Mars: Conquest and Colonization

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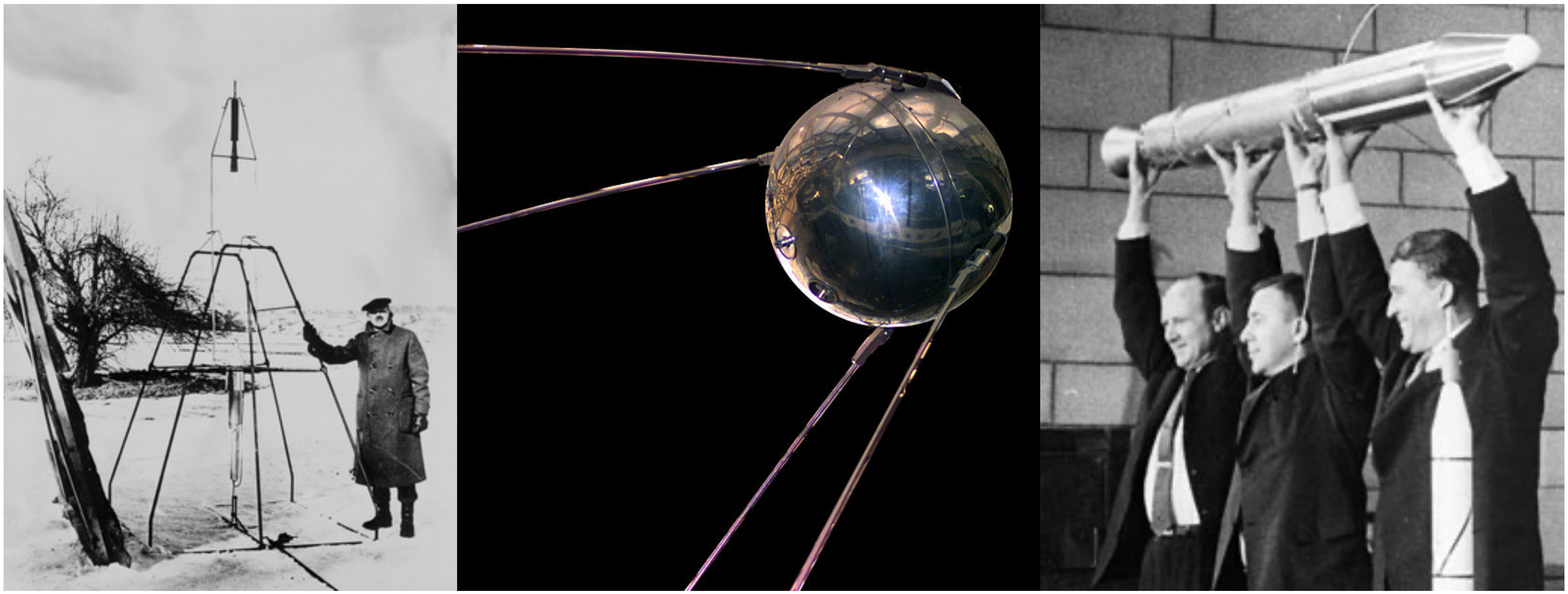
Beginnings of the Space Age *



* Reference: From page 2 of a presentation by JPLer Brian Muirhead entitled "*Take Risk Don't Fail* - Challenges and Power of Exploration from Space" on March 18, 2023.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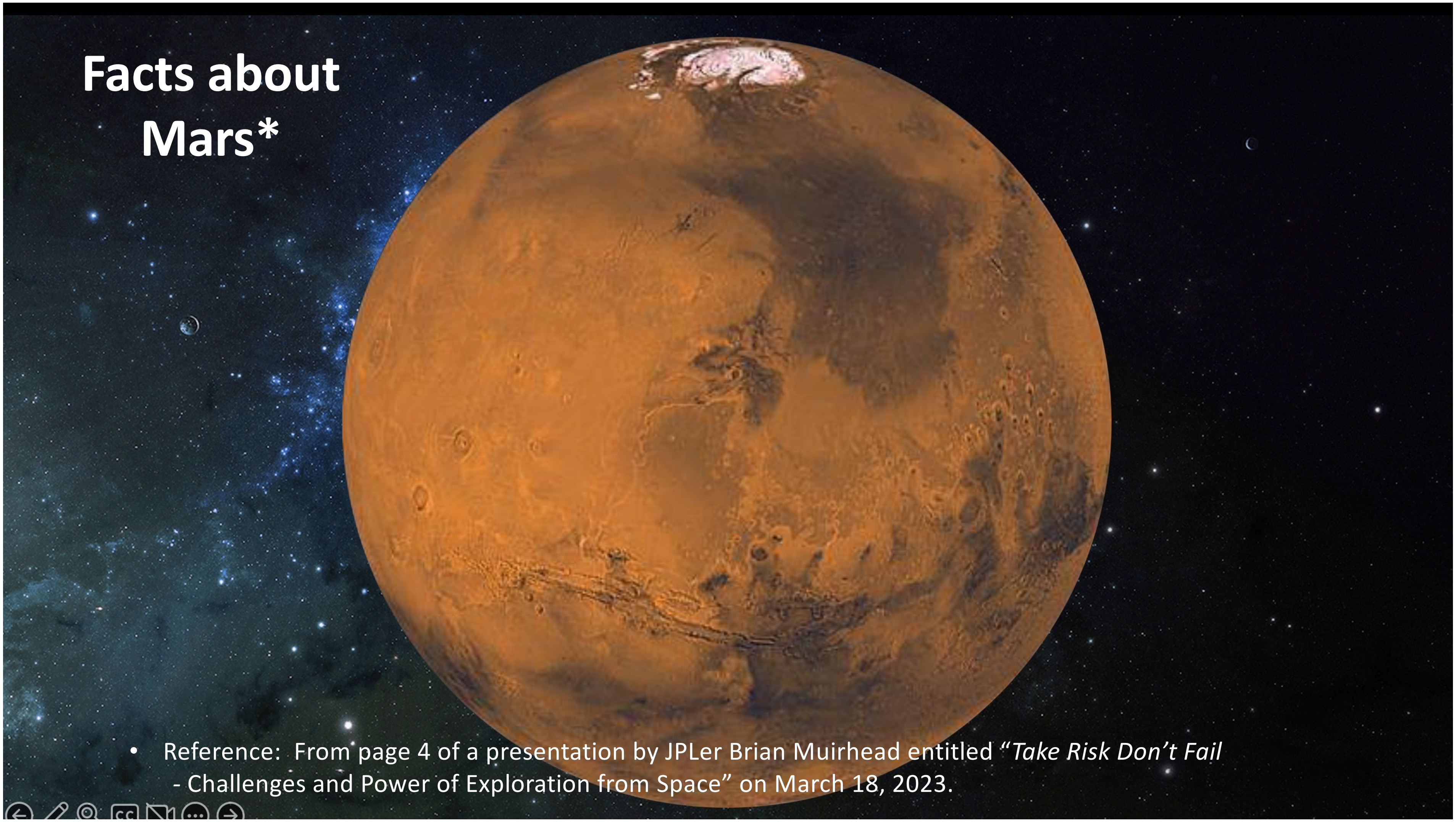
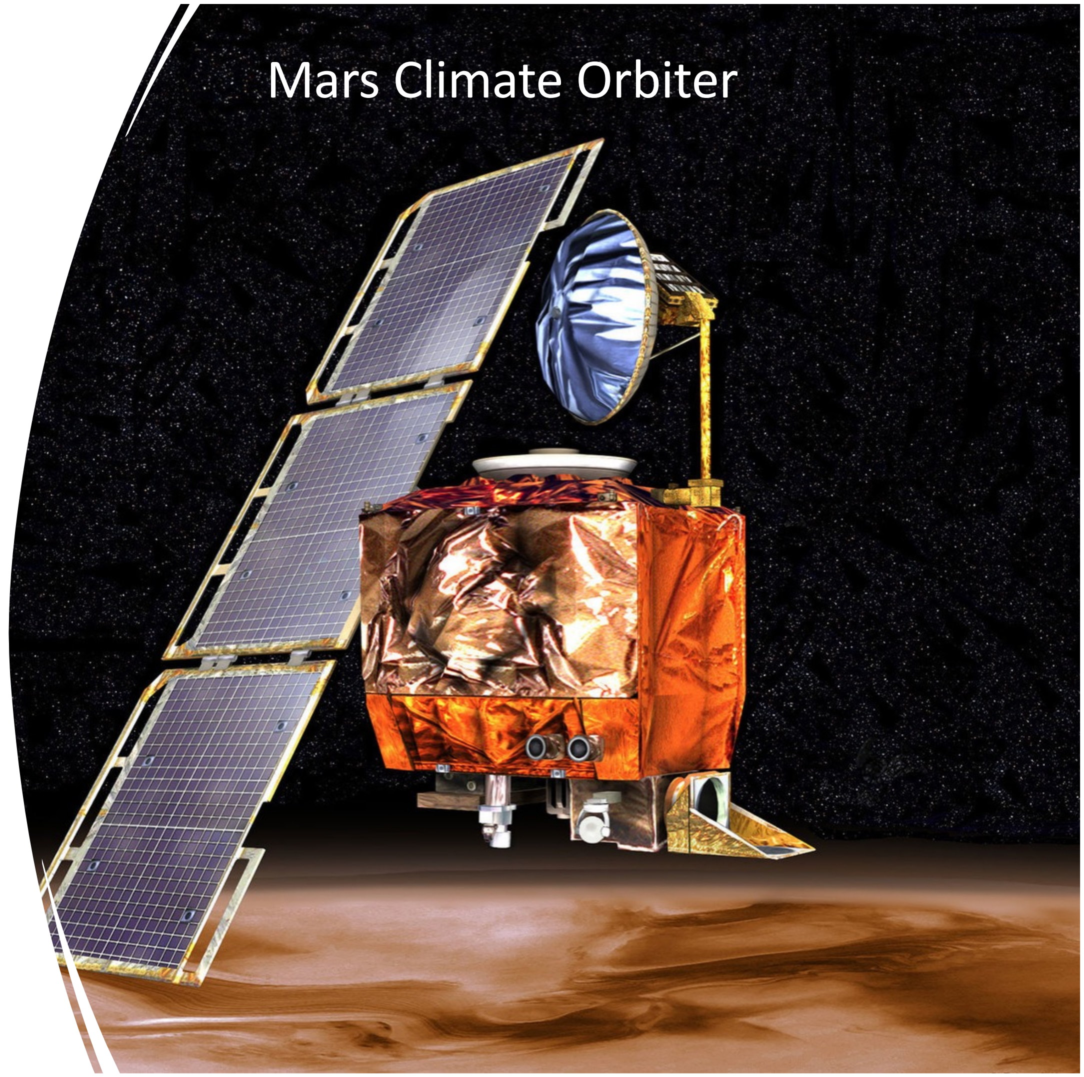

Facts about Mars*
• Reference: From page 4 of a presentation by JPLer Brian Muirhead entitled "*Take Risk Don't Fail* - Challenges and Power of Exploration from Space" on March 18, 2023.

Mars is hard !

- Engineering interplanetary journeys is complicated, and the exploration of Mars has experienced a high failure rate, especially the early attempts.
- Roughly sixty percent of all spacecraft destined for Mars failed before completing their missions and some failed before their observations could begin.



Mars Climate Orbiter Failure Lessons Learned -1

- Driving Event: The Mars Climate Orbiter (MCO) Mission objective was to orbit Mars as the first interplanetary weather satellite and provide a communications relay for the Mars Polar Lander (MPL) which was due to reach Mars in December 1999. The MCO was launched on December 11, 1998, and was lost sometime following the spacecraft's entry into Mars occultation during the Mars Orbit Insertion (MOI) maneuver. The spacecraft's carrier signal was last seen at approximately 09:04:52 UTC on Thursday, September 23, 1999.
- Lessons Learned: The MCO Mishap Investigation board (MIB) has determined that the root cause for the loss of the MCO spacecraft was the failure to use metric units in the coding of a ground software file, "Small Forces," used in trajectory models. Specifically, thruster performance data in English (British Imperial) units instead of metric units was used in the software application code titled SM_FORCES (small forces). A file called Angular Momentum Desaturation (AMD) contained the output data from the SM_FORCES software. The data in the AMD file was required to be in metric units per existing software interface documentation, and the trajectory modelers assumed the data was provided in metric units per the requirements.

Mars Climate Orbiter Failure Lessons Learned - 2

- The root cause of the Mars Climate Orbiter (MCO) mission failure was identified as cumulative navigation errors.
- These errors resulted, in part, from operational procedures and software that were inadequately reviewed, evaluated, and implemented.
- A high degree of formality, anomaly follow-up and close out, selection of reviewers and penetration of technical issues is essential in the review process, including the design, operational, and peer reviews.

Overview of NASA's Project Management Process

- NASAs project management approach is based on ***life cycles***, ***Key Decision Points (KDPs),*** and evolving *programmatic products* during each life-cycle phase in NASA's process for managing projects, which is:
- **Formulation**—following approval to begin formulation by the **Decision Authority** (NASA AA or MDAA) depending on the complexity of the project) at **KDP-A** projects then begin:
  - **Phase A**: Concept & Technology Development Phase. At the completion of KDP-B the project then begins:
  - **Phase B**: Preliminary Design & Technology Completion Phase
- **Approval (for Implementation)—**acknowledgment by the **Decision Authority** (NASA AA or MDAA depending on the complexity of the project) that the project has met Formulation requirements at **KDP-C** and is ready to proceed to Implementation. By approving a project, the **Decision Authority** commits to the time-phased cost plan based on technical scope and schedule necessary to continue into Implementation.
- **Implementation**—execution of approved plans for the development and operation of the project and use of control systems to ensure performance to approved plans and requirements and continued alignment with the Agency's strategic goals. During implementation the project begin:
  - **Phase C:** Final Design & Fabrication. At completion of KDP-D the project then begins:
  - **Phase D:** System Assembly, Integration & Test, Launch & Checkout. Following **KDP-E** during this effort,
  - **Phase E** begins for a project with operations & sustainment. Following **KDP-F** the project begins:
  - **Phase F** or Closeout.
- **Evaluation**—continual self and independent assessment of the performance of a program or project and incorporation of the assessment findings to ensure adequacy of planning and execution according to approved plans and requirements.

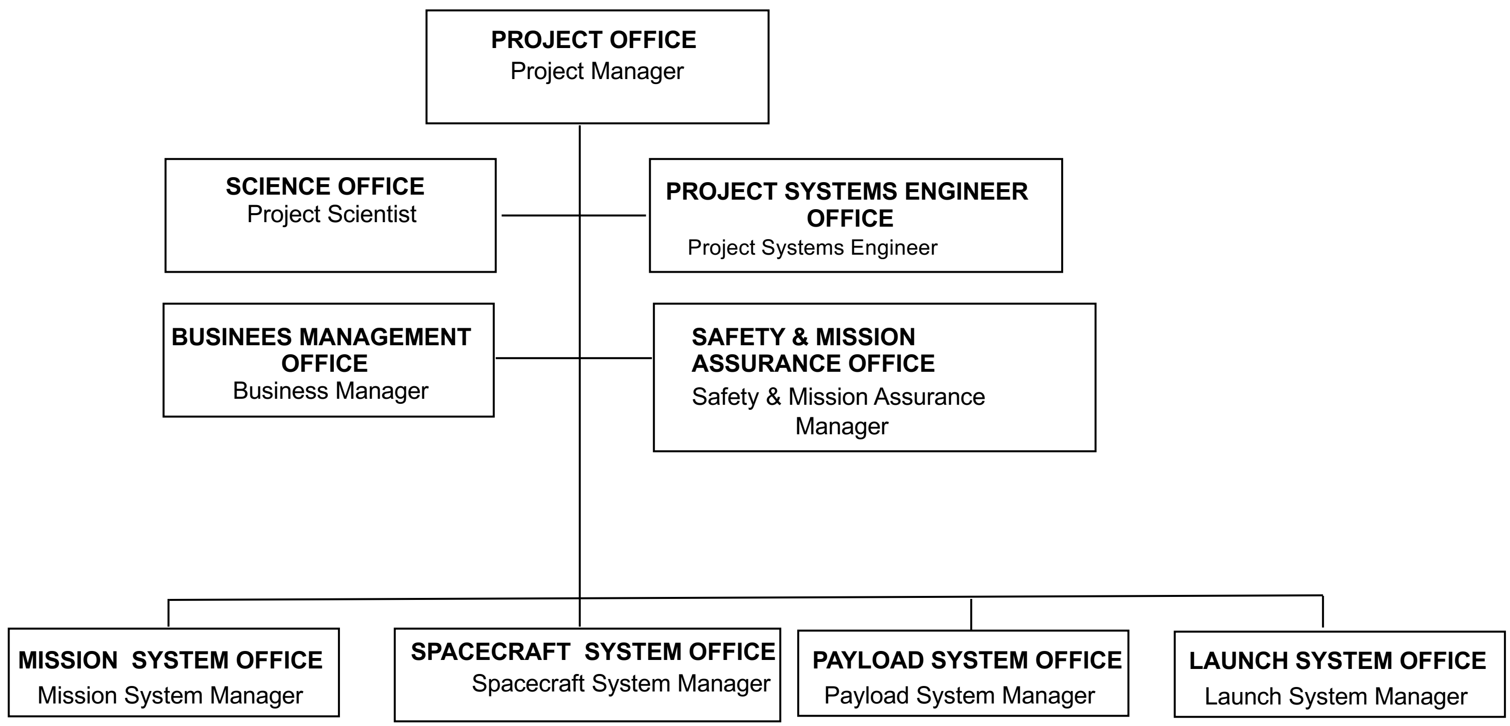
Formulation Key Tasks Prior to Approval (for implementation)

- Identifying how the program or project supports the Agency's strategic goals
- Assessing feasibility, technology, and concepts
- **Performing trade studies; assessing and possibly mitigating risks**
- Maturing technologies
- **Building teams**
- **Establishing high-level requirements**
- **Requirements flow down, and success criteria**
- **Developing system-level preliminary designs**
- Developing operations concepts and acquisition strategies
- Assessing the relevant industrial base/supply chain to ensure program or project success
- **Preparing plans, cost estimates, budget submissions, and schedules essential to the success of a program or project**; and
- Establishing control systems to ensure performance of those plans and alignment with current Agency strategies.

Building Teams – Key Roles for a Space Mission Project

- **Project Manager** is responsible for the formulation and implementation of the project. This includes responsibility and accountability for the project safety; technical integrity; technical, cost, and schedule performance; and mission success.
- **Project Systems Engineer (PSE)** is responsible for making sure that all of the Systems in a space mission work together so that the space mission meets its objectives.
- **Safety & Mission Assurance Manager** provides independent oversight and support throughout for NASA to ensure the safety of our workforce and facility in the design, development, evaluation, and performance of hazardous operations.
- A **System Manager** on NASA space projects involves overseeing and coordinating the development, integration, and operation of a complex system within space missions. This role is critical to ensure that various components and subsystems of a spacecraft, ground, mission operations, etc. work together harmoniously to achieve the mission's objectives.

Typical Space Mission Organization



PSEs and Technology Readiness Level (TRL)

TRL 9
- Actual system "flight proven" through successful mission operations

TRL 8
- Actual system completed and "flight qualified" through test and demonstration (ground or space)

TRL 7
- System prototype demonstration in a space environment

TRL 6
- System/subsystem model or prototype demonstration in a relevant environment (ground or space)

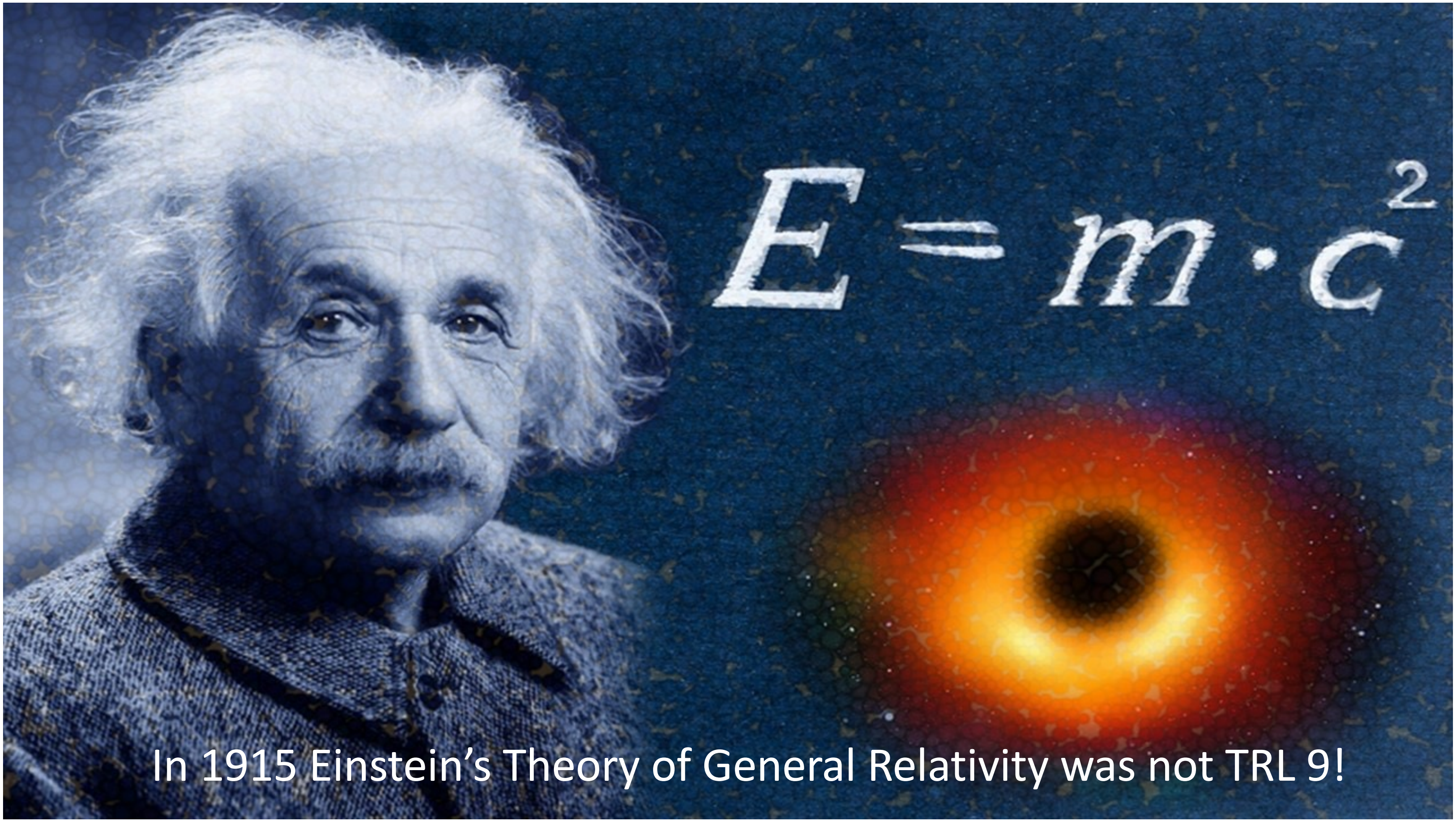
TRL 5
- Component and/or breadboard validation in relevant environment

TRL 4
- Component and/or breadboard validation in laboratory environment

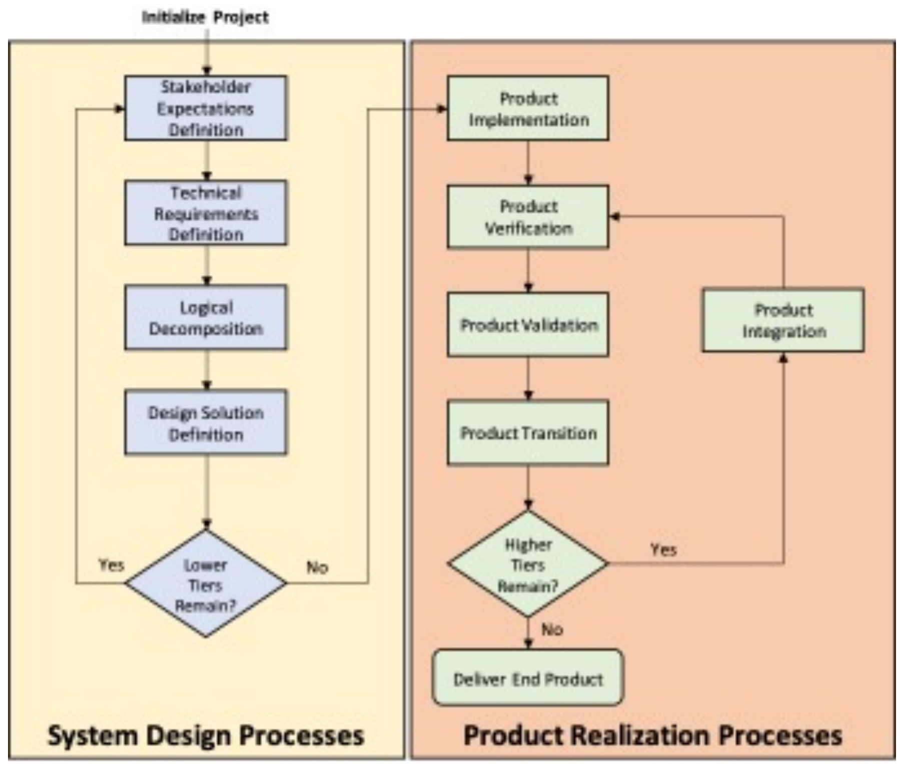
TRL 3
- Analytical and experimental critical function and/or characteristic proof-of-concept

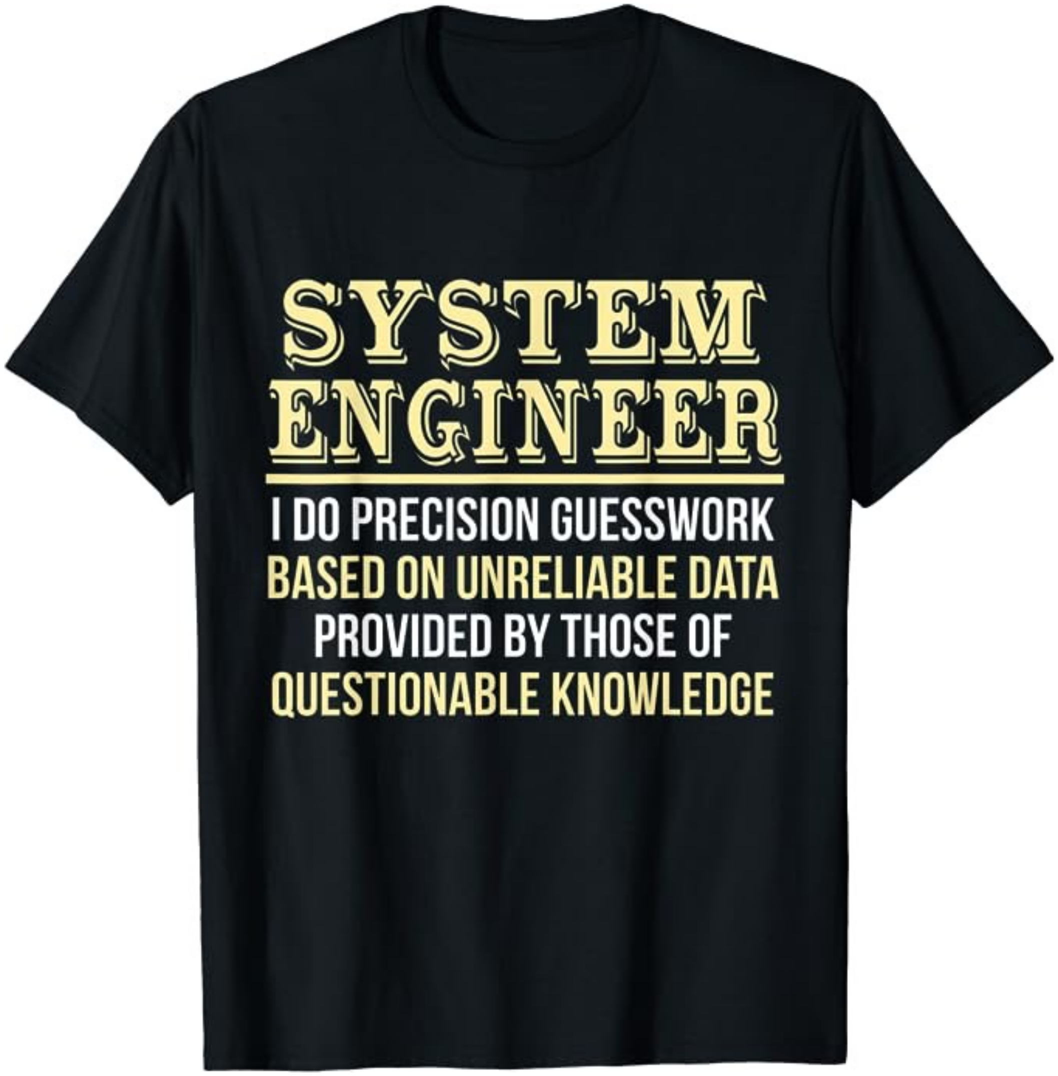
TRL 2
- Technology concept and/or application formulated

TRL 1
- Basic principles observed and reported


$E = m \cdot c^2$
In 1915 Einstein's Theory of General Relativity was not TRL 9!

Developing System-Level Preliminary Designs[4]

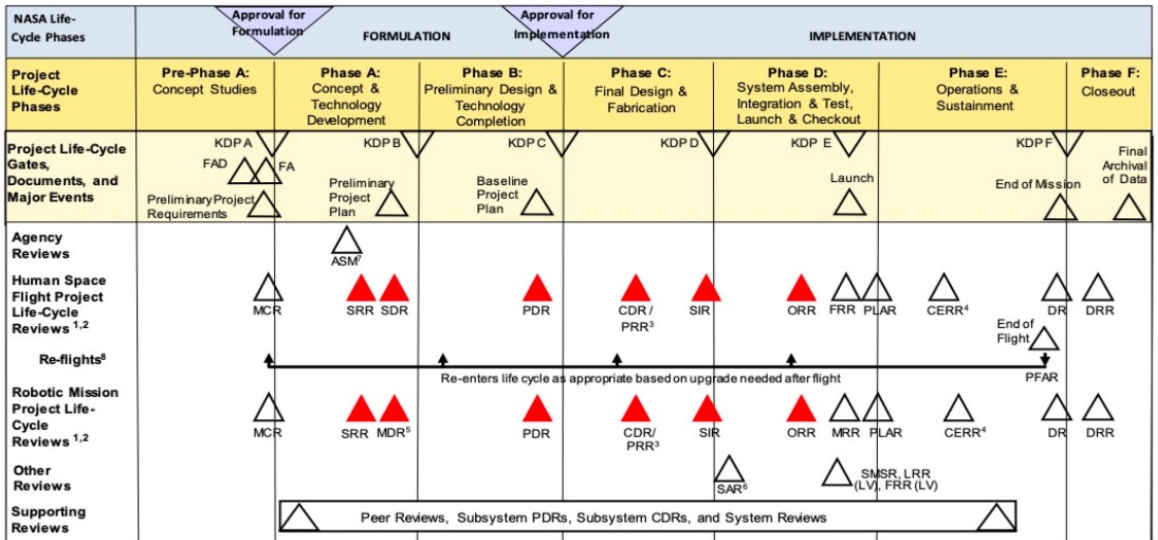



SYSTEM
ENGINEER
I DO PRECISION GUESSWORK
BASED ON UNRELIABLE DATA
PROVIDED BY THOSE OF
QUESTIONABLE KNOWLEDGE


ACCESS
RISK
CONTROL
RISK
REVIEW
CONTROLS
IDENTITY
RISK
RISK
MANAGEMENT
PROCESS

Could this risk have been prevented?

NASA Project Life Cycle



FOOTNOTES

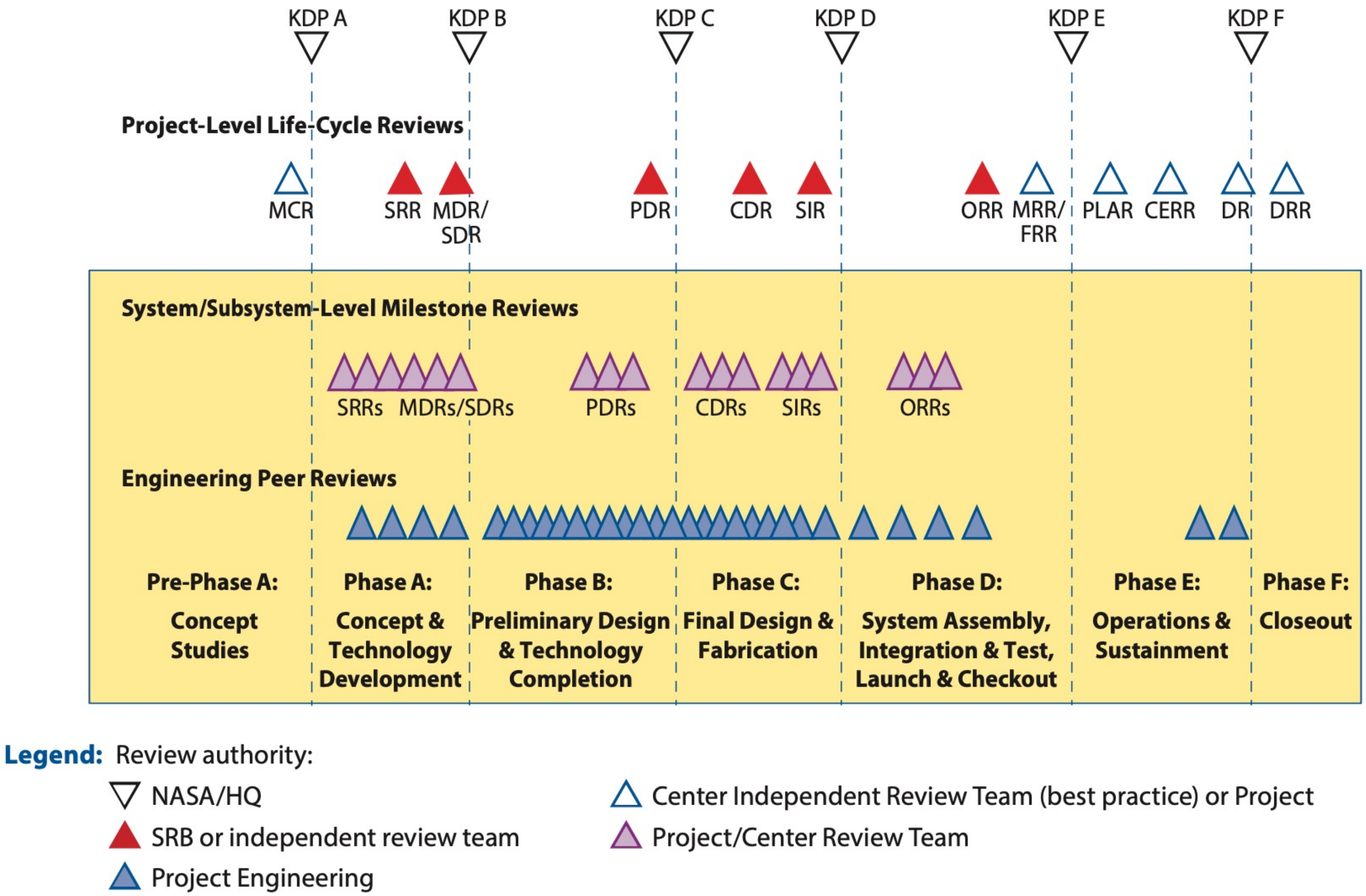
1. Flexibility is allowed as to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan.
2. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Table 2-5.
3. PRR is needed only when there are multiple copies of systems. It does not require an SRB. Timing is notional.
4. CERRs are established at the discretion of Program Offices.
5. For robotic missions, the SRR and the MDR may be combined.
6. SAR generally applies to human space flight.
7. Timing of the ASM is determined by the MDAA or AA, as compliant with NPD 1000.5 and may take place at any time during Phase A.
8. Placement of arrows is notional. See Section 2.2.4.3 for more guidance on reflights.

ACRONYMS

ASM - Acquisition Strategy Meeting
CDR - Critical Design Review
CERR - Critical Events Readiness Review
DR - Decommissioning Review
DRR - Disposal Readiness Review
FA - Formulation Agreement
FAD - Formulation Authorization Document
FRR - Flight Readiness Review
KDP - Key Decision Point
LRR - Launch Readiness Review
LV - Launch Vehicle
MCR – Mission Concept Review
MDR - Mission Definition Review
MRR - Mission Readiness Review
ORR - Operational Readiness Review
PDR - Preliminary Design Review
PFAR - Post-Flight Assessment Review
PLAR - Post-Launch Assessment Review
PRR - Production Readiness Review
SAR - System Acceptance Review
SDR - System Definition Review
SIR - System Integration Review
SMSR - Safety and Mission Success Review
SRB - Standing Review Board
SRR - System Requirements Review

▲ Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB to conduct other reviews.

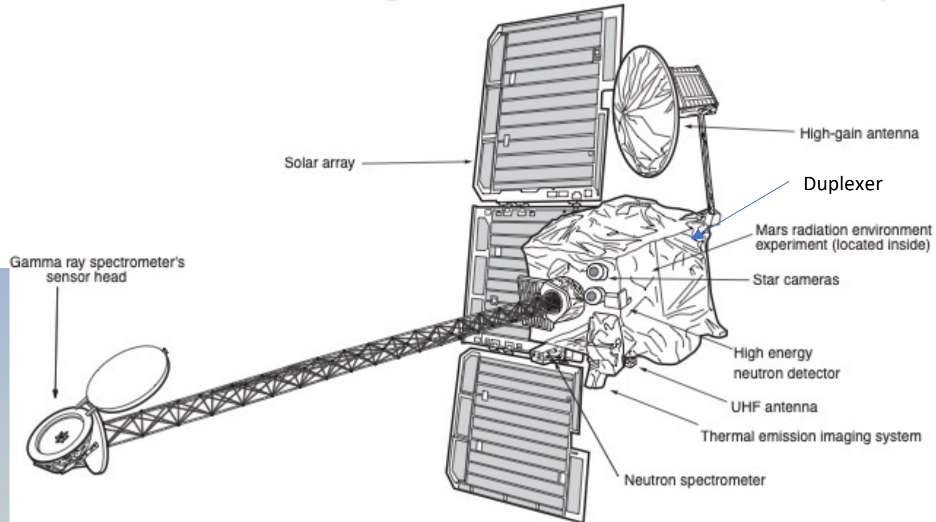
Work Led by the Project Throughout the Life Cycle



Background

- 2001 Mars Odyssey Project Manager from 2013 to 2021
  - First Detection of Frozen Water Beneath the Surface of Mars (May 28, 2002)*

Space Missions in a Nutshell Using the Schematic of Odyssey



2001 Mars Odyssey spacecraft

Reference* https://www.jpl.nasa.gov/timeline/

What is going on at Mars? NASA is operating 3 orbiters and 2 rovers plus 1 helicopter. ESA is operating 2 orbiters

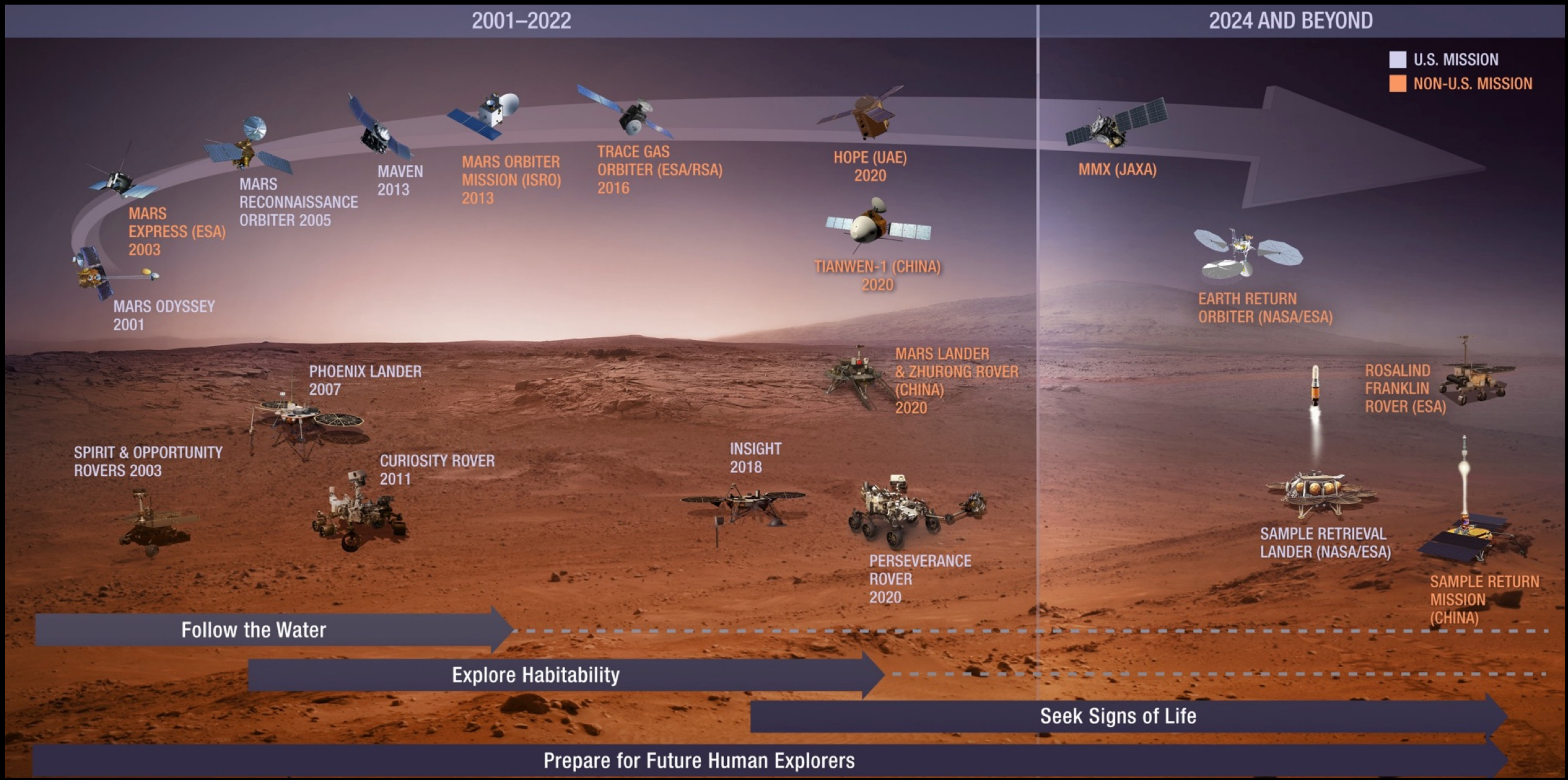
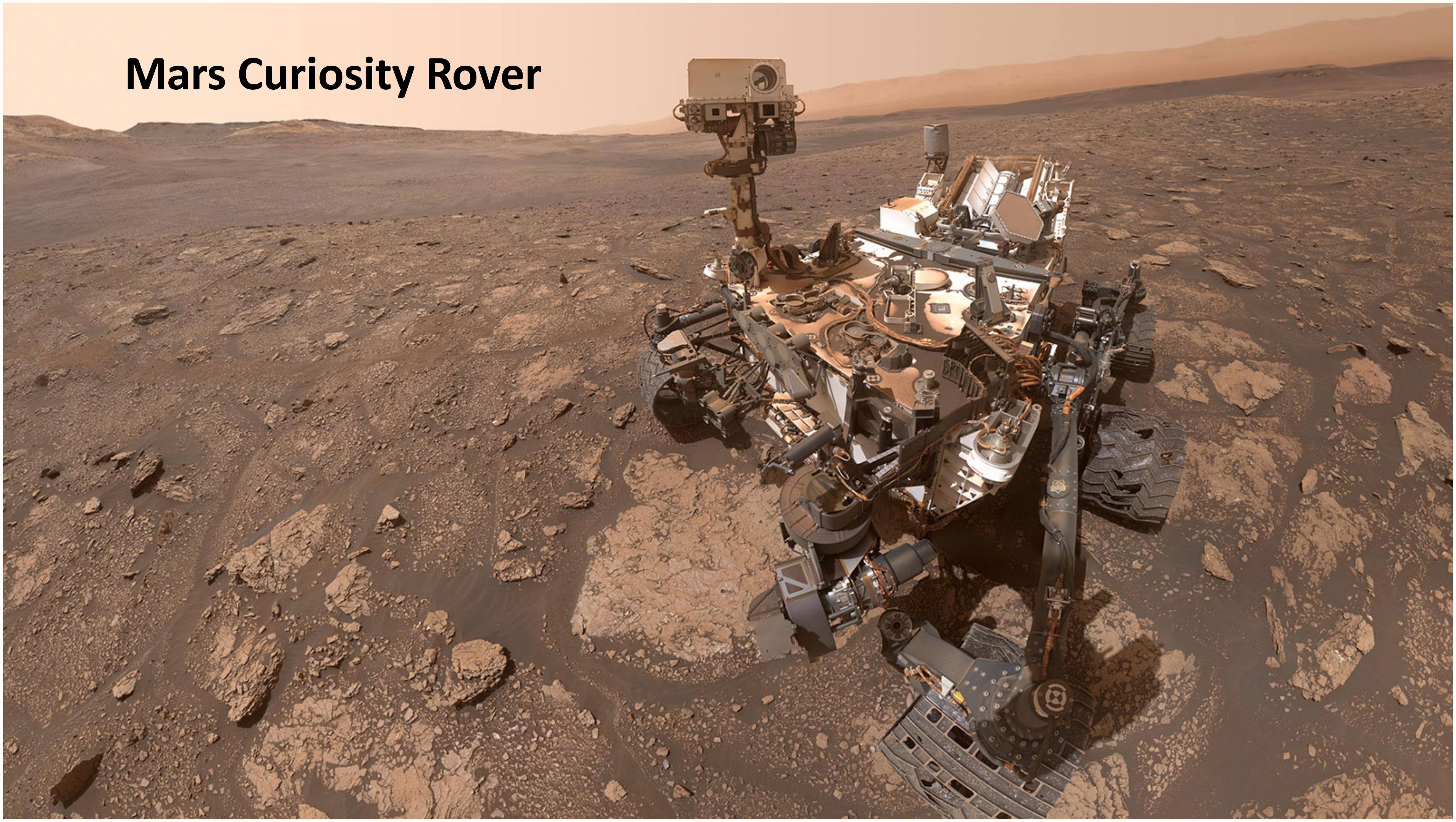
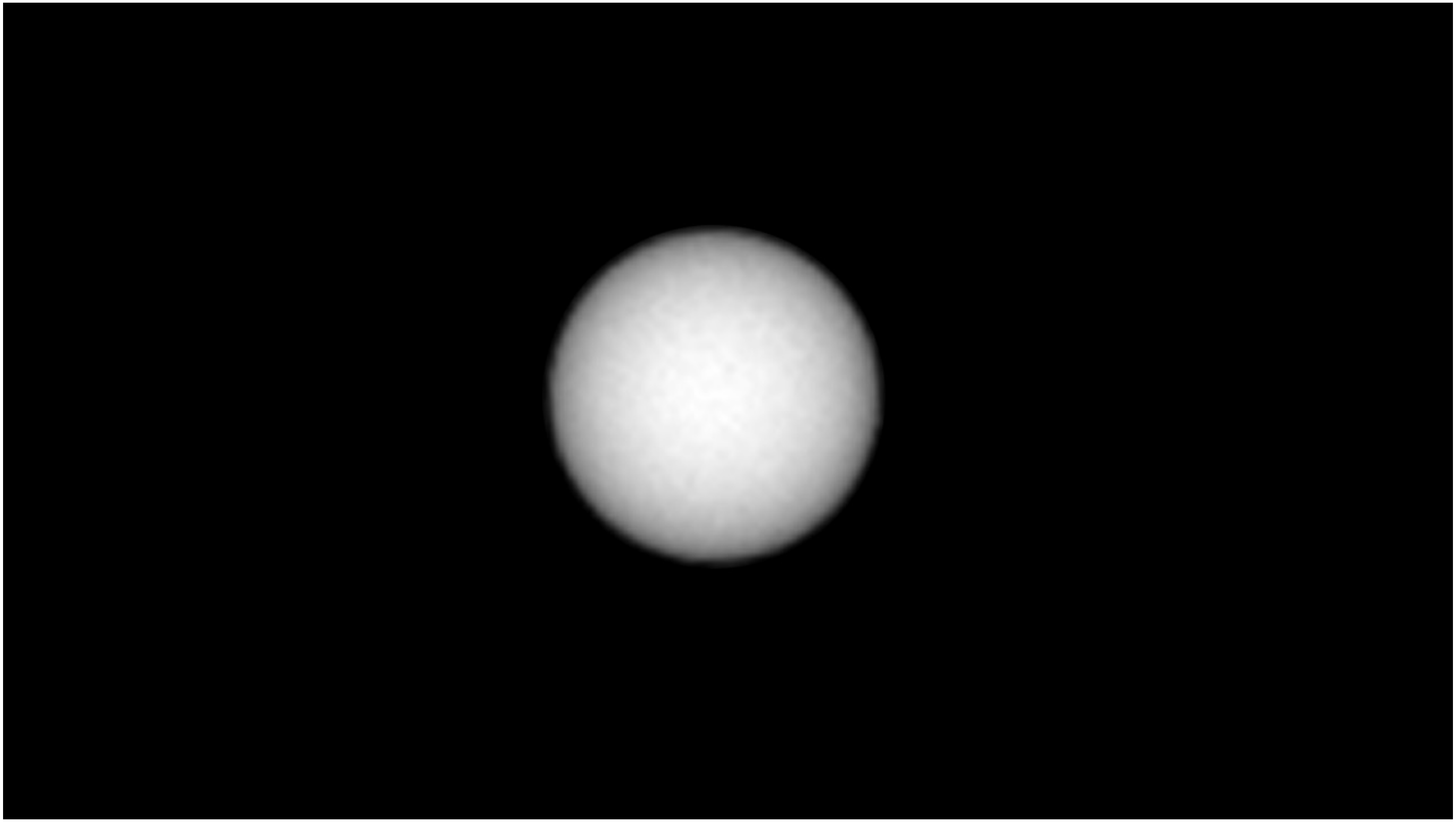


Chart is from A. Yingst at the Mars Exploration Program Analysis Group (MEPAG) meeting of Feb. 27, 2023

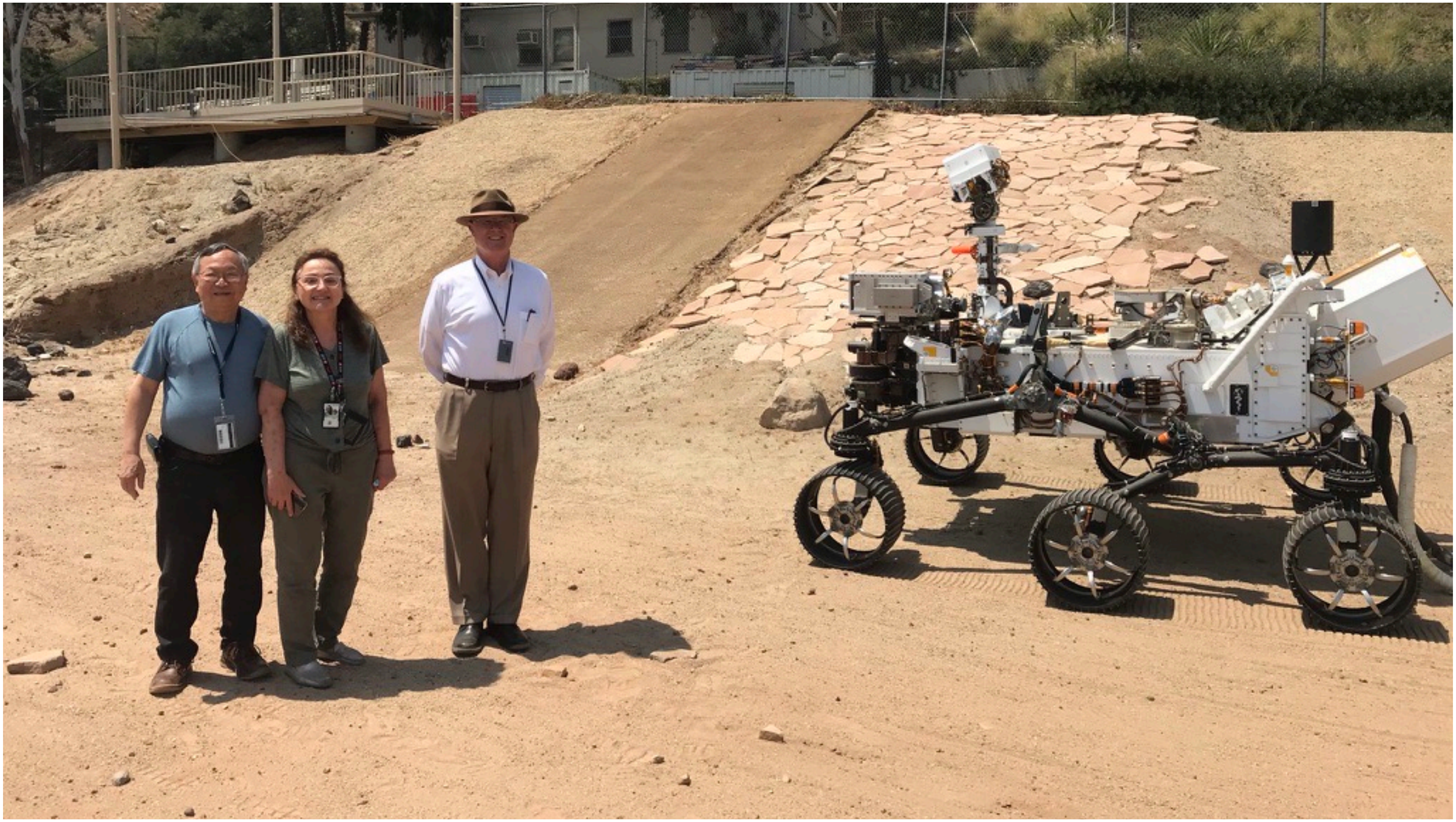

Mars Curiosity Rover

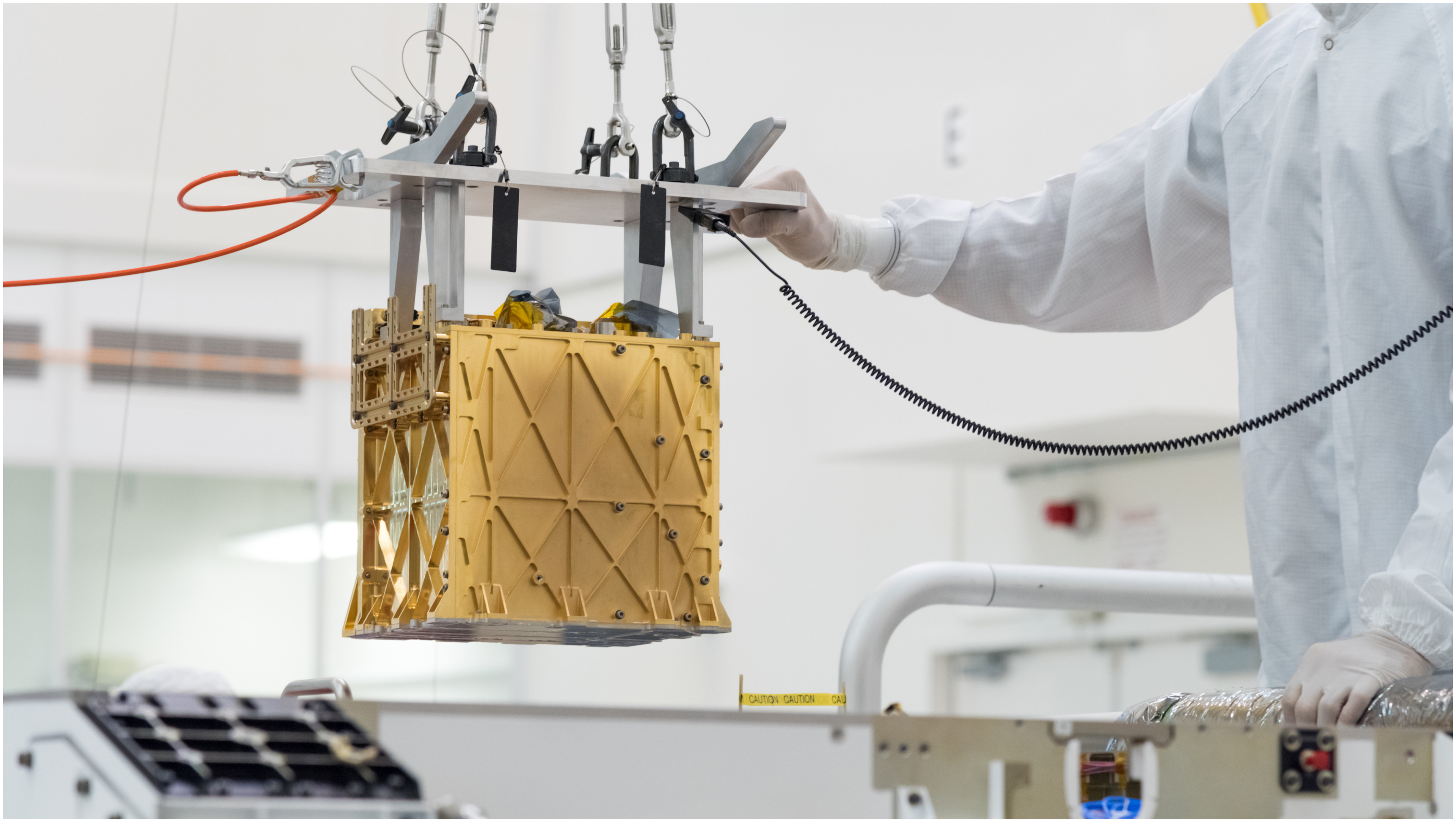
Wheel of Mars Curiosity rover after 10 years of operations



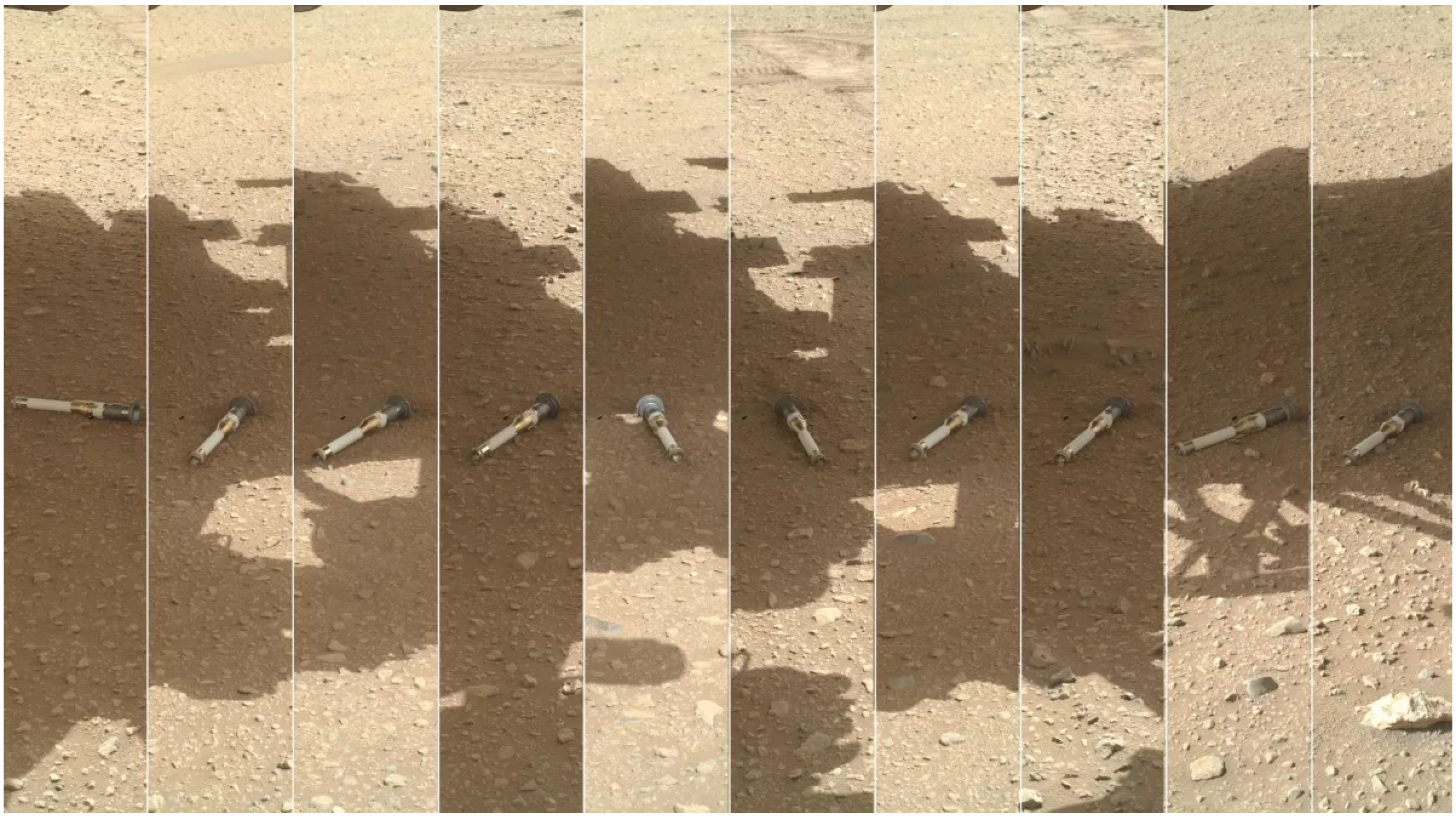

NASA’s Perseverance Mars rover
landed on Mars on February 18, 2021.
It took this selfie over a rock
nicknamed “Rochette,” on
September10, 2021

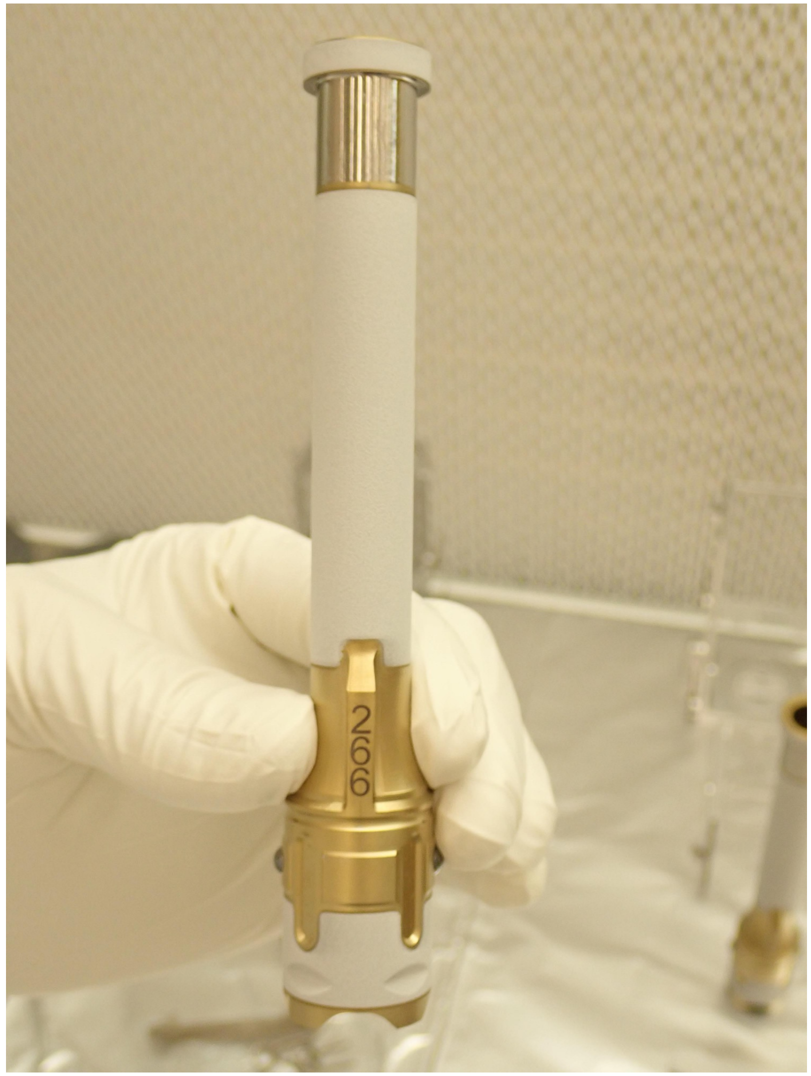
Perseverance's Sol 200 Auto-Nav Drive on September 12, 2021




CAUTION CAUTION

Caching Samples at Three Forks (10 samples)

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What’s Next for Mars?

ARTEMIS

With Artemis missions, NASA will:

- Collaborate with international and commercial partners to establish the first long-term presence on the Moon,
- Land the first woman and first person of color on the Moon, and
- Use what we learn on and around the Moon to take the next giant leap: sending the first astronauts to Mars.

Artist's depiction of a female astronaut on the surface of Mars. (Image credit: janiecbros/Getty Images)


Thank You.