Jet Propulsion Laboratory
California Institute of Technology

Emerging Capabilities for the Next Mars Orbiter

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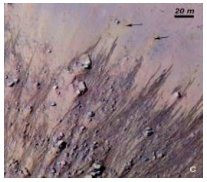
Next Orbiter Can Support Many Potential Next Steps

Now through 2020 | Early '20's | Mid-'20's | Late '20's through '30's

Mars 2020

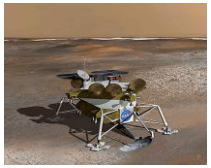
Next Mars Orbiter
(Options: Remote Sensing, Relay/Comm, Rendezvous, Round Trip EP)

Accessing Special Resources & Regions



Round-trip Missions
(Return from Mars to Earth, Sample Retrieval)

Precursors Advancing Exploration Capabilities



Other Objectives + Emplacement of Infrastructure for Human Missions

Can be a
Long-Duration Asset
servicing
Multiple Stakeholder interests

Multiple Pathways provide flexibility to adapt to new knowledge and partnerships

Introduction - Some Context

- MRO launched in August 2005 – 9 years in Mars orbit
  - First to use Atlas V family of launch vehicles
  - Highest deep-space planetary mission data rates and volumes, to date
  - Largest and most capable payload to Mars, to date
  - Provided <1m resolution reconnaissance , multispectral imaging, atmospheric and regional observing, radar sounding and relay telecommunications
  - Successful Ka-band and optical navigation demonstrations

- The intervening decade has brought significant new capabilities
  - Larger and more diverse launch vehicles
  - Commercial space industry and NASA continue to develop and demonstrate Solar Electric Propulsion (SEP) components that support a broad range of missions
  - Commercial space has developed large lightweight solar arrays for TeleSats and for SEP – NASA has developed even larger arrays
  - Improved instruments and detectors, optical communications, improved radio communications components are also available for future Mars missions

What might a Mars orbiter offer in the early 2020s?

- Have potential for multi-use to support diverse agency objectives
- Mission-class between Discovery and New Frontiers
- Improved capabilities versus previous orbiter missions
  - High-power, High-Isp Solar Electric Propulsion (SEP) Thrusters
  - High-power, Lightweight Solar Arrays
  - Very High Data Rate Telecommunications (Ka-band and Optical)

  (All these have flown or have been qualified to fly since MRO)

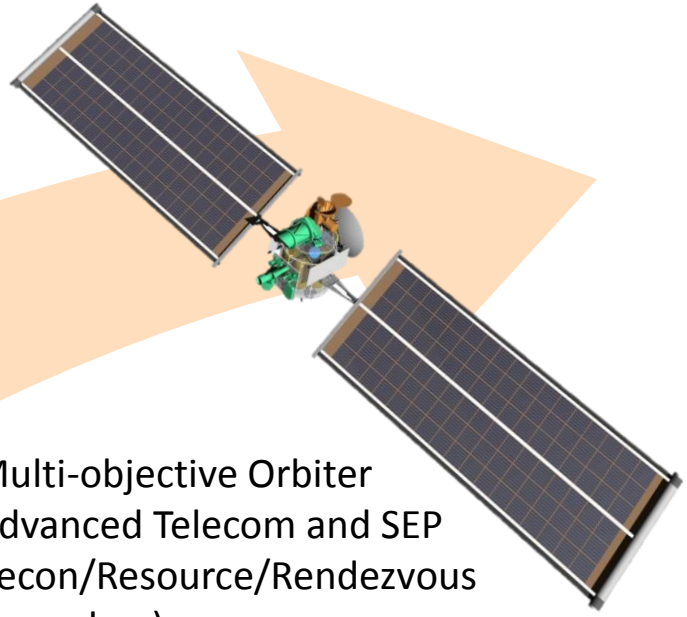
- Using these new capabilities, an orbiter could provide
  - Significantly more payload mass and data return
  - Abundant electrical power to payloads
  - Increased variety of access to orbits at Mars
  - On-orbit rendezvous

Using Electric Propulsion – Mass, Power, Orbit barriers are lowered

Capabilities of the mission can be set based on what MEP and our Partners are willing to financially support

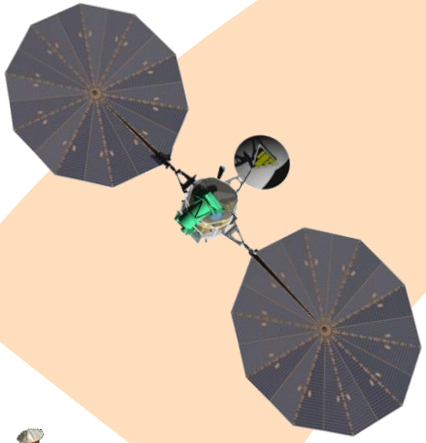
Capability and Mission Range for 2022 Orbiters

Exploration SEP
NASA Components
1000 – 2000 kg Bus
200 – 800 kg P/L
>5 kW for P/L



Commercial SEP
COTS Components
500 – 1000 kg Bus
100 – 200 kg P/L
>2 kW for P/L

Multi-objective Orbiter
Advanced Telecom and SEP
Recon/Resource/Rendezvous
(new class)



Telecom/Recon/Resource
Rendezvous Orbiter (MRO upgrade)

Telecom/Recon+
Orbiter (MRO-class)

Bi-Prop
Telecom/Recon Orbiter

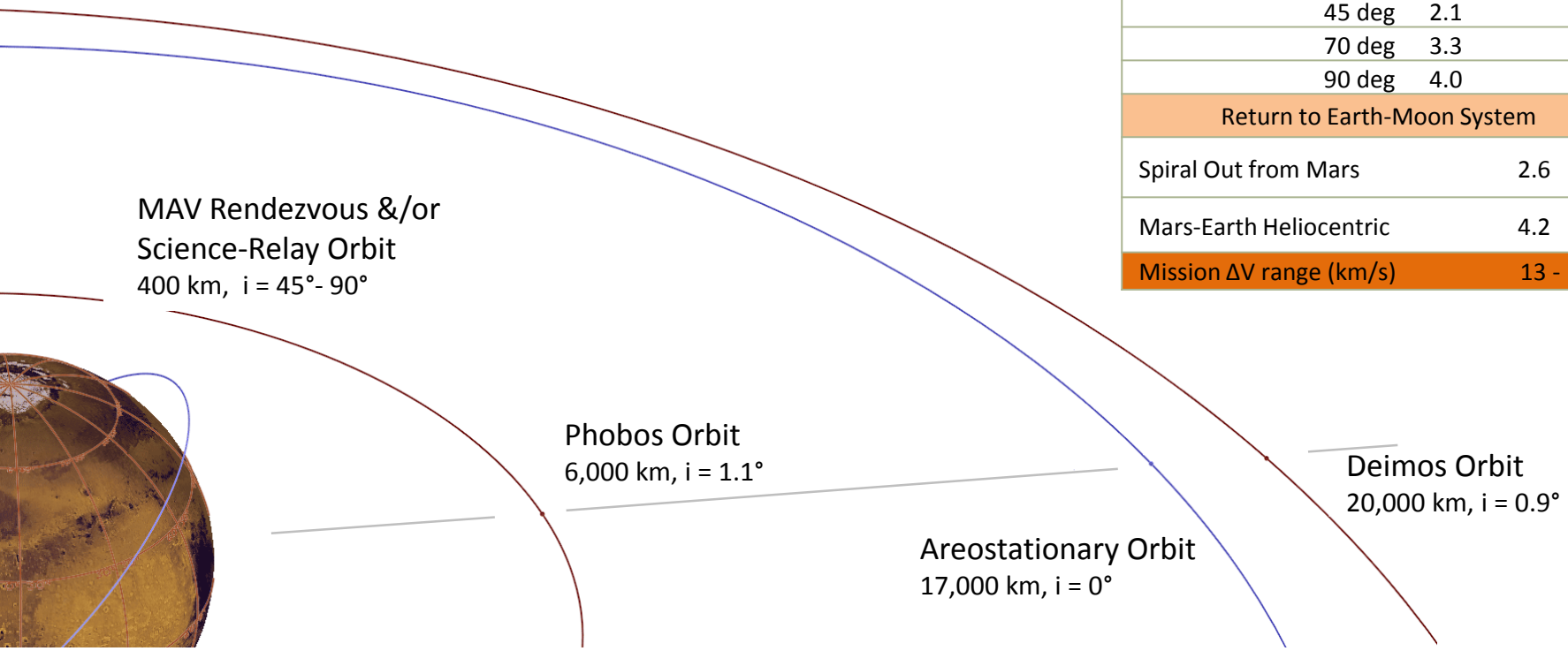
Telecom/Recon
Replacement Orbiter
(MRO-lite)

All missions benefit from SEP orbits and payload power

Benefits of SEP 1: Mars Orbit Destinations

- SEP interplanetary delivery to <u>any inclination</u>
- Spirals start above 200,000 km altitude
- Fuel cost for inclination change is cheaper when farther away

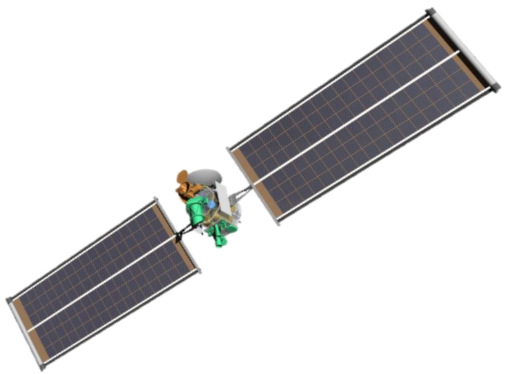
Mission Delta V Usage (km/s)		
Outbound to Mars		
Earth-Mars Heliocentric	4.0	6.6 km/s
Spiral to Areostationary	0.6	
Spiral to Phobos	0.7	
Spiral to 320km, 0 deg	1.3	
Additional ΔV for inclination change from Phobos altitude to 320 km at inclination of:		
30 deg	1.2	Pick one
45 deg	2.1	
70 deg	3.3	
90 deg	4.0	
Return to Earth-Moon System		
Spiral Out from Mars	2.6	6.8 km/s
Mars-Earth Heliocentric	4.2	
Mission ΔV range (km/s)	13 - 17	

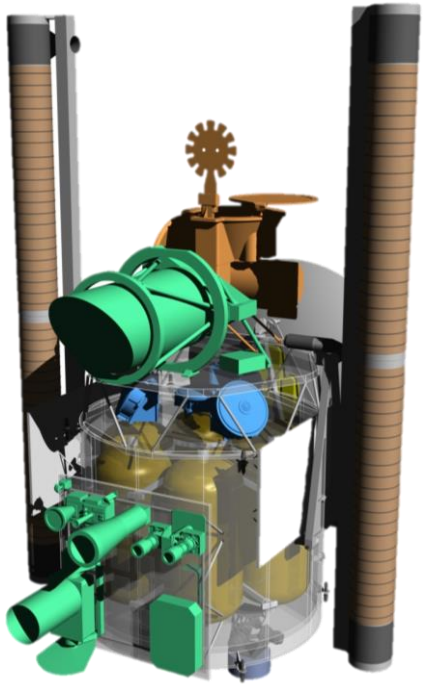


Benefits of SEP 2: Excess Power for Payloads

- SEP systems to Mars require 7-30 kW (at 1 AU)
- Roughly, for operations at Mars, divide the nominal power by 3 and subtract 1 kW for orbiter bus needs
  - E.g., A 15 kW SEP system allows 4kW of P/L power in Mars orbit
- Several instruments and components might benefit from extra power
  - Active Instruments e.g, Radar, Lidar
  - Telecommunications e.g., Optical lasers and RF amplifiers
  - ?? Creative thinking might open interesting opportunities
- Issues
  - For high power systems, heat rejection is more challenging
  - Batteries can get bulky for eclipse operations

Example Strategic Orbiter Characteristics





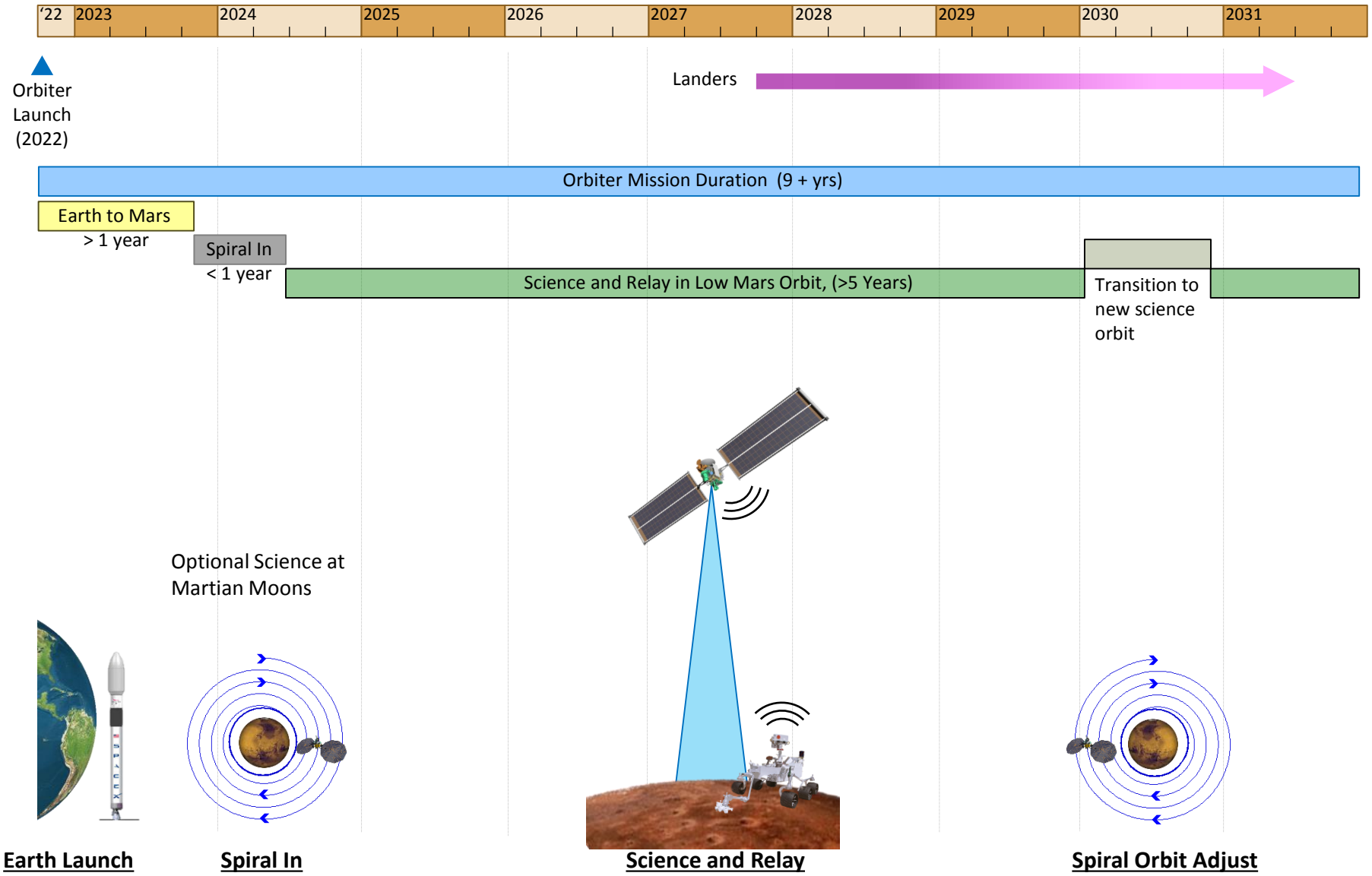
ARM-based Orbiter	
Engine	**ARMi**
# Active	1
# Spares	1
Throughput Used	30%
LV	**F9**
C3	11
Array Type	ROSA
BoL Power (kW)	29
P/L power at Mars	8
Launch Mass (kg)	**2513**
Dry Bus Mass	1183
Mass for ALL payloads	300
Propellant	1029
Total Duration (Yr)	9.1
Outbound	1.6
At Mars	5.4*
Inbound	2.1

* Assumes Lander mission two opportunities later with one Mars year mission, then return to Earth

- This is one example to show feasibility and capability
- Many many orbiter variations possible
  - Launch vehicle
  - Thruster types/number
  - Array types
  - Telecom configuration
  - Payload placement
  - Bus/tank configuration
- Can trade payload mass and return fuel for plane change ΔV at Mars

Mission Context

Notional Timeline and Launch Dates



Further Questions

- Discussions of questions and concerns is encouraged
- Suggestions for how to make use of Mars orbiter resources and opportunities are welcome
- Please Contact your favorite Mars Program scientist and/or Rob Lock
  - robert.e.lock@jpl.nasa.gov
  - (818) 393-2525

Potential Launch Vehicles

- Current orbiter concepts fit on smaller Atlas V and Falcon-9 launch vehicles
- SEP missions can use any C3 and still reach Mars
- Reducing C3 increases launch and arrival mass but takes more time in cruise
- Launch mass does not vary significantly by launch opportunity

Atlas V 411

Falcon-9