Earth-Independent Medical Operations (EIMO) Concept of Operations (ConOps)

Human Research Program
Exploration Medical Capability Element

HRP IWS
13 February 2024

Marina Parker, PhD, Mike Krihak, PhD, Chris Laing, Jorge Bardina, PhD, Arian Anderson, MD

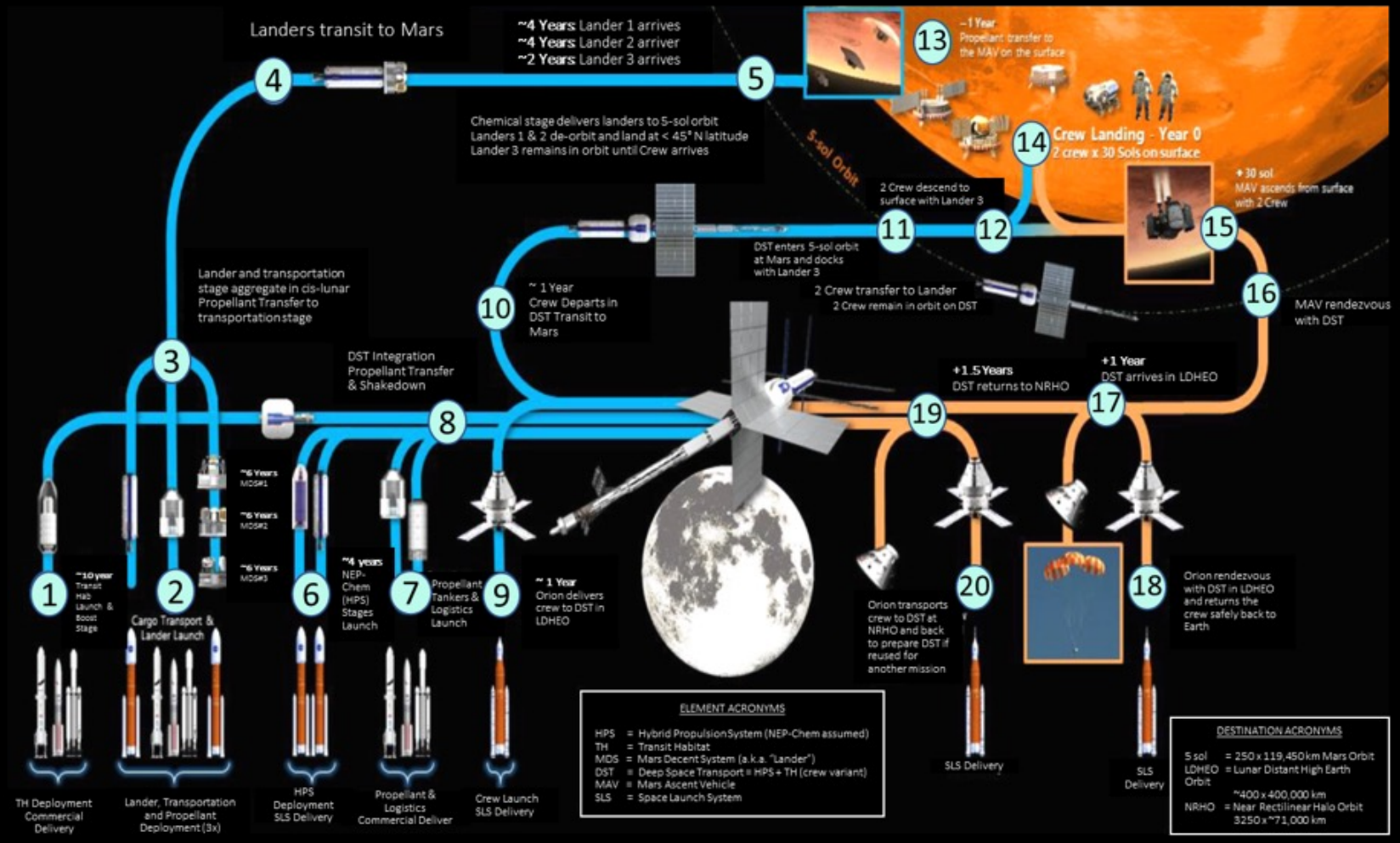
"Expanding the Boundaries of Space Medicine and Technology"

ExMC
EXPLORATION MEDICAL CAPABILITY

- **Progressive Earth-independent** crew health & performance systems for Mars-class missions
- Monitor and maintain crew health and performance during **communication delays and in an environment that does not allow emergency evacuation or terrestrial medical assistance**
- **Validate readiness of systems and operations** to support crew health and performance for the initial human Mars exploration campaign

Notional Mars Mission Overview

Short Stay, Date-Agnostic (Events = # years before Boots on Mars)



As Distance from Earth ↑, Medical Risk ↑

International Space Station → Gateway → Lunar Surface → Mars Transit

CURRENT STATE

- 180-day to 360-day mission duration
- Strong consumables resupply
- Real-time communications
- Regular sample returns to Earth
- Emergency evacuations possible
- Relatively large internal volume
- Limited onboard medical care (Earth-reliant)

EXPLORATION CLASS MISSION

- 650-day to > 900-day mission duration
- Zero consumables resupply
- No real-time communications + blackouts
- No sample returns to Earth
- No evacuations possible
- (Likely) much smaller internal volume
- Expanded onboard medical care (crew/vehicle-reliant)

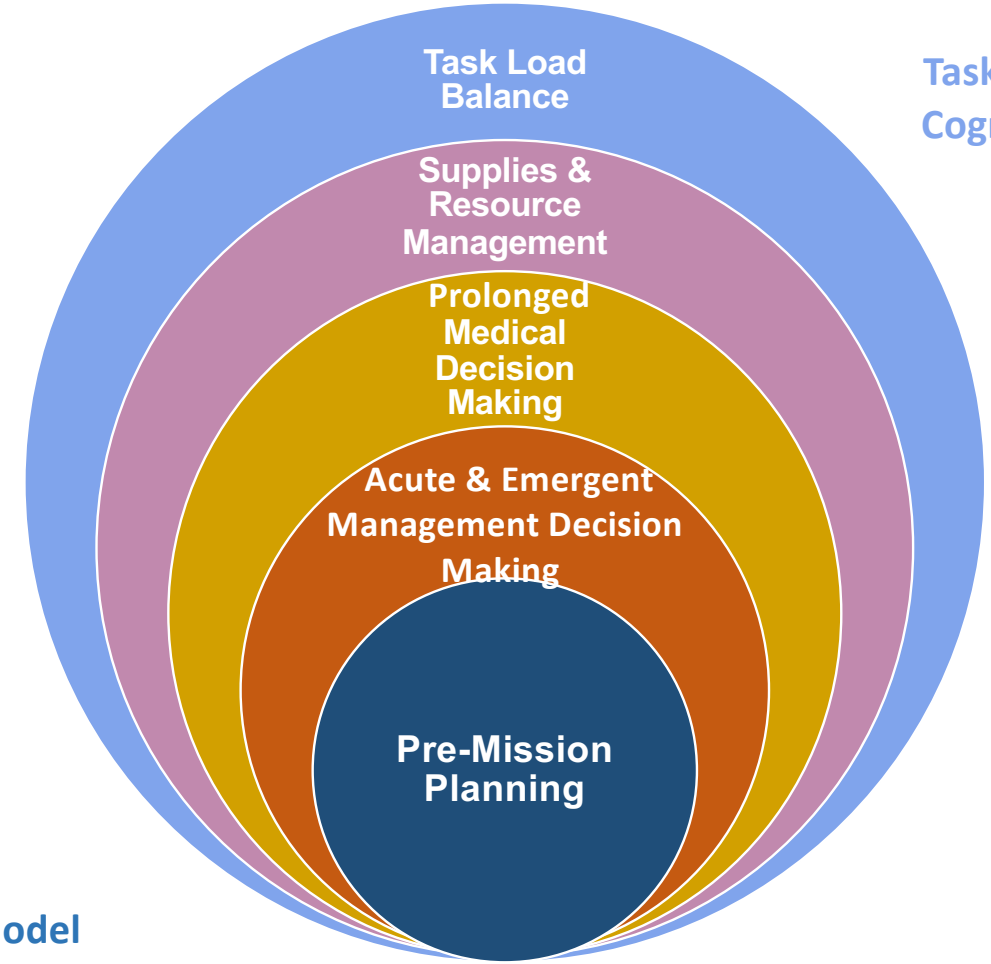
EIMO ConOps Aims

- EIMO – The gradual transition of medical care and decision making from terrestrial to space-based assets, enabling support of astronaut health and performance and reducing overall mission risk

Initial Expectations

- Purpose – Systems Engineering (SE) Team to provide a *preliminary* vision/concept of an EIMO Medical System for Mars via Concept ConOps and Foundational Requirements
  - Pave the way for an Earth Independent Medical System – to be revised over time to fully capture stakeholders' Needs, Goals, and Objectives (NGOs)
- Scope – EIMO Concept of Operations highlighting crew and system autonomy

EIMO Components



Task Switching
Cognitive Load

Limited Mass/Volume
∅ Re-supply

↑ On-Board KSAs

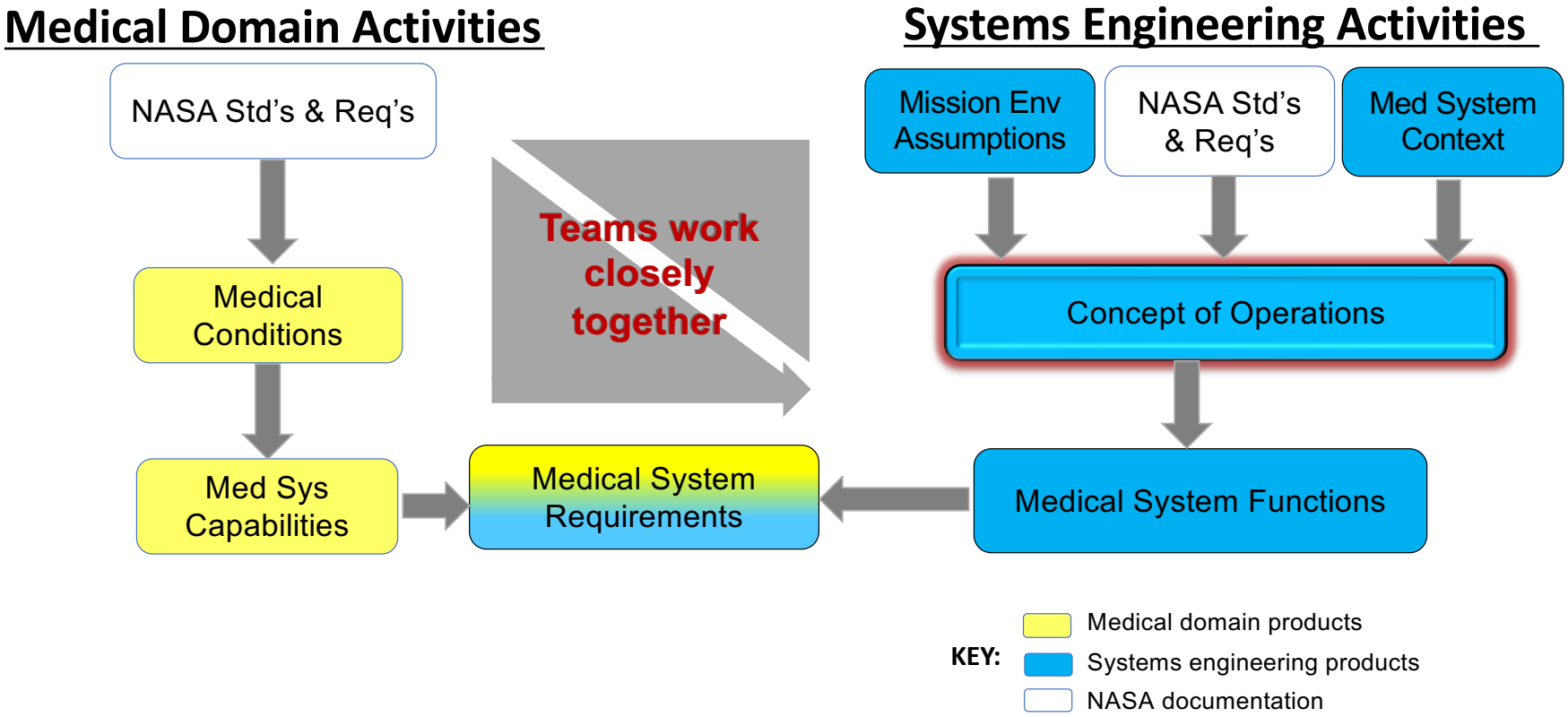
Medical KSA and/or augmentation tools

Medical Model

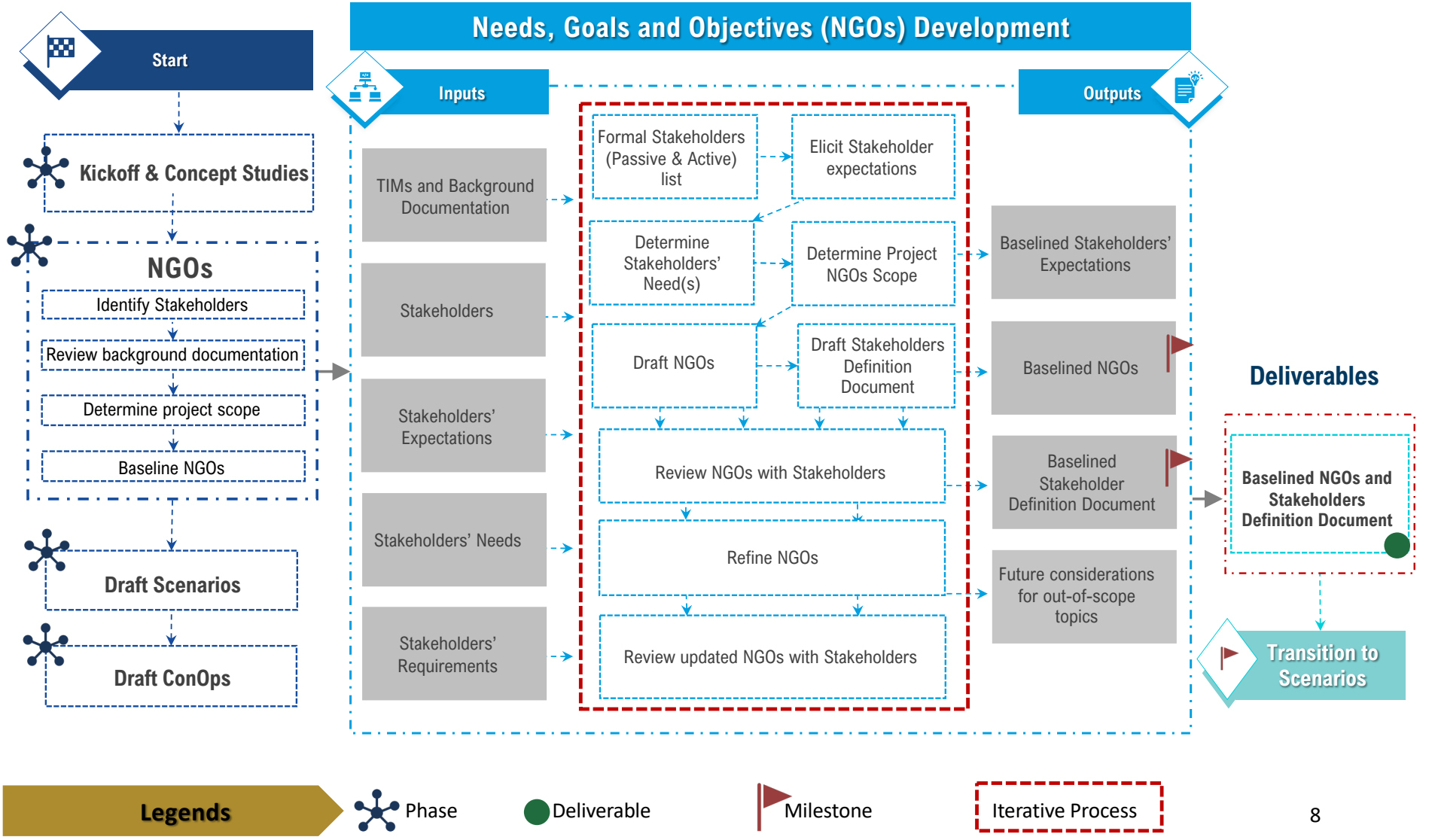
KSAs – Knowledge Skills and Abilities

ExMC SE Process

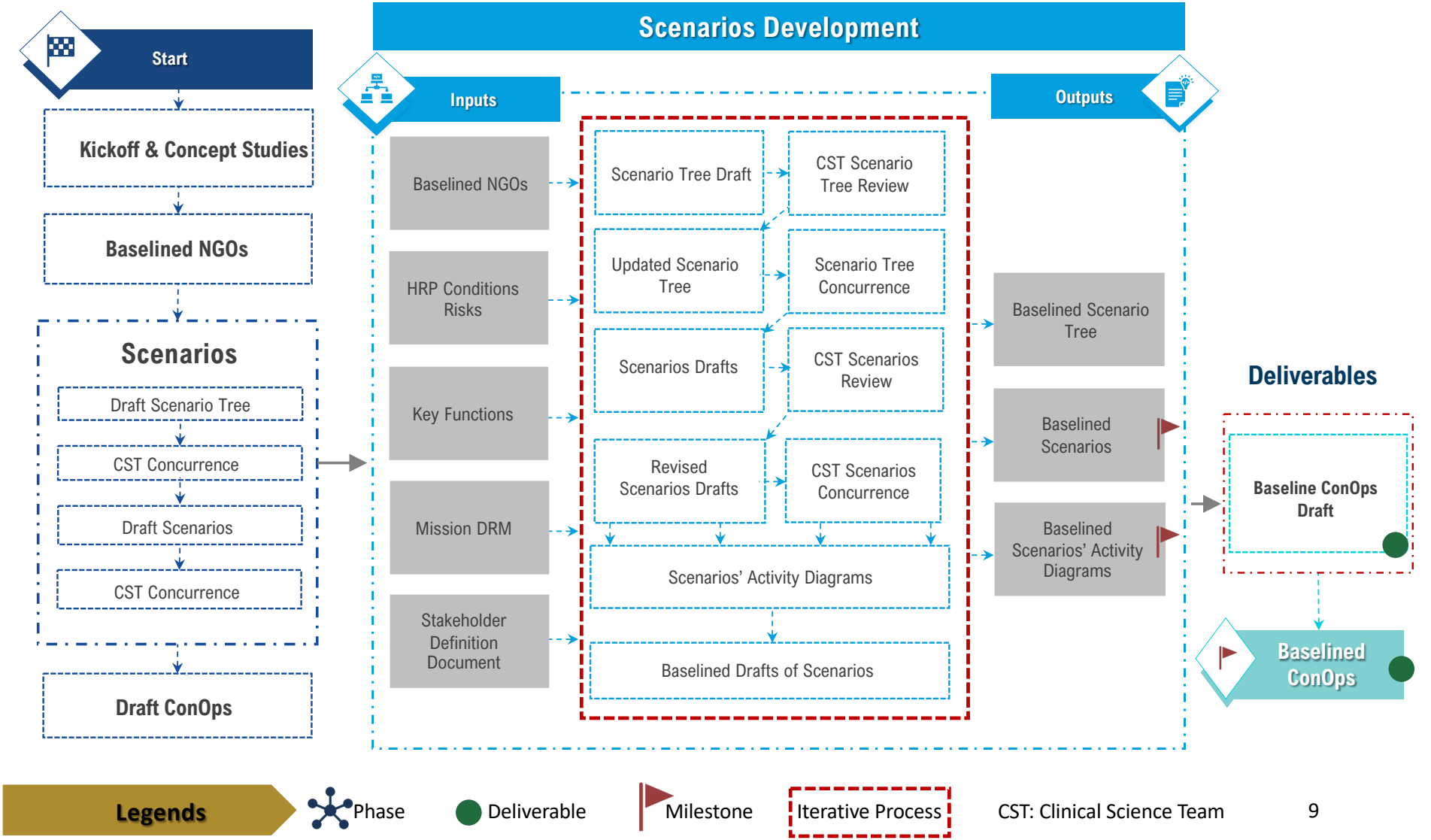
- A process of integrating clinical and systems engineering inputs to generate recommendations for medical system design



EIMO Concept of Operations Process



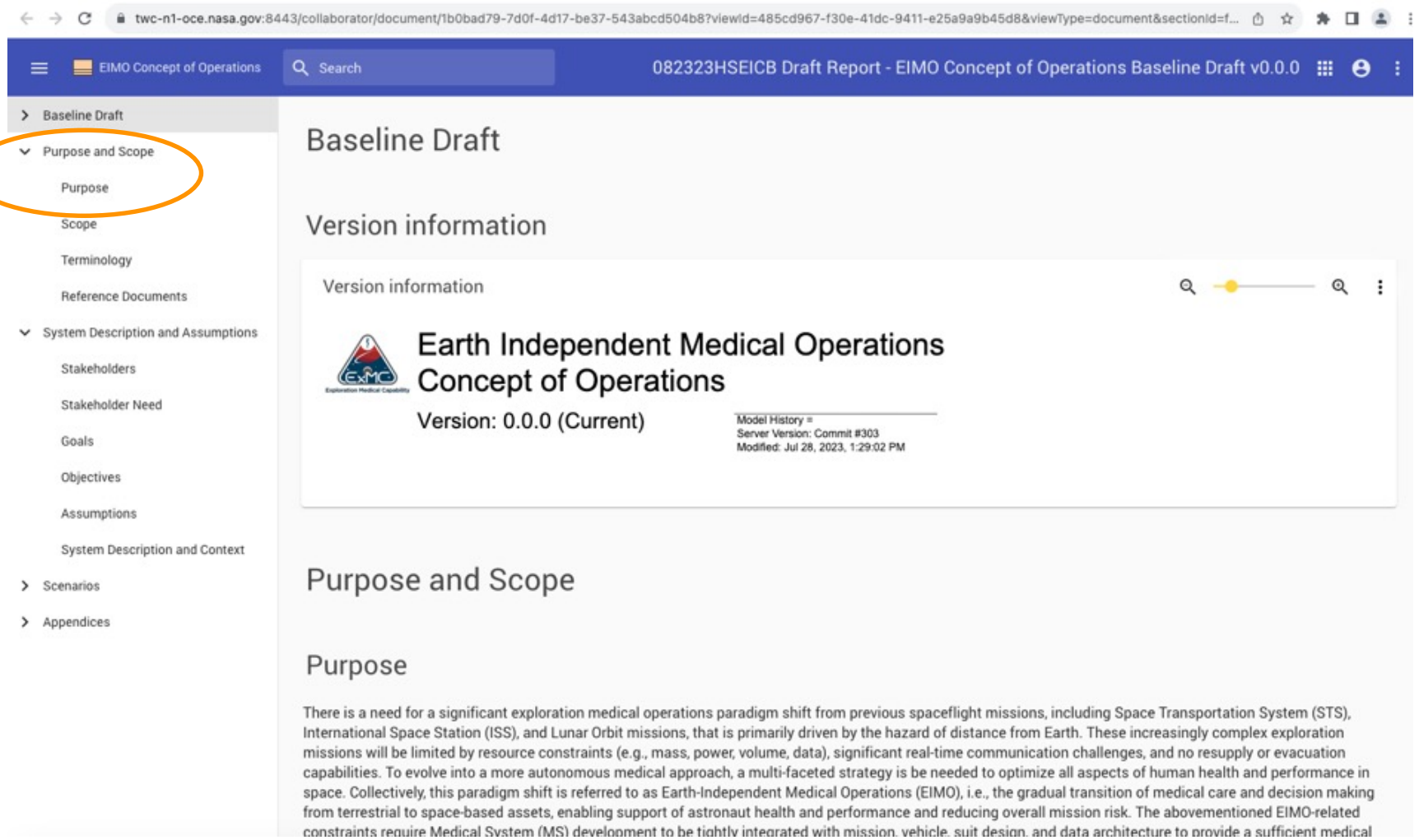
EIMO Concept of Operations Process



Legends Phase Deliverable Milestone Iterative Process

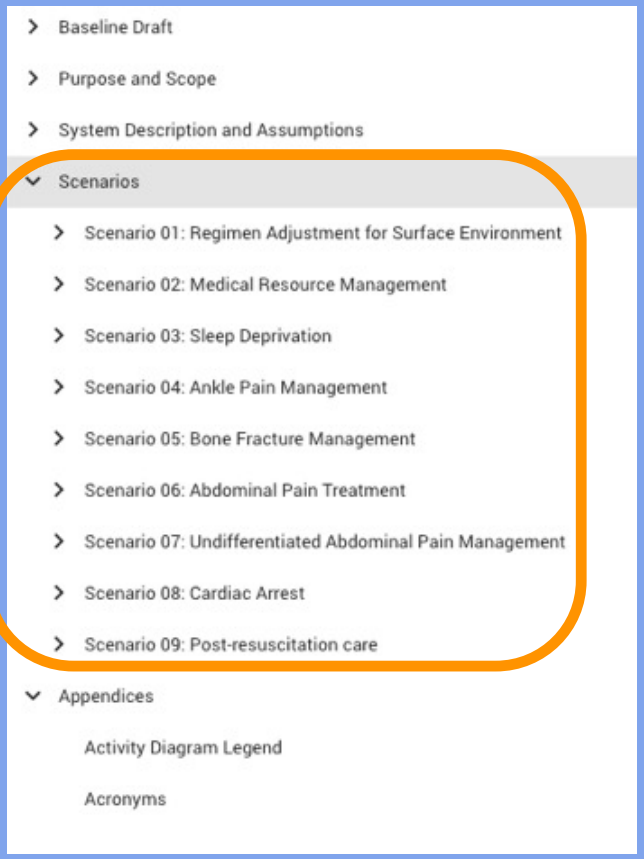
CST: Clinical Science Team

EIMO Concept of Operations Overview



EIMO Scenarios Content

Nine scenarios developed for the ConOps

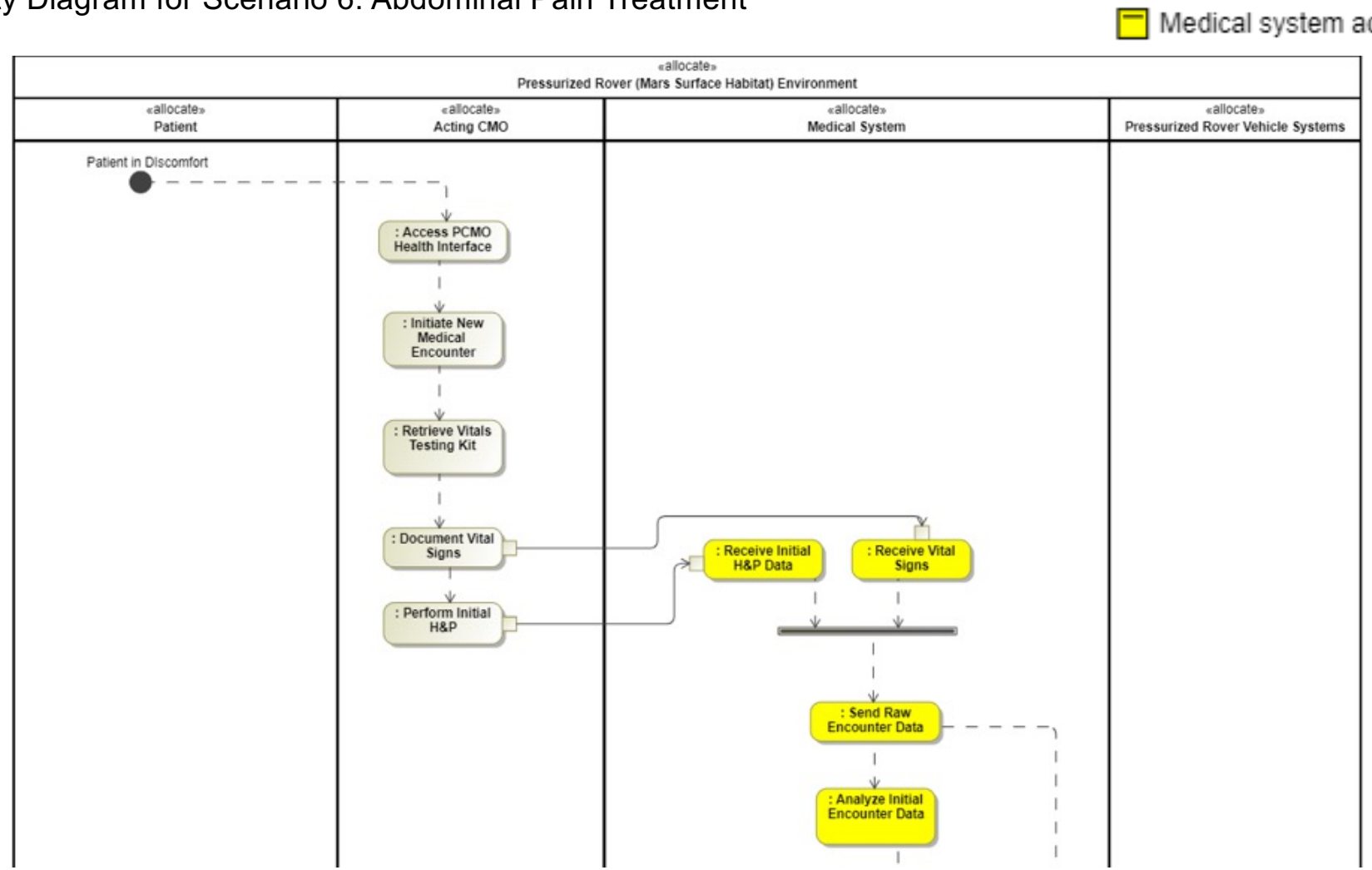


Each Scenario contains:

i. Scenario Information
ii. Highlighted EIMO Components
iii. Context
iv. Relevant EIMO Objectives
v. Environment
vi. Assumptions
vii. Highlighted Functionality
viii. Narrative
ix. Activity Diagram

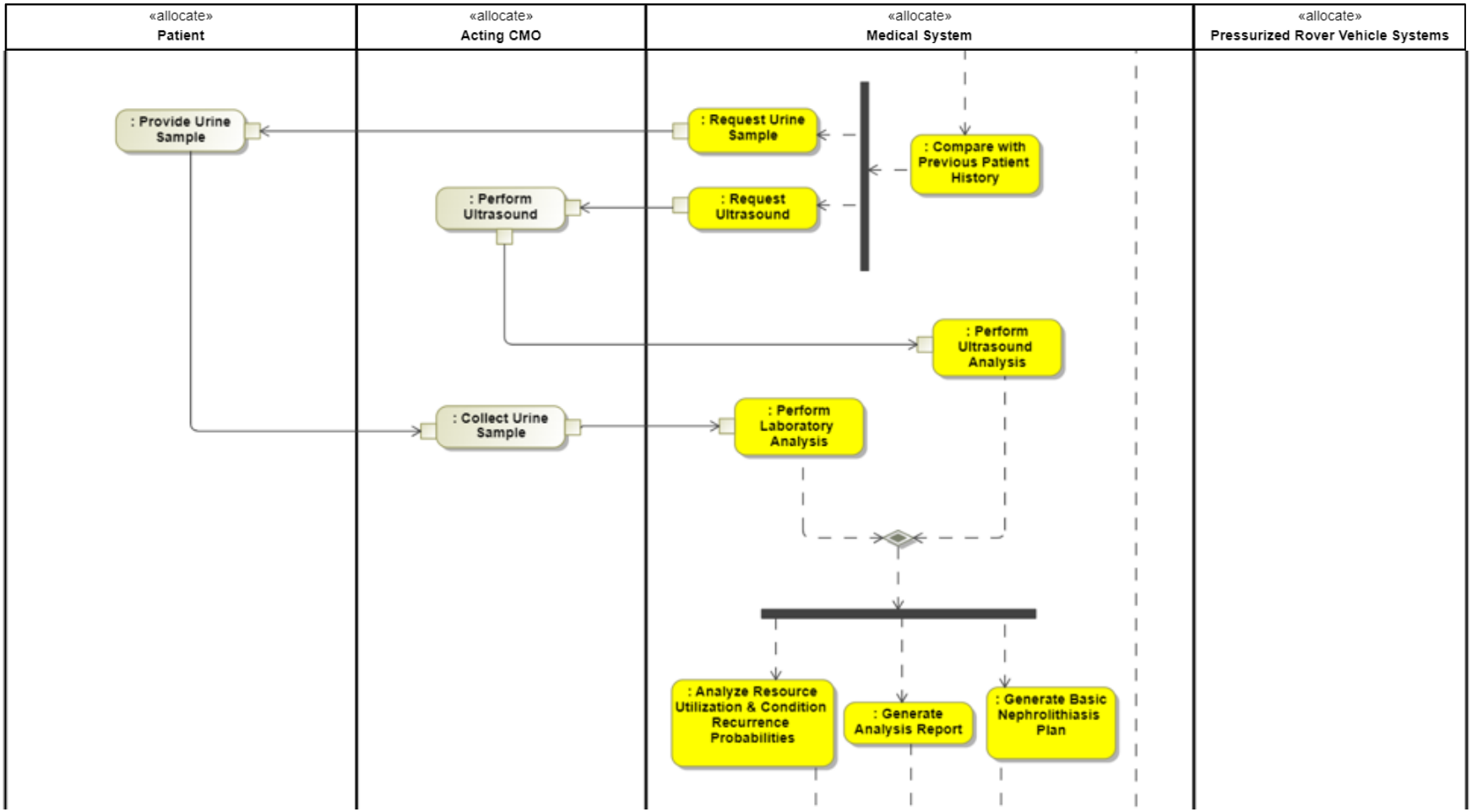
ConOps Model Report

Activity Diagram for Scenario 6: Abdominal Pain Treatment



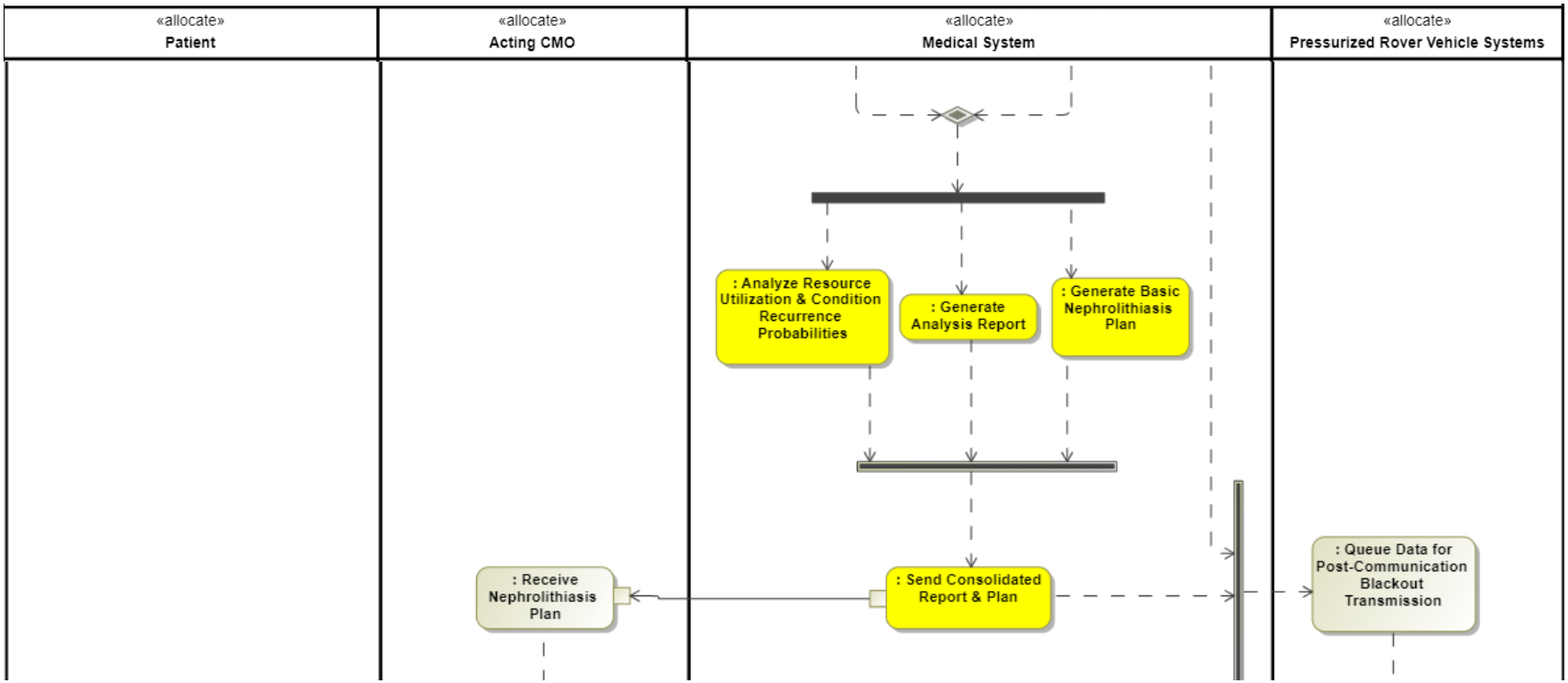
ConOps Model Report

Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued



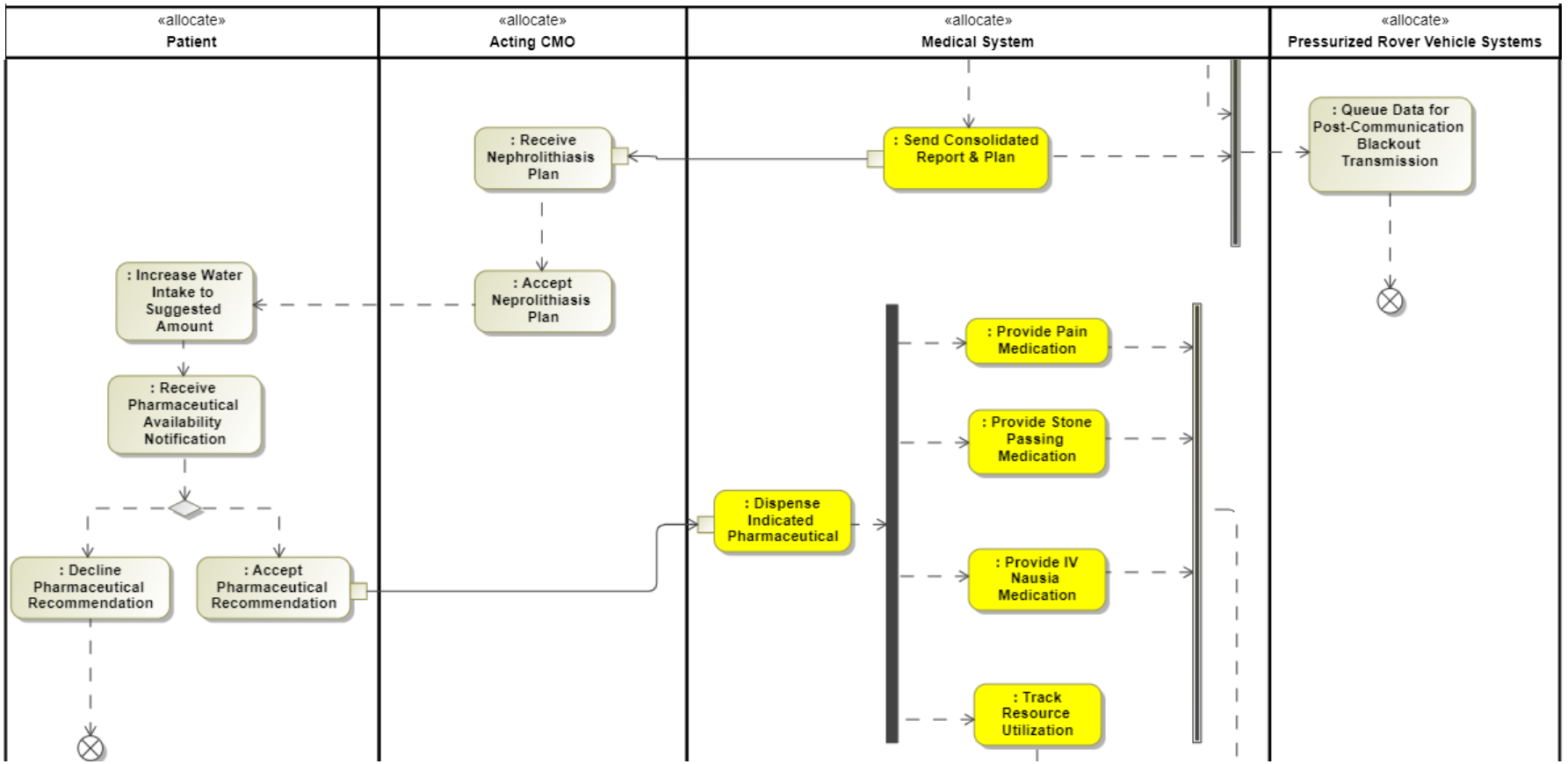
ConOps Model Report

Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued



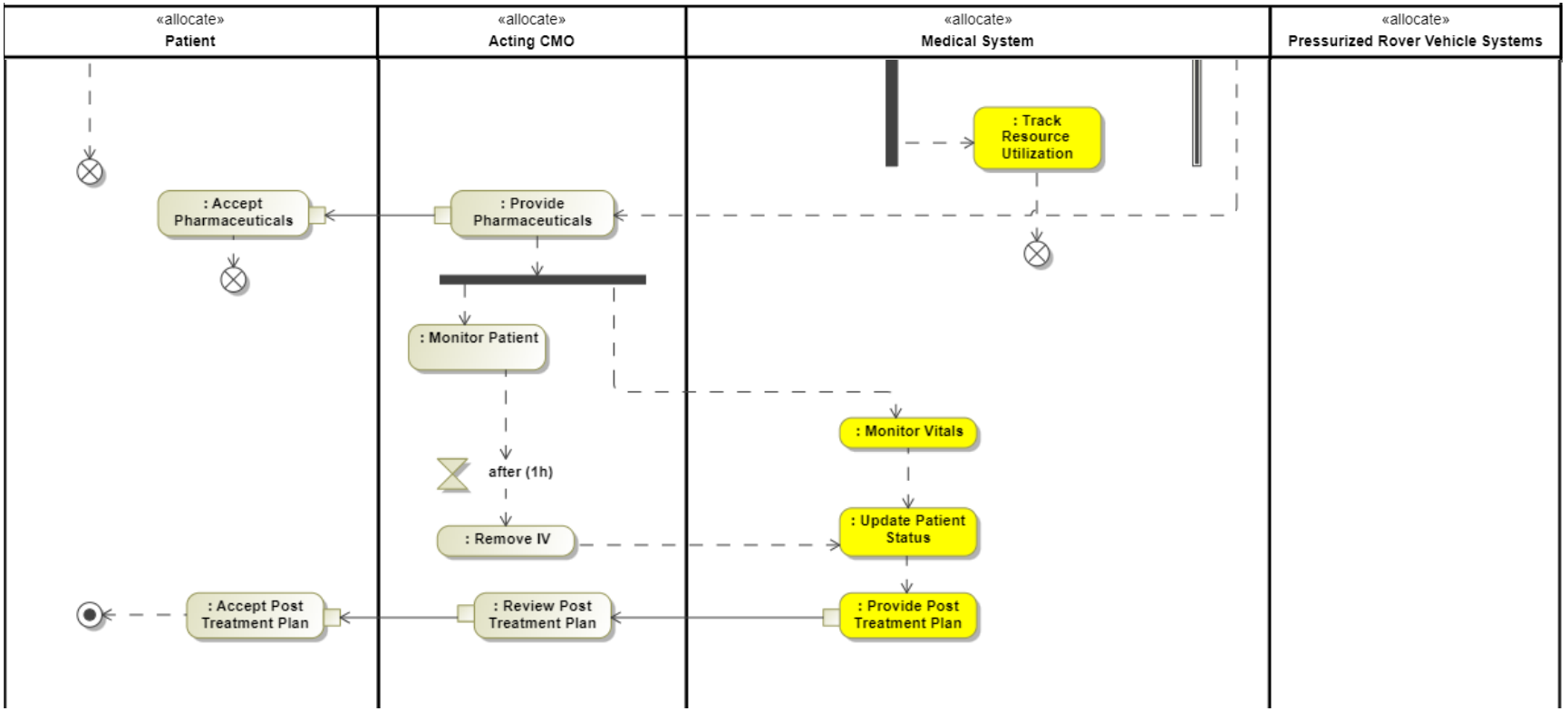
ConOps Model Report

Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued



ConOps Model Report

Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued



To view our ConOps Model Report:

- Email Marina Parker, Mike Krihak or Chris Laing to for access approval
  - NAMS Requests needed for web access are handled by the SE Team

Status of EIMO System Model

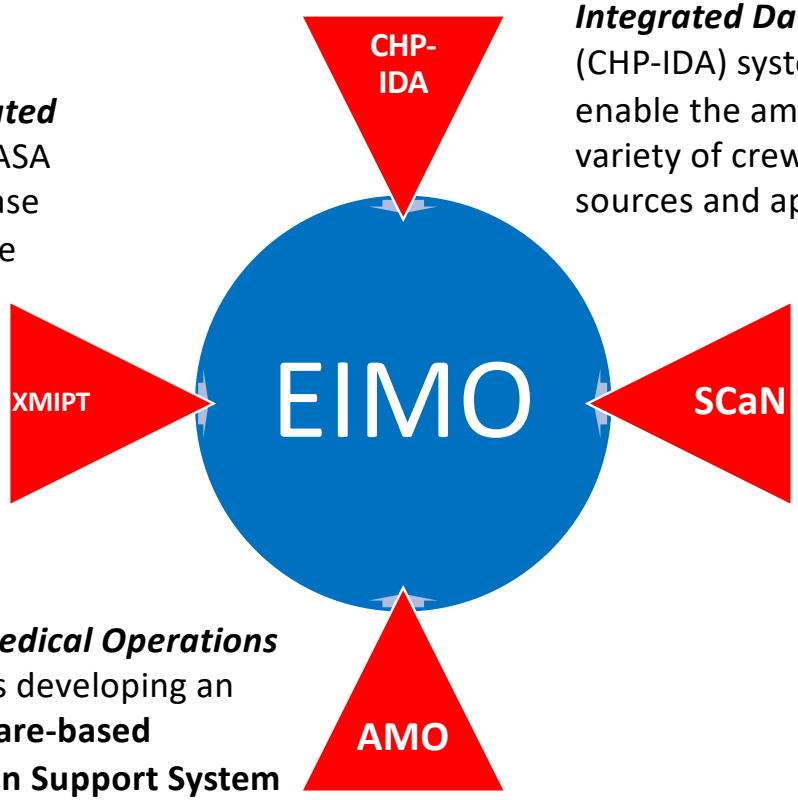
- Summary:
  - The EIMO ConOps was a joint development effort between the ExMC System Engineering Team and the ExMC Clinical Science Team.
  - The EIMO ConOps is comprised of the needs, goals, and objectives that are supported by nine medical scenarios in an MBSE model.
  - Currently reworking ConOps content to better highlight clinical practice differences present under EIMO conditions
  - We have begun requirements development for L2,3, & 4 baseline delivery

Questions and Discussions

EIMO Intersects

Exploration Medical Integrated Product Team (XMIPT) at NASA is seeking solutions to increase the mass, power, and volume efficiency of its exploration medical system.

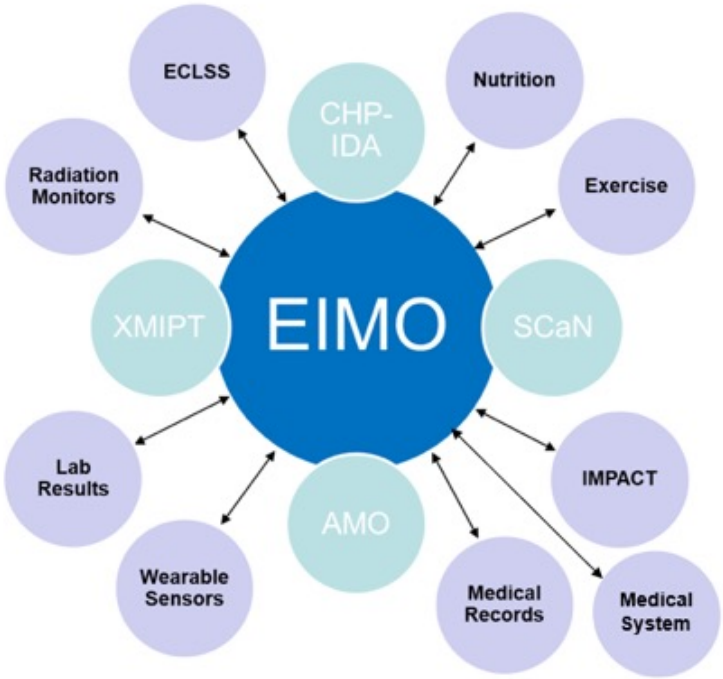
Crew Health and Performance – Integrated Data Architecture (CHP-IDA) system as a platform to enable the amalgamation of a variety of crew-relevant data sources and applications.



Autonomous Medical Operations (AMO) project is developing an on-board **software-based Medical Decision Support System (MDSS)** which will enable astronauts to diagnose and treat emergent conditions in a timely manner.

Space Communication and Navigation (SCaN) provides communications and navigation services over the full operational life cycle of a mission from launch to de-orbit.

EIMO Ecosystem: a "System of Systems"



EIMO utilizes data streams from multiple sources to assess Crew Health & Performance and makes recommendations using AI-supported natural language processing and machine learning techniques

EIMO (Earth Independent Medical Operations)
ECLSS (Environmental Control & Life Support System)
CHP-IDA (Crew Health & Performance Integrated Data Architecture)
XMIPT (Exploration Medical Integrated Product Team)
AMO (Autonomous Medical Operations)
SCaN (Space Communications and Navigation)
IMPACT (Informing Mission Planning via Analysis of Complex Tradespaces)

Components Overview

1

Pre-Mission Planning

- On-board knowledge, skill & abilities (KSA) requirements
- Allocation & training of KSA by crewmember
- On-board routine training / practice modules / Just-In-Time Training (JITT)

2

Acute & Emergent Management Decision Making

- Communication latency and reduced data transmission bandwidth
- KSA with on-board Clinical Decision Support System (CDSS)
  - Leverage mixed reality augmentation, AI, & machine learning

3

Prolonged Medical Decision Making

- Non-emergent medical condition management less dependent on real time ground support
- Requirement for high baseline KSA and access to on-board CDSS

Components Overview

4

Supplies & Resource Management

- Exploration class missions cannot rely on resupply.
- Expiration dates, lack of maintenance, and environmental/operational stressors = selective supplies to account for mass, volume, stability, durability, and re-usability

5

Task Load Management

- Delays / lack of ground support = increased task demand, task switching & higher cognitive load (all shown to impair decision making)
- Identification of tasks that can be **automated** to reduce cognitive load demands
  - Inventory, resource location, storage & retrieval of medical record information