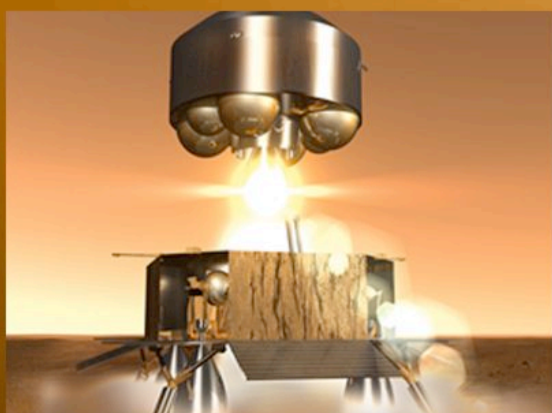
Mars Sample Return - Technical Challenges

Frank Jordan NASA - JPL



Mars Sample Return
Technical Challenges

- **Background**
  - 1998 - 1999 Partnership (launch in 2003 and 2006)
    - NASA
    - CNES
    - ASI
- **Current International Interest**
  - NASA - ESA - others
- **Primary Lesson from Past Studies**
  - Sample Return requires at least two mission elements
    - Lander – Surface sample collection
      – Ascent to orbit
    - Orbiter – Captures sample in orbit
      – Returns to Earth

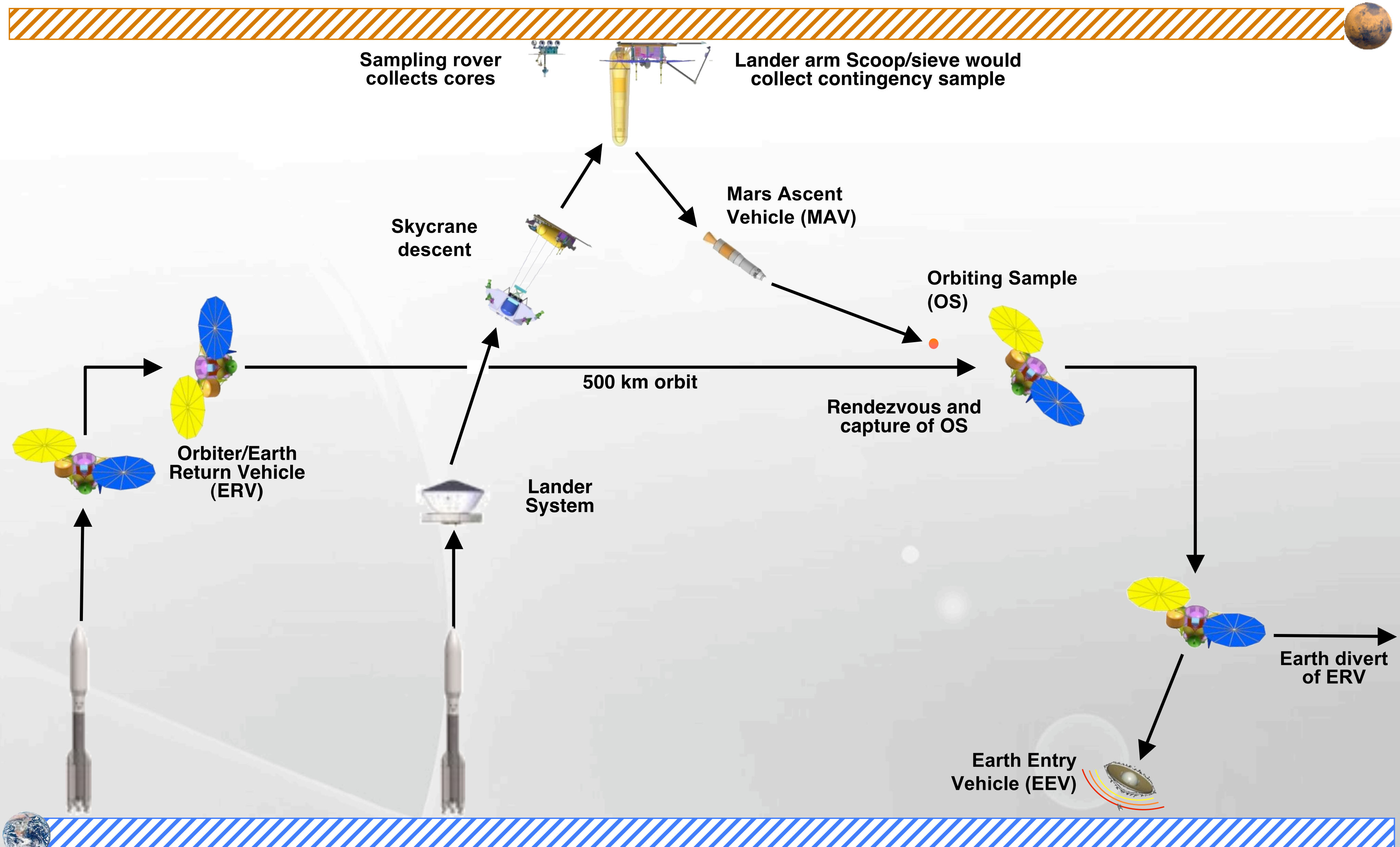
Mars Sample Return
Technical Challenges

What the Mission Should Accomplish - Current Science View

Return to Earth a Sample from the Martian Surface

- 500 gms
- Rock cores, surface regolith, atmosphere
- Mid-latitude location
  - ± 30˚ lat
  - ≤ sea level
- Landing accuracy ~ few kilometers
- Mobility beyond the safe landing zone
- Samples individually encapsulated
  - Kept at room temperature

Mars Sample Return
(Strawman Scenario)



2018 MSR: Dual Launch Architecture, 1 Stg.

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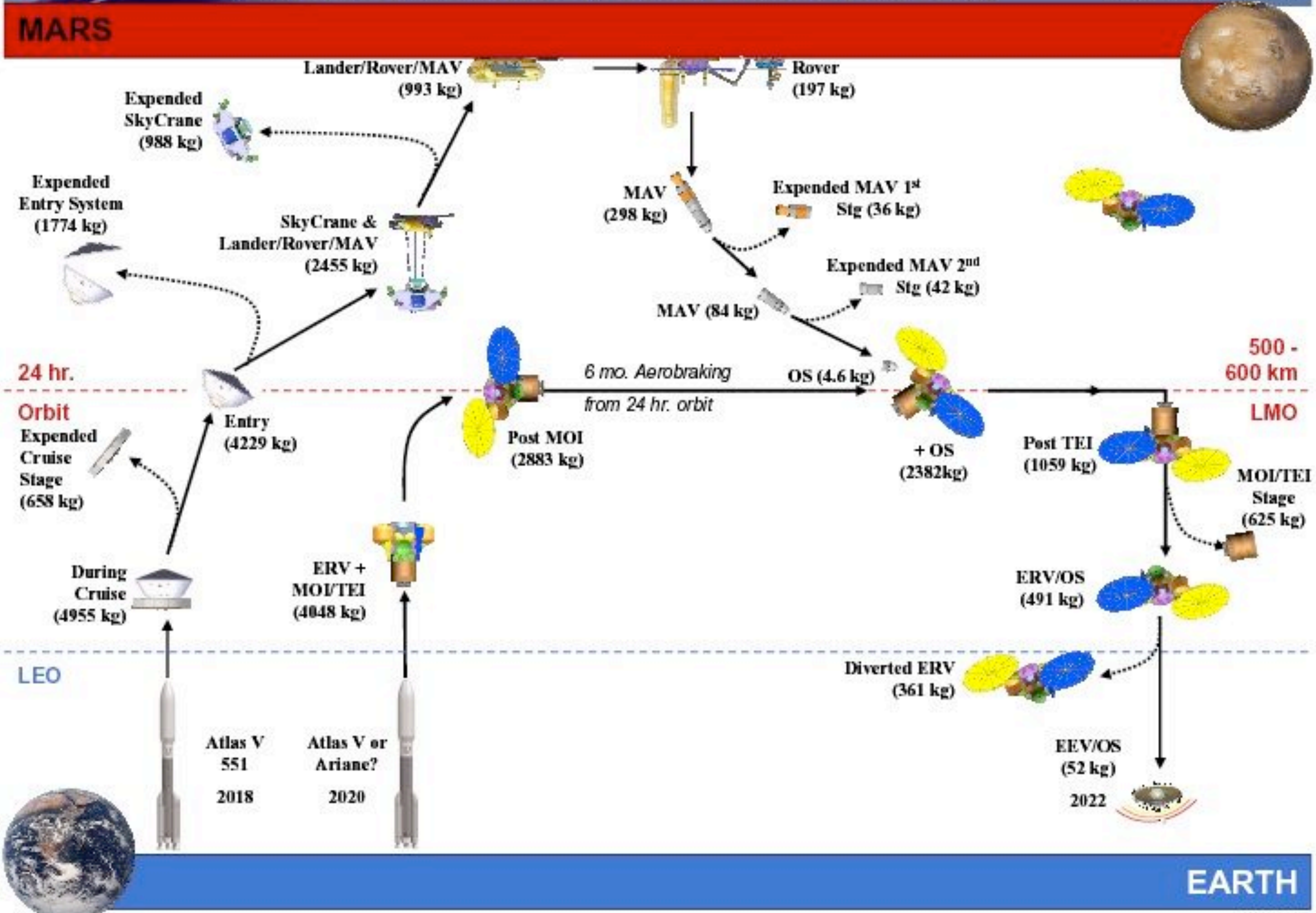


6/26/2008

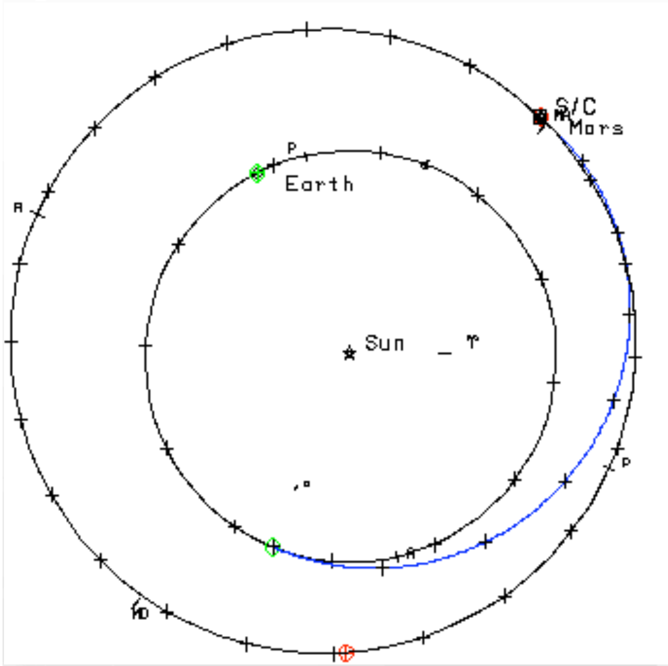
Mission Design Issues / Design Assumptions

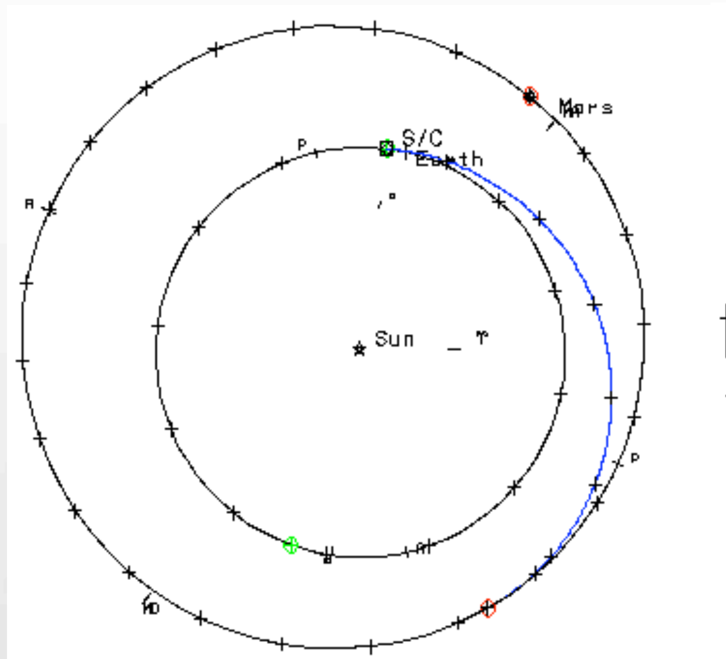
Number of flight elements	At least two: • Orbiter / Earth Return 3500 – 4000 kg • Lander / Mars Ascent 4300 – 4800 kg
Reference launch vehicles	Lander – U.S. Atlas V 551 Orbiter – Europe Ariane 5 ECA
Sequence of flights	Orbiter, then Lander / Lander, then Orbiter/ same opportunity
Earth-to-Mars / Mars-to-Earth trajectories	Direct flights (transit times less than a year) for lander. Orbiter may need Earth swingby with transit times more than a year.
Lander atmosphere entry	Direct from transit trajectory
Orbiter achievement of Mars orbit	Propulsive ΔV to high Mars orbit, aerobraking to low Mars orbit, propulsion staging
Sample collection on surface	Accurate landing for ease of mobility to compelling sample sites Rover with site characterization instruments and coring Lander-based sampling system
Sample return to orbiter	Mars ascent vehicle and rendezvous/capture in orbit
Sample return from Mars orbit to Earth's surface	Propulsive ΔV to Earth-vicinity transit trajectory Surface landing

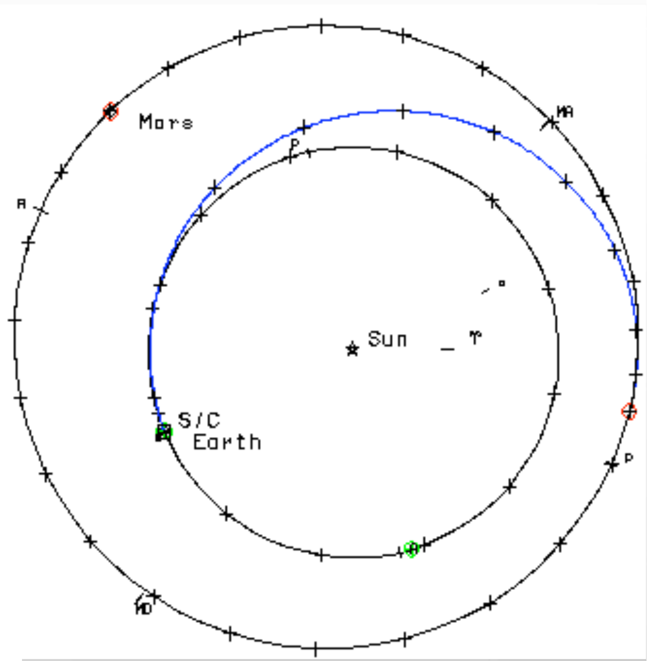
Roundtrip Flight Time

Example: 2018 Lander: Return to Earth in Either 2021 or 2023

Launch Lander in 2018	Orbiter Launch by 2018 Return in 2021	Orbiter Launch by 2020 Return in 2023
Earth to Mars in 233.0 days	Mars to Earth in 196.0 days	Mars to Earth in 279.0 days
	@ Mars 500 Days	**@ Mars 1268 Days**

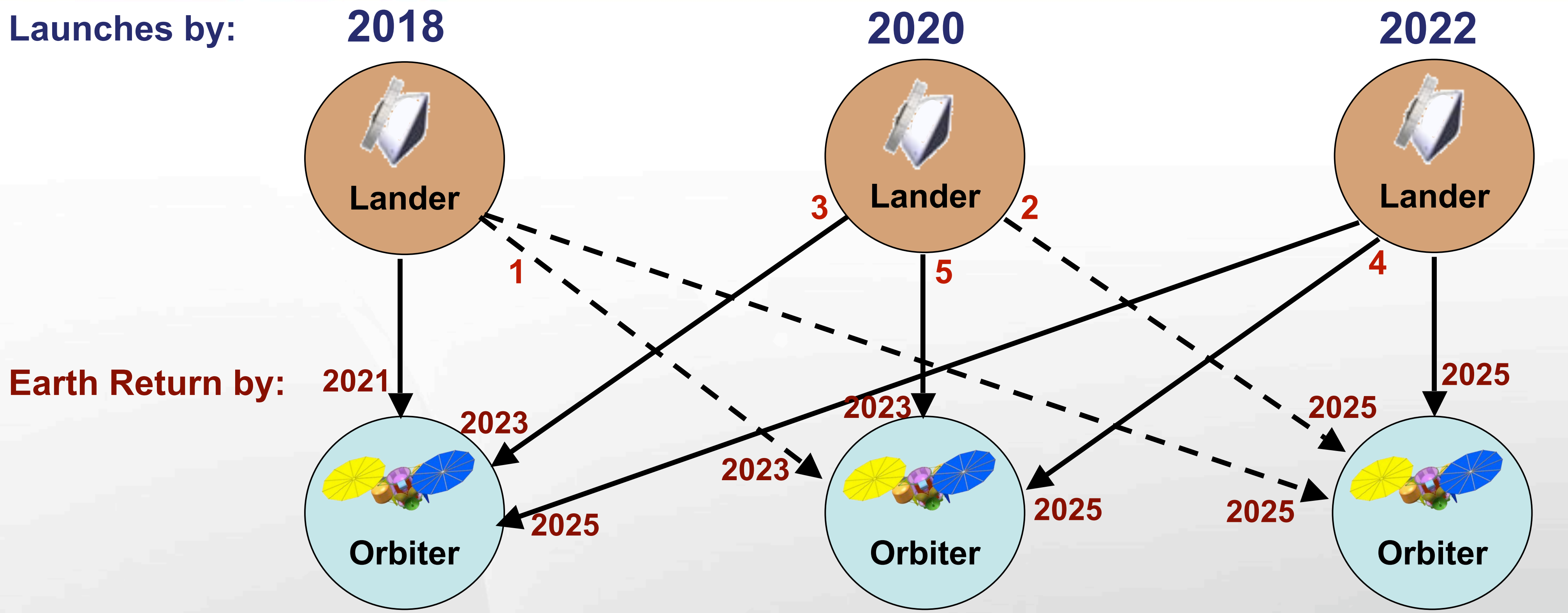




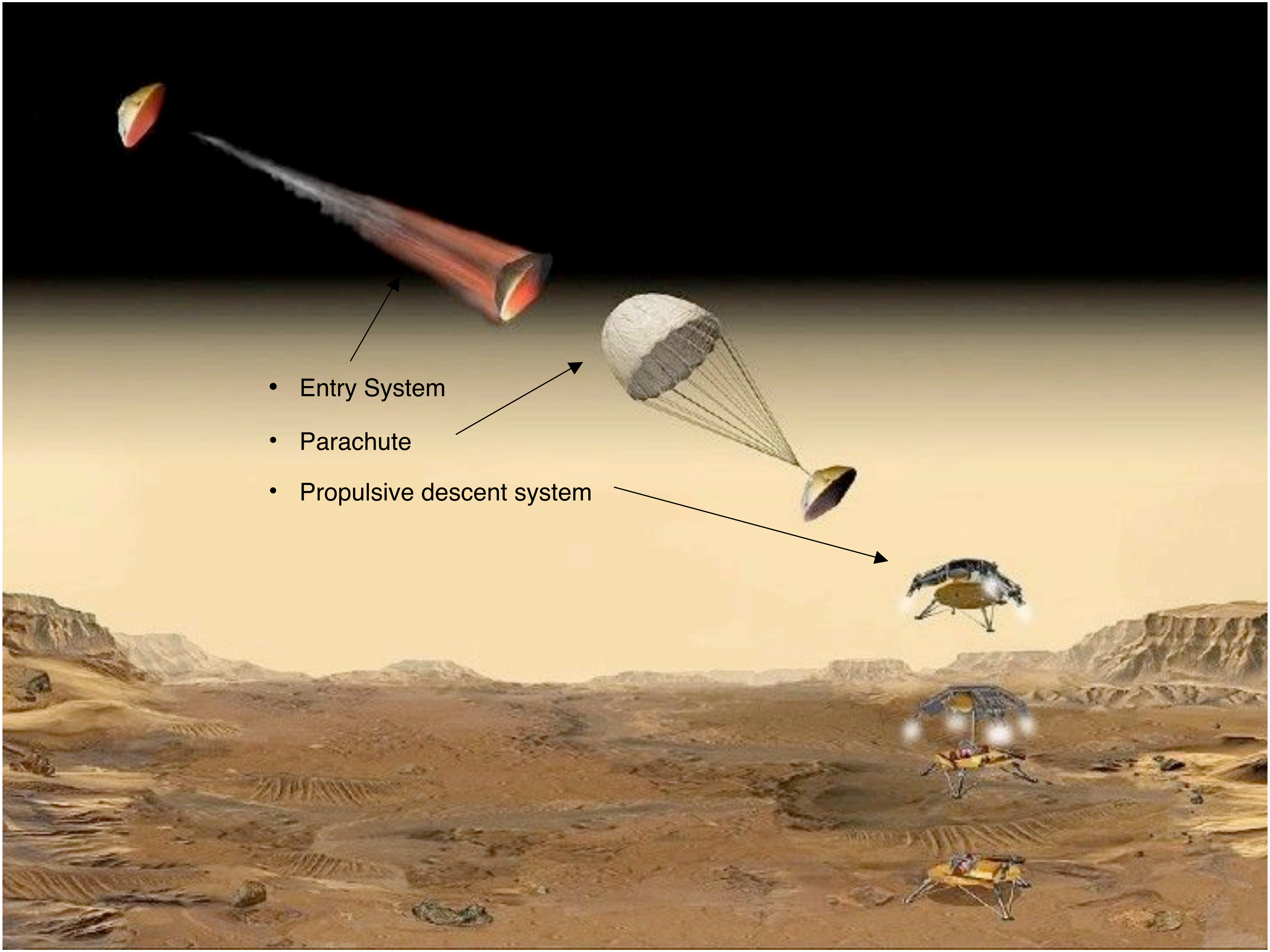


	929 Day Total (2.54 yrs)	**1780 Day Total (5.38 yrs)**
Leave Earth: 05/30/2018	**Leave Mars:** 06/01/2020	**Leave Mars:** 07/09/2022
Arrive Mars: 01/18/2019	**Arrive Earth:** 12/14/2020	**Arrive Earth:** 04/14/2023
		+ 6 months to acquire northern hemisphere

Orbiter – Lander Sequences 2018 - 2022

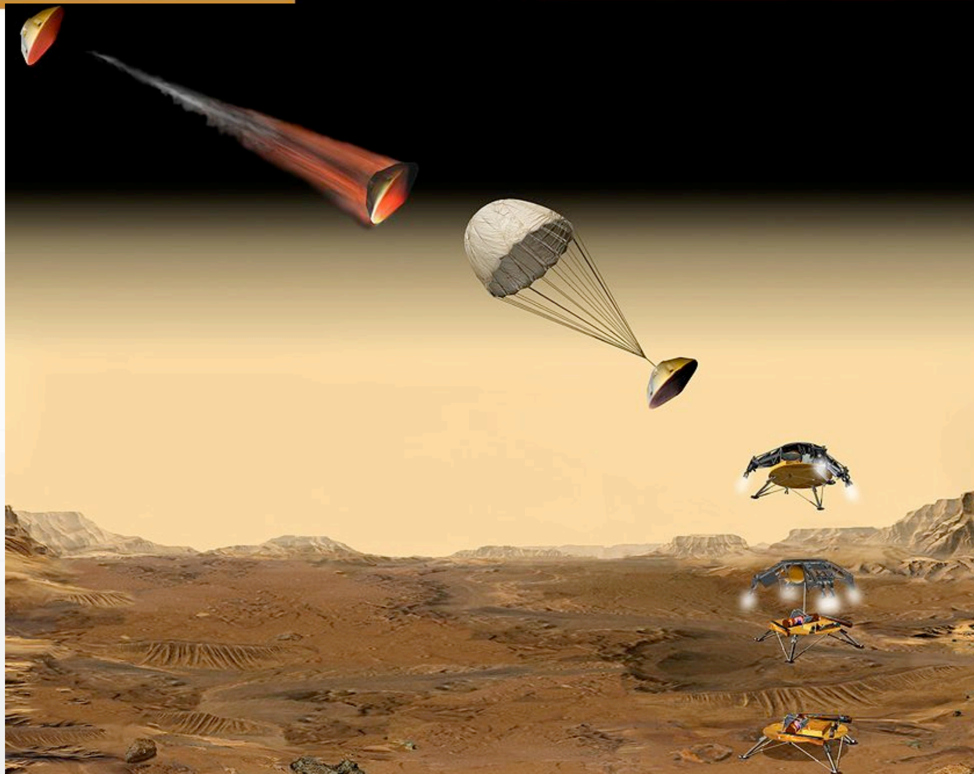


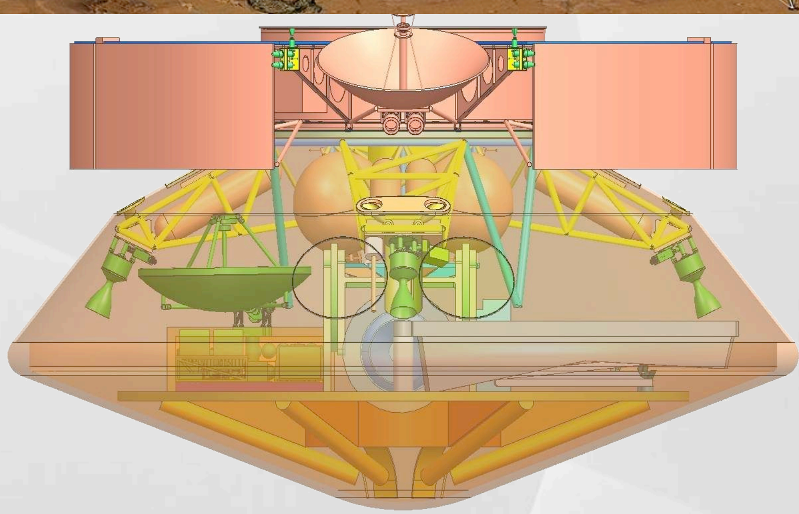
- All combinations will work
- **Numbered scenarios in the publication**
- 2023 and 2025 Earth return require Earth flyby and additional 6 months
- Orbiter used for MAV ascent telecom
- Previous orbiter required for ascent telecom



• Entry System
• Parachute
• Propulsive descent system

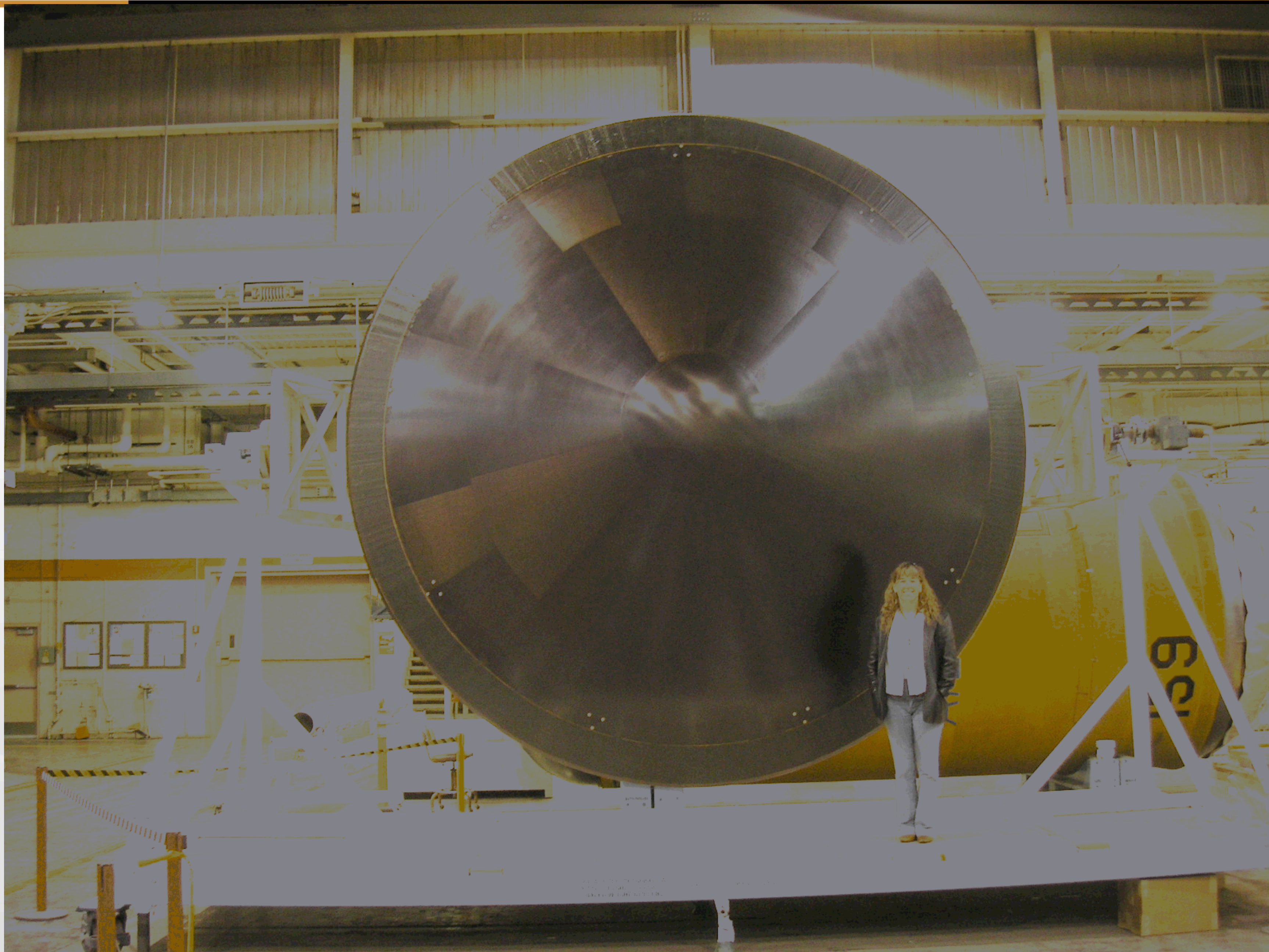
Entry/Descent/Landing (EDL)





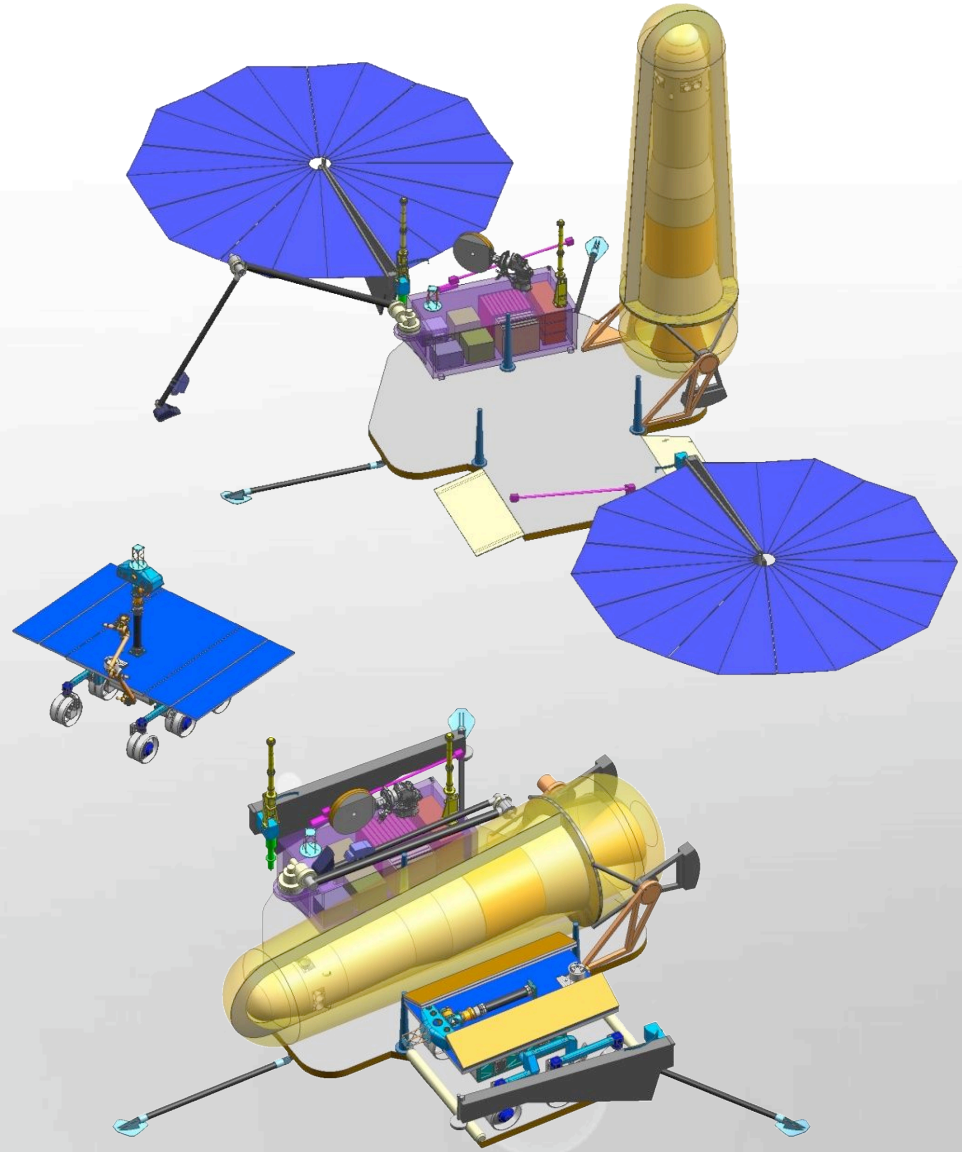
- **Mid-latitude Landing site**
  - +/- 30 deg latitude
  - Less than 0km altitude
- **EDL System Elements (Mars Science Lander Heritage)**
  - 4.5m aeroshell
  - Skycrane Descent Stage
- **Precision Landing**
  - < 3-4 km

Flight Heatshield at Lockheed Martin

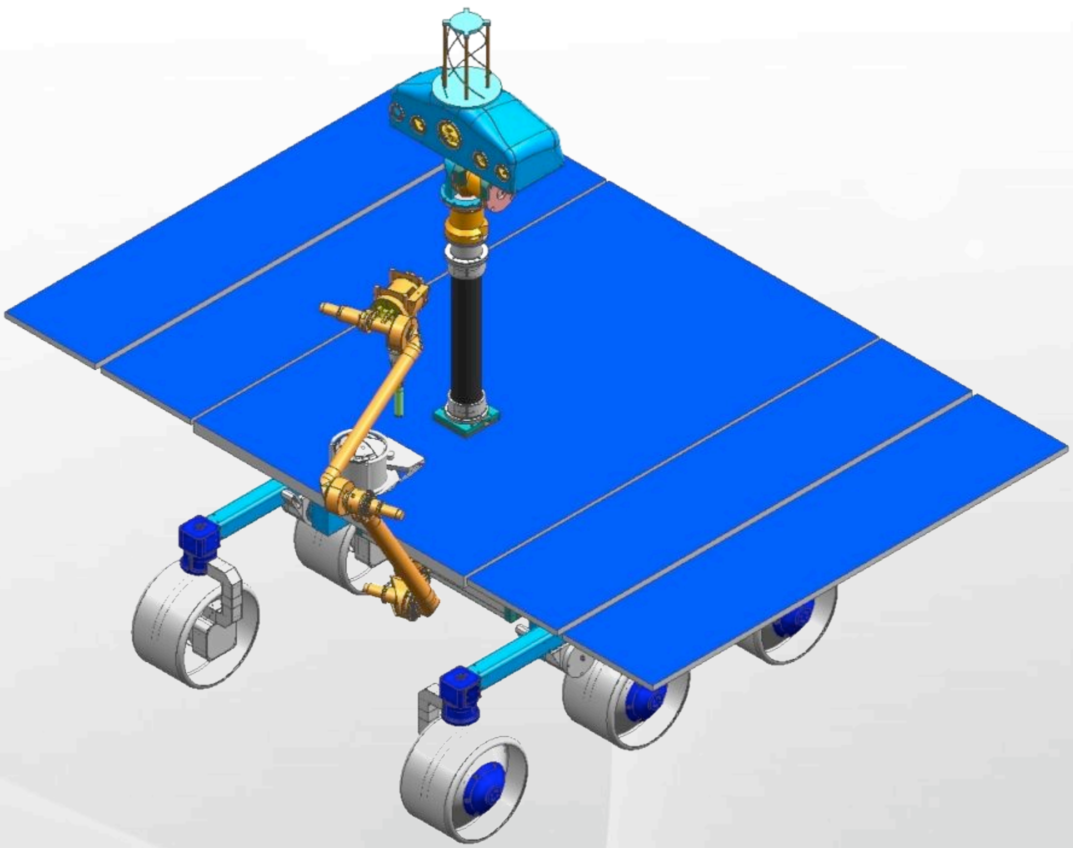


Pallet Lander Concept

- Assumes soft landing delivery.
- Would support ~600kg of payload including payload-specific accommodations.
  - Mars Ascent Vehicle (MAV) & support
  - Lander sample collector (2m arm, scoop, arm mounted color camera)
  - Lander sample handling and loading subsystem
  - Orbiting Sample (OS) container
  - Sampling Rover & support
- Pallet would sit on surface with 3 or more outriggers for stability, horizontal to 0.5 deg.
- Would provide C&DH and telecomm functions for entire lander system.
- Would provide solar power for lander and payload.
- Total Mass <1000kg



MSR Sampling Rover



- Would collect ~20 cores of rock and regolith from several areas.
- Level of instrumentation for sample selection includes site scientific characterization.
- Would return samples to encapsulated lander
- Assumes high heritage from Mars Exploration Rovers and/or ExoMars.
- Mass ~200kg

Landing Accuracy

Capabilities vs Concepts

Unguided (MER, Phoenix, Exomars):

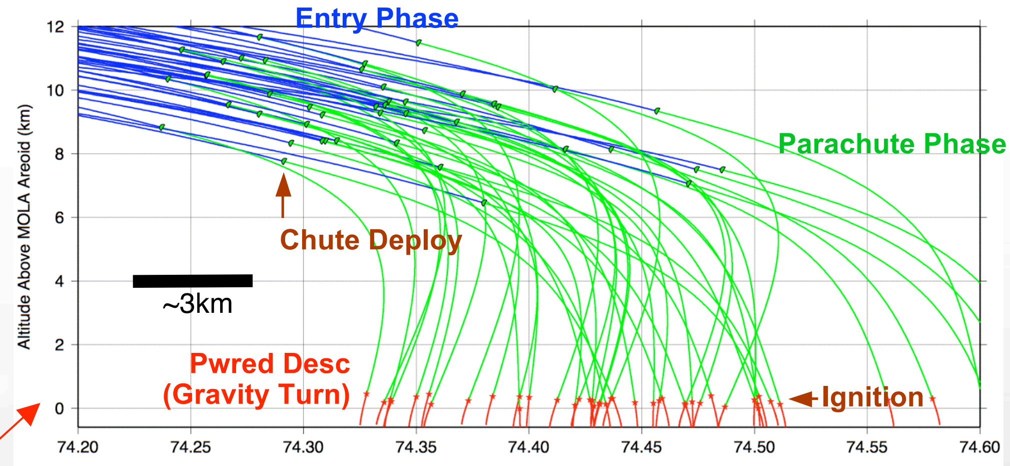
50 km radius

Guided entry phase (MSL):

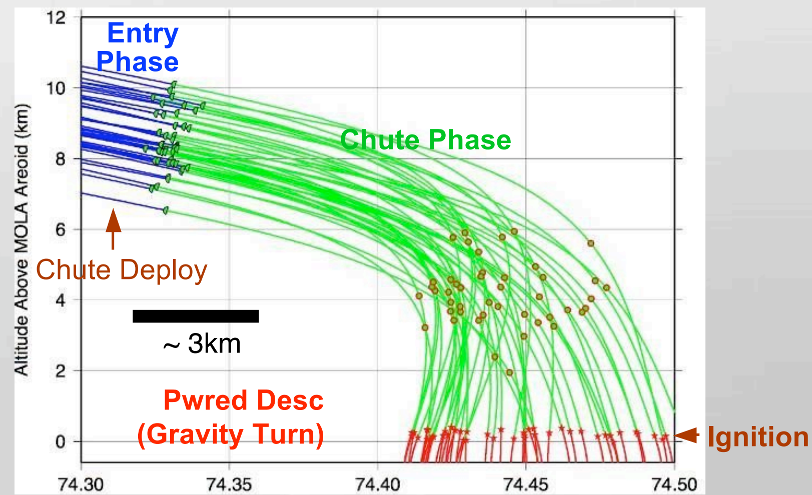
10 km radius

Guided entry phase and optimised parachute opening (enhanced MSL):

3 km radius

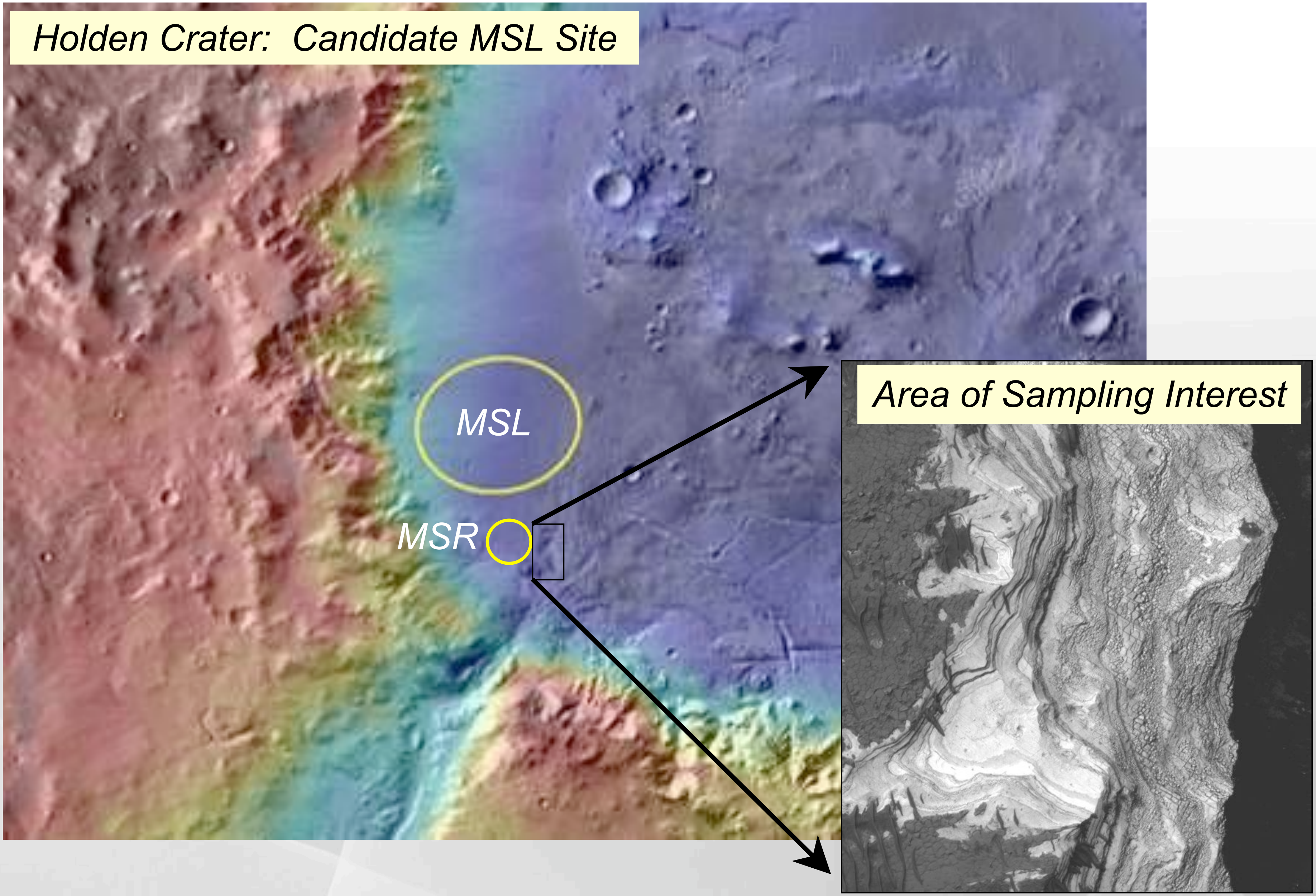


MSL 2009 System
Triggers chute deployment on speed

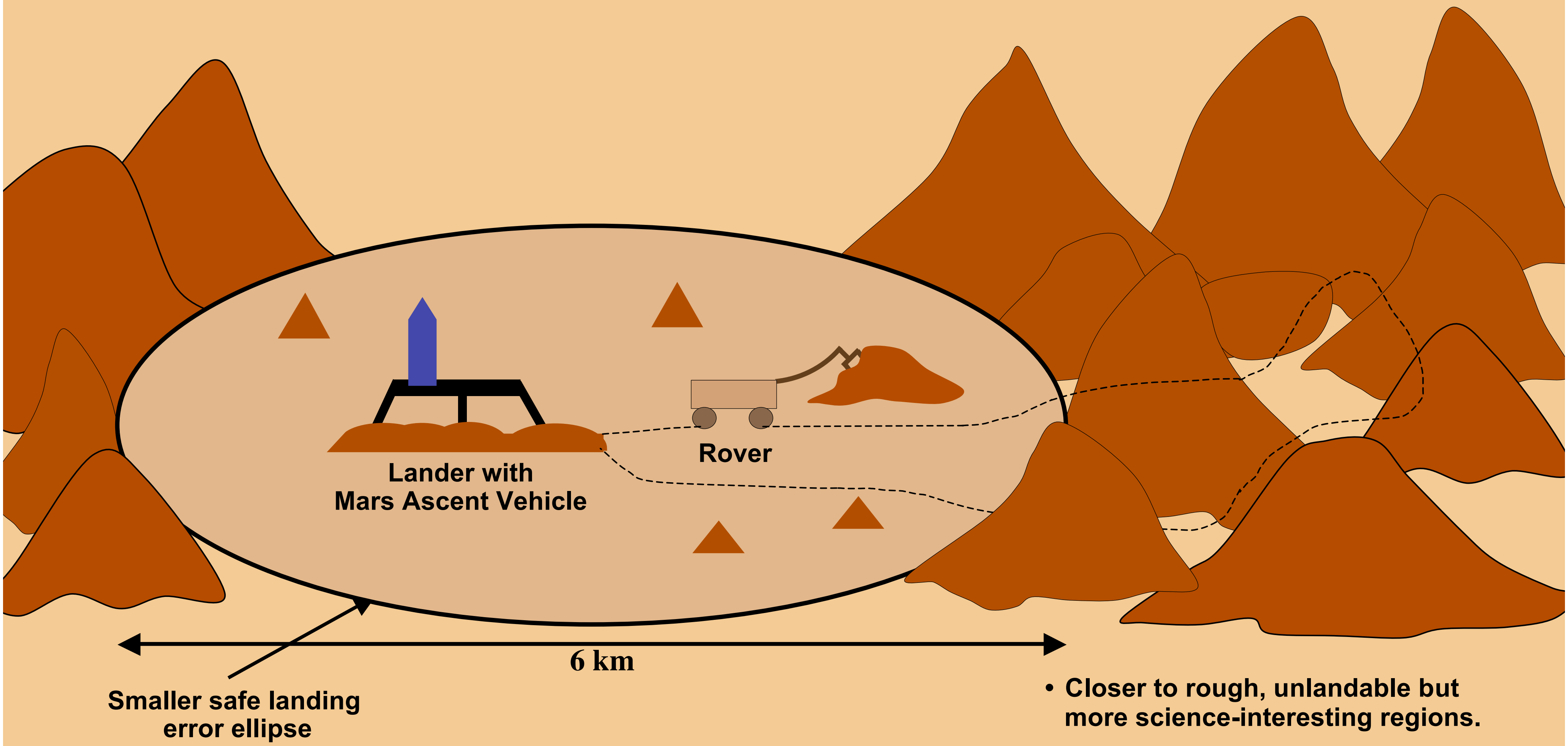


Improved accuracy, triggers chute Deploymemt on position

Sampling Strategy Impact on Science

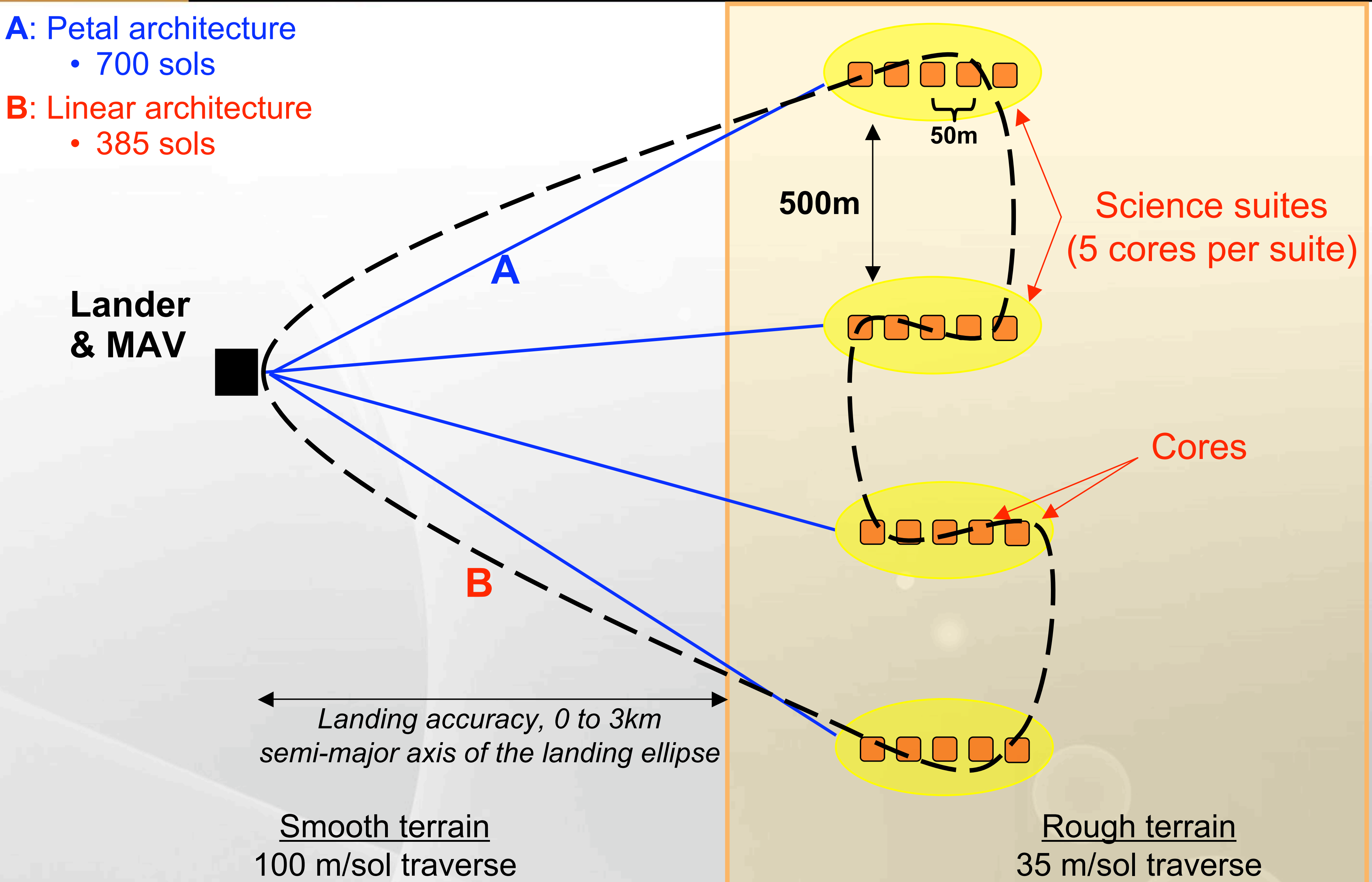


Benefits of Improved Landing Accuracy

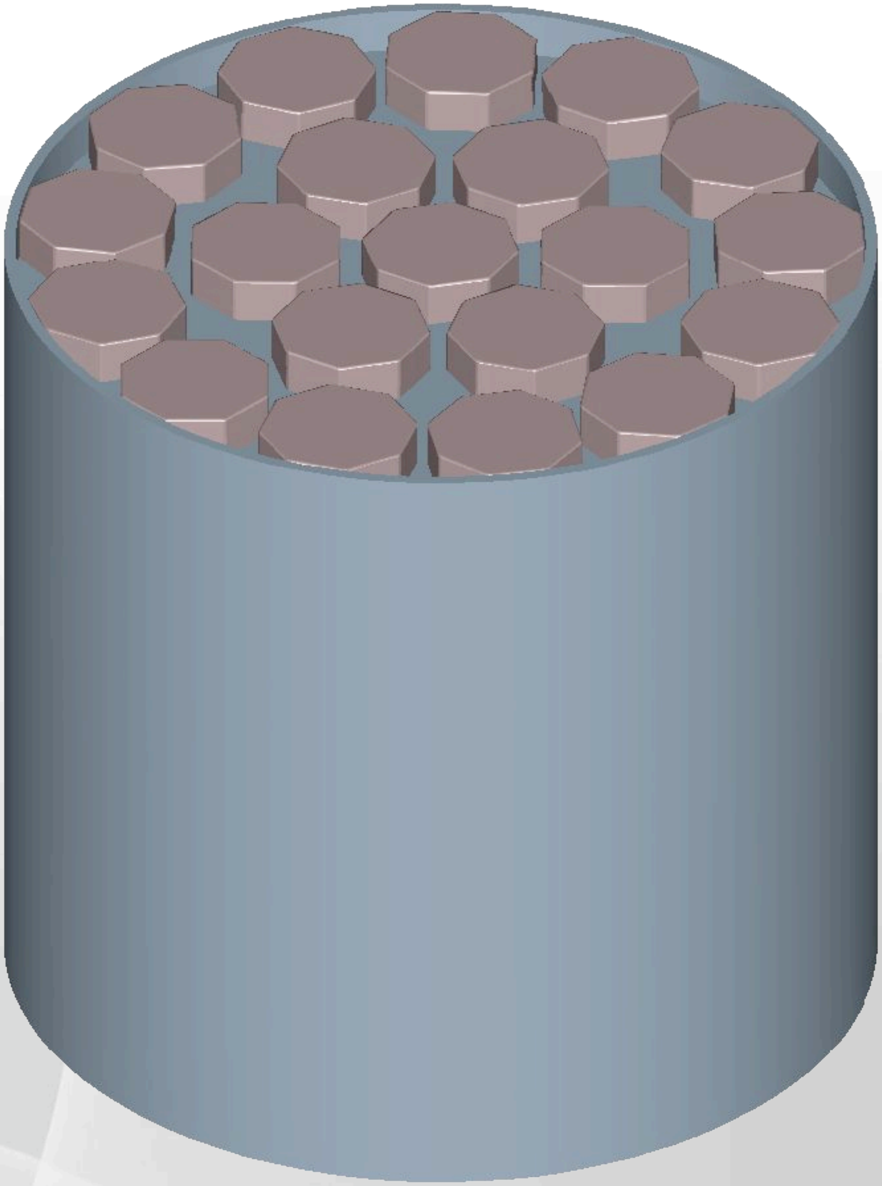


- Closer to rough, unlandable but more science-interesting regions.
- Can land in tighter, safe areas.

Surface Exploration for "Go To" Sites



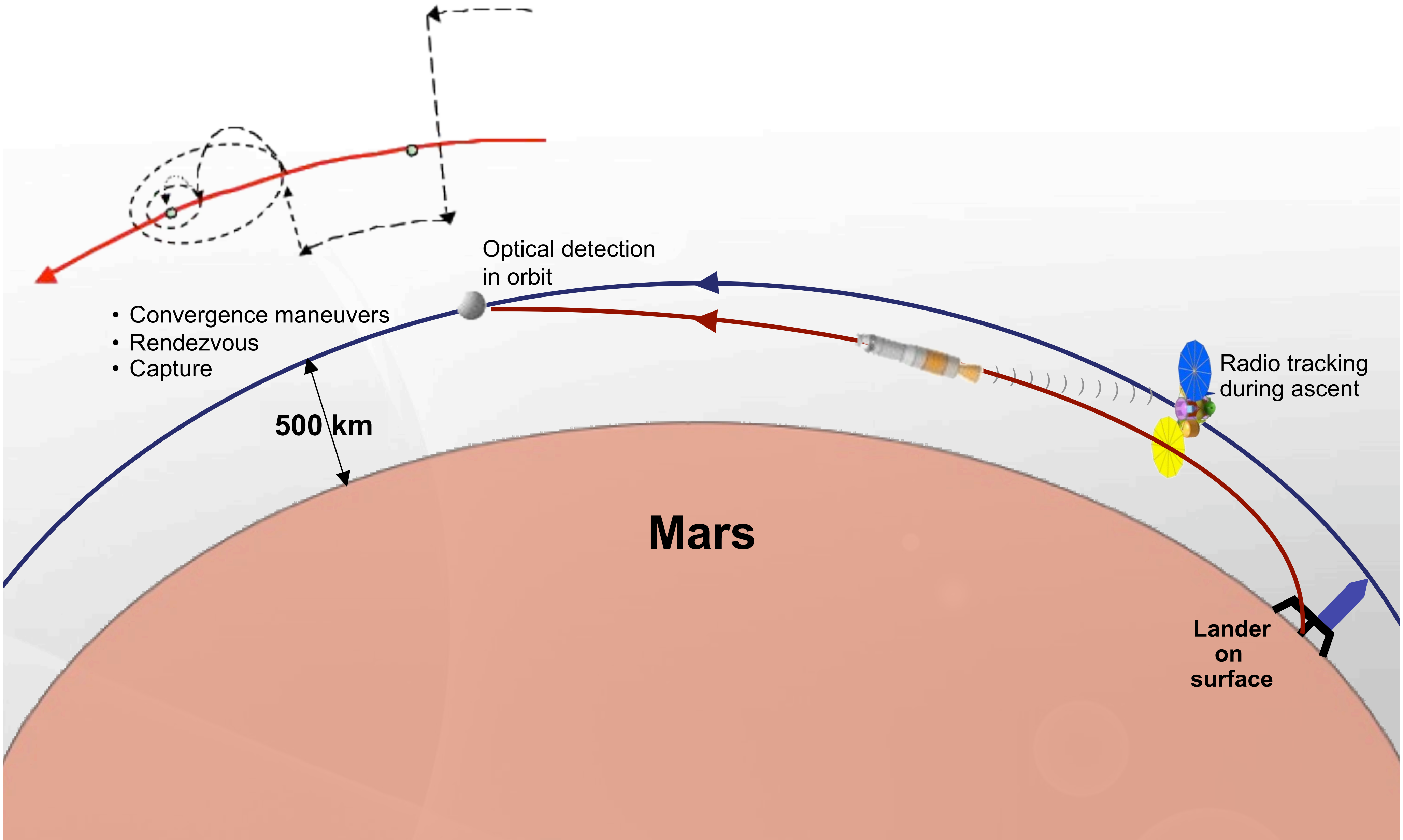
20 Cores in Container



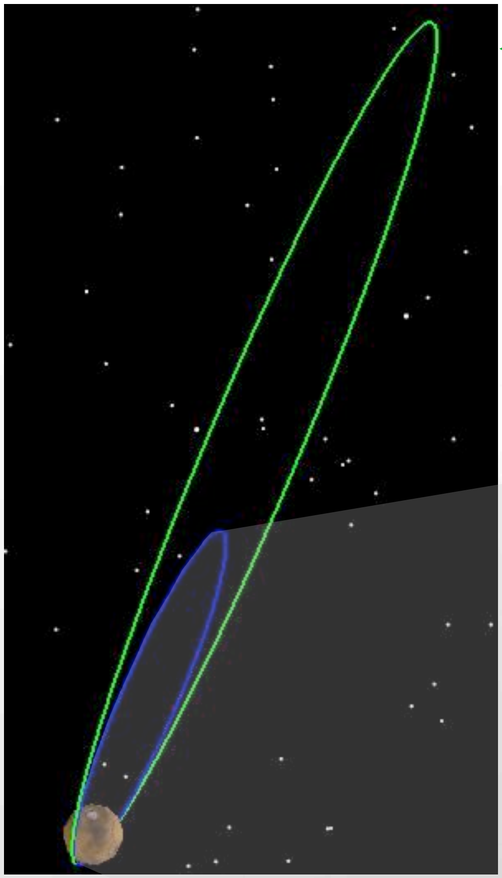
Mars Ascent

- Would launch into 500 +/- 100km orbit, +/0.2deg. inclination.
- Continuous telemetry for critical event coverage during ascent
- ~~300kg (including OS)
- ~~50kg support equipment needed (erection system and thermal enclosure)

Achieving Orbit

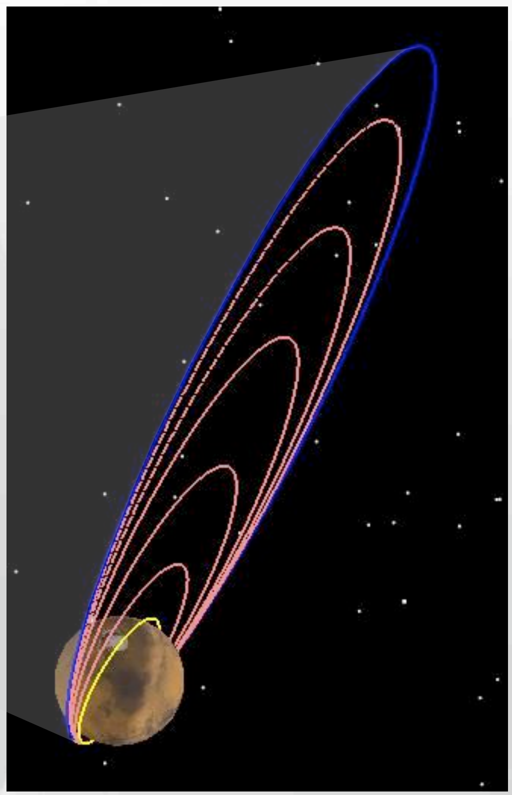


MSR Orbiter Mission Design
Achieving Mars Orbit



MOI capture into a 96-hour orbit

Propulsive burn down to a 24-hour orbit

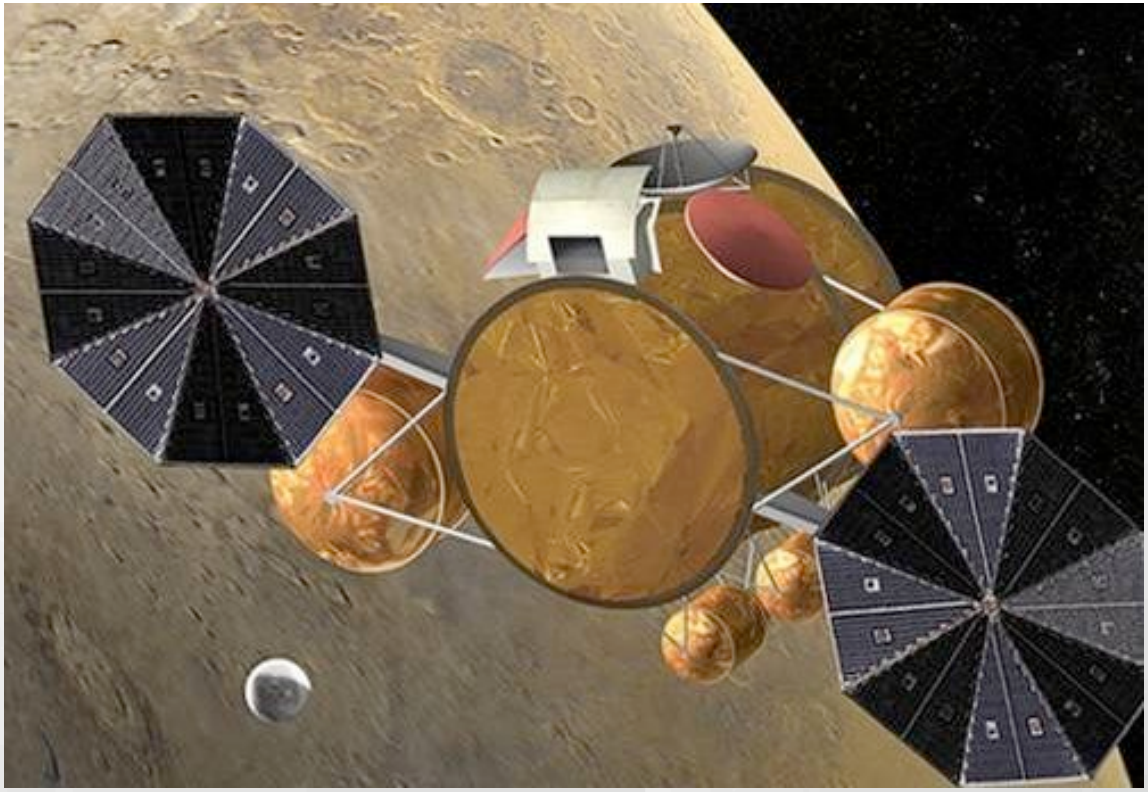


24-hour orbit

Intermediate aerobraking orbits down to rendezvous orbit

500 km X 500 km rendezvous orbit

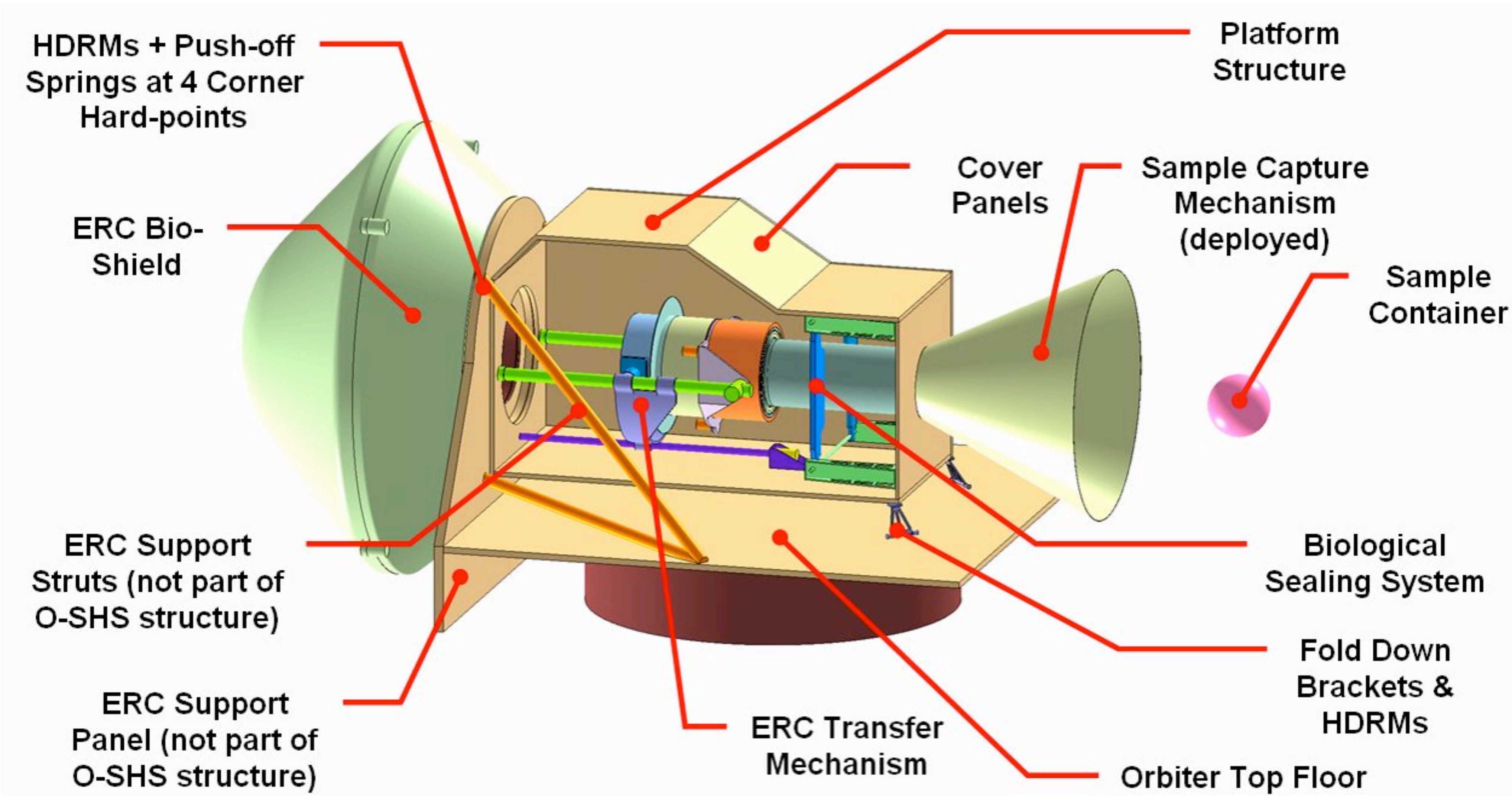
Earth Return Vehicle/Orbiter



Orbiter/Earth Return Vehicle

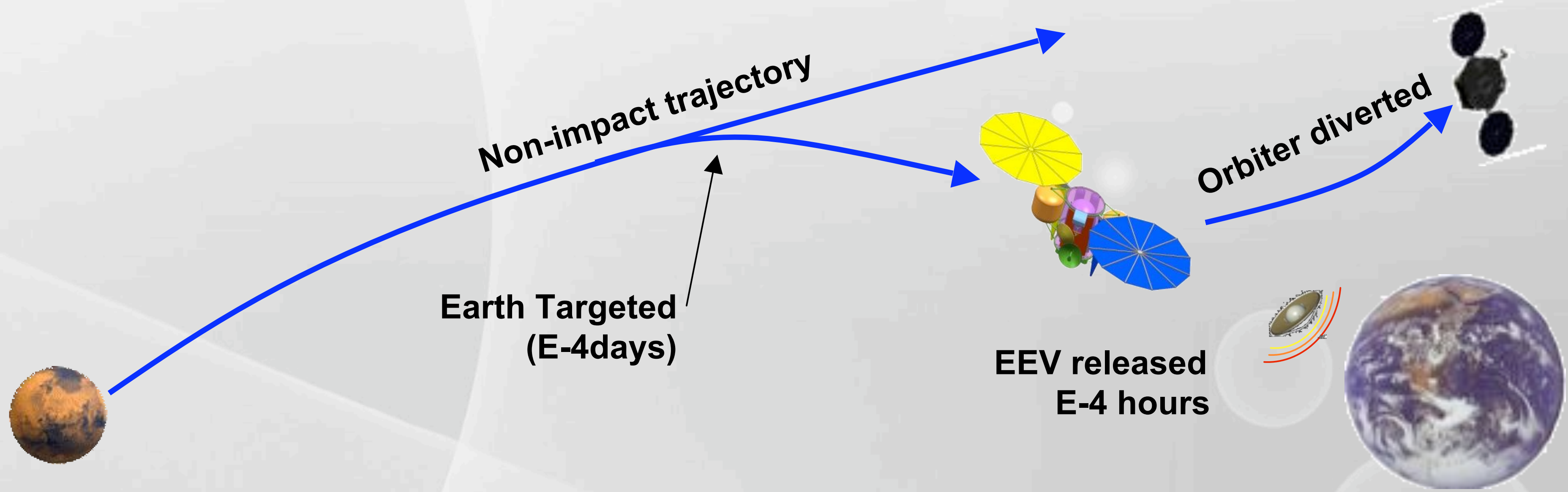
- ~4500kg (~3500kg fuel)
- Would aerobrake for about 6-9 months
- OS detection and rendezvous
- Would carry the EEV
- Would return with trajectory biased away from Earth, target Earth for release of EEV, and then divert after EEV release

Bio-Container/EEV Interface Phase A2 Implementation

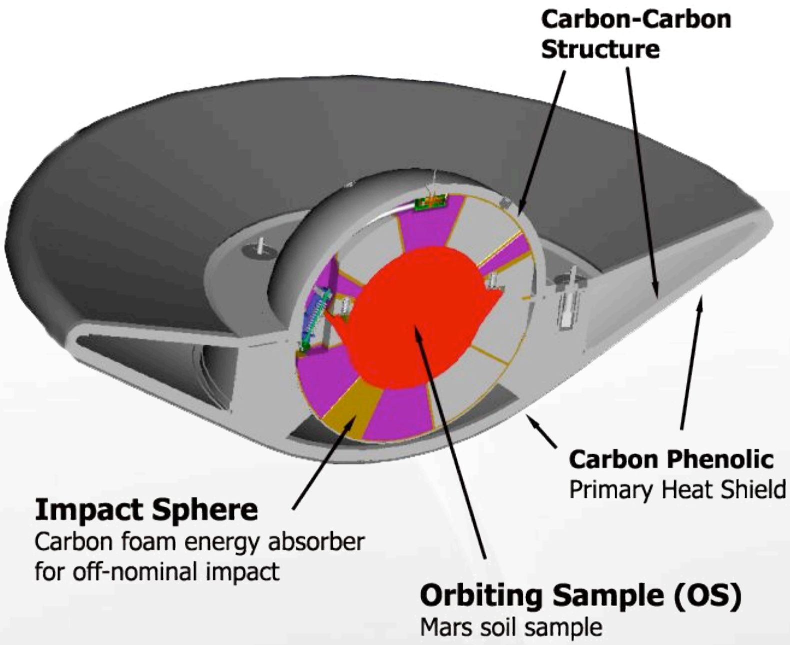


At Earth Return Schematic

- Orbiter heads for Earth on non-impact trajectory, targets Earth few days out.
  - Multiple navigation teams cross checking for ultra-safety
  - Orbiter targets Earth only after sample containment verified
- Sealed samples are deployed to Earth atmospheric entry in an Earth Entry Vehicle at about 4 hours out .
- Orbiter is diverted away from Earth entry for long-lived heliocentric orbit



Earth Entry Vehicle



LaRC Earth Entry Vehicle

- 0.9m diameter, 60° sphere-cone blunt body
- 44kg entry mass, including OS
- Design responsive to stringent Earth return planetary protection requirements
- Self-righting configuration
- No parachute
- Samples could be subjected to as much as 2500g's at impact.

Surface Landing on Earth

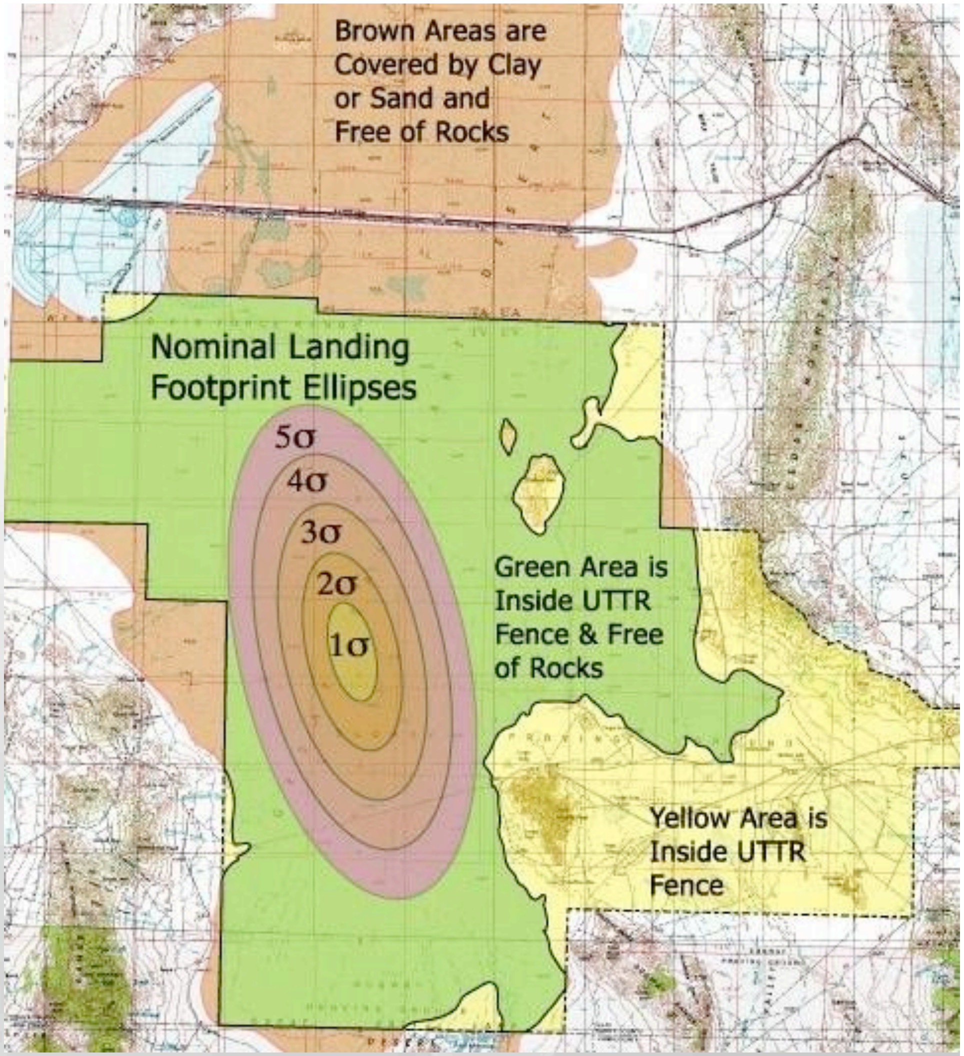
Earth's surface chosen as landing location (rather than water)

- Easier retrieval
- Less risk of sample getting lost
- No threat of sinking

However

- Less places to land
- For a return in 2023 and 2025, Northern Hemisphere acquired only after:
  - Fly-by of Earth
  - 6-month orbit and return to Earth

UTTR



UTTR is a potential landing site

Summary of Technical Challenges

- Orbit mechanics of a complex (2-mission) flight set
- Entry, descent, and landing at Mars
- Surface sample collection
- Mars surface-to-orbit ascent
- Rendezvous and capture of sample in Mars orbit
- Earth-return, re-entry, landing, and pick-up
- Bio-protection of the Earth from Mars
-
-
-
- Systems Engineering of all of the above

Technology Investment Needs

Graphic w/building blocks for which near-term technology investment is required: