National Aeronautics and Space Administration

NASA's Strategic Analysis Cycle 2021 (SAC21)
Human Mars Architecture

Michelle Rucker, NASA ESDMD Mars Architecture Team
2022 IEEE Aerospace Conference, Big Sky
March 7, 2022

2022 IEEE Aerospace Conference, Paper 8.0108
NASA's Strategic Analysis Cycle 2021 (SAC21) Human Mars Architecture

Michelle A. Rucker
NASA Johnson Space Center

Douglas A. Craig
NASA Headquarters

Laura M. Burke
NASA Glenn Research Center

Patrick R. Chai
NASA Langley Research Center

Michael B. Chappell
NASA Marshall Space Flight Center

Bret G. Drake
Aerospace Corporation

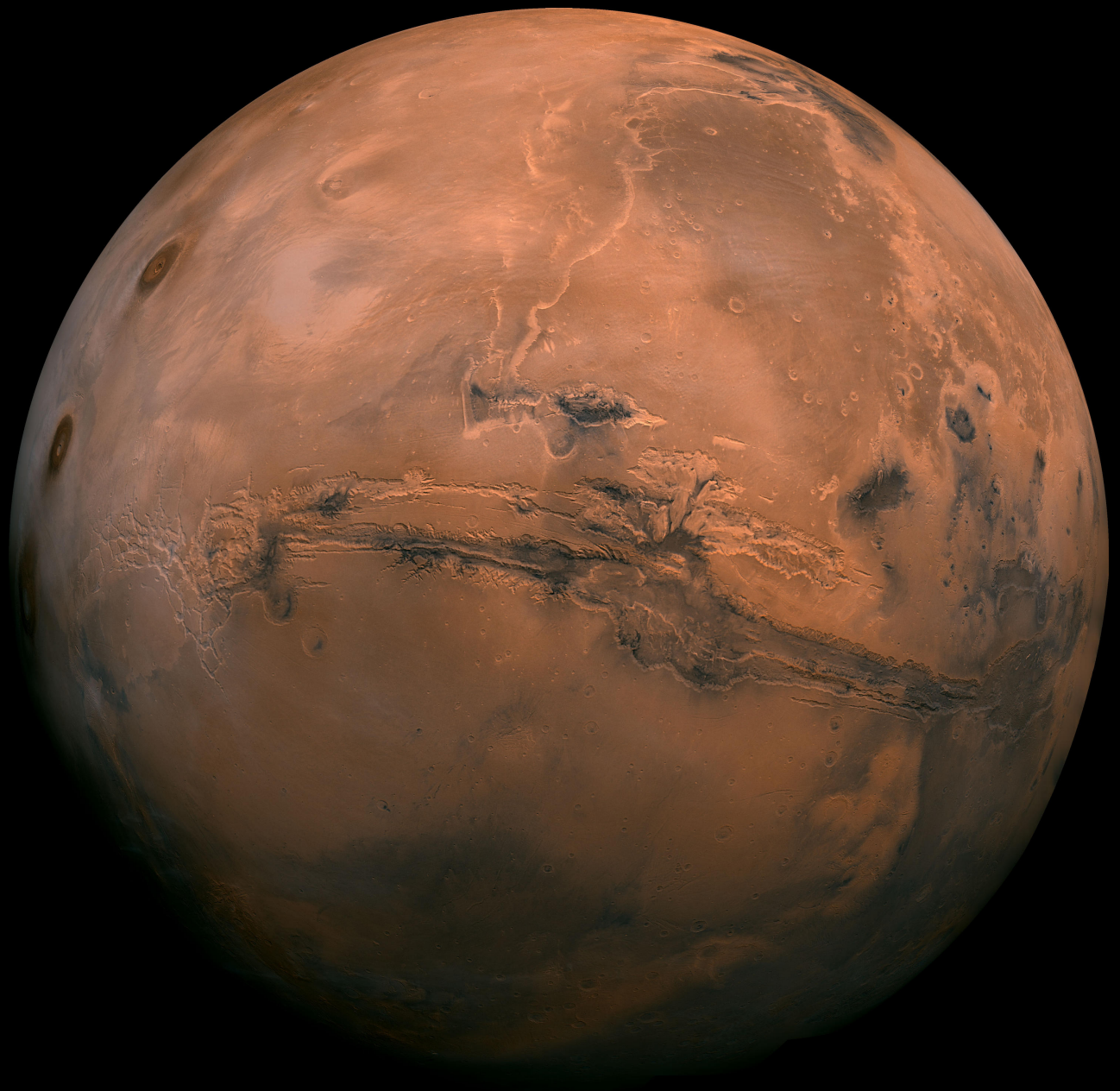
Stephen J. Edwards
NASA Marshall Space Flight Center

Stephen Hoffman
Aerospace Corporation

Andrew C. McCrea
NASA Langley Research Center

Douglas J. Trent
NASA Marshall Space Flight Center

Patrick A. Troutman
NASA Langley Research Center

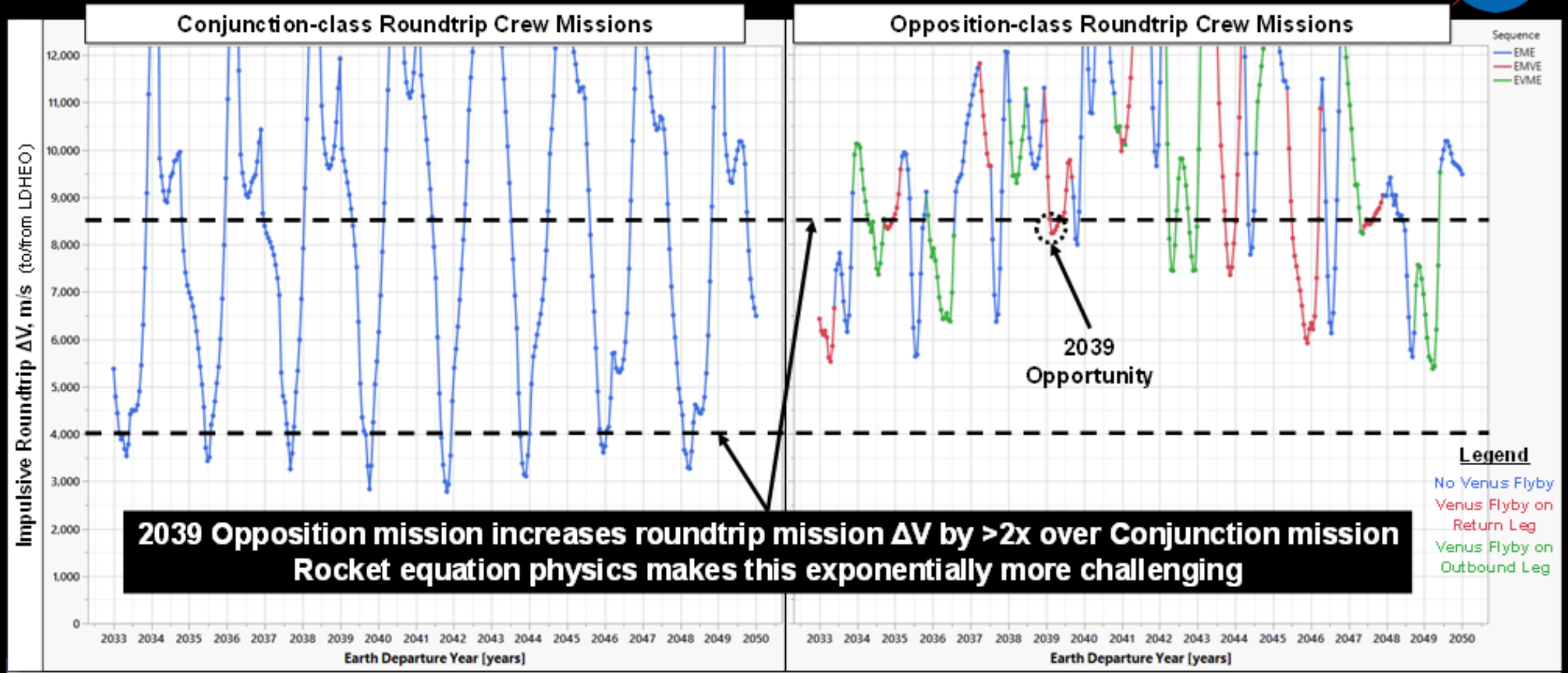


Mars poses three unique problems for Human Spaceflight

1. Distance
2. Time Away from Earth
3. Mars Entry, Descent, Landing – *and Ascent*

NASA's human Mars Architecture Team was challenged to further Explore #2

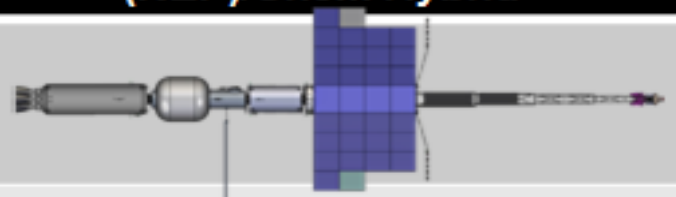
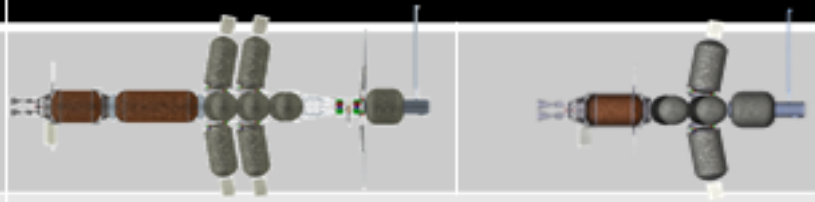
Challenge Accepted:
Explore Opposition Class Trade Space



Opposition-class missions are shorter duration—but require much more energy

High Energy Transits Require High Energy Transports

Two nuclear-enabled options were assessed

2039 Mission Opportunity Shown	Nuclear Electric Propulsion (NEP)/Chem Hybrid		Nuclear Thermal Propulsion (NTP)	
Vehicle Concept (not to scale)				
Primary Technologies	➢ Deployable modular radiators ➢ 100kWe Class Hall Thrusters ➢ Liquid Oxygen (LOX)/Liquid Methane (LCH_4) Chemical Propulsion ➢ Zero Boiloff LOX/LCH_4 Storage		➢ Nuclear Thermal Rockets 900s Isp, 25k lb_f thrust ➢ Zero Boiloff Liquid Hydrogen (LH_2) Storage	
Mission Characteristics	Variant 1	Variant 2	Variant 1	Variant 2
Total Time Away from Earth	870 days	960 days	800 days	960 days
Time in Deep Space	730 days	850 days	690 days	850 days
Time in Mars Vicinity	50 days	50 days	50 days	50 days
"All-Up" Crew Stack Mass Aggregated in High Earth Orbit	~600 t	~300t	~600t	~285t

Analysis goal was to explore 2 year (730 day) round-trip missions. Relaxing transit duration cuts stack masses in half, which translates to fewer Earth-launched vehicle fueling flights

SAC21 Reference First Human Mars Mission Concept

WHO

Current analysis includes 4 crew

2 remain in Mars orbit while 2 explore the Mars surface

WHAT

Nuclear Transportation

Landers and Surface Systems

Mars Ascent and Earth Return

WHERE

Cislunar, Deep Space and 5-sol Mars orbit

Mars Surface

WHEN

2039 opportunity analyzed

Crew away from Earth ~2.5 years

~30 sols on Mars

WHY

Science, Exploration, and U.S. leadership

HOW

1 *Pre-Deployed Cargo Phase*

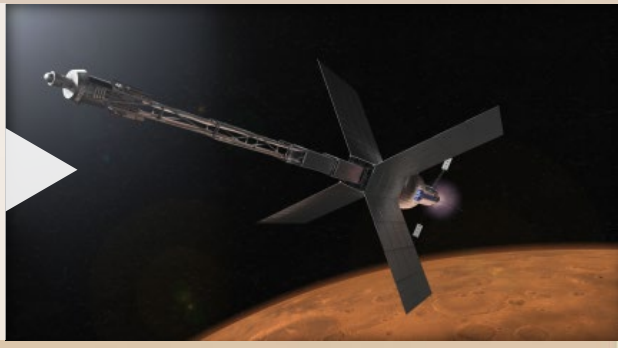
2 *Crewed Surface Exploration Phase*
"Light" Exploration Footprint

SAC21 First Mars Reference Mission

Reference architecture for *analysis purposes only.* Should not be considered “the plan”

TRANSIT HABITAT (TH) AND HYBRID NUCLEAR ELECTRIC PROPULSION (NEP) / CHEMICAL STAGE

- Supports four crew on the long mission to Mars
- Two crew remain in orbit while two crew visit the Mars surface



1 PRE-DEPLOYED CARGO

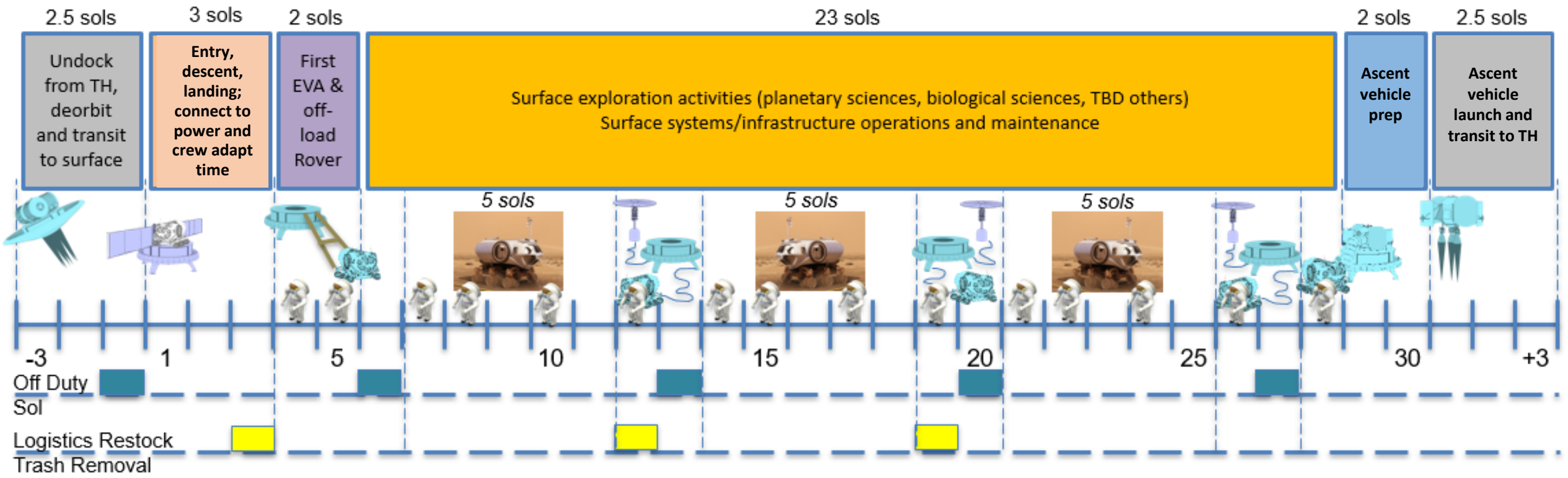
- 25-ton class payload Mars lander
- Ascent vehicle propellant, Fission Surface Power, and surface mobility/propellant transfer system

2 PRE-DEPLOYED CREW ASCENT VEHICLE

- Partially-fueled

3 CREW

- Two crew land/live in pressurized rover
- Provides habitation and mobility for 30 days
- Supports science and exploration operations



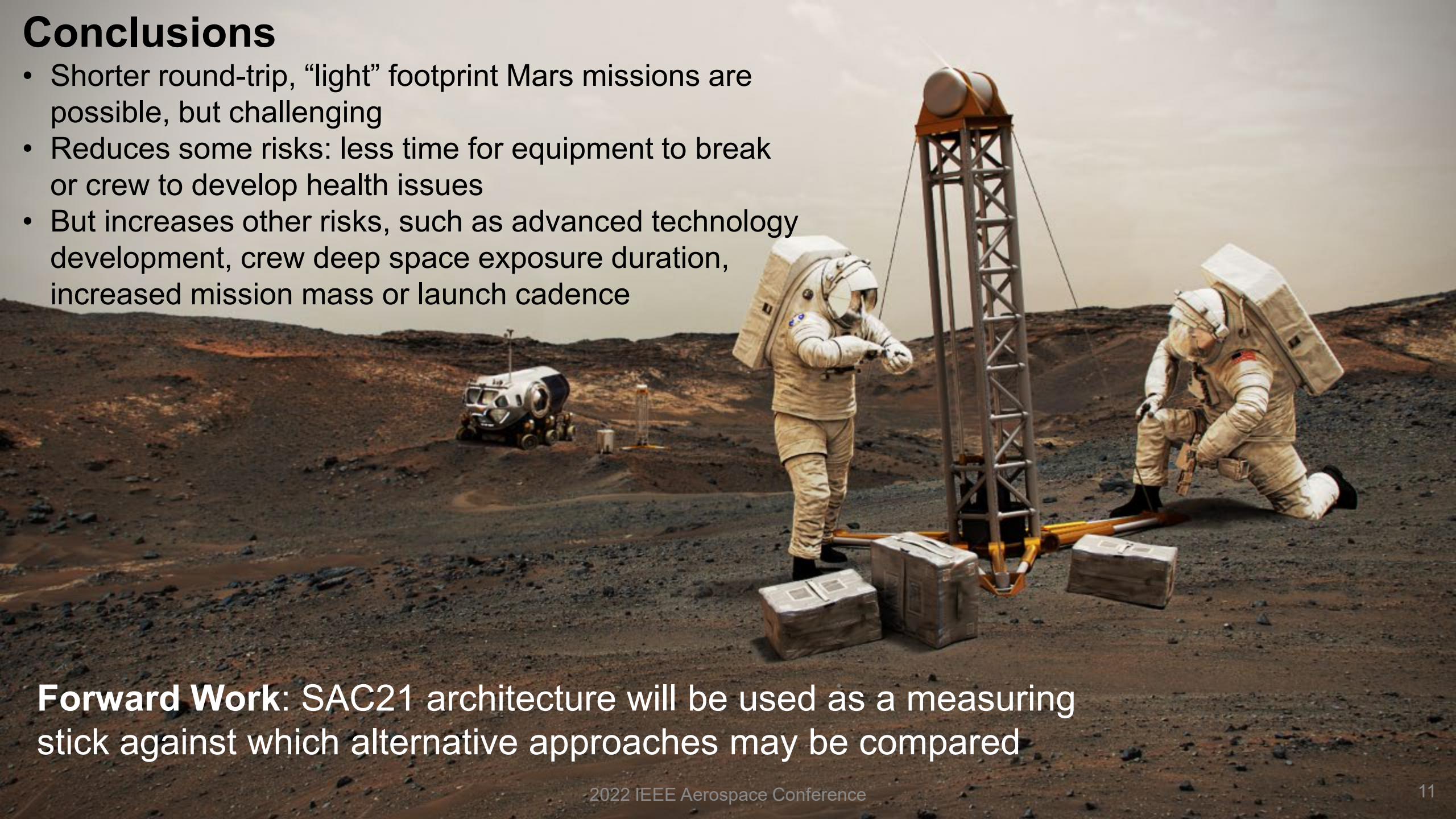
This short-stay mission reference timeline was developed to anchor surface operations analysis, in particular to understand how much time would be available for science and exploration after partitioning out anticipated crew and equipment care allocations. Again, this timeline should not be misconstrued as “the plan.”

Key Technical Risks Identified

Transit propulsion system failures; transit habitat mass growth and integration with propulsion element; loss of habitable environment on Mars; ascent vehicle refueling on the martian surface; advanced EVA; entry, descent and landing criticality; and long-duration spaceflight crew health and performance

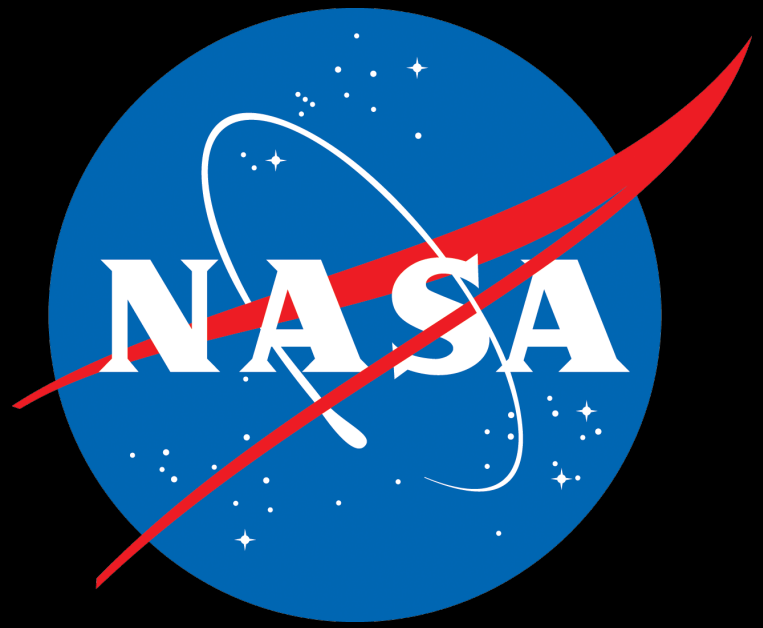
Conclusions

- Shorter round-trip, “light” footprint Mars missions are possible, but challenging
- Reduces some risks: less time for equipment to break or crew to develop health issues
- But increases other risks, such as advanced technology development, crew deep space exposure duration, increased mission mass or launch cadence



Forward Work: SAC21 architecture will be used as a measuring stick against which alternative approaches may be compared


Questions?


NASA