



# Exploration Medical Capability Systems Engineering Overview and Update

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2020 NASA Human Research Program Investigators' Workshop  
January 27 - 30, 2019 | Galveston Island Convention Center

- Deep space exploration missions present new challenges to crew health and performance:
  - Effects of hazards on crew health and performance are not completely known for long durations or deep space
  - Communication delays, blackout periods
  - No resupply, prepositioning at best
  - No medical evacuation



*Deep space will be different...*

- Limited flight resources (e.g., mass, power, volume, data) → view Crew Health and Performance (CHP) as **an integrated part of flight system development.**
- We are applying systems engineering within HRP to better integrate with exploration offices that are in formulation.

- **Protect from environmental hazards**
  - Radiation protection
  - Noise, vibration, CO<sub>2</sub>, etc.
- **Keep healthy crew well**
  - Exercise
  - Other physiological countermeasures
  - Food
  - Behavioral health
- **Prevent, diagnose, treat, manage long-term health care**
  - Data system
    - Medical Data Capture
    - Medical Training
  - Medical devices
  - Medical supplies
- **Support crew to accomplish mission tasks**
  - Procedures
  - Training
  - User interfaces



# SE Approach to Get There



Stakeholder needs, goals

NASA Standards

Program requirements & architecture

System functions & behaviors

System requirements & architecture

Subsystem requirements & architecture

Characterize system

Analyze & trade

Design & Build

NASA/TM-2017-219290



## Interpretation of NASA-STD-3001 Levels of Care for Exploration Medical System Development

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EHR/IC/IE  
Human Health & Performance Contract  
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MEI Technologies  
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### Medical System Concept of Operations for Mars Exploration Missions

Exploration Medical Capability (ExMC) Element Human Research Program

Verify that this is the correct version before use.

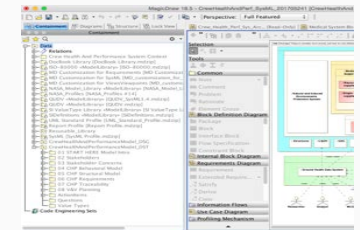
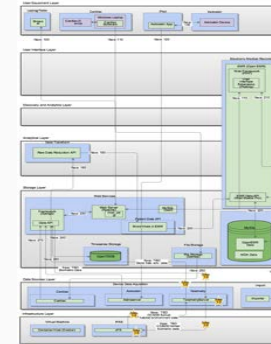
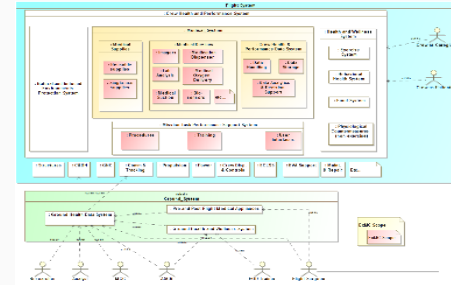
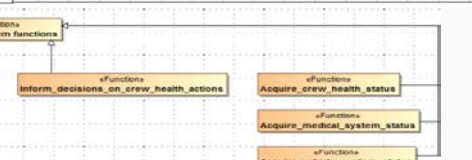
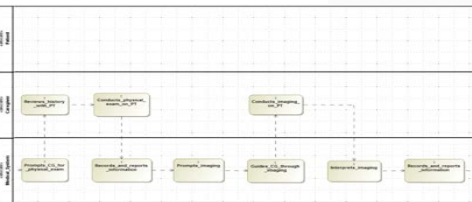
Pre-Baseline

February 2017

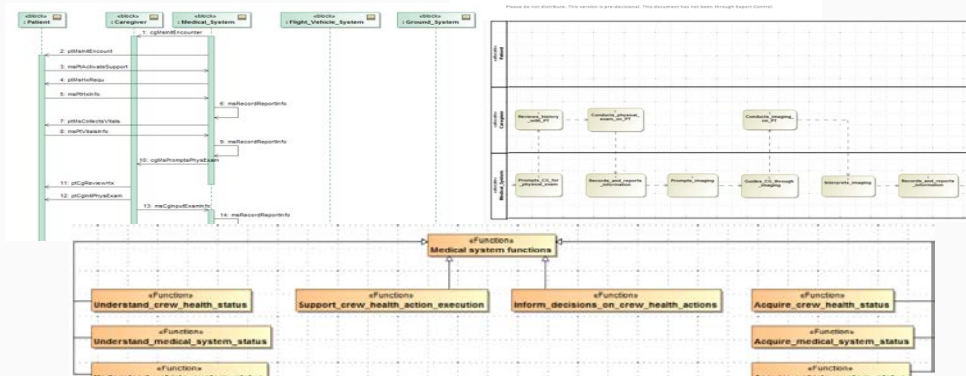


National Aeronautics and Space Administration  
Lyndon B. Johnson Space Center  
Houston, Texas

Pre-baseline version. This system is based on the current baseline through support team.



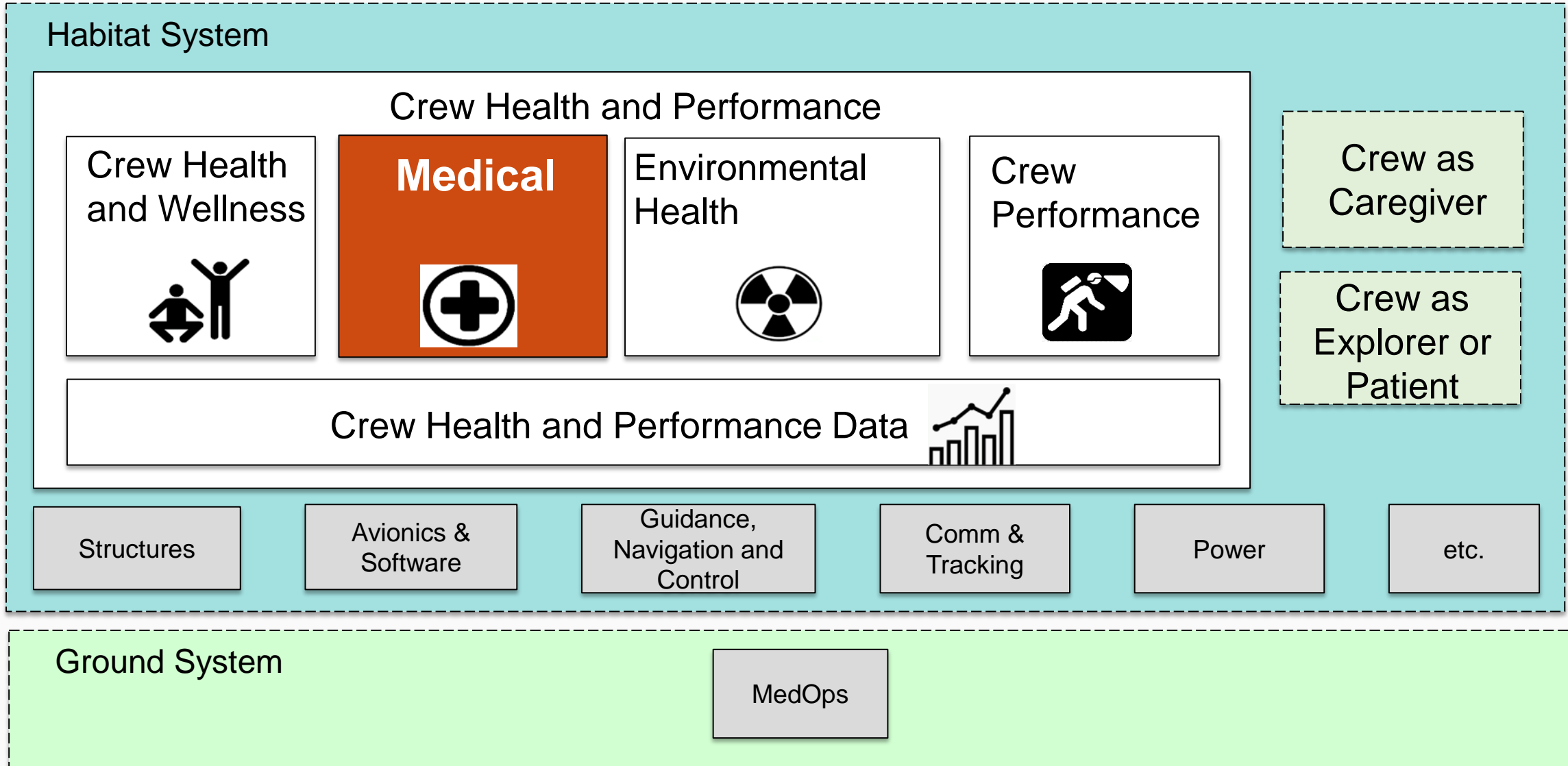
Using Model-Based Systems Engineering:



Do we have the capabilities to meet the needs?  
Do we need altered allocations?

*The needs identified by this work will drive future ExMC research*

# Applying Systems Engineering to Integrate – Context in Representative System



Scope

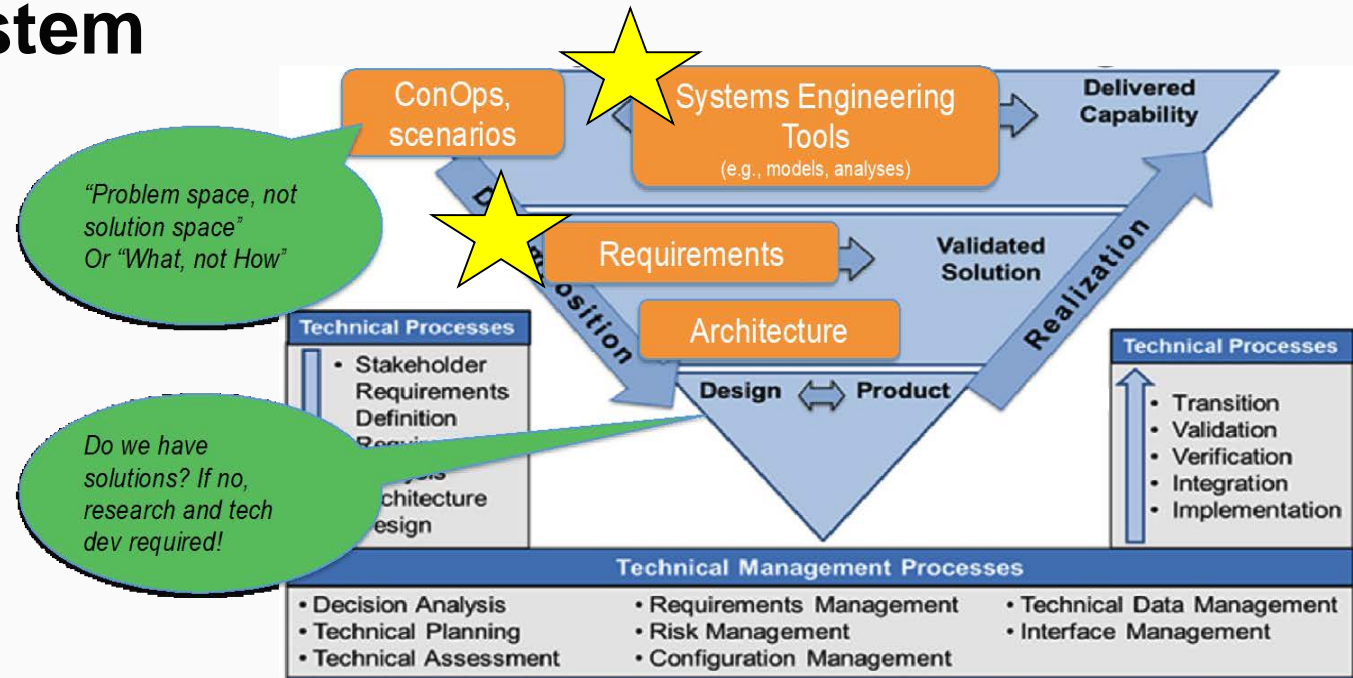
Outcomes

## 1. Level of Care IV Medical System Requirements

## 2. Trade Space Analysis Tools Pilot II

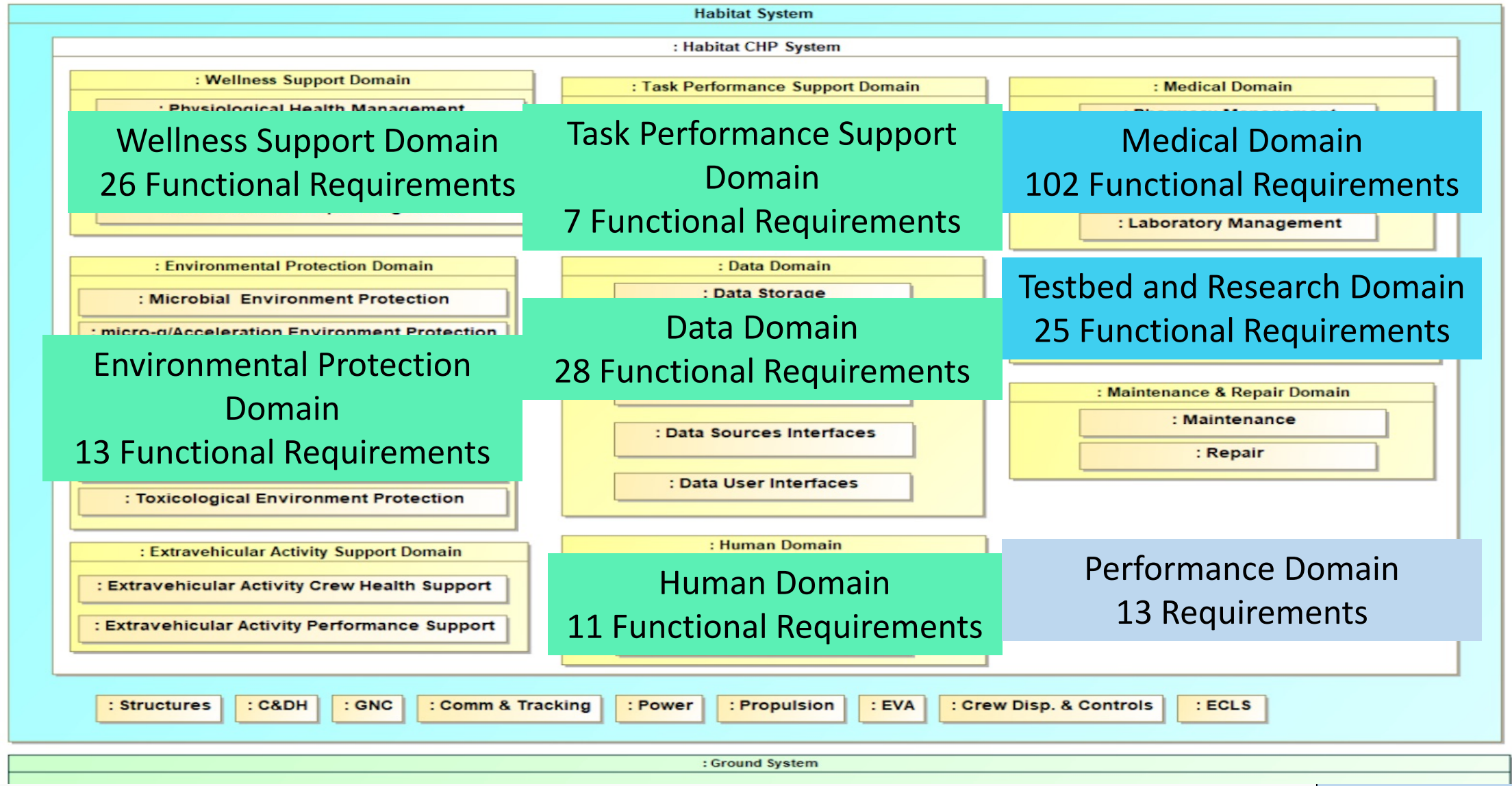
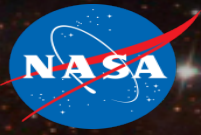
## 3. IMPACT Prototype .1

## 4. MIAMI Partnership

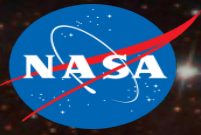


<https://map.dau.mil/ocwpedia/Pages/ArticleDetails.aspx?aid=9c591ad6-8f69-49dd-a61d-4096e7b3086c>

# Level of Care IV Medical System Requirements



# Requirements relationships to discipline inputs



*Input from clinicians - Capability Category: Perform Imaging*

Requirement	Hab-MedSys-0001	Hab-MedSys-0002	Hab-MedSys-0006	Hab-MedSys-0007	Hab-MedSys-0011	Hab-MedSys-0012	Hab-MedSys-0013	Hab-MedSys-0016	Hab-MedSys-0017	Hab-MedSys-0018	Hab-MedSys-0019	Hab-MedSys-0020	Hab-MedSys-0021	Hab-MedSys-0022	Hab-MedSys-0023	Hab-MedSys-0024	Hab-MedSys-0035	Hab-MedSys-0036	Hab-MedSys-0038	Hab-MedSys-0039	Hab-MedSys-0040
00_Clinical Capability Category																					
Administer and Manage Medications	1																				
Assess and Monitor Vital Signs	5																				
Dietary Control / Nutrition Monitoring	1																				
Document Care	3																				
Interview Patient	1																				
Knowledge Augmentation	5																				
Monitor & Assess Environment	1																				
Monitor and Control Sleep and Fatigue	2																				
<b>Perform Imaging</b>	1																				
Perform Laboratory Analysis	1																				
Perform Physical Exam and Conduct Screening exams/tests	2																				
Perform Procedures	1																				
Support Behavioral Health	1																				
Support Musculoskeletal Health	1																				
01_Clinical Capability	1																				
Configure Environment for Care	1																				
Document Care																					
Interview Patient																					
Perform Procedures																					
Personal Protection																					
Support Musculoskeletal Health																					

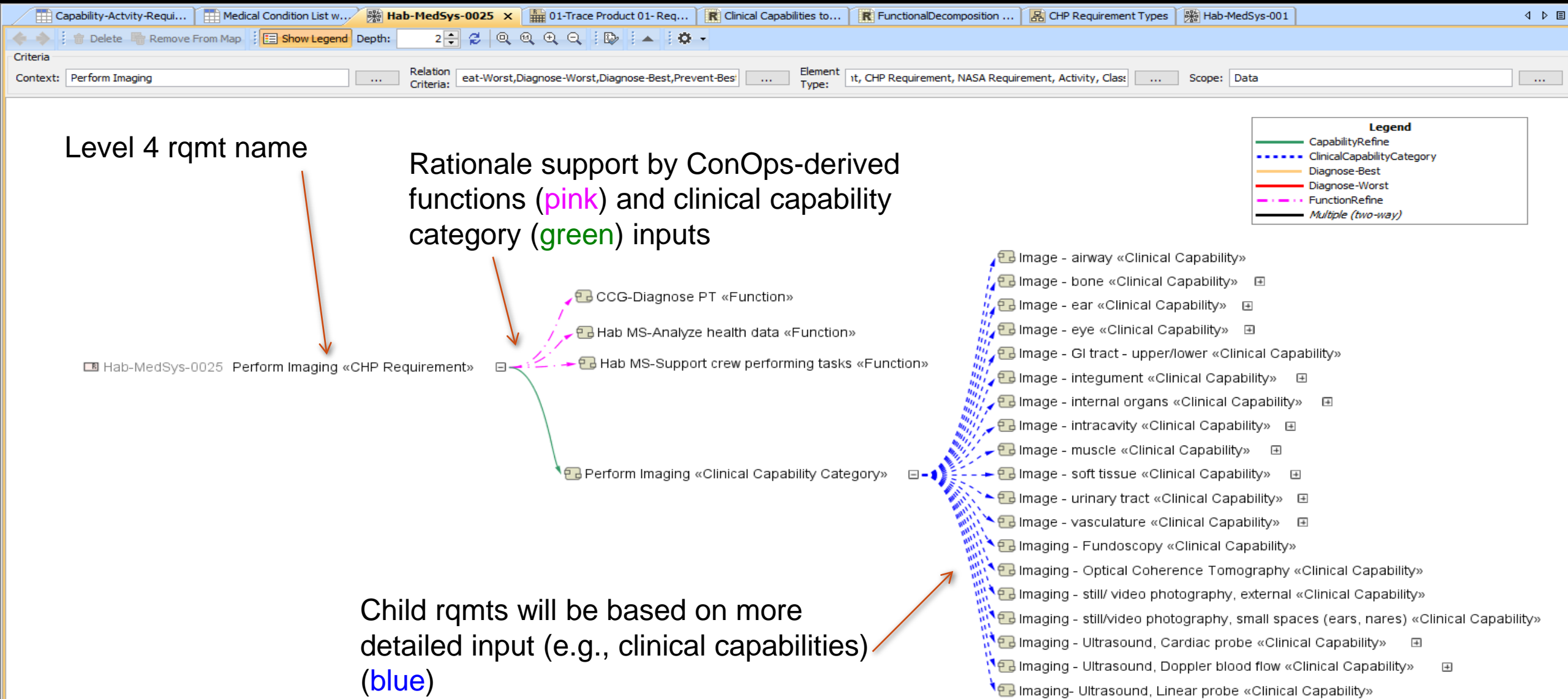
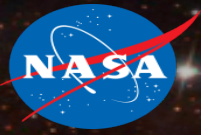
*Output from Rqmts Team - Rqmt: Perform Imaging*

Example question for current iteration:  
 Are the requirement text and rationale statements a reasonable reflection of intent for the related inputs?

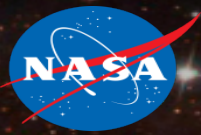
**This is building the bridge between SME content and engineering language!**



# Visualizing the requirement “legs to stand on”

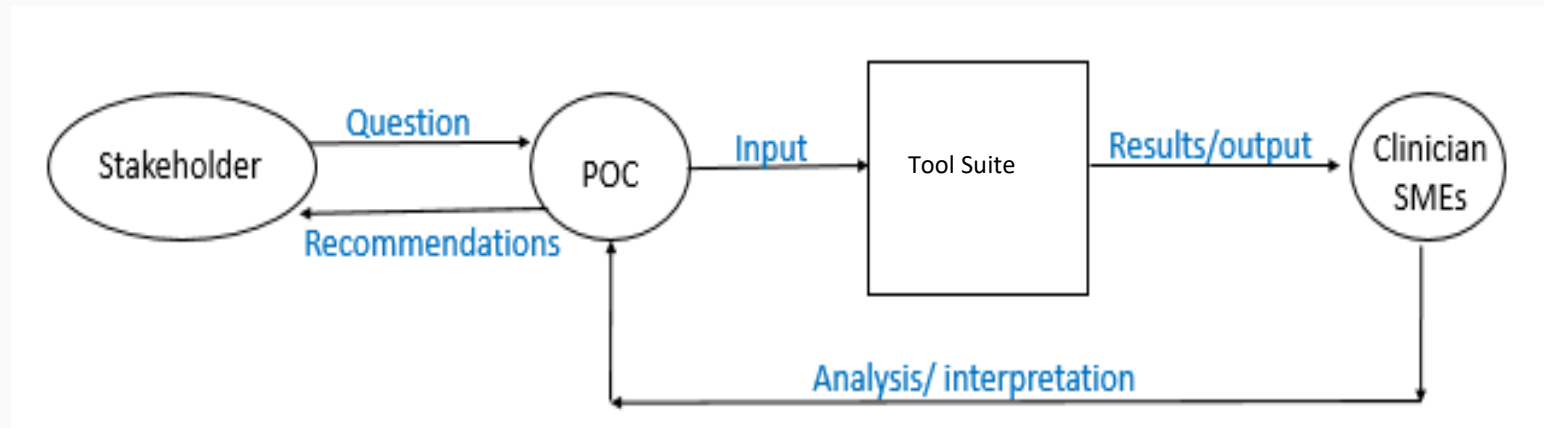


# Purpose of the Tool Suite



## ExMC's Need:

Provide a data-driven means to inform human health and performance risk mitigation interests during resource-constrained exploration mission development.



### Eventually want to answer questions like these:

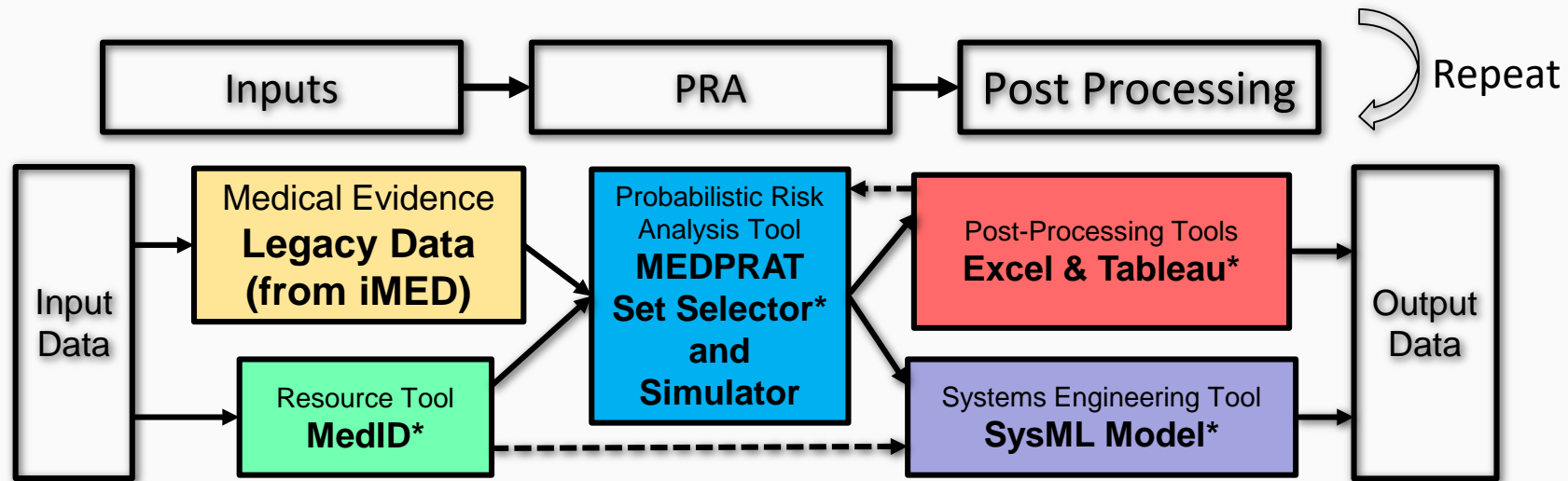
- Does 1 kg of meds or water or an AED best reduce medical risk?
- What is the benefit of changing crew's water rations from 2 to 3L daily on medical risk?
- If we could reduce the mass or volume of hardware X by 50%, would it be sufficient in value to manifest?

# Trade Space Analysis Tools Pilot Project II Configuration

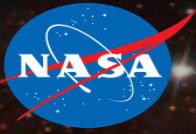


## Phase 2 Pilot Project in FY19

- More integration among the tools
- Defined interfaces
- Shorter lead times in getting results
- Updated MedID resource data
- Exercised the new MEDPRAT set selector (optimizer) extensively
- More sophisticated post-processing to expedite interpretation of results
- Identified effects on the overall system (conditions, requirements) using the SysML model



\* = areas with significant development of new capability during Phase 2



## 1) Enable systematic trade study evaluations

Aid stakeholders in making informed decisions regarding developing a medical system.

## 2) Inform Research Priorities

Aid stakeholders in making informed decisions regarding the funding and prioritization of research. Assess the risk buy-down with metrics for risk, resource characterizations, and requirements satisfaction.

**Memorandum of Agreement**

**Between the**

**Human Research Program Exploration Medical Capability  
Systems Engineering (ExMC SE) Team**

**And**

**the Model-Based Systems Engineering Infusion and Modernization Initiative  
(MIAMI)**

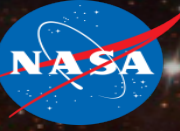
The purpose of this Memorandum of Agreement (MOA) is to define the partnership supporting the advancement of Model-Based Systems Engineering (MBSE) practices as applied to exploration medical and health systems.

This is a living document and will be updated as needed.



In summary, ExMC has:

- Established a Systems Engineering team, processes, and products to integrate with exploration programs
- Built a bridge across medical and engineering domains
- Created a capability to provide traceable, defensible system development products



# Backup

# Example Medical Functional Requirements



ID	Name	Text	Rationale
Hab-MedSys-0024	Provide pharmacy	The Habitat Medical System shall provide an in-flight pharmacy to the crew members.	Pharmaceutical intervention and prevention, as provided by the in-flight pharmacy, is an essential component of risk management planning for crew healthcare during spaceflight. This includes prepare, administer, document, monitoring, inventory, analyze efficacy of med, titrate, or choose new medication if needed. Pharmaceuticals assist crewmembers with adaptation to the spaceflight environment as well as help manage unexpected medical events that could occur, such as illness or injury. Types of medications needed are specified at Level 5.
Hab-MedSys-0005	Track medical inventory	The Habitat Medical System shall track medical inventory.	Ensure that medical inventory (supplies, equipment, and medications) is tracked at all times including when inventory is dispensed. Specific medical inventories, including quantities, availability, track history, etc., are specified at Level 5.
Hab-MedSys-0030	Perform airway procedures	The Habitat Medical System shall enable caregivers to perform airway procedures.	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 for 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.



# Example Medical Data System Requirements



ID	Name	Text	Rationale
Hab-DataSys-0005	Extract data	The Habitat Data System shall extract data.	The Habitat Data System needs to extract data from different Habitat sources; including medical and non-medical equipment, biosensors, video cameras, physical environment, and crew. For example, diagnostic and treatment of a severe skin rash with pain would require the Habitat Data System to retrieve patient's information from medical record, activity logs, exposure to hazards like toxins, fire, chemical, and environmental conditions.
Hab-DataSys-0018	Associate Data	The Habitat Data System shall associate data.	Data associations are needed to organize the information based on entitlement rules. Rules to provide privileges to users and applications to access and modify data like read, write, and execute. Associations on the data system elements (e.g., crew, folders, set of applications) and sub-elements (e.g., user, file, application) as defined in the CHP system. For example, medical data associated with specific crewmember (e.g., ECG record, lab test results, images, etc.). Other associations are needed to relate operation manual and user procedures to specific medical equipment.
Hab-DataSys-0030	Control user access	The Habitat Data System shall control user access.	The Habitat Data System needs the capability to control user access. For example, access is controlled with user privileges in standard operations and emergency situations. User access controls may include different control types based on users, levels and permissions.

# Example Medical Interface Requirements



ID	Name	Text	Rationale
Hab-WellSys-0001	Provide musculoskeletal countermeasures	The Habitat Wellness Support System shall provide countermeasures to maintain musculoskeletal health.	The Habitat Wellness Support System needs to maintain musculoskeletal health. Physiological countermeasures include conditioning activities such as exercise, hygiene, diet and nutritional supplements, pharmaceuticals, novel hardware technologies, etc.
Hab-WellSys-0016	Track food nutritional intake	The Habitat Wellness Support System shall track food nutritional intake.	The Habitat Wellness Support System needs to track nutritional intake to assess crew health. For example, track daily intake of carbohydrates, proteins, fats, vitamins and minerals.
Hab-WellSys-0023	Maintain sleep patterns	The Habitat Wellness Support System shall maintain sleep patterns.	The Habitat Wellness Support System needs to provide capabilities to maintain healthy sleep patterns with sleep and wake schedules not connected to sun light. A healthy sleep pattern improves the circadian rhythm and cognitive performance, reduces stress, and prevents fatigue-induced errors. Sleep patterns are affected by environmental conditions, including artificial light. Countermeasures may include light management, training, medication, and pharmacology interventions. Specific sleep patterns and management are to be defined at Level 5.

# Example Technical Performance Requirements



ID	Name	Text	Rationale
Hab-MedSys-1002	Provide Safety	The Habitat Medical System shall provide safety.	<p>There is the need to provide system safety in the performance of clinical activities (i.e., planned, unplanned, research and testbed activities) to mitigate potential risk to human life, health, and environment in the intended contexts of use. For example, "There is a need to ensure that the risks to crewmember safety and health are assessed prior to any tests, training, and human experiments involving crewmembers," (ISS MORD - SSP 50260, 3.2.5 Crew Surgeon Medical Supervision of Hazardous Training, Testing or Life Sciences Experiments on Crewmembers). Safety metrics, guidelines and procedures are specified at Level 5. (<i>Crew Health and Performance System Concept of Operations for Gateway Missions (Level IV), October 2018; ConOps, Goal #1 CHP Management (i.e., maintain crew health, well-being and safety)</i>)).</p>
Hab-MedSys-1010	Provide Extensibility	The Habitat Medical System shall provide extensibility.	<p>There is the need to provide system extensibility in the performance of clinical activities (i.e., planned, unplanned, research and testbed activities) for medical care in the Habitat. Extensibility should allow to provide medical care considering future growth of the system, the level of effort required to implement the extension, and the impact to existing care functions. The ability to expand the capabilities to address advances in medical sciences, ever-increasing space activities and workload, changes and addition of resources, and increased automatization. For example, advances in mobility aids should be expected to allow "crewmember translation, as well as the translation of equipment or other crew, suited or unsuited, pressurized or unpressurized. Mobility aids assist in the stabilization of the crew, as well as stopping, starting, or changing of direction," (NASA-STD-3001, Vol. 2, Section 8.5.7 Mobility Aid Structural Strength. Extensibility metrics, guidelines and procedures are specified at Level 5. (<i>Crew Health and Performance System Concept of Operations for Gateway Missions (Level IV), October 2018; ConOps, Goal #5 System Extensibility</i>)).</p>