

Lessons Learned from Medical System Foundation Development for Long-Duration Lunar Orbit and Surface Missions

**Human Research Program
Exploration Medical Capability Element**

**HRP IWS
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Mary Susan Kaetzer, Sarah Lumpkins, Christopher Laing, Jorge Bardina, Michael Krihak, Kerry McGuire, John Odina

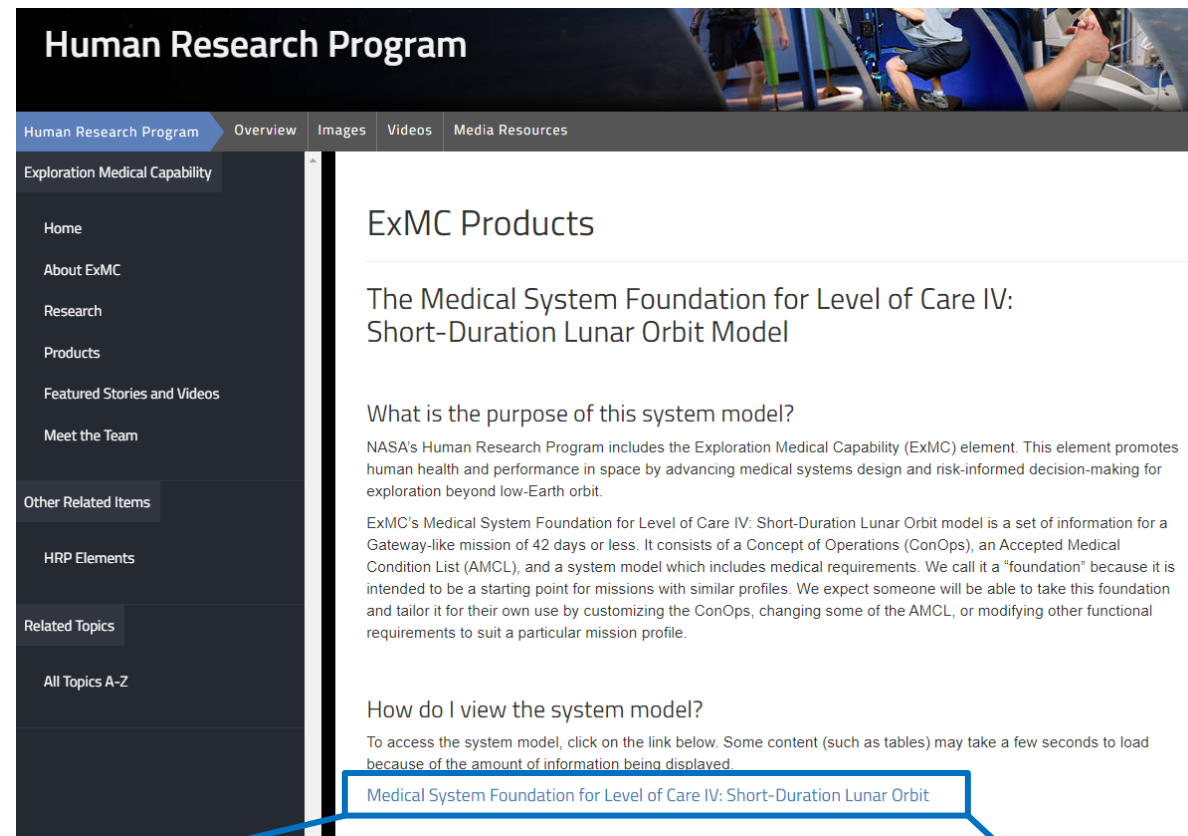
“Expanding the Boundaries of Space Medicine and Technology”

- **Two ExMC Medical System Foundation Projects:**

- Short-Duration Lunar Orbit – Complete and Available to the Public
- Long-Duration Lunar Orbit and Lunar Surface – Undergoing Roadshows

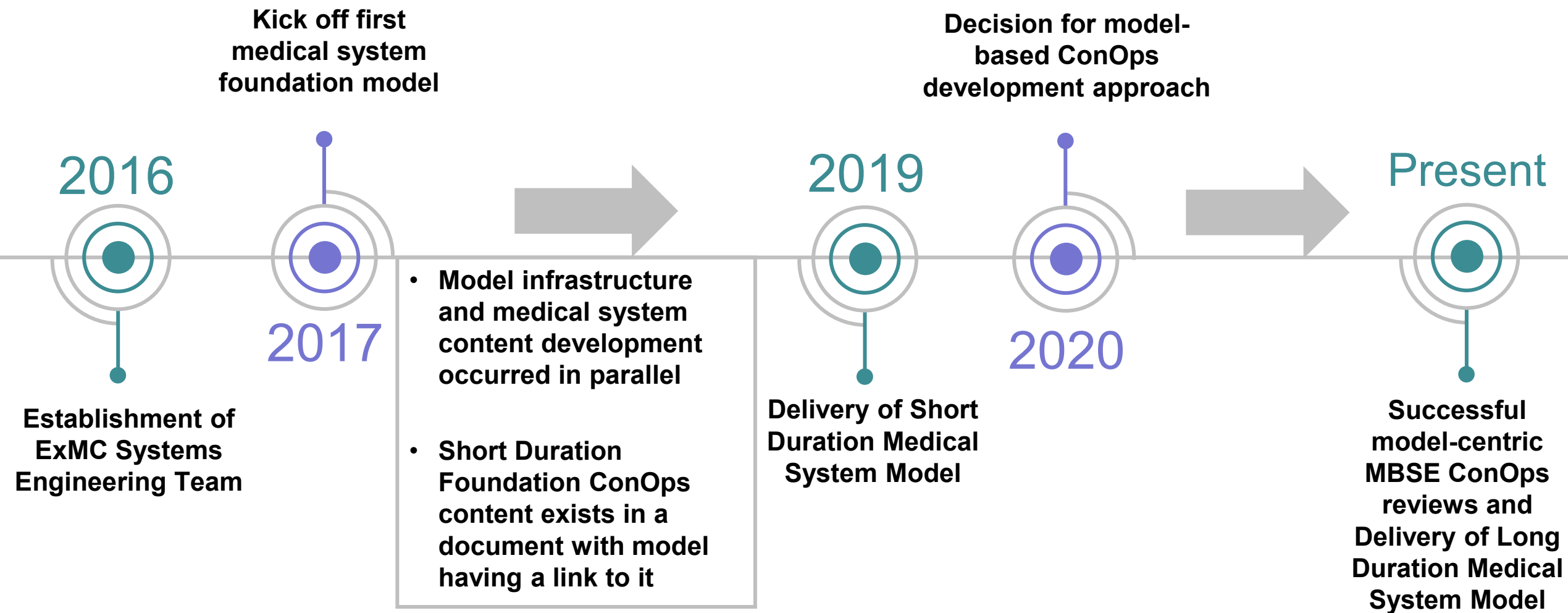
- **Major Differences in Process:**

- Concept of Operations (ConOps) is in Model-Based Systems Engineering (MBSE) format
- Adopted Agile Project Approach
- Model infrastructure was already established



Medical System Foundation for Level of Care IV: Short-Duration Lunar Orbit


Introduction: ExMC Modeling History



Concepts of Operations

[Level of Care IV Medical System ConOps \(HRP_48012 Baseline\)](#)

Level of Care IV CHP ConOps (Not available outside NASA)

 [Level of Care IV Habitat Medical System Scenarios](#)

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HRP-48012



Recommendation for a Medical System Concept of Operations for Gateway Missions

Exploration Medical Capability (ExMC) Element
Human Research Program



Concept of Operations

Concept of Operations

 > 

Medical System > Concept of Operations

Purpose & Scope

01 Purpose 02 Scope 03 Change Authority 04 Report Terminology Applicable Documents Reference Documents

Mission Descriptions & Assumptions

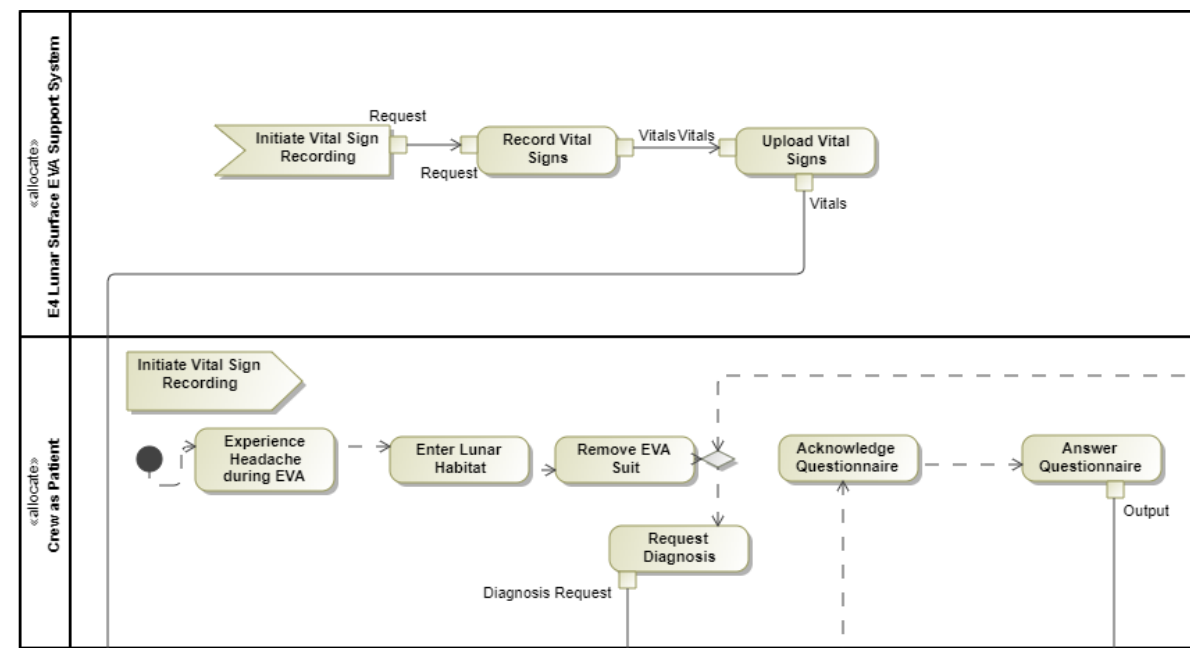
This section identifies the stakeholders, the stakeholder needs, Medical System goals, and assumptions the Systems Engineering team used to define the Medical System specified in this report. Stakeholder needs identify why this Medical System exists from the points of view of those affected by the Medical System. Goals identify the ends the Systems Engineering team works towards while specifying the Medical System. While specifying the Medical System, Systems Engineers and Clinicians identify constraints that limit the system. To address those constraints, the model captures the Assumptions made about the operating and habitat environments, as well as the Medical System itself.

- Ability to hyperlink to references inside and outside of the model
- Graphical representation of content allows for better collaboration between team members and stakeholders' understanding
- Centralized Source of Truth for the project that follows a consistent format

Applicable Documents Table

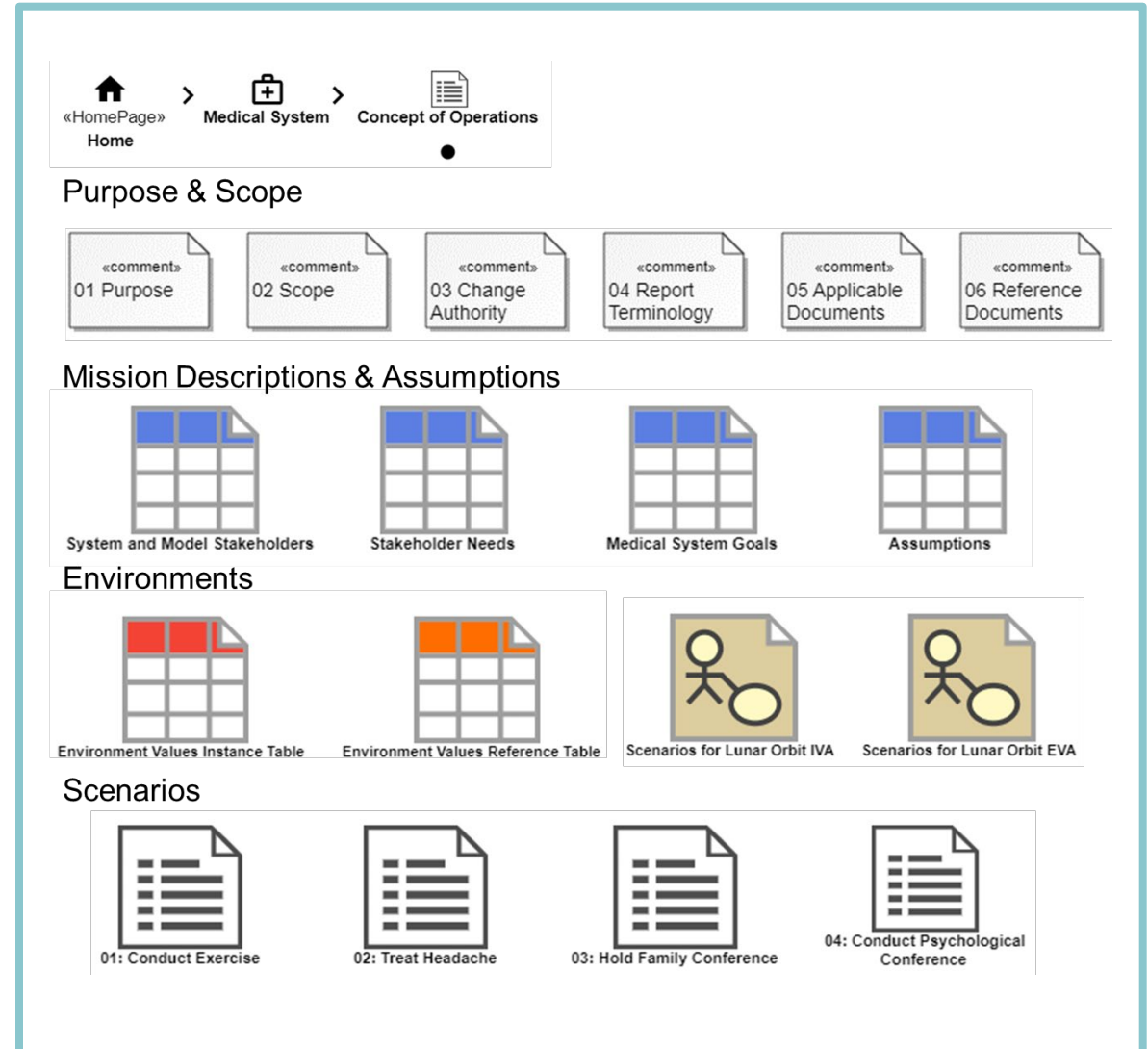
Document Reference with Hyperlink

- | | |
|---|--|
| 1 | ExMC-SE-001 SEMP (Not available outside of NASA) |
| 2 | HRP-47067 Rev C (Not available outside of NASA) |



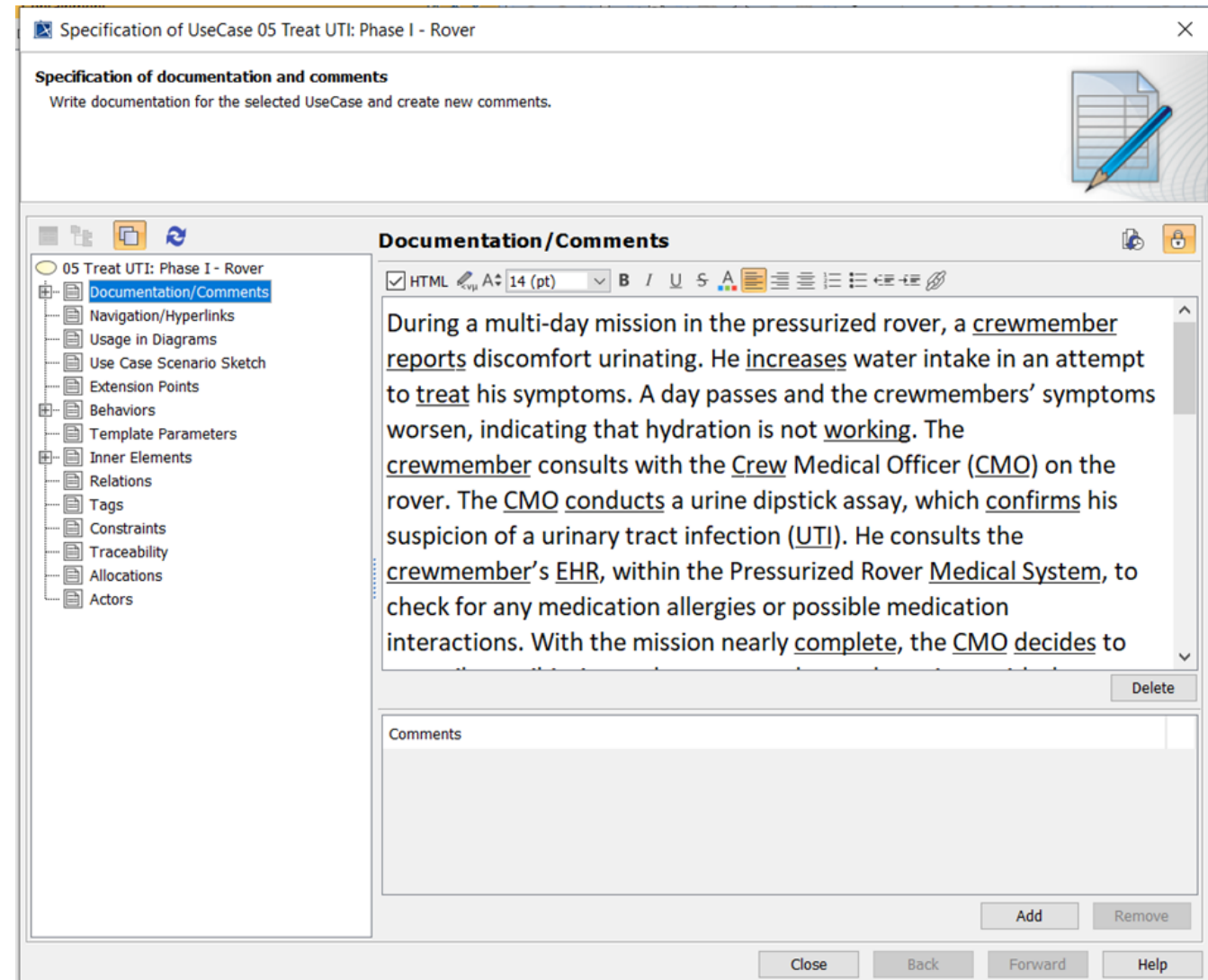
Standardize Organization of Concept of Operation

- Originally did not impose a standard model report format
- Follow the structure of a document-based Concept of Operations
- Commonality between projects and emulating the traditional document-format facilitates stakeholders' review



Start Somethings Outside of the Model

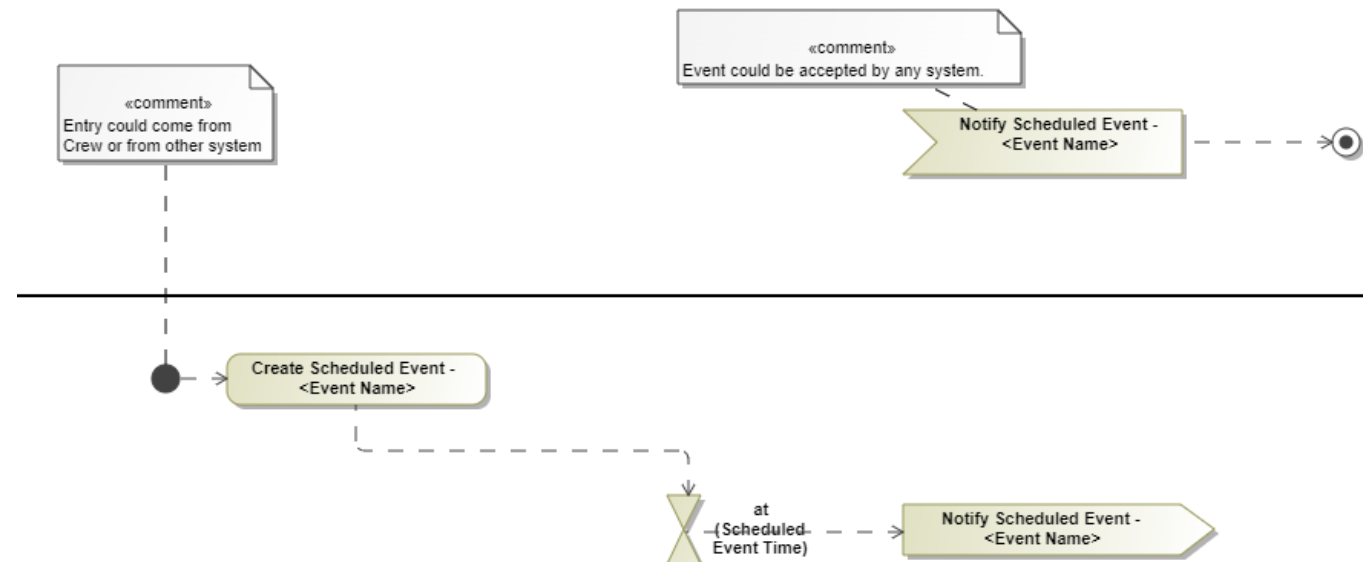
- ConOps content can have a significant amount of text
- Subject Matter Experts are not trained MBSE practitioners
- Starting content outside of the model allows for early and frequent reviews without extra training
- Content added to model after reviews



Implementation of Patterns

- Originally each SE team member drafted activity diagrams independently
- Common functionality was implemented differently
- Design patterns allowed for harmonization of the activity diagrams
 - Scenario Activity Diagrams were easier to understand
 - Team identified missing functionality of the system
- Future projects will implement patterns before drafting activity diagrams

Example: Scheduling

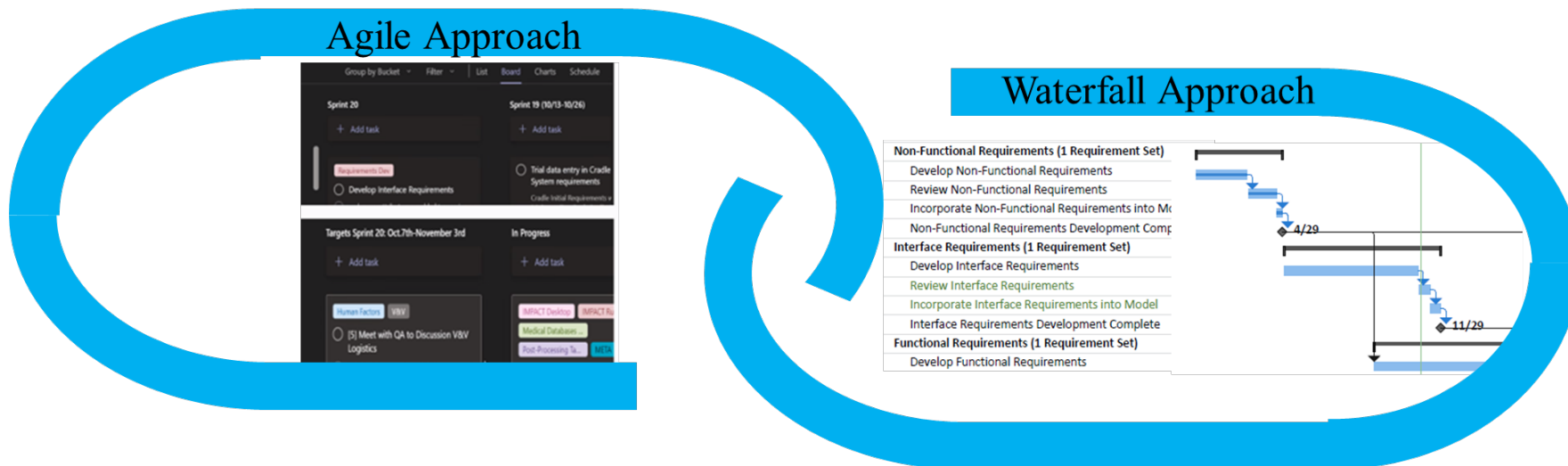


- **Waterfall Schedule Approach**

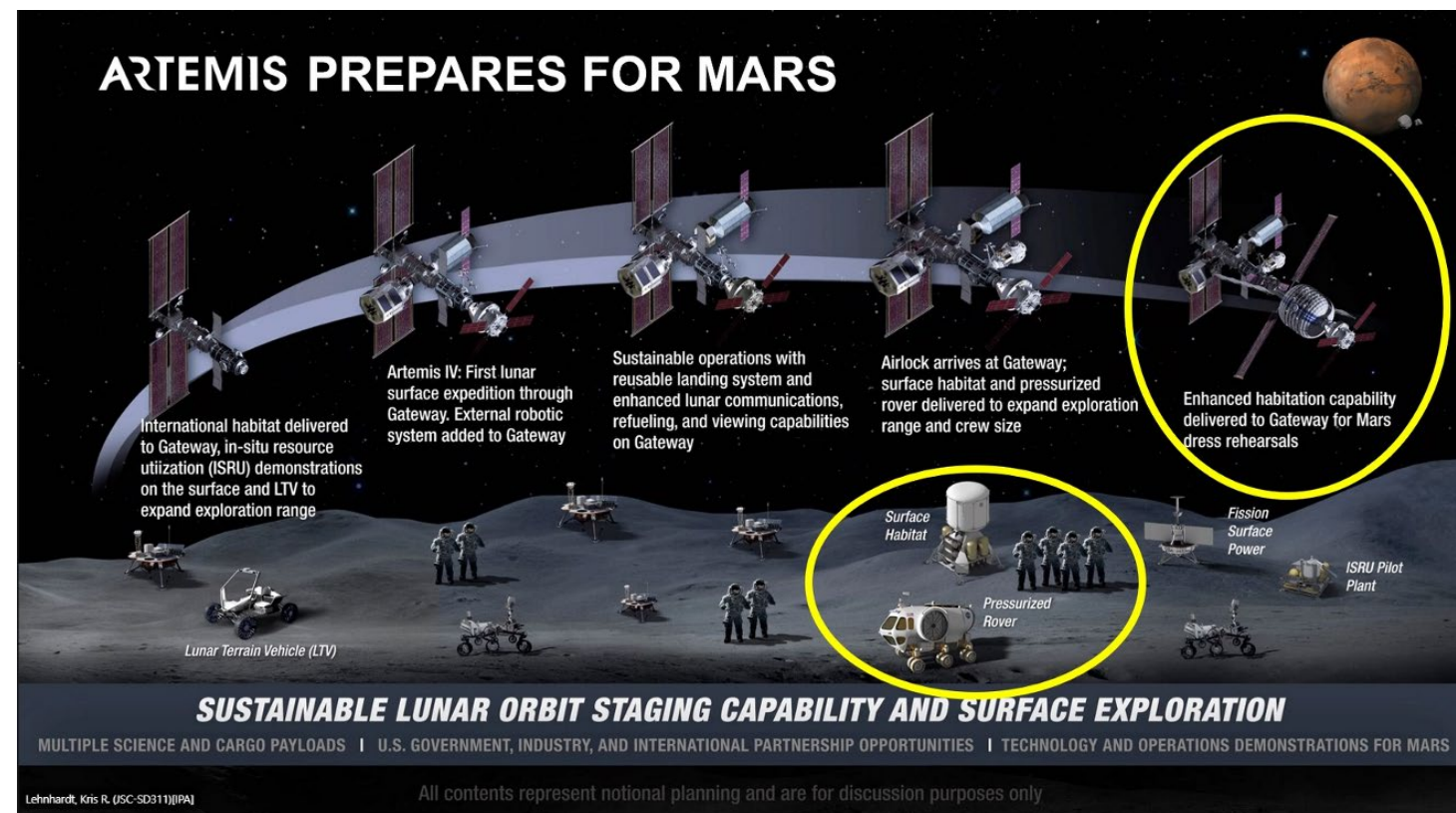
- Used to track competing milestones and deliverable timelines across the SE team and non-SE system stakeholders (e.g., clinicians and management)
- Integrated schedule lists tasks granularly and in a prescribed order

- **Agile Development Approach**

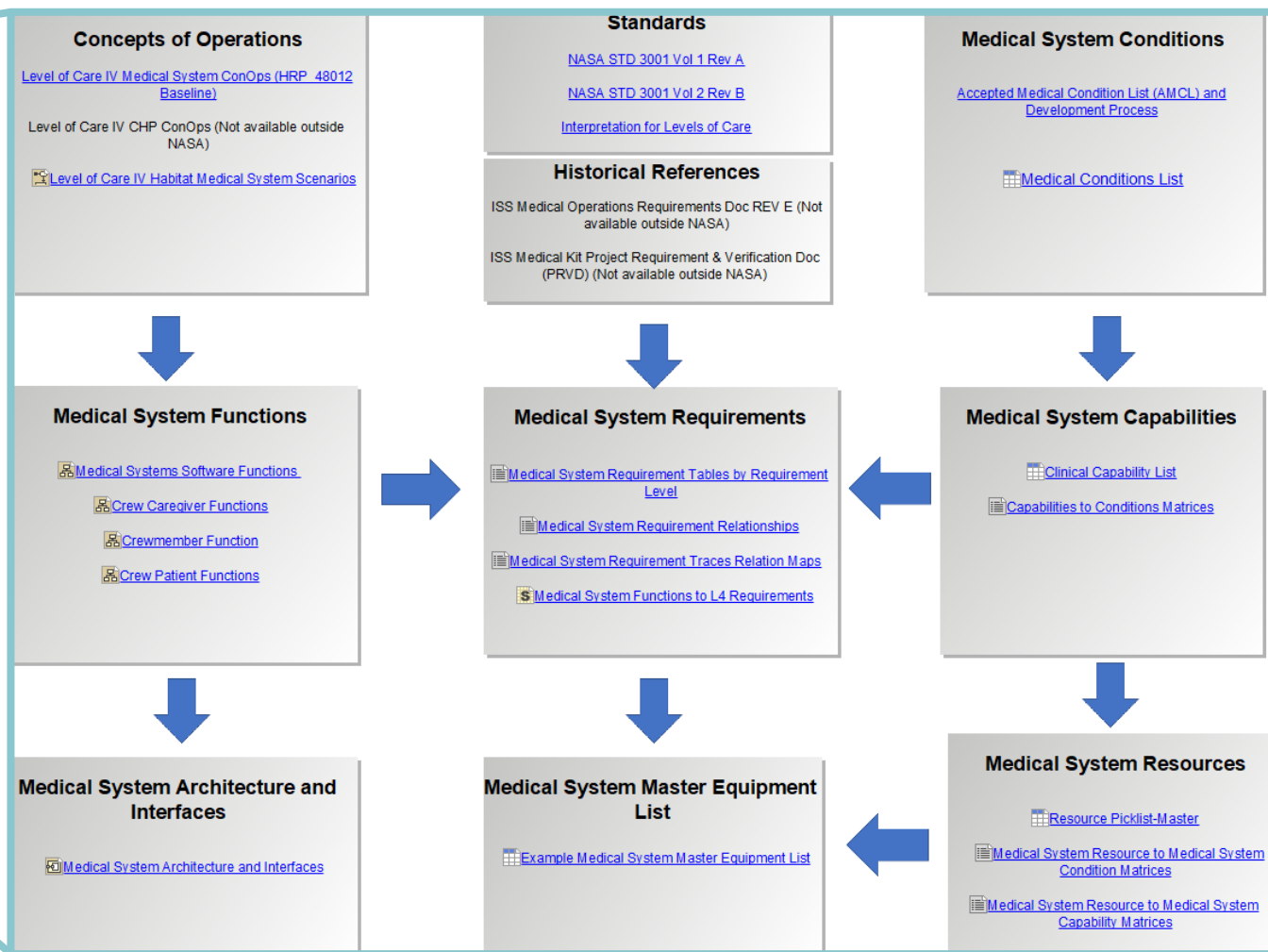
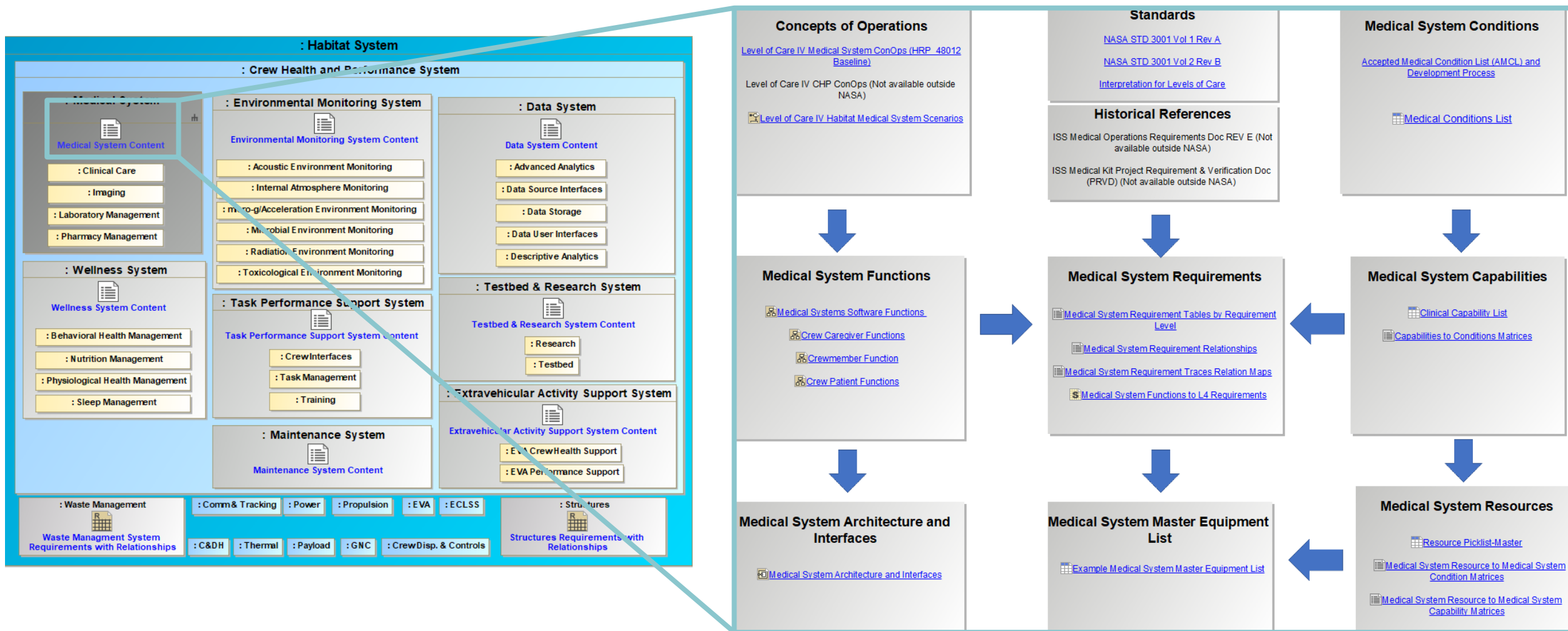
- Uses Sprints: fixed time period for performing a set of tasks
- Facilitates iterations with stakeholders to verify that the SE understanding of functionality meets the stakeholders' expectations



- Synergistic with MBSE because portions of model can be updated as information becomes available
- Artemis program information incorporated
- Human Factors Feedback incorporated



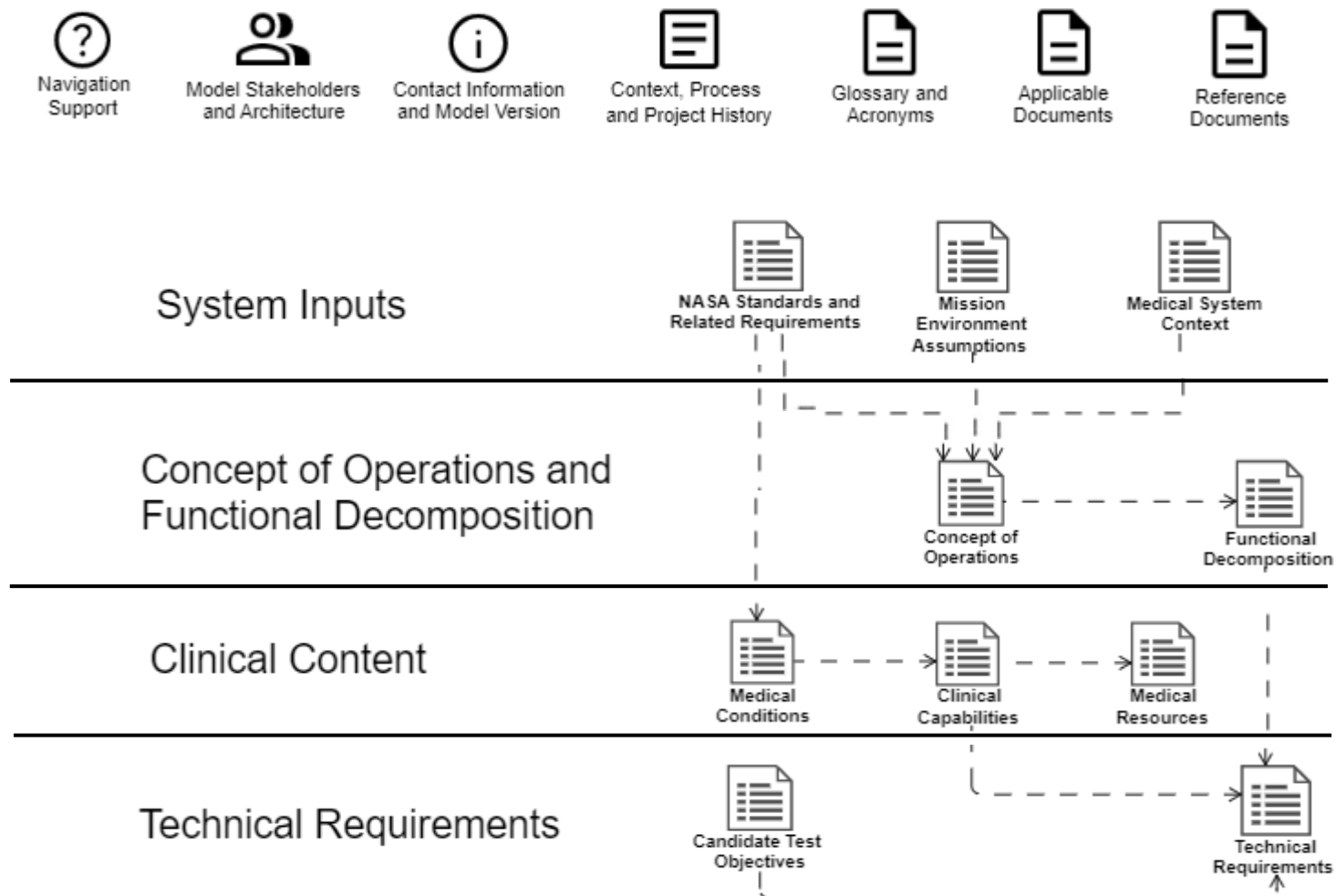
Short Duration Layout





Medical System Foundation for Level of Care IV: Long Duration Lunar Orbit and Lunar Surface

Information about the Medical System Foundation

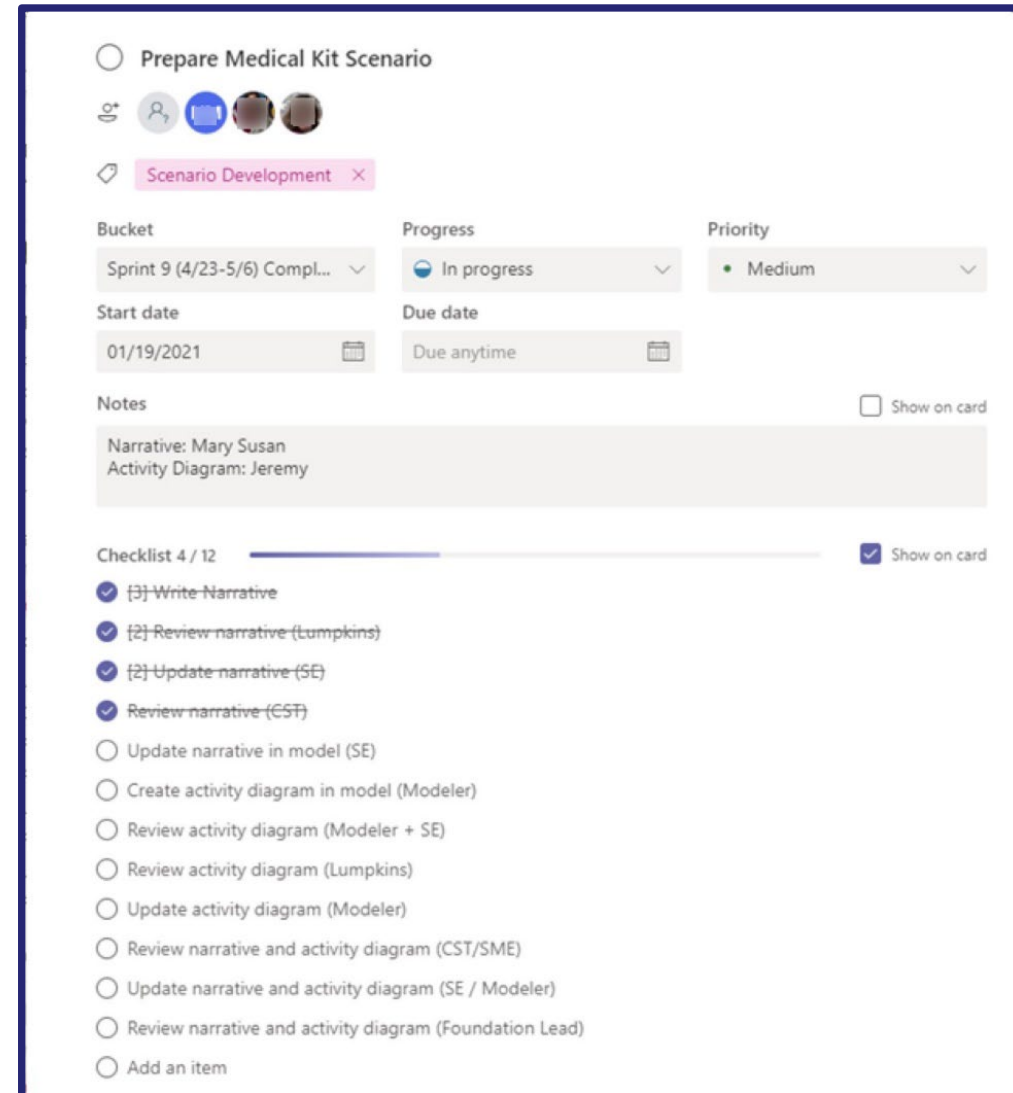


Implementation of Sprints

Initial process included one planner board for the project with each task including checklist feature to document all steps to complete task

Issues resolved:

- All the task steps generally couldn't be completed in a single sprint (e.g., reviews by non-SE team stakeholders)
- Task cards did not provide sufficient detail to track daily progress of the project's various teams



○ Prepare Medical Kit Scenario

👤 👤 👤 👤

🔖 Scenario Development ✕

Bucket: Sprint 9 (4/23-5/6) Compl... ▾

Progress: In progress ▾

Priority: Medium ▾

Start date: 01/19/2021 📅

Due date: Due anytime 📅

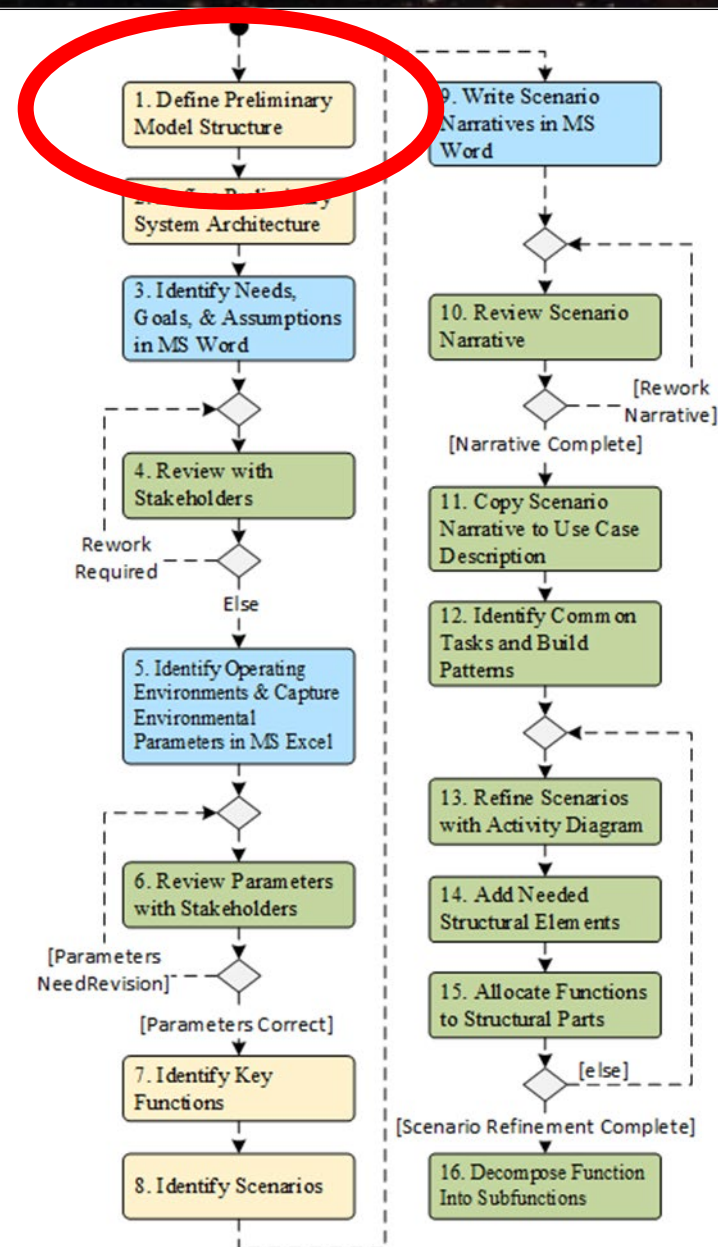
Notes: ☐ Show on card

Narrative: Mary Susan
Activity Diagram: Jeremy

Checklist 4 / 12 ☒ Show on card

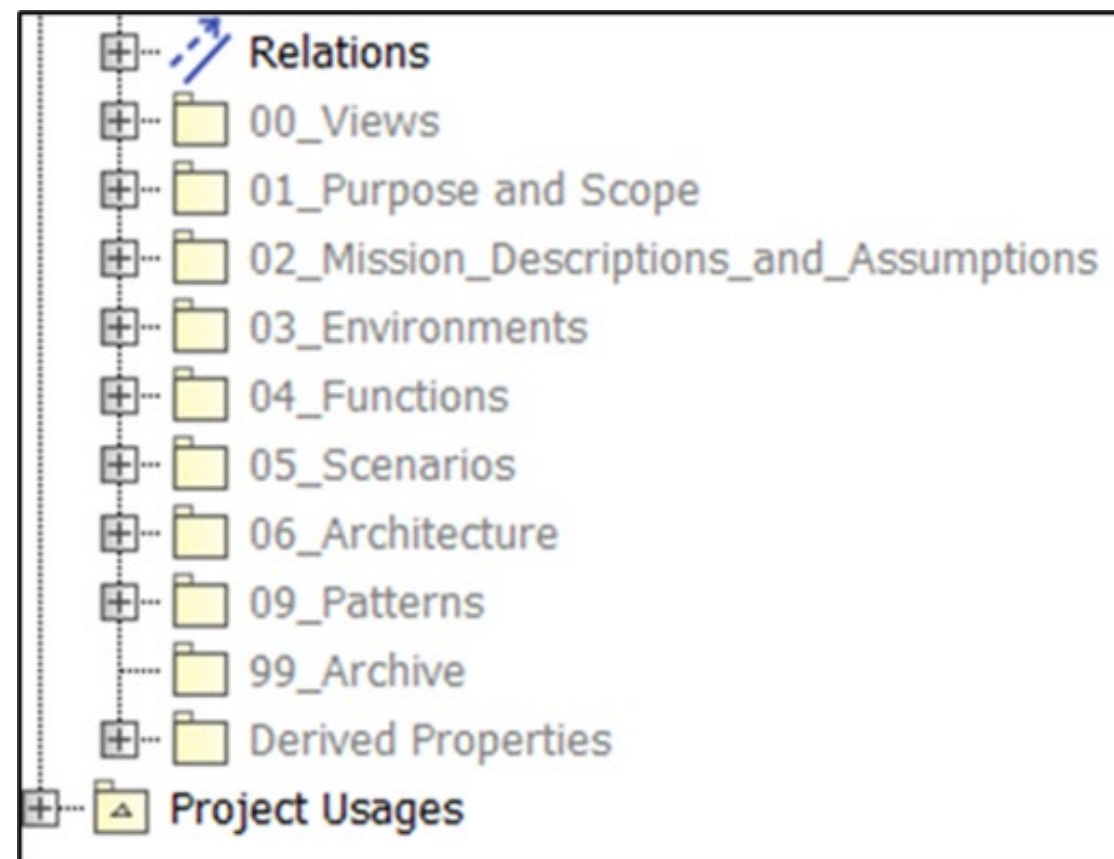
- ✓ [3] Write Narrative
- ✓ [2] Review narrative (Lumpkins)
- ✓ [2] Update narrative (SE)
- ✓ Review narrative (CST)
- Update narrative in model (SE)
- Create activity diagram in model (Modeler)
- Review activity diagram (Modeler + SE)
- Review activity diagram (Lumpkins)
- Update activity diagram (Modeler)
- Review narrative and activity diagram (CST/SME)
- Update narrative and activity diagram (SE / Modeler)
- Review narrative and activity diagram (Foundation Lead)
- Add an item

- First step of ExMC Model Development is to Define Preliminary Model Structure
- Model Infrastructure was Established



Standardize Model Layout

- All ExMC products adopt a similar model organization
- Facilitates cross-project work and large teams
- Benefit for both team members and stakeholders



- **Developing Medical System Foundations within ExMC is an ongoing journey**
- **Lessons learned along the way will continue to guide our development process**
- **Emphasis is on iterative reviews in order to have a useful product for our stakeholders**
- **Next steps are to update the Long Duration Lunar Orbit and Lunar Surface Medical System Foundation to follow the latest version of NASA Standard 3001, and make the foundation publicly available**

<https://www.nasa.gov/hrp/elements/exmc/products>

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The Medical System Foundation for Level of Care IV: Short Duration Lunar Orbit Model

What is the purpose of this system model?

The Medical System Foundation for Level of Care IV: Short Duration Lunar Orbit is a set of information that consists of a Concept of Operations (ConOps), an Accepted Medical Condition List, and a system model. The Exploration Medical Capabilities (ExMC) Element Systems Engineering (SE) and clinical teams perform a functional decomposition of the ConOps content to derive requirements and identify example resources that satisfy some of the requirements. The system model captures the products of this process. This content can serve as a foundation for future exploration NASA programs developing medical systems to modify to their specific Design Reference Mission (DRM).

How do I view the system model?

At this time, we recommend using Internet Explorer 11 to view the model. Other browsers (e.g., Chrome, Firefox) can be used to view the model and you need to follow these instructions first: <https://docs.nomagic.com/plugins/servlet/mobile?contentId=36311903#content/view/36311903>

To access the system model click on the link below. Some content (e.g., tables) may take a few seconds to load because of the amount of information being displayed.

[Medical System Foundation for Level of Care IV: Short Duration Lunar Orbit](#)

What was our process in generating the content in this system model?

Our SE team followed the SE and human systems integration approaches that are documented in the [NASA Systems Engineering Handbook](#), [NASA Systems Engineering Processes and Requirements](#) and the [Human Systems Integration Practitioner's Guide](#). We work directly with Subject Matter Experts (SMEs), such as health care providers, to generate the content. All content was reviewed and approved by our ExMC Control Board (CB).

The SE team has authored the following papers and presented the following presentations outlining our approach:

- Mindock, J., Reilly, J., Rubin, D., Urbina, M., Hailey, M., Cerro, J. A., ... & Reyes, D. (2017). Systems Engineering for Space Exploration Medical Capabilities. In *AIAA SPACE and Astronautics Forum and Exposition* (pp. 5236 - 5251).