Mars Exploration Program
- A Pathway to Future Missions –

Presented at the 1st Human Landing Site Workshop

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#JOURNEYTOMARS

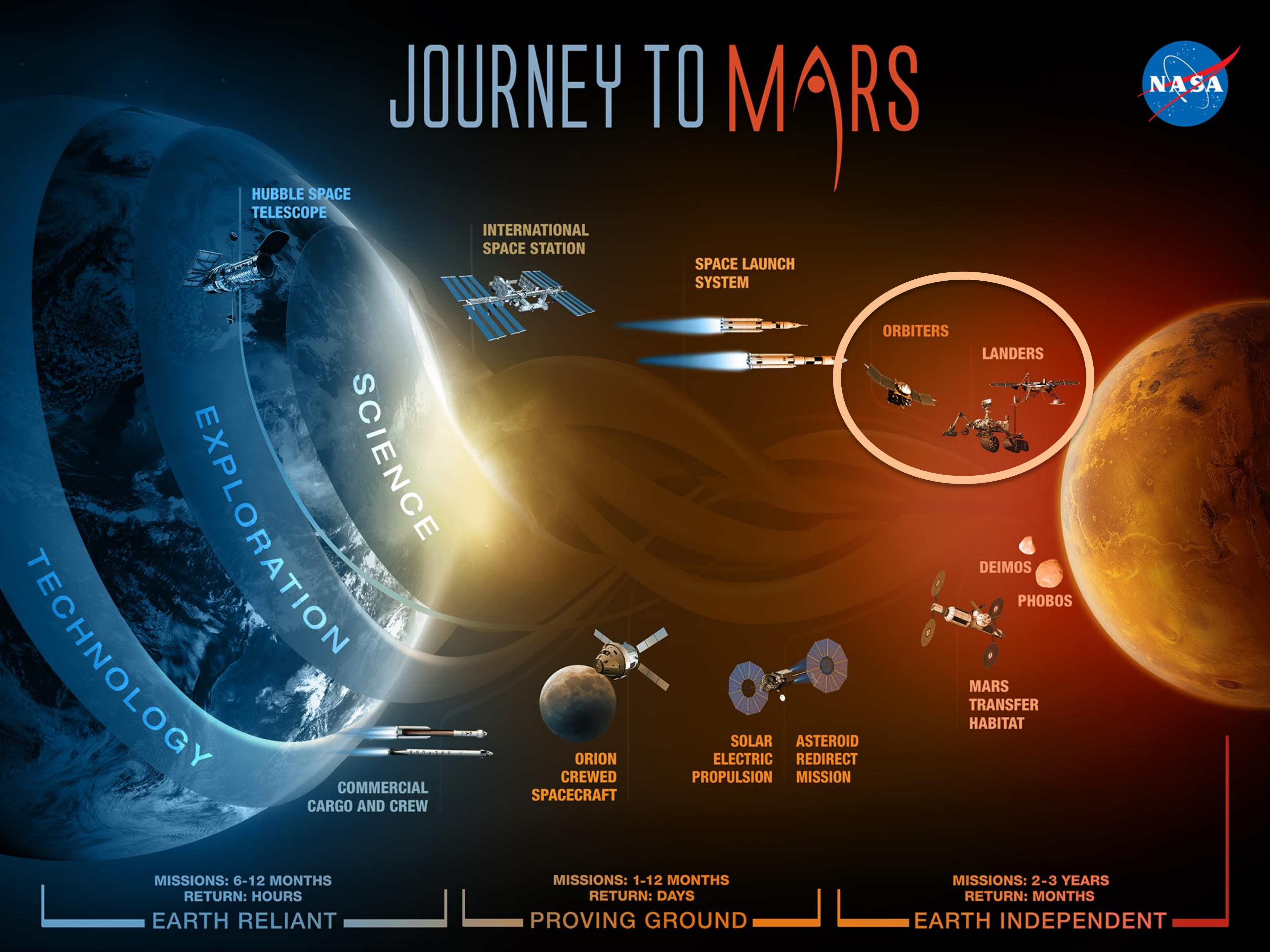
Mars – a Frontier Opened by Science Precursors

- Mars Exploration Program (MEP) continues to produce remarkable science and generate public interest in exploring Mars

- Planning for the future is a pressing priority, as the 2022 launch opportunity is only 5 years from the current budget planning horizon

- Collaboration on Science/Exploration synergies is an opportunity to excel in the 2020s

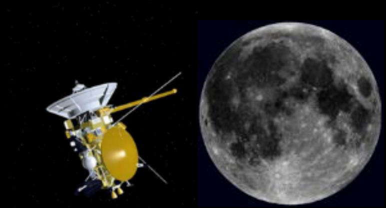
"Panorama compliments of the Curiosity rover"
9 Sept 2015



JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSFER HABITAT
ORION CREWED SPACECRAFT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

What We’ve Learned and Still Need to Learn at Mars

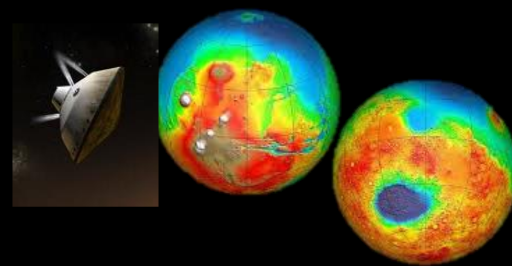
Orbital environment and operations



Learned:
- Deep space navigation
- Orbit transfer near low-gravity bodies
- Gravity assist
- Aero-braking
- Gravitational potential
- Mars’ moons characteristics
- ISRU potential

To Learn:
- Return flight from Mars to Earth
- Autonomous Rendezvous & Docking
- ISRU feasibility
- Resource characterization of Mars moons
- High-power SEP

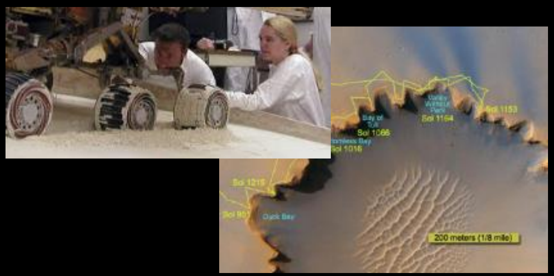
Capture, EDL & Ascent at Mars



Learned:
- Spatial/temporal temperature variability
- Density and composition variability
- Storm structure, duration and intensity
- 1 mT Payload
- ~10 km Accuracy

To Learn:
- Ascent from Mars
- Large mass EDL
- Precision EDL
- Aero-capture
- Site topography and roughness
- Long-term atmospheric variability

Surface Operations at Mars

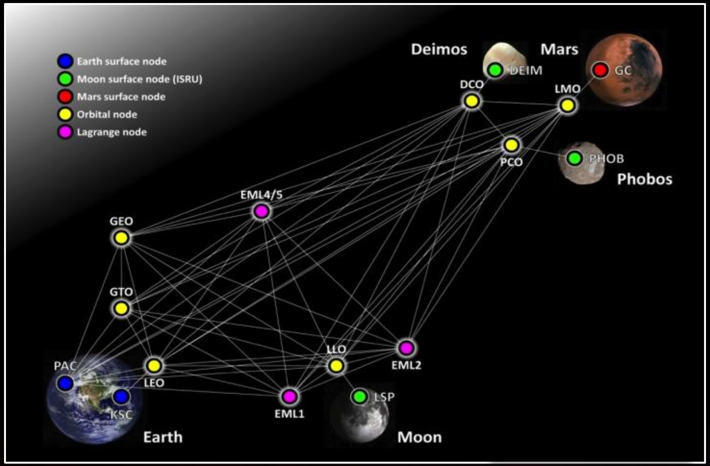


Learned:
- Global topography: elevation and boulder distributions
- Remnant magnetic field
- Dust impacts on Solar Power / Mechanisms
- Radiation dose
- Global resource distribution
- Relay strategies, operations cadence

To Learn:
- Landing site resource survey
- Dust effects on human health, suits & seals
- Rad/ECLSS in Mars in environment
- Power sufficient for ISRU
- Surface Navigation

Strong Science and Exploration synergies motivate future Precursor collaboration

Resilient Architectures for Mars Exploration

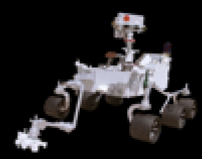
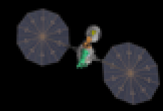


Graphic used courtesy of de Weck et al

- There are many different architectures and implementation approaches that can be employed on the Journey to Mars
  - The first step of each architecture is the same – develop/validate common required capabilities
- NASA is studying precursor mission concepts for the 2020s to reduce the risk for these architectures and acquire relevant operational experience for the Journey to Mars

#JOURNEYTOMARS

Conceptual Integrated Campaign for Mars Precursors "in the 2020's"

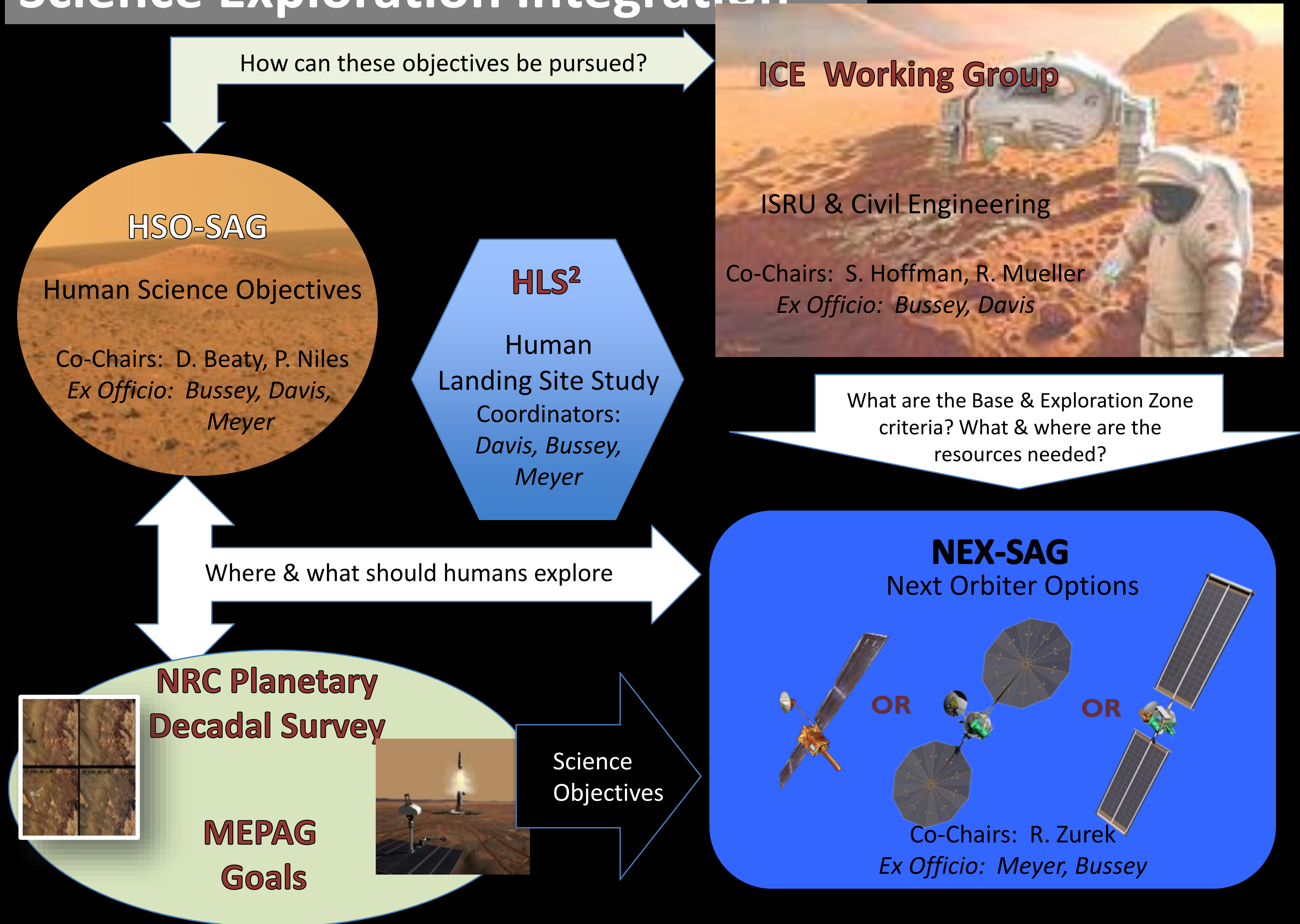
Mars 2020	Mars Orbiter 2022	Round-Trip Surface to Surface	Exploration Precursors
			
ISRU Prototype	Resource Survey	Dust Toxicity	ISRU Production
EDL Instruments	Landing Site Selection	EDL Evolution/ Instruments	Surface Power for ISRU
Sample Acquisition	Optical Comm/Relay	Mars Ascent	Rad/ECLSS Validation
In Situ Science	SEP	Surface Navigation	Increased EDL Mass & Precision
Habitable Conditions	Rendezvous	Returned Sample Analysis	Science Instruments
Ancient Life	Remote Sensing Instruments		

LEGEND

- Exploration
- Cross-Cutting (Exploration-Technology-Science)
- Science

Robotic precursors pursuing round-trip objectives intrinsically inform strategic exploration planning by providing invaluable flight experience

Science Exploration Integration

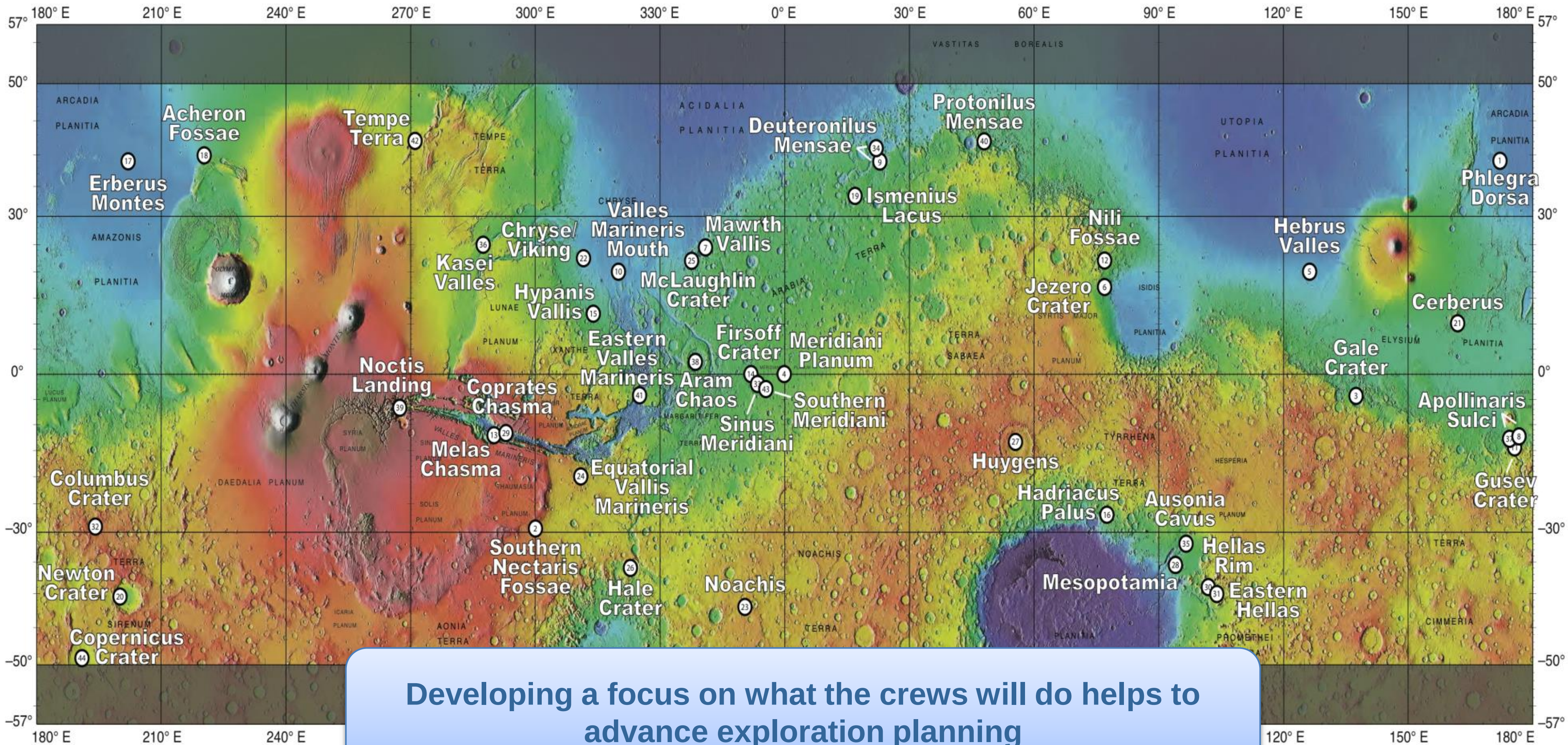


Next Orbiter (NEX-SAG) Findings

- SEP brings the advantages of orbit flexibility and increased payload mass & power
- Advanced telecom provides necessary coverage for high-resolution data
- Considerable overlap between science goals and human exploration resource prospecting interests & derived objectives yield similar, mature instrument approaches
  - **Visible imaging** *of HiRISE-class or better (~15-30 cm/pixel)*
  - **Polarimetric synthetic aperture radar** *imaging with penetration depth of a few (<10) meters and spatial resolution of ~15 m/pixel to search for shallow ground ice and crustal structure*
  - **Short-wave IR spectral** *mapping with a spatial resolution of ~6 m/pixel (3 x CRISM) with sufficient spectral resolution to detect key minerals*
  - **Long-wave atmospheric sounding** *for wind, temperature, & water vapor profiles with 5 km vertical resolution*
  - **Thermal IR sounding** *for aerosol (dust & ice) profiles*
  - **Multi-band thermal IR** *mapping of thermo-physical surface properties (e.g., ice overburden) and surface composition*
  - **Wide-angle imaging** *to monitor weather and surface frosts (global, km-scale)*

MARS

Potential Exploration Zones for Human Missions to the Surface of Mars



Developing a focus on what the crews will do helps to advance exploration planning

(00) Exploration Zones proposed for humans to Mars. At the equator, circles are ~100km radius

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MARS

Lunar footprints

Mars wheelprints

Time for the next step!