



Architectural Framework for Conceptualizing Exploration Class Medical Missions

**Human Research Program
Exploration Medical Capability Element**

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

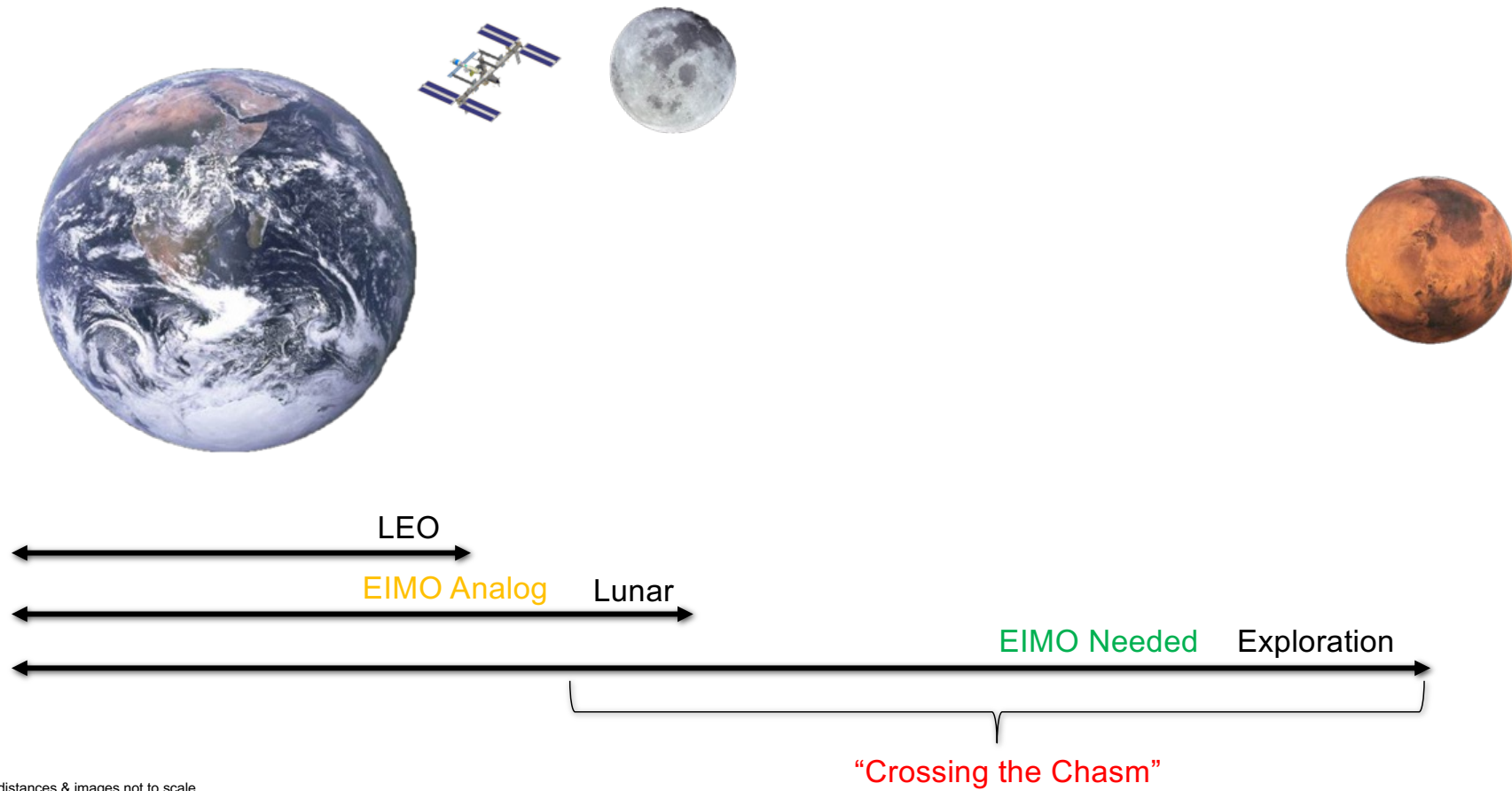


Agenda



- **Overview of relation to ExMC Earth Independent Medical Operations (EIMO) project**
- **Motivation for current project**
- **Use of Digital Engineering methodologies**
- **Architecture Process**
- **Current State**
- **Future Direction**
- **Q&A**

ExMC - Earth Independent Medical Operations (EIMO)



*distances & images not to scale

Motivation for Current Project



- **Crew Health and Performance (CHP) as an ecosystem will need to undergo a shift to support capabilities associated with EIMO**
 - What are the “as-is” set of capabilities?
 - What new capabilities need to be integrated into a holistic CHP system to enable EIMO?
 - Autonomy through Autonomous Systems/Agents
 - Clinical Decision Support
 - Resource Tracking
 - Additional Capabilities (TBD)
- **Does the current CHP framework impose constraints on the integration effort?**
 - Can viewing CHP through the lens of a System of Systems allow for greater integration opportunities?
 - Increased collaboration
 - Reducing siloes
 - Increased interoperability
 - Aids in alignment of common goals/objectives
 - Does it help promote more visibility of how the human must interface under an EIMO paradigm?

Utilizing Digital Engineering Principles



- **Shift within NASA towards Model Based Systems Engineering (MBSE)**
 - Moving away from “document” centric practices towards digital model representations of complex systems
 - Complex systems can be modeled, traceability can be maintained, and analysis/simulation can be conducted
- **ExMC has been utilizing digital engineering tools to deliver robust Systems Engineering (SE) products**
 - Short Duration Lunar Orbit Model (SDLO)
 - Long Duration Lunar Orbit & Lunar Surface (LDLOLS)
 - Clinical Decision Support System (CDSS)
 - Earth Independent Medical Operations (EIMO)
- **The current System of Systems Architecture project also makes use of MBSE**

What is a System of Systems?



System of Systems (SoS)

- Collection of individual systems that interact to provide a unique set of capabilities that none of the constituent systems can accomplish on their own

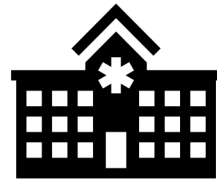
Common Characteristics of SoS

- Operational independence
- Managerial independence
- Heterogeneity
- Data Intensive
- Independent lifecycles
- Geographic distribution
- **Emergence of capabilities**

Examples of SoS

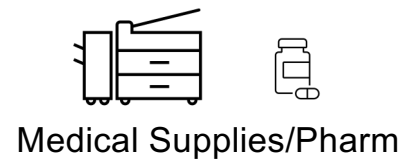
- Internet
- “Smart” houses
- Federal/local disaster response
- **Hospital – Level 1 Trauma Center**

Hospital as a SoS

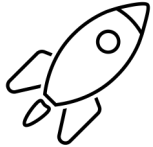


Hospital

Hospital as a SoS



EIMO CHP as a SoS



Vehicle Systems



Future Systems Patient Telemetry



Clinical Lab Analysis



EHR/Data Access Point



CHP

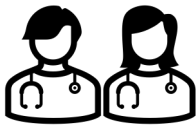


Clinical Imaging



AI

Agent/System



CMOs



Medical Supplies/Pharm

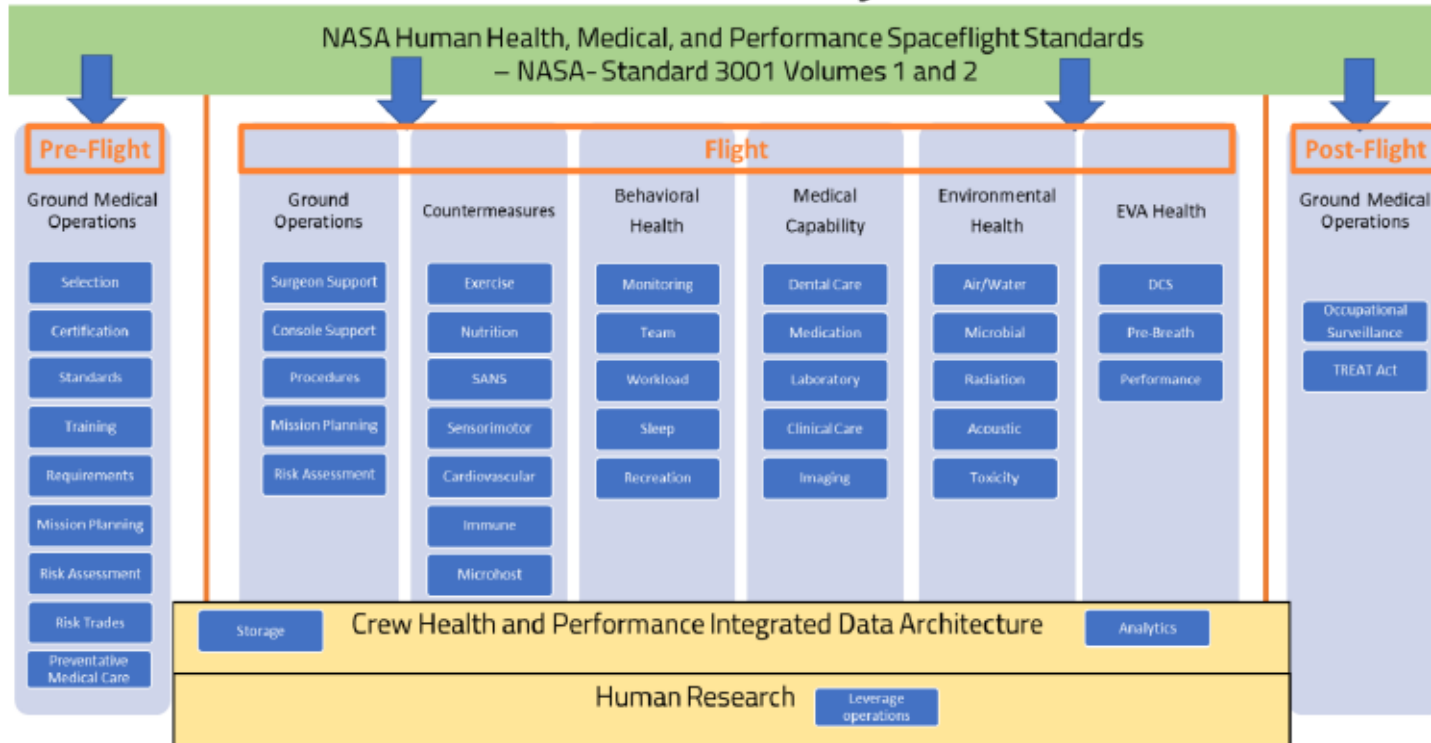


Ground Communication

Which framework do we use?

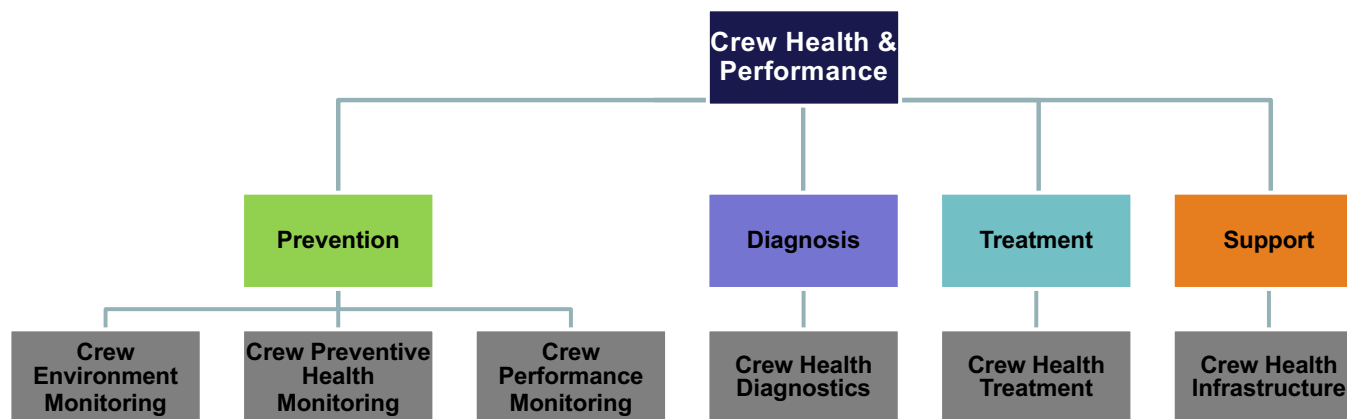


Crew Health and Performance System Mental Model



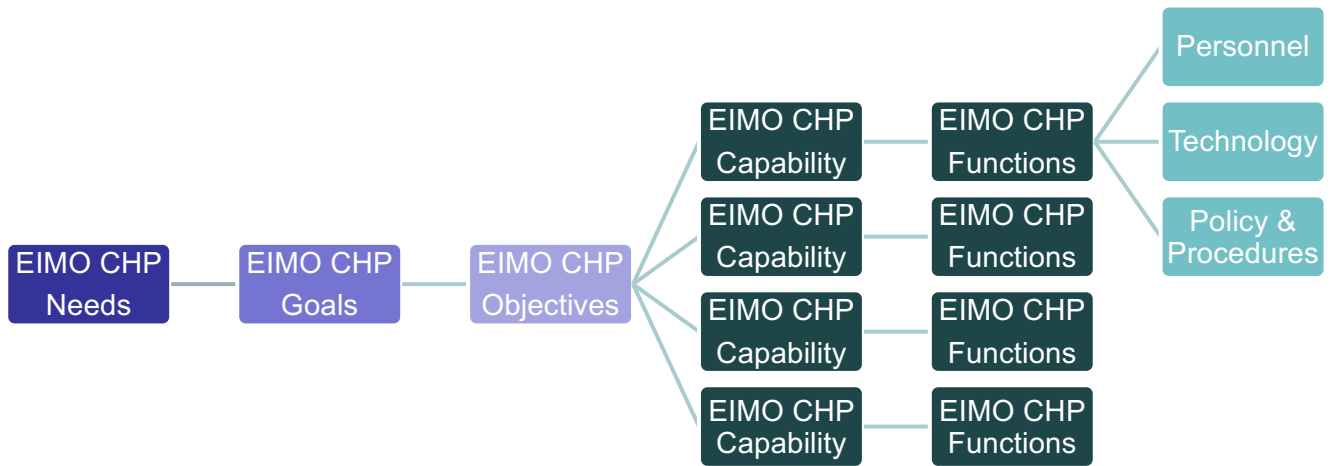
*HH&P System Mental Model

Proposed Unified Medical Capability Framework – Aligning with NASA STD 3001*



*NASA-STD-3001 V.1 Rev C & 3001 V.2 Rev D

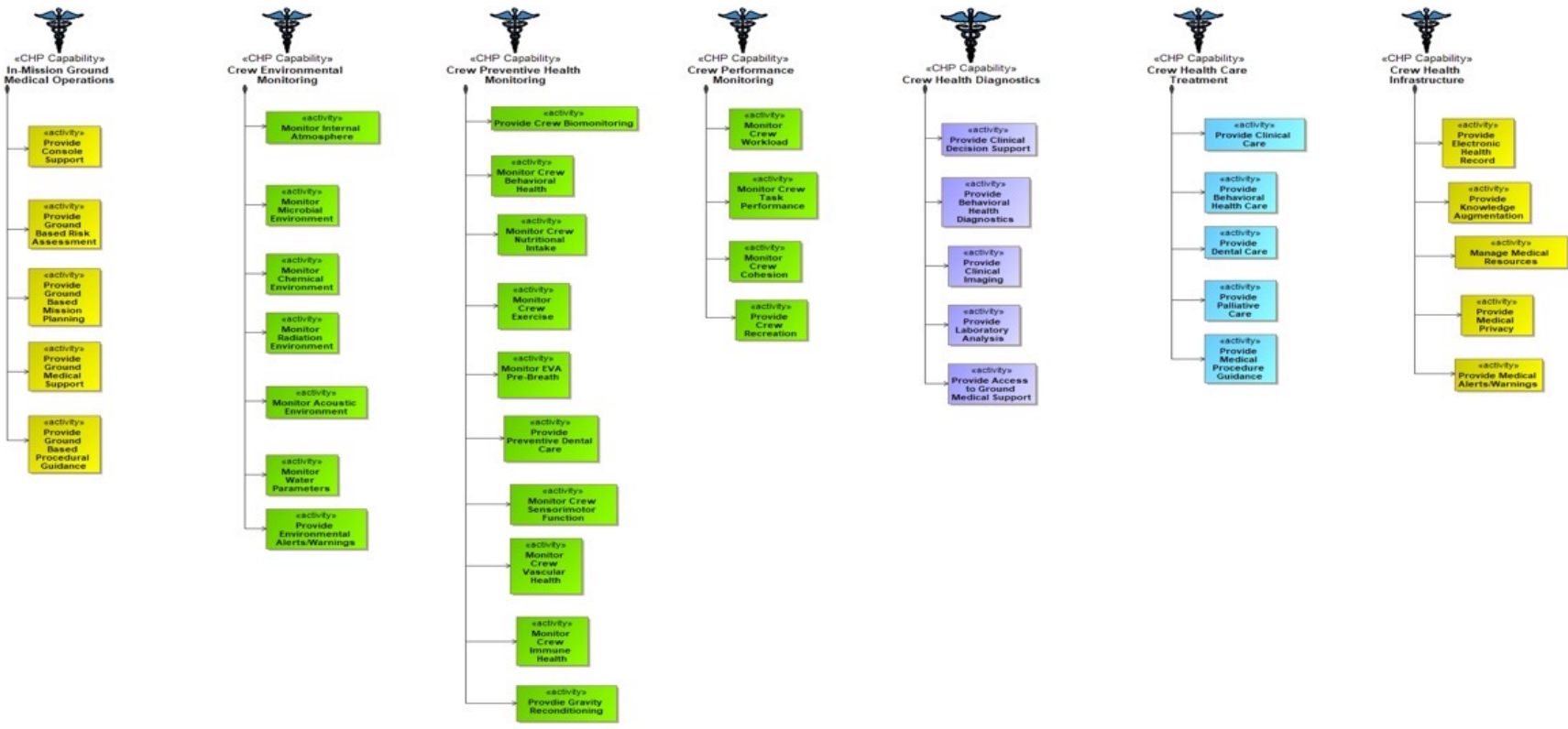
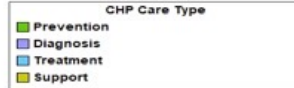
Current effort towards an EIMO CHP SoS



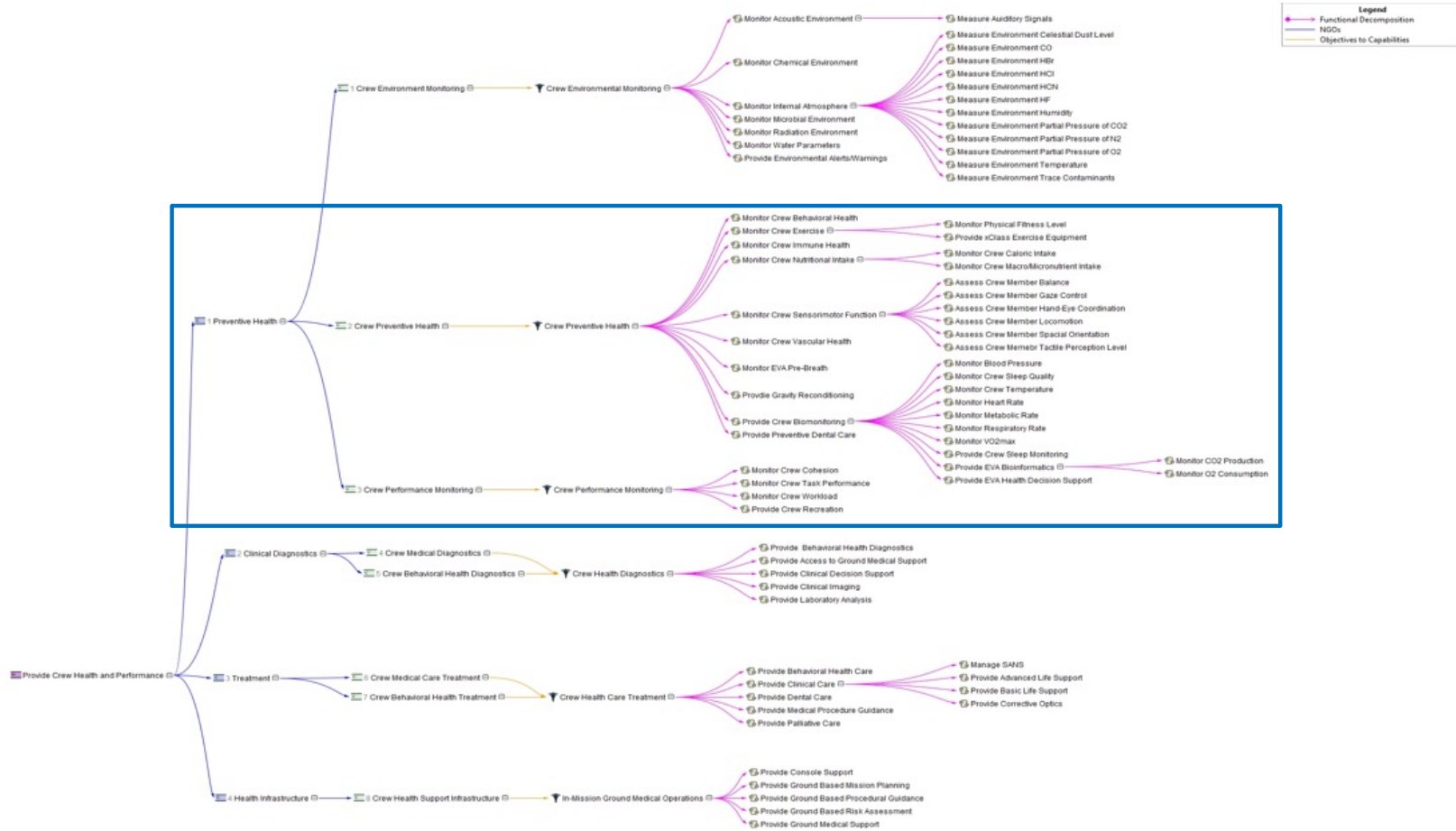
Proposed CHP Framework Capabilities & Functions – MBSE Execution



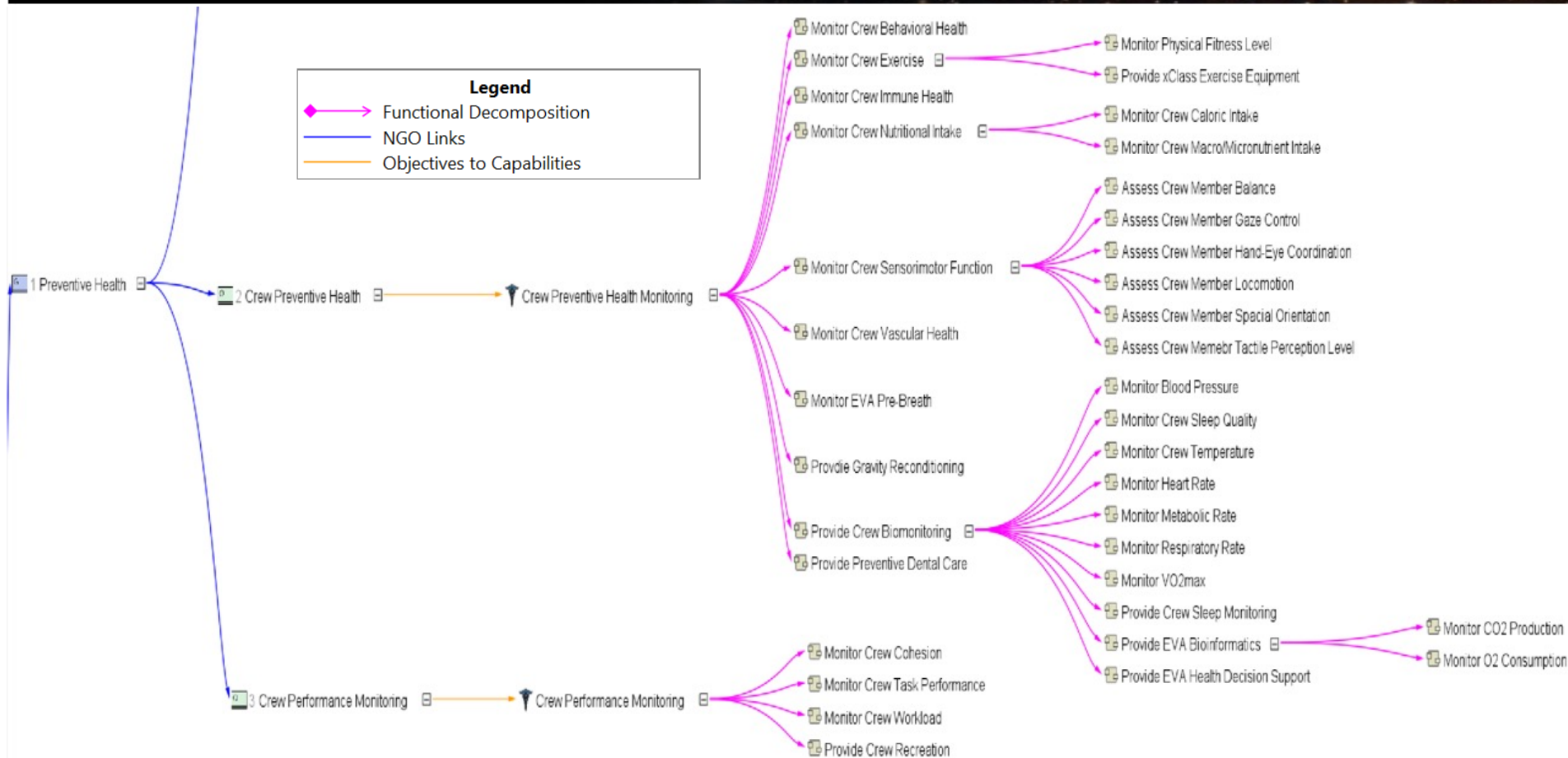
bdd [Package] 02 In-Mission Segment [CHP Functional Decomposition Hierarchy]



CHP End-to-End Decomposition Tree – MBSE Execution



CHP End-to-End Decomposition Tree – MBSE Execution



Proposed CHP Architectural Framework – Current State



- **Emergent Properties coming into view**
 - Medical System
 - Level of Crew Autonomy through implementation of autonomous systems
 - Autonomy
 - Autonomous Systems
 - Visualization of Task Loading
- **Begin to realize interfaces more holistically**
- **Visualize areas of potential interoperability**
- **Visualization on where common hardware/software overlap areas are**
- **Additional SoS Characteristics not yet realized**

Future Direction of Proposed CHP SoS Framework



- **Expand the model further**
 - Differentiate new capabilities available as a EIMO CHP system
 - Allocate functions to physical architecture elements
 - Deploy parametric analysis in support of visualizing Human EIMO CHP system
 - Crew Task load measurement based on architecture
 - Autonomy
- **Usage in EIMO Medical System project**
 - Requirements development
 - Interface points
- **Future use in ExMC projects looking at exploration class medical missions**

EIMO CHP SoS

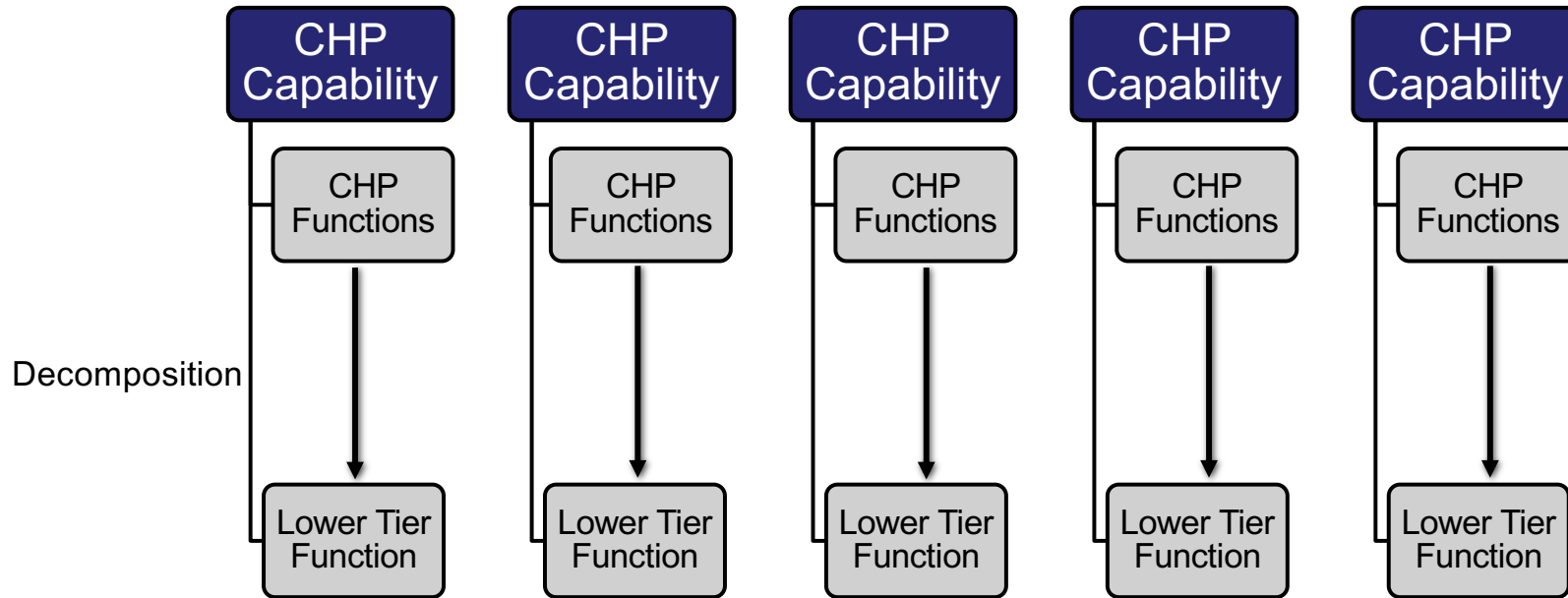


- Questions?

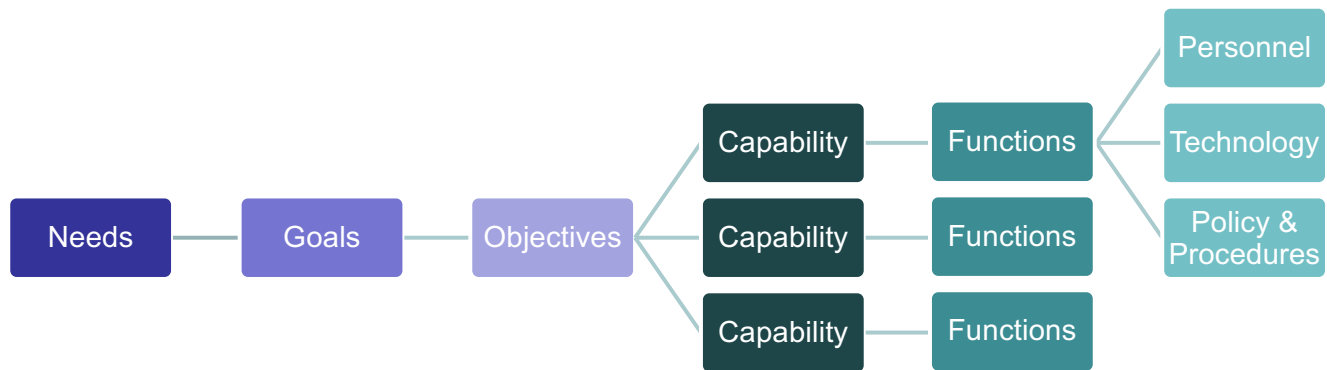
Backup slides



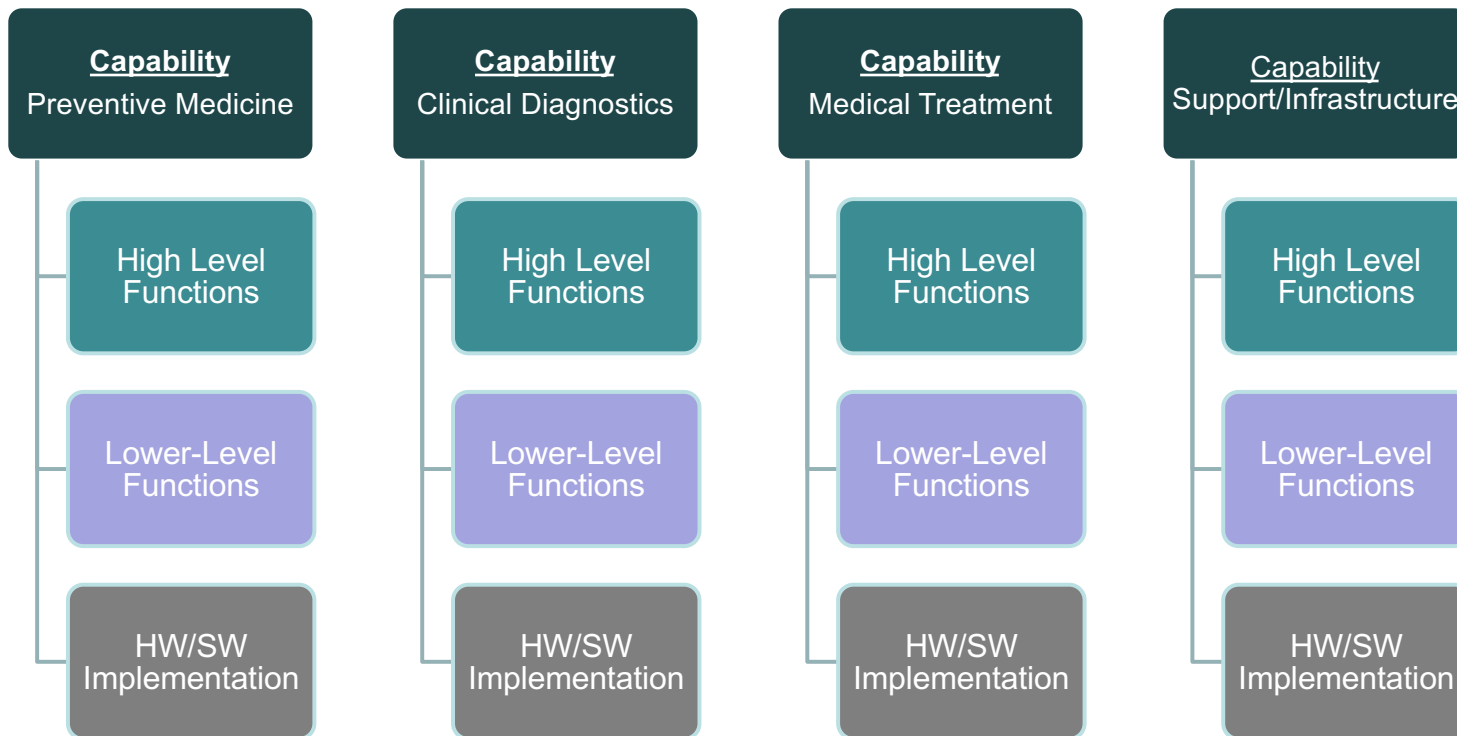
EIMO CHP SoS Functional Decomposition



How to Conceptualize a Hospital SoS

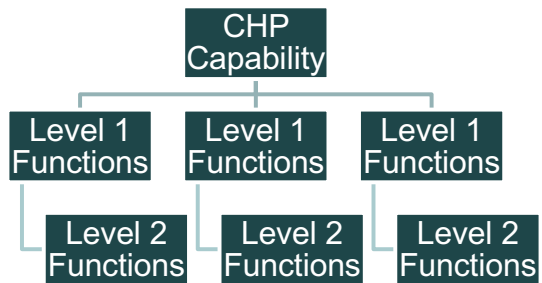


How to Conceptualize a Hospital SoS

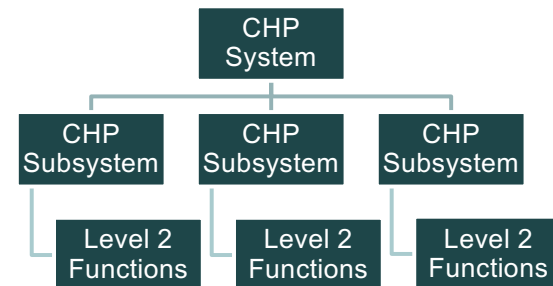




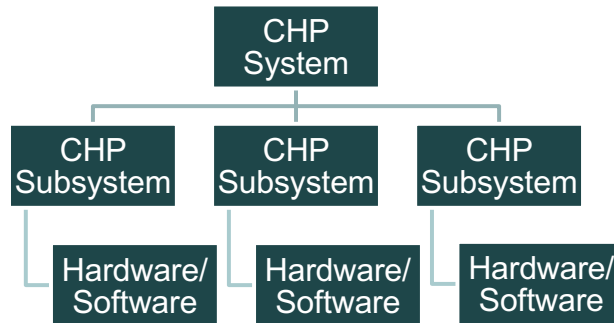
- **Functional Architecture**



- **Logical Architecture**



- **Physical Architecture**

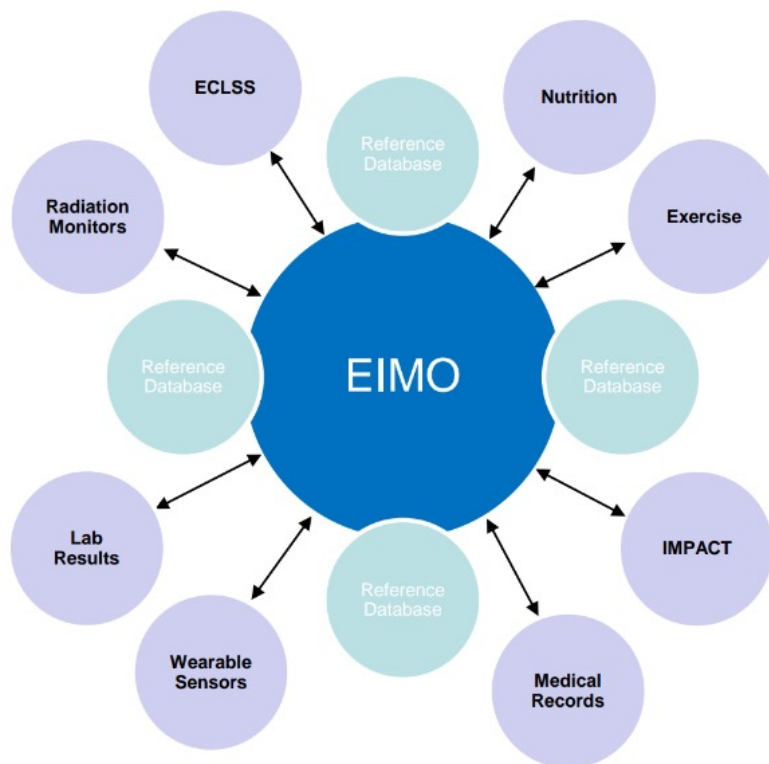


Architecture Process

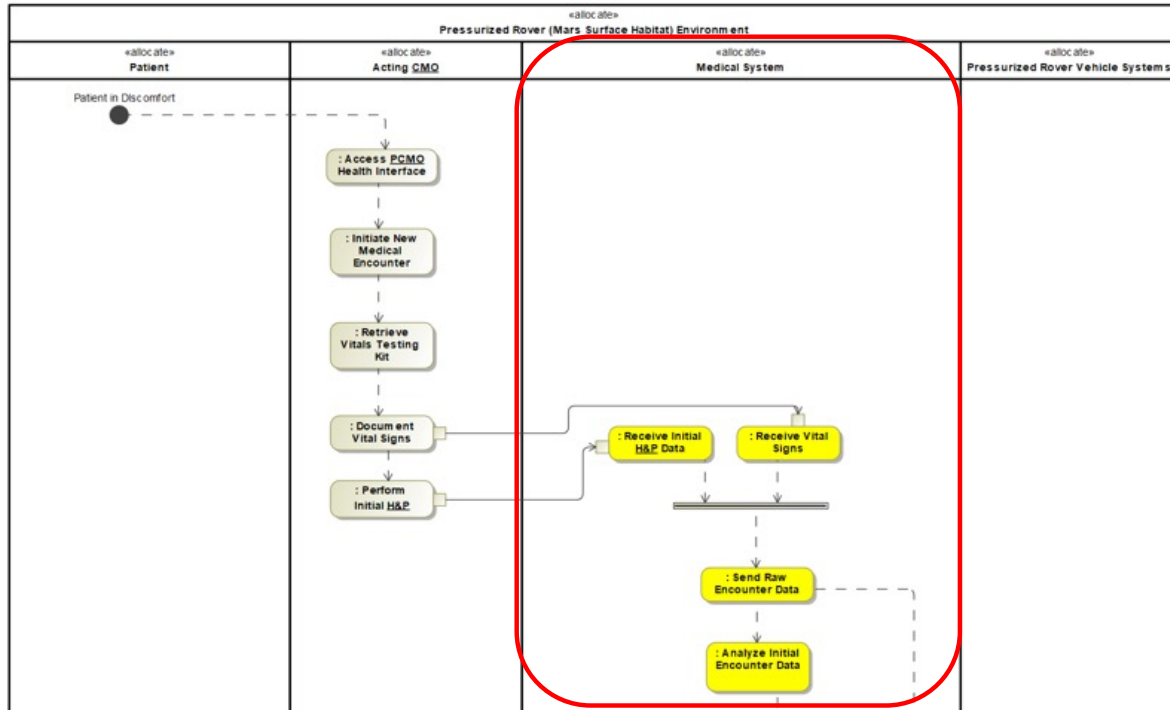


- **Functional Architecture**
 - Decomposing high level CHP capabilities to functions several levels deep
- **Logical Architecture**
 - Decomposing the CHP system into logical groupings of subsystems that would potentially serve as an abstraction gap to connect the functional architecture to the physical architecture
 - i.e. ECLSS, Integrated Data Architecture (IDA) System, etc.
- **Physical Architecture**
 - Describes what hardware or software the system will need to perform the functions of the system
 - i.e. Biosensors, environmental sensors, AI modality, imaging devices, etc.

Ecosystem as Presented in TIM2



Current EIMO CONOPs



*Example from scenario #6 on abdominal pain

How to Conceptualize a SoS

