Human Health and Performance System

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What is the goal?

- HRP – provide a systematic countermeasure to the known risks of exploration spaceflight.
- Start with gaining scientific understanding of the challenges.
- End with solutions and countermeasures that are delivered in the form of a vehicle subsystem and mission architecture focused on optimizing human health and performance.

Start with the Medical Risk?

Why? Because it becomes an integrating risk for Human Health and Performance.

ExMC Responsibilities

Risk Title: Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions

Description: Given that medical conditions will occur during human spaceflight missions, there is a possibility of adverse health outcomes and decrements in performance during these missions and for long term health.

Other ExMC Risks:

1. Risk of bone fracture due to spaceflight induced changes in bone.
2. Risk of ineffective or toxic medications due to long term storage.
3. Risk of renal stone formation.

Risk or Concern	Current ExMC Ownership	Likely future ExMC Ownership
Concern of Clinically Relevant Unpredicted Effects of Medication		X
Concern of Intervertebral Disc Damage upon and immediately after re-exposure to Gravity		X
Risk Factor of Inadequate Nutrition		X
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure		X
Risk of Acute Radiation Syndromes Due to Solar Particle Events (SPEs)		X
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		X
Risk of Adverse Health & Performance Effects of Celestial Dust Exposure		X
Risk of Adverse Health Effects Due to Host-Microorganism Interactions		X
Risk of Adverse Health Event Due to Altered Immune Response		X
Risk of an Incompatible Vehicle/Habitat Design		
Risk of Bone Fracture due to Spaceflight-induced Changes to Bone	X	X
Risk of Cardiac Rhythm Problems		X
Risk Of Cardiovascular Disease and Other Degenerative Tissue Effects From Radiation Exposure		X
Risk of Decompression Sickness		X
Risk Of Early Onset Osteoporosis Due To Spaceflight		
Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight		X
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance		X
Risk of Inadequate Critical Task Design		
Risk of Inadequate Design of Human and Automation/Robotic Integration		
Risk of Inadequate Human-Computer Interaction		
Risk of Ineffective or Toxic Medications Due to Long Term Storage	X	X
Risk of Injury and Compromised Performance Due to EVA Operations		X
Risk of Injury from Dynamic Loads		X
Risk of Orthostatic Intolerance During Re-Exposure to Gravity		X
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team		
Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System		X
Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload		X
Risk of Performance Errors Due to Training Deficiencies		
Risk of Radiation Carcinogenesis		X
Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity		
Risk of Renal Stone Formation	X	X
Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations		X
Risk of Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities	X	X

Color	Meaning
	Currently Own
	Health and Treatment Consequence
	Long-Term Health
	Performance Decrement with possible Medical Treatment

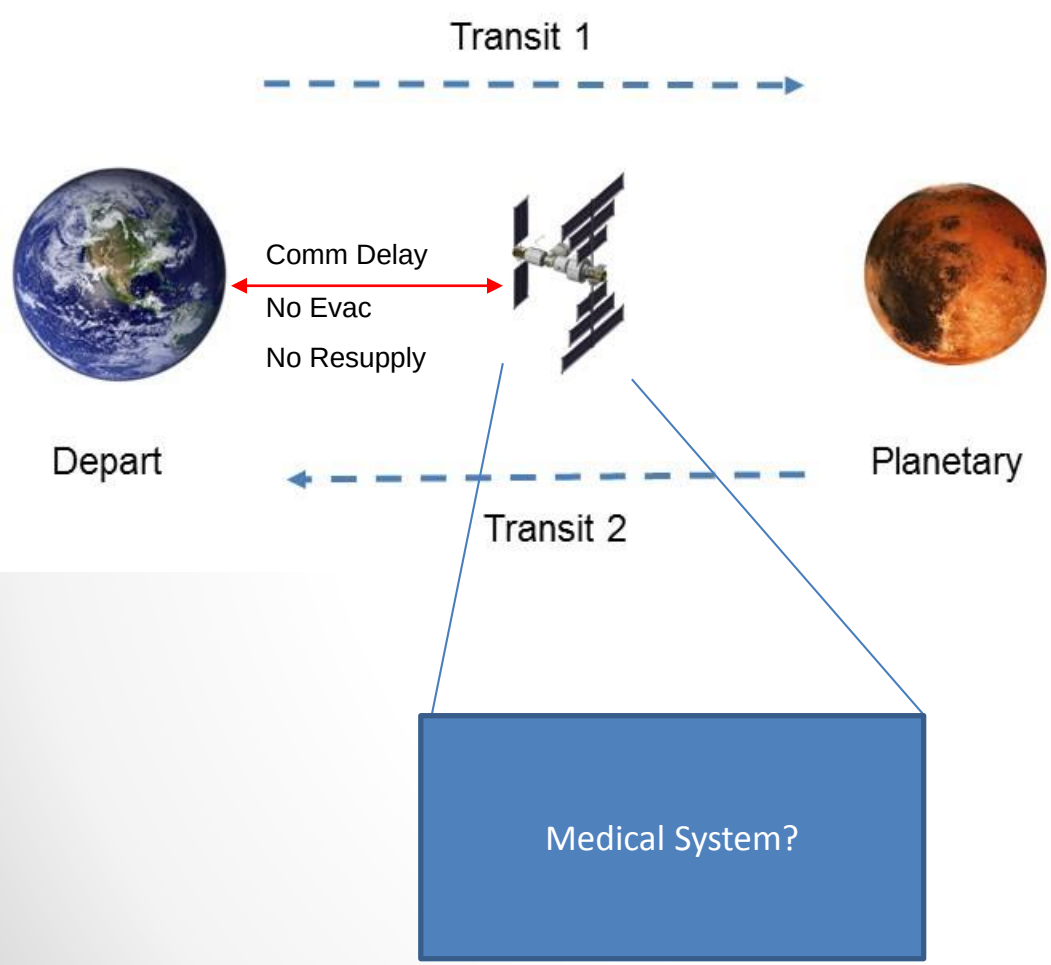
All of these risks interface with medical

Forward Plan

- Risk Mitigation Strategy
  - Planning
    - Concept of Operations Development (Ops Risk Reduction)
  - Characterization of Risk
    - Models and Metrics – Integrated Medical Model (IMM), MONSTR prototype
    - Active Data Gathering – Medical Consumables Tracker (MCT), biosensors, Flexible Ultrasound
  - Active Risk Reduction
    - Medical Support – Exploration Medical System Demonstrator (EMSD), Data Architecture
    - Technology Development – Oxygen Concentrator Module, Medical Suction, IVGen…
    - Training
    - Medical Decision Support
    - Integration of Medical with Vehicle Designers and ECLSS SMTs

Medical System Development

The Medical System Goal



Provide the crew with the best chance to accomplish mission and get home healthy

Medical Operations

- Nominal Operations
- Contingency Operations
  - Routine
  - Urgent
  - Emergent

Background

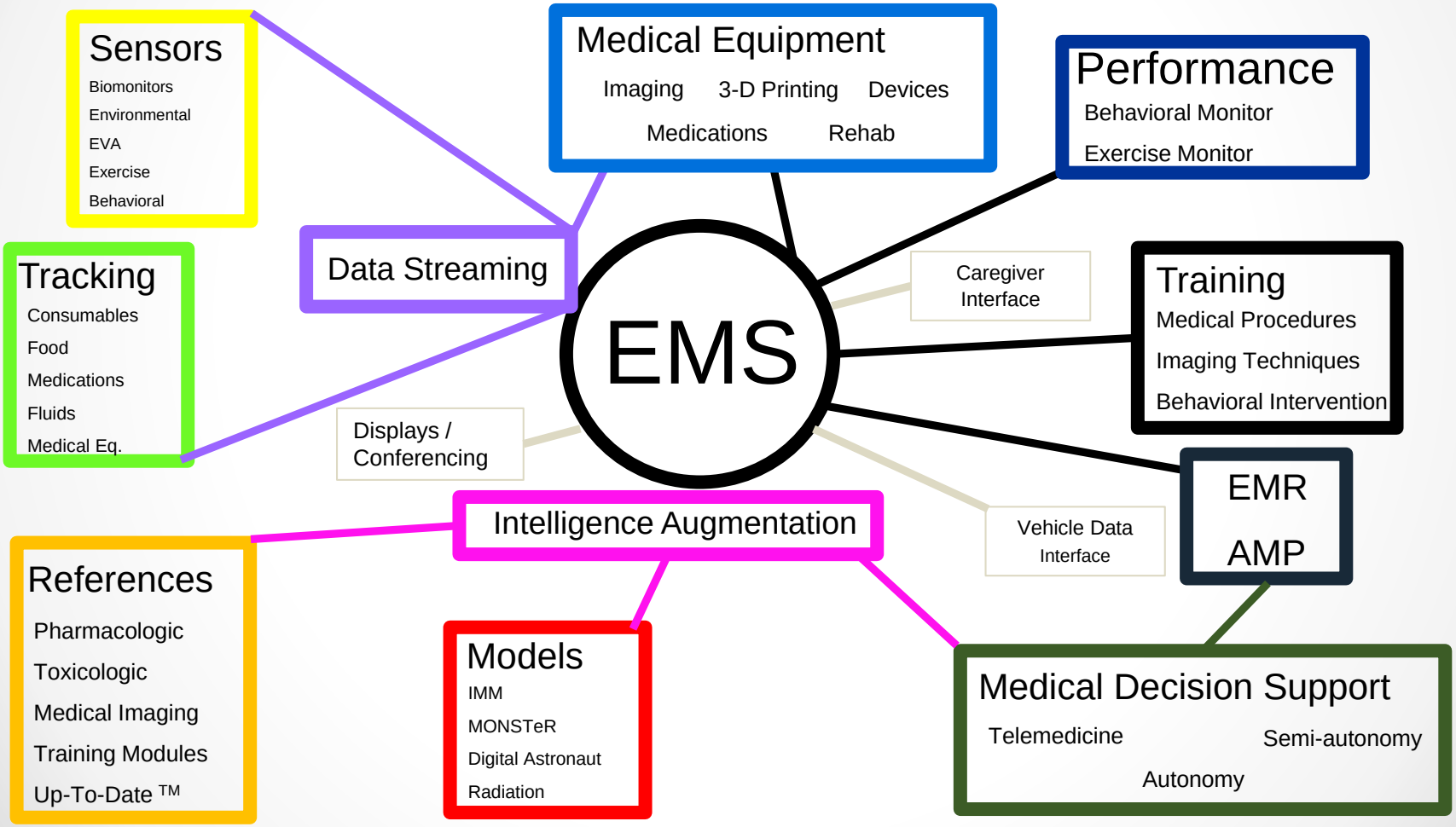
- Exploration Medicine is unique:
  - **NO regular resupply of materials**
  - **NO real-time communications**
  - NO potential for **evacuation** if serious medical concerns arise.

- Medical care includes:
  - Screening
  - Prevention
  - diagnostic capability
  - treatment capability
  - follow up care
  - prognosis

- Characterize the likely medical risks
- Identify medical needs to address those risks
- Create a medical system to optimize crew response to those risks
- Engage in a testing pathway to validate and improve that system
- Work with vehicle engineers and flight surgeons to ensure useful implementation of that system

Exploration requires Stay and Fight Medicine, not Retreat Medicine.

Medical System Capture Diagram



Gap Restructuring

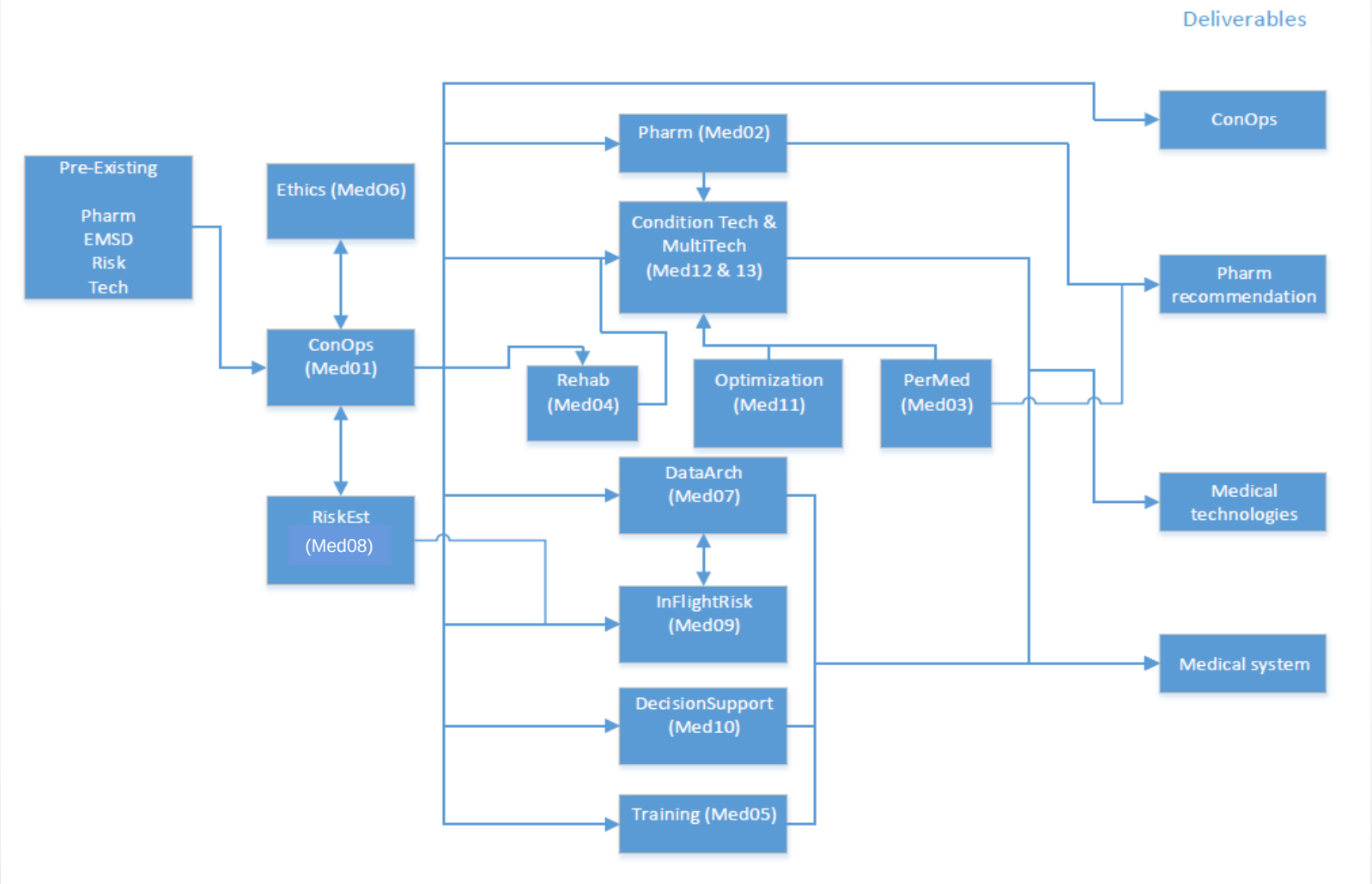
- Goal: develop a system
- Gap restructuring to enable that system
- Earliest Gap Needs:
  - Risk Assessment (Med08)
  - Concept of operations needs to guide system development (Med01)
  - Data Architecture development (Med07)
  - Early incremental testing of the system concepts (Med 01)
  - Vehicle Integration strategy (Med 01)

Medical Risk

New Gaps

Med01	We do not have a concept of operations for medical care during exploration missions.
Med02	We do not have the capability to provide a safe and effective pharmacy for exploration missions.
Med03	We do not know how we are going to apply personalized medicine to reduce health risk for a selected crew.
Med04	We do not have a defined rehabilitation capability for injured or de-conditioned crew members during exploration missions.
Med05	We do not know how to train crew for medical decision making or to perform diagnostic and therapeutic medical procedures to enable extended mission or autonomous operations.
Med06	We do not know how to define medical planning or operational needs for ethical issues that may arise during exploration missions.
Med07	We do not have the capability to comprehensively process medically-relevant information to support medical operations during exploration missions.
Med08	We do not have quantified knowledge bases and modeling to estimate medical risk incurred on exploration missions.
Med09	We do not have the capability to predict estimated medical risk posture during exploration missions based on current crew health and resources.
Med10	We do not have the capability to provide computed medical decision support during exploration missions.
Med11	We do not have the capability to minimize medical system resource utilization during exploration missions.
Med12	We do not have the capability to mitigate select medical conditions
Med13	We do not have the capability to implement medical resources that enhance operational innovation for medical needs

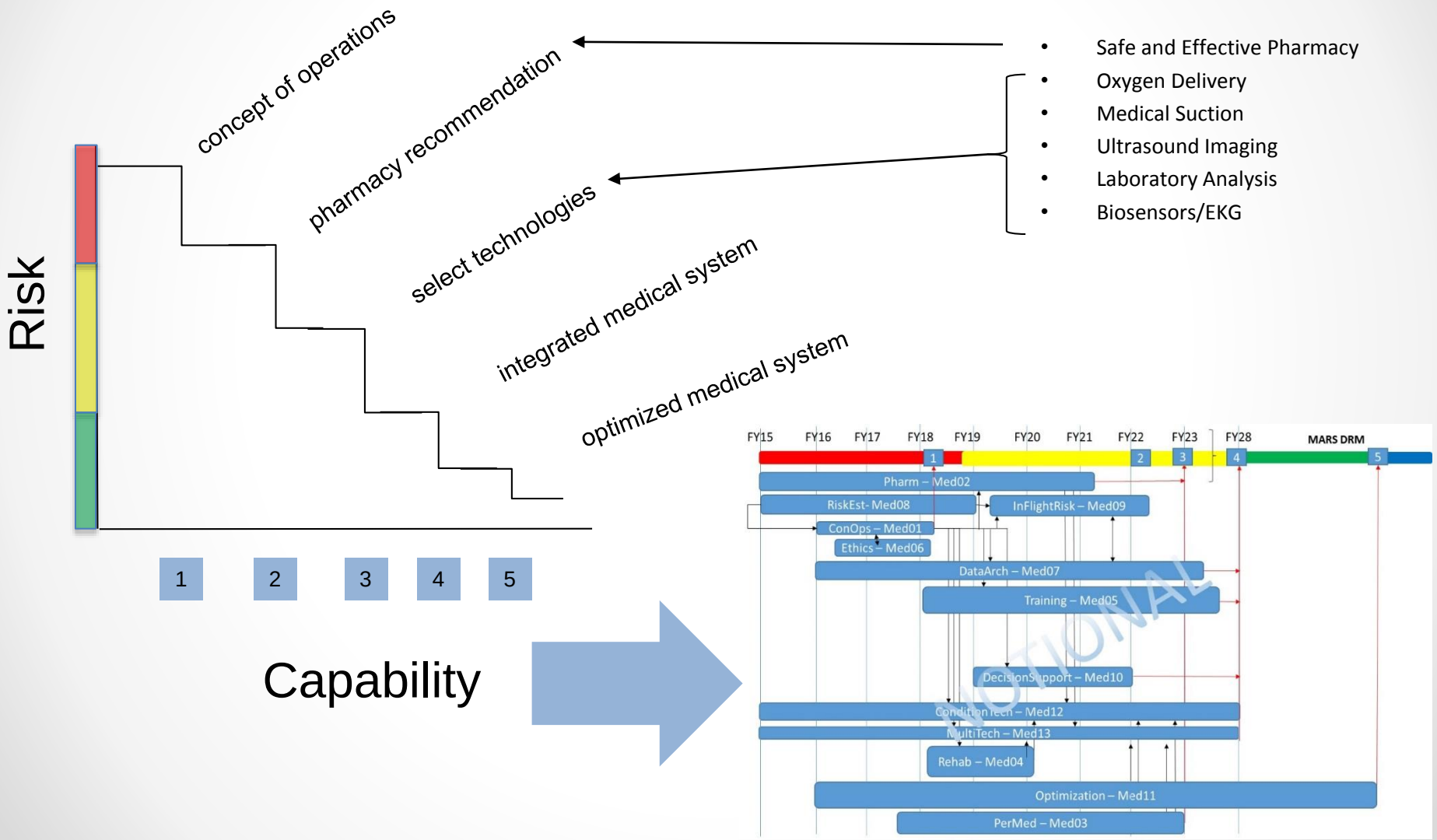
Gap Conceptual Flow



The Concept of Operations Drives System Design

Notional

Gap Restructuring Enables System Creation

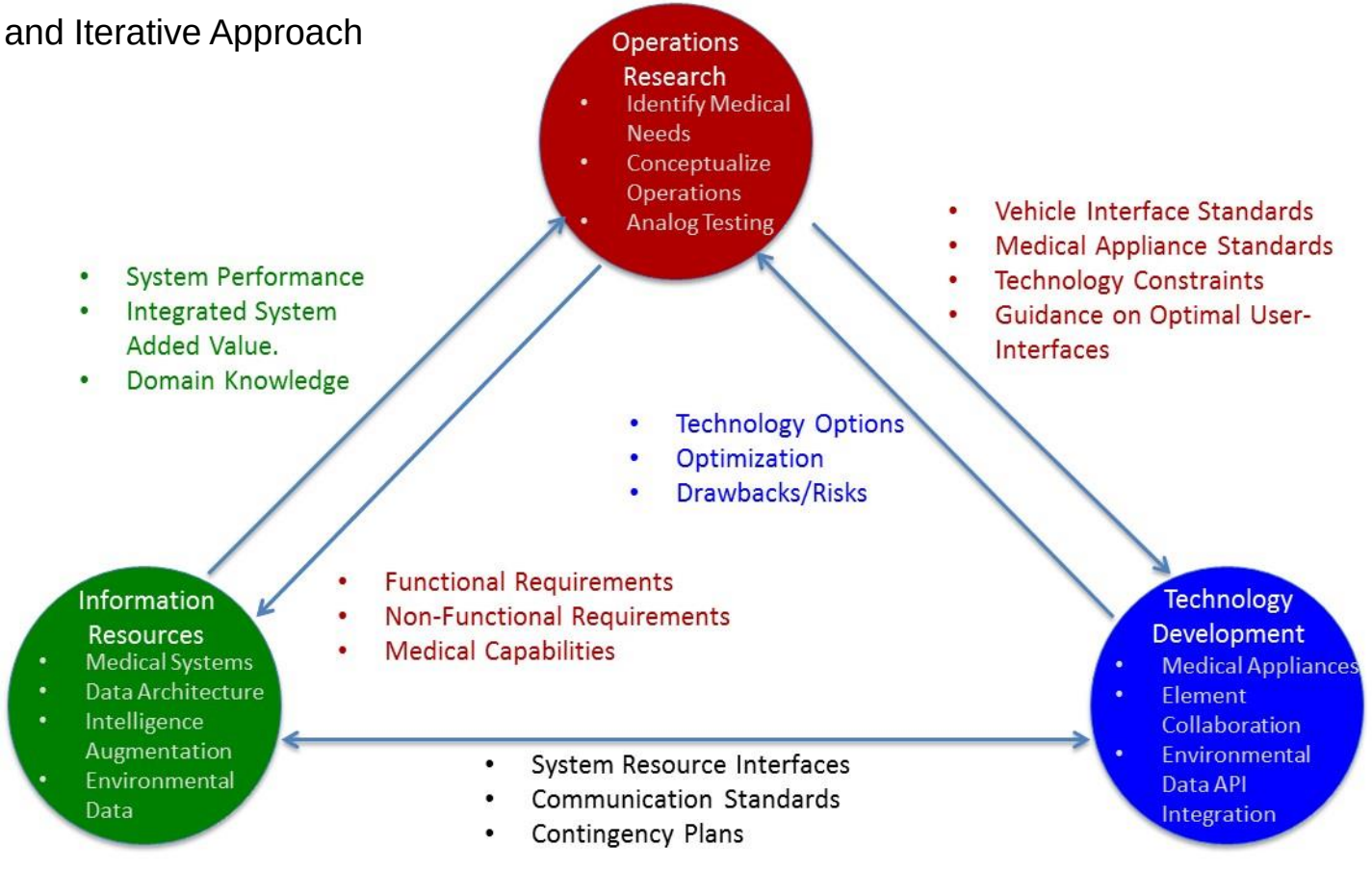


How to decompose the work

Incremental and Iterative Approach

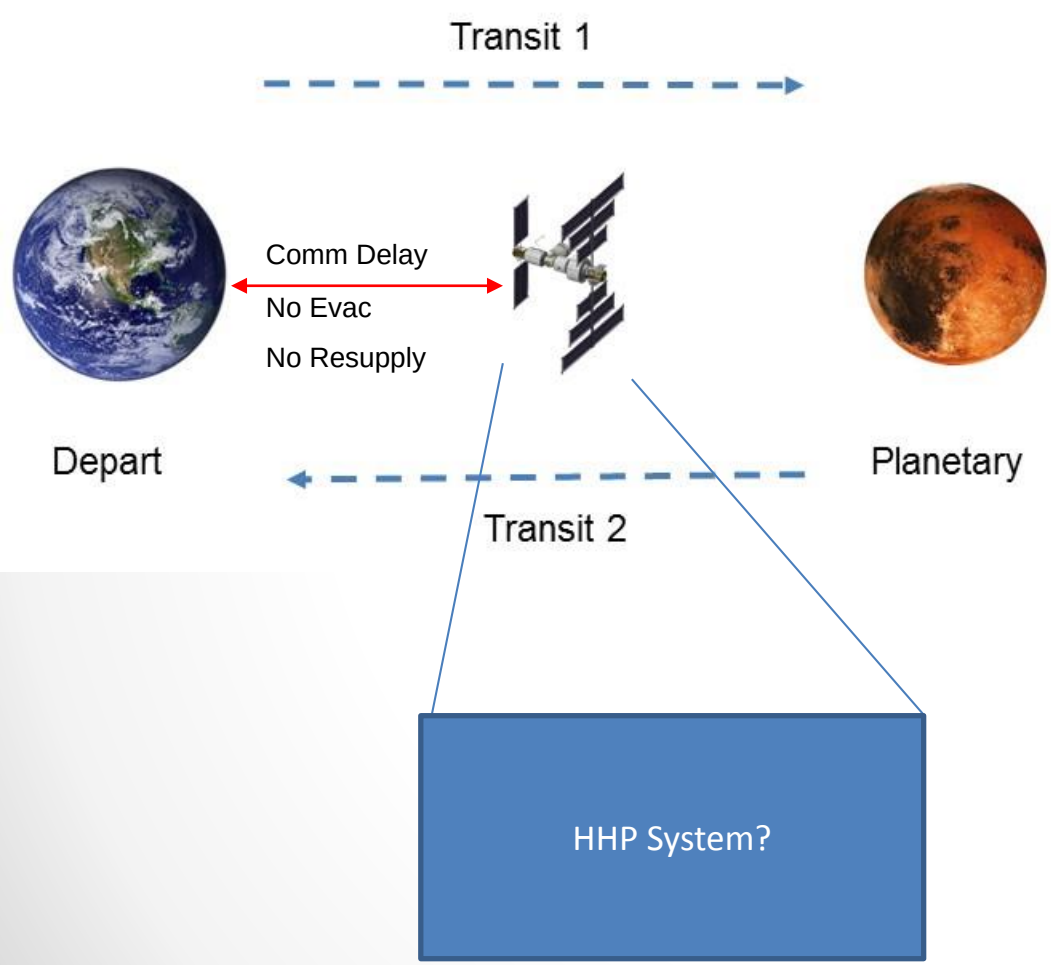
Pedigree:

DoDAF



Relationships between research divisions in the Exploration Medical Capability Element.

The HHP Goal



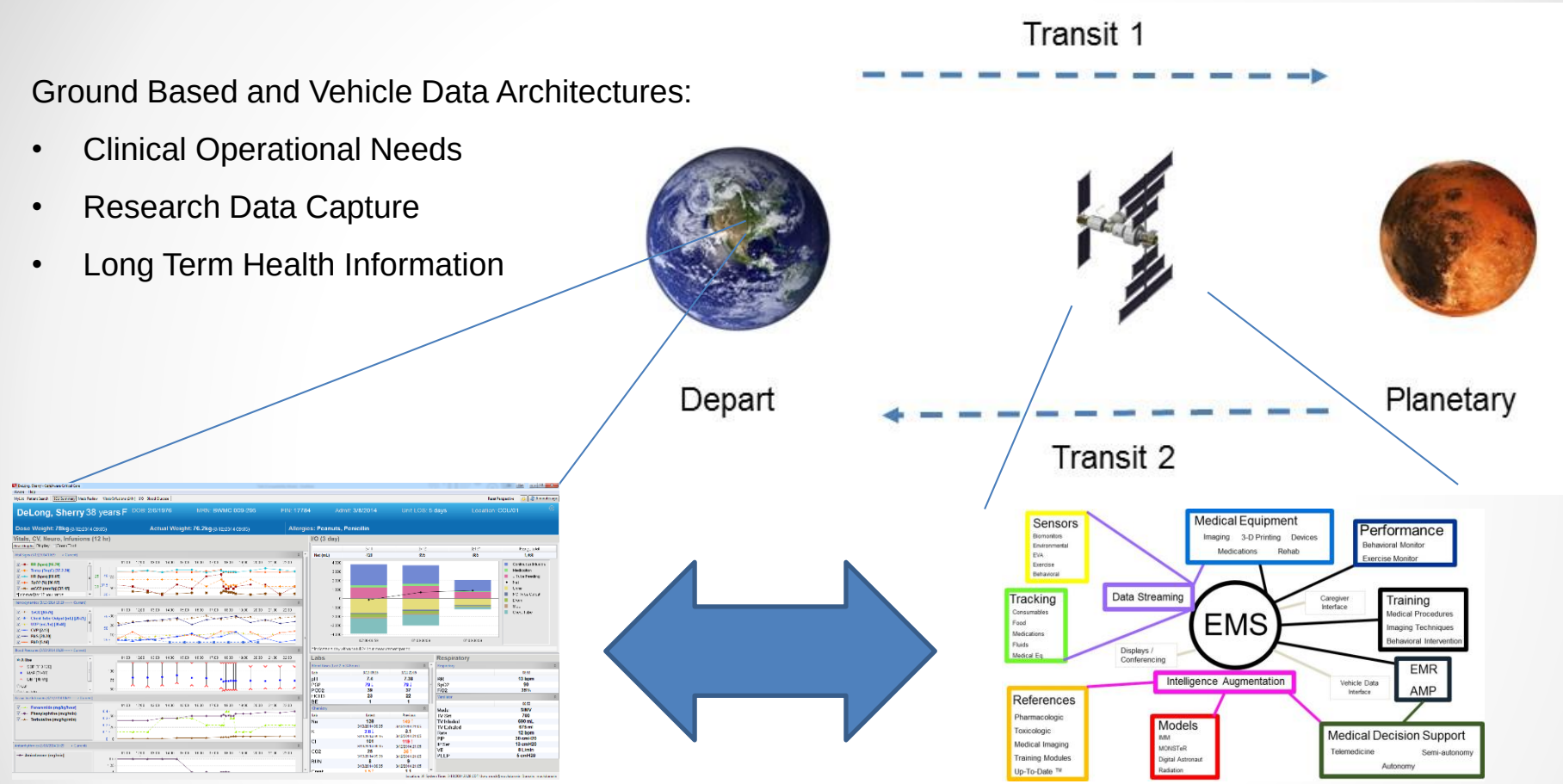
HHP System Operations

- Risk monitoring
  - Vehicle
  - Environment
  - Crew
  - SYSTEM
- Countermeasure readiness and deployment
- Maximize mission objective attainment while minimizing crew casualty

Medical Data Architecture

Ground Based and Vehicle Data Architectures:

- Clinical Operational Needs
- Research Data Capture
- Long Term Health Information



- Flight Surgeon/BME
- External Consults

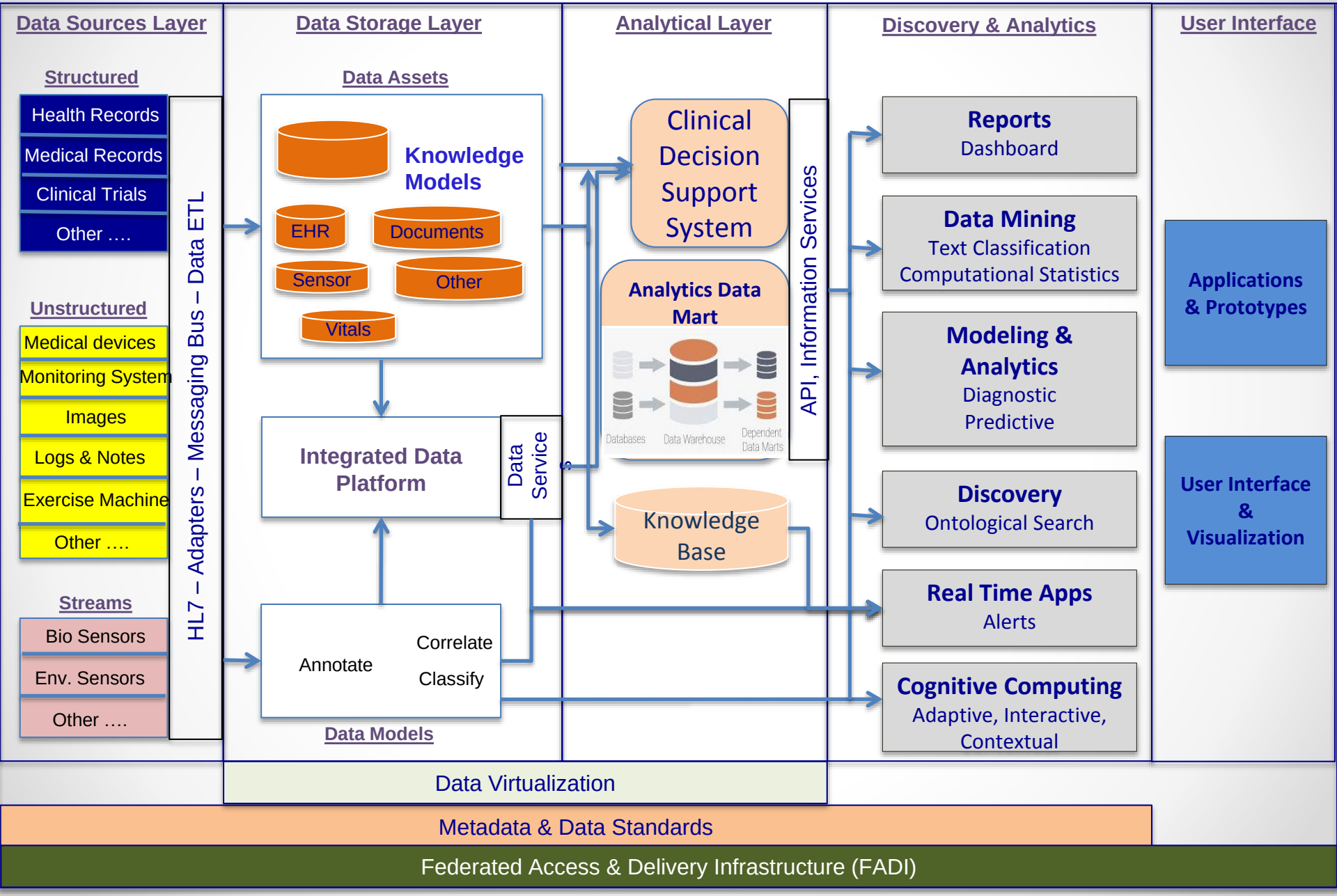
Mirrored Delayed Data Presentation for situational awareness/support

Vehicle Exploration Medical System

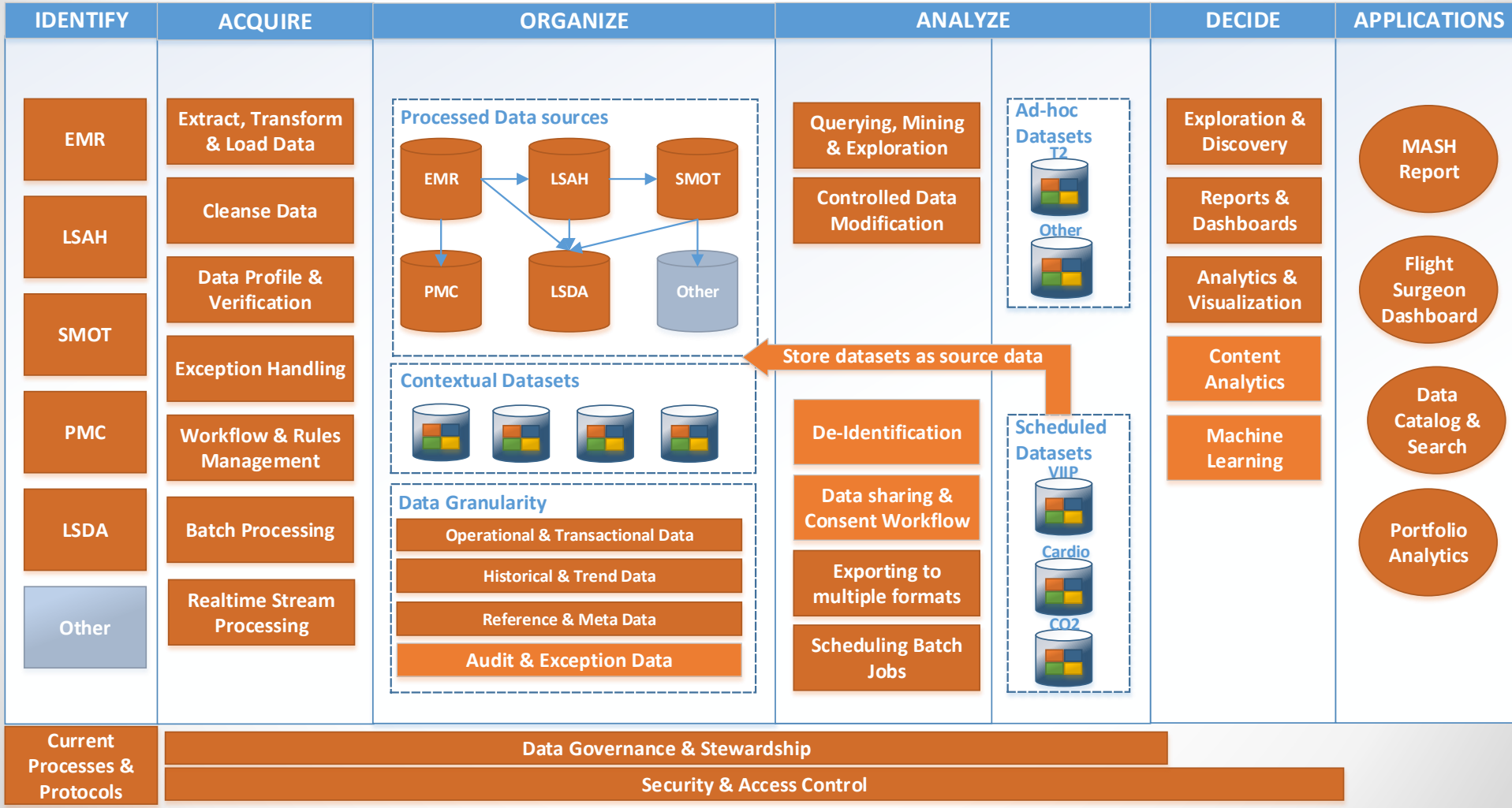
- Crew Medical Officer
- Crew Medical Support

Real-Time Data Processing for Crew

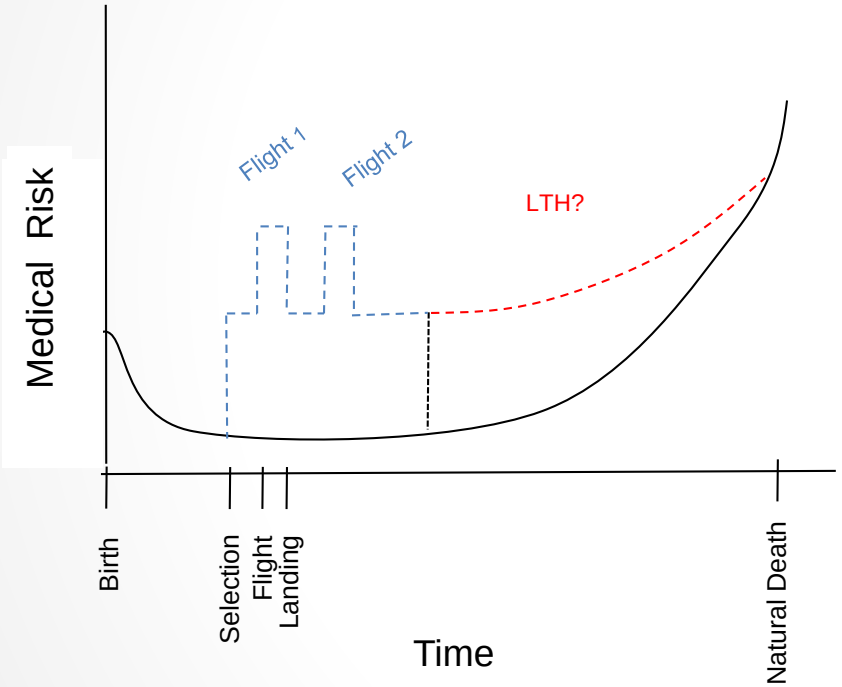
ExMC Data Architecture (ARC)



Ground-based Data Architecture (JSC)



Long Term Health Directions



Long Term Health

1. R + 1yr: come back to preflight baseline?
   a. Effects post flight?
   b. Back to Pre-flight baseline?
2. Astronaut Career: come back to pre-selection baseline?
   a. Effects on career?
   b. Can they fly again?
3. Lifetime
   a. Effects on lifetime risk?
   b. Will they have problems later in life?

2013 Mortality Multiple Cause Micro-data Files

http://www.cdc.gov/nchs/data_access/Vitalstatsonline.htm

Long Term Health Recommendations

We do not understand LTH effects sufficiently to advise interventions

Long Term Health Definitions

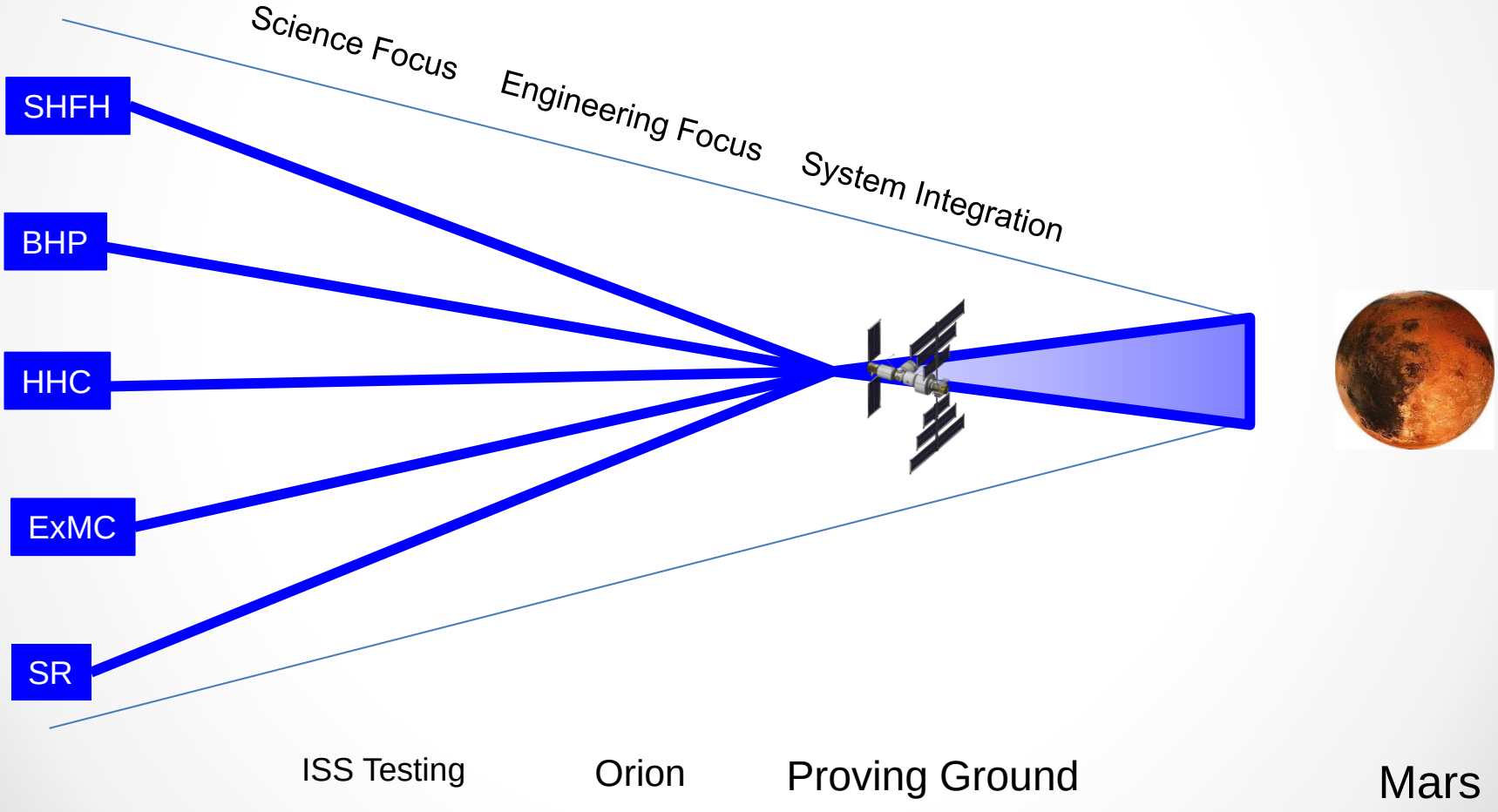
1. R + 1yr
2. Astronaut Career
3. Lifetime

- Generate a list of conditions with potential LTH consequences
- LSAH/HRP joint project to define relevant clinical and research data collection to monitor through program evolution
- Construct a Medical Data Architecture to support data collection and analysis
- Occupational Health to set triggers for intervening on data trends that are concerning
- Periodic re-evaluation of data collected to narrow or expand scope as more is learned about long term health effects

Three Sources of Information

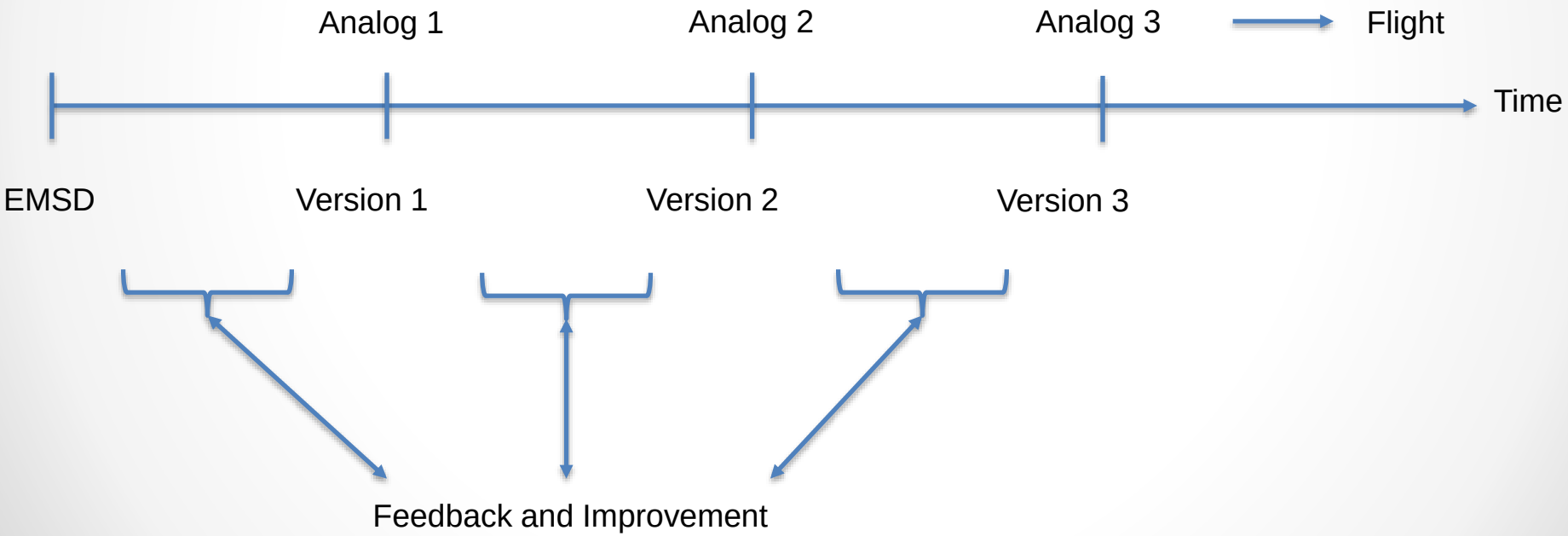
- Clinical Medical
- Human Performance
- Research

HHP System Development



Systems Testing and Development

Exploration Medical System Analog
Testing and Evaluation



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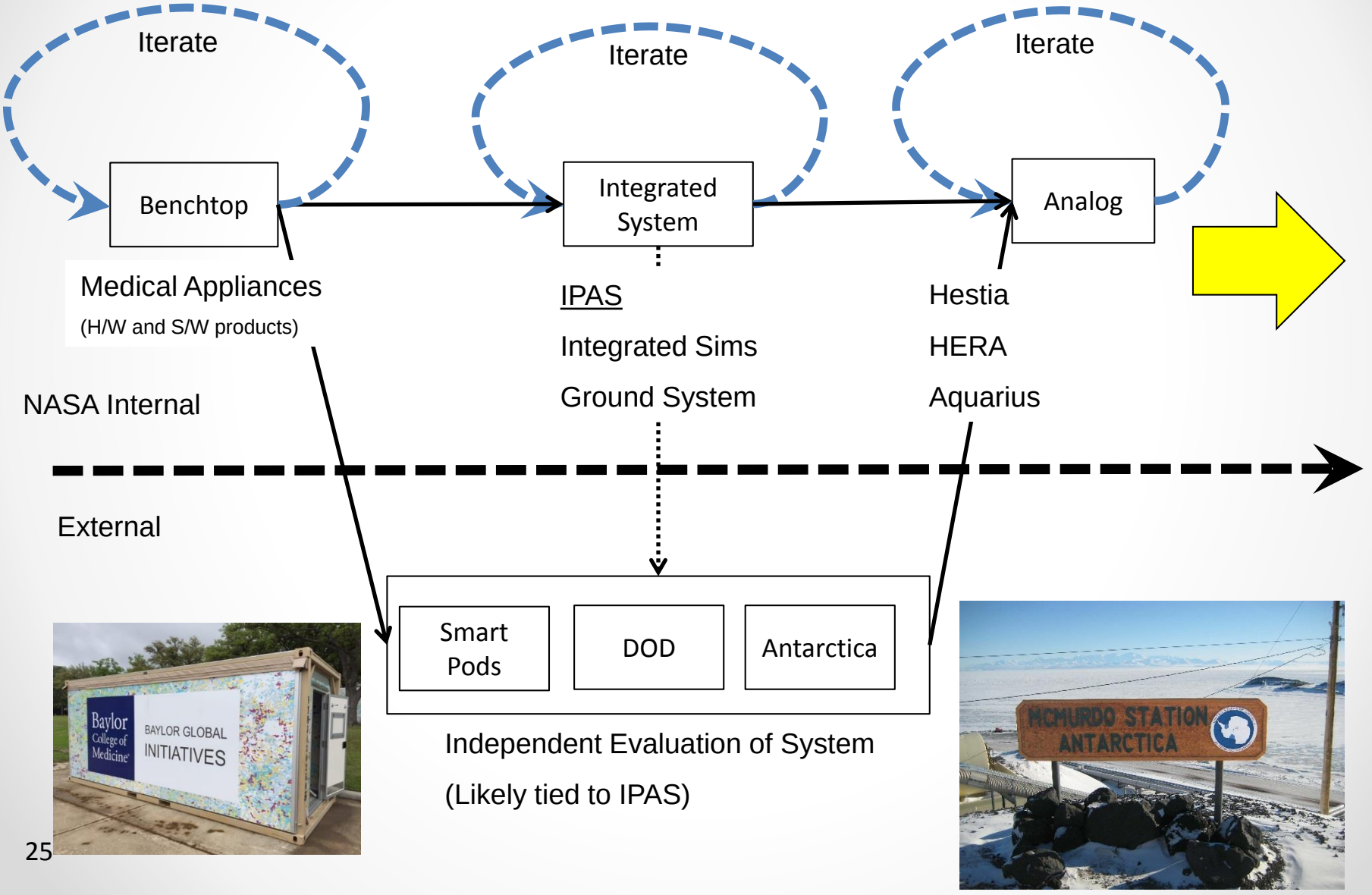
MDA Test Bed Roadmap

Phase	Test Bed 1	Test Bed 2	Test Bed 3	Test Bed 4
Capability	• MDA System Definition • Biomedical Device Integration Definition • Image Analysis • Data Mining • Basic UI	• MDA System Enhancements • Biomedical Device Provisioning • Knowledge Base • Improved UI • Interface Engine	• Multi-agent Data Mining • Computed Problem Solving • Semantic Relations Network • Optimized UI • Ground System Int.	• Computed Clinical Diagnosis • Augmented Intelligence • Remote Data Asset Synchronization • FDIR • Analog Test Prep
Medical Resources	• Astroskin • EKG • Dose Tracker	• Medical Consumables Tracking • Flexible Ultrasound • ELA • PUMA	• BHP appliances, apps and data • HHC appliance apps and data • Ground System Data Analytics Platform	• Vehicle Resources Oxygen, Medical Suction • Vehicle subsystem integration (ECLSS, Avionics, Power, Thermal)

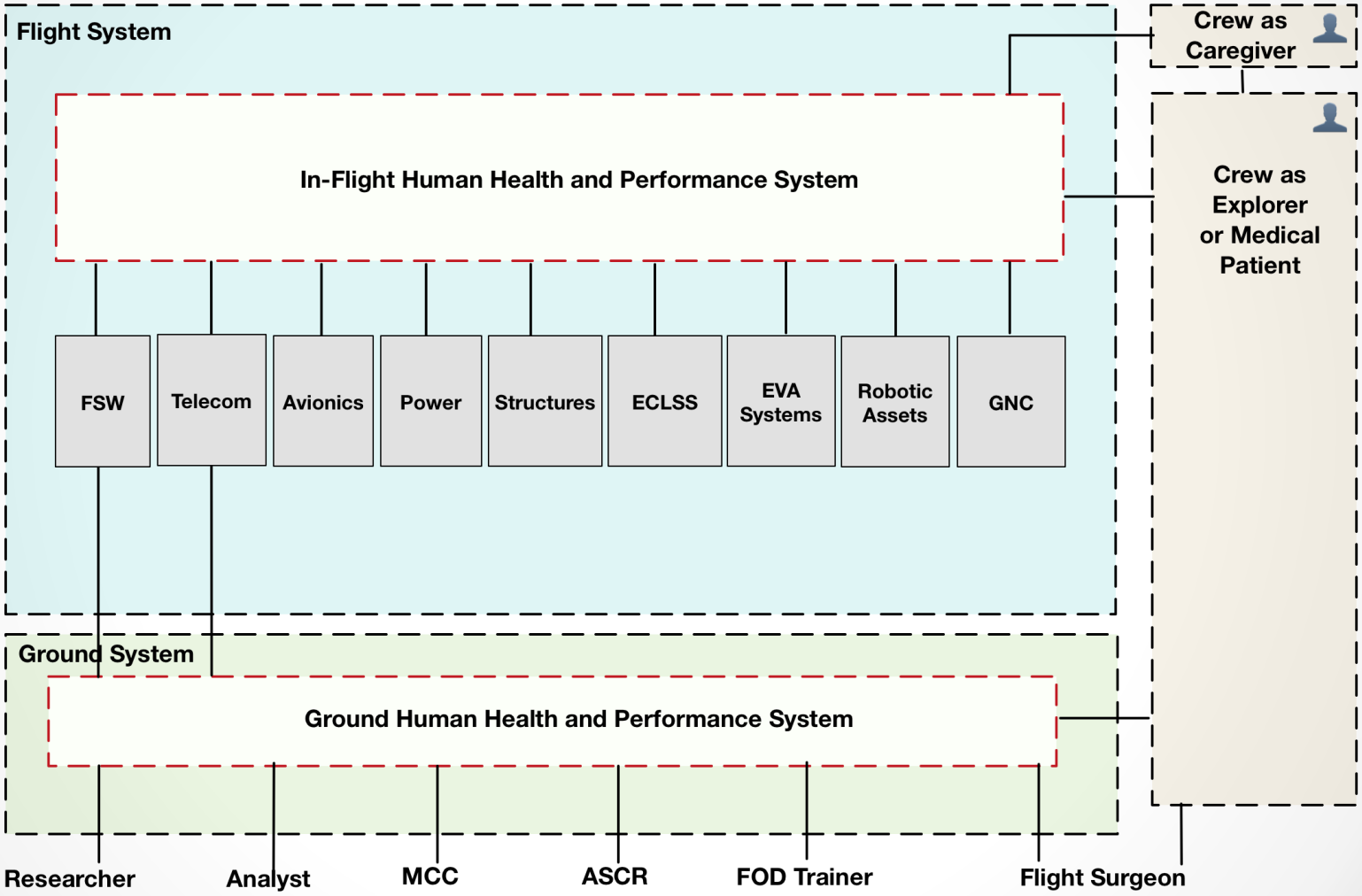
Integrated System Testing



Backup

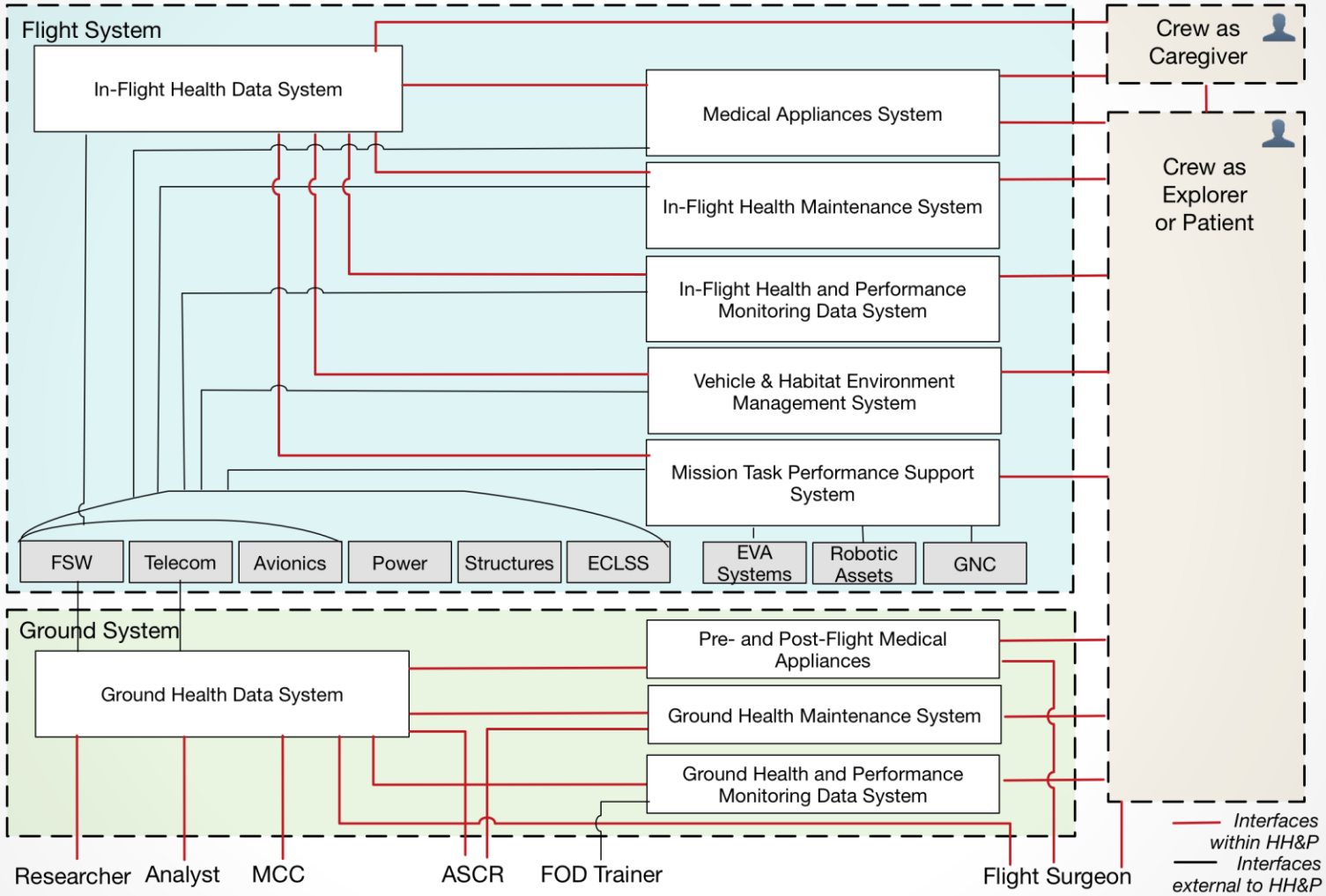
Work in Progress
4/19/16

Human Health and Performance System Block Diagram



Work in Progress
4/17/16

Human Health and Performance System Block Diagram



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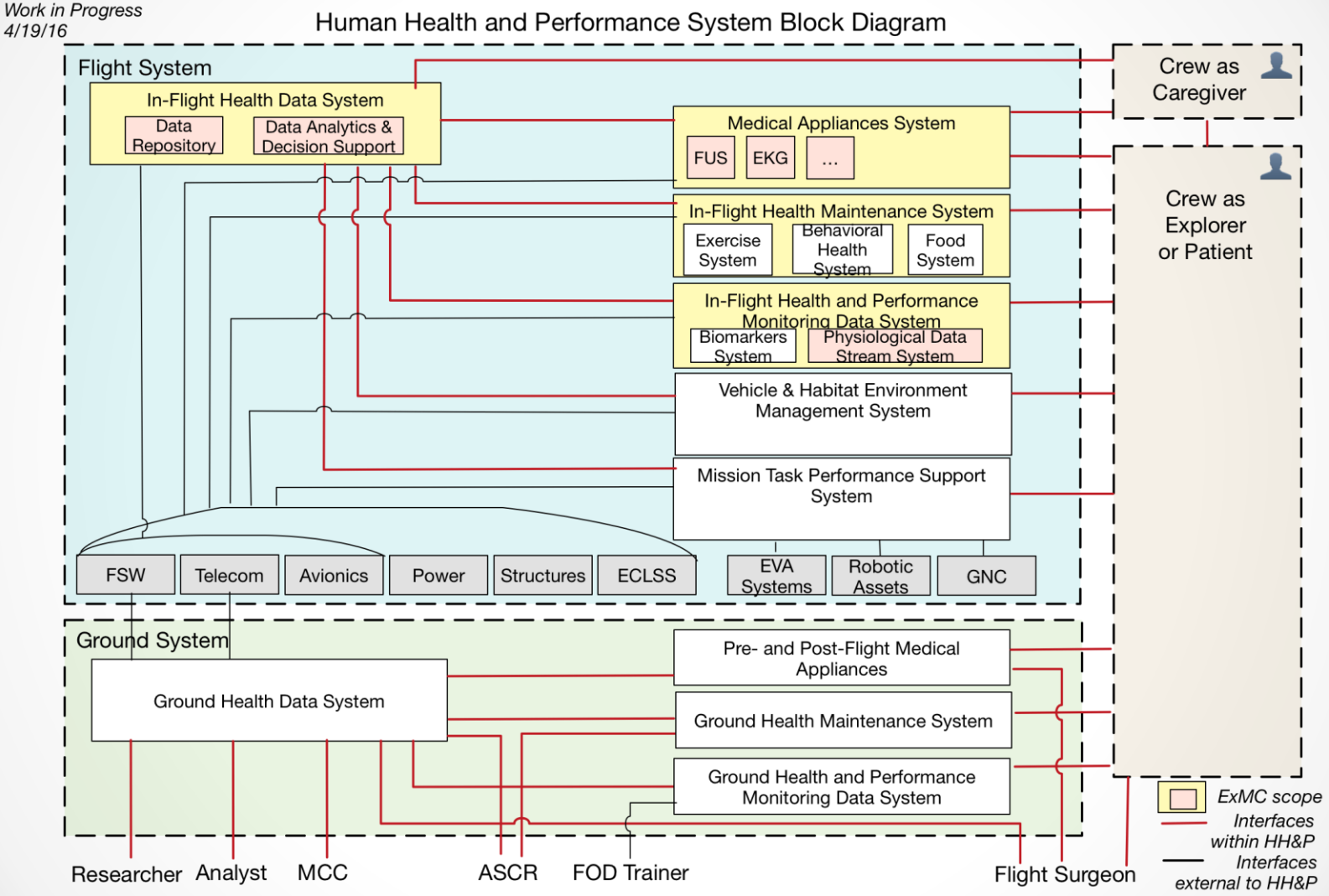

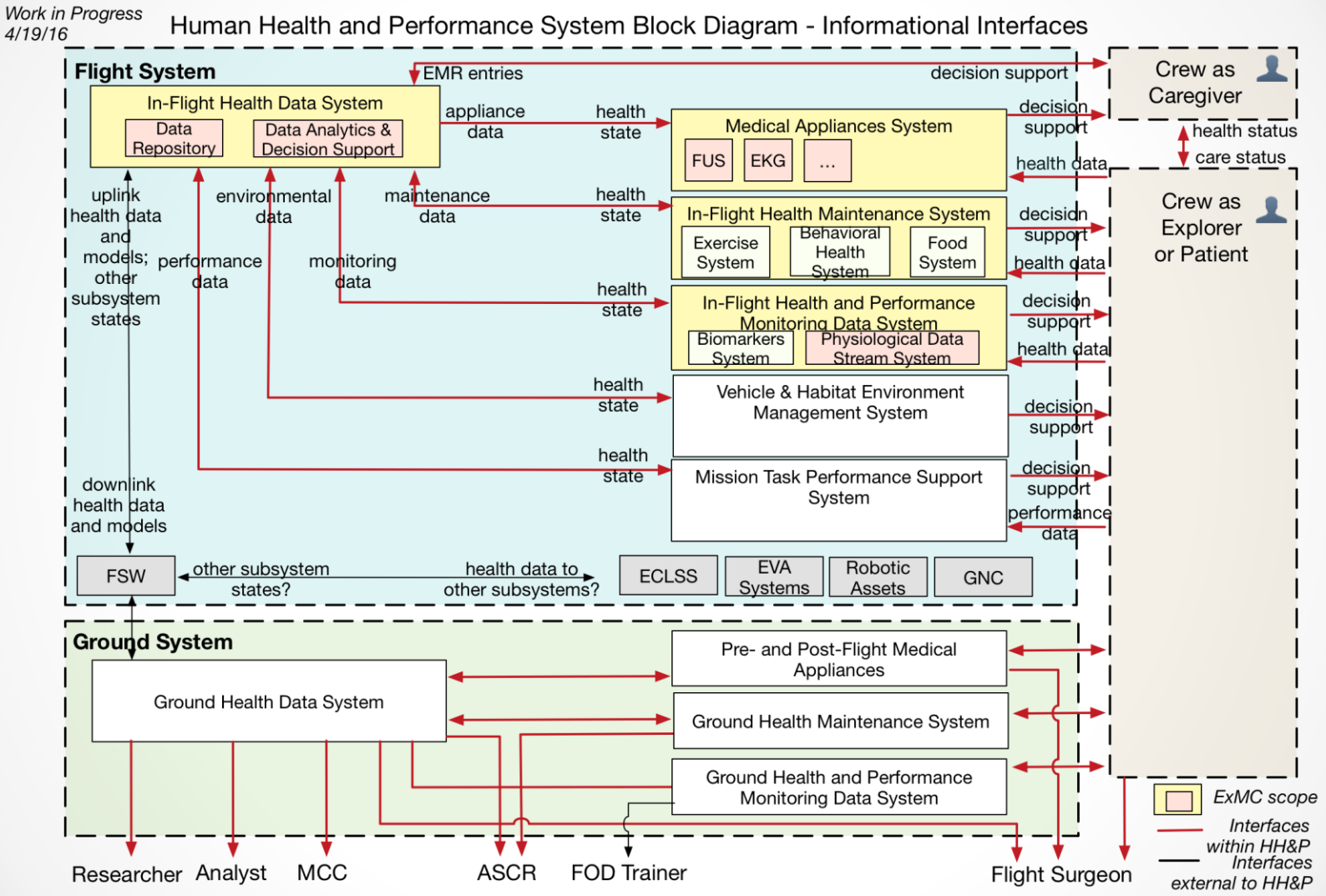
Work in Progress
4/19/16
Human Health and Performance System Block Diagram - Informational Interfaces
Flight System
EMR entries
decision support
In-Flight Health Data System
Data Repository
Data Analytics & Decision Support
appliance data
health state
Medical Appliances System
FUS
EKG
...
decision support
health data
Crew as Caregiver
health status
care status
Crew as Explorer or Patient
uplink health data and models; other subsystem states
environmental data
maintenance data
performance data
monitoring data
In-Flight Health Maintenance System
Exercise System
Behavioral Health System
Food System
In-Flight Health and Performance Monitoring Data System
Biomarkers System
Physiological Data Stream System
Vehicle & Habitat Environment Management System
Mission Task Performance Support System
performance data
downlink health data and models
FSW
other subsystem states?
health data to other subsystems?
ECLSS
EVA Systems
Robotic Assets
GNC
Ground System
Ground Health Data System
Pre- and Post-Flight Medical Appliances
Ground Health Maintenance System
Ground Health and Performance Monitoring Data System
Researcher
Analyst
MCC
ASCR
FOD Trainer
Flight Surgeon
ExMC scope
Interfaces within HH&P
Interfaces external to HH&P

Medical Decision Support System (MDSS)

A knowledge system designed to use patient medical data and medical knowledge to generate case-specific assessment and recommendations to help medical staff make medical decisions

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Hybrid Approach for Implementation

- Knowledge based
  - Use of knowledge bases
  - Inference engine
  - Decisions based on rules
- Non-knowledge based
  - Machine learning
  - Neural Networks (ANN/CNN) and algorithms
  - Derive knowledge from patient data
  - Learn from decision trees

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Medical Decision Support Module