EXPLORATION MEDICAL CAPABILITY

USING SYSTEMS ENGINEERING TO TRANSLATE RESEARCH INTO ACTION

Human Research Program
Exploration Medical Capability Element

HRP IWS
January 2020

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“Expanding the Boundaries of Space Medicine and Technology”

Overview

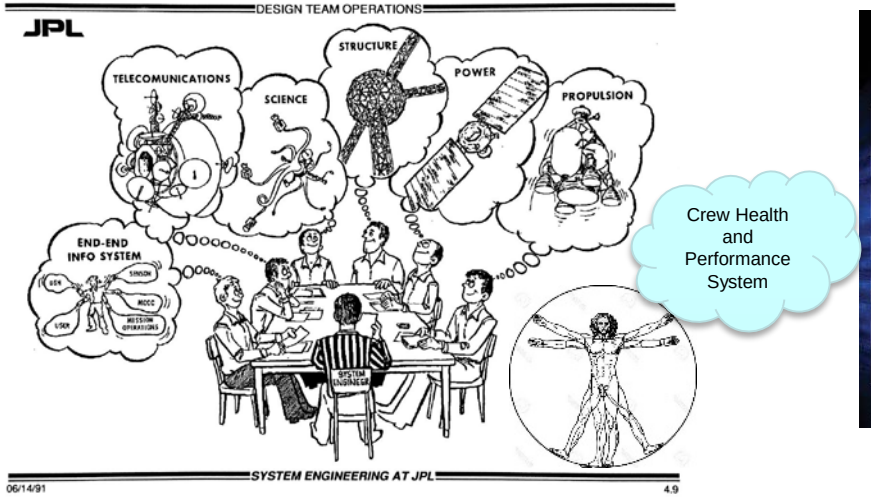
- **Background**
- **ExMC Systems Engineering Research**
- **Method**
- **Action – Current & Future**
- **Closing**

Background

- **ExMC Systems Engineering (SE): what we do**
  - This team will enable planning of an integrated crew health and performance system for exploration missions to lunar space and Mars. It will help to define how NASA plans to do medicine for human spaceflight in the exploration paradigm and what a medical system should supply in order to accomplish the medical needs.

- **Importance of a Systems Engineering approach for an integrated system design**
  - establishes a methodical and repeatable process to define, develop, assess, and manage technical medical system design needs for future missions
  - reinforces looking at the “big picture” and acknowledges a multi-disciplinary approach to a system
  - achieves stakeholder functional, physical, and operational performance requirements in the intended use environment over the planned life of the system within cost, schedule, and other constraints. *(NASA Systems Engineering Handbook, Rev 2)*

Need (what we need)



Crew Health and Performance System

Method (how we should do it)

Implementation (getting it done)

SE Team and associates: 20+ individuals across 4 NASA centers

- Systems Engineers
- Biomedical Engineers
- Software Engineers
- Data Scientists
- Data Programmers
- Mathematicians
- Physicians
- Nurses
- Pharmacists
- Student Interns
- Project Managers and Leads
- Contract Managers

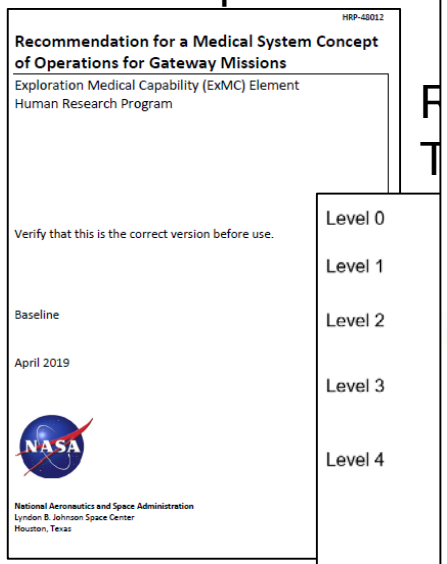
ExMC Systems Engineering Research

- **Medical System Foundation**
  - a starting point for requirements and a candidate system
- **Medical System Trade Analysis**
  - candidate system compared against other system options
- **Research and Technology Prioritization**
  - method for to focus future efforts on high impact research and technology development

ExMC Systems Engineering Research

- **Medical System Foundation – a starting point for requirements and a candidate system**
  - medical system architecture
  - associated functional and non-functional requireme
  - requirements rationale
  - traces to placeholder upper level requirements
  - traces to the current versions of NASA Standards
  - traces down to placeholder lower level requiremen
  - relevant documentation (i.e.: Concept of Operation

ConOps


HRP-48012

Recommendation for a Medical System Concept of Operations for Gateway Missions

Exploration Medical Capability (ExMC) Element
Human Research Program

Verify that this is the correct version before use.

Baseline

April 2019

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

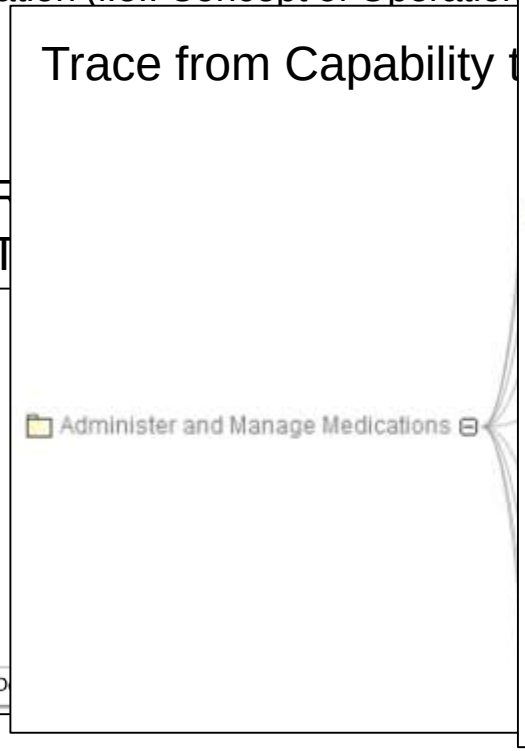
Level 0

Level 1

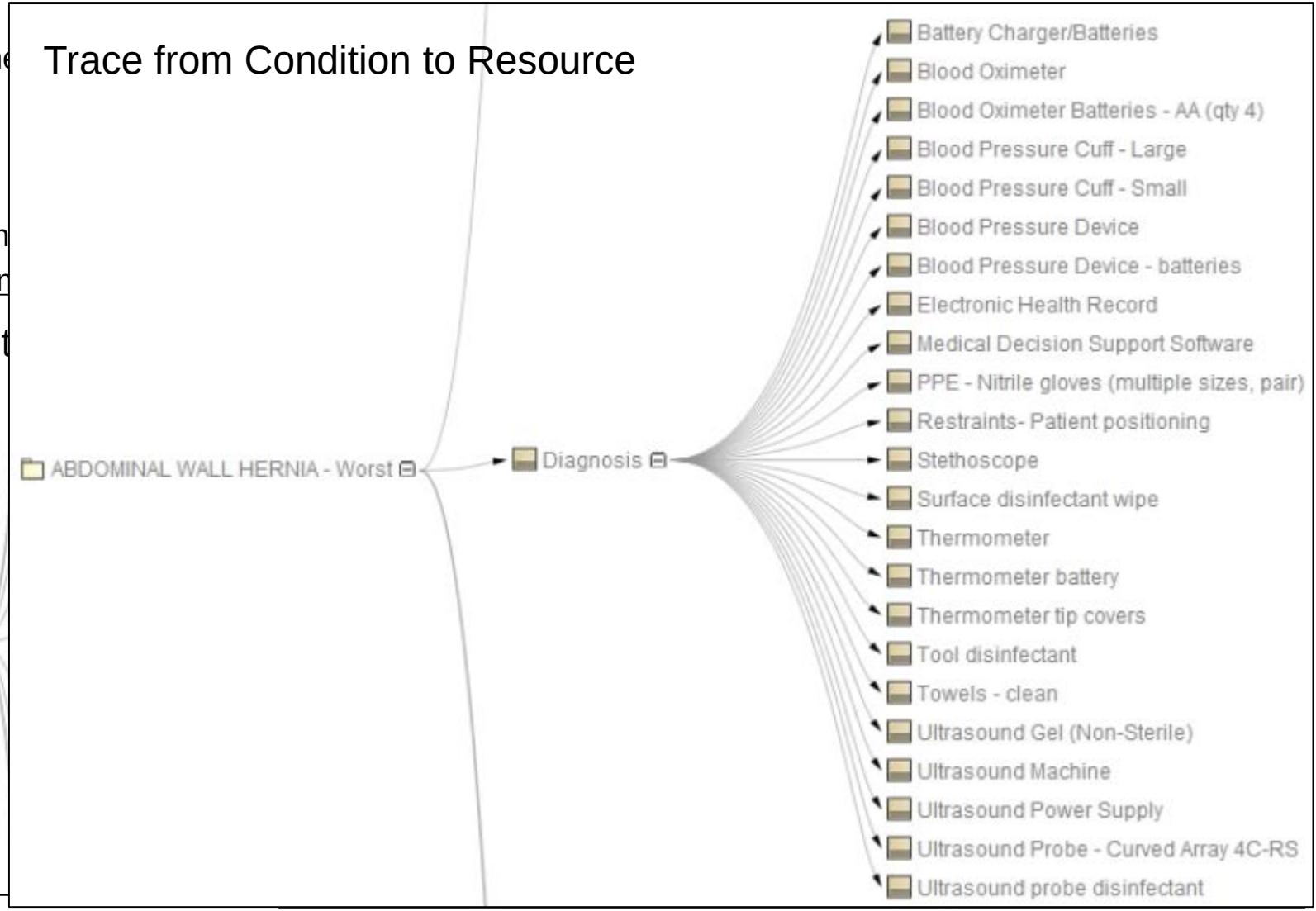
Level 2

Level 3

Level 4


Trace from Capability t

Administer and Manage Medications


Trace from Condition to Resource

ABDOMINAL WALL HERNIA - Worst

Diagnosis

Battery Charger/Batteries
Blood Oximeter
Blood Oximeter Batteries - AA (qty 4)
Blood Pressure Cuff - Large
Blood Pressure Cuff - Small
Blood Pressure Device
Blood Pressure Device - batteries
Electronic Health Record
Medical Decision Support Software
PPE - Nitrile gloves (multiple sizes, pair)
Restraints- Patient positioning
Stethoscope
Surface disinfectant wipe
Thermometer
Thermometer battery
Thermometer tip covers
Tool disinfectant
Towels - clean
Ultrasound Gel (Non-Sterile)
Ultrasound Machine
Ultrasound Power Supply
Ultrasound Probe - Curved Array 4C-RS
Ultrasound probe disinfectant

ExMC Systems Engineering Research

- **Medical System Trade Analysis – candidate system compared against other system options**
  - *Definition of trades from the ConOps*
  - ExMC will characterize the above candidate system from the foundation using a series of trade analysis
    - This will help identify the type of resources, mass and volume, amount of power, etc. that a medical system would need in order to meet certain risk levels. – what if scenarios…identifies the trade space
  - As time passes, and better information is developed (i.e.: better technology, changes in condition incidence rates), the information used by the tool suite can be updated, and the analysis performed again

Why provide medical system trade analysis capabilities:

There's always room for negotiation...or is there!

How to avoid this?

Prepare for backing up your stance:

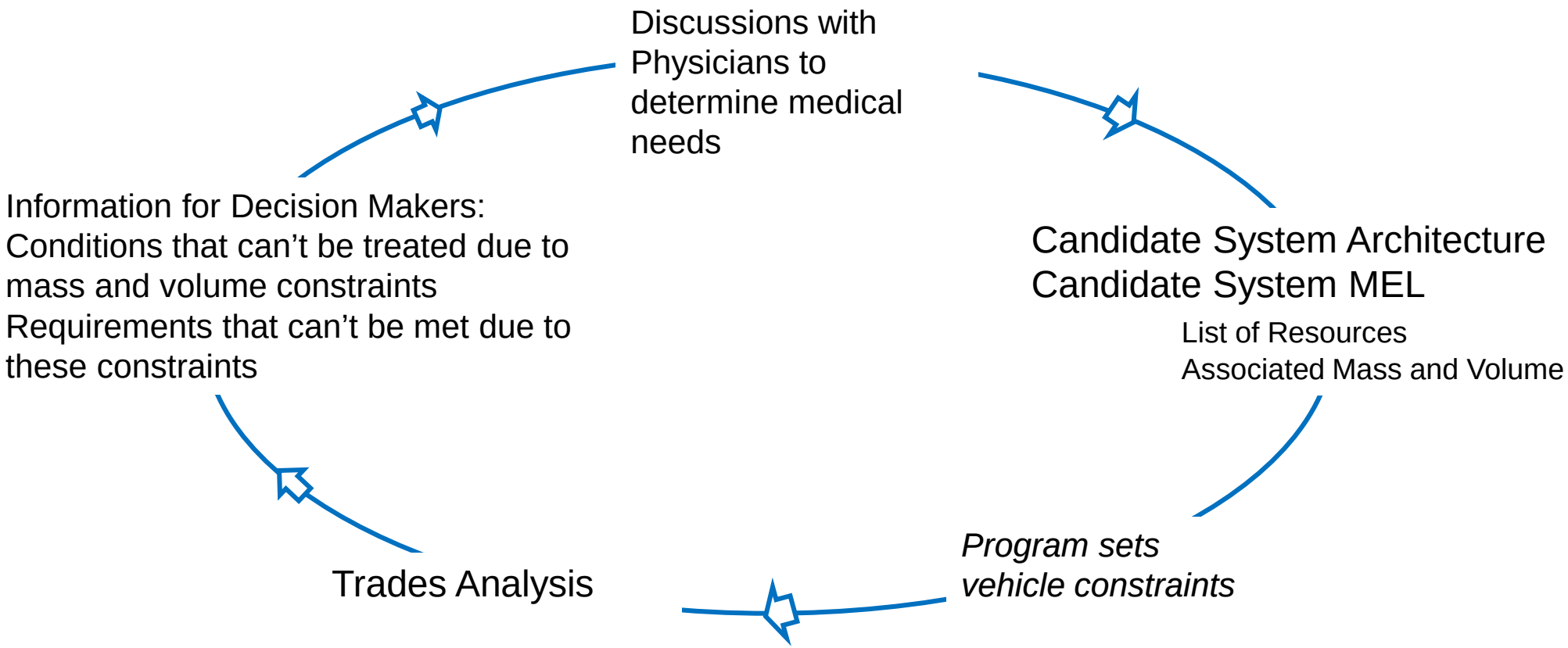
If you settle for 20% less mass/volume, then these are the requirements/medical capability the vehicle won't have

Visual correlation between requirements and candidate system

Make it easy to see/explain/analyze with trades

ExMC Systems Engineering Research

1 potential trades scenario



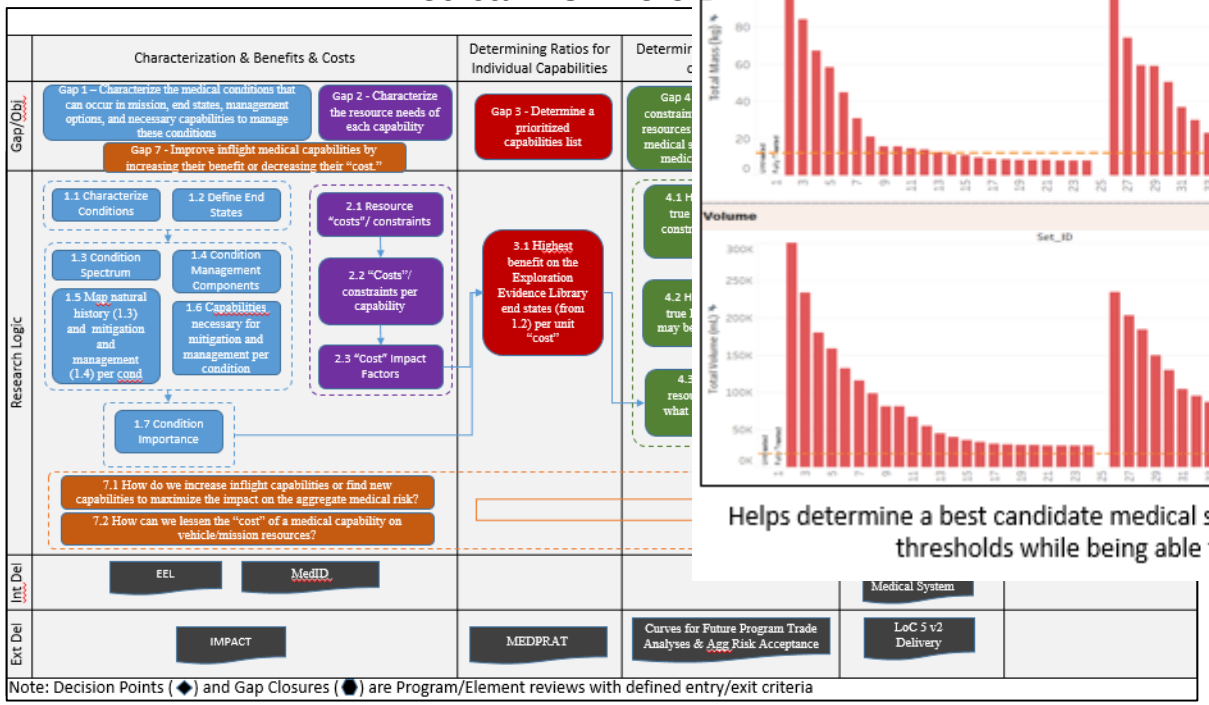
NASA Systems Engineering Handbook, Rev 2

ExMC Systems Engineering Research

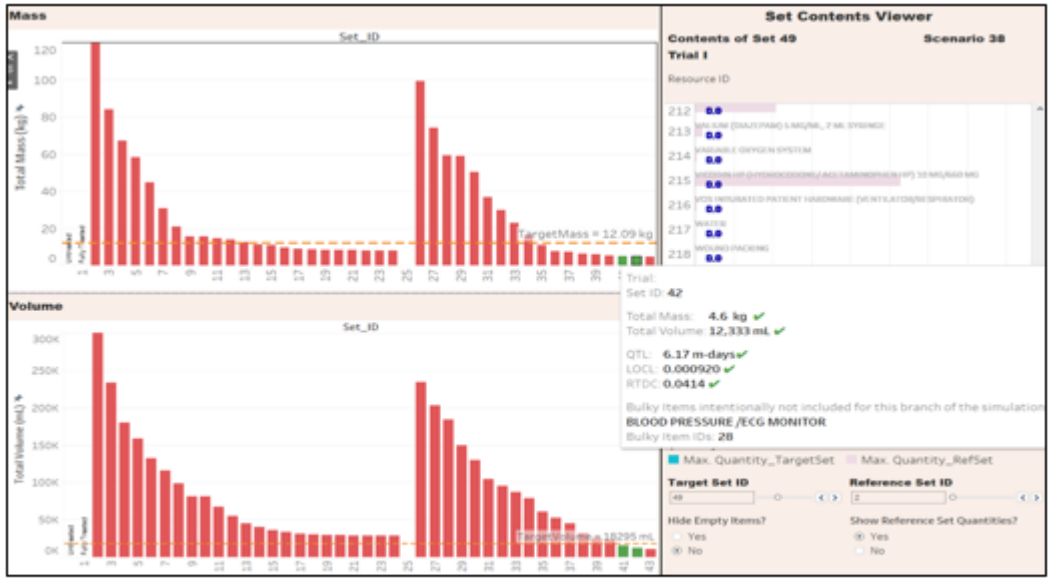
- **Research and Technology Prioritization - method by which to focus future efforts on high impact research and technology development**
  - The knowledge gained from identifying potential medical systems and performing these trade analyses provides ExMC with support for evidence-based prioritization of future projects.
  - By focusing research efforts on high impact capabilities, the element can aid in the reduction of risk and the provision of a better medical system.

HRP Human Research Roadmap (HRR)

Medical Risk Refo



Example outputs of prioritization & trade tools

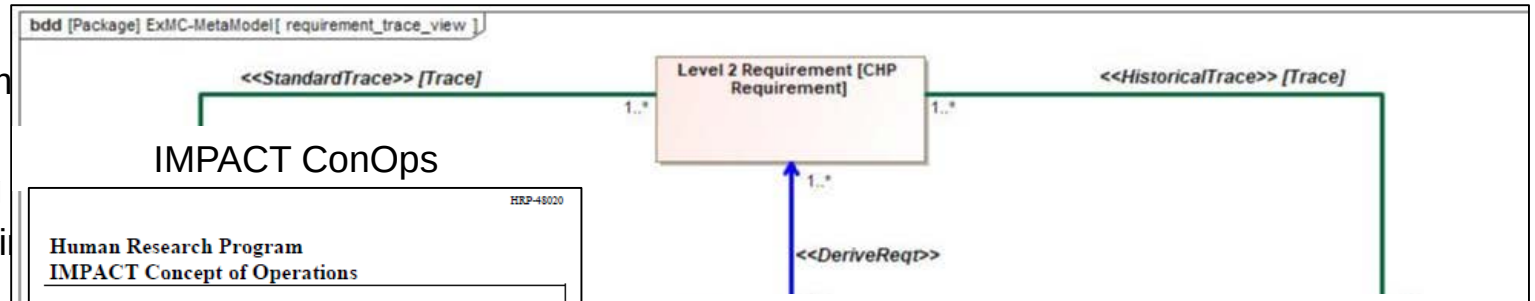


Helps determine a best candidate medical set to meet all constraints and acceptable risk thresholds while being able to view the set contents easily

Method

- **A systems modeling tool and language - a platform for candidate systems**
  - using systems engineering model language, the systems modeling tool will contain a digital model of the system, thereby allowing the SE team to utilize a model-based systems engineering (MBSE) approach to develop the architecture of the medical system and its requirements.
- **Tool suite – a platform for system trades**
  - ability to identify how well a candidate medical system
  - ability to utilize dynamic medical content repositories
  - ability to perform probabilistic risk assessments using
  - ability to identify an optimized medical system by setti

Meta Model



IMPACT ConOps


HRP-48020

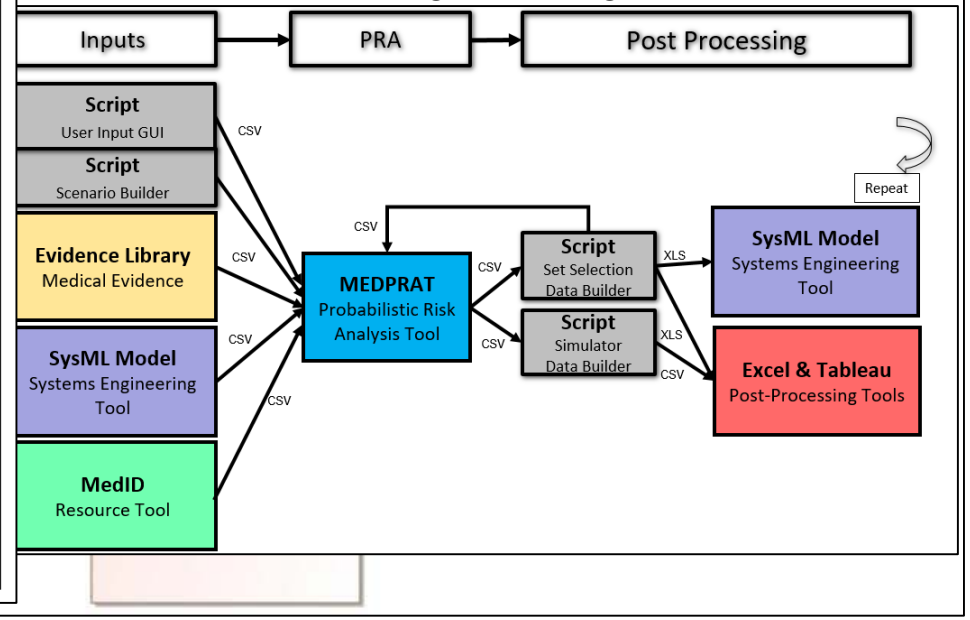
Human Research Program
IMPACT Concept of Operations

Verify this is the correct version before use

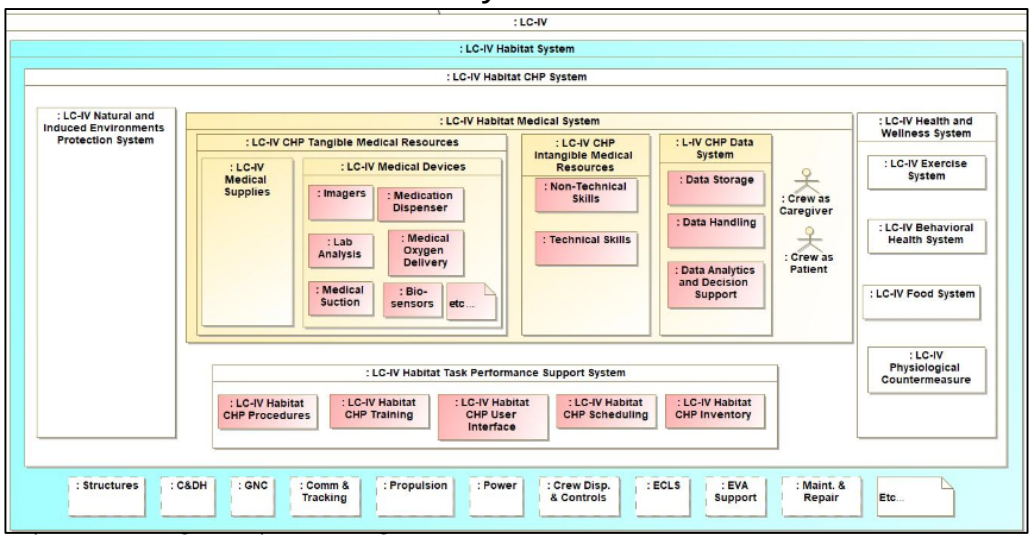
December 2019
Baseline

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

IMPACT integration diagram



Modeled System Architecture



Action - Current

- **ExMC's recommended medical system foundation as a starting point for future missions**
  - Drafts of concept of operations, architecture, high level requirements, recommended lunar-like mid-level requirements already completed
  - Info sent to Gateway for potential use; embraced idea that Crew Health and Performance has a seat at the table
  - Orion use of the methodology for some of the clinical content
  - HLS scoping use of this methodology
- **Trades**
  - Infrastructure and methodology in work for performing trades on the medical system...in the middle of prototype development
  - Potentially can be used for HLS
  - Targeting missions to Mars
- **Research and Technology Prioritization**
  - An organized architecture already defined and traced to NASA-STD-3001
  - Draft Model already in place with traces
  - ExMC will be using current pilot capabilities to aid in this year's PPBE effort

Action - Future

- **Tool suite is an extensible platform, with additional work, it can be used by non-ExMC groups and for non-medical systems**

- **Multiple Mission Phases**
  - In addition to pre-mission planning, the systems engineering tools ExMC is developing can also be used throughout various mission phases.
- **Multiple Stakeholders**
  - Potential uses of these products and stakeholders who may benefit from their use.
  - ExMC is starting to discuss with SA-CHS any additional requirements they may have as the first external stakeholders

Closing

- **Where we are currently in these efforts and the forward work we have to compete the efforts will be seen in the rest of the Presentation in this session**
- **Systems Engineering Products for Medical System Design**
  - Exploration Medical Capability (ExMC) Medical System Requirements Overview and Update
  - Trade Study Evaluation Tool Suite (TSETS) an ExMC Decision-support Tool Suite Pilot Project
  - Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)
  - Using the Accepted Medical Condition List (AMCL) Process to Scope the Orion Medical System

BackUp

Definitions per NASA SE Handbook

- **At NASA, “systems engineering” is defined as a methodical, multi-disciplinary approach for the design, realization, technical management, operations, and retirement of a system.**
- **A “system” is the combination of elements that function together to produce the capability required to meet a need.**
- **The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose; that is, all things required to produce system-level results.**
- **The results include system-level qualities, properties, characteristics, functions, behavior, and performance.**

NASA Systems Engineering Handbook, Rev 2

Approach to Get There

Stakeholder needs, goals

NASA Standards


NASA/TM-2017-219290

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

Program requirements & architecture

System functions & behaviors


Medical System Concept of Operations for Mars Exploration Missions

Exploration Medical Capability (ExMC) Element
Human Research Program

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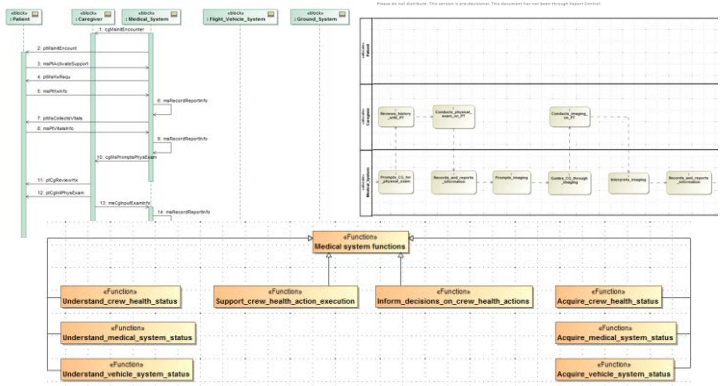
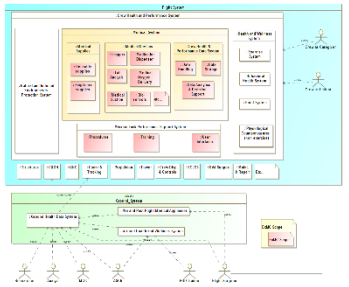
Pre-Baseline

February 2017

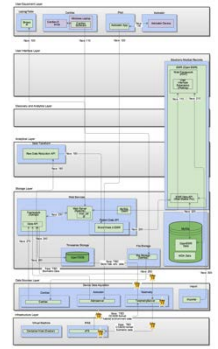
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas



System requirements & architecture



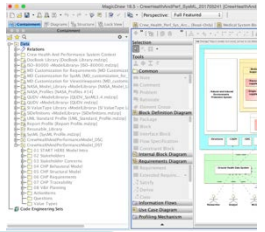
Subsystem requirements & architecture



Characterize system

Do we have the capabilities to meet the needs?
Do we fit in allocations?

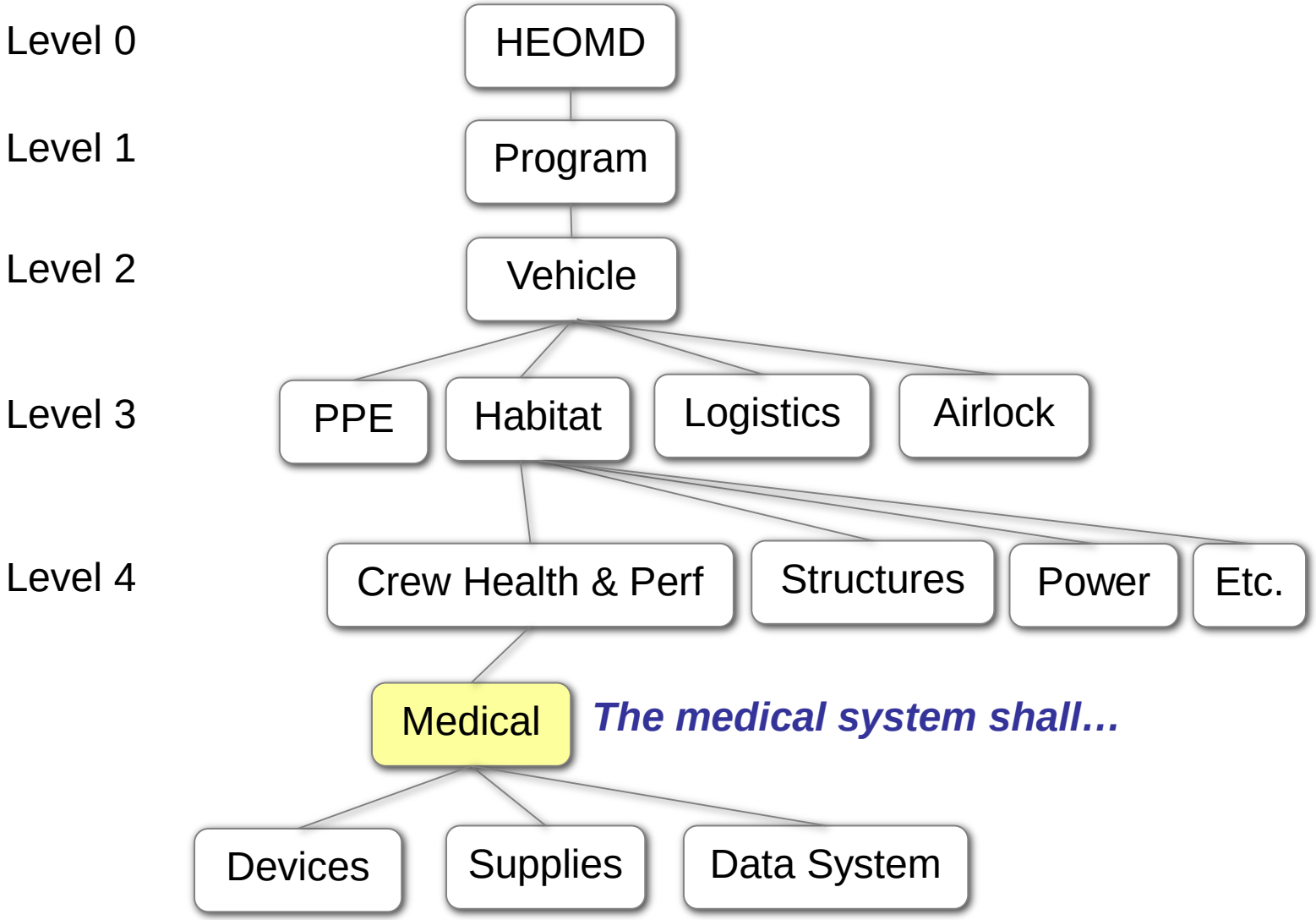
Analyze & trade



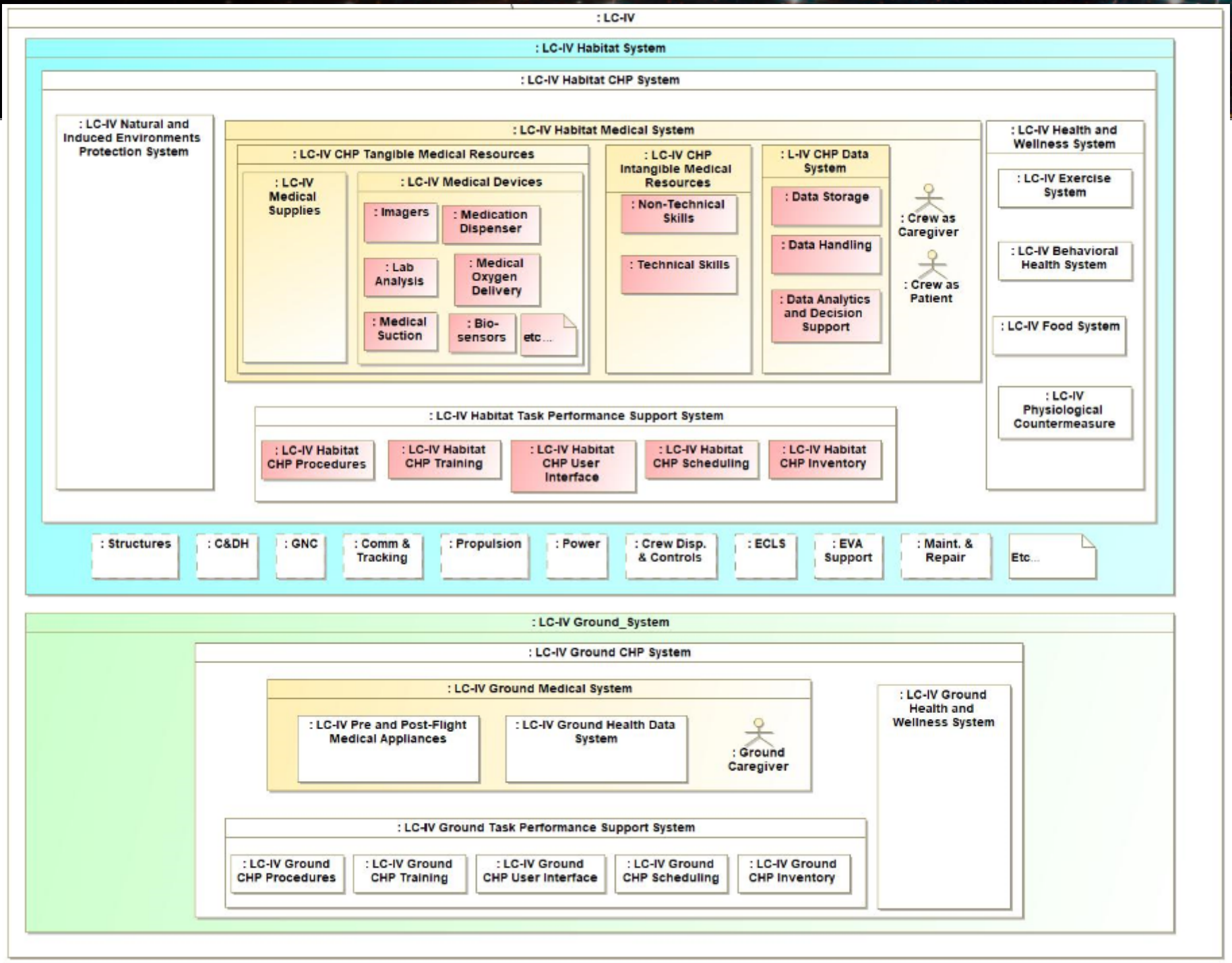
Design & Build

Began with DST (Mars transit) to develop body of work and using that infrastructure for DSG and DST in FY18.

NOT Official – best guess on requirements context



HRP is supporting the development of these through our team


: LC-IV
: LC-IV Habitat System
: LC-IV Habitat CHP System
: LC-IV Natural and Induced Environments Protection System
: LC-IV Habitat Medical System
: LC-IV CHP Tangible Medical Resources
: LC-IV Medical Supplies
: LC-IV Medical Devices
: Imagers
: Medication Dispenser
: Lab Analysis
: Medical Oxygen Delivery
: Medical Suction
: Bio-sensors
etc...
: LC-IV CHP Intangible Medical Resources
: Non-Technical Skills
: Technical Skills
: L-IV CHP Data System
: Data Storage
: Data Handling
: Data Analytics and Decision Support
: Crew as Caregiver
: Crew as Patient
: LC-IV Health and Wellness System
: LC-IV Exercise System
: LC-IV Behavioral Health System
: LC-IV Food System
: LC-IV Physiological Countermeasure
: LC-IV Habitat Task Performance Support System
: LC-IV Habitat CHP Procedures
: LC-IV Habitat CHP Training
: LC-IV Habitat CHP User Interface
: LC-IV Habitat CHP Scheduling
: LC-IV Habitat CHP Inventory
: Structures
: C&DH
: GNC
: Comm & Tracking
: Propulsion
: Power
: Crew Disp. & Controls
: ECLS
: EVA Support
: Maint. & Repair
Etc...
: LC-IV Ground_System
: LC-IV Ground CHP System
: LC-IV Ground Medical System
: LC-IV Pre and Post-Flight Medical Appliances
: LC-IV Ground Health Data System
: Ground Caregiver
: LC-IV Ground Health and Wellness System
: LC-IV Ground Task Performance Support System
: LC-IV Ground CHP Procedures
: LC-IV Ground CHP Training
: LC-IV Ground CHP User Interface
: LC-IV Ground CHP Scheduling
: LC-IV Ground CHP Inventory