



# Exploration Medical Capability Medical System Recommendations for Gateway

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**Develop clinical content to inform medical system design**

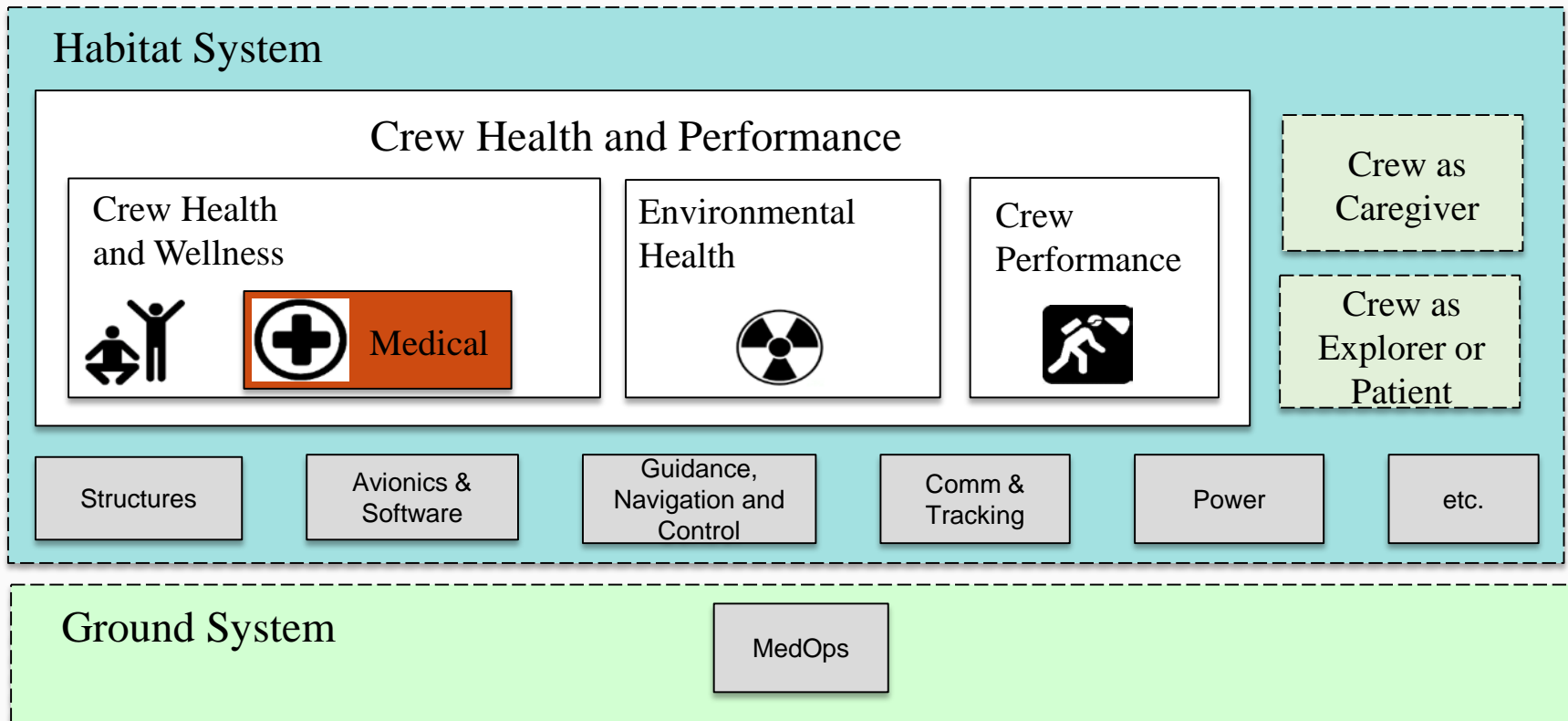
**Iterate on content with wider ExMC team**

**Capture processes used to perform these tasks**



- **Medical System content development**
- **Using model content to inform system design**
- **SME collaboration to refine systems using clinical content**

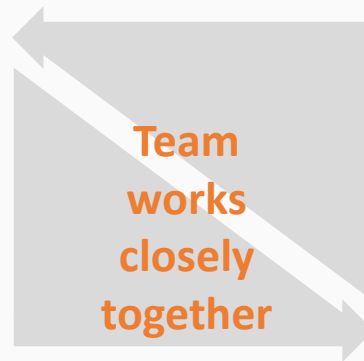
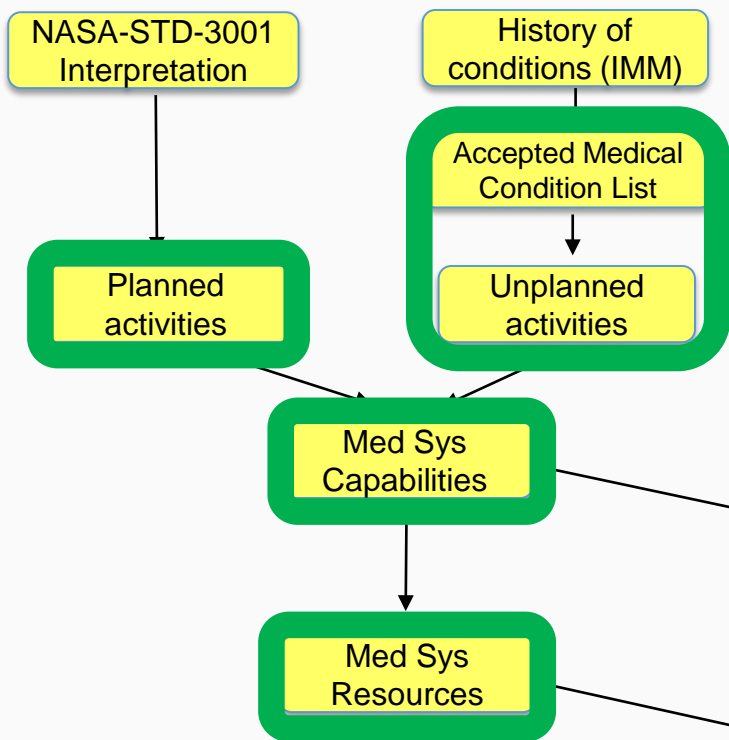
# Medical Subsystem Of A Habitat CH&P System



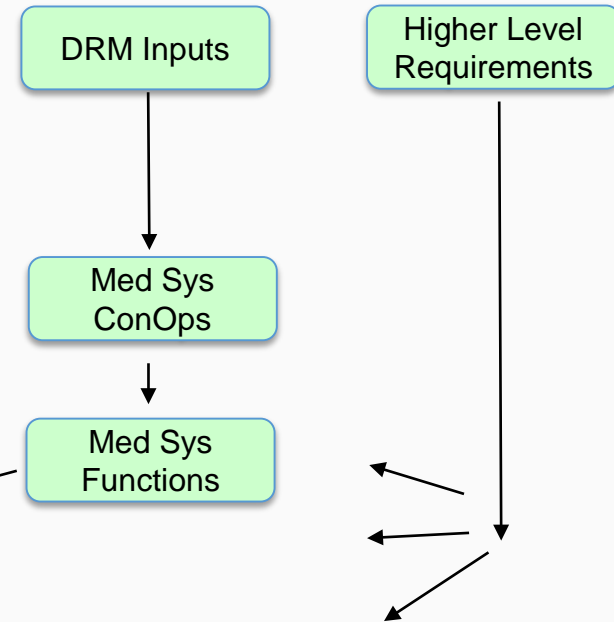
# ExMC Activities to get to Requirements



## Medical Domain Activities



## Sys Eng Activities

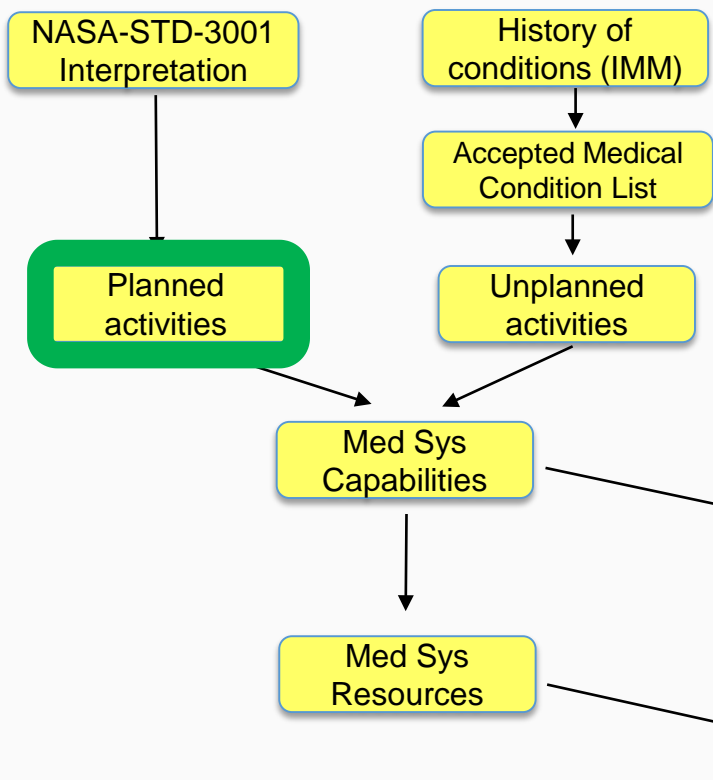


Do we have the capabilities to meet the needs?  
Do we need altered allocations?

# Planned Activities

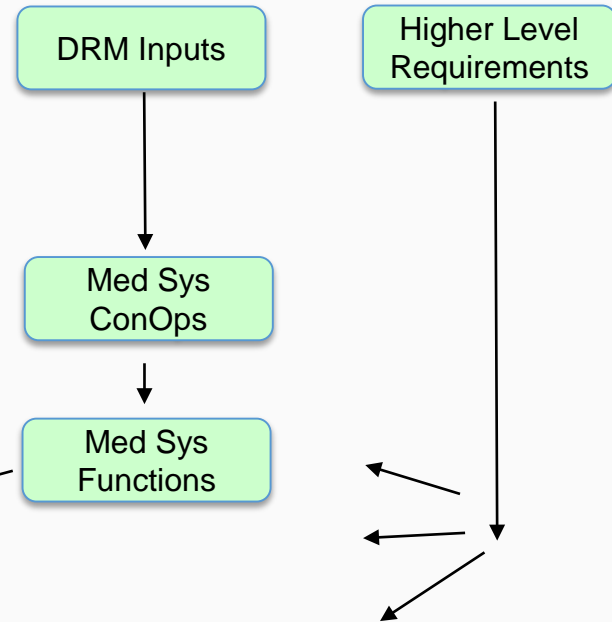


## Medical Domain Activities



Team works closely together

## Sys Eng Activities



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

Scheduled medical care that is expected or required to occur



- **Review of ISS Documentation - IDRDR**
- **Mission Assumptions / Medical Care Philosophy**
  - DRM
  - Level of Care based upon ExMC interpretation of NASA STD 3001
  - ‘Program’ goals and objectives





## **Scheduled medical care that is expected or required to occur**

- Maintain crew health
- Monitor for potential contingency medical events
- Provide a test bed for future exploration missions

### **Examples**

#### *Planned Activities*

- Private Medical Conference
- Periodic Eye Exam

#### *Testbed Planned Activities*

- Periodic Dental Exam
- Bone Health Evaluation

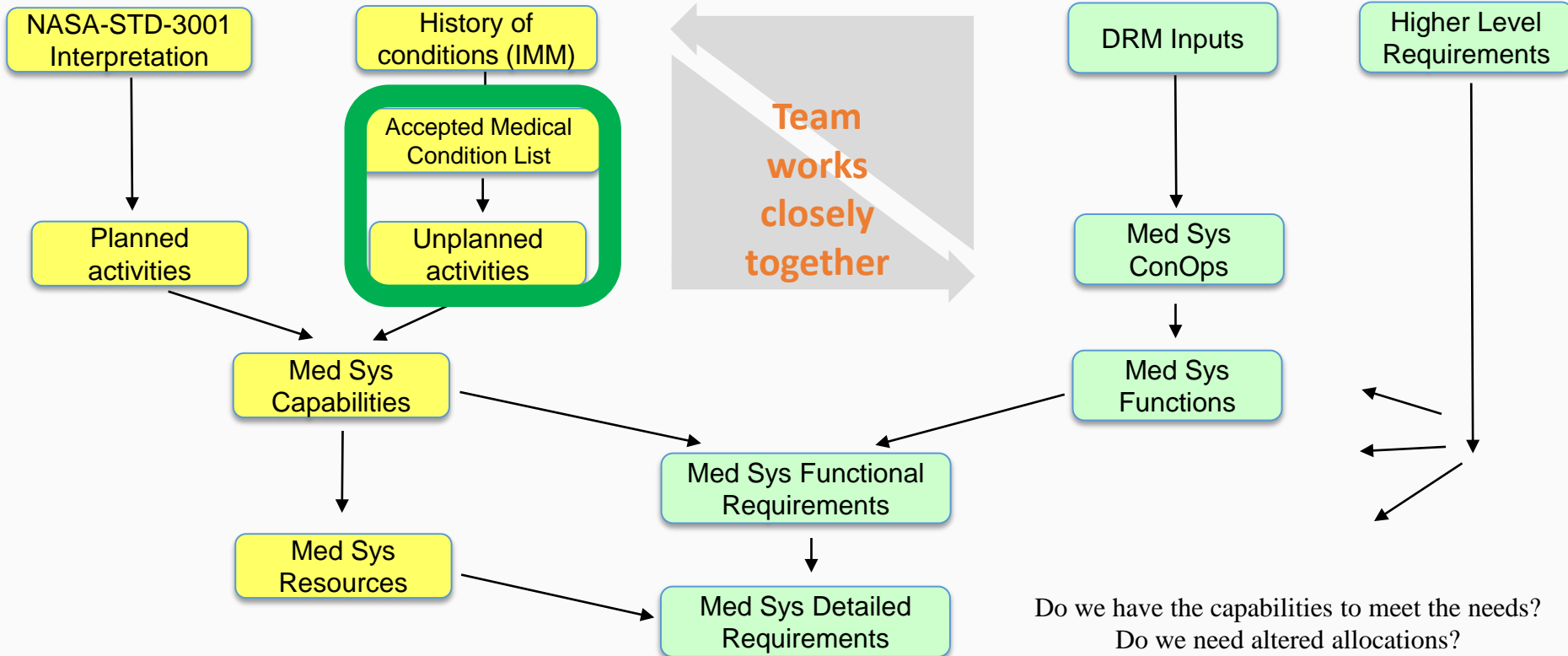
# Unplanned Activities



Team activities to get to requirements

## Medical Domain Activities

## Sys Eng Activities



Medical care not expected or required to occur but addressed on an as-needed basis



- **Process uses list of conditions that influence mission planning**
- **ExMC started with the IMM Condition List**
  - Has evidence base and metrics that support the likelihood of occurrence
  - Each condition as defined by best case and worst case
- **Process has stakeholders rank order list, thus providing context for discussion**
  - Probability of occurrence
  - Complexity score – Large # resources or difficult management
  - Futility score – likely to result in death or disability despite treatment

*Source: Development of an Accepted Medical Condition List for Exploration Medical Capability Scoping, ExMC Working Group, July 2018*

# Accepted Medical Condition List - Example

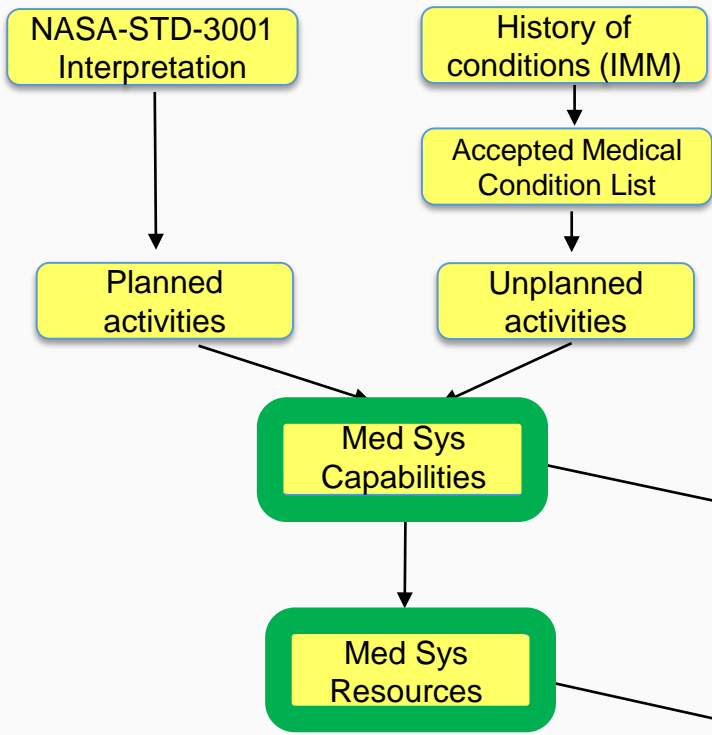


Medical Condition	Best / Worst	Definition	Plan to Treat	Characterization
SKIN RASH	Best	The best case scenario is defined as mild to moderate and uncomplicated skin rash that responds to treatment.	Plan to Treat	N/A
SKIN RASH	Worst	The worst case scenario is defined as a moderate to severe skin rash, covering an extensive area and that might be refractory to treatment.	Plan to Treat with Conditions	Treat to best case only
SMALL BOWEL OBSTRUCTION	Best	The best case scenario is defined as an uncomplicated course of small bowel obstruction which responds to conservative medical treatment (antibiotics and symptomatic treatment) and involves relatively minor functional impairment.	Plan to Treat	N/A
SMALL BOWEL OBSTRUCTION	Worst	The worst case scenario is defined as having a complicated course of small bowel obstruction that is not responsive to conservative treatment and involves significant systemic symptoms, such as severe pain, such as fever, leukocytosis, tachycardia, elevated BUN, serum amylase or alkaline phosphatase, metabolic acidosis and a major functional impairment.	Plan to Treat with Conditions	Treat to best case, add antipyretics/pain control, IV fluids; consider medical evac

# Capabilities and Resources

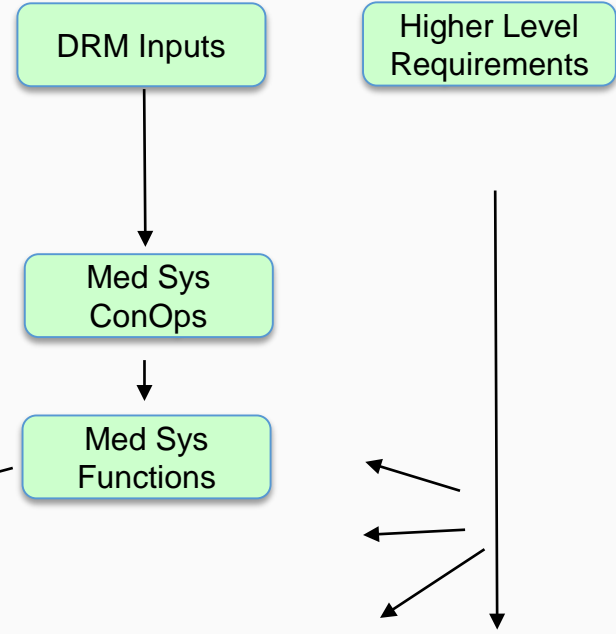


## Medical Domain Activities



Team works closely together

## Sys Eng Activities



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

Action provided by a caregiver to address a condition or planned activity  
Tangible and intangible assets used for a planned activity or condition



- **Review existing documentation**
  - ISS Medical Kit contents list / Med Checklist
  - IDRDR Annex 4
  - IMED database – resources
- **Medical Optimization Network for Space Telemedicine Resources (MONSTR) database**
- **Trace to planned activity and condition**



**18 categories of capabilities, 165 unique capabilities**

**440 unique resources**

**Each Planned and Unplanned (condition) activity is traced to capabilities and resources using SysML model**

# Capabilities and Resources - Examples



Condition	Capability Category	Capability	Resources
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)	EMR interface, Refrigerator, Needle (23G) 1.5", Needle [25g] 1.5", Syringe (3cc), Syringe (10cc), Syringe (5cc), Intraosseous Injection device, Bandaid (2x3), Bandaid Dot, Bandaid strip (1x3), Syringe (1cc Insulin syringe with SQ needle), PPE - Nitrile gloves (multiple sizes, pair), Sharps container, Biohazard Trash Bag, BZK wipes
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Oral	EMR interface, Potable water
DENTAL AVULSION (TOOTH LOSS)	Administer and Manage Medications	Medication - Topical	EMR interface, Refrigerator, Cotton swabs - sterile, Cotton swabs - clean, Cotton balls, PPE - Nitrile gloves (multiple sizes, pair), Biohazard Trash Bag



# Medical Content seen in SysML model



## Legend

- Diagnose-Best
- Diagnose-Worst
- Prevent-Best
- Prevent-Worst
- Treat-Best
- Treat-Worst
- Multiple (one-way)

### 01\_Clinical Capability

#### Administer and Manage Medications

- Medication - Chronic Disease Management
- Medication - Crew Preference
- Medication - Blood Products
- Medication - Inhaled/Nebulized
- Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)
- Medication - Oral
- Medication - Parenteral Fluids
- Medication - Reconciliation
- Medication - Topical

#### Assess and Monitor Vital Signs

#### Configure Environment for Care

#### Dietary Control / Nutrition Monitoring

#### Document Care

#### Evacuation

#### In-Flight Prevention

#### Interview Patient

#### Knowledge Augmentation

#### KSA

#### Medical System Support

#### Monitor & Assess Environment

#### Monitor and Control Sleep and Fatigue

#### Perform Imaging

	BURNS SECONDARY TO FI...	CARDIOGENIC SHOCK SEC...	CHEST INJURY	CHOKING/OBSTRUCTED AI...	CONSTIPATION (SPACE AL...	Decompression Sickness S...	DENTAL ABSCESS	DENTAL AVULSION (TOOT...	DENTAL CARIES	DENTAL CROWN LOSS	DENTAL EXPOSED PULP	DENTAL FILLING LOSS	DEPRESSION	DIARRHEA	ELBOW DISLOCATION	ELBOW SPRAIN/STRAIN	EYE CHEMICAL BURN	EYE CORNEAL ULCER	EYE INFECTION	EYE IRRITATION/ABRASIO...	EYE PENETRATION (FOREI...	FINGER DISLOCATION	Fingernail Delamination Se...	GASTROENTERITIS
01_Clinical Capability	38	60	100	38	56	8	83	86	46	46	66	64	95	74	77	58	87	81	79	77	77	58	4	68
Administer and Manage Medications	8		3		2		6	6			4	3	2	2	4	2	6	6	4	4	4	2		3
Medication - Chronic Disease Management																								
Medication - Crew Preference																								
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Medication - Parenteral Fluids																								
Medication - Reconciliation																								
Medication - Topical																								
Assess and Monitor Vital Signs	16	10	12	6	10		12	10	8		10	6	6	14	8	10	12	12	12	12	12	8		14
Configure Environment for Care	12	12	12		12		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		11
Dietary Control / Nutrition Monitoring					6		2	2		2	2	2	8	10										6
Document Care	2	2	2	2	2		2	4	2	2	1	2	2	2	2	2	2	2	2	2	2	2		2
Evacuation	2		1				1	2					1		1		1	1	1	1	1			
In-Flight Prevention	2		2	2	6	4	4	6	2	4	2	4	12	6	2	4	2	6	6	2	2	2		4
Interview Patient	6	6	6	2	6		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		6
Knowledge Augmentation	4	4	6	1	2		4	2	2	3	4	4	2	2	6	4	4	4	4	4	4	4		4
KSA																								
Medical System Support	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4		4
Monitor & Assess Environment	4														6									
Monitor and Control Sleep and Fatigue													6											
Perform Imaging	4	10					2	2	2	2	2	2			8		2	2	2	2	2	4		

# Capabilities and Resources - Examples



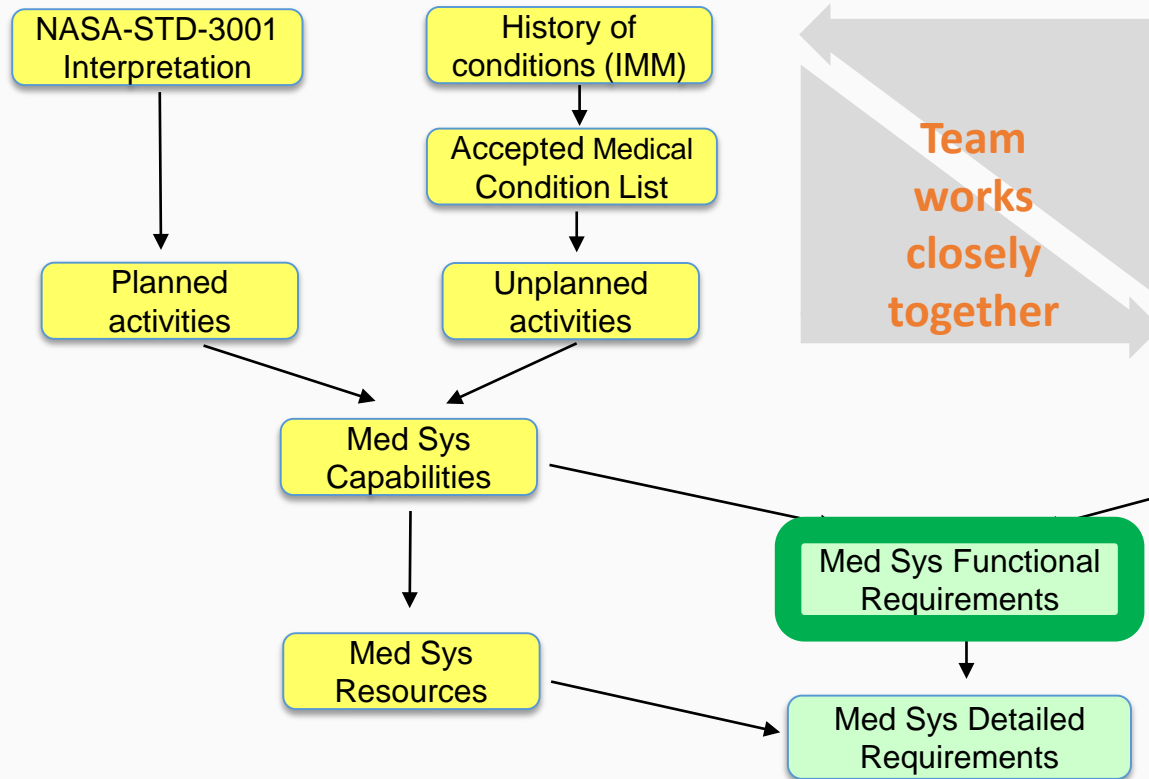
Resource	Capability
Syringe (10cc)	Airway - Endotracheal Intubation, Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular), Breathing - Needle Thorocostomy, Circulation - IO Access, Circulation - IV Access, GI/GU/Chest - Percutaneous drainage Bladder/Gallbladder/Appendix/Chest, Nose - Nasal Packing (Anterior + Posterior), GI/GU - Urinary Catheterization, Screening Exam/Test - Intracranial pressure, Wound Care - Repair, multiple layer, Wound Care - Repair, Single layer
Syringe (1cc Insulin syringe with SQ needle)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)
Syringe (3cc)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular)
Syringe (5cc)	Medication - Injectable (IV, IO, SQ, Intraarticular, Intraocular),



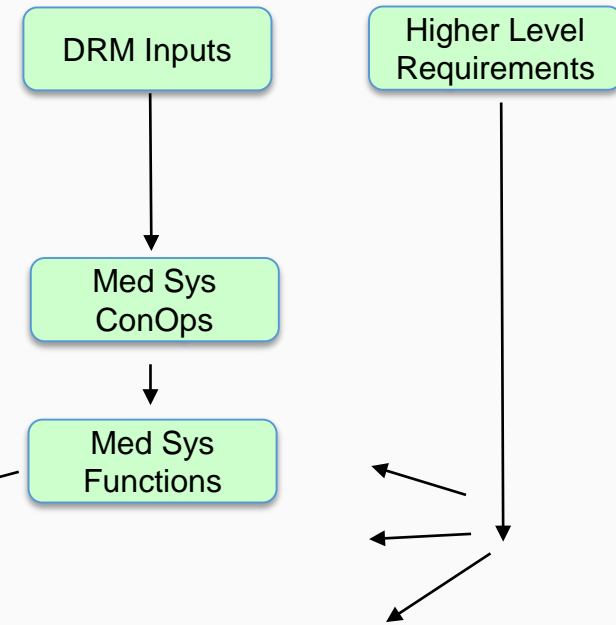
# Functional Requirements



## Medical Domain Activities



## Sys Eng Activities



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

# Key Requirement Development Concepts



- **Type of requirements – project goal was high-level functional**

- Functional – *what* has to be done
  - Performance – *how well* it has to be done, often quantitative
  - Interface – define in relation to external systems
    - e.g., mechanical, information, electrical
  - -ilities, operational, physical characteristics
- ← In scope
- } Not in scope

- **Level of detail**

- Starting point for this set is the clinical capability categories
  - Binned many individual capabilities to become lower level child requirements
  - Identified placeholders for higher level parent requirements

- **Content**

- Single requirement can cover input from planned activities, testbed planned activities, unplanned activities, and functional decomposition content (based on ConOps)

# Example Inputs to Requirements



## Clinical Capability Listing example

DSG Clinical Capability Hierarchy											
DSG Activity Type	DSG Activity Name	Clinical Capability Category	Clinical Capability	Comments	Prevent Best	Prevent-Worst	Diagnose-Best	Diagnose-Worst	Treat-Best	Treat-Worst	
DSG UnPlanned Activity	xxx	Perform Imaging	Image - ear				ACUTE SINUSITIS;	ACUTE SINUSITIS; BAROTRAUMA (EAR/SINUS BLOCK); PHARYNGITIS			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - eye				ACUTE ANGLE-CLOSURE GLAUCOMA; EYE CHEMICAL BURN; EYE TRAUMA	ACUTE ANGLE-CLOSURE GLAUCOMA; EYE CHEMICAL BURN; EYE TRAUMA			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - integument				ACUTE COMPARTMENT SYNDROME; ANAPHYLAXIS; CHEST INJURY	ACUTE COMPARTMENT SYNDROME; ANAPHYLAXIS; CHEST INJURY			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - intracavity				DENTAL ABSCESS; DENTAL AVULSION (TOOTH LOSS); DENTAL CROWN	DENTAL ABSCESS; DENTAL AVULSION (TOOTH LOSS); DENTAL CROWN			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - muscle				ACUTE COMPARTMENT SYNDROME; CHEST INJURY; ELBOW DISLOCATION	ACUTE COMPARTMENT SYNDROME; CHEST INJURY; ELBOW DISLOCATION			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - soft tissue				ACUTE COMPARTMENT SYNDROME; ELBOW DISLOCATION; HIP DISLOCATION	ACUTE COMPARTMENT SYNDROME; ELBOW DISLOCATION; HIP DISLOCATION			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - vasculature				ABDOMINAL INJURY; ACUTE COMPARTMENT SYNDROME; CHEST INJURY	ABDOMINAL INJURY; ACUTE COMPARTMENT SYNDROME; CHEST INJURY			
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging - Fundoscopy	may be necessary if ISS proves out that OCT works for everything this domain							
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging - Optical Coherence Tomography								
DSG Testbed Planned Activity	HSI Assessment	Perform Imaging	Imaging - still/ video photography, external								
DSG Testbed Planned Activity	Periodic Dental Exam	Perform Imaging	Imaging - still/ video photography, external								
DSG Testbed Planned Activity	Periodic Physical Exam	Perform Imaging	Imaging - still/video photography, small spaces (ears, nares)	this is the only imaging we do on ISS (not counting SANS imaging needs)							
DSG UnPlanned Activity	xxx	Perform Imaging	Imaging - Ultrasound, Cardiac probe				ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK	ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK			
DSG UnPlanned Activity	xxx	Perform Imaging	Imaging - Ultrasound, Doppler blood flow				ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK	ATRIAL FIBRILLATION/ ATRIAL FLUTTER; CARDIOGENIC SHOCK			
DSG Planned Activity	Periodic Eye Exam	Perform Imaging	Imaging- Ultrasound, Linear probe								
DSG Testbed Planned Activity	Bone Health Evaluation	Perform Imaging	Imaging- Ultrasound, Linear probe								
DSG UnPlanned Activity	xxx	Perform Imaging	Perform Imaging Imaging - Image Ears				HEARING LOSS	HEARING LOSS			
DSG UnPlanned Activity	xxx	Perform Imaging	Image - urinary tract				ABDOMINAL INJURY; NEPHROLITHIASIS	ABDOMINAL INJURY; NEPHROLITHIASIS			



# Requirements Organization

- **Provide Appropriate Level of Care**
- **Environment Configuration for Medical Care**
  - Configure Environment for Care
  - Habitat Medical Systems Inventory
- **Knowledge-Based Support for Crew Performing Medical Tasks**
  - Augment Crew Knowledge
  - Analyze Health Data
  - Data Presentation
  - Support Crew Performing Tasks
- **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
- **Maintaining Current State of Medical System**
  - Document Care
  - Update Habitat Medical System
  - Analyze Engineering Data
- **In-Flight Prevention**
  - Equipment Procedure
  - Exercise Protocol
  - Hygiene
  - Personal Protection
  - Radiation Exposure
  - Private Conference



## Clinical Capability Category: Perform imaging

### Text

The Habitat Medical System shall perform imaging.

### Rationale

This capability supports the periodic eye exam planned activity, testbed planned activities such as physical exams, dental exams, and HSI assessments, and diagnosis and treatment of many medical conditions. Specific imaging modalities and target anatomical areas are specified at Level 5.

Imaging capability is essential for all medical aspects. This includes medical examinations for internal physiological health to surface physiological health.



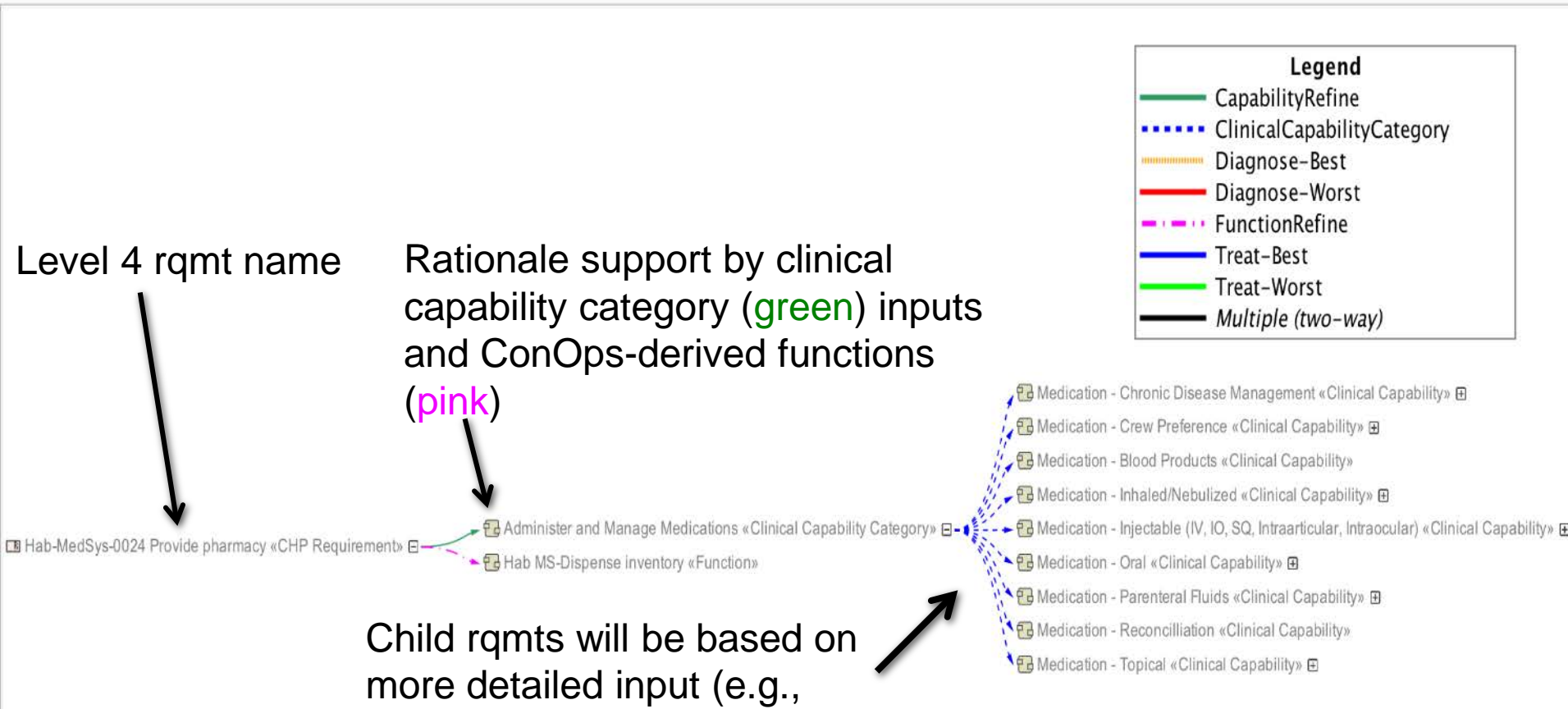
# Requirement Examples

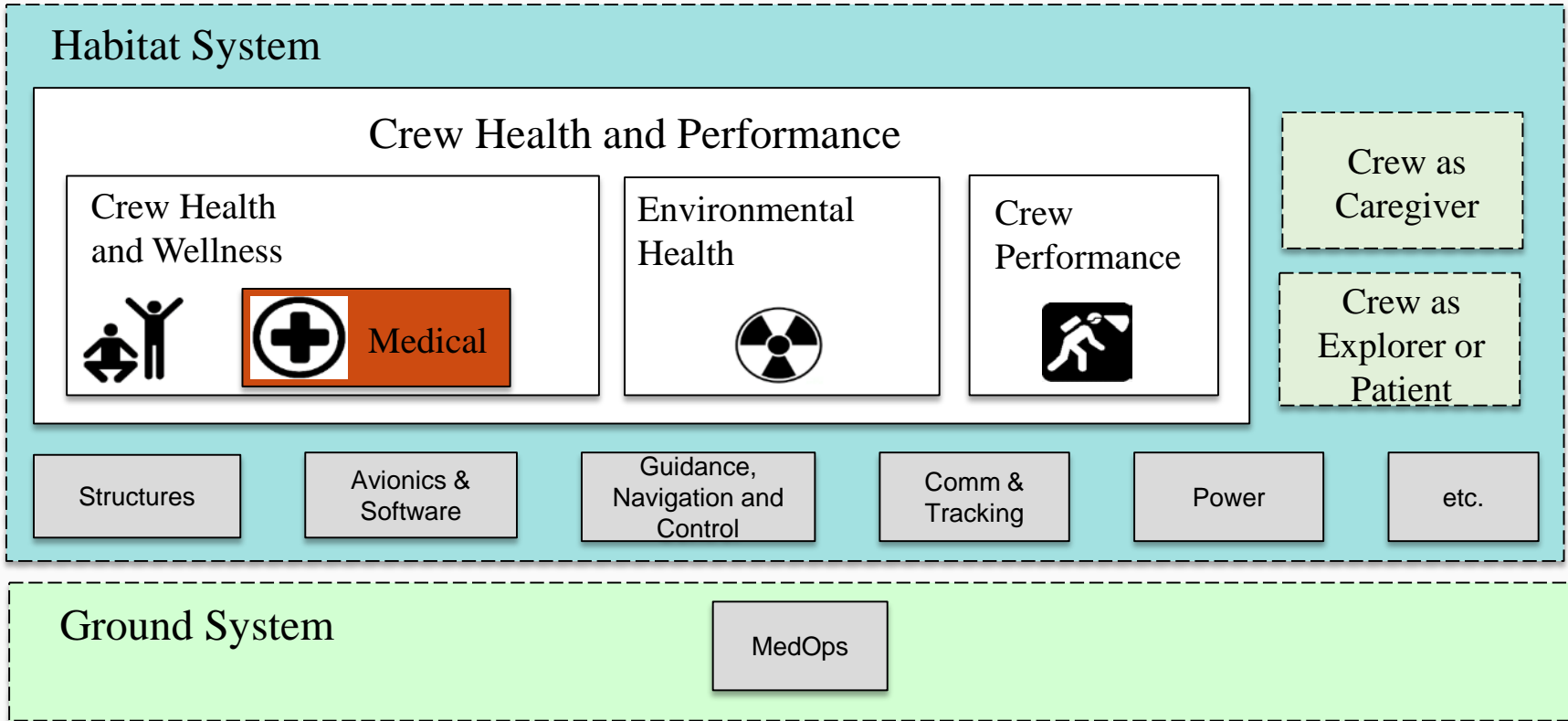


ID	Name	Text	Rationale
Hab-MedSys-0024	Provide pharmacy	<b>The Habitat Medical System shall provide an in-flight pharmacy to the crew members.</b>	Pharmaceutical intervention and prevention, as provided by the in-flight pharmacy, is an essential component of risk management planning for crew healthcare 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	<b>The Habitat Medical System shall track medical inventory.</b>	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-0204	Perform genitourinary procedures	<b>The Habitat Medical System shall enable caregivers to perform genitourinary procedures.</b>	The medical system needs to provide capabilities (e.g., tools, technology, skills, medications) to perform genitourinary (GU) procedures (such as decompression of bladder). These procedures are needed for treatment of conditions such as urinary retention. Types of GU procedures are specified at Level 5.



# Visualizing the Substance Behind Requirements

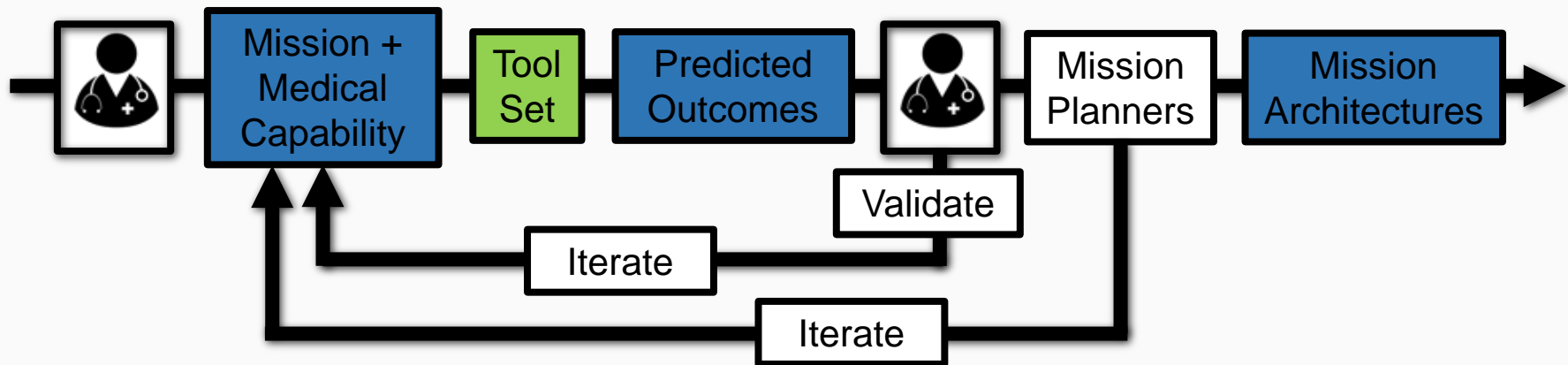




# Collaborations – Trade Space Tool Suite



Provide a means for the medical community's and crew's interests to be represented during deep space mission development to quantify the mass, volume, power impacts, and risks that a potential medical capability could have on crew health outcomes to inform medical capability in context of mission architectures



# Collaborations – Medical Data Architecture



**Burns, Ahhh It**  
 48y M 08/15/1988  
 HT: 1.7m WT: 72Kg  
 PFS: Chuck Berry M.D.

Recycle

Vital Signs  
 HR: 100 SpO2: 100%  
 RR: 12 Temp: 37C  
 BP: 110/66

Allergies  
 Penicillin Acetaminophen

History  
 Dyslipidemia

Medications  
 Atorvastatin

**Active Problems**  
 Dyslipidemia Status: **Managed**  
 Noted: 3/4/2015 by Dr. Berry  
 Found Total Cholesterol 240mg/dl on routine testing  
 Prescribed Atorvastatin

**Medications**  
 Atorvastatin 20mg Once Daily Since: 3/5/2009 Prescribed by: Dr. Berry

**Allergies/Intolerances**  
 Penicillin Reaction: Hives  
 Noted: 3/4/1998 by Dr. Childs  
 Acetaminophen Reaction: Vomiting  
 Noted: 7/8/2010 by Dr. Berry

**Exercise**

**Immunizations**

**Nutrition**

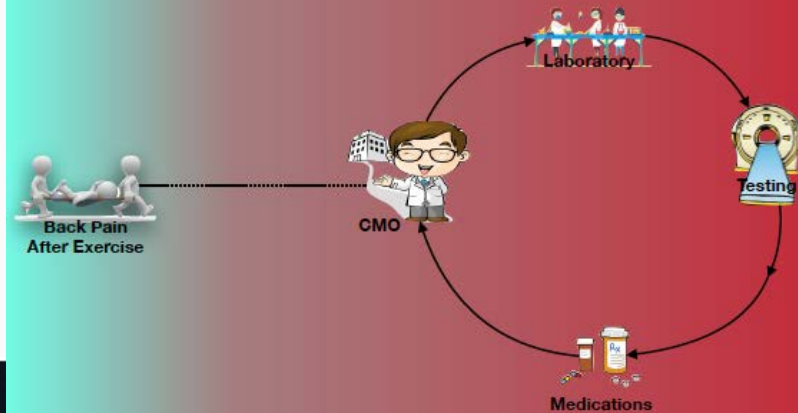
**Encounter History**

Date	Type	Reason	Provider
2/5/2035	Dental	Routine	CMO
2/5/2035	Routine Medical	Scheduled Exam	CMO
1/3/2035	ContingencyMedical	Injured finger	CMO
10/15/2034	Psychology	Pre flight screening	

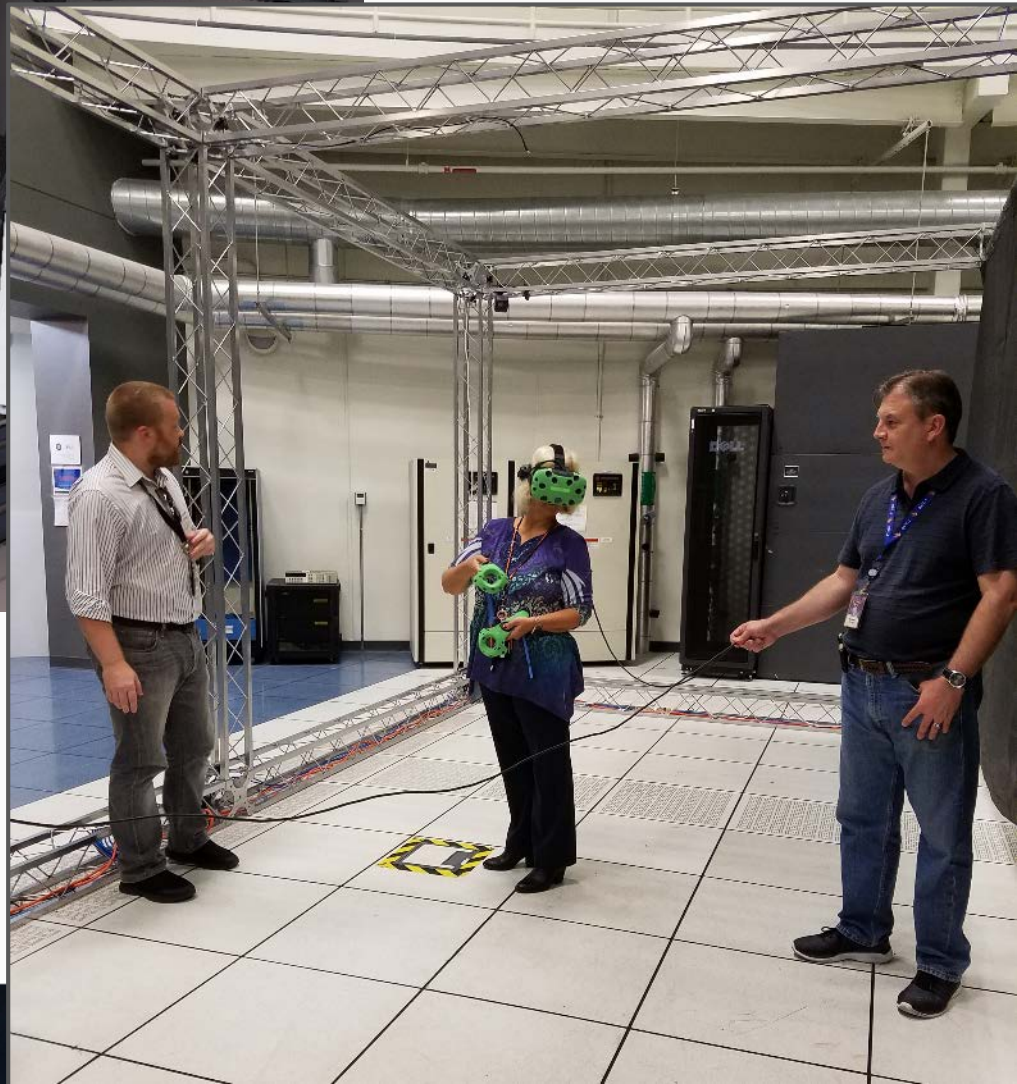
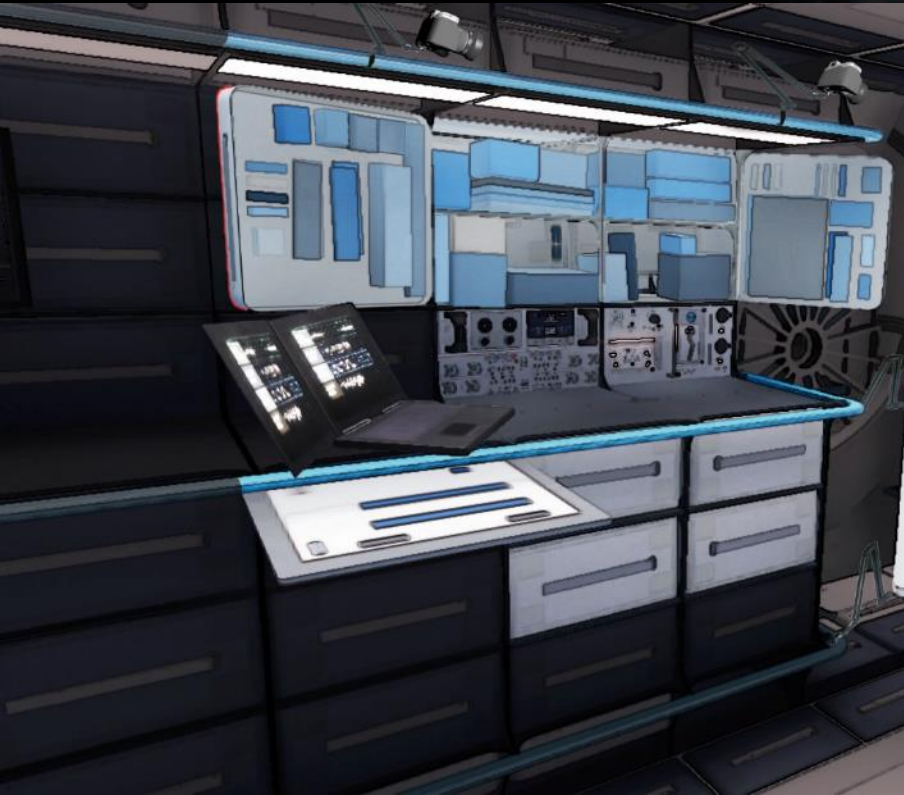
Home Summary Notes Labs Tests

## MDA 2.0 Flow

Cycle 1: Open Encounter, Clinical Impression, and stratification



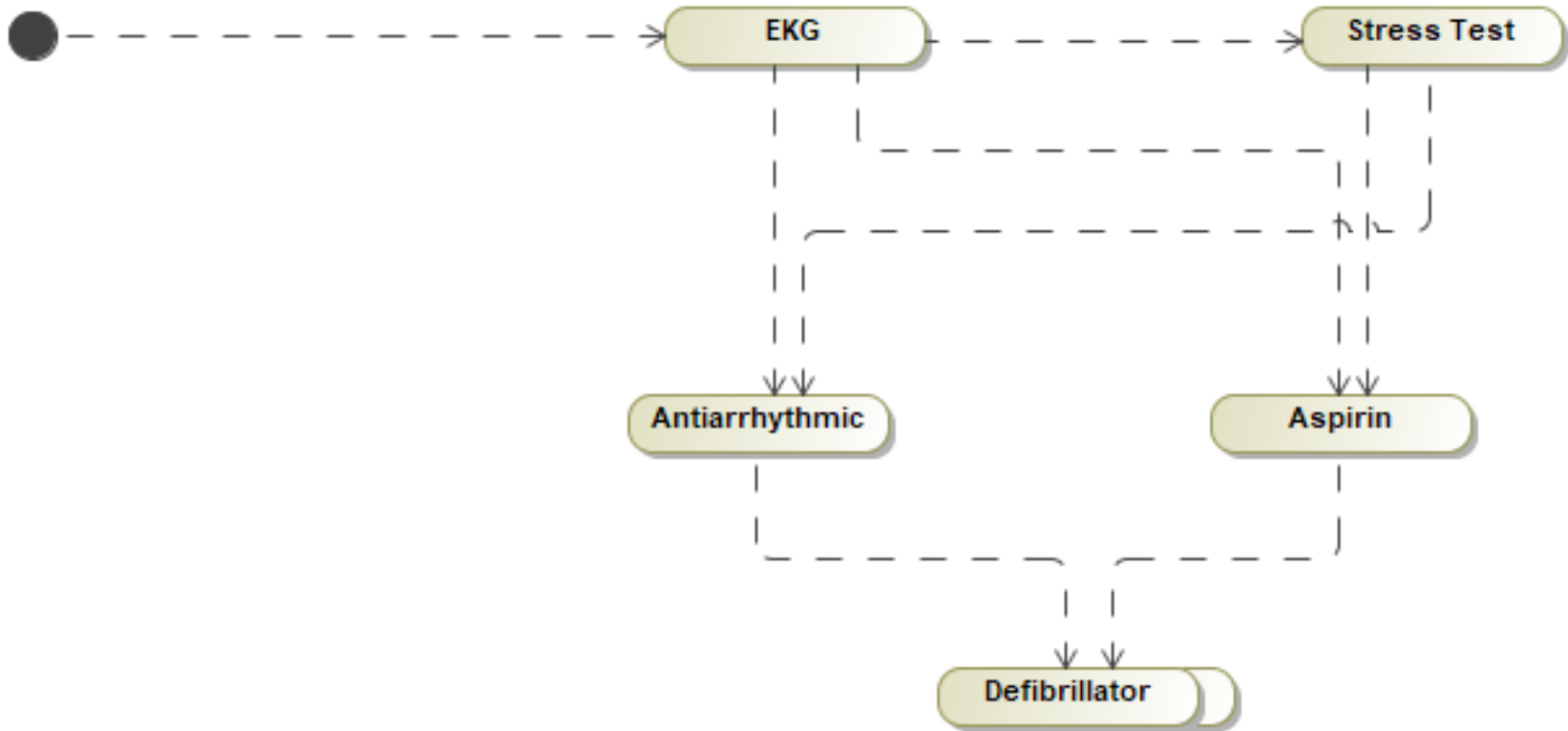
# Collaborations - Medical Workstation



# Collaborations - Power Calculation



Arrhythmia  
Symptoms





# Collaborations - Power Calculation



The screenshot shows the MagicDraw 18.5 interface for a simulation. The main window displays a line graph titled "totalPower" showing power consumption over time. The y-axis is labeled "totalPower" and ranges from 0 to 300. The x-axis is labeled "time(ms)" and ranges from 0 to 75,000. The graph shows a step-wise increase in power consumption over time, starting at 0, rising to approximately 100 at 5,000ms, then to 200 at 10,000ms, and continuing to rise in steps to about 300 by 75,000ms.

Below the graph, the console window displays log messages:

```
00:00:00,000 : Instance Specification devices is initialized.
00:00:00,000 : Initial solving ...
00:00:00,000 : Initial solving completed.
00:00:01,746 : **** State Machine DynamicPowerRollUpPattern execution is terminated. ****
00:00:01,749 : **** Instance Specification devices execution is terminated. ****
00:00:00,000 : **** Instance Specification devices is initialized. ****
00:00:00,000 : Initial solving ...
00:00:00,000 : Initial solving completed.
00:00:00,000 : **** Instance Specification devices is started! ****
00:00:36,903 WARN: the signal TurnOn has not been consumed and removed from
00:00:59,639 WARN: the signal TurnOn has not been consumed and removed from
00:01:05,912 WARN: the signal TurnOn has not been consumed and removed from
```

The variables window shows the following data:

Name	Value
ARED : ARED [On] {subsets sub...	devices.ared : ARED@6d2b1004
audiometer : Audiometer [On] {...	devices.audiometer : Audiometer@37c5
audiometer power supply : Audi...	devices.audiometer power supply : Audi...
back Brace : Back Brace [On] {su...	devices.back Brace : Back Brace@19eb6
battery Charger : Battery Charge...	devices.battery Charger : Battery Charge...
blood Oximeter : Blood Oximete...	devices.blood Oximeter : Blood Oximete...
blood Oximeter Sensor - SpCO : ...	devices.blood Oximeter Sensor - SpCO : ...
blood Oximeter Sensor - SpHb : ...	devices.blood Oximeter Sensor - SpHb : ...
blood Pressure Cuff - Large : Blo...	devices.blood Pressure Cuff - Large : Blo...
sum : total {totalPower = power...	total@79d595c



**Build a bridge between engineering and medical domains and developed a common language**

**Established processes and products to integrate between medical and exploration programs**

**Provided notional content for a medical system that can be used to inform initial Gateway planning**

# Questions?



# Thank you!



# BACK-UP SLIDES