



Identifying and Closing Medical Capability Gaps for 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.**

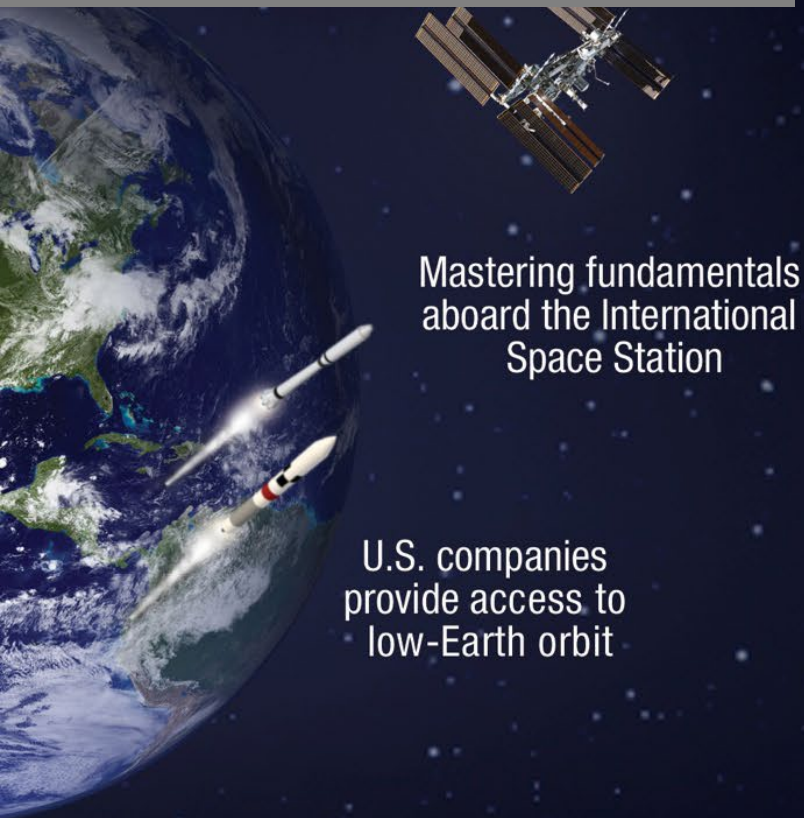
Background: Exploration Paradigm



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

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



PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

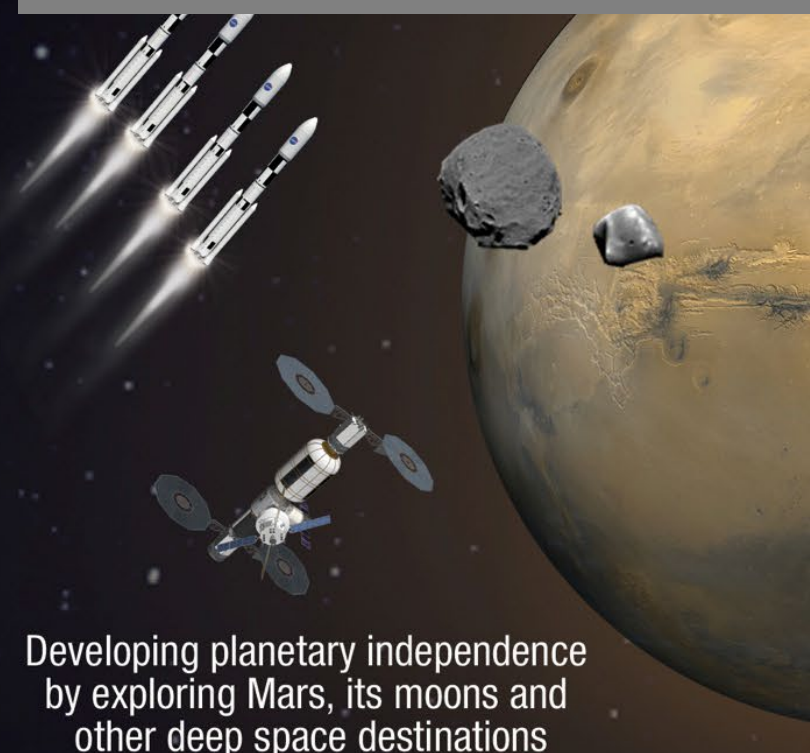
- Near Real Time Communications
- Evacuation Capability (72 – 144 hrs)
- **Limited** Consumables Resupply



EARTH INDEPENDENT

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

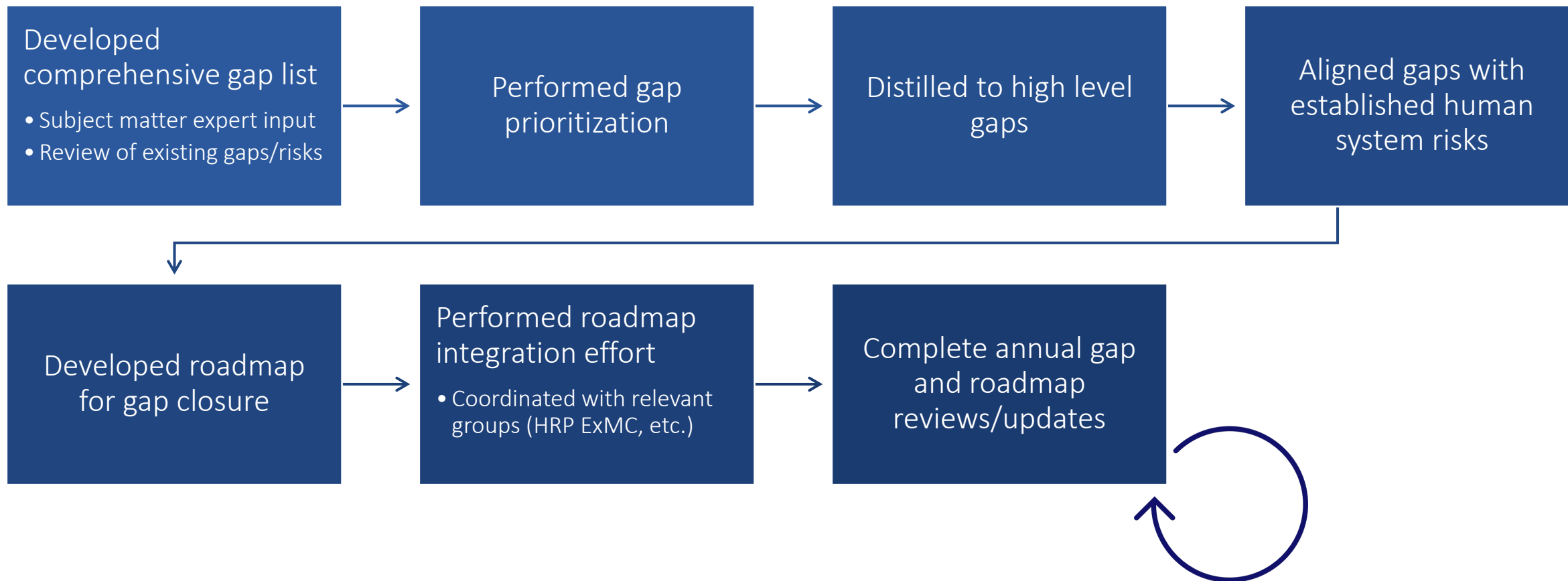
- **No** Real Time Communications
- **No** Evacuation Capability
- **No** Consumables Resupply





- **Exploration Systems Development Mission Directorate (ESDMD) uses [Capability Gaps](#) to identify technology development required to enable future exploration missions¹**
- **Human System Risk Board (HSRB) tracks [Human System Risks](#) 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 [Human System Capability Gaps](#)¹**
 - Mapped to the primary associated Human System Risks

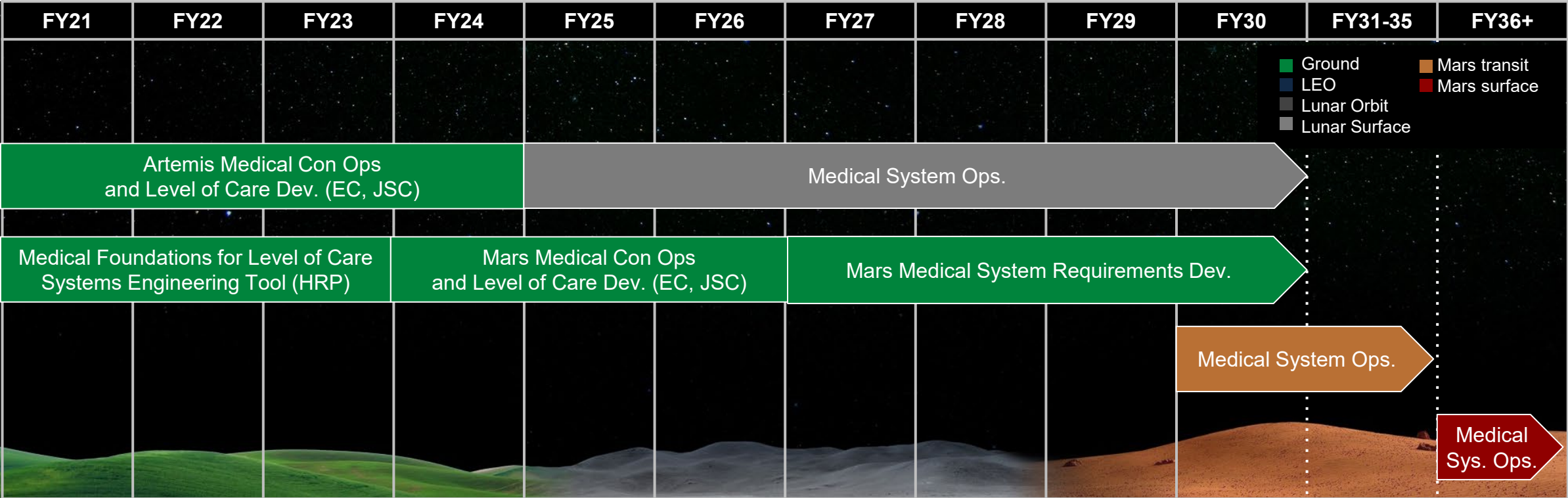
XMIPT Gap and Roadmap Development Process



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



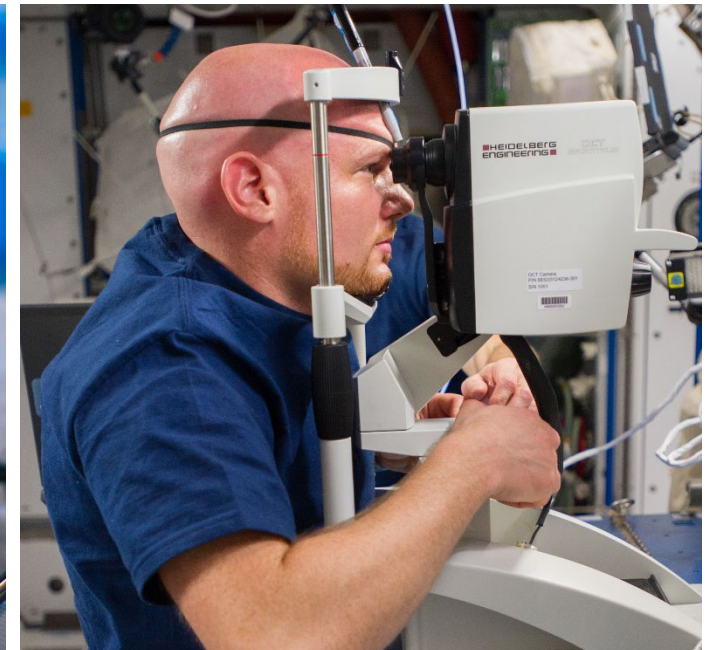
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
<p>Medical Imaging, Diagnostics, and Treatment Technologies</p>	<p>Flight-tested medical imaging, diagnostic, and treatment technologies necessary to effectively manage medical conditions relevant to exploration missions that meet constraints (e.g., mass, volume, power, data, etc.), integrate with medical decision-support tools, and enable increasingly Earth-independent operations.</p>	<p>Medical Conditions SANS Cardiovascular Bone Fracture Renal Stones EVA Urinary Retention Non-ionizing Radiation Electrical Shock</p>



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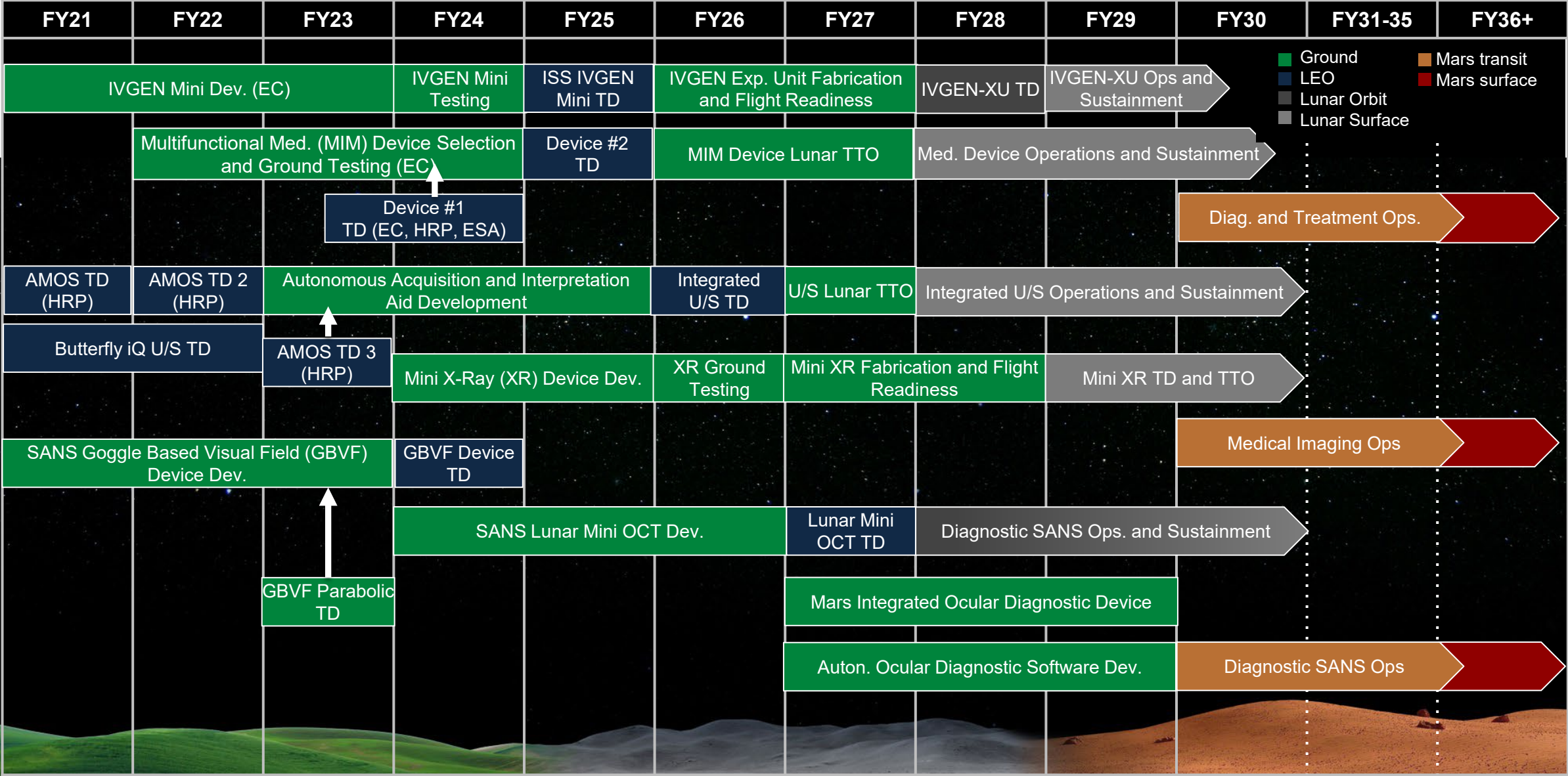


ESA



NASA

Medical Imaging, Diagnostics, and Treatment

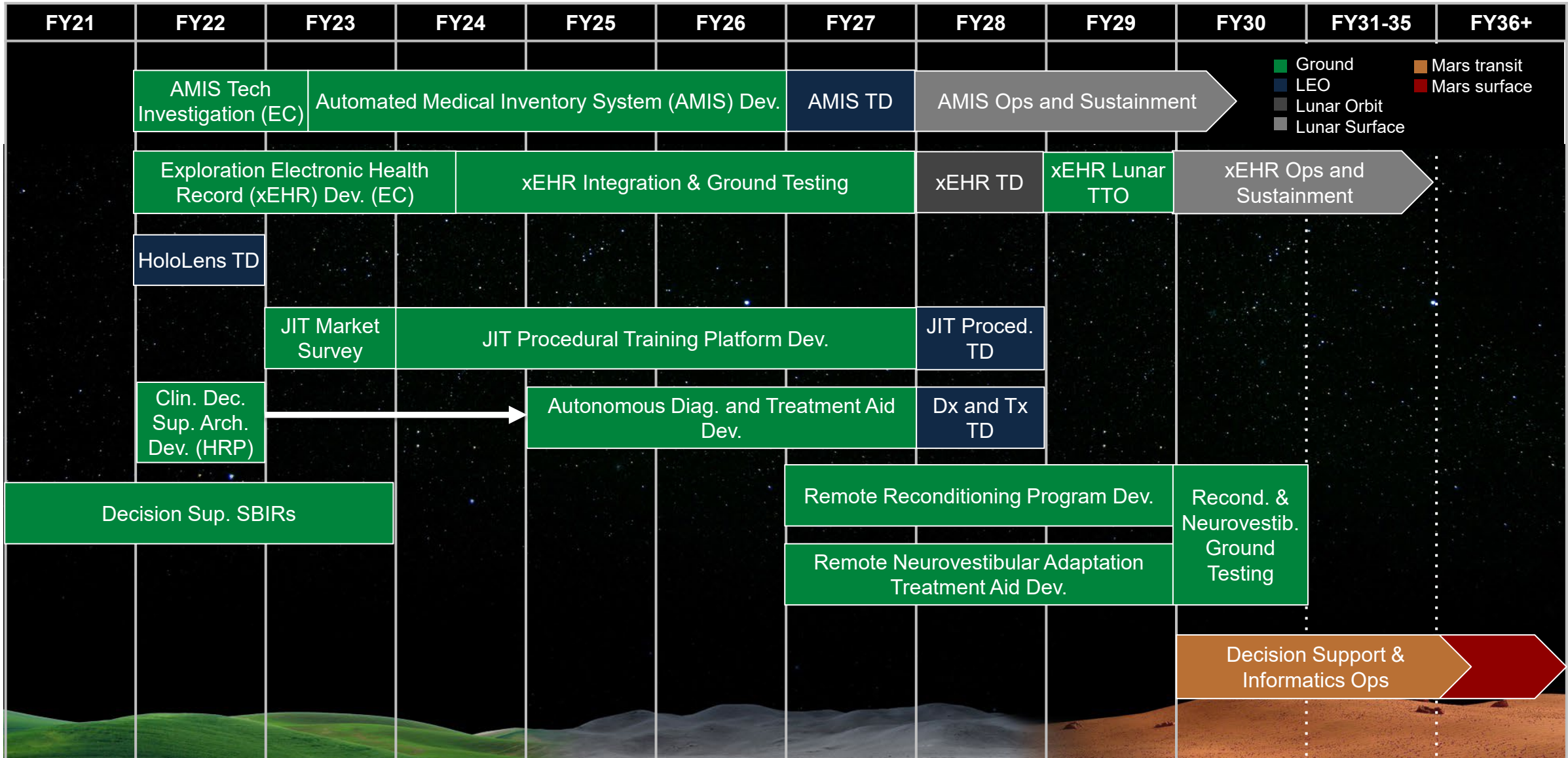


Operational Medical Decision Support Software and Informatics



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

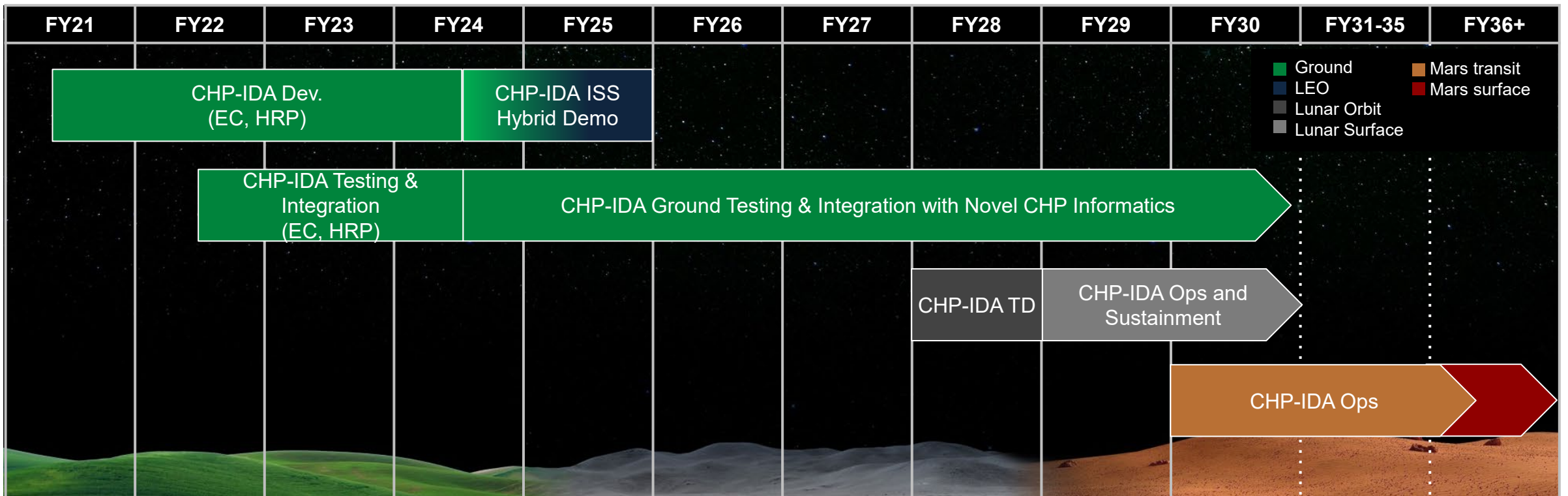
Operational Medical Decision Support Software and Informatics



CHP Integrated Data Architecture



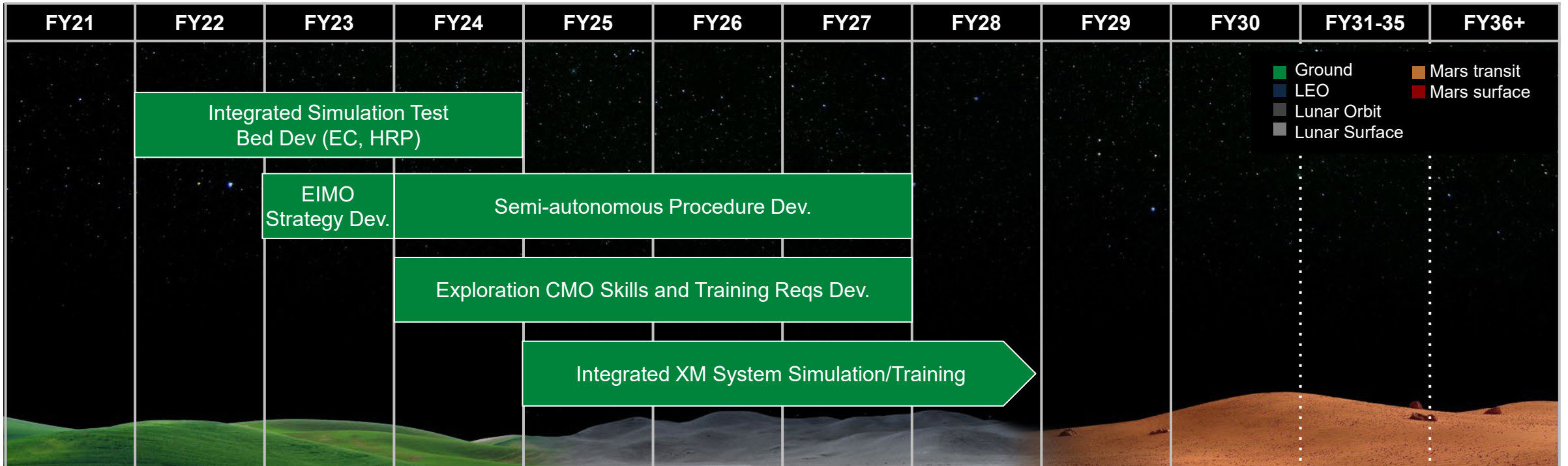
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Crew Health & Performance Integrated Data Architecture	Data architecture integrated across all crewmembers, vehicle systems, and mission phases to enable multi-system crew health and performance assurance (e.g., monitoring,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



Integrated Medical Simulation Technologies



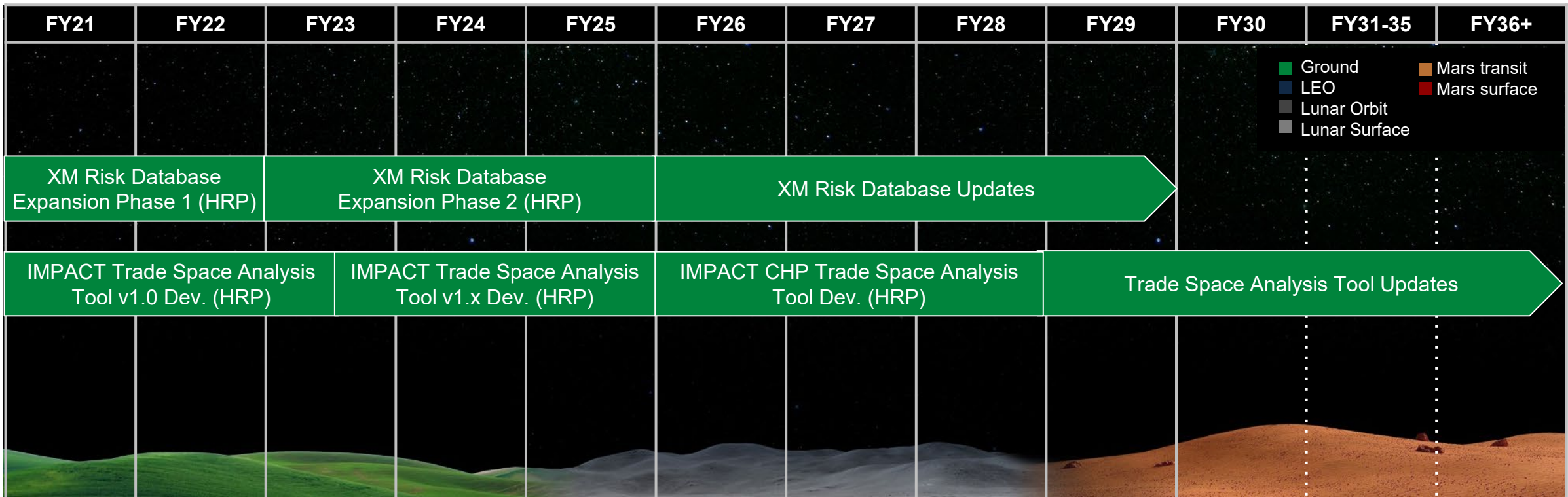
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Integrated Medical Simulation Technologies	Integrated medical ground simulation capabilities incorporating medical hardware- and software-based diagnostic and treatment aides to enable development of crew procedures and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



Medical Risk Model and Trade Space Analysis Tools



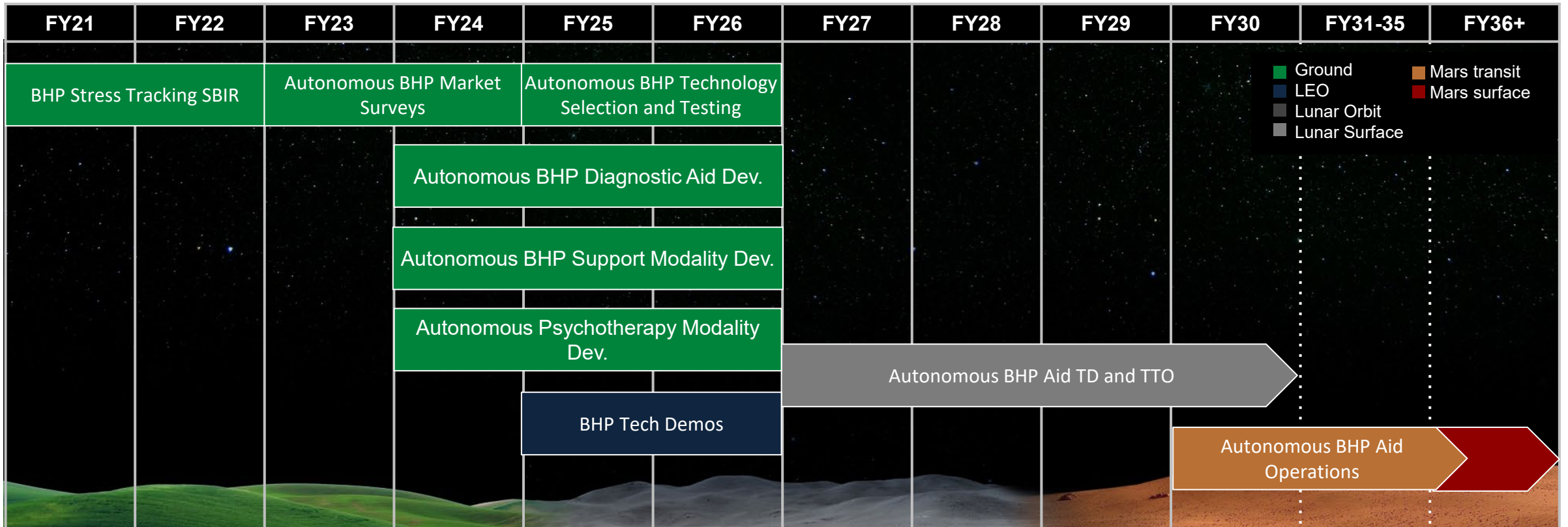
Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Medical Risk Model and Trade Space Analysis Tools	Quantitative medical risk models and trade space analysis tools that utilize up to date terrestrial and spaceflight medical evidence databases to inform mission-specific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



Semi-autonomous Behavioral Health and Performance



Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
Semi-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



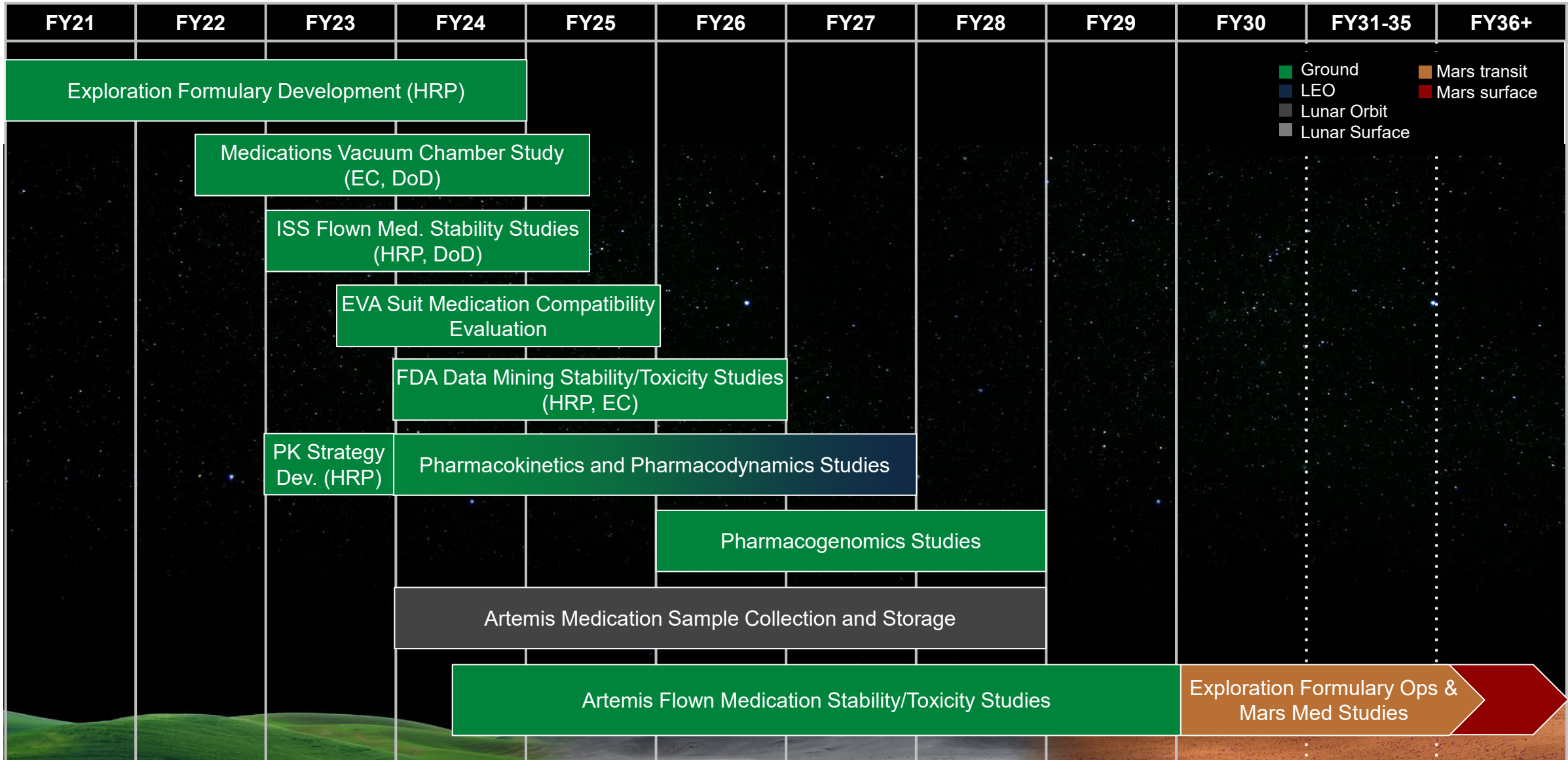
Safe and Effective Pharmaceuticals



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



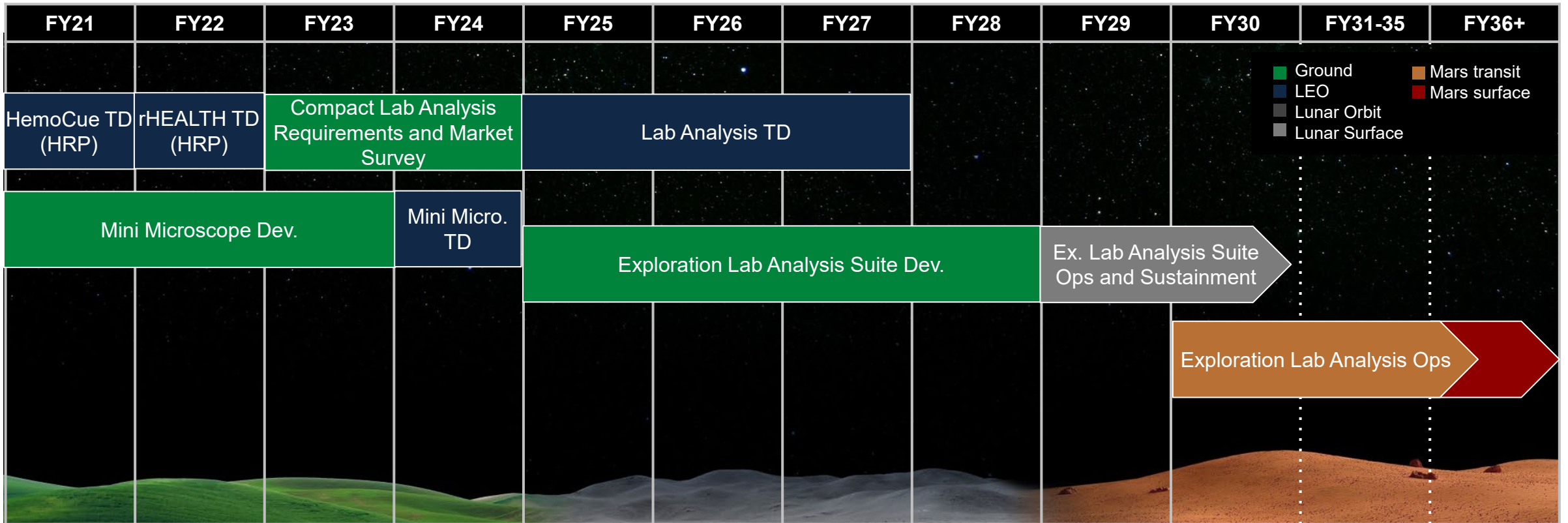
Safe and Effective Pharmaceuticals



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 in-situ to enable Earth independent human research and medical operations for exploration missions with limited sample return capability.	Medical Conditions Food and Nutrition Pharm





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.**