

Human Spaceflight Missions Beyond Low Earth Orbit

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Disclosure Information



- I have no financial relationships to disclose.
- I will not discuss off-label use and/or investigational use in my presentation.

Background: Exploration Paradigm



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

- Real Time Communications
- Evacuation Capability (1.5 36 hrs)
- Strong Consumables Resupply



Mastering fundamentals aboard the International Space Station

U.S. companies provide access to low-Earth orbit

PROVING GROUND

MISSION: 1 TO 12 MONTHS RETURN TO EARTH: DAYS

- Near Real Time Communications
- Evacuation Capability (72 144 hrs)
- Limited Consumables Resupply



Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

EARTH INDEPENDENT

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

- No Real Time Communications
- No Evacuation Capability
- No Consumables Resupply



Developing planetary independence by exploring Mars, its moons and other deep space destinations

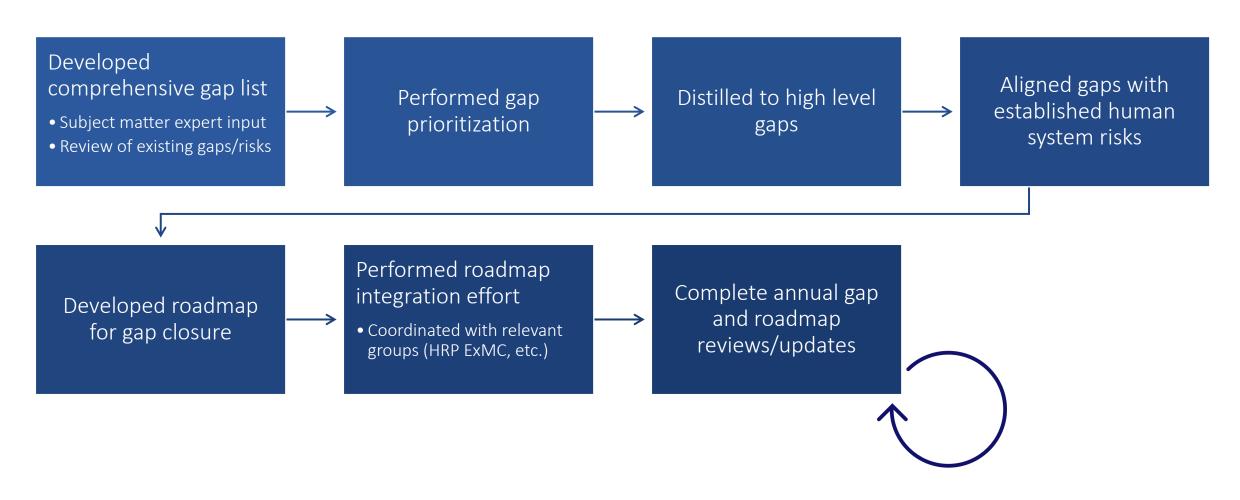
Background: NASA Capability Gaps and Human System Risks



- Exploration Systems Development Mission Directorate (ESDMD) uses <u>Capability Gaps</u> to identify technology development required to enable future exploration missions¹
- Human System Risk Board (HSRB) tracks <u>Human System Risks</u> encountered in human spaceflight²
 - Human System Risk: Recognized potential undesired flight crew health or performance outcome that has a clear consequence and attendant likelihood supported by evidence for a given Design Reference Mission (DRM)²
- Crew Health and Performance (CHP) Systems Capability Leadership Team (SCLT) coordinated with the HRP External Programs team to developed the <u>Human System</u> <u>Capability Gaps¹</u>
 - Mapped to the primary associated Human System Risks

XMIPT Gap and Roadmap Development Process

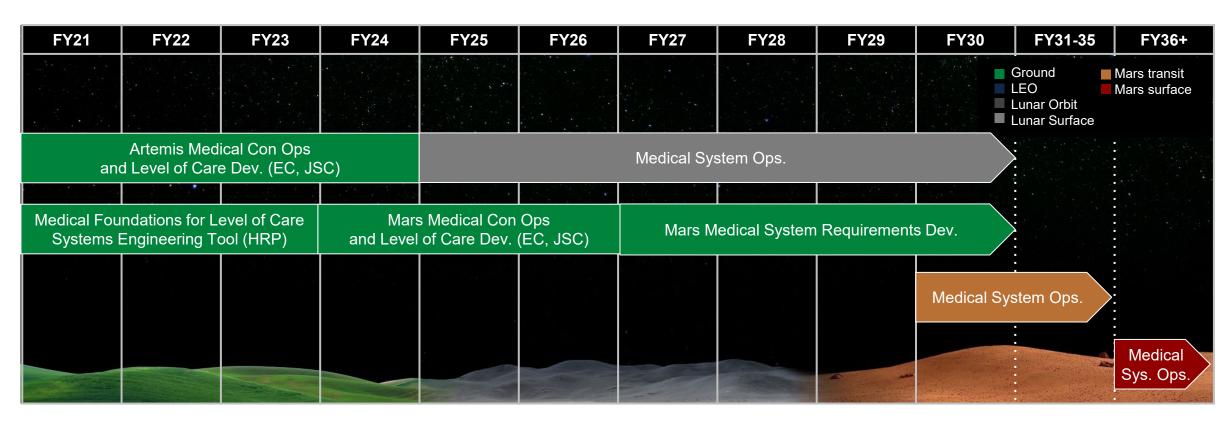




Medical Concepts of Operations



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Medical Concepts of Operations	Development of mission specific medical concept of operations and evidence-based medical standards to inform required medical capabilities for increasingly Earth-independent operations.	Medical Conditions Behavioral Med.



Medical Imaging, Diagnostics, and Treatment



Capability Gap Name

Capability Gap Statement

Primary Associated Human System Risks

Medical Imaging, Diagnostics, and Treatment Technologies

Flight-tested medical imaging, diagnostic, and treatment technologies necessary to effectively manage medical conditions relevant to exploration missions that meet constraints (e.g., mass, volume, power, data, etc.),, integrate with medical decision-support tools, and enable increasingly Earth-independent operations.

Medical Conditions
SANS
Cardiovascular
Bone Fracture
Renal Stones
EVA
Urinary Retention
Non-ionizing Radiation
Electrical Shock



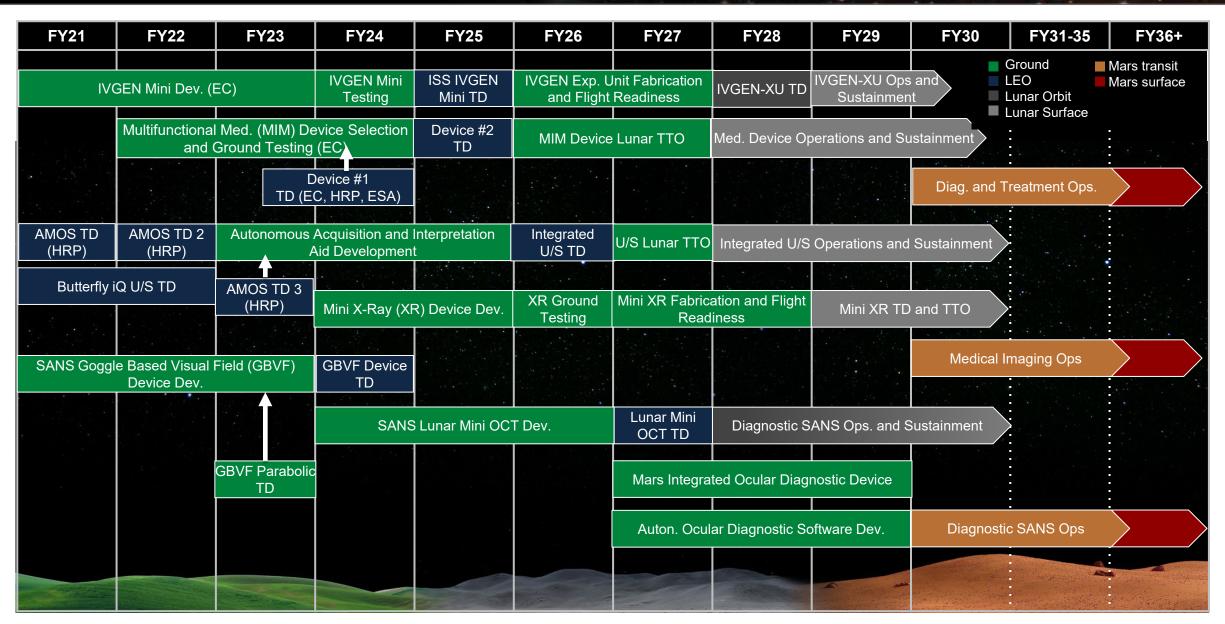




NASA ESA NASA

Medical Imaging, Diagnostics, and Treatment





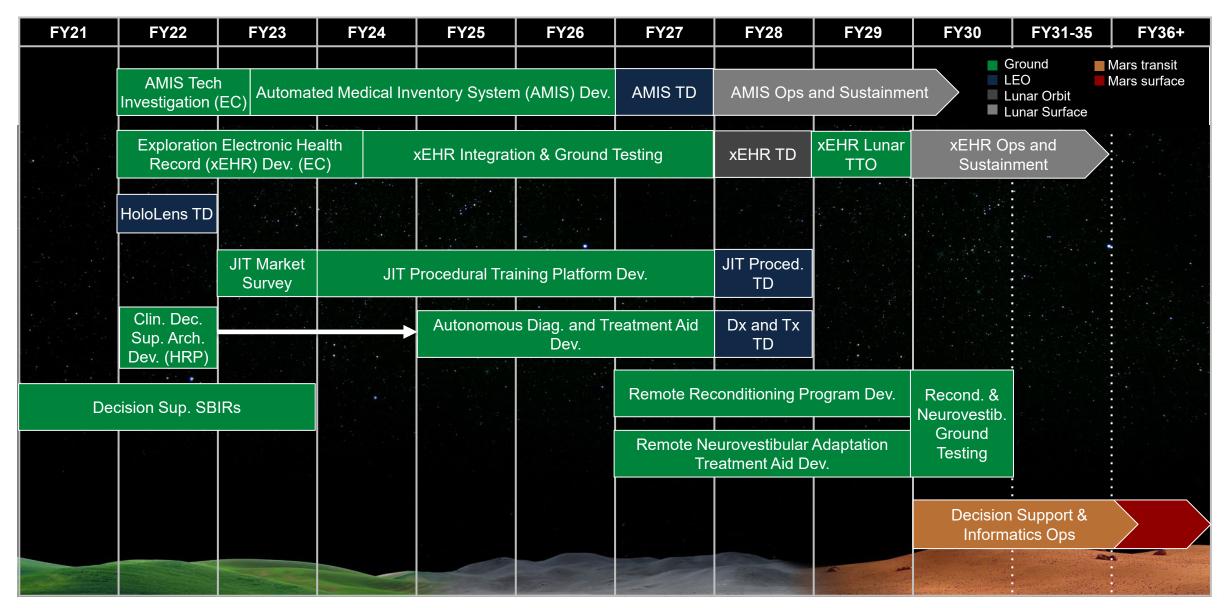
Operational Medical Decision Support Software and Informatics



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Operational Medical Decision Support Software & Informatics	In-flight medical decision support software that guides crew through diagnosis and treatment as well as medical informatics such as an electronic health record and inventory tracking capability all of which utilize a Crew Health and Performance Integrated Data Architecture to enable data-driven medical decision making during increasingly Earth-independent operations.	Human Systems Integration Architecture (HSIA) Medical Conditions Crew Egress Sensorimotor

Operational Medical Decision Support Software and Informatics

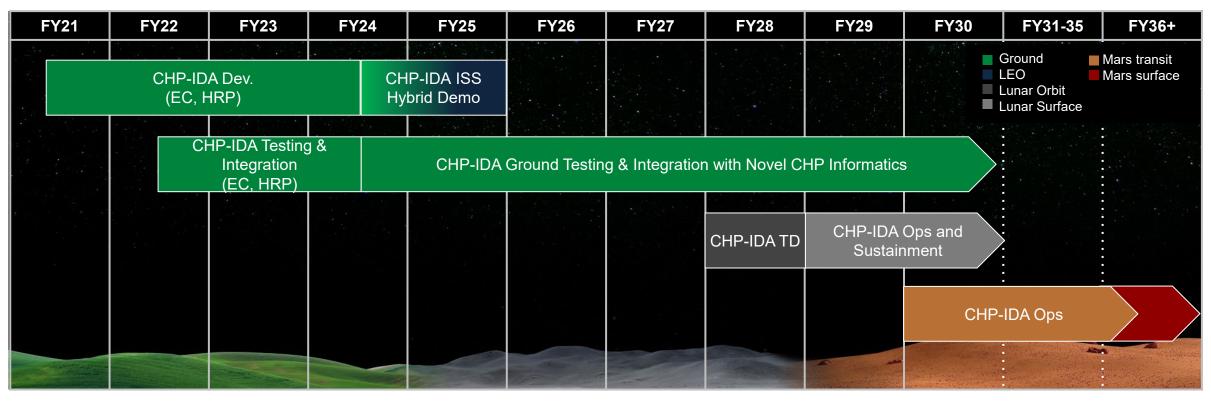




CHP Integrated Data Architecture



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks			
Crew Health & Performance Integrated Data Architecture	Data architecture integrated across all crewmembers, vehicle systems, and mission phases to enable multi-system crew health and performance assurance (e.g., monitoring, decision support, data collection, analytics, visualization, etc.).	Human Systems Integration Architecture (HSIA)			



Integrated Medical Simulation Technologies



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks			
Integrated Medical Simulation Technologies	Integrated medical ground simulation capabilities incorporating medical hardware- and software-based diagnostic and treatment aides to enable development of crew procedures and training protocols that decrease reliance on ground support and enable increasingly Earthindependent medical operations.	Medical Conditions Human Systems Integration Architecture (HSIA)			

FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31-35	FY36+
										Ground LEO	■ Mars transit ■ Mars surface
		rated Simulatio ed Dev (EC, HF								Lunar Orbit Lunar Surface	Wars surrace
		EIMO Strategy Dev.	Se	mi-autonomou	s Procedure	Dev.					
			Exploration	on CMO Skills	and Training	Reqs Dev.					
				Integrate	ad XM System	m Simulation/T	raining				
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Medical Risk Model and Trade Space Analysis Tools



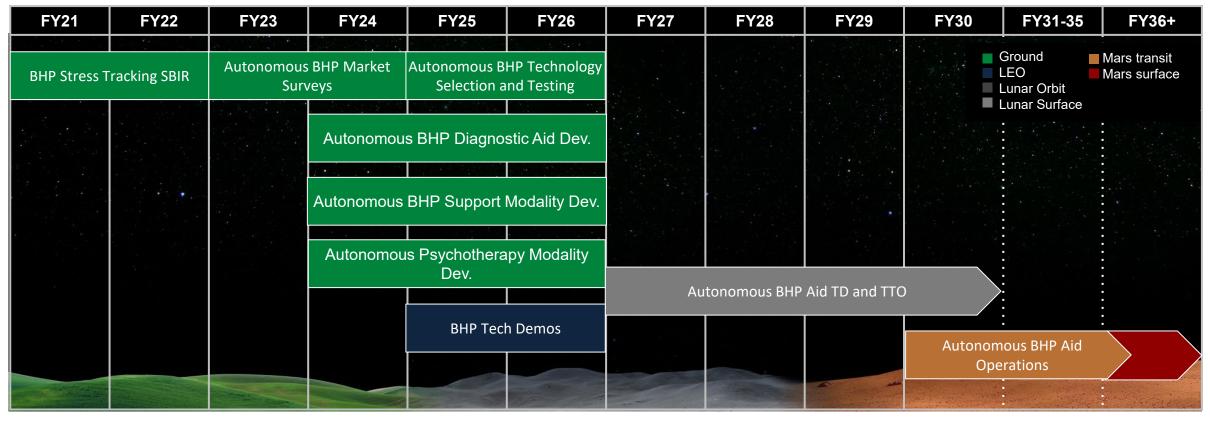
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Medical Risk Model and Trade Space Analysis Tool	Quantitative medical risk models and trade space analysis tools that utilize up to date terrestrial and spaceflight medical evidence databases to inform mission-specific medical concept of operations, system design, and system optimization and enable increasingly Earth independent operations.	Medical Conditions

FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31-35	FY36+
										Ground LEO Lunar Orbit Lunar Surface	Mars transit Mars surface
XM Risk Database XM Risk Database Expansion Phase 1 (HRP) Expansion Phase 2 (HRP)					XM Risk Database Updates						
	rade Space An 1.0 Dev. (HRP		ACT Trade Sp Tool v1.x De\	oace Analysis /. (HRP)	IMPACT CHP Trade Space Analysis Tool Dev. (HRP)				rade Space Analysis Tool Updates		
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Semi-autonomous Behavioral Health and Performance



	Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Sen	ni-autonomous Behavioral Health and Performance Technologies	Semi-autonomous behavioral health diagnosis, treatment, and support tools that decrease reliance on real-time ground support to enable behavioral health and performance during increasingly Earthindependent operations.	Behavioral Med. Sleep Loss Team Risk



Safe and Effective Pharmaceuticals



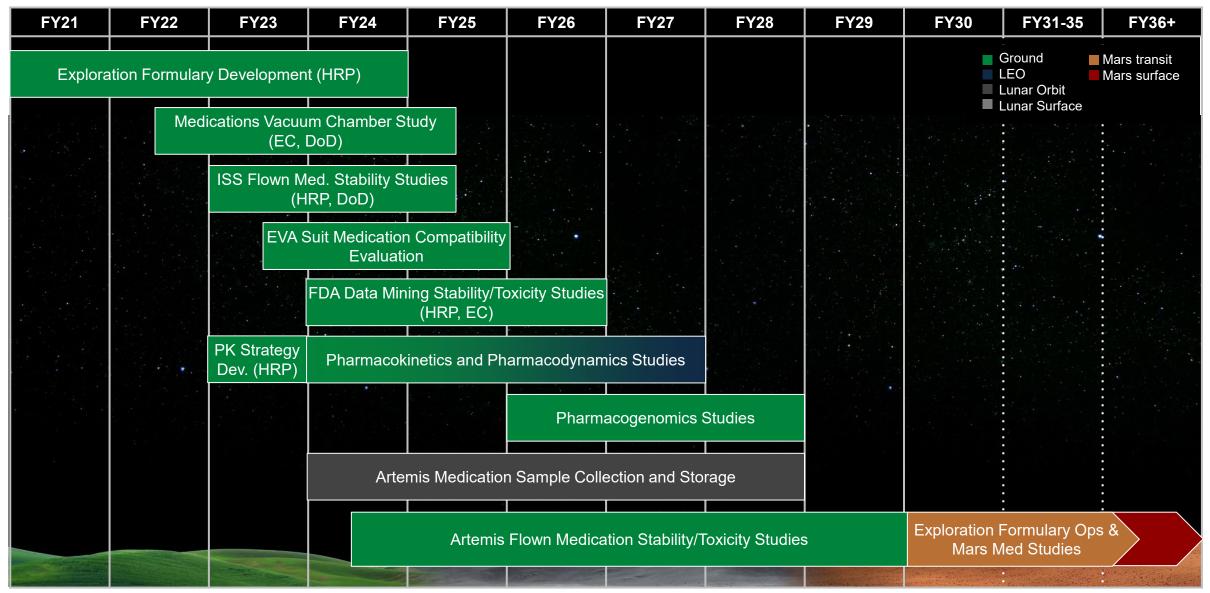
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Safe and Effective Pharmaceuticals	Capability to maintain medication safety and effectiveness over the course of all exploration mission concepts despite increased exposure to environmental stressors including deep space radiation.	Pharm



NASA

Safe and Effective Pharmaceuticals





In-situ Sample Storage, Processing, and Analysis



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
In-situ Sample Storage, Processing & Analysis	Technologies to store, process, and analyze a variety of biological and non-biological samples insitu to enable Earth independent human research and medical operations for exploration missions with limited sample return capability.	Medical Conditions Food and Nutrition Pharm

FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31-35	FY36+	
										Ground LEO	Mars transit	
HemoCue TD (HRP)	rHEALTH TD (HRP)	Requirement	ab Analysis s and Market vey	L	Lab Analysis TD					LEO Lunar Orbit Lunar Surface	Mars surface	
Min	i Microscopo F	Dov	Mini Micro.									
IVIII	Mini Microscope Dev.		TD	Ехр	oloration Lab A	nalysis Suite	Dev.	Ex. Lab Anal Ops and Sus				
								Exploration	n Lab Analysis	Ops		

References



- 1. NASA CHP Systems Capability Leadership Team, "Human System Capability Gaps and Mappings to Human System Risks," NASA, Houston, 2022.
- 2. JSC Health and Medical Technical Authority, "Human System Risk Management Plan," NASA, Houston, 2020.