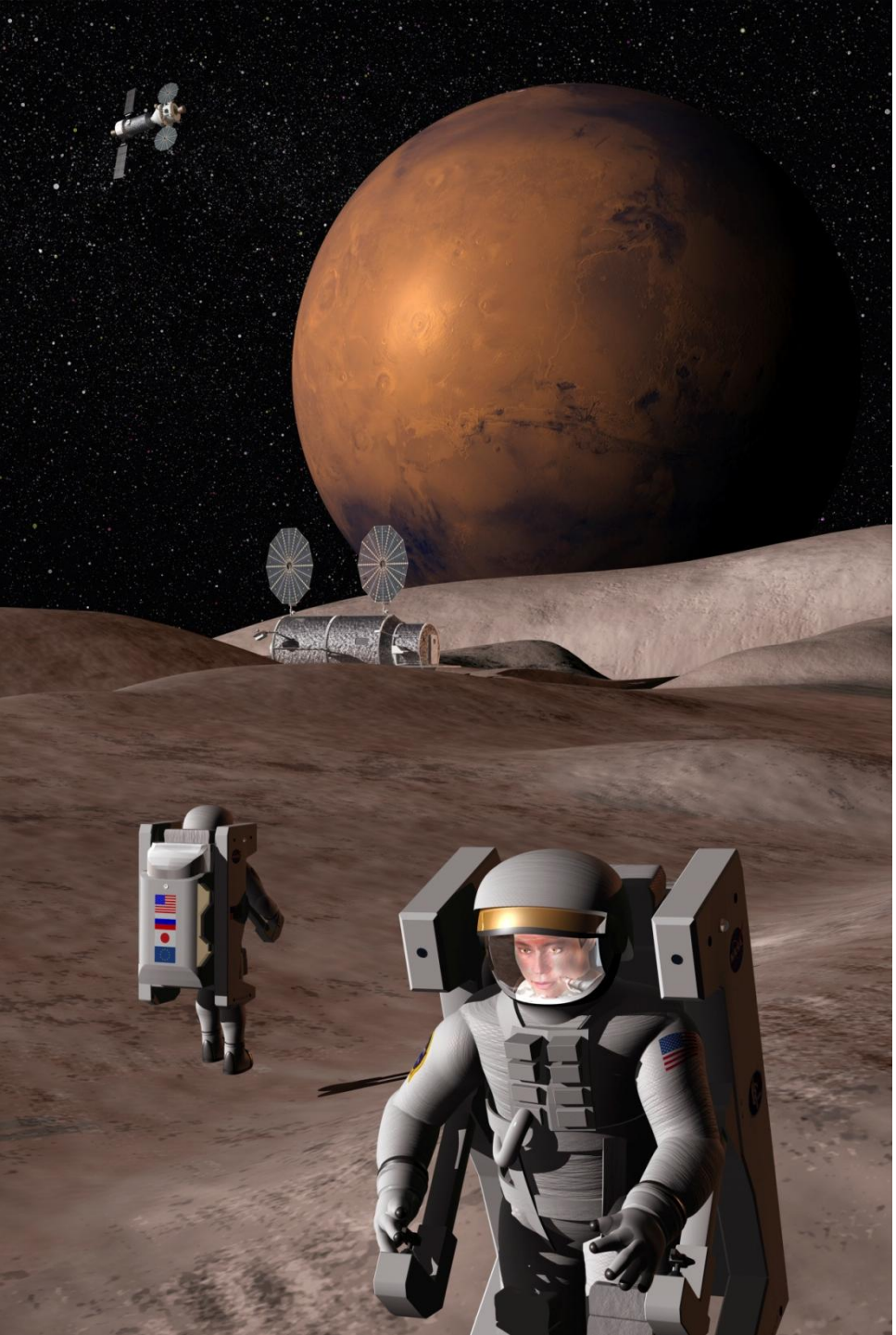


Comparison of Deimos and Phobos as Destinations for Human Exploration, and Identification of Preferred Landing Sites

Joshua Hopkins and William Pratt

Lockheed Martin

AIAA Space 2011 Conference
September 27, 2011

FISO Colloquium, October 19, 2011

Stepping Stones

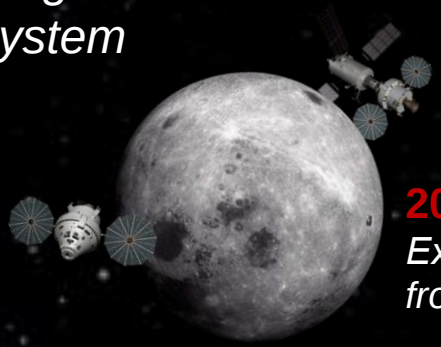
Exploring a series of increasingly challenging destinations on the way to Mars…

Stepping Stones is a series of increasingly challenging exploration missions, building incrementally towards America's long term goal of exploring Mars. Each mission will also address science objectives relating to the formation of the solar system and the origins of life.

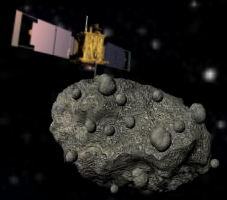
2023
Deimos Scout

2031-2035
Red Rocks: Explore Mars from Deimos

2019, 2024, 2025, 2029
Plymouth Rock: Humans Explore Asteroid 2008 EA9 and others



2018
Explore the Moon's Far Side from Earth-Moon L_2 Point



2017
Human Lunar Flyby

2016
Asteroid Survey

2017
Asteroid Scout

2016
SLS Test Flight

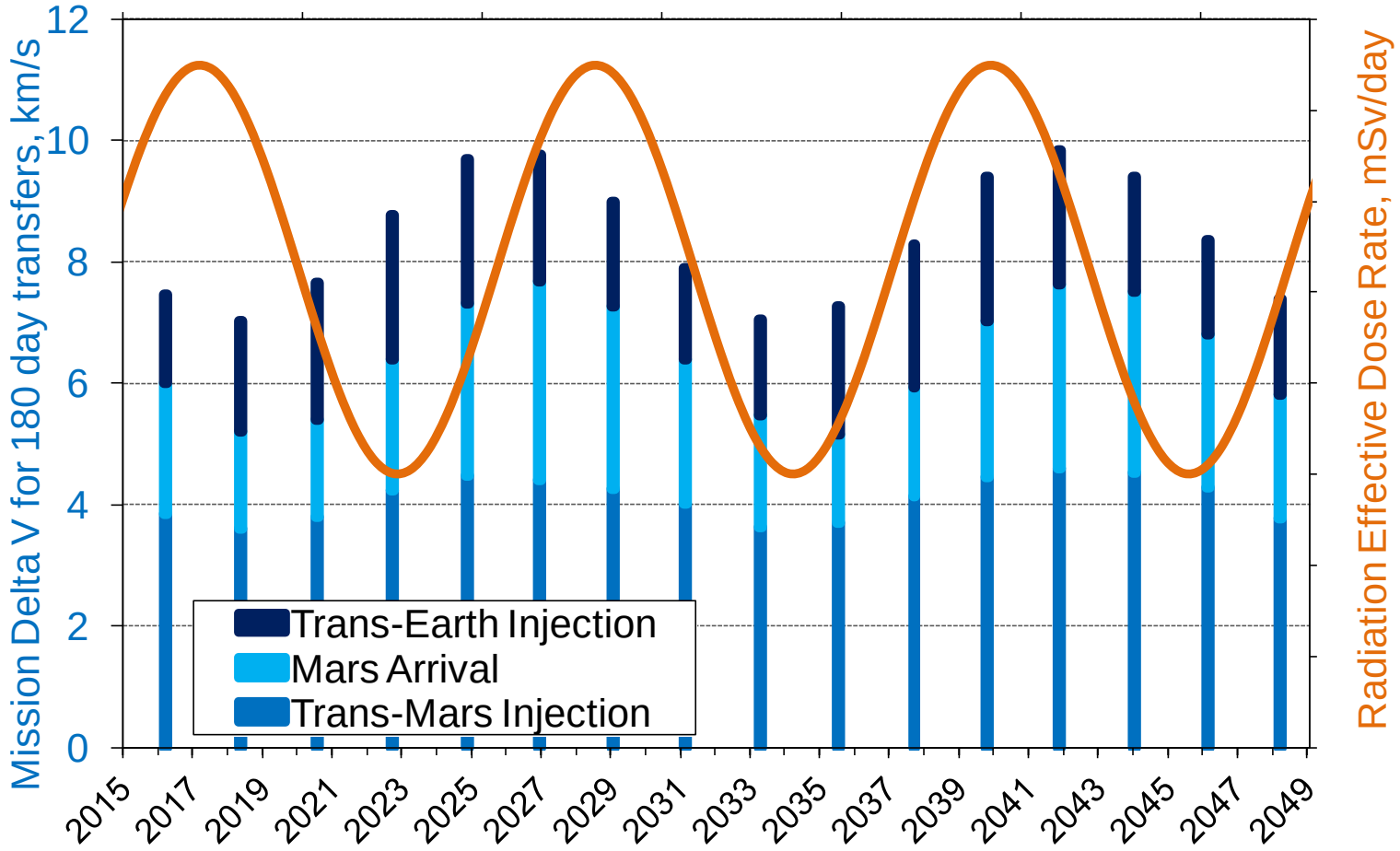
A human mission to the moons of Mars will need capabilities such as heavy-lift launch , tele-operation of rovers from orbit, operating on a low-gravity body, long term cryo-propellant storage, and maintaining crew health during long term deep space exposure. These capabilities will be developed and demonstrated through a series of Stepping Stones missions.

Deimos photo courtesy of NASA-JPL, University of Arizona

Summary

- A human mission to one of the two moons of Mars would be an easier precursor to a mission to land on Mars itself.
- Astronauts would explore the moon in person and teleoperate rovers on the surface of Mars with minimal lag time, with the goal of returning samples to Earth.
- “Red Rocks” mission to land on a Martian moon would follow “Plymouth Rock” missions to a Near Earth Asteroid.
- Comparison of Deimos and Phobos revealed Deimos is the preferred destination for this mission.
- We identified specific areas on Deimos and Phobos as optimal landing sites for an early mission focused on teleoperation.

2033-2035 is the Best Opportunity



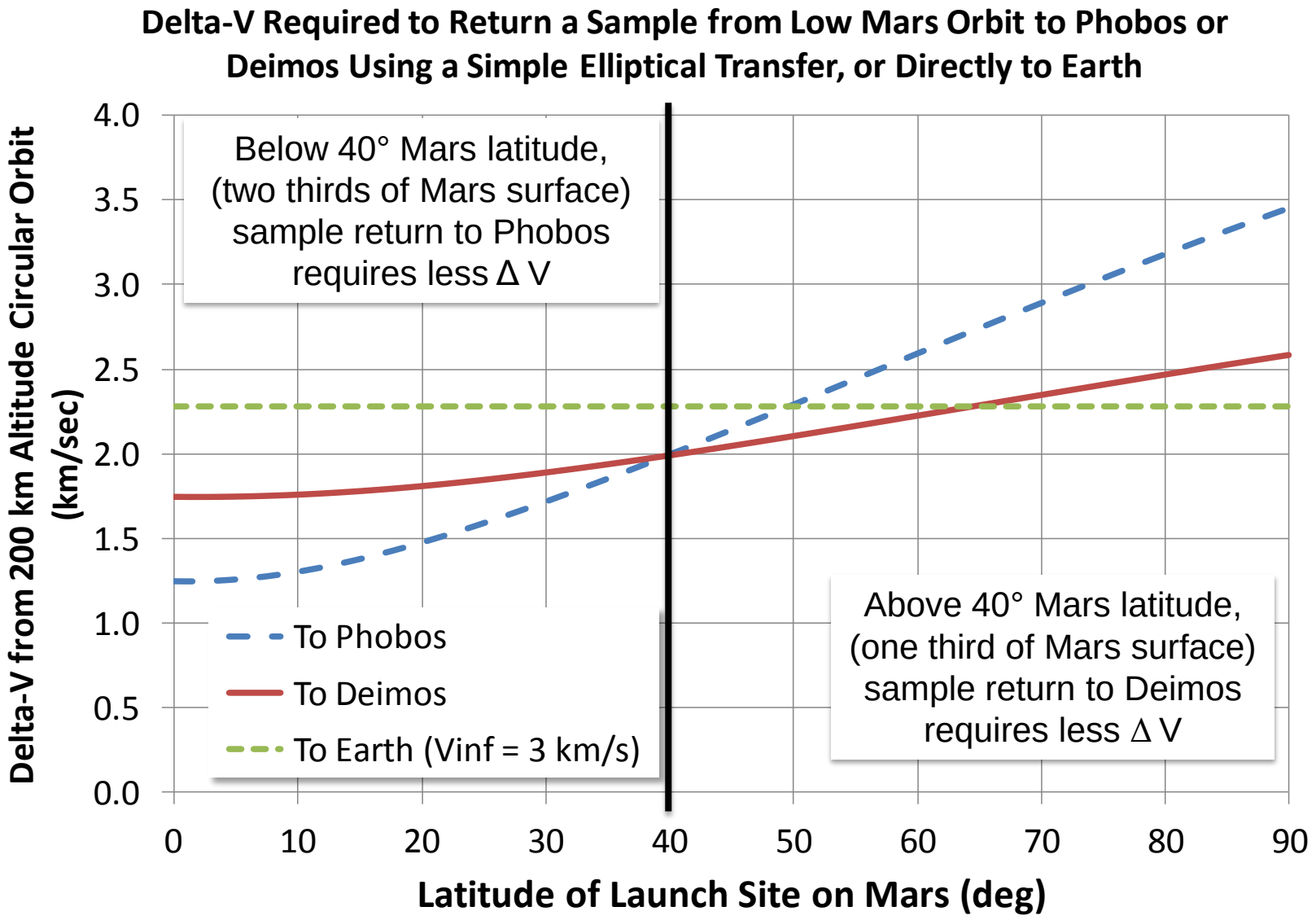
- **Optimum phases of 15 year orbital mechanics cycle and 11 year solar cycle (which protects from cosmic rays) probably coincide in 2033**


Deimos: 23,460 km orbit radius, 30 hr period
Phobos:
9377 km orbit radius
7.7 hr period

Deimos versus Phobos

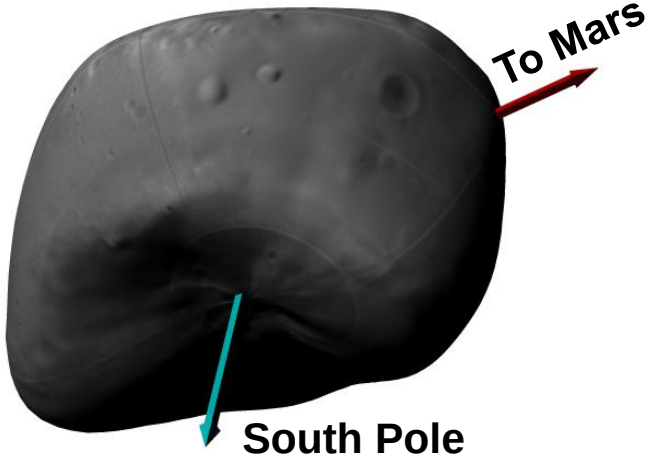
	Deimos	Phobos
Mars arrival (2033) plus Earth return (2035) ΔV	**~2.9 km/s**	~3.3 km/s
Two-way speed of light lag to nadir point on Mars	0.134 s	0.040 s
Max visible Mars latitude (with 5º elevation mask)	**77.6º**	64.8º
Fraction of Mars surface visible	**97.5%**	90.5%
Duration of comm line-of-sight to asset on Mars equator	**59.6 hrs**	4.2 hours
Gap between comm passes to equatorial asset on Mars	71.8 hours	**6.9 hrs**
% time a Mars surface site is in view	**45%**	38%
Max eclipse duration	84 min	**54 min**
Max eclipse % of orbit period	**4.6%**	12.0%
Max continuous lighting duration in Northern hemisphere	**~300 days**	~140 days
Average eclipse season duration	**~83 days**	~228 days
Max continuous lighting duration in Southern hemisphere	**~225 days**	~95 days

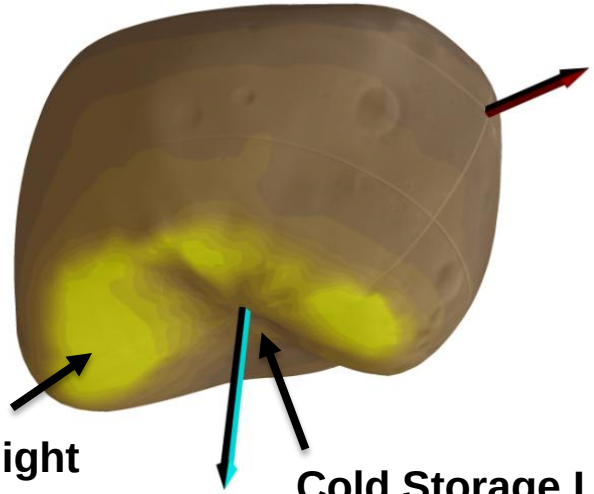
Mars Sample Return Delta-V



Southern Hemisphere of Deimos

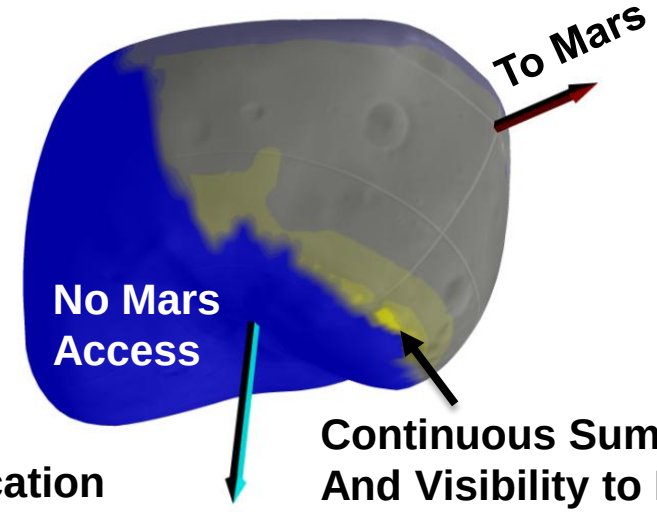
Viking Orbiter Image F355B51-B59
(Credit: NASA/JPL/Emily Lakdawalla)





Continuous
Summer Sunlight

Cold Storage Location

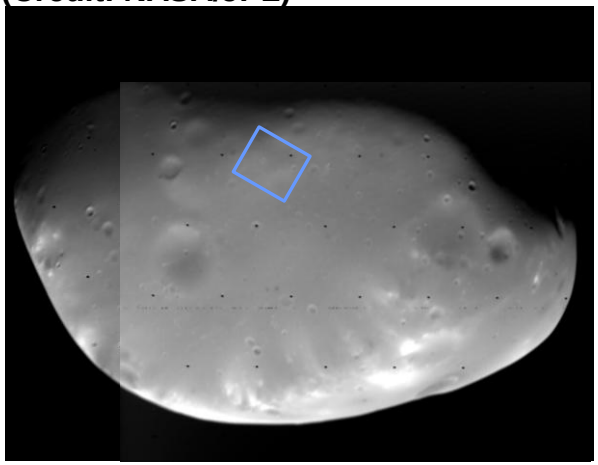


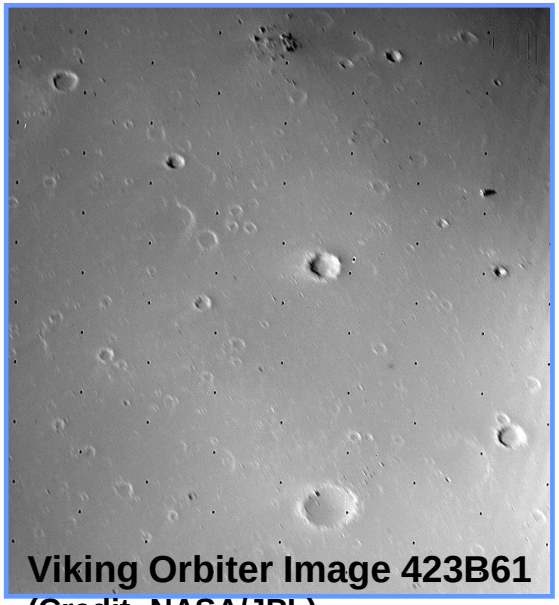
Continuous Sumer Sunlight
And Visibility to Mars
(51° South, 7° East)

Deimos photomap courtesy of Phil Stooke, University of Western Ontario

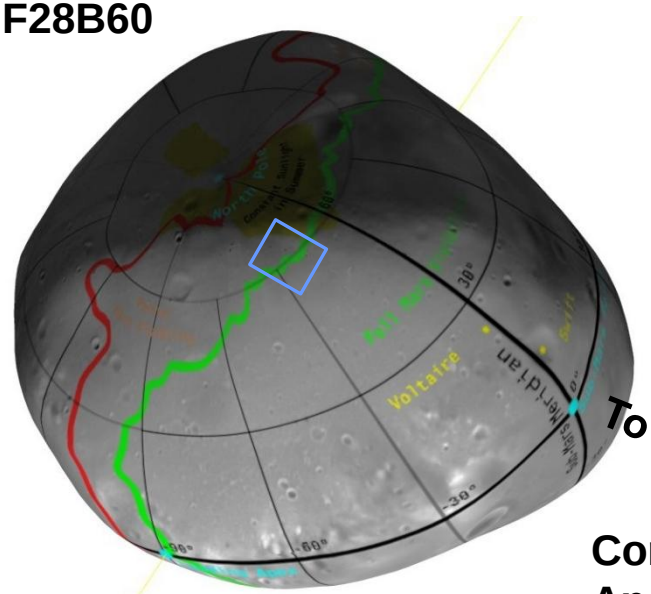
Northern Hemisphere of Deimos

Viking Orbiter Image F28B61 and F28B60
(Credit: NASA/JPL)

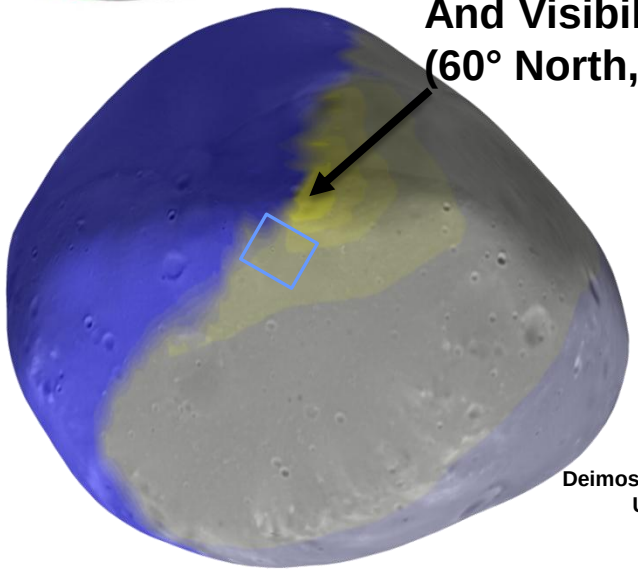




Viking Orbiter Image 423B61
(Credit: NASA/JPL)



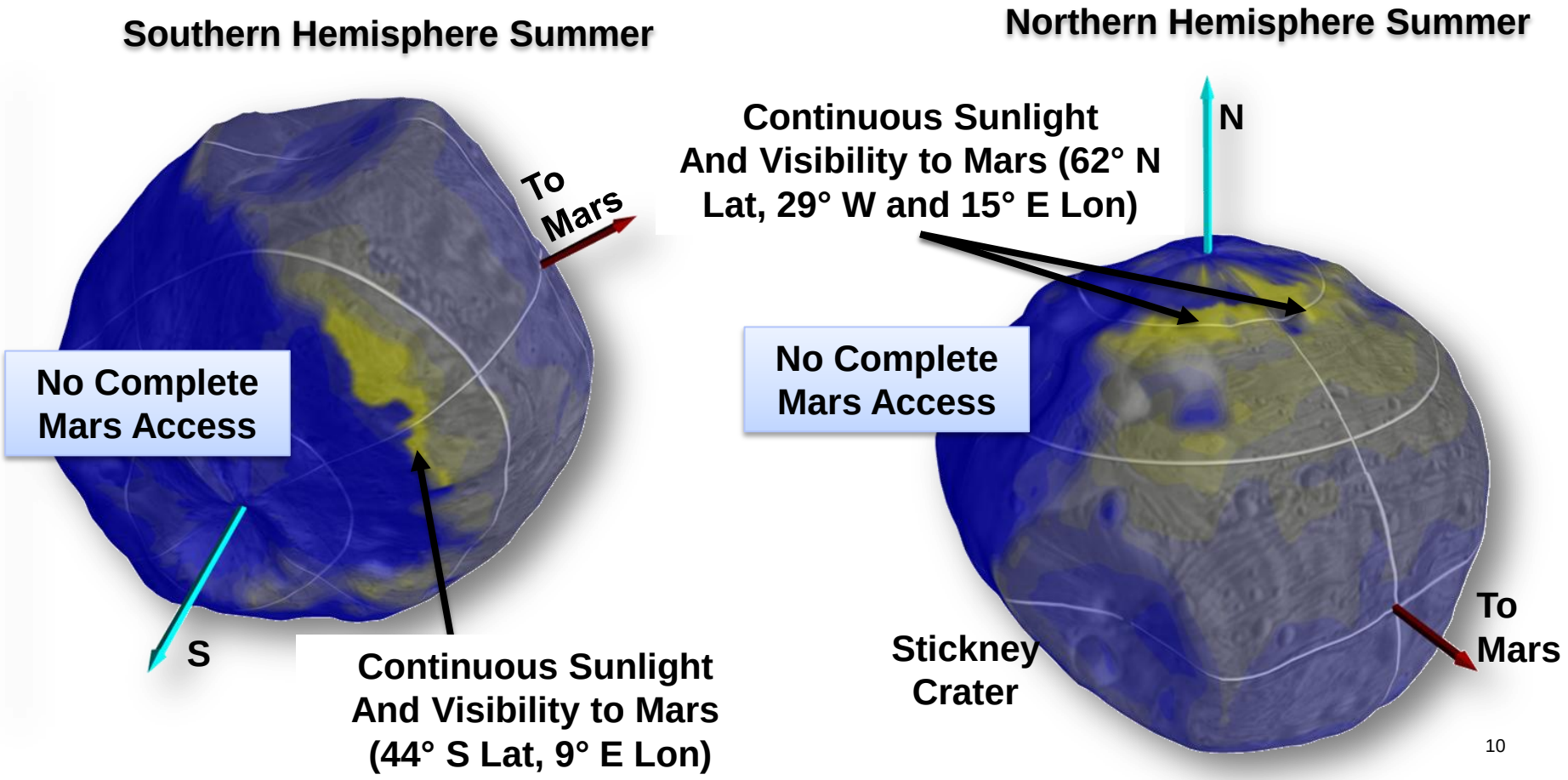
Continuous Sumer Sunlight And Visibility to Mars (60° North, 0° East)



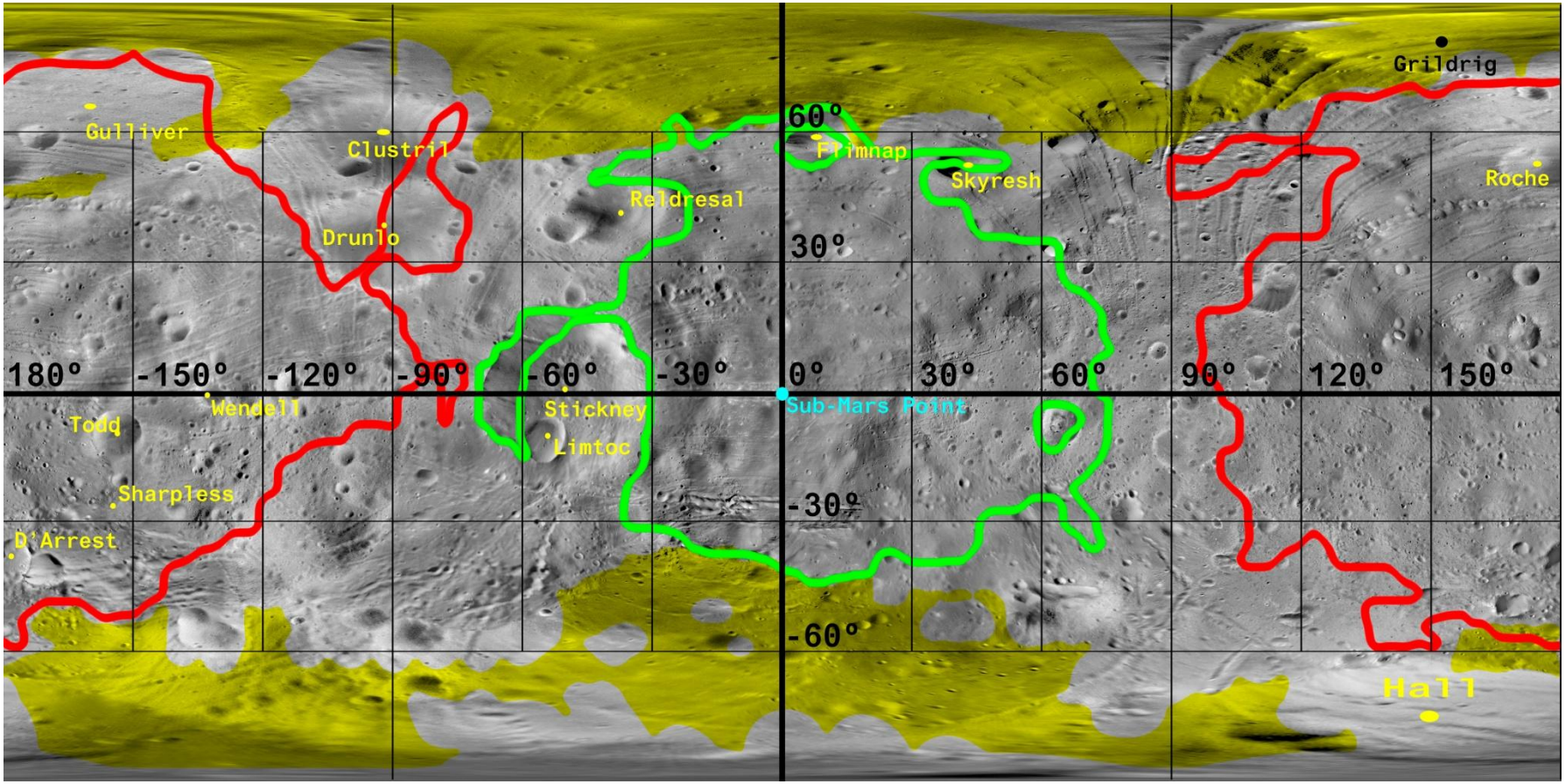
Deimos photomap courtesy of Phil Stooke, University of Western Ontario

Potential Landing Sites on Phobos

- **Phobos also has regions with steady sunlight and full Mars visibility (but the regions are very small and periods of constant sunlight are much shorter).**



Phobos Lighting and Mars Visibility

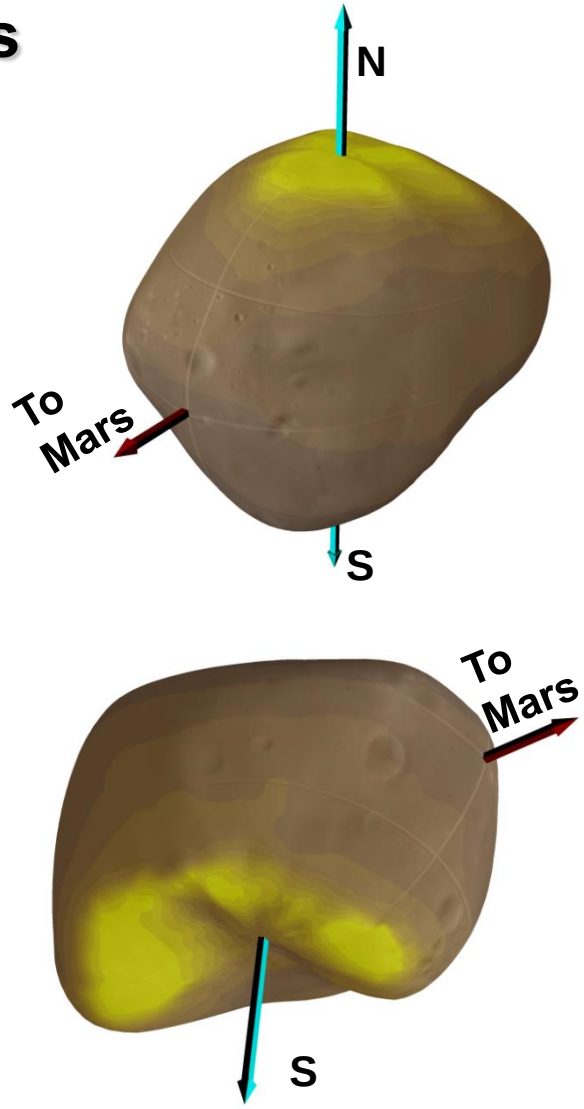


- **Yellow regions have continuous sunlight during respective summer**
- **Inside green boundary all of Mars is visible**
- **Between green and red boundary part of Mars is visible**

Phobos photomap courtesy of Phil Stooke, University of Western Ontario

Advantages of Deimos

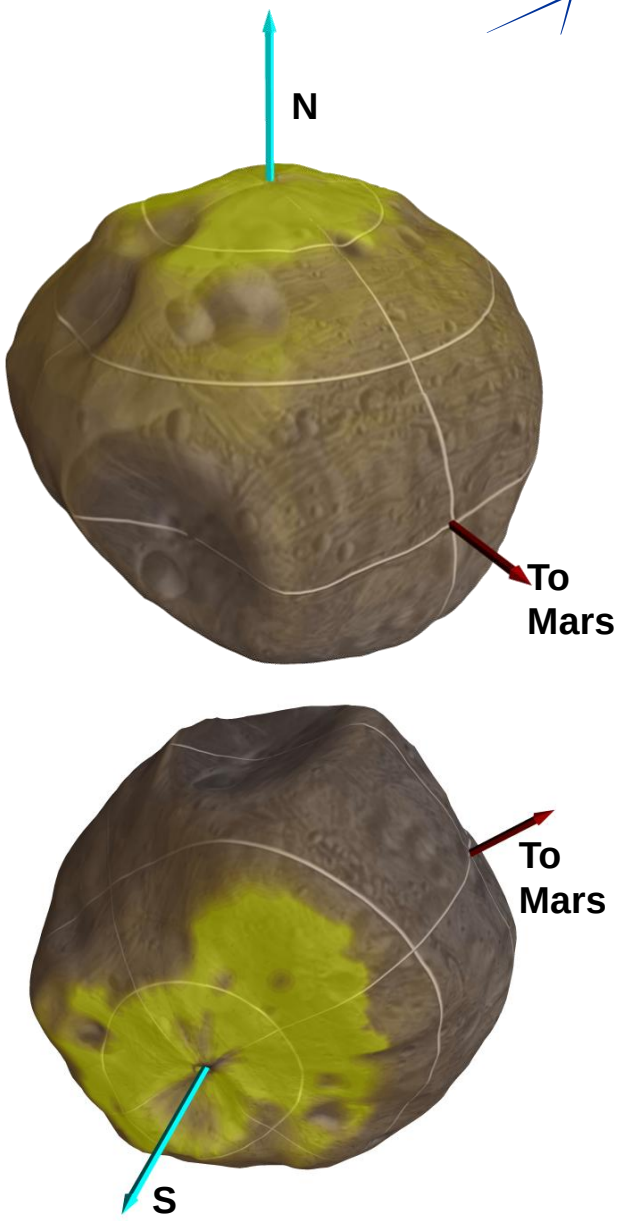
- Round trip ΔV from Earth to Deimos is about 400 m/s lower than to Phobos
- Longer communications access to assets on Martian surface
- Communications access to higher Martian latitudes
- Superior line-of-sight to Earth from Deimos due to fewer Martian occultations
- Twice as much time with constant sunlight and only a third of the eclipse season duration as Phobos



Deimos photomap courtesy of Phil Stooke, University of Western Ontario

Advantages of Phobos

- The gap between comm passes to Martian surface assets is much shorter.
- The maximum possible eclipse duration is 30 min shorter on Phobos.
- Phobos appears to be more geologically interesting than Deimos.
- Sample return to Phobos is easier from low latitude Mars sites.



Phobos photomap courtesy of Phil Stooke, University of Western Ontario

Example Mission

Depart Earth April 17 2033

C3 = 9.2 km²/s²

Transfer 201 days

Arrive Mars Nov 4 2033

Arrive Deimos Nov 8 2033

Stay at Southern Site 114 days

Depart for orbit Mar 2 2034

Eclipse Season begins

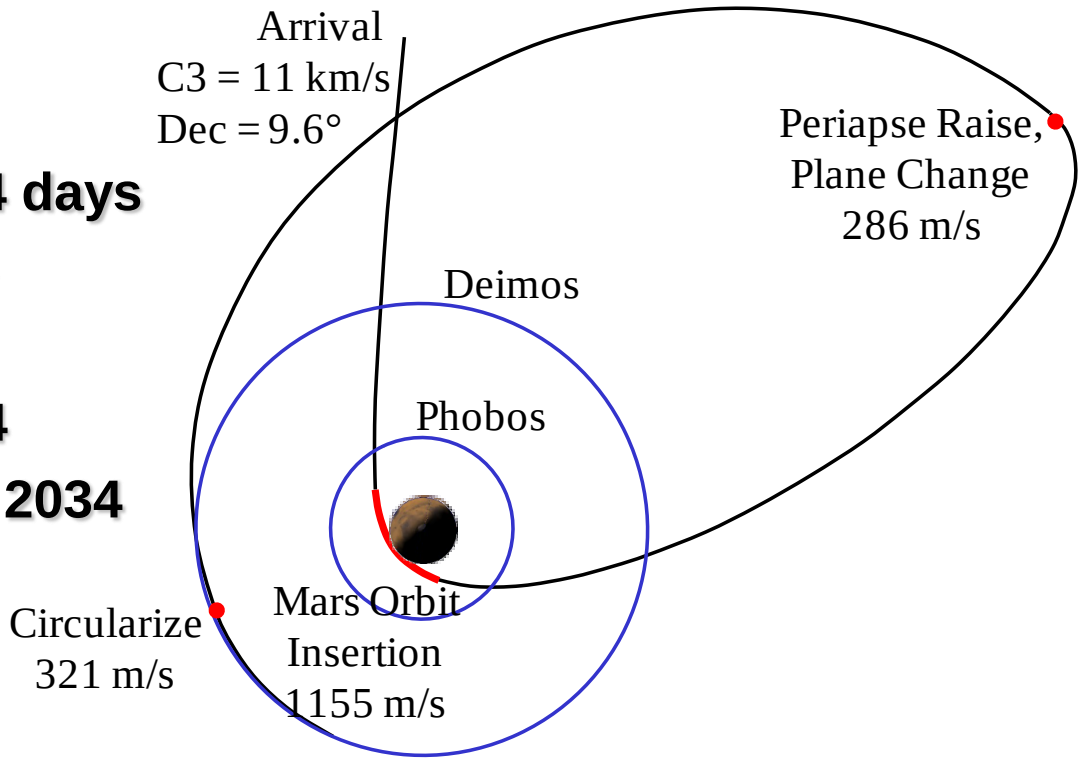
Vernal Equinox 4/11/2034

Land at North Site April 20 2034

Stay 373 days

Depart Mars 5/7/2035

Transfer 199 days



Conclusion

- **For a solar-powered mission with a focus on tele-robotic operation of Mars surface assets, Deimos is a better choice of location than Phobos, due to its superior coverage of sites on the Martian surface and extended durations of constant sunlight.**
- **A human mission to Deimos could visit the identified Northern and Southern sites during their respective summer seasons**
- **Human missions to Deimos are possible with relatively few new technologies**