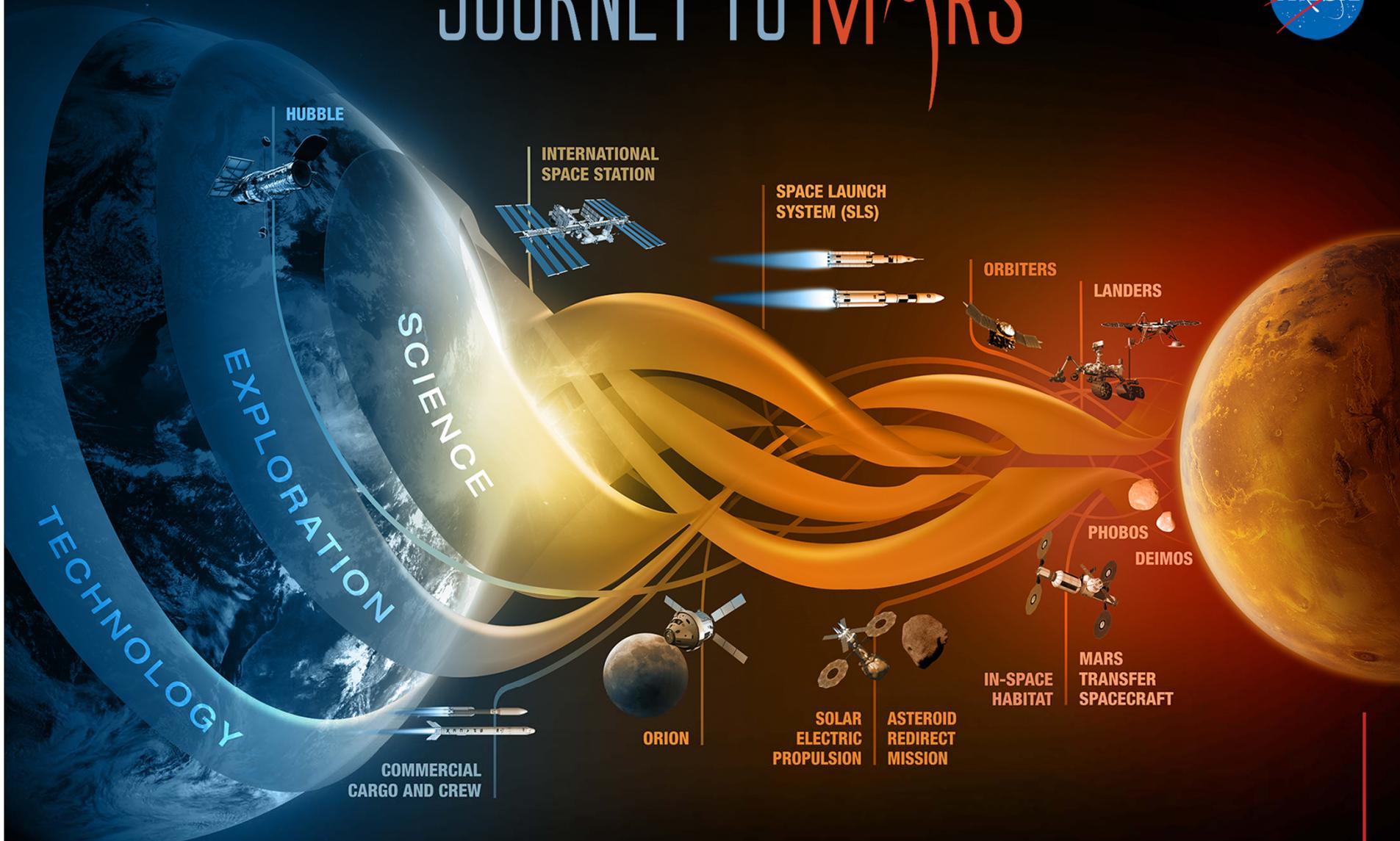


JOURNEY TO MARS



HUBBLE

INTERNATIONAL SPACE STATION

SPACE LAUNCH SYSTEM (SLS)

ORBITERS

LANDERS

SCIENCE

EXPLORATION

TECHNOLOGY

COMMERCIAL CARGO AND CREW

ORION

SOLAR ELECTRIC PROPULSION

ASTEROID REDIRECT MISSION

IN-SPACE HABITAT

MARS TRANSFER SPACECRAFT

PHOBOS

DEIMOS

MISSIONS: 6-12 MONTHS
RETURN: HOURS

MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS

MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS

EARTH RELIANT

PROVING GROUND

EARTH INDEPENDENT

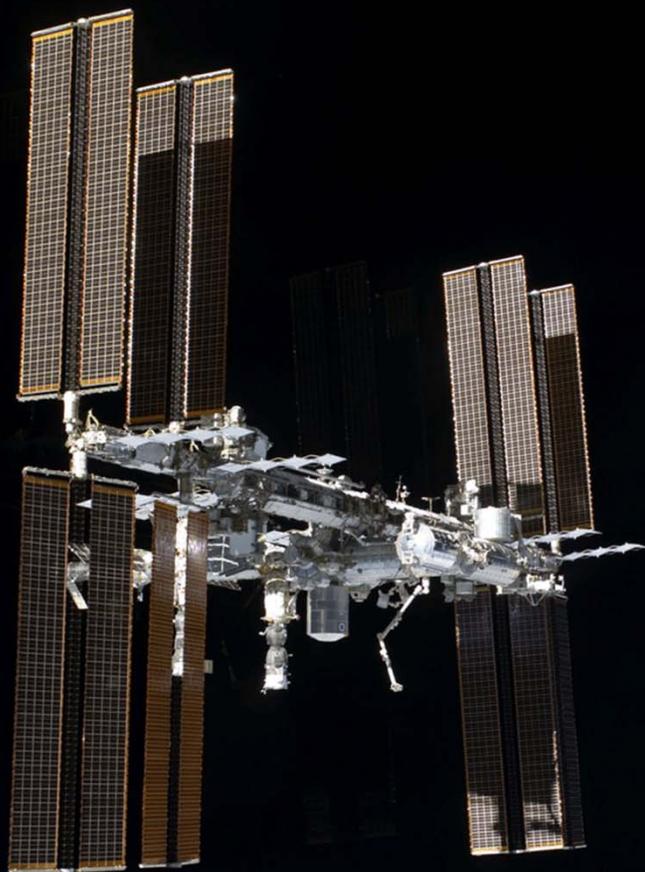


Strategic Principles for Sustainable Exploration

- Implementable in the *near-term with the buying power of current budgets* and in the longer term with budgets commensurate with economic growth;
- *Exploration enables science and science enables exploration, leveraging robotic expertise for human exploration of the solar system*
- Application of *high Technology Readiness Level (TRL) technologies* for near term missions, while focusing sustained investments on *technologies and capabilities* to address challenges of future missions;
- *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for *U.S. commercial business* to further enhance the experience and business base;
- *Multi-use, evolvable* space infrastructure, minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- Substantial new *international and commercial partnerships*, leveraging the current International Space Station relationships while building new cooperative ventures.



ISS: Cornerstone of Future Human Space Exploration



Enable long duration human spaceflight beyond LEO

Enable a commercial market in LEO

Advance benefits to humanity through research

Basis for international HSF exploration partnerships

Commercial Crew Program



- **The Commercial Crew Program (CCP) is an essential element of the the broader strategy to achieve our nation's goals in space.**
- **CCP will re-establish the capability to launch astronauts from US soil.**
- **CCP will increase the ISS crew time available for research by an amount equivalent to one additional astronaut dedicated to research.**
 - This is critical to accomplishing the human research required for deep space exploration during the lifetime of ISS
- **Commercial transportation is vital to expanding the commercial market for low Earth orbit services, enabling NASA and its international and commercial partners to extend human presence into the solar system and to the surface of Mars.**



SpaceX: Pad Abort Test Static Test Firing



Boeing: Test 1 Water Landing and Rotation to Stable 2

Space Launch System, Orion, and Ground Systems



Beginning human exploration beyond LEO as soon as practicable helps secure our future in space.

Space
Launch
System

Orion
Crew Capsule

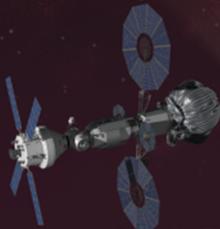


Ground Systems
Development & Operations

Technology Path to Pioneering Space



Asteroid Retrieval Mission



Hypersonic Inflatable Aerodynamic Decelerator



Optical Communications

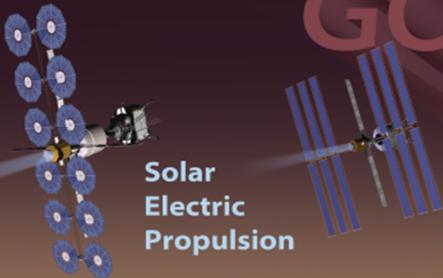


GO

LAND

LIVE

Solar Electric Propulsion



Low-Density Supersonic Decelerator



Environmental Control & Life Support System



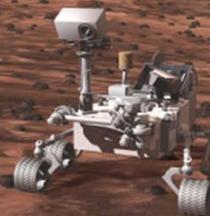
Surface Power



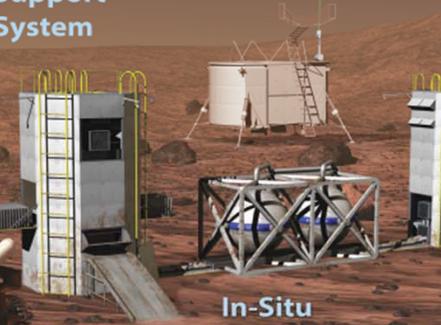
Next Generation Spacesuit



Robotics & Autonomy



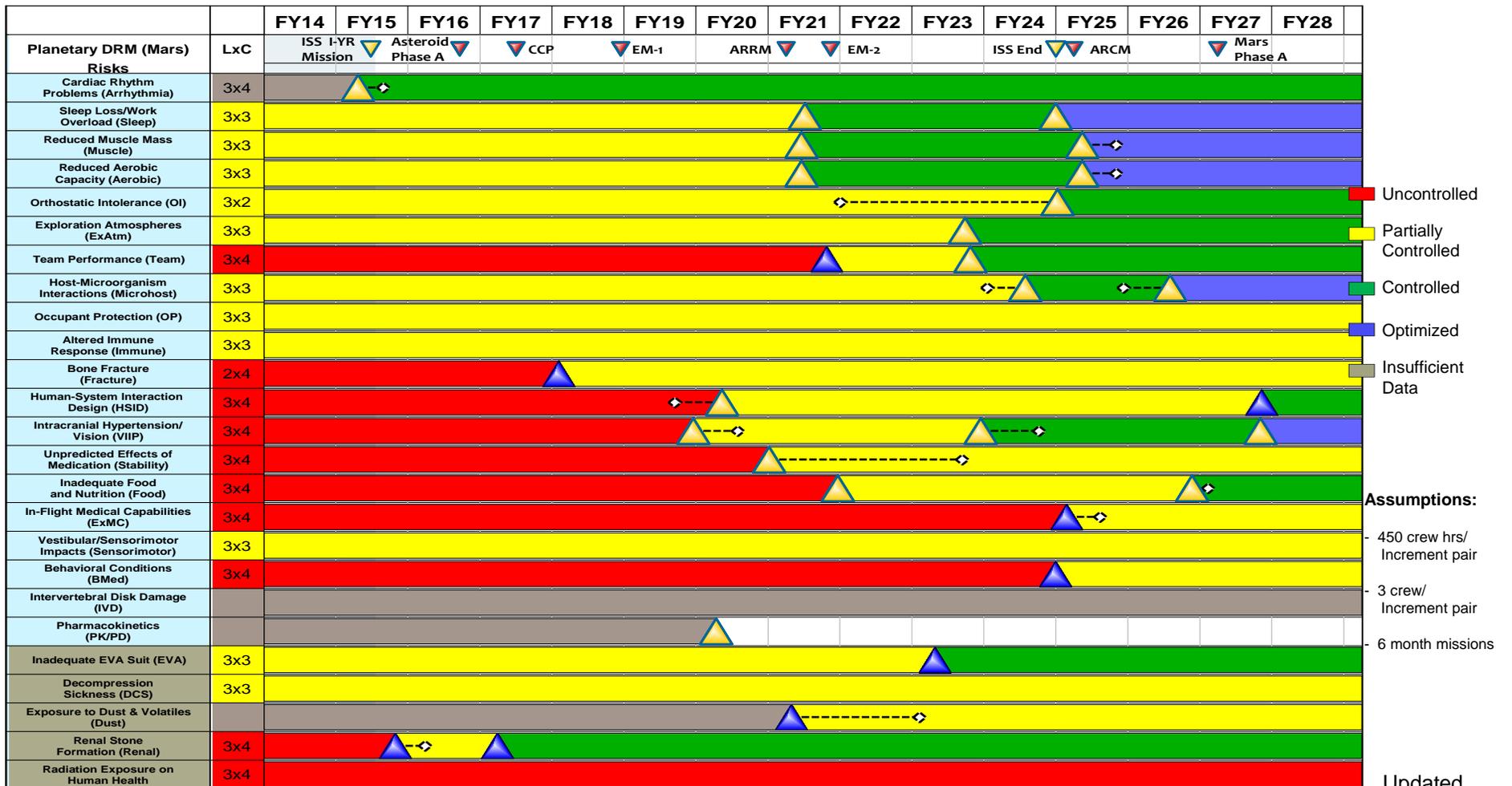
In-Situ Resource Utilization



nasa.gov

Human Exploration and Operations

Human Research Program: Integrated Path to Risk Reduction



■ Uncontrolled
■ Partially Controlled
■ Controlled
■ Optimized
■ Insufficient Data

Assumptions:
 - 450 crew hrs/ Increment pair
 - 3 crew/ Increment pair
 - 6 month missions

■ ISS Required ■ ISS Not Required ▲ Milestones Requires ISS ◆ Milestone Shift

Updated
 4/20/15
 Rev. C draft

Capabilities for Pioneering Space: Steps on the Journey to Mars



	Capability \ Mission	ISS	Cis-lunar Short Stay (e.g. ARM)	Cis-lunar Long Stay	Mars Orbit	Mars Moons	Mars Surface
Working in Space and On Mars	In Situ Resource Utilization & Surface Power		Exploratory ISRU	Exploratory ISRU		Exploratory ISRU	Operational ISRU & High Power
	Surface Habitat & Mobility					Long Duration	Long Duration / Range
	Human/Robotic & Autonomous Ops	System Testing	Crew-tended	Earth Supervised	Earth Monitored	Earth Monitored	Earth Monitored
	Exploration EVA	System Testing	Limited Duration	Full Duration	Full Duration	Frequent EVA	Frequent EVA
Staying Healthy	Crew Health	Long Duration	Short Duration	Long Duration	Long Duration	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	Surface Enhanced	Surface Enhanced
Transportation	Ascent from Planetary Surfaces					Protoflight Use	Operational Capability
	Entry, Descent & Landing				High Mass Pathfinder		Operational Capability
	In-space Power & Prop		Low power	Low Power	High Power	High 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		

ISS Technology Demonstration Plan



Capability Gap	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
ECLSS															
Reliable CO2 Removal + lower ppCO2	▲ CDRA-5	▲ sorbent exp	▲ CDRA upgrades	▲ next gen system											
Smaller, simpler O2 Gen								▲ next gen OGA							
High pressure O2 for EVA & medical use															
Reliable urine processing ~85% recovery			▲ alt pt	▲ ISS UPA upgrad	▲ next gen UPA										
Reliable water processing w/ reduced expendables				▲ MF bed mod	▲ cat reactor mod										
Common biocide with on orbit replenishment															
Waste management					▲ UWMS			▲ HMC							
Additional O2 recovery from CO2 >75%															
Additional water from brine >85% recovery															
Logistics Reduction				▲ REALM											
Environmental Monitoring															
Trace Gas (on orbit, no grab sample return)	▲ AQM					▲ SAM									
Targeted Gases (fire products, NH3, hydrazine)															
Water (individual compounds)				▲ suite											
Microbial (ID & qty species)				▲ COTS											
Major Constitutents (small, no maintenance)															
Particulates															
Acoustic (automated, alerting, no crew time)															
EVA															
PLSS & Pressure Garment ug test															
EMU upgrades															
Fire Safety and Response															
Emergency Mask (single cartridge)	▲ dual														
Contingency Air Monitor (overlap with targeted gas)															
Smoke Eater															
Water Mist PFE															
Crew Health & Performance Technologies															
Exercise Equipment															
Medical Equipment															
Food System															
Thermal (including Cryo)															
ZBOT (Phases 1-3)															
Phase Change Material															
Variable Heat Rejection radiators, single loop fluids															
Power & Energy Storage															
Solar arrays															
Energy Storage															
Comm & Navigation															
High speed comm/internetworking	▲ DTN & OPALS, SCAN TB														
Position, navigation, and timing															
Structures & Materials															
Materials/In-space manufacturing	▲ 3D print (plastic)	▲ BEAM													
Structures & Health Monitoring															
Radiation Monitoring & Shielding															
ISRU (trash processing, resource prospecting, in-situ manufacturing) Plans under construction.															
Autonomous Operations															
Automated Rendezvous & Docking	▲ TOCA	▲ AMO EXPRESS	▲ ISS crew autonomy 2.0												
Robotics															
Robotic refueling															
Free flyer robots (IVA & EVA)															
Human assist robots	▲ Robonaut														
Telerobotics															

■ no committed funding
■ some \$, but insufficient funding for ISS demo
■ sufficient funding to ISS demo
▲ Funded ISS demo
▲ Proposed ISS demo (not yet funded)