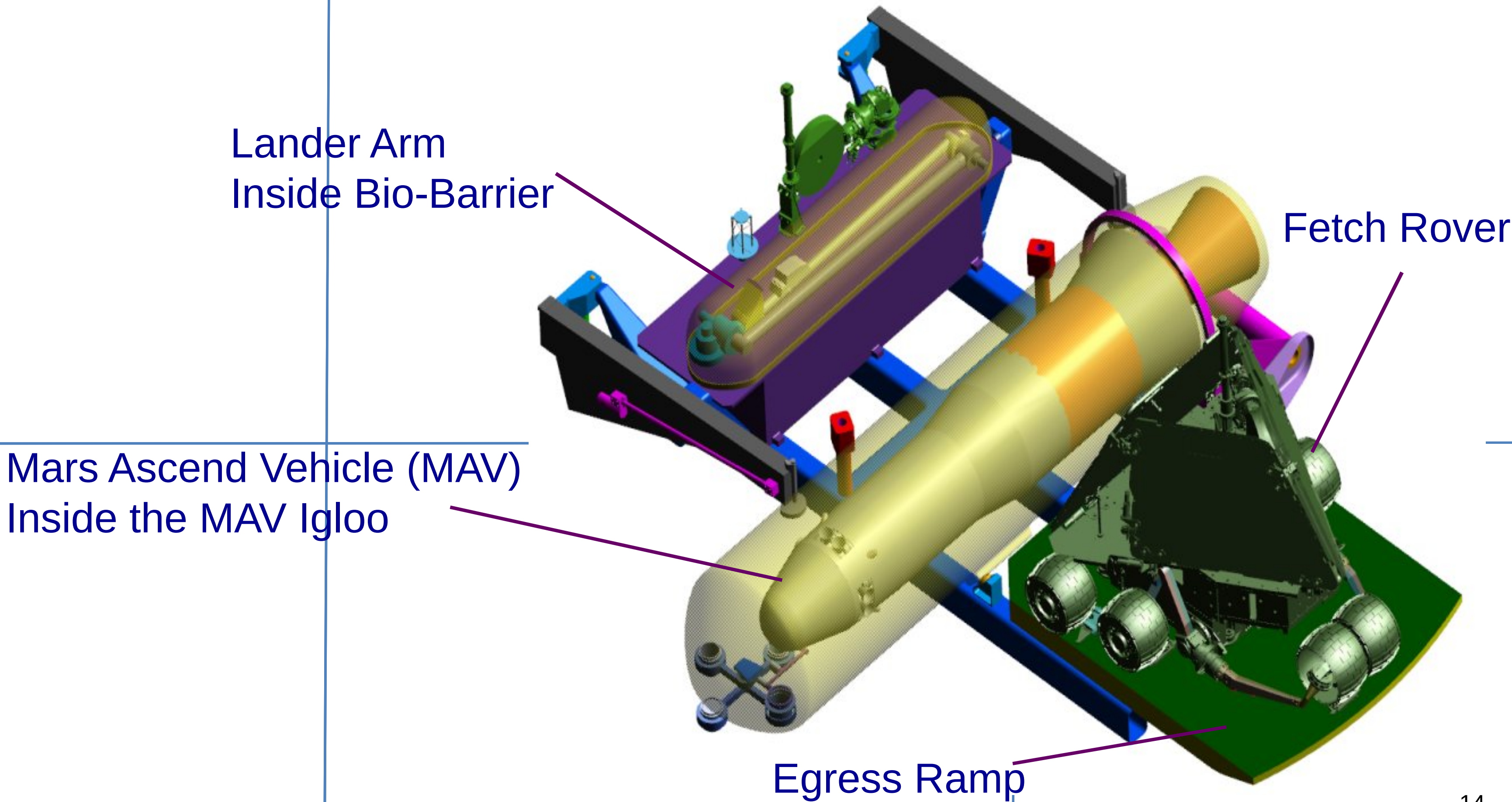
MSR Lander – Element # 2

- Function: Pick up cached sample & launch it into Mars orbit

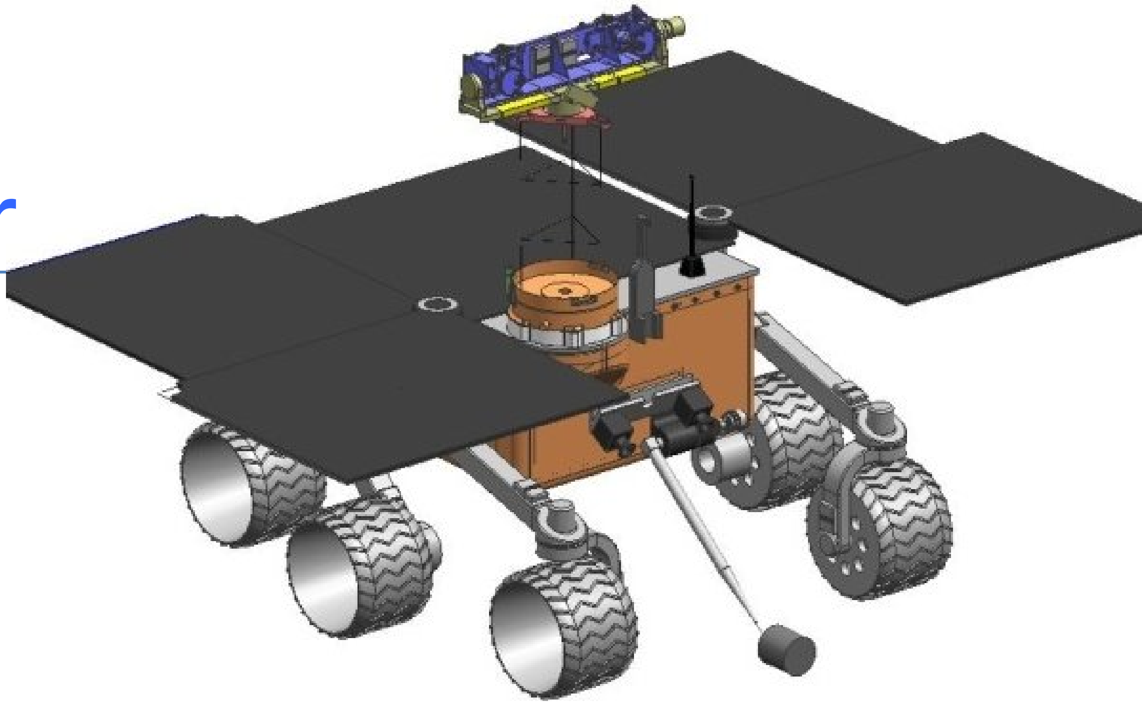
- Delivered to the surface using Sky Crane
  - o MAV ~ 300kg
  - o Fetch Rover ~ 150kg
  - o Platform/others ~ 550kg



MSR Lander – Element # 2



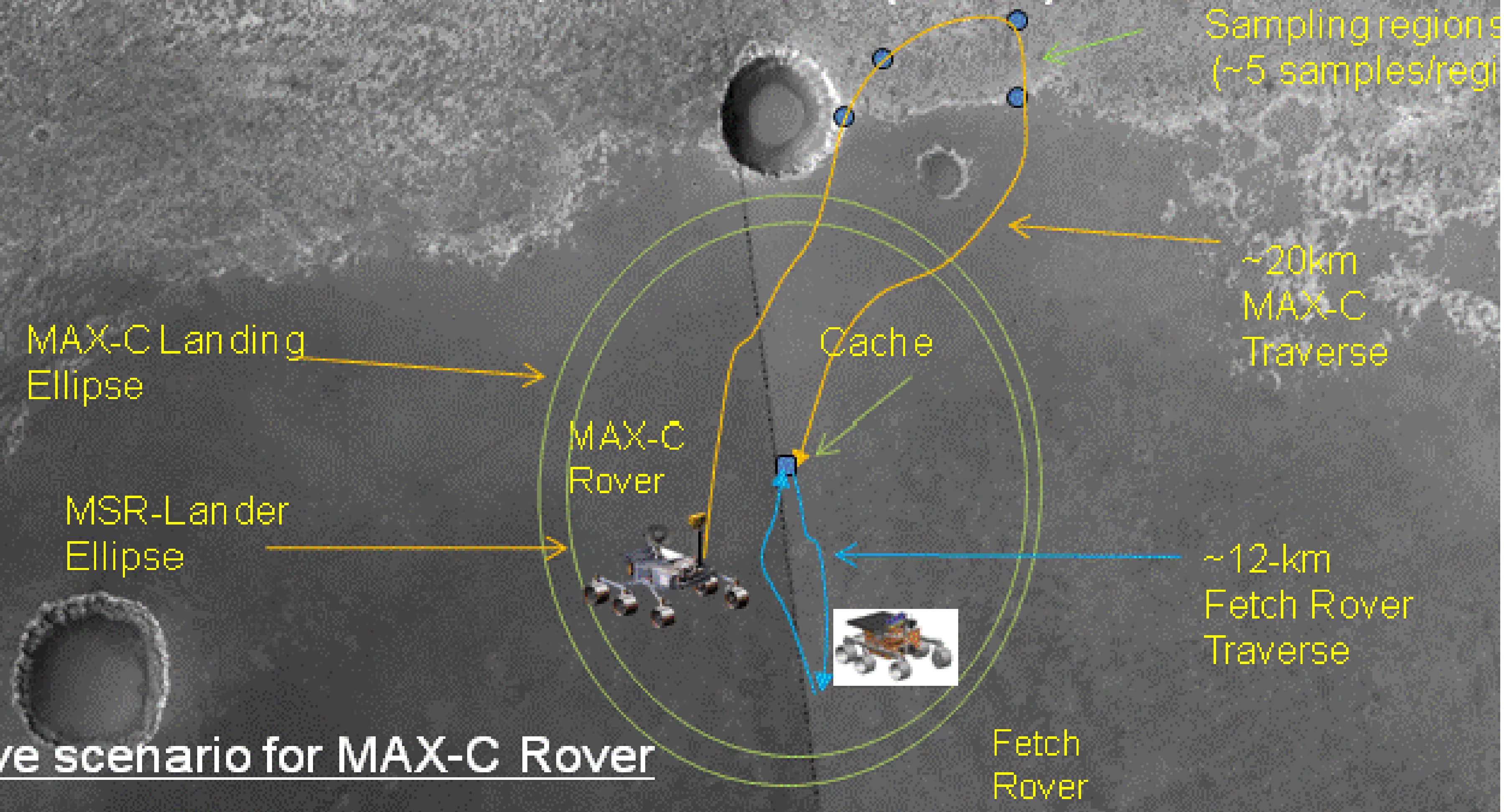
Fetch Rover



- 150 kg
- Similar to MER design, but with repackaged MSL avionics
- Enhanced autonomous driving (increased image processing)
- 1-DOF arm for pickup cached sample
- Retrieves cache within ~3-months of surface mission operation
  - One Earth-year design lifetime

Drive Scenario for Fetch Rover

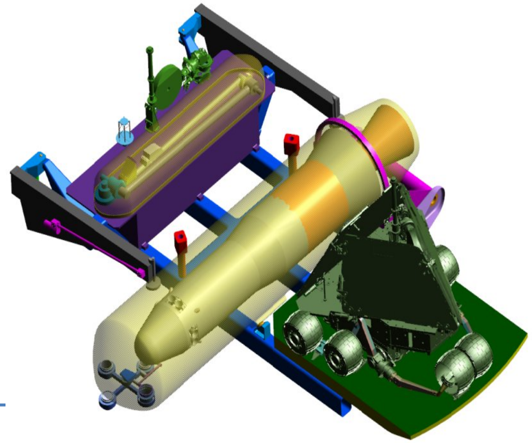
- Drive 2 x 6 = 12 km to retrieve cache and return it to MSR lander
- **Total drive distance is 2 x 6 = 12km; total time = 80 sols (150m/sol)**

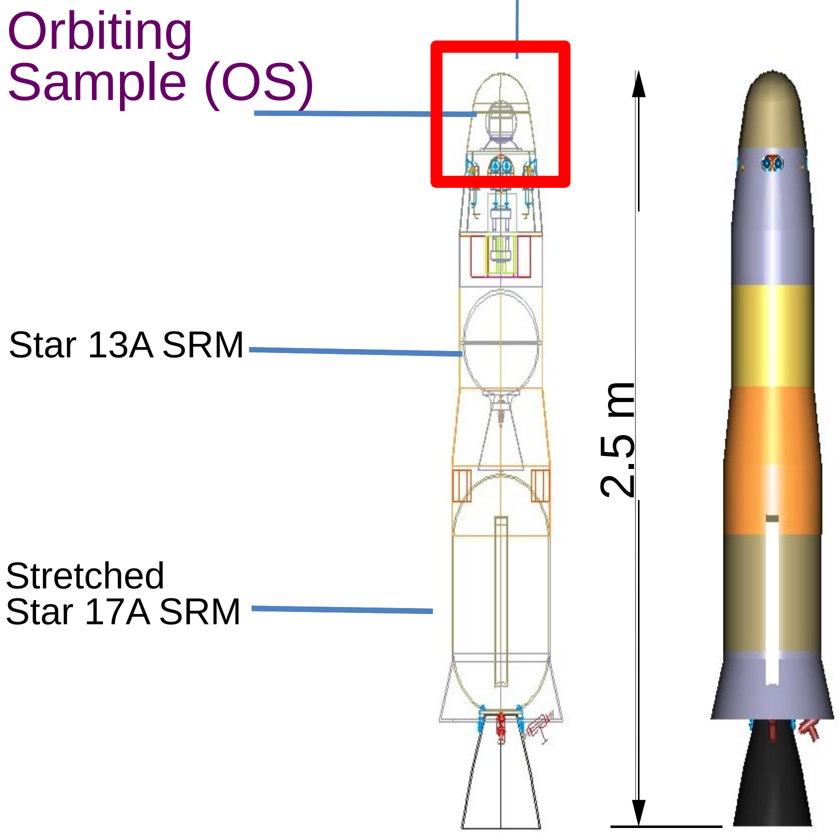


Drive scenario for MAX-C Rover

- Drive 10km out of ellipse at 150m/sol = 67 sols
- Cache 4 suites = 220 sols; driving 2 km
- Drive back 8km to center of Fetch Rover ellipse at 150m/sol = 53 sols
- **Total drive distance is 20km; total time = 385 sols (~500 with 30% contingency)**

Mars Ascent Vehicle

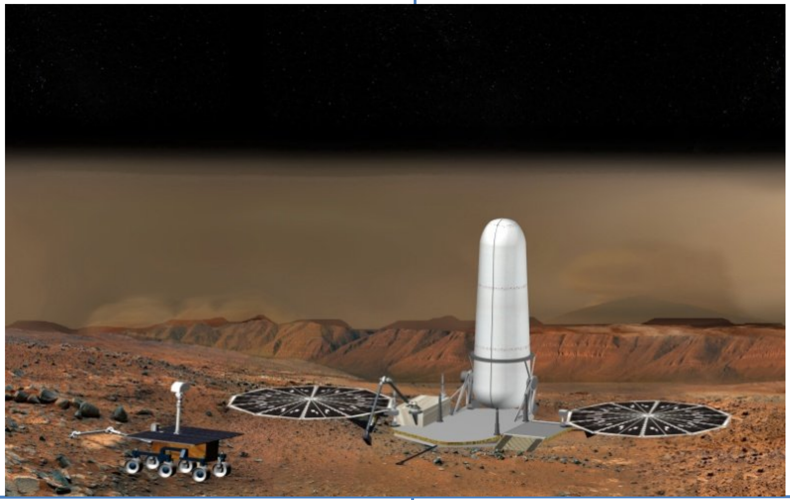


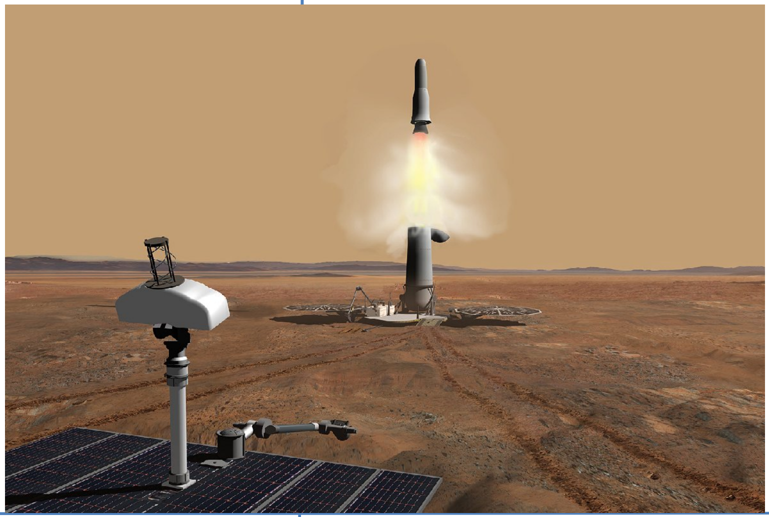


Strawman Approach:

- Two-stage launch vehicle Using solid rocket motors (SRMs)
  - o 3-axis mono-prop system for control
- Kept thermally stable in an RHU augmented thermal igloo
- One-year lifetime on surface
- Incremental testing and Earth-based high-altitude testing

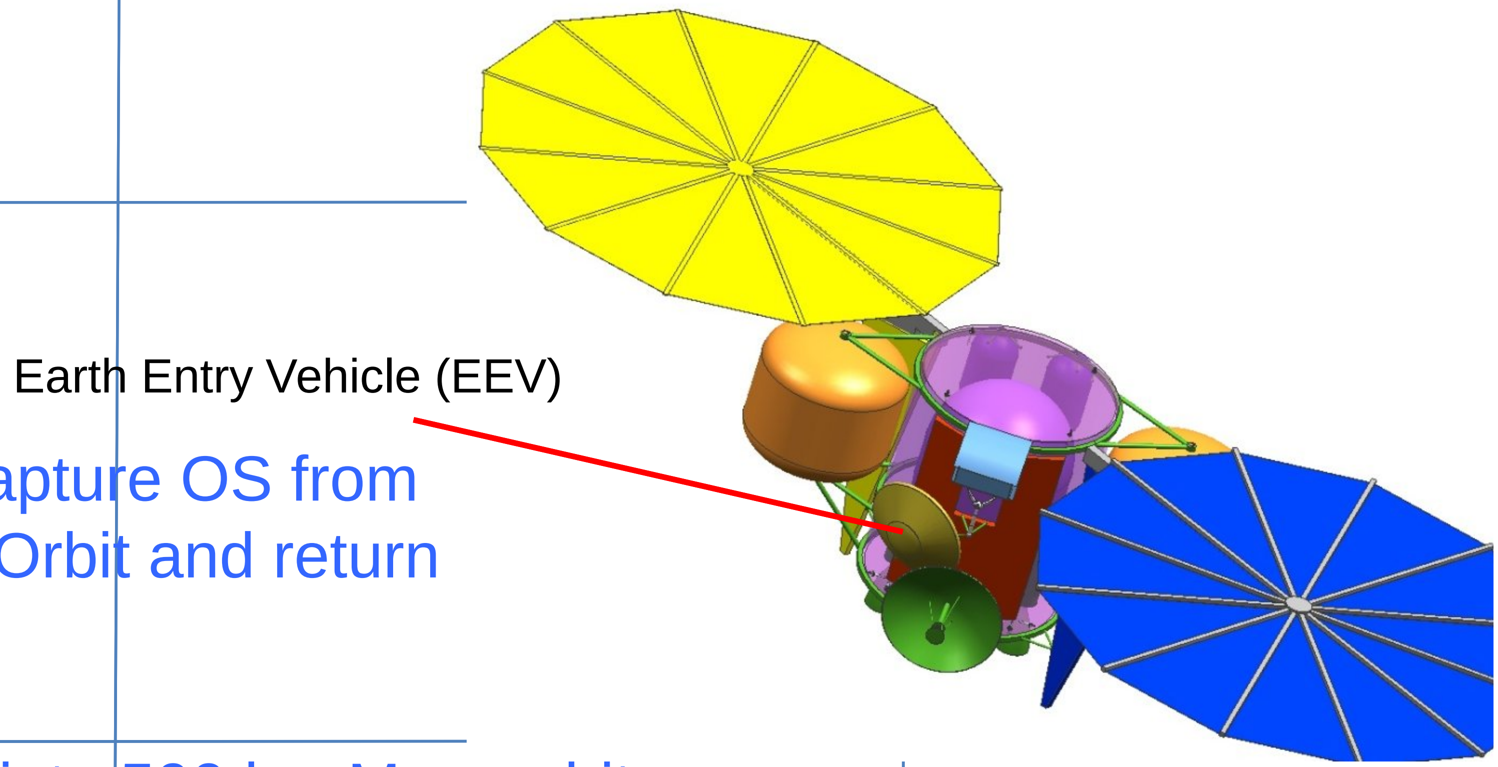
Orbiting Sample





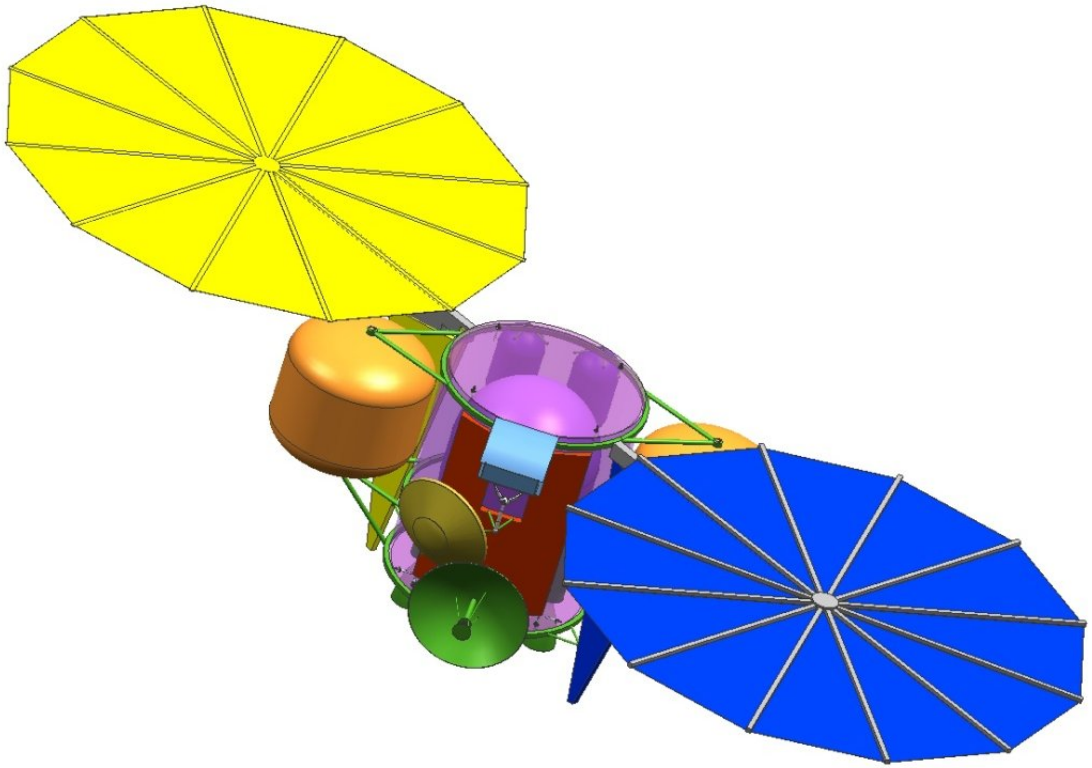
- The MAV launches 5kg Orbiting Sample (OS) into 500+/-100 km orbit, +/-0.2deg

MSR Orbiter – Element # 3



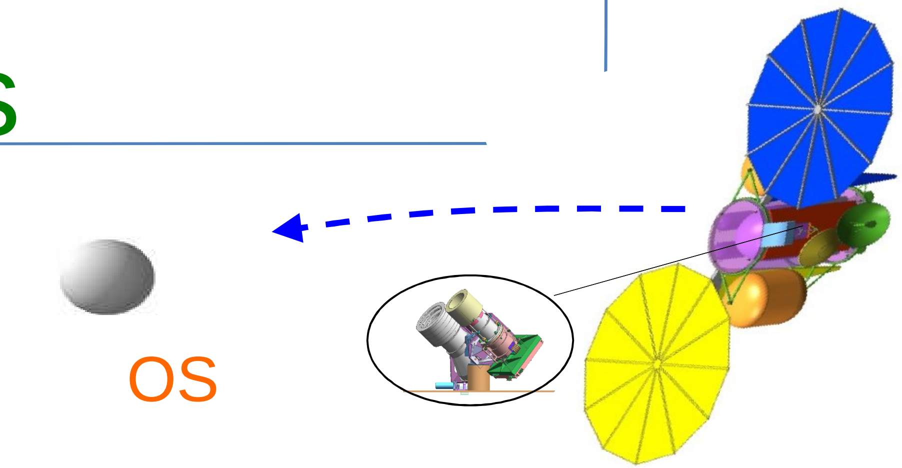
- Function: Capture OS from the Martian Orbit and return it to Earth
- Aerobreaks into 500 km Mars orbit
- Rendezvous with OS, capture and transfer OS into Earth Entry Vehicle (EEV)
- Return to Earth

MSR Orbiter



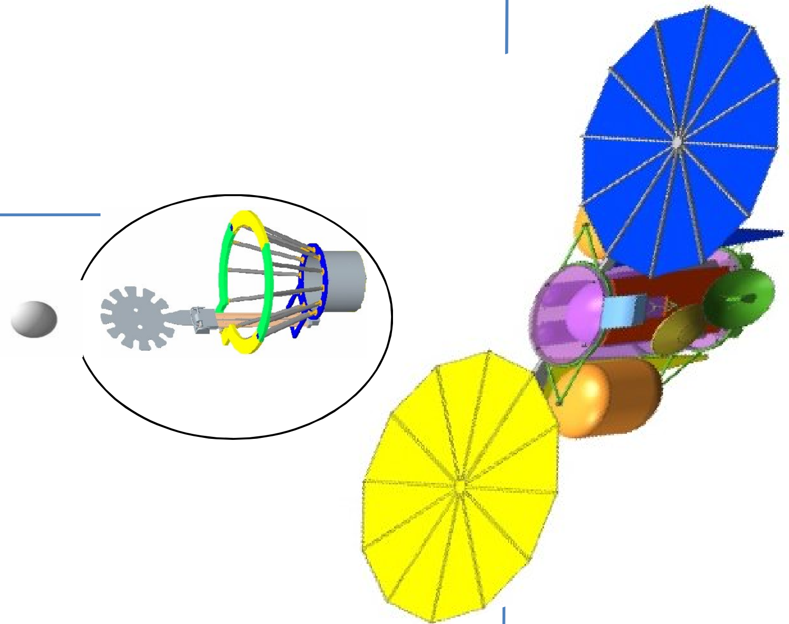
- Requires twice the propellant needed by typical Mars orbiters
  - Get into Mars orbit and then get out
  - 1000 kg dry mass; 2000 kg propellant

Rendezvous



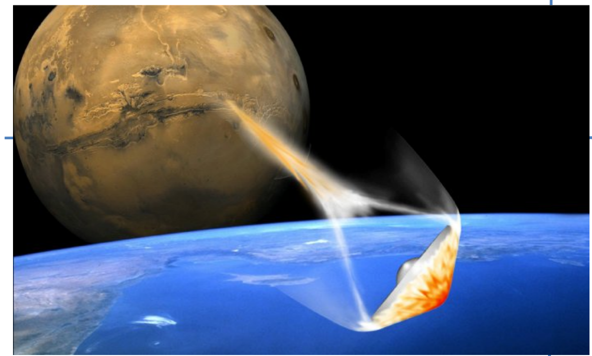
- Optical detection from as far as 10,000km
- Autonomous operation for last 10s of meters
- OS has a battery operated UHF beacon for coarse location as backup
- Orbital Express improves confidence for processes/algorithms

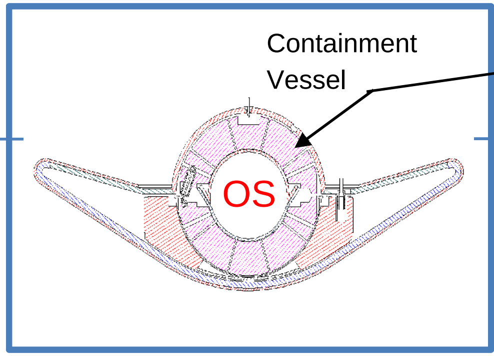
Capture

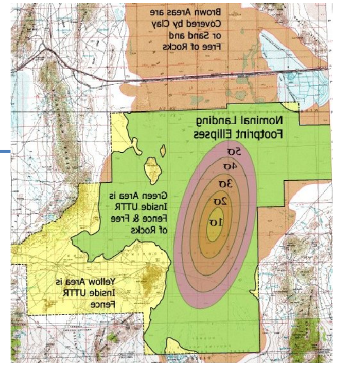


- Capture basket concept designed
- Prototype demonstrated on a NASA C-9 zero-g aircraft flight campaign

Earth Return

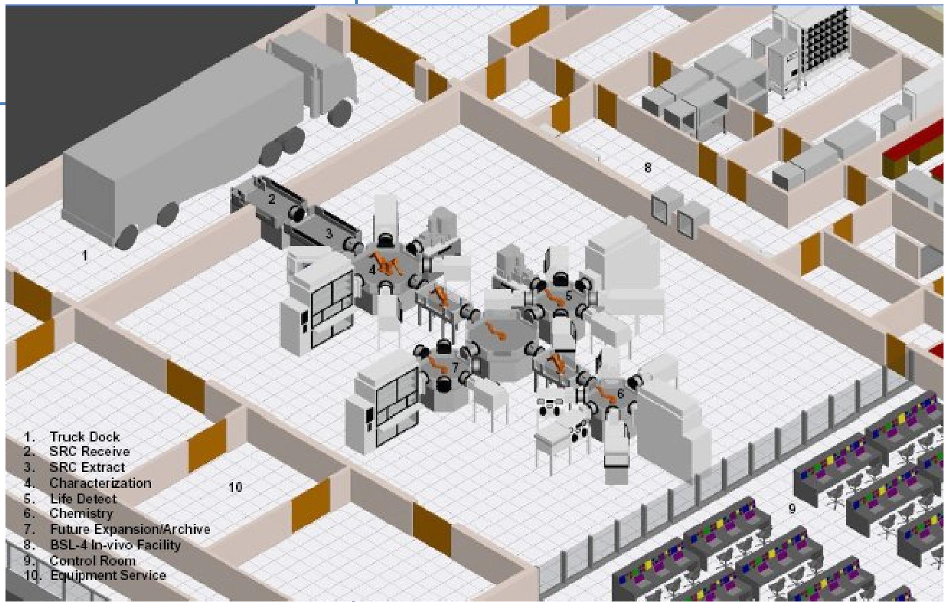






- 0.9m diameter, 60° sphere-cone blunt body
- Self-righting configuration
- No parachute required
- Hard landing on heat shield structure, with crushable material
- Stringent Earth planetary protection requirements
  - Goal of <10^{-6} chance of inadvertent release of an unsterilized >0.2 micron Mars particle

Sample Handling Facility: Element # 4



Functions:

- Contain samples as if potentially hazardous
- Keep samples isolated from Earth-sourced contaminants
- Provide capability to conduct biohazard test protocol as a prerequisite to release of samples from containment

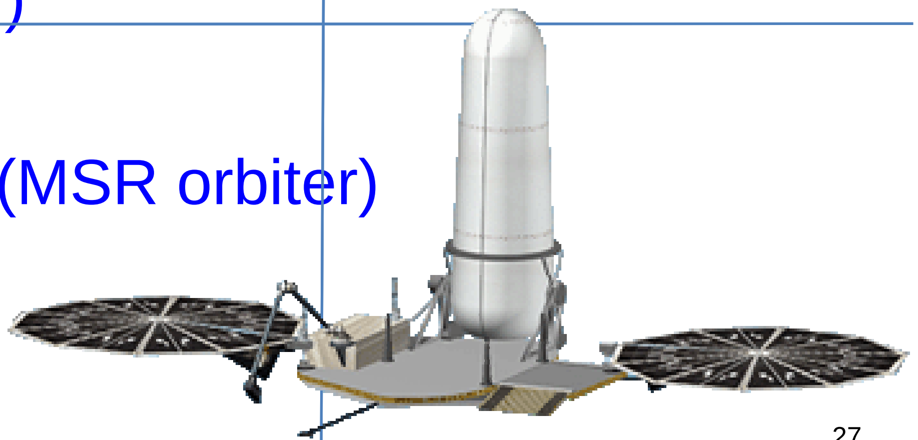
So, Are We Ready for MSR?

Existing Technical Capabilities

- **Navigation:**
  - Reliable and precise navigation to entry corridor (~1.5km, knowledge)
- **EDL:**
  - Skycrane providing landing capability of ~1000 kg payloads
  - Guided entry providing ~10km (radius) landing accuracy
- **Mobility:**
  - Long traverse capabilities using autonomous hazard avoidance utilizing stereo cameras
- **Instrument placement:**
  - Single command with less than ~1 cm error
- **Sample Acquisition:**
  - Development of a drill for MSL and its sample transfer subsystem
- **Telecom:**
  - Direct to Earth and relay communication capability
- **Planetary Protection:**
  - Ability to satisfy forward planetary protection for landers and orbiters
- **Rendezvous and Capture:**
  - DARPA Orbital Express
- **Sample Return:**
  - Genesis and Stardust missions

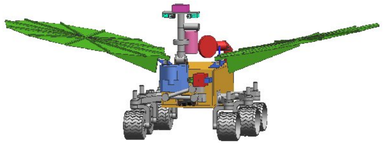
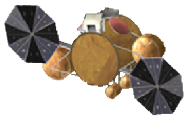
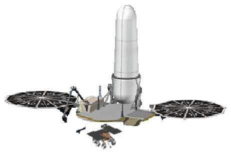
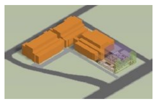
Tall Pole Technologies

- Defined as *key* technologies that require *significant* development
  1. Sample acquisition and encapsulation (MAX-C)
  2. Mars Ascent Vehicle (MAV)
  3. Back planetary protection (MSR orbiter)

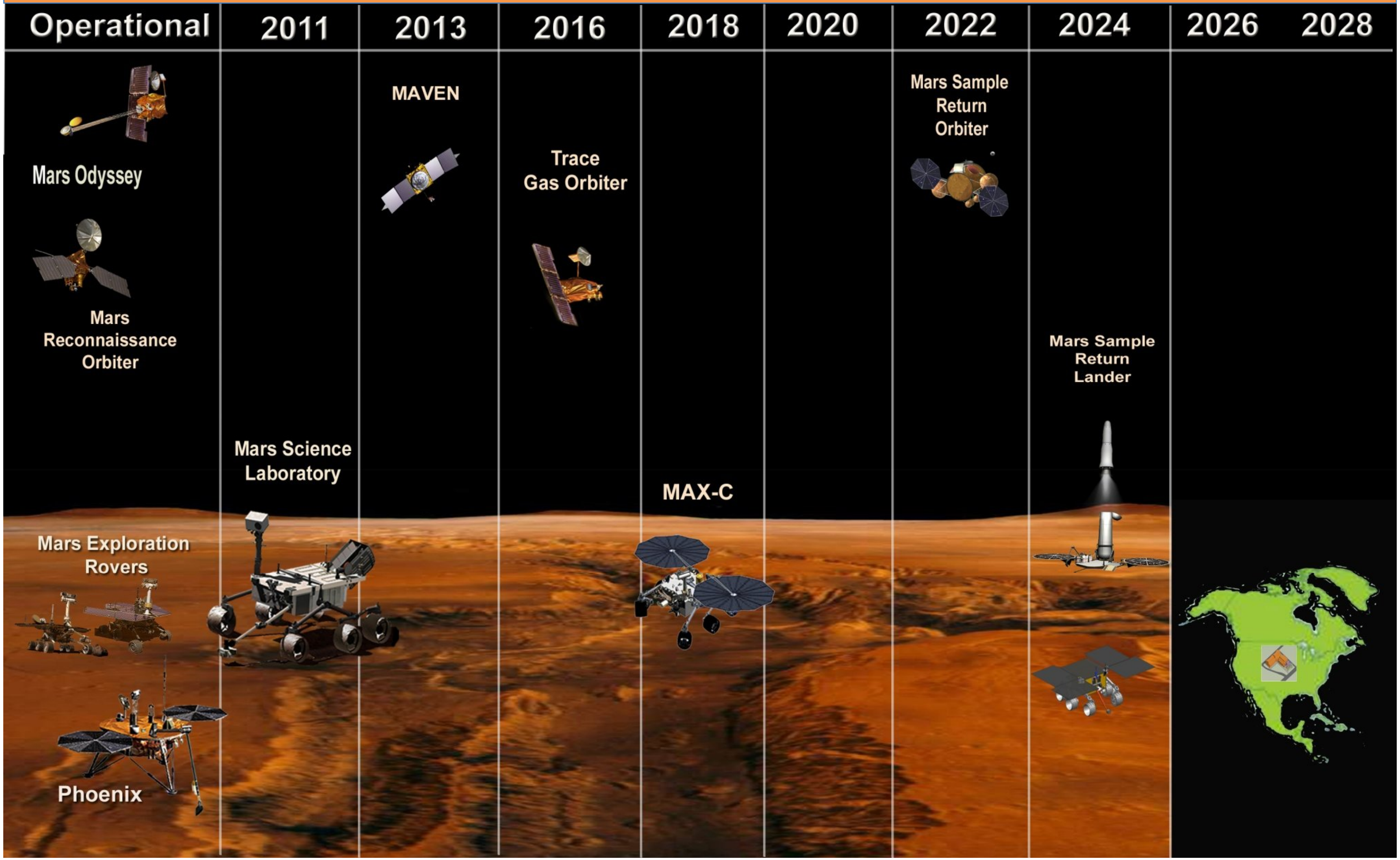


Preliminary Cost Estimates

FY'15 $$

	Team-X w/ 50% A-D & 25% E Reserves	Analogy with past missions (quantized to 0.5B)	Independent (Aerospace Corporation)
	~$2.2 B	~$2.0 B	~$2.1 B
	~$1.4 B	~ $1.5 B	~$1.1 B
	~$2.4 B	~ 3.0 B	~$2.5 B
	~$0.5 B	~$0.5 B	~$0.3 B
	~$6.5 B	~$7.0 B	~$6.0 B

Notional Schedule For Multi-Element Campaign To Return Samples From Mars



- MSR contributes to the eventual human landing
  - Toxicity analysis of the returned sample
  - Information does not age by the time of human travel

Summary

- **Strong Scientific Impetus**
  - Sample return is necessary to achieve the next major step in understanding Mars and the Solar System
  - Compelling sites for sample return have been identified

- **Engineering Readiness**
  - Prior missions have developed many capabilities critical to sample return
  - Key remaining technical challenges are identified/understood, with technology plans defined

Robust Program Architecture

- Should not be viewed as an “isolated (flagship) mission” but as a cohesive multi-element campaign that builds on the past decade of Mars exploration
  - Approach amenable to international partnership