

# OVERVIEW OF EXPLORATION MEDICAL CAPABILITY SYSTEMS ENGINEERING LEVEL 4 REQUIREMENTS FOR MEDICAL LEVEL-OF-CARE IV IN SPACE LUNAR ORBIT HABITAT

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## ABSTRACT

This paper presents how the Exploration Medical Capability Element of the National Aeronautics and Space Administration’s Human Research Program using Model-Based System Engineering is defining Level 4 Foundational Requirements to provide Medical Level-of-Care IV in a space Habitat during exploration missions.

## OVERVIEW

The National Aeronautics and Space Administration’s (NASA) Exploration Medical Capability (ExMC) Element of the Human Research Program is using a Model-Based System Engineering (MBSE) approach to define requirements to the Habitat System for the performance of medical activities in space missions.

The ExMC is developing this work founded on a vision for NASA of the Crew Health and Performance (CHP) System in space exploration missions. This vision comprises of system goals, stakeholder needs and mission activities as identified by ExMC subject matter experts and clinicians. The ExMC developed documents of medical clinical capabilities and concept of operations (ConOps), which together with NASA and International Space Station (ISS) standards and documents, provide the foundation of the Habitat CHP Systems and the capability to develop technical requirements, system architectures, interfaces, and verification and validation criteria [1].

As shown in Figure 1, formal MBSE modeling facilitates the communication of properties and behaviors of complex domains supporting the development of system requirements, design, analysis, verification and validation activities throughout the project life cycle, allowing one model as a single source for all project actions and decisions. Technical requirements specify the necessary functions and features of the system to perform medical activities while system design defines how those needs will be met. Requirements specified at every system level provide the system architecture foundation within the MBSE life-cycle. Here requirements are specified as Level 4 for the CHP Habitat system, denoted with a unique identifier and name, and a “shall” statement with a rationale justifying the requirement.

## REQUIREMENTS

The CHP Habitat Medical System and the CHP Habitat Data Systems with 102 and 28 Level 4 Requirements have been delivered and approved by the HRP Control Board, respectively. The HRP ExMC Systems Requirements team developed these requirements in collaboration with the review and vetting process of the HRP ExMC Systems Engineering team and clinicians at Ames Research Center (ARC) and Johnson Space Center (JSC). These requirements represent the first component

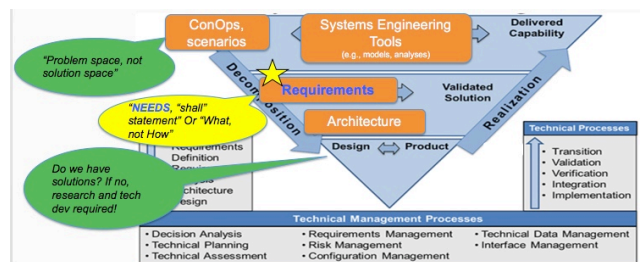


Figure 1. View of Requirements in the System Engineering Lifecycle. (Ref: Based on DoD graphics [2] and NASA NPR 7123.1C [3]).

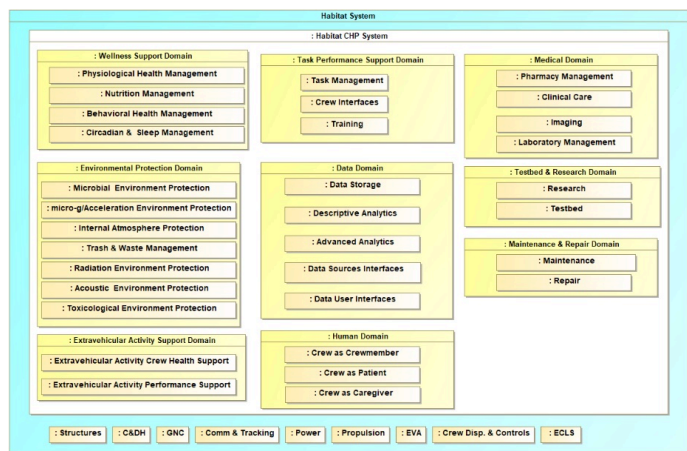


Figure 2. Context Architectural View of the CHP System [5].

of the CHP system in the Habitat for space missions (see Figure 2), and provide a system engineering foundation to support medical system delivery for exploration system maturation.

Presently, the requirements have been reviewed and distributed together with additional requirements comprising CHP and Non-CHP Habitat systems. The medical system needs are beyond the purview of the CHP Habitat Medical System as defined in the Concept of Operations [4,5] in terms of interfaces and activities performed by other systems and needs to provide In-Flight Level-of-Care IV in the Habitat as defined in NASA Standard [6-8] for prevention, diagnostic and treatment of medical conditions in space.

Present analysis of the functional and non-functional requirements derived from the CHP ConOps includes systems and scenarios, and clinical capabilities for in-flight prevention, diagnoses and treatment of medical conditions. This work has developed a new set of requirements addressing the Habitat CHP domain including the Medical System and interface activities with the Data, Wellness Support, Task Performance Support, Environmental Monitoring, and Research & Testbed systems, and other domains of the Habitat including interface activities with the Maintenance, Waste Management, Extra-Vehicular Activity and Structures systems.

*Requirement Development based on Functional Decomposition and Concept of Operations*

The development of functional requirements based on Functional decomposition [9] and ConOps documents is described below. For example, Figure 3 shows "Analyze health data" as an attribute of the Habitat CHP Medical System and the binding context "Synthesize health data" of the medical requirement developed to address this need.

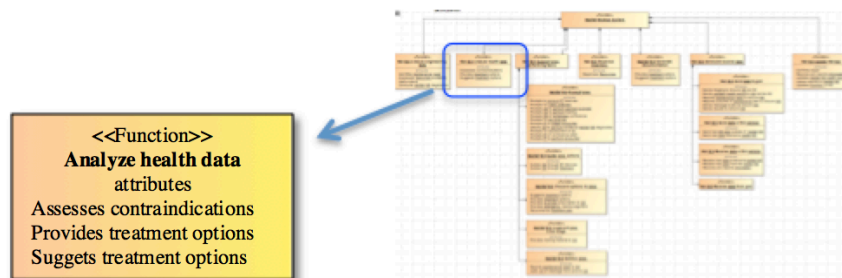


Figure 3. Functional Decomposition source [1].

Functional Decomposition: **Analyze health data**

ID: *Hab-MedSysy-0007*

Name: *Synthesize health data*

Text: *The Habitat Medical System shall synthesize health status data.*

Rationale: *The Habitat Medical System will combine health data from the medical system, the patient, the relevant physical and environmental data from the vehicle, and the information and data from the ground medical system to establish crew health status.*

*Requirement Development based on Clinical Capabilities and Concept of Operations*

The clinical information delivered by the ExMC clinicians contains 258 clinical capabilities to address prevention, diagnosis, and treatment of medical conditions in each in-flight planned activity as well as accepted medical conditions in each in-flight unplanned activity to be conducted in the Habitat [10]. These clinical capabilities address a large number of activities classified in 20 clinical categories as shown in Table 1 below.

Table 1. Clinical Categories

|  |                                       |                                   |
|--|---------------------------------------|-----------------------------------|
| Administer and Manage Medications      | Interview Patient                     | Perform Laboratory Analysis       |
| Assess and Monitor Vital Signs         | Knowledge Augmentation                | Perform Physical Exam and Conduct |
| Configure Environment for Care         | KSA                                   | Screening exams/tests             |
| Dietary Control / Nutrition Monitoring | Medical System Support                | Perform Procedures                |
| Document Care                          | Monitor & Assess Environment          | Perform waveform monitoring       |
| Evacuation                             | Monitor and Control Sleep and Fatigue | Personal Protection               |
| In-Flight Prevention                   | Perform Imaging                       | Support Behavioral Health         |

While Planned Clinical Capabilities are based on NASA documents including NASA-STD-3001 standard [6,7] and interpretation of the standard [8], unplanned capabilities are based on NASA's historical documents including the medical operations requirements documents (MORD) [11,12] and accepted medical conditions including stakeholders rank order [13], and likelihood of occurrence [14].

An example of the development of functional requirements based on Clinical Capability is shown below. Table 2 shows a brief list of Planned Clinical Activities under two Clinical Categories: "Perform imaging" and "Perform procedure."

*Table 2. Two example Clinical Categories with their associated Capabilities*

|   |   |
|---|---|
| <p><b>Perform Imaging</b></p> <p>Image - airway<br/>         Image - bone<br/>         Image - ear<br/>         Image - eye<br/>         Image - GI tract - upper/lower<br/>         Image - integument<br/>         Image - internal organs<br/>         Image - intracavity<br/>         Image - muscle<br/>         Image - soft tissue<br/>         Image - urinary tract<br/>         Image - vasculature<br/>         Imaging - still/ video photography, external<br/>         ...</p> | <p><b>Perform Procedures</b></p> <p>Airway - Abdominal Thrust/Chest Compression<br/>         Airway - Airway Adjuncts<br/>         Airway - Endotracheal Intubation<br/>         Airway - Foreign Body Removal<br/>         Airway - Suction<br/>         Airway - Supraglottic Intubation<br/>         Anesthesia - Local<br/>         Anesthesia - Moderate Sedation<br/>         Anesthesia - Regional<br/>         Breathing - Automated Ventilation<br/>         Breathing - Chest Tube<br/>         Breathing - Continuous Positive Airway Pressure (CPAP)<br/>         Breathing - Hyperbaric Therapy<br/>         ...</p> |
|---|---|

The information associated with these activities provides the foundation of the Level 4 Systems Engineering Requirements on "Perform imaging" and "Perform airway procedure" which are shown below with their unique ID, Name, Text and Rationale.

Clinical Capability Category: Perform imaging

ID: Hab-MedSysy-0025

Name: **Perform imaging**

Text: *The Habitat Medical System shall support caregivers performing imaging.*

Rationale: *The Habitat medical system needs to provide capabilities (e.g., tools, technology, skills, medications) to perform imaging of the body (integument, vasculature, bone, ear, eye, internal organs etc.). Imaging capability is essential for all phases of medical care (prevention, diagnosis, treatment) and includes external and internal imaging of the body. Specific imaging modalities and target anatomical areas are specified at Level 5.*

Clinical Capability Category: Perform procedure

ID: Hab-MedSysy-0030

Name: **Perform airway procedures**

Text: *The Habitat Medical System shall enable caregivers to perform airway procedures.*

Rationale: *The Habitat Medical System requires capabilities (e.g., tools, technology, skills, medications) to perform procedures that support the maintenance of an open airway (abdominal thrusts, supraglottic intubation, suction, etc.). These procedures are needed to support the treatment of unexpected medical conditions such as choking, severe allergic reactions, and sudden cardiac arrest. Types of airway procedures are specified at Level 5.*

### *Habitat Medical System Requirements*

The development of the Habitat Medical Systems Requirements represents the foundational research work developed with the participation of the ExMC element team consisting of systems engineers and subject matter experts geographically dispersed across different NASA Centers.

The analysis of the functional and non-functional needs in the Habitat to provide in-flight prevention, diagnosis and treatment of medical conditions led to a new set of 270 In-Flight Habitat Medical System Level 4 Engineering

Requirements for space missions. These requirements are distributed in different systems of the Habitat according to the scope of influence and responsibility of each system as defined or implied by the ConOps documents. The distribution of these requirements is shown in Figure 4.

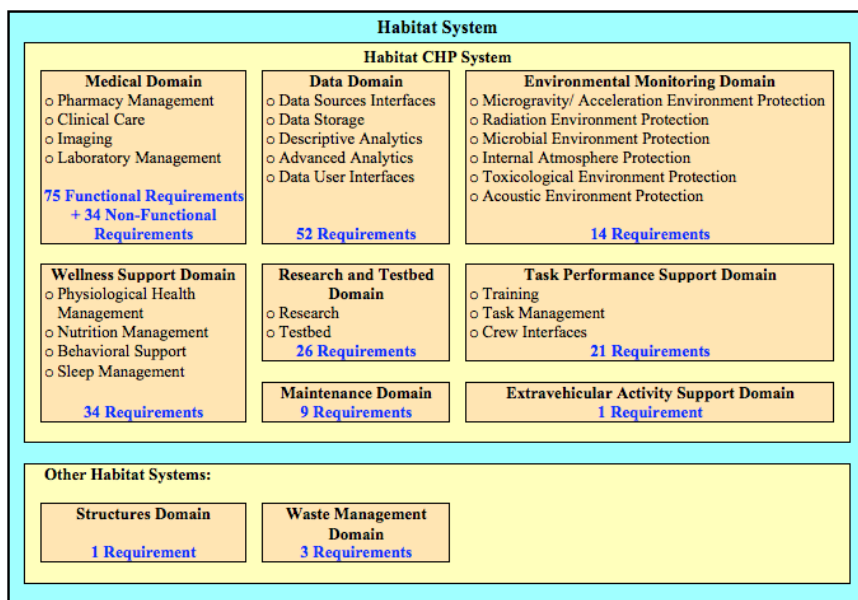


Figure 4. Distribution of Habitat Medical Systems Level 4 Engineering Requirements. Requirement groupings are shown as bulleted text and the number of requirements for each System are provided. (Ref.: Based on Model [1]).

A brief sample of the requirements is shown in Figure 5 as a condensed view showing ID, Name, Text, and Rationale of the corresponding broader version developed. This figure only shows 4 of the 72 functional requirements of the Habitat Medical System, while similar information is available for each one of the 270 requirements.

| Assess and Monitor Vital Signs |                       |   |  |
|--------------------------------|-----------------------|---|--|
| ID                             | Name                  | Text  | Rationale  |
| L4-Hab-MedSys-0019             | Interpret vital signs | The Habitat Medical System shall interpret vital signs. | This capability enables interpretation of vital sign data and supports collaborative decision making with the ground system. This capability ensures caregivers have the necessary information to interpret crewmembers vital sign, and other physiologic metrics, including waveforms for the purposes of diagnosis and treatment. Specific data to be interpreted as needed by the caregiver are specified at Level 5. |
| L4-Hab-MedSys-0020             | Collect vital signs   | The Habitat Medical System shall collect vital signs.   | Vital sign collection is needed during examinations for most planned activities and the diagnosis and treatment of conditions. Collecting crewmembers vital signs and other physiological metrics, including waveforms for the purposes of diagnosis and treatment, provides medical information that will be stored in the habit data system. Specific vital signs are specified at Level 5.                            |
| L4-Hab-MedSys-0021             | Monitor vital signs   | The Habitat Medical System shall monitor vital signs.   | Vital sign monitoring is needed during planned physical exams, as well to support the diagnosis and treatment of medical conditions. This capability ensures that caregivers have the necessary equipment and support to monitor crewmembers vital signs and other physiologic metrics including waveforms. Specific data to be monitored are defined at Level 5.  |
| L4-Hab-MedSys-0022             | Record vital signs    | The Habitat Medical System shall record vital signs.    | Recording vital signs (e.g., ECG waveforms) and other physiological metrics (e.g., measures of blood pressure, body mass and temperature) for the purposes of diagnosis and treatment, provides medical information that will be stored in the habit data system. Specific data to be recorded are defined at Level 5.   |

Figure 5. Sample of level 4 Habitat Medical System Requirements.

The Functional Requirements of the Habitat Medical System are further classified in categories and sub-categories shown in Table 3. This classification facilitates their comprehension and traceability to higher and lower level requirements and clinical capabilities.

Table 3. Habitat Medical System Level 4 Functional Requirements Categories

- Provide Appropriate Level of Care
- Environment Configuration for Medical Care
  - Configure Environment for Care
  - Habitat Medical System Inventory
- Knowledge-Based Support for Crew Performing Medical Tasks
  - Augment Crew Knowledge
- Medical Assessment and Monitoring
  - Analyze Health Data
- Habitat Medical Human System
  - Crew - Crew as caregiver
  - Crew as patient
  - Crew as crewmember

- **Caregiver/Patient Interactions**
  - Interview Patient
  - Perform Physical Exam and Conduct Screening exams/tests
  - Assess and Monitor Vital Signs
  - Administer and Manage Medications
  - Perform Imaging
  - Perform Laboratory Analysis
  - Perform Procedures
  - Personal Protection
- **Medical Assessment and Monitoring**
  - Dietary Control / Nutrition Monitoring
  - Monitor and Assess Environment
  - Monitor and Control Sleep and Fatigue
  - Support Behavioral Health
  - Support Musculoskeletal Health
  - Support Physical Therapy
- **Maintaining Current State of Medical System**
  - Document Care

These requirement categories provide further guidance considering the large number of requirements, clinical capabilities, and complexity of the information addressed. For example, just listing the Names and ID of the functional requirements of the Medical System leads to a large list, as shown below in Table 4. These requirements also include Text, Rationale, Comments, Traces, and other information not shown in this table due to its extent. This information is available in the ExMC MBSE Model.

*Table 4. Habitat Medical System Level 4 Functional Categories and Requirement ID and Names*

**Provide Appropriate Level of Care**

- L4-Hab-MedSys-0199 Provide first aid
- L4-Hab-MedSys-0200 Provide basic life support
- L4-Hab-MedSys-0201 Provide advanced life support
- L4-Hab-MedSys-0202 Provide primary care
- L4-Hab-MedSys-0204 Provide dental care
- L4-Hab-MedSys-0205 Provide preventive care
- L4-Hab-MedSys-0220 Adjust crew health management

**Environment Configuration for Medical Care - Configure**

**Environment for Care**

- L4-Hab-MedSys-0002 Provide crew physical access to medical inventory
- L4-Hab-MedSys-0078 Prepare medical supplies for habitat evacuation
- L4-Hab-MedSys-0083 Provide crew role-based privileges
- L4-Hab-MedSys-0084 Provide access to other habitat system resources
- L4-Hab-MedSys-0223 Share medical records
- L4-Hab-MedSys-0224 Access medical records
- L4-Hab-MedSys-0225 Access wellness records
- L4-Hab-MedSys-0231 Access task performance records

**Environment Configuration for Medical Care - Habitat Medical System Inventory**

- L4-Hab-MedSys-0003 Prepare habitat for medical activities
- L4-Hab-MedSys-0028 Manage biological material

**Knowledge-Based Support for Crew Performing Medical Tasks -**

**Habitat Medical System - Augment Crew Knowledge**

- L4-Hab-MedSys-0006 Access knowledge augmentation
- L4-Hab-MedSys-0116 Update medical records

**Knowledge-Based Support for Crew Performing Medical Tasks -**

**Habitat Medical System - Analyze Health Data**

- L4-Hab-MedSys-0007 Synthesize health data
- L4-Hab-MedSys-0219 Assess crew status
- L4-Hab-MedSys-0232 Interpret task performance data

**Habitat Medical System - Crew - Crew as caregiver**

- L4-Hab-MedSys-0095 Access medical decision support
- L4-Hab-MedSys-0097 Diagnose patient
- L4-Hab-MedSys-0098 Treat patient
- L4-Hab-MedSys-0170 Interview patient

**Habitat Medical System - Crew - Crew as patient**

- L4-Hab-MedSys-0099 Activate medical support

**Habitat Medical System - Crew - Crew as crewmember**

- L4-Hab-MedSys-0107 Participate in private medical conferences

**Caregiver/Patient Interactions - Interview Patient**

- L4-Hab-MedSys-0016 Collect medical data throughout caregiver and patient interaction

**Caregiver/Patient Interactions - Perform Physical Exam and Conduct Screening exams/tests**

- L4-Hab-MedSys-0017 Conduct screening exam
- L4-Hab-MedSys-0018 Perform physical exam

**Caregiver/Patient Interactions - Assess and Monitor Vital Signs**

- L4-Hab-MedSys-0019 Interpret vital signs
- L4-Hab-MedSys-0020 Collect vital signs
- L4-Hab-MedSys-0021 Monitor vital signs
- L4-Hab-MedSys-0022 Record vital signs

**Caregiver/Patient Interactions - Administer and Manage Medications**

- L4-Hab-MedSys-0024 Provide pharmacy

**Caregiver/Patient Interactions - Perform Imaging**

- L4-Hab-MedSys-0025 Perform Imaging

**Caregiver/Patient Interactions - Perform Laboratory Analysis**

- L4-Hab-MedSys-0026 Perform Laboratory Analysis

**Caregiver/Patient Interactions - Perform Procedures**

- L4-Hab-MedSys-0029 Perform wound care
- L4-Hab-MedSys-0030 Perform airway procedures
- L4-Hab-MedSys-0031 Perform anesthesia procedures
- L4-Hab-MedSys-0032 Perform breathing procedures
- L4-Hab-MedSys-0033 Perform circulation procedures
- L4-Hab-MedSys-00L44 Perform dental procedures
- L4-Hab-MedSys-00L45 Perform eye procedures
- L4-Hab-MedSys-00L46 Perform gastrointestinal procedures
- L4-Hab-MedSys-00L47 Perform immobilization procedures
- L4-Hab-MedSys-00L48 Perform musculoskeletal procedures
- L4-Hab-MedSys-0039 Perform ENT procedures
- L4-Hab-MedSys-0204 Perform genitourinary procedures
- L4-Hab-MedSys-0211 Perform medical suctioning procedures

**Caregiver/Patient Interactions - Personal Protection**

- L4-Hab-MedSys-0041 Provide biohazard waste containment
- L4-Hab-MedSys-0042 Provide eye protection
- L4-Hab-MedSys-0044 Provide medical skin protection
- L4-Hab-MedSys-0046 Provide menstrual flow absorption
- L4-Hab-MedSys-0047 Provide postmortem containment of body
- L4-Hab-MedSys-0049 Provide sharps containment

**Medical Assessment and Monitoring - Dietary Control / Nutrition Monitoring**

- L4-Hab-MedSys-0050 Adjust nutritional management
- L4-Hab-MedSys-0226 Interpret crew nutritional health status

**Medical Assessment and Monitoring - Monitor and Assess Environment**

- L4-Hab-MedSys-0051 Interpret habitat environment monitoring data
- L4-Hab-MedSys-0229 Access environmental monitoring records
- L4-Hab-MedSys-0230 Adjust habitat environment



**Medical Assessment and Monitoring - Monitor and Control Sleep and Fatigue**

- L4-Hab-MedSys-0052 Interpret crew sleep health status
- L4-Hab-MedSys-0053 Interpret crew fatigue status

**Medical Assessment and Monitoring - Support Behavioral Health**

- L4-Hab-MedSys-0054 Interpret behavioral health status
- L4-Hab-MedSys-0227 Adjust behavioral health countermeasures

**Medical Assessment and Monitoring - Support Musculoskeletal Health**

- L4-Hab-MedSys-0055 Interpret physiological health status

- L4-Hab-MedSys-0056 Adjust physiological health countermeasures
- L4-Hab-MedSys-0221 Monitor crew health
- L4-Hab-MedSys-0233 Adjust task management

**Medical Assessment and Monitoring - Support Physical Therapy**

- L4-Hab-MedSys-0218 Access physical therapy consultation

**Maintaining Current State of Medical System - Document Care**

- L4-Hab-MedSys-0057 Record medical findings/results
- L4-Hab-MedSys-0058 Record occurrence of medical action
- L4-Hab-MedSys-0059 Record interpretations
- L4-Hab-MedSys-0222 Document crew health status

The Non-Functional Requirements of the Habitat Medical System address technical performance, design, reliability, and other -ilities needs of the system that complement the functional needs of the medical system. Although they do not address all the non-functional characteristics of the system [15], they do provide the most relevant requirements considered at this time and are shown below in Table 5.

Table 5. Habitat Medical System Level 4 Non-Functional Requirement ID and Names

**Accessibility**

- Hab-MedSys-1072 Lifecycle Accessibility

**Human Risk**

- Hab-MedSys-1041 Loss of Crew Risk
- Hab-MedSys-1042 Transfer Mission to Definitive Care Risk
- Hab-MedSys-1043 Quality Time Lost Risk

**Maintainability**

- Hab-MedSys-1048 Preventive Maintenance
- Hab-MedSys-1049 Corrective Maintenance
- Hab-MedSys-1050 Lifecycle Modularity
- Hab-MedSys-1051 Lifecycle Adaptability
- Hab-MedSys-1052 Lifecycle Replaceability

**Performance**

- Hab-MedSys-1044 Time behavior
- Hab-MedSys-1045 Minimize Resource utilization
- Hab-MedSys-1046 Provide Ground Awareness
- Hab-MedSys-1047 Provide Interoperability
- Hab-MedSys-1071 Operational Time
- Hab-MedSys-1074 Failure Notification

**Physical Constraints**

- Hab-MedSys-1062 Operational Habitat Environment

- Hab-MedSys-1063 Non-operating Environment
- Hab-MedSys-1064 Power Interfaces
- Hab-MedSys-1065 Structural Interfaces
- Hab-MedSys-1066 Fluid Interfaces
- Hab-MedSys-1067 Data Interfaces
- Hab-MedSys-1073 Toxicity Minimization

**Reliability**

- Hab-MedSys-1053 Repair Time
- Hab-MedSys-1054 Failure tolerance
- Hab-MedSys-1055 Failure Propagation
- Hab-MedSys-1056 Operational Life
- Hab-MedSys-1057 Unintentional operation

**Resource Allocation**

- Hab-MedSys-1068 Minimize Mass
- Hab-MedSys-1069 Minimize Power
- Hab-MedSys-1070 Minimize Volume

**Security**

- Hab-MedSys-1058 User Confidentiality
- Hab-MedSys-1059 System Integrity
- Hab-MedSys-1060 Action Accountability
- Hab-MedSys-1061 System Authentication

**TRACEABILITY**

The traceability of the requirements as shown in Figure 6 ensures that the requirements address each one of the clinical activities and ConOps functions of the Habitat Medical System. The left graphic shows traces of clinical capabilities and functional requirements, while the right graphic shows traces of a Level 4 requirement and the associated Level 5 child requirements.

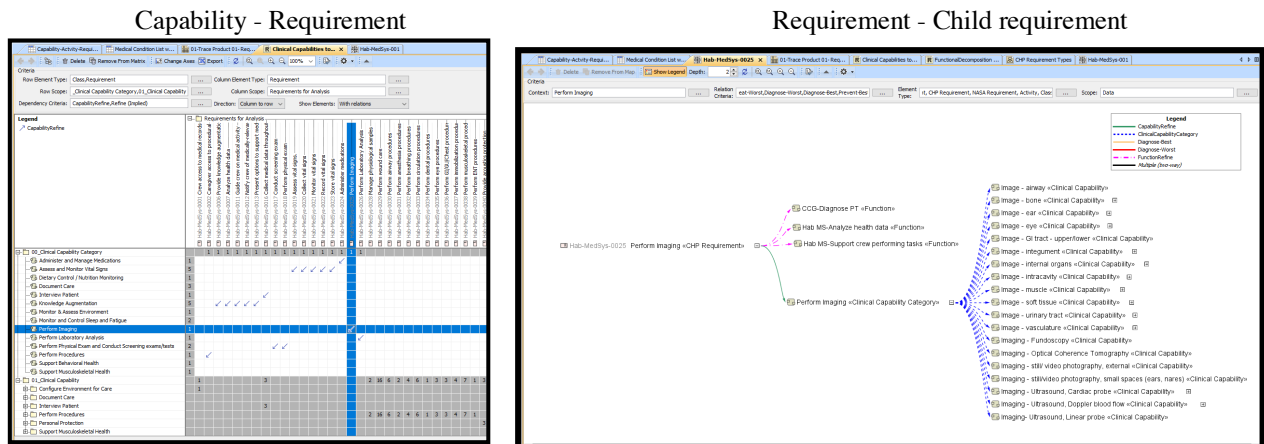


Figure 6. Requirements traceability [1].

## CONCLUSIONS

The ExMC Systems Engineering Requirement Team developed 270 Level 4 Systems Engineering Foundational Requirements to provide In-Flight Level-Of-Care IV prevention, diagnosis and treatment of medical conditions in Space Lunar Orbit Habitat. These requirements address needs in the Habitat System as follows:

### Habitat CHP Medical Domain

- *75 Functional Requirements of the Habitat CHP Medical System*
- *34 Non-Functional Requirements of the Habitat CHP Medical System*

### Habitat CHP Domain

- *52 Functional Requirements of the Habitat CHP Data System*
- *34 Functional Requirements of the Habitat CHP Wellness Support System*
- *21 Functional Requirements of the Habitat CHP Task Performance Support System*
- *14 Functional Requirements of the Habitat CHP Environmental Monitoring System*
- *26 Functional Requirements of the Habitat CHP Research and Testbed System*
- *9 Requirements of the Habitat Maintenance System*
- *1 Requirements of the Habitat EVA System*

### Habitat Domain

- *3 Requirements of the Habitat Waste System*
- *1 Requirements of the Habitat Structures System*

This requirement development is based on available information obtained from different resources:

- Concept of Operations for space missions with draft document narratives of system and sub-systems needs to maintain crew health and enable mission success, and complementary information from the functional decomposition of the system addressing the sub-systems of the space Habitat.
- Comprehensive list of Clinical Capabilities addressing in-flight planned and unplanned activities for space missions.
- Reviews from subject matter experts developed by the ExMC Systems Engineering and clinician team following the ExMC SE MBSE formal approach to deliver the system needs as Foundational Requirements as a basis to provide medical care for space Habitat missions.

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## REFERENCES

- [1] NASA Human Research Program, Experimental Medical Capability Element, Level of Care IV: Short-Duration Lunar Orbit Medical System Foundation, NASA, [Online]. Available: [http://js-ev-draw01.ndc.nasa.gov/magicdraw/DSG-CHP-Model-html/Lev%20Care%20IV%20Foundation\\_10.html](http://js-ev-draw01.ndc.nasa.gov/magicdraw/DSG-CHP-Model-html/Lev%20Care%20IV%20Foundation_10.html).
- [2] DAU, Systems Engineering, Chapter 3, *Figure 2: Systems Engineering Processes*, March 20, 2019, [Online]. Available: <https://www.dau.edu/guidebooks/Shared%20Documents/Chapter%203%20Systems%20Engineering.pdf>
- [3] NASA Procedural Requirements *NPR 7123.1C*, NASA Systems Engineering Processes and Requirements, February 14, 2020 to February 14, 2025, [Online]. Available: <https://nodis3.gsfc.nasa.gov>
- [4] Medical System *Concept of Operations for Deep Space Gateway Habitat (Draft)*, NASA, Human Research Program, Exploration Medical Capability element, Systems Engineering, October 2017.

- [5] *Crew Health and Performance System Concept of Operations for Gateway Missions (Draft)*, NASA, Human Research Program, Exploration Medical Capability element, Systems Engineering, October 2018.
- [6] *NASA-STD-3001 VOL 1 REV A CHANGE 1 NASA Space Flight Human-System Standard, Volume 1: Crew Health*, February 12, 2015.
- [7] *NASA-STD-3001 VOL 2 REV A NASA Space Flight Human-System Standard, Volume 2: Human Factors, Habitability, and Environmental Health*, February 10, 2015.
- [8] Hailey, M., M. Urbina, D. Reyes, and E. Antonsen, *Interpretation of NASA-STD-3001 Levels of Care for Exploration Medical System Development*, NASA, TM 2017-219290, Johnson Space Center, Texas, April 2017.
- [9] *Functional Decomposition diagrams*, (Excel file, NASA Human Research Program, Experimental Medical Capability element, Systems Engineering, 2018).
- [10] *Medical Category and Planned-Unplanned-Research and Testbed Planned Activity list*, (Excel file, NASA Human Research Program, Experimental Medical Capability element, Systems Engineering, 2020).
- [11] *International Space Station Medical Operations Requirements Document (ISS MORD)*, NASA, International Space Station Program, SSP 50260, Rev. C., Johnson Space Center, Houston, Texas, February 2006.
- [12] *Exploration System Development Medical Operations Requirements Document (MORD)*, NASA, ESD 10024, October 2, 2015.
- [13] NASA Human Research Program, *Human Research Roadmap: Evidence-Risks-Gaps-Tasks*, Human Research Program Architecture, NASA, [Online]. Available: <https://humanresearchroadmap.nasa.gov/architecture/>.
- [14] J. Myers, *Integrated Medical Model*, Exploration Medical Capability, Human Research Program, NASA, [Online]. Available: <https://humanresearchroadmap.nasa.gov/tasks/task.aspx?i=686>.
- [15] *ISO/IEC 25010:2011 Systems and Software Engineering - Systems and Software Quality Requirements and Evaluation (SQuaRE) - System and Software Quality Model*, [Online]. Available: <https://www.iso.org/standard/35733.html>.