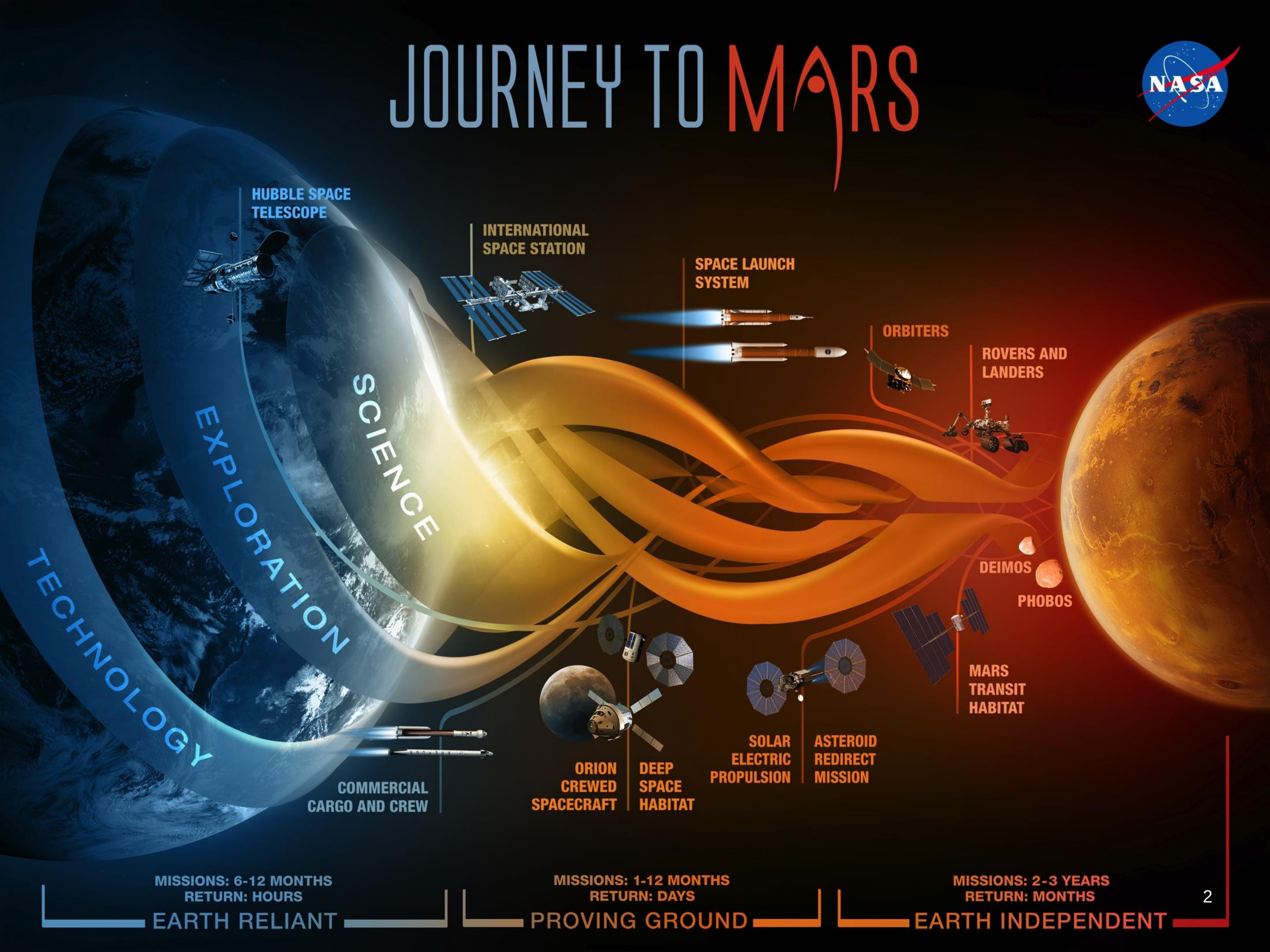
National Aeronautics and Space Administration

Human Exploration & Operations Progress and Plans on the Journey to Mars

NAC HEO Committee

March 2016

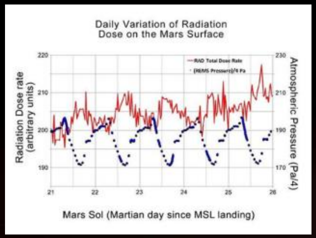

JOURNEY TO MARS
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
ROVERS AND LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
COMMERCIAL CARGO AND CREW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

Human Exploration of Mars Is Hard

Common Capability Needs Identified from Multiple Studies

800-1,100 Days

Total time crew is away from Earth – for orbit missions all in Micro-g and Radiation



Long Surface Stay

500 Days

44 min

Maximum two way communication time delay

Autonomous Operations

130 t

Heavy-Lift Mass

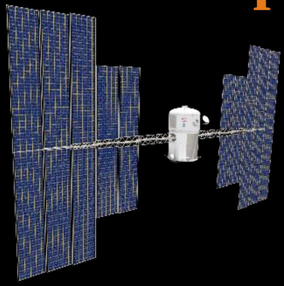
Multiple

Launches per mission

11.2 km/s

Earth Entry Speed

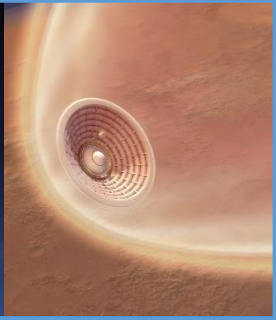
Reliable In-Space Transportation



Total continuous transportation power

20-30 t

Ability to land large payloads

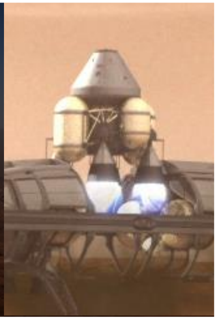


Surface Operations

Dust Toxicity and Long Range Exploration

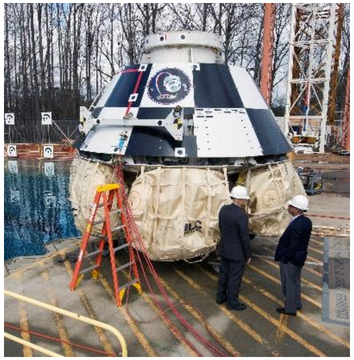
20 t

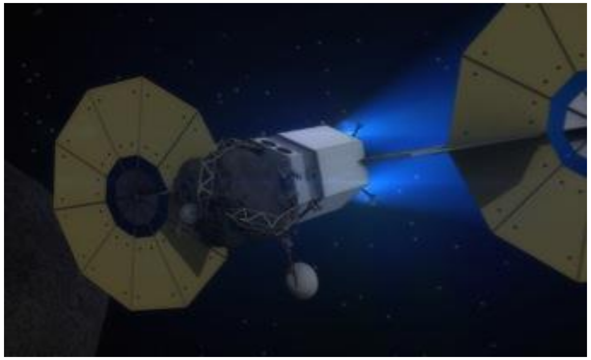
Oxygen produced for ascent to orbit - ISRU



Mars is Achievable If We Take the Long View

- **Space Launch System**
  - Engines
  - Stages (including EUS)
  - Boosters
- **Orion Crew Vehicle**
- **Ground System Development and Operations**
- **Commercial Crew & Cargo Vehicles**
- **Asteroid Redirect Mission**
  - Capture mechanism
  - Solar electric propulsion
  - Spacecraft bus and solar arrays
- **ISS Experiments & Research**





HEOMD has more space systems development ongoing today than at any time since Apollo!

Transition from ISS to Cislunar Space: Framework

Today

Ends with testing, research and demos complete*

Phase 0: Exploration Systems ***Testing on ISS***

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Ends with one year crewed Mars class shakedown cruise

Phase 2: ***Cislunar Validation*** of Exploration Capability

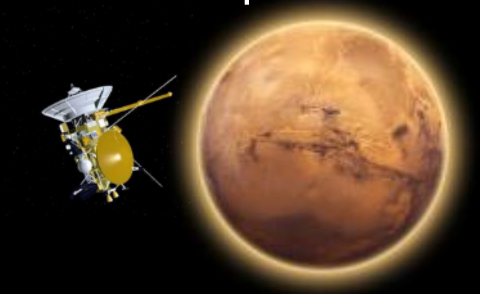
Mid-2020s

2030

*There are several other considerations for ISS end-of-life

What We've Learned Thus Far and Still Need to Learn

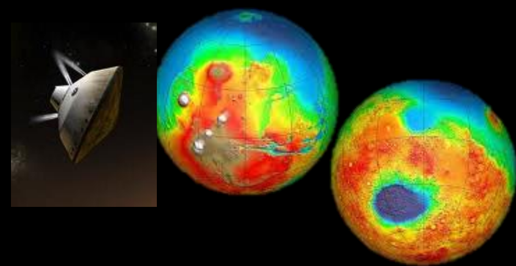
Orbital Environment and Operations



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

To Learn:
- Return flight from Mars to Earth
- Autonomous rendezvous and docking
- ISRU feasibility
- Resource characterization of Mars's moons
- High-power SEP

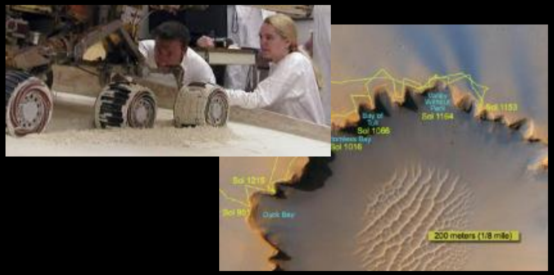
Capture, EDL, and Ascent at Mars



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:
- Water once flowed and was stable
- 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, and seals
- Rad/ECLSS in Mars environment
- Power sufficient for ISRU
- Surface navigation

NAC Recommendation – Dec 2015

“In preparation for the 2017 transition of Administrations, the Council recommends that NASA further develop their plan for future Human Exploration, such that it:

(1) Provides a consistent vision across all elements of the program;

(2) Allows selection of technology investments on a timely basis;

(3) Enhances advocacy and continuity of support that transcends Administrations; and

(4) Provides the ability to respond to changes in the external environment (e.g., funding changes or technology breakthroughs).”

Capabilities for Pioneering Space: Steps on the Journey to Mars

	Capability \ Mission	ISS	Cis-lunar Short Stay (e.g. ARM)	Cis-lunar Long Stay	Cis-Mars Robotic	Mars Orbit	Mars Surface
Working in Space and On Mars	In Situ Resource Utilization & Surface Power		Exploratory ISRU Regolith	Exploratory ISRU	Exploratory ISRU & Atmosphere	Exploratory ISRU	Operational ISRU & High Power
	Habitation & Mobility	Long Duration with Resupply	Initial Short Duration	Initial Long Duration		Resource Site Survey	Long Duration / Range
	Human/Robotic & Autonomous Ops	System Testing	Crew-tended	Earth Supervised	Earth Monitored	Autonomous Rendezvous & Dock	Earth Monitored
	Exploration EVA	System Testing	Limited Duration	Full Duration	Full Duration	Full Duration	Frequent EVA
Staying Healthy	Crew Health	Long Duration	Short Duration	Long Duration	Dust Toxicity	Long Duration	Long Duration
	Environmental Control & Life Support	Long Duration	Short Duration	Long Duration	Long Duration	Long Duration	Long Duration
	Radiation Safety	Increased Understanding	Forecasting	Forecasting Shelter	Forecasting Shelter	Forecasting Shelter	Forecasting & Surface Enhanced
Transportation	Ascent from Planetary Surfaces				Sub-Scale MAV	Sub-Scale MAV	Human Scale MAV
	Entry, Descent & Landing				Sub-Scale/Aero Capture	Sub-Scale/Aero Capture	Human Scale EDL
	In-space Power & Prop		Low power	Low Power	Medium Power	Medium Power	High Power
	Beyond LEO: SLS & Orion		Initial Capability	Initial Capability	Full Capability	Full Capability	Full Capability
	Commercial Cargo & Crew	Cargo/Crew	Opportunity	Opportunity	Opportunity	Opportunity	Opportunity
	Communication & Navigation	RF	RF & Initial Optical	Optical	Deep Space Optical	Deep Space Optical	Deep Space Optical
		EARTH RELIANT	PROVING GROUND				EARTH INDEPENDENT

Capability Development Risk Reduction

Sufficiently Funded
Partially Funded

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	Radiation Safety	Increased Understanding	Forecasting	Forecasting Shelter	Forecasting Shelter	Forecasting Shelter	Forecasting & Surface Enhanced
Transportation	Ascent from Planetary Surfaces				Sub-Scale MAV	Sub-Scale MAV	Human Scale MAV
	Entry, Descent & Landing				Sub-Scale/Aero Capture	Sub-Scale/Aero Capture	Human Scale EDL
	In-space Power & Prop		Low power	Low Power	Medium Power	Medium Power	High Power
	Beyond LEO: SLS & Orion		Initial Capability	Initial Capability	Full Capability	Full Capability	Full Capability
	Commercial Cargo & Crew	Cargo/Crew	Opportunity	Opportunity	Opportunity	Opportunity	Opportunity
	Communication & Navigation	RF	RF & Initial Optical	Optical	Deep Space Optical	Deep Space Optical	Deep Space Optical
		EARTH RELIANT	PROVING GROUND				EARTH INDEPENDENT

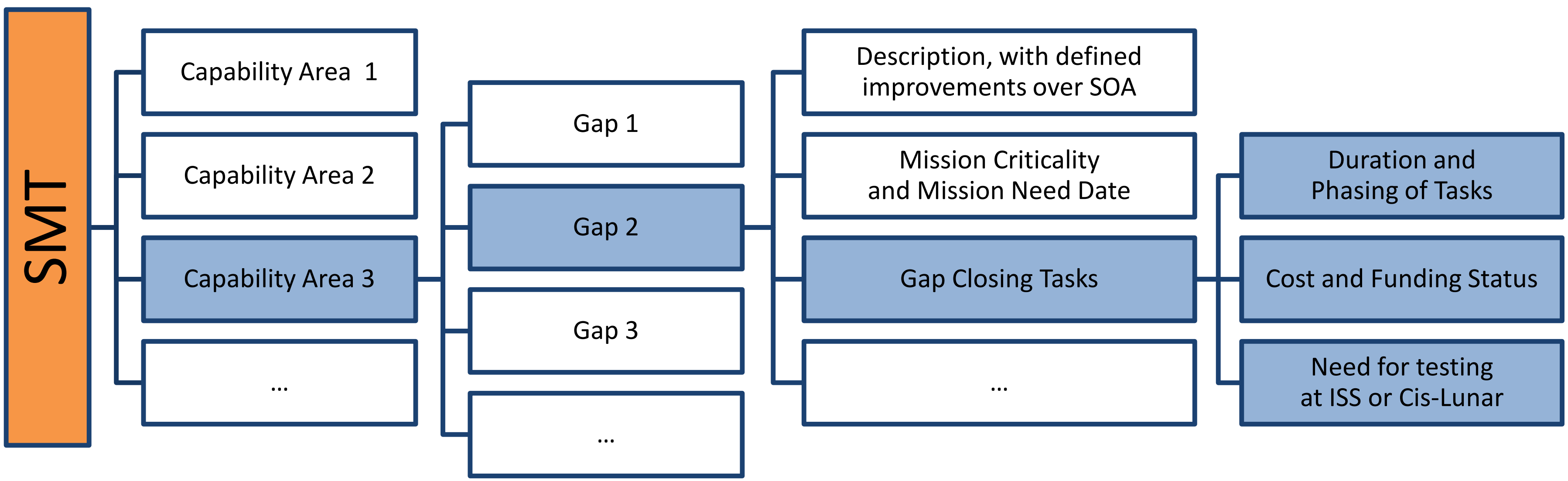
System Maturation Teams

SMTs comprise technical experts
from across Centers and Programs

System Maturation Team
Autonomous Mission Operations (AMO)
Communication and Navigation (Comm/Nav)
Crew Health & Protection and Radiation (CHP)
Environmental Control and Life Support Systems and Environmental Monitoring (ECLSS-EM)
Entry, Descent and Landing (EDL)
Extra-vehicle Activity (EVA)
Fire Safety
Human-Robotic Mission Operations (Robotics)
In-Situ Resource Utilization (ISRU)
Power and Energy Storage (Power)
Propulsion
Thermal (including cryo)
Discipline Team - Crosscutting
Avionics
Structures, Mechanisms, Materials and Processes (SMMP)
Dormancy Operations

System Maturation Team Data Hierarchy

- System Maturation Teams (e.g. Propulsion) – divided into Capability Areas
  - **Capability Areas** (e.g. High Thrust Propulsion) – divided into Gaps
    - **Gap** (e.g. Pump-Fed LOX/CH4 In-Space Engine) – defines a capability advancement over the current state of the art along with mission criticality and mission need date; gap is closed by performing multiple Gap Closing Tasks
    - **Gap Closing Tasks** (e.g. Power Pack Development) – defines task duration and phasing, cost and funding status, and development testing locations (ISS or cis-lunar)



2017 Astronaut Selection Timeline

18,300 Applicants

(3x more than received in 2012)

- **Dec 14 2015** — Vacancy Announcement opens in USAJOBS
- **Feb-Sep 2016** — Qualifications Inquiry form sent to Supervisors/References and civilian applicants contacted by mail to obtain an FAA medical exam
- **Oct-Dec 2016** — Highly Qualified applications reviewed to determine Interviewees
- **Feb-Apr 2017** — Interviewees brought to JSC for initial interview, medical evaluation, and orientation
- **May 2016** — Finalists determined
- **June 2017** — Astronaut Candidate Class of 2017 announced
- **August 2017** — Astronaut Candidate Class of 2017 reports to the Johnson Space Center


THE JOURNEY TO MARS HAS ALREADY BEGUN.
MARS
NASA
#JOURNEYTOMARS