



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

Human Research Program  
Exploration Medical Capability Element

HRP IWS  
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“Expanding the Boundaries of Space Medicine and Technology”

# MOON TO MARS OBJECTIVES

SEPTEMBER 2022

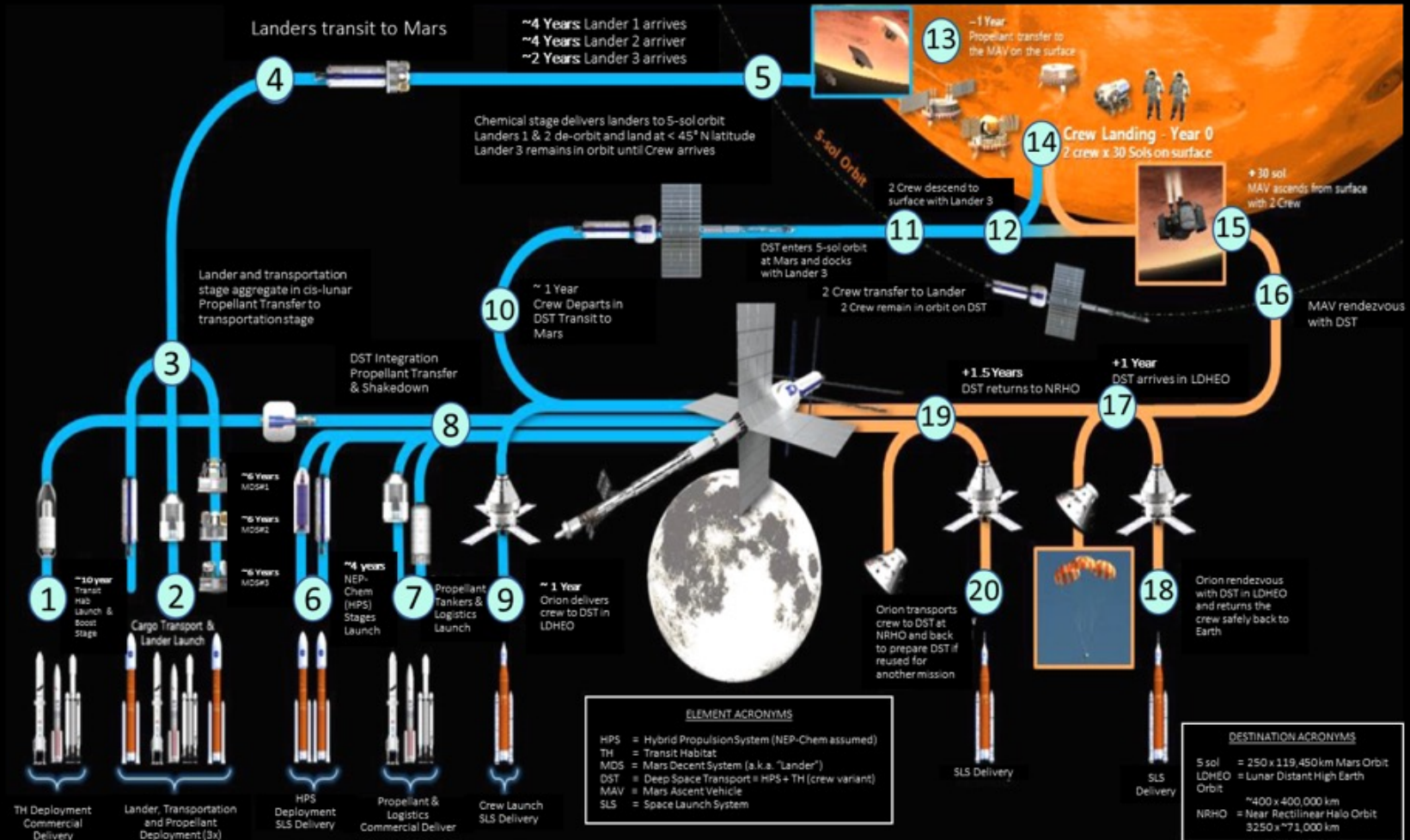
- **Progressive Earth-independent** crew health & performance systems for Mars-class missions
- Monitor and maintain crew health and performance during **communication delays and in an environment that does not allow emergency evacuation or terrestrial medical assistance**
- **Validate readiness of systems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



**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**

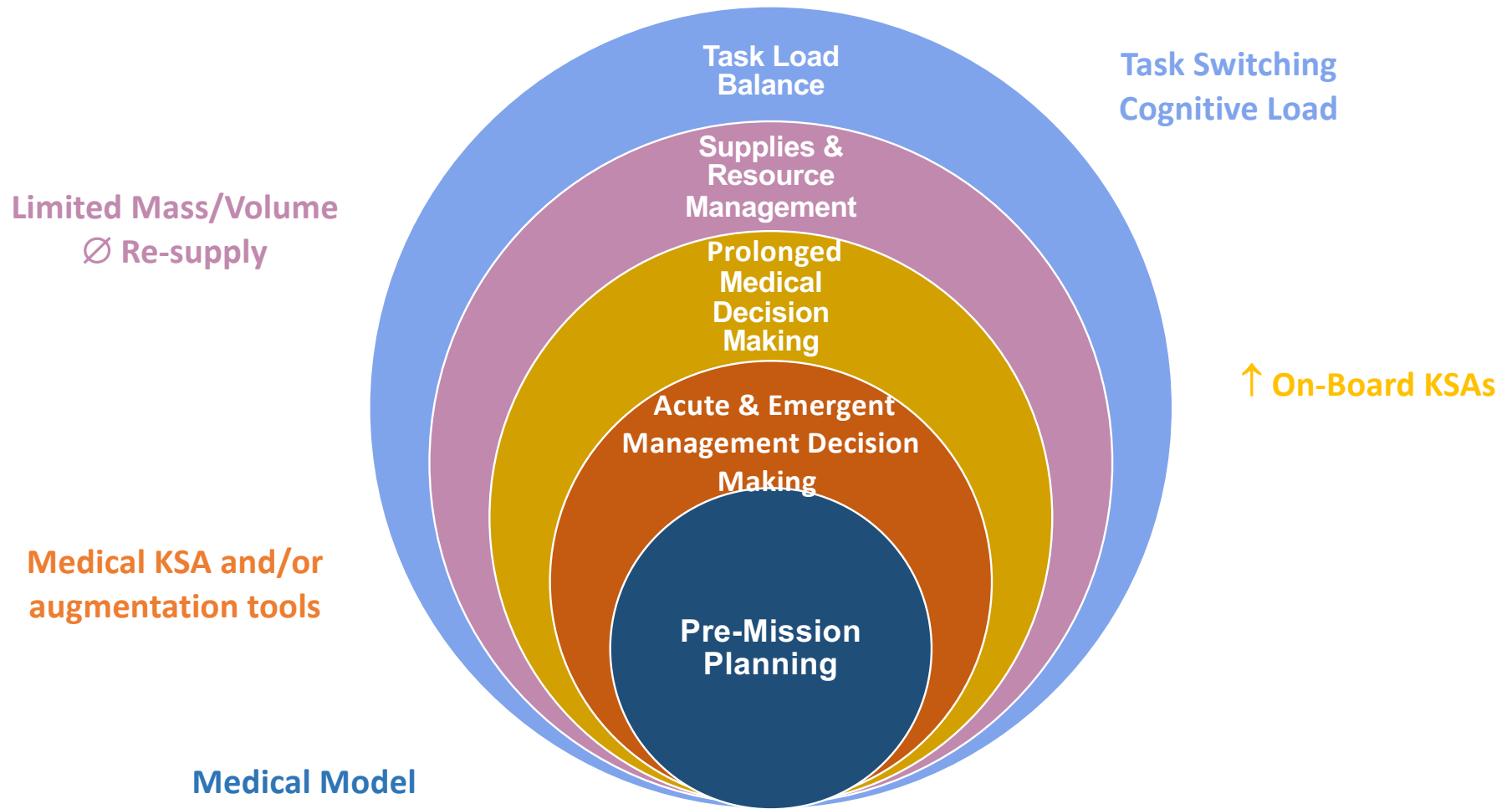
- 650-day to > 900-day mission duration
- Zero consumables resupply
- No real-time communications + blackouts
- No sample returns to Earth
- No evacuations possible
- (Likely) much smaller internal volume
- Expanded onboard medical care (crew/vehicle-reliant)



- **EIMO** – 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

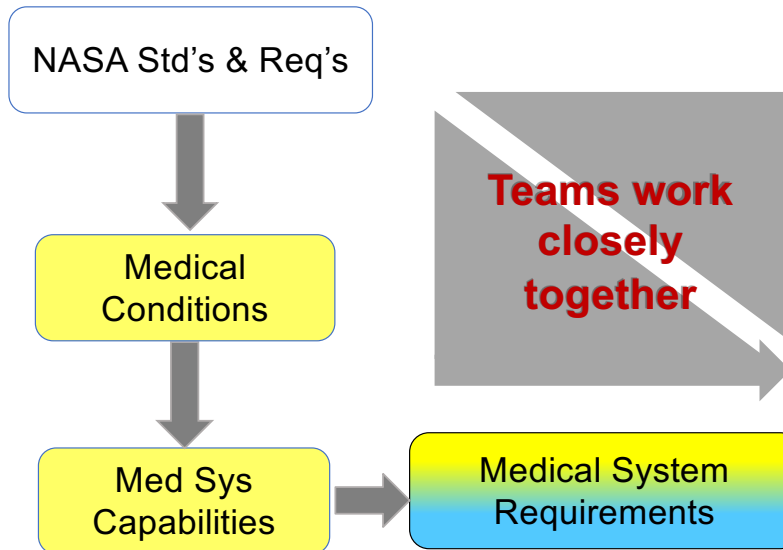
- **Purpose** – Systems Engineering (SE) Team to provide a *preliminary* vision/concept of an EIMO Medical System for Mars via Concept ConOps and Foundational Requirements
  - Pave the way for an Earth Independent Medical System – to be revised over time to fully capture stakeholders' Needs, Goals, and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



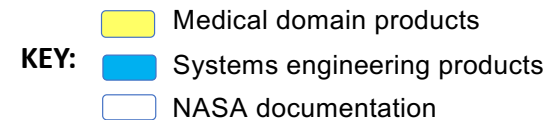
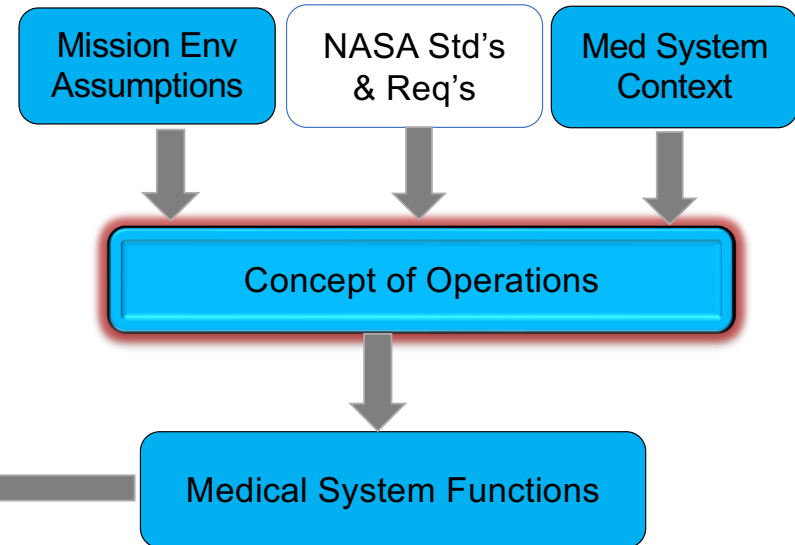


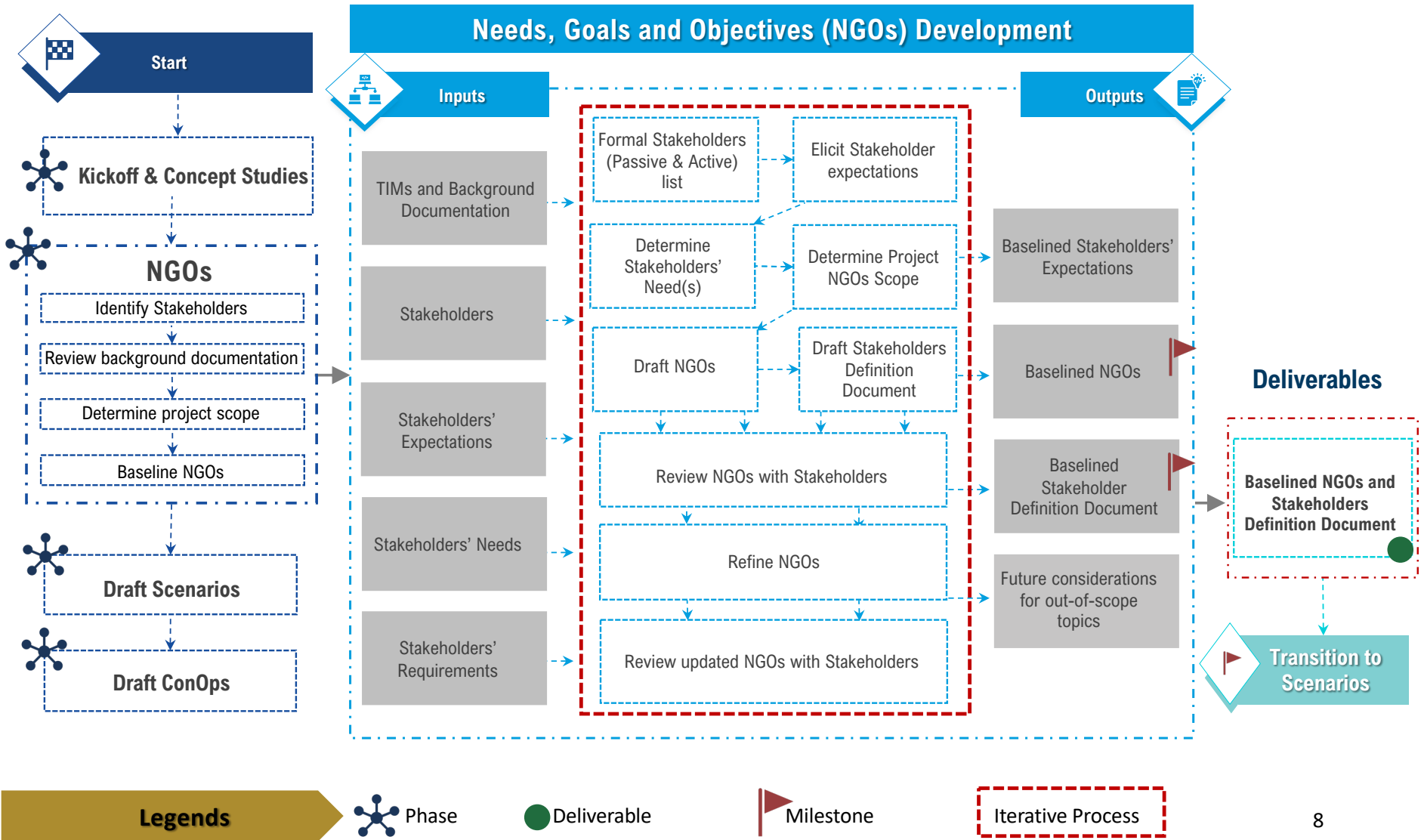
- A process of integrating clinical and systems engineering inputs to generate recommendations for medical system design

## Medical Domain Activities

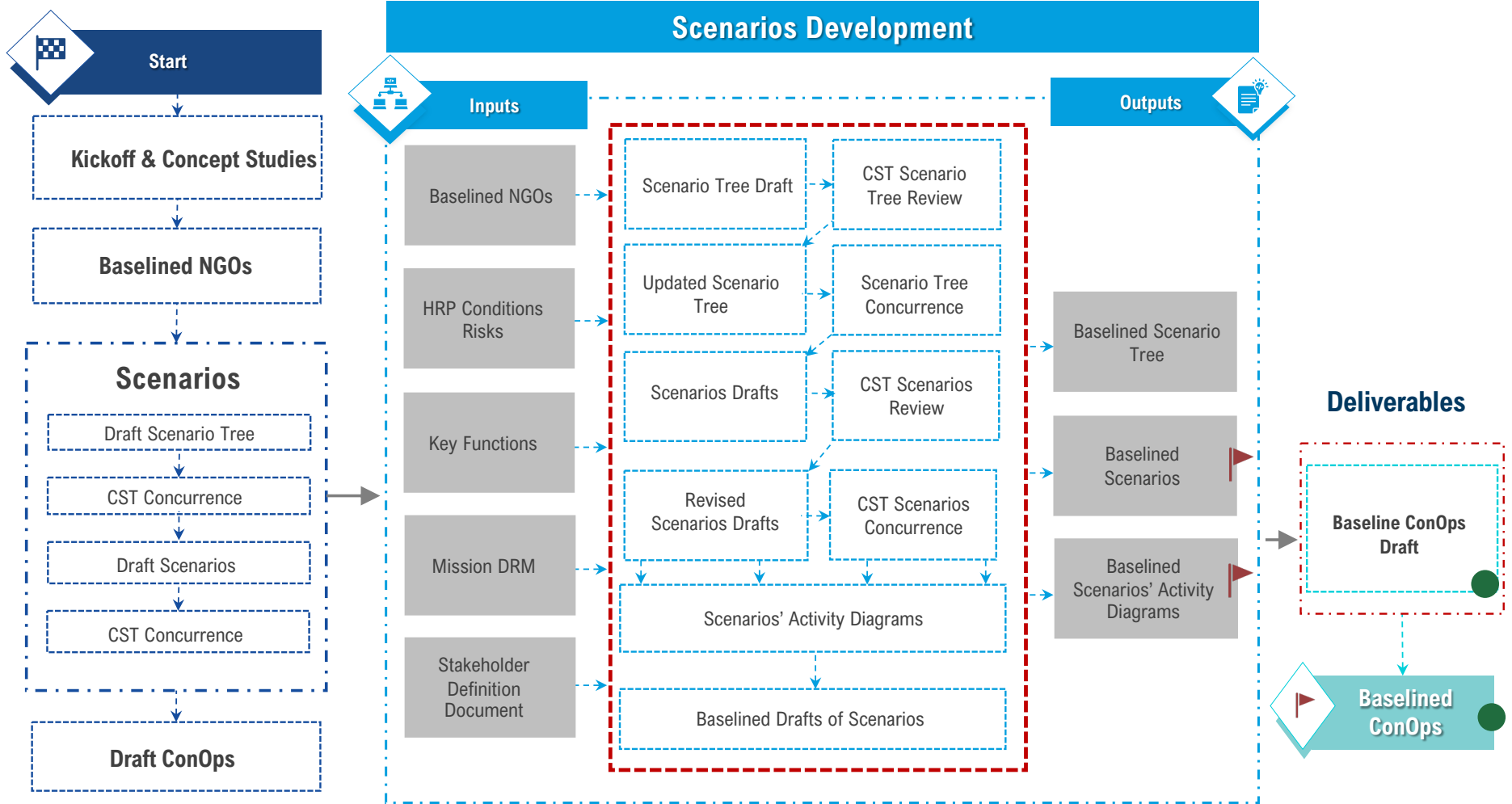


## Systems Engineering Activities









## Legends

- Phase
- Deliverable
- Milestone
- Iterative Process
- CST: Clinical Science Team



twc-n1-occe.nasa.gov:8443/collaborator/document/1b0bad79-7d0f-4d17-be37-543abcd504b8?viewid=485cd967-f30e-41dc-9411-e25a9a9b45d8&viewType=document&sectionId=f...


EIMO Concept of Operations Search 082323HSEICB Draft Report - EIMO Concept of Operations Baseline Draft v0.0.0

- Baseline Draft
  - Purpose and Scope**
    - Purpose**
    - Scope
    - Terminology
    - Reference Documents
  - System Description and Assumptions
    - Stakeholders
    - Stakeholder Need
    - Goals
    - Objectives
    - Assumptions
    - System Description and Context
  - Scenarios
  - Appendices

## Baseline Draft

### Version information

Version information



## Earth Independent Medical Operations Concept of Operations

Version: 0.0.0 (Current)

Model History =  
Server Version: Commit #303  
Modified: Jul 28, 2023, 1:29:02 PM

## Purpose and Scope

### Purpose

There is a need for a significant exploration medical operations paradigm shift from previous spaceflight missions, including Space Transportation System (STS), International Space Station (ISS), and Lunar Orbit missions, that is primarily driven by the hazard of distance from Earth. These increasingly complex exploration missions will be limited by resource constraints (e.g., mass, power, volume, data), significant real-time communication challenges, and no resupply or evacuation capabilities. To evolve into a more autonomous medical approach, a multi-faceted strategy is needed to optimize all aspects of human health and performance in space. Collectively, this paradigm shift is referred to as Earth-Independent Medical Operations (EIMO), i.e., 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. The abovementioned EIMO-related constraints require Medical System (MS) development to be tightly integrated with mission, vehicle, suit design, and data architecture to provide a sufficient medical



## Nine scenarios developed for the ConOps

- > Baseline Draft
- > Purpose and Scope
- > System Description and Assumptions
- ✓ Scenarios
  - > Scenario 01: Regimen Adjustment for Surface Environment
  - > Scenario 02: Medical Resource Management
  - > Scenario 03: Sleep Deprivation
  - > Scenario 04: Ankle Pain Management
  - > Scenario 05: Bone Fracture Management
  - > Scenario 06: Abdominal Pain Treatment
  - > Scenario 07: Undifferentiated Abdominal Pain Management
  - > Scenario 08: Cardiac Arrest
  - > Scenario 09: Post-resuscitation care
- ▼ Appendices
  - Activity Diagram Legend
  - Acronyms

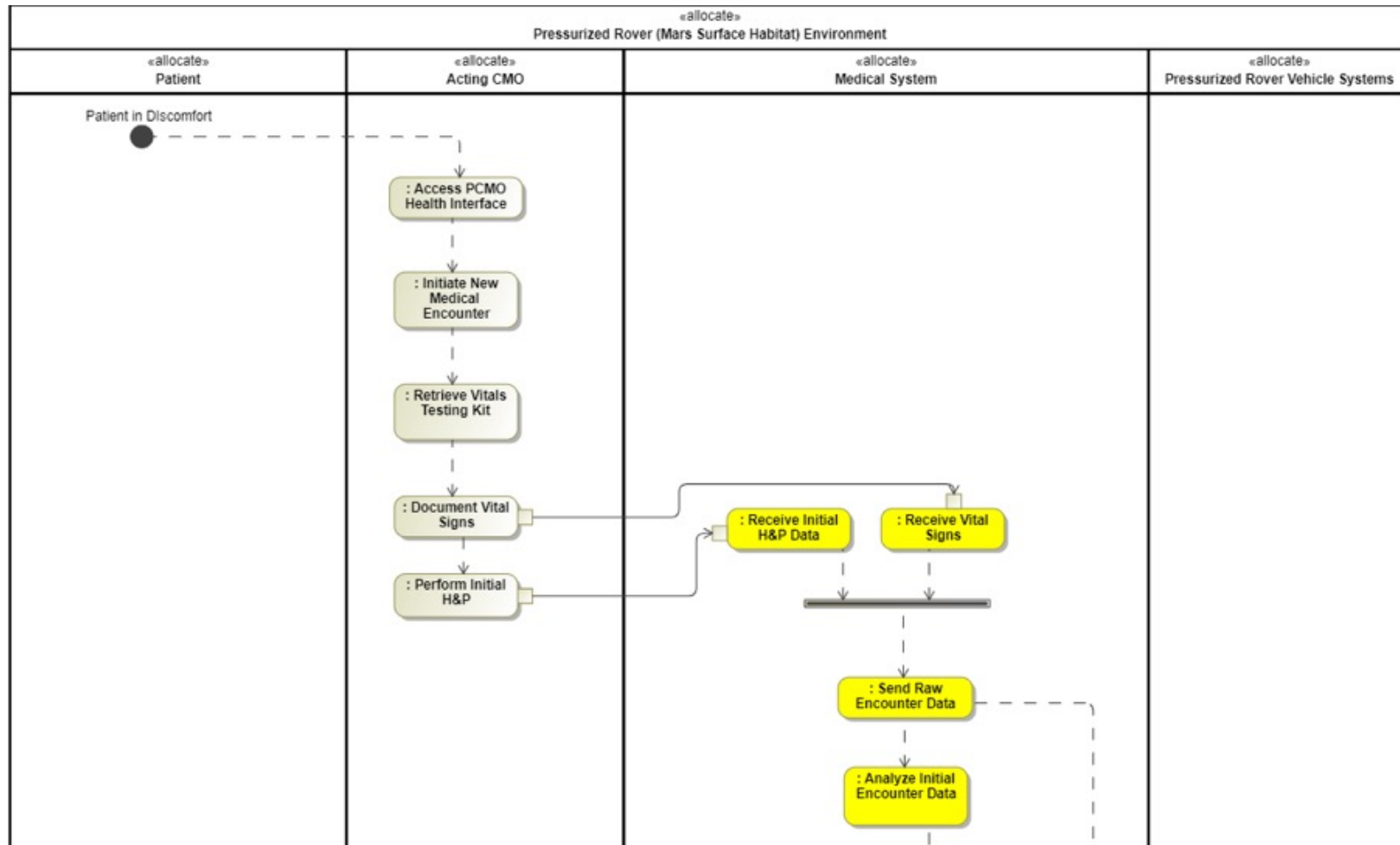
## Each Scenario contains:

- 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




## Activity Diagram for Scenario 6: Abdominal Pain Treatment

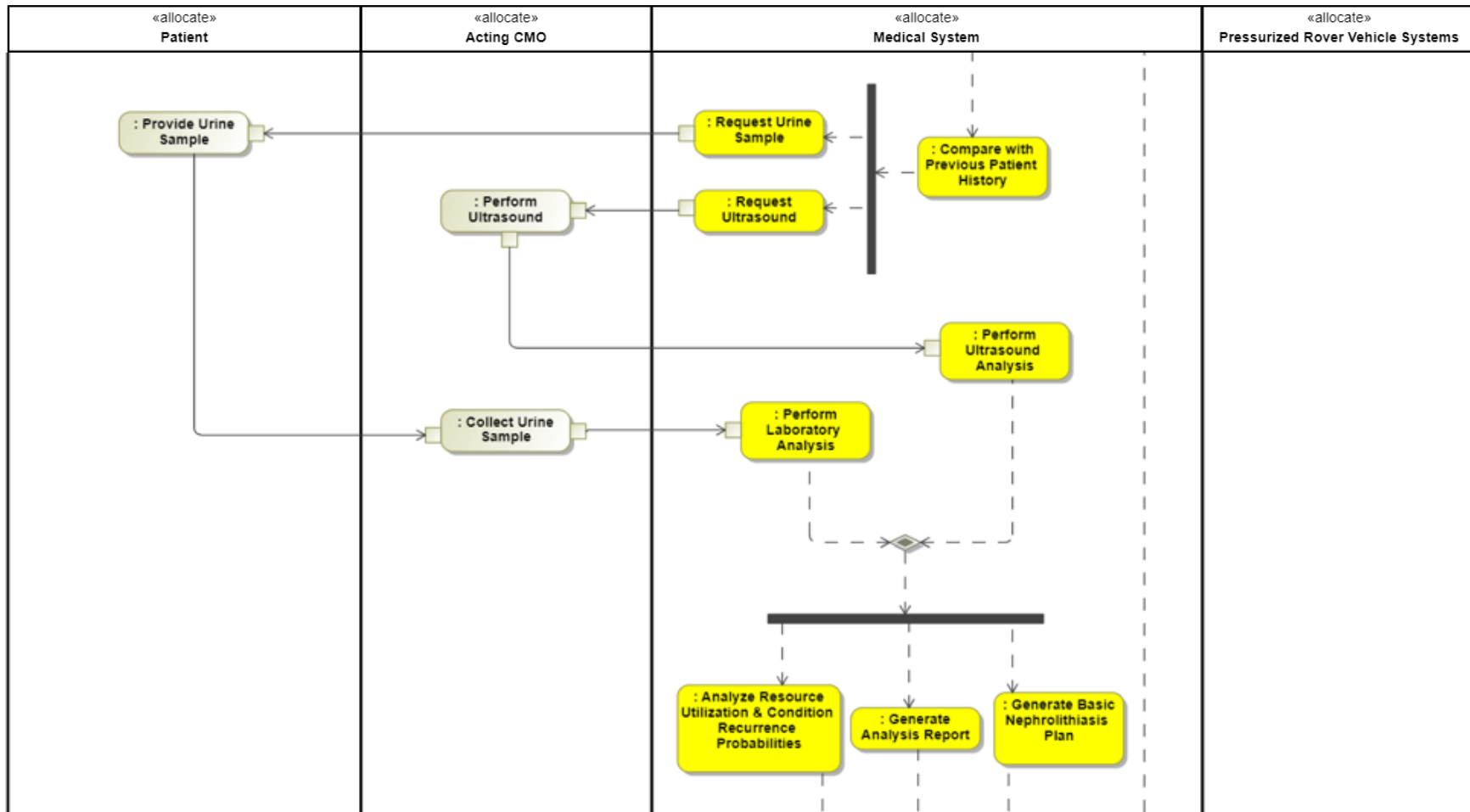
Medical system actions





## Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued

 Medical system actions

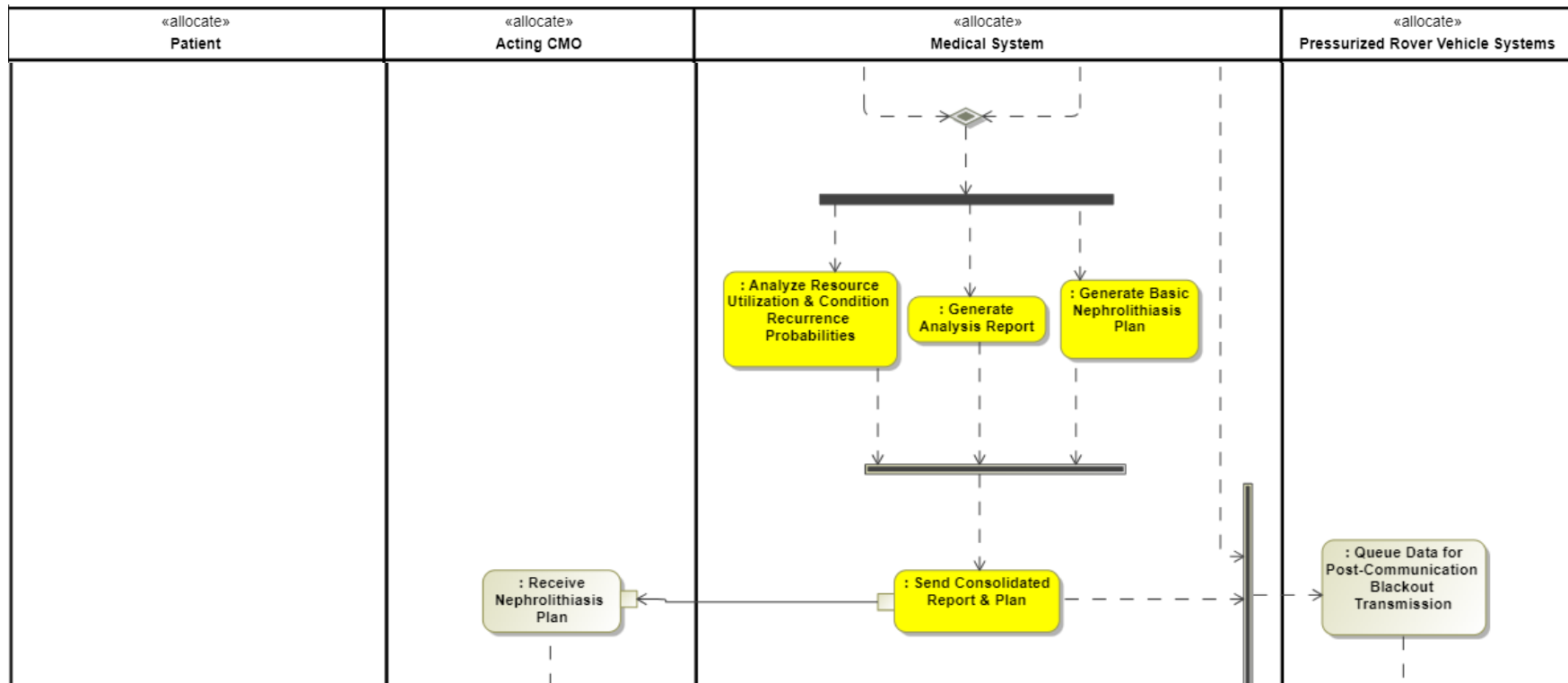






## Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued

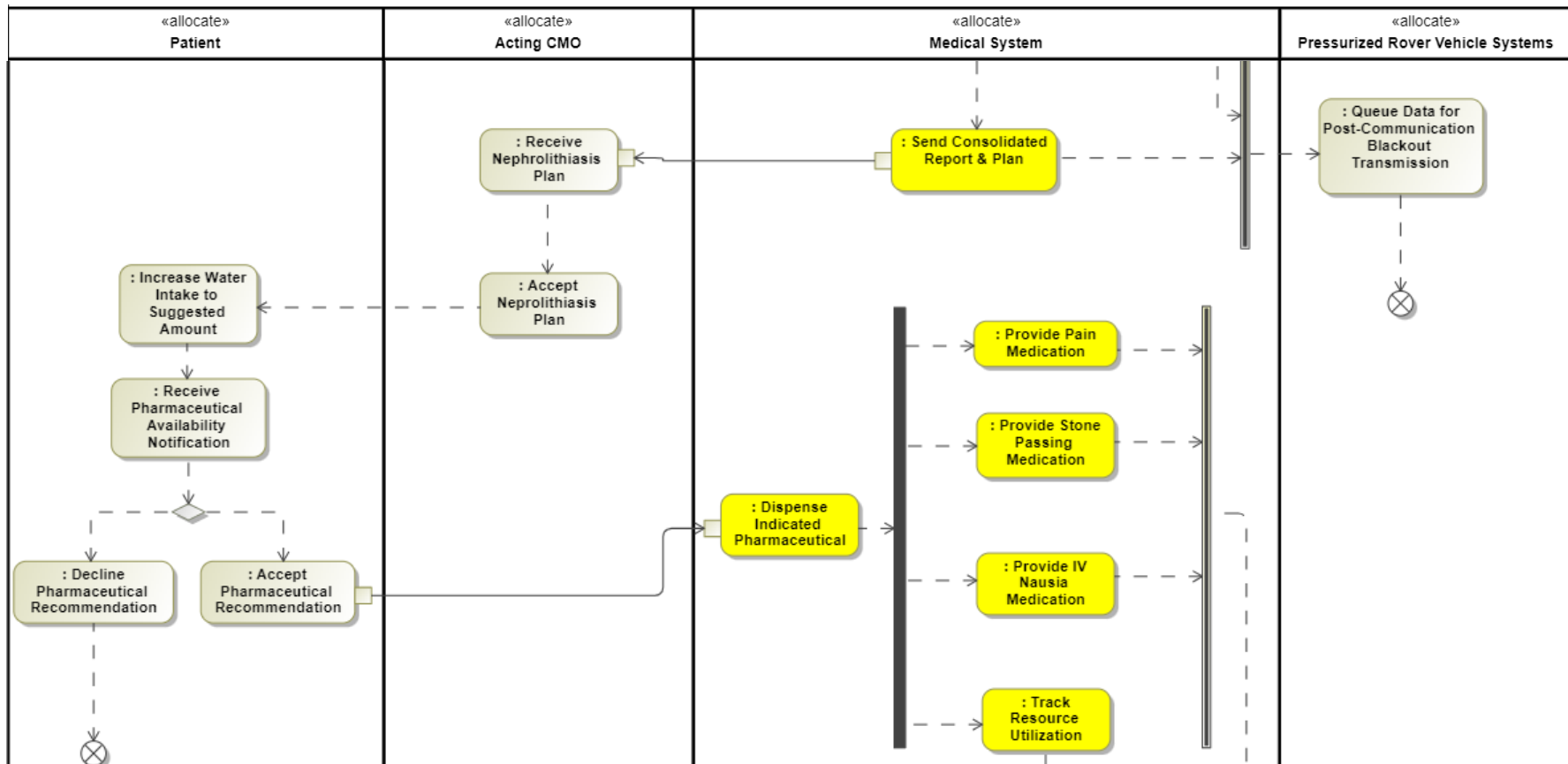
Medical system actions





## Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued

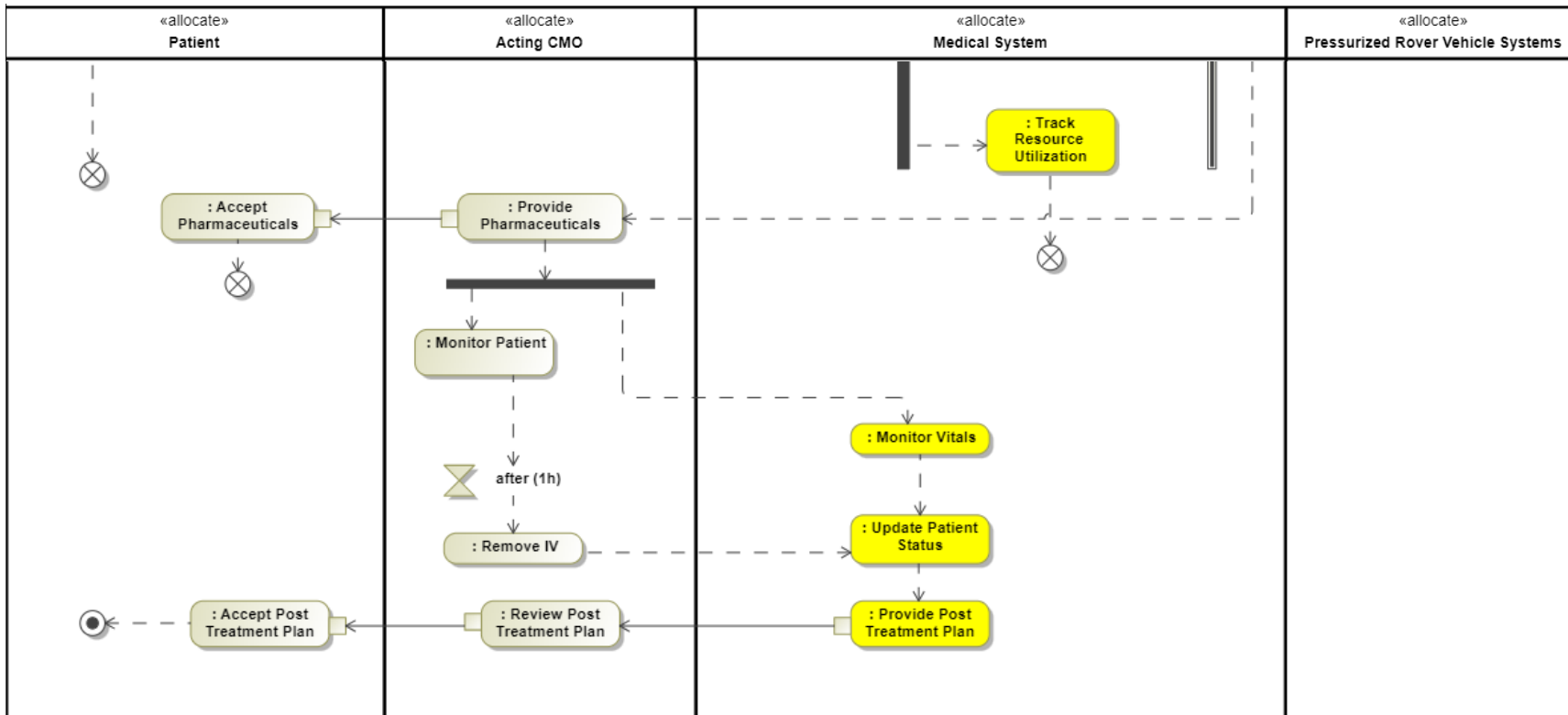
Medical system actions





## Activity Diagram for Scenario 6: Abdominal Pain Treatment Continued

Medical system actions



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

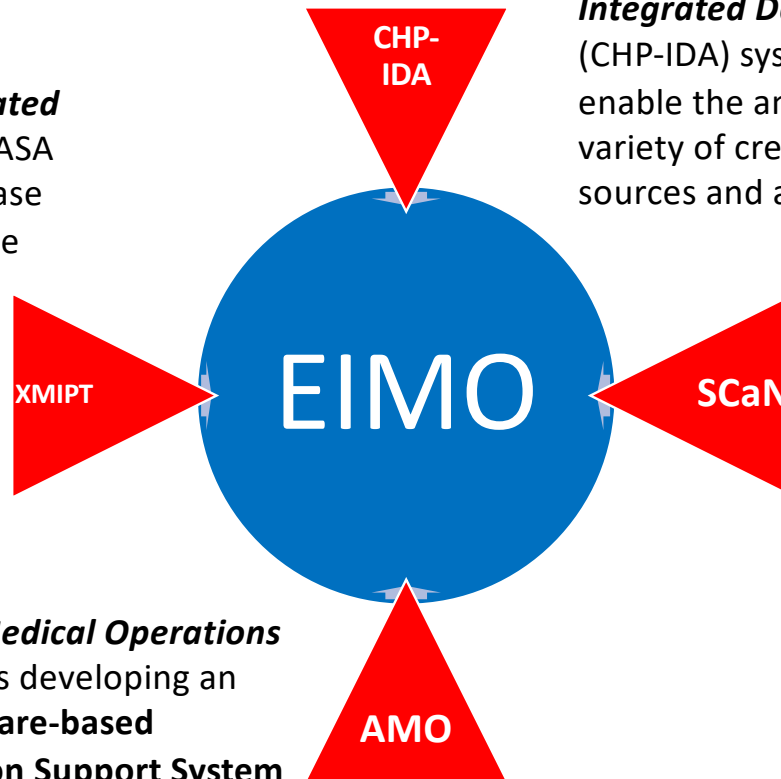






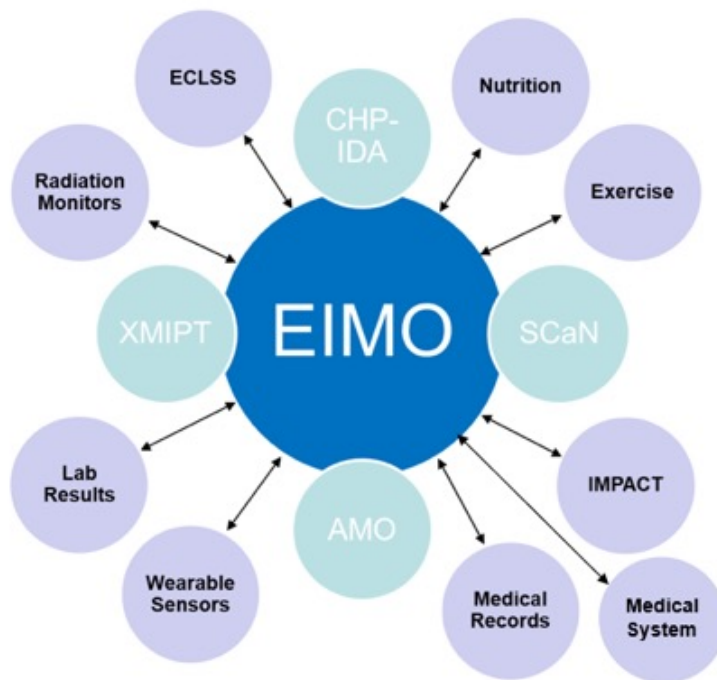
**Exploration Medical Integrated Product Team (XMIPT)** at NASA is seeking solutions to increase the mass, power, and volume efficiency of its exploration medical system.

**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.



**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.

**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 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