

## JSC/EC5 Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** Phobos: Simulation-Driven Design for Exploration

**Date:** November 10, 2015

**Time:** 1:00 p.m. – 2:00 p.m.

**Location:** JSC/B5S/R3102

**DAA 1676 Form #: 34713**

This is a link to all lecture material [\\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY16 Knowledge Capture\20151110 Crues\\_Phobos Simulation\\_Driven Design\FOR 1676 Review & Public Release](\\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY16 Knowledge Capture\20151110 Crues_Phobos Simulation_Driven Design\FOR 1676 Review & Public Release)

### **Assessment of Export Control Applicability:**

This presentation has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to STI for distribution through NTRS or NA&SD (public or non-public) and YouTube viewing.

\* This file is also attached to this 1676 and will be used for distribution.

*For 1676 review use Synopsis Crues Phobos 11-10-2015.docx*

**Presenter:** Dr. Edwin “Zack” Crues

**Synopsis:** Dr. Edwin “Zack” Crues will present an overview of the current use of modeling and simulation technologies by the NASA Exploration Systems Simulations (NExSyS) team in investigating the spacecraft and missions for the human exploration of Mars’ moon Phobos.

**Biography:** Dr. Edwin “Zack” Crues has over 25 years of professional experience in developing spacecraft simulation and simulation technologies. Dr. Crues is currently a member of the Simulation and Graphics branch at NASA’s Johnson Space Center in Houston, Texas where he leads the development of simulation technologies and the application of those technologies in the simulation of NASA’s current and proposed crewed spacecraft. He has developed hundreds of models and simulations for NASA spacecraft including Shuttle, International Space Station (ISS), Orion, Altair, Morpheus, and the Multi-Mission Space Exploration Vehicle. Dr. Crues’ recent research focus has been developing and applying distributed computation and distributed simulation technologies. This includes a large-scale distributed simulation of NASA’s proposed human space exploration missions. Dr. Crues also has international experience in developing simulations of European Space Agency launch systems and Japanese Aerospace Exploration Agency spacecraft.

Dr. Crues is also involved in the advancement of modeling and simulation education. He has served on a number industrial advisory boards for university aerospace programs. He is a co-founder of an interoperable simulation competition sponsored by the Society for Modeling and Simulation International. Dr. Crues has taught commercial and university courses in object oriented programming,

modeling and simulation. He earned his bachelor's degree, master's degree, and doctorate in aerospace engineering from the University of Texas at Austin.

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# Phobos: Simulation Driven Design for Exploration



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Simulation and Graphics Branch (ER7)

NASA Johnson Space Center

November 10, 2015





# Overview

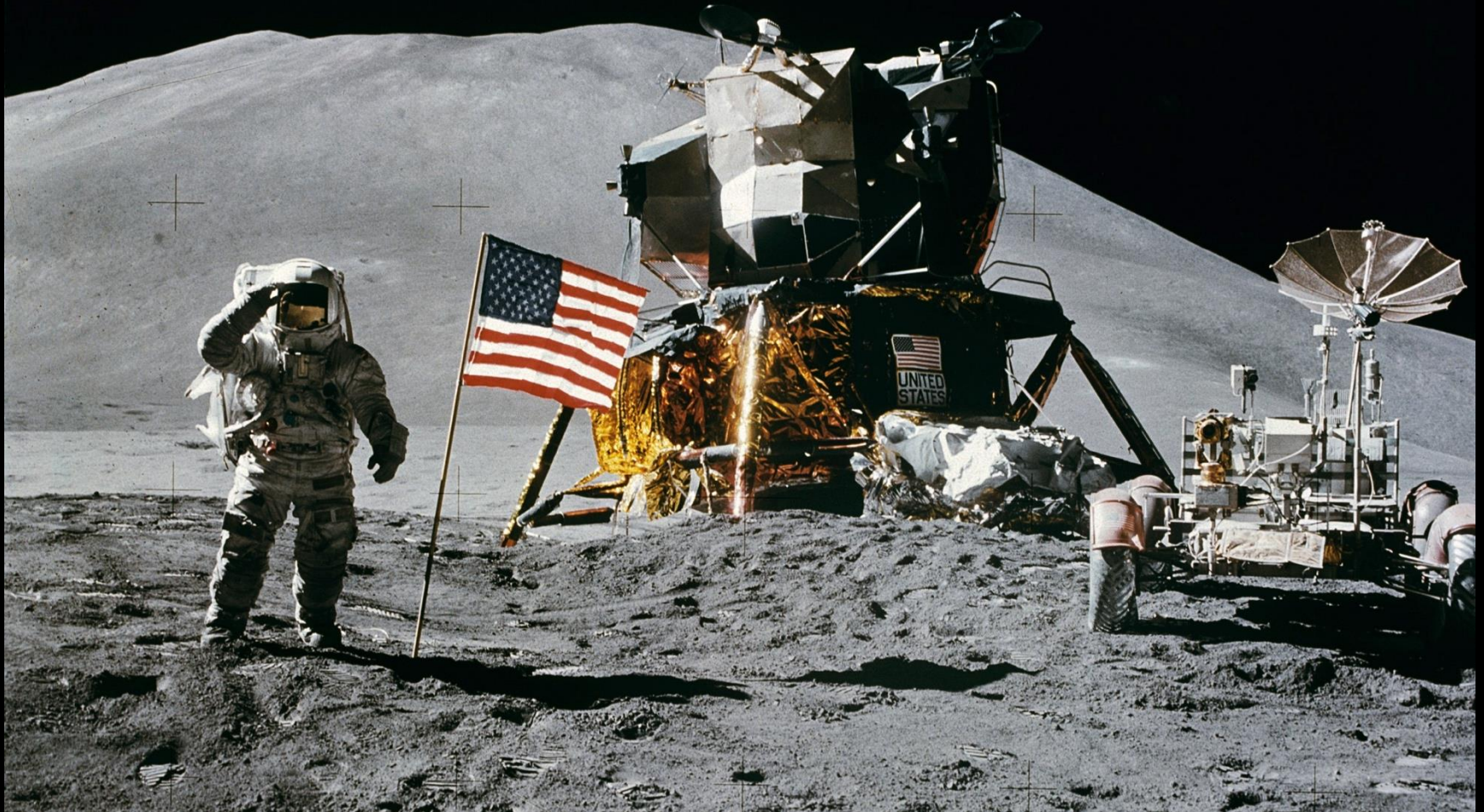


- NASA's Human Space Exploration
- Exploring Mars
- Space Station Phobos
- Simulation: Doing More with Less
- Simulating Phobos Exploration
- Wrapping Things Up
- Questions?





# NASA's Human Space Exploration





# NASA's Human Space Exploration



*Doing More With Less*

- Consider NASA's Human Space Exploration
  - Past: Mercury, Gemini, Apollo, Skylab and Shuttle
  - Current: International Space Station (ISS)
  - Developing: Space Launch System (SLS) and Orion
  - Conceptual: Asteroids and Journey to Mars
- Exploration objectives have expanded but budgets have contracted
  - NASA's budget in 1966 was 4.4% of federal budget
  - NASA's budget today is 0.4% of federal budget
- Advances in Modeling and Simulation (M&S) are helping NASA do more with less





# NASA's Human Space Exploration



*Past: Mercury, Gemini, Apollo, Skylab, and Shuttle*

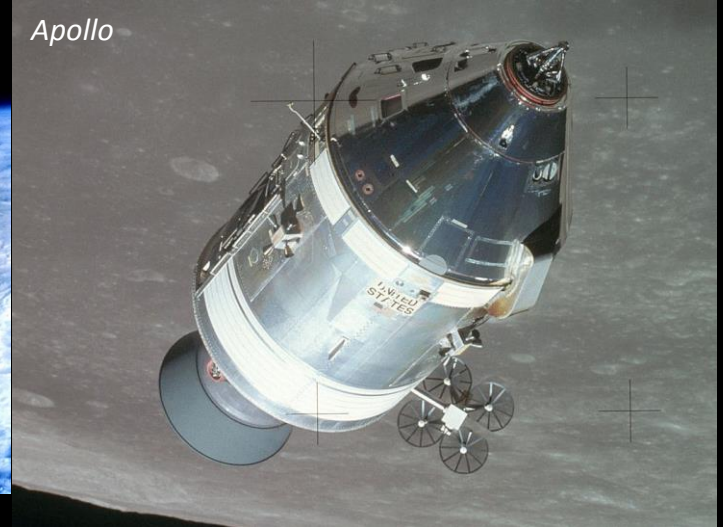
*Mercury*



*Gemini*



*Apollo*



*Apollo Moon Landings*



*Skylab*



*Shuttle*

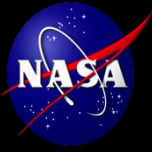






# NASA's Human Space Exploration

*Present: International Space Station (ISS)*





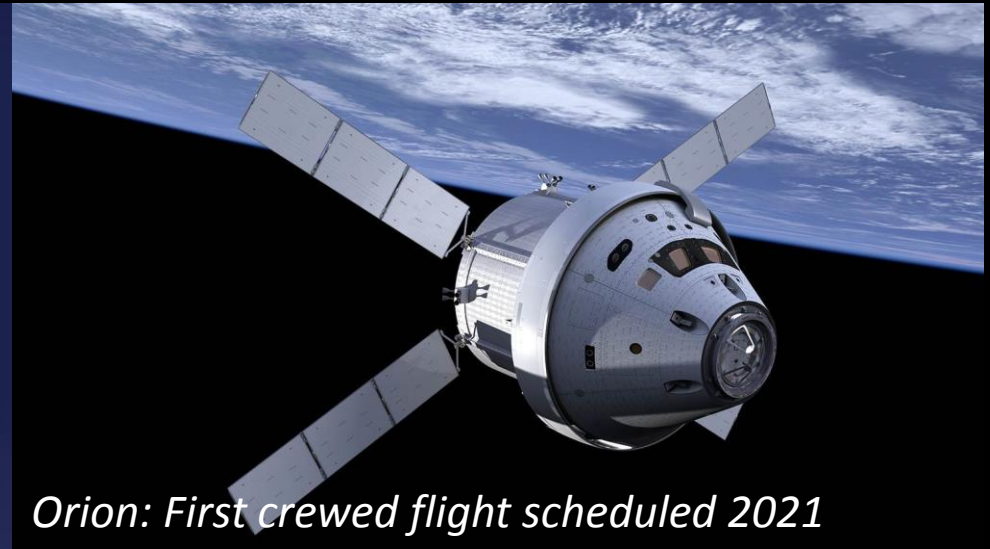


# NASA's Human Space Exploration



*Developing: SLS and Orion*

*Space Launch System:  
First launch scheduled 2018*



*Orion: First crewed flight scheduled 2021*



*Orion EFT-1: Dec 2014*

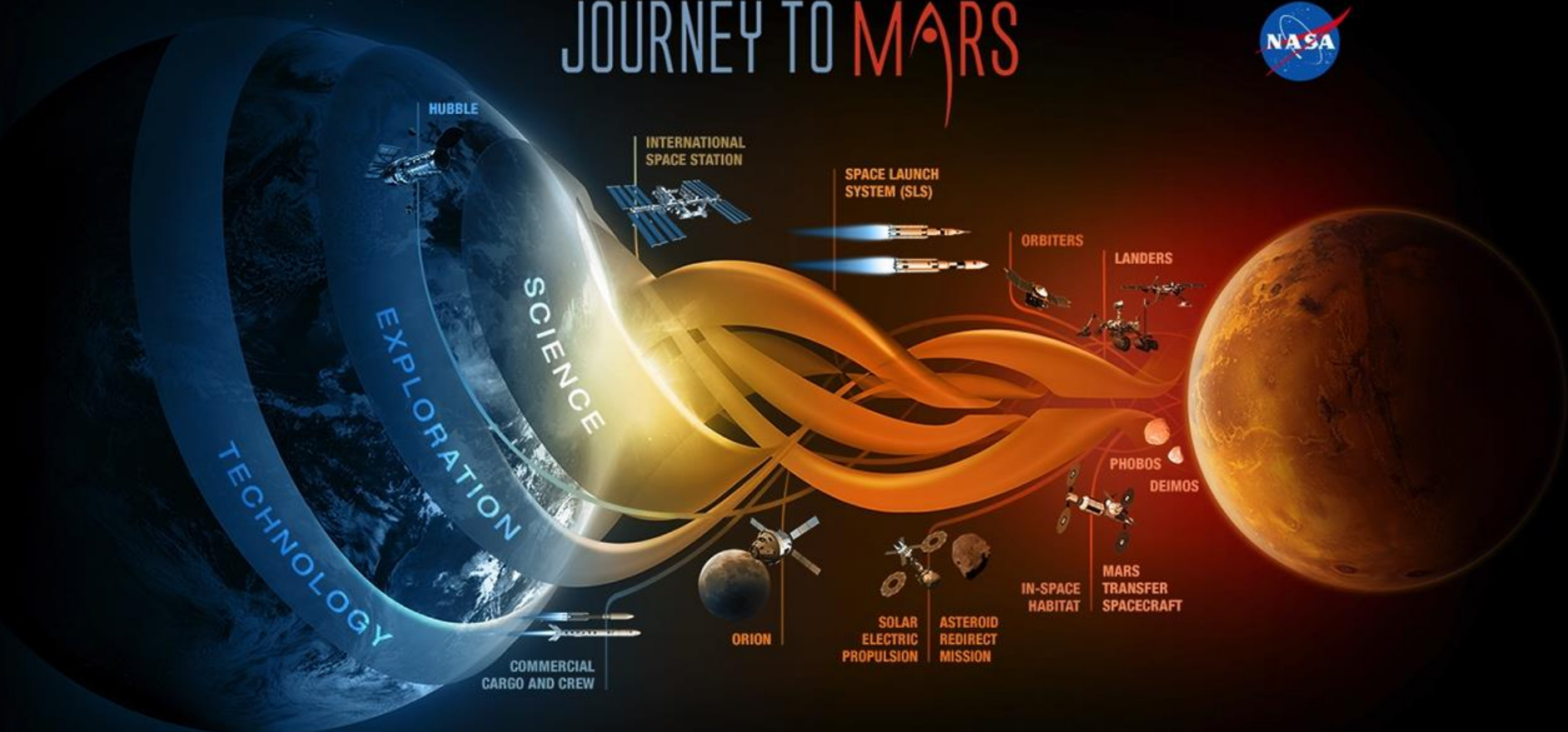


# NASA's Human Space Exploration

## *Concept of the Future*

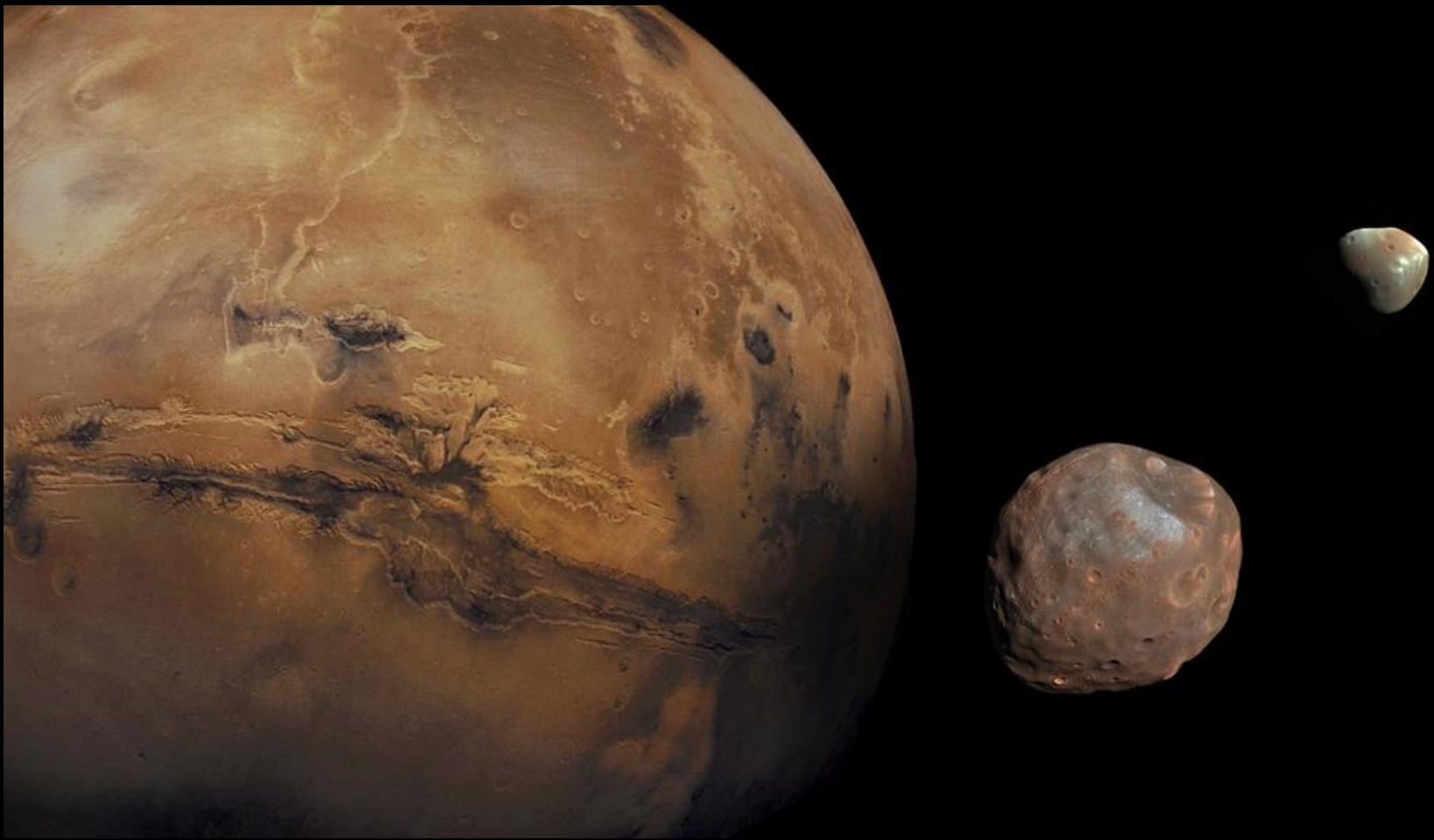


### JOURNEY TO MARS





# Exploring Mars







# Exploring Mars



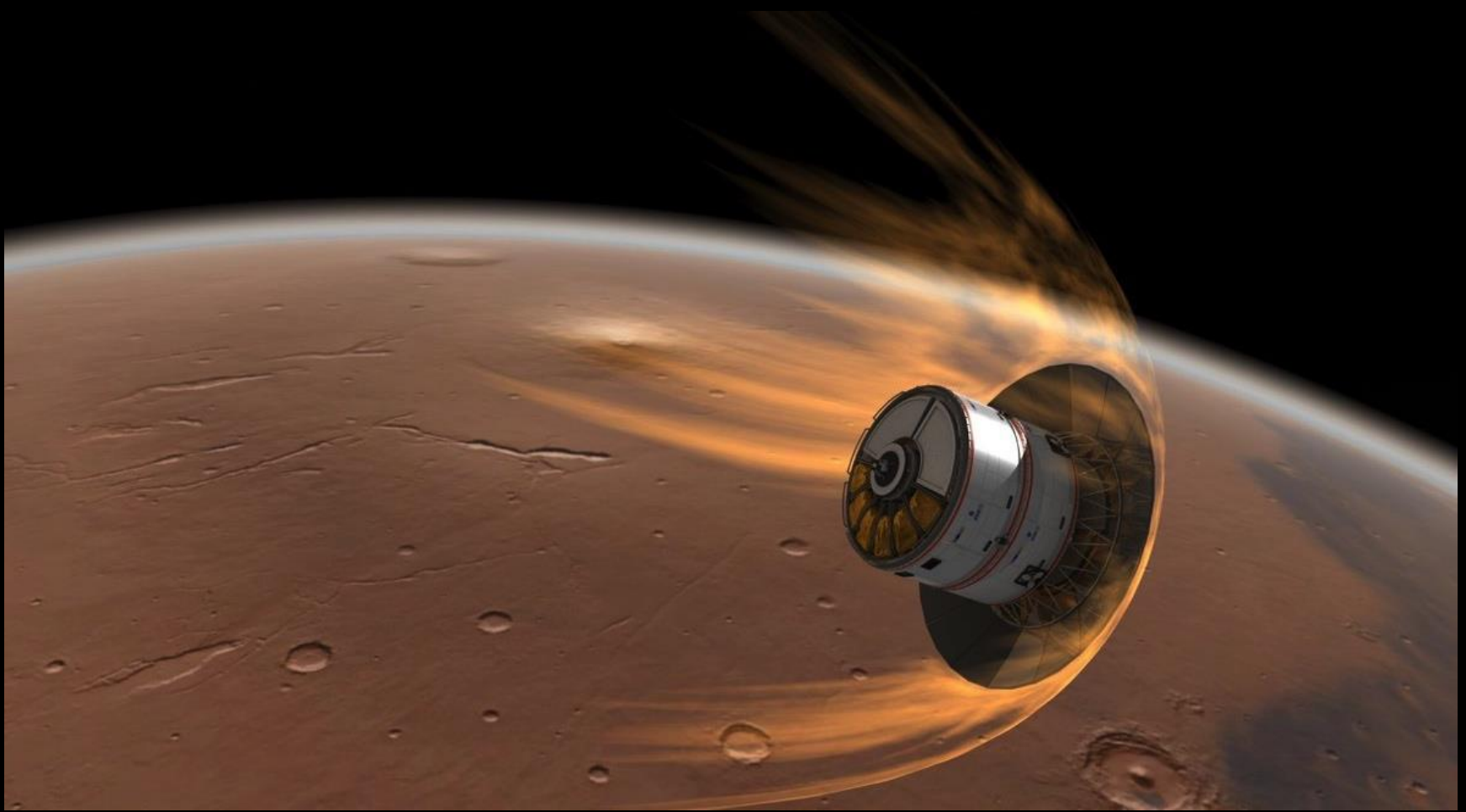
## *A Few Facts about the 4<sup>th</sup> Rock from the Sun*

- Distance from Earth (3<sup>rd</sup> Rock from the Sun):
  - Closest: 55 million km (~0.37 AU) (~3.1 light min)
  - Average: 225 million km (~1.50 AU) (~12.5 light min)
  - Furthest: 401 million km (~2.67 AU) (~22.3 light min)
- Mean Radius: 3389.5±0.2 km
- Surface Gravity: 3.711 m/s<sup>2</sup> (0.376 g)
- Atmosphere: 0.636 (0.4–0.87) kPa; primarily CO<sub>2</sub>
- Martian Day (1 Sol): 24h 39m 35.24409s
- Martian Year: 687 days (~1.88 years) or 669 sols
- Two small irregularly shaped moons in essentially equatorial orbits:
  - Phobos: 27 × 22 × 18 km in 7.653 hour orbit
  - Deimos: 15 × 12.2 × 11 km in 30.312 hour orbit
- NASA is considering missions to put humans on Mars in the 2030s



# Exploring Mars

*Deep Gravity Well and Thin Atmosphere*





# Exploring Mars

## *Boots on the Ground in 2030s*

Image from the movie "The Martian"







# Exploring Mars

*Landing on Mars is Hard*



- One of the most challenging phases of a Mars mission is entry into and descent through the atmosphere and landing on the surface
- Question: Is there a useful human exploration prelude mission that prepares us for landing humans on Mars?
- As a stepping stone prior to a Mars surface landing mission, NASA is exploring the possibilities of Phobos



# Space Station Phobos





# Space Station Phobos



## *Interesting Things About Phobos*

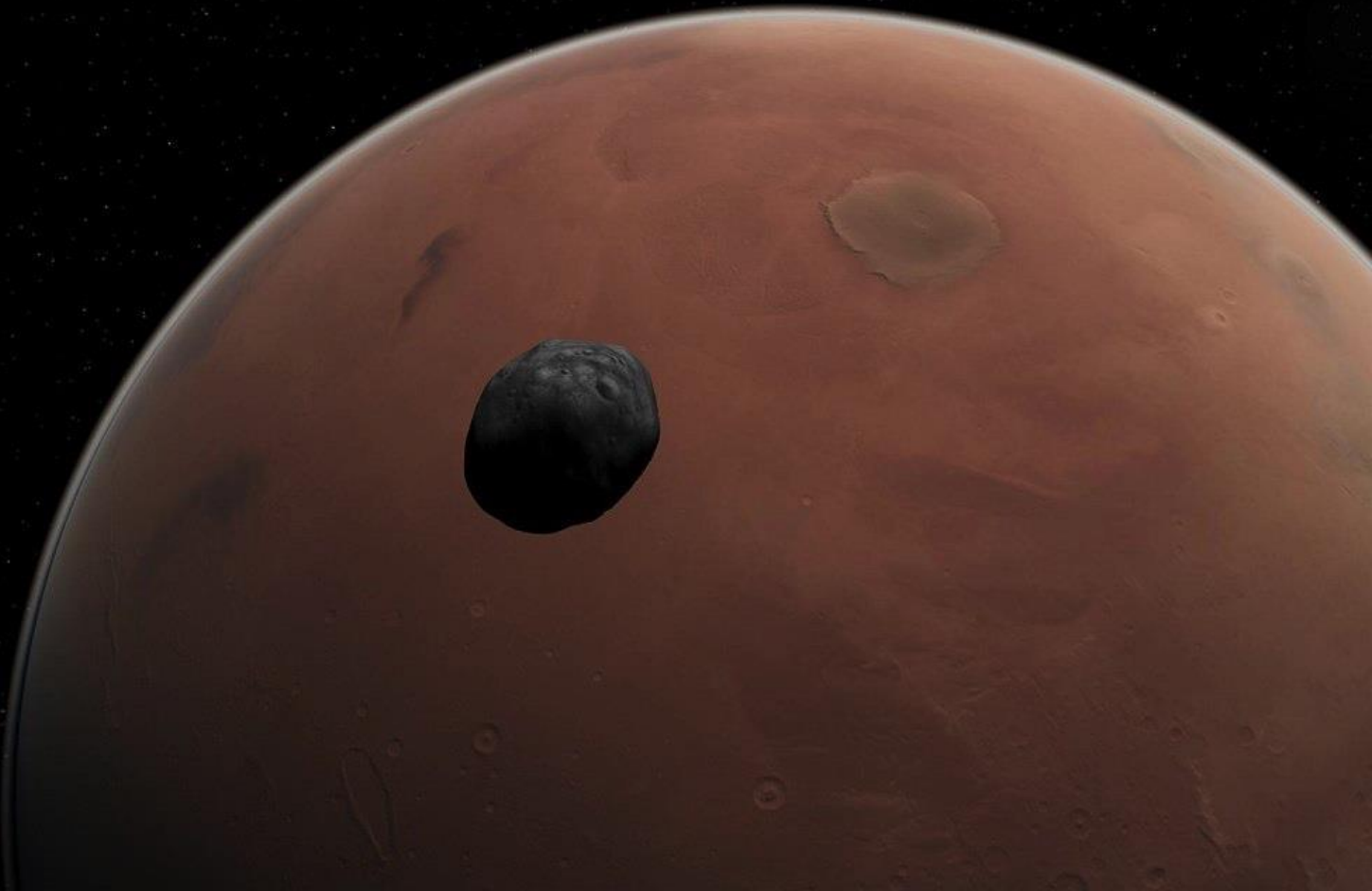
- Phobos is the larger of Mars' two moons
- Phobos has an interesting orbit:
  - Relatively Close: 9376 km semi-major axis (2.76 Mars radii)
  - Short Period: 7 h 39.2 min
  - Almost Equatorial: 1.093° inclination
  - Almost Circular: 0.0151 eccentricity
- Phobos has very low gravity: 0.0057 m/s<sup>2</sup> (0.00058 g)
- Phobos has some interesting morphological features
- Landing on Phobos is easy compared to Mars
- This makes Phobos an interesting destination for observing Mars





# Space Station Phobos

*Keeping an Eye on Mars*





# Simulation: Doing More With Less



- We've already established that NASA needs to do more with less
  - NASA is changing the balance between hardware prototyping, flight testing, modeling and simulation
- Prototyping and Flight Test
  - Historically, NASA has relied on relatively expensive hardware prototyping and flight testing
  - It is difficult and very expensive to flight test hardware for a Mars mission
- Modeling and Simulation (M&S)
  - NASA has historically made some use of M&S design and analysis
  - Computational capabilities have increased dramatically, simulation systems have matured, and confidence in M&S based design and analysis has grown
- NASA is using more M&S based design and analysis to compliment less prototyping and flight test opportunities



# Simulation: Doing More With Less



## *Key M&S Concepts*

- M&S is not a substitute for prototyping and testing
  - M&S relies on prototyping and testing for validation
- The purpose of models and simulations are to answer questions
  - M&S is a way of gaining understanding and insight into places we've never been and problems we don't know how to solve . . . yet
- You always have to be able to answer the question . . .  
“How do you know the results are correct?”
  - “All models are wrong; some are useful.” – George Box
- When used appropriately, M&S can provide insight into the integrated behavior of a complex system in a timely and cost efficient manor





# Simulating Phobos Exploration

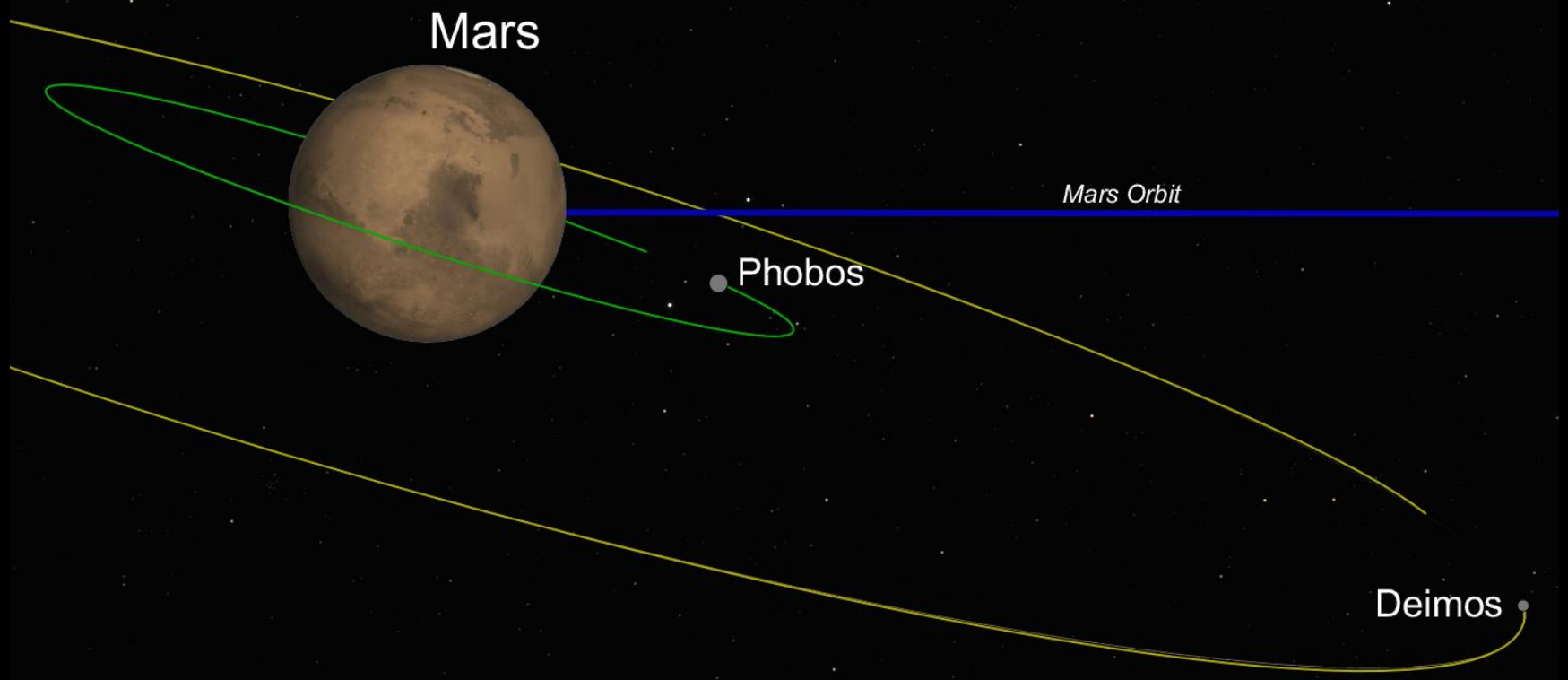


- How does M&S help with the exploration of Phobos?
- To date, we've never landed on Phobos; we've only had distant fly-bys.
- However, we do know some things about Phobos
- With that knowledge and our experience with similar environments, we can formulate models of Phobos
- These models can be used to simulate many aspects of a human mission to Phobos and then, ultimately, Mars
- So, what kind of models and simulations are we talking about?



# Simulating Phobos Exploration

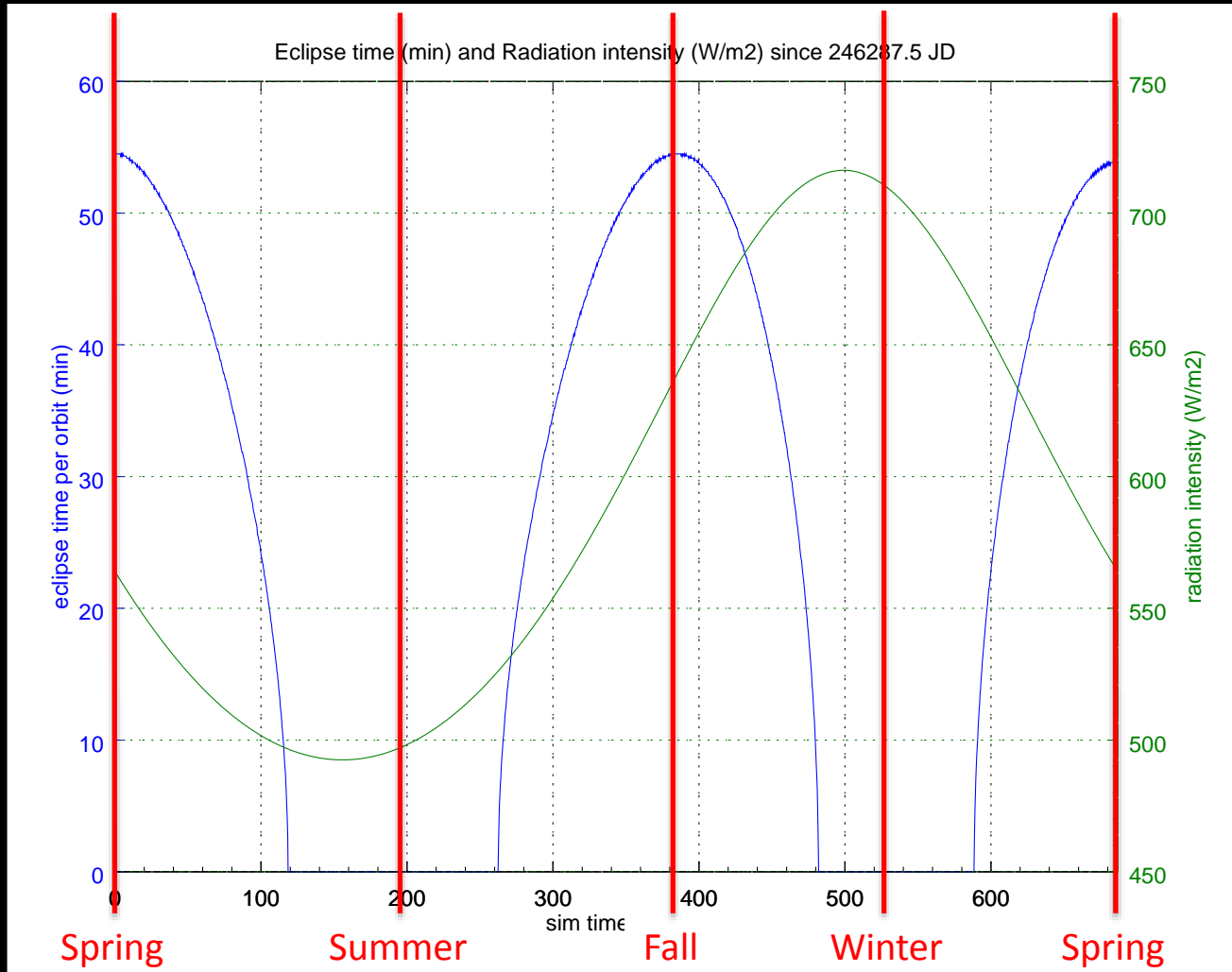
## *Orbital Dynamics*





# Simulating Phobos Exploration

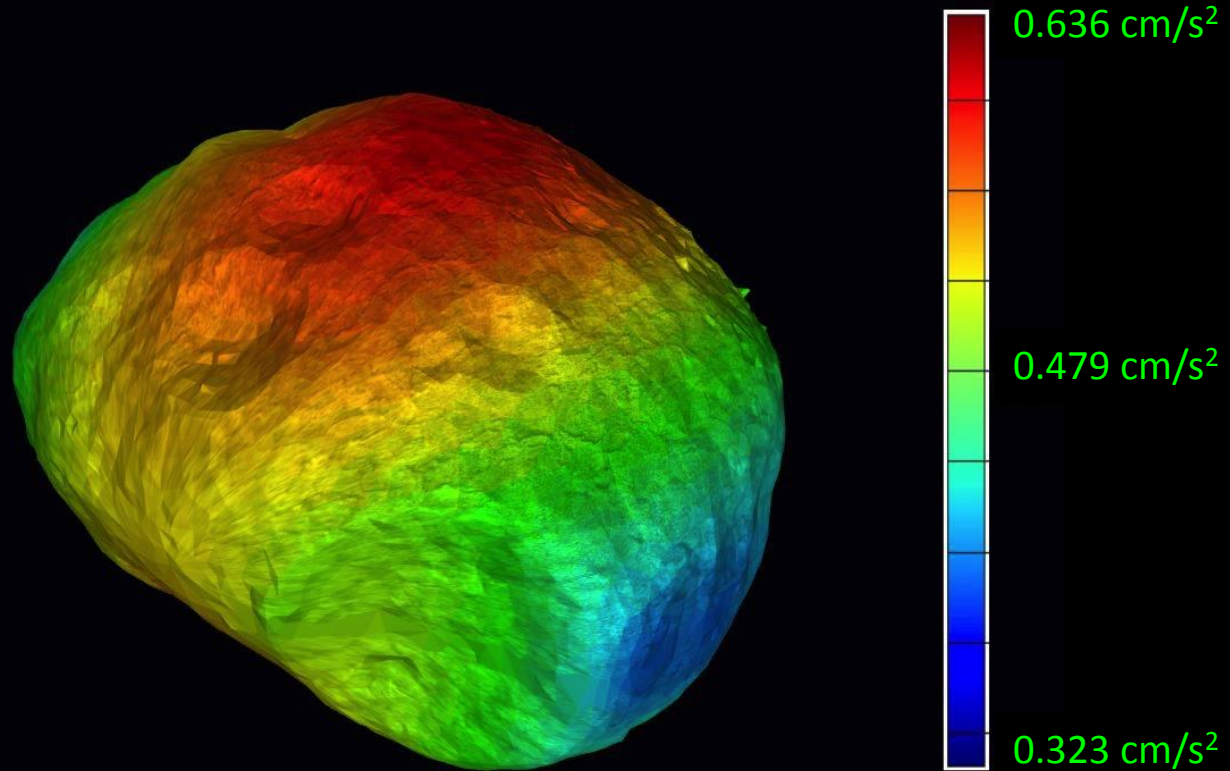
## *Orbital Affects on Phobos Lighting*





# Simulating Phobos Exploration

## *Irregularly Shaped Body*



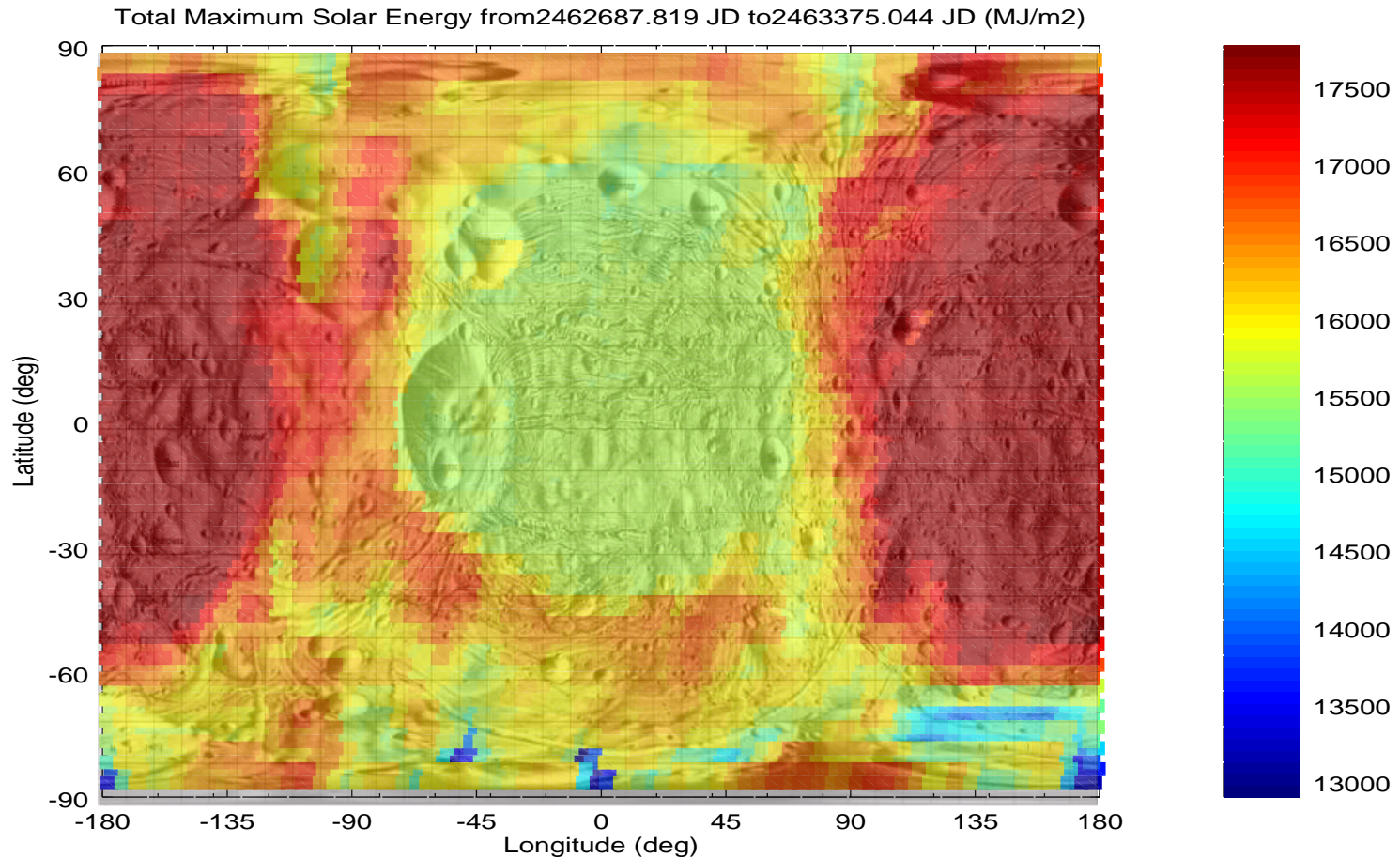
Phobos' Surface Acceleration Field





# Simulating Phobos Exploration

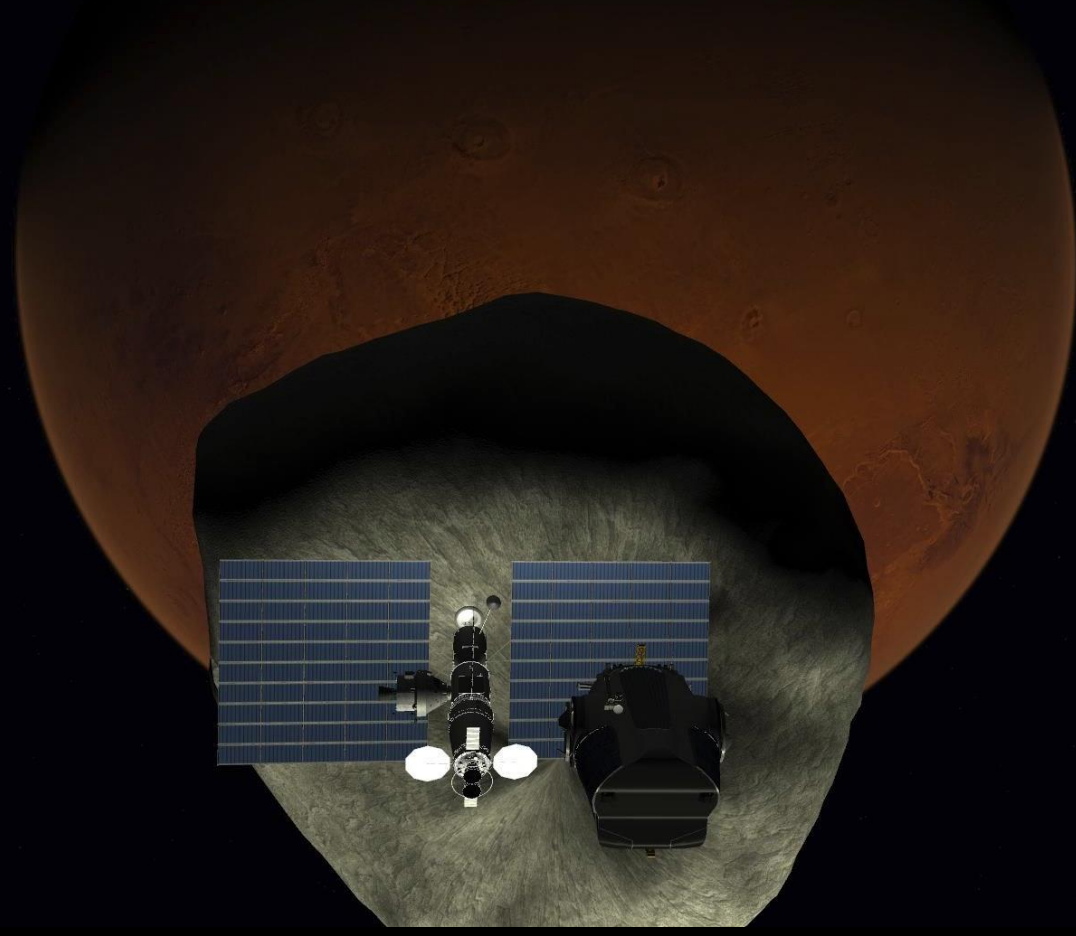
## *Complex Environmental Lighting*





# Simulating Phobos Exploration

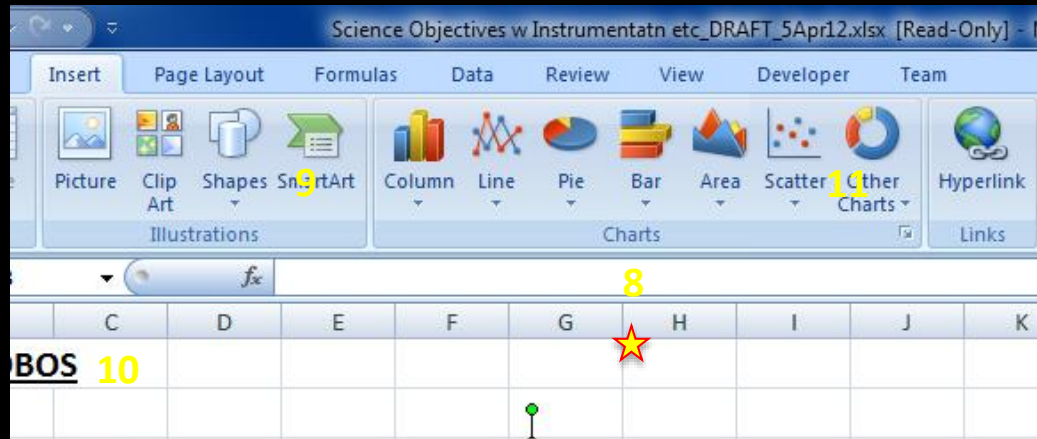
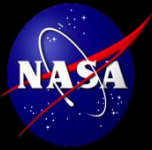
*Multiple Exploration Spacecraft*





# Simulating Phobos Exploration

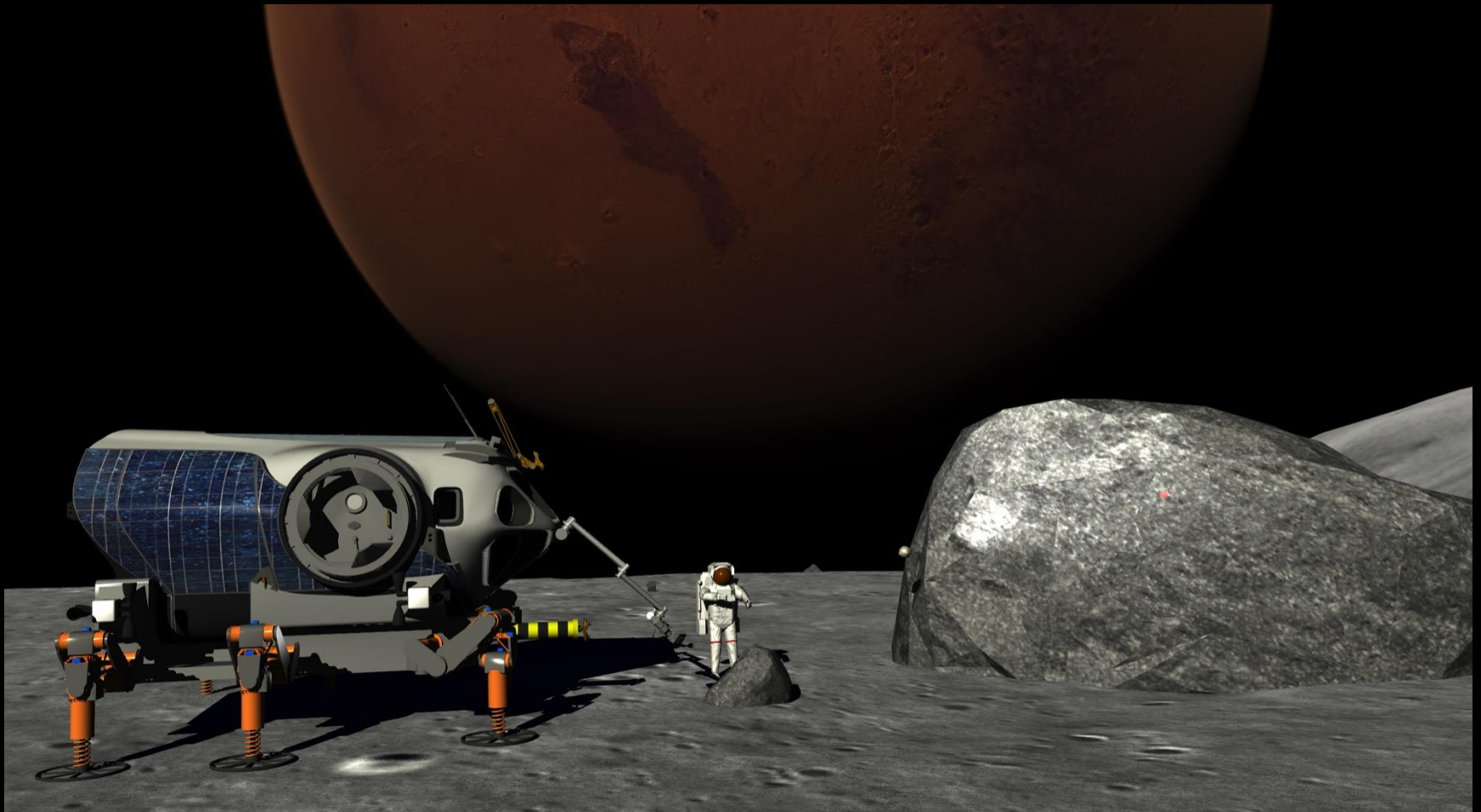
## *Systematic Scientific Exploration*





# Simulating Phobos Exploration

## *Complex Surface Operations*







# Wrapping Things Up



- NASA is considering human missions to Mars in the 2030s
- Phobos may be a stepping stone to Mars
- Advancements in Modeling and Simulation (M&S) are enabling new approaches to space systems development
  - Changing the balance between prototyping, testing, modeling and simulation
  - Providing meaningful insight into new destinations and conceptual exploration systems
  - Providing ways to investigate the integrated behavior of complex space systems early in the design process
- M&S is providing insight into the exploration of Phobos
  - Understanding the environment
  - Formulating new concepts of operation
  - Evaluating the potential for Phobos as a stepping stone to Mars

# Questions?

Image from the movie "The Martian"

