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.
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
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.
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)
<table>
<thead>
<tr>
<th>Med01</th>
<th>We do not have a concept of operations for medical care during exploration missions.</th>
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<tbody>
<tr>
<td>Med02</td>
<td>We do not have the capability to provide a safe and effective pharmacy for exploration missions.</td>
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<tr>
<td>Med03</td>
<td>We do not know how we are going to apply personalized medicine to reduce health risk for a selected crew.</td>
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<td>Med04</td>
<td>We do not have a defined rehabilitation capability for injured or de-conditioned crew members during exploration missions.</td>
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<tr>
<td>Med05</td>
<td>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.</td>
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<tr>
<td>Med06</td>
<td>We do not know how to define medical planning or operational needs for ethical issues that may arise during exploration missions.</td>
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<tr>
<td>Med07</td>
<td>We do not have the capability to comprehensively process medically-relevant information to support medical operations during exploration missions.</td>
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<tr>
<td>Med08</td>
<td>We do not have quantified knowledge bases and modeling to estimate medical risk incurred on exploration missions.</td>
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<tr>
<td>Med09</td>
<td>We do not have the capability to predict estimated medical risk posture during exploration missions based on current crew health and resources.</td>
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<tr>
<td>Med10</td>
<td>We do not have the capability to provide computed medical decision support during exploration missions.</td>
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<tr>
<td>Med11</td>
<td>We do not have the capability to minimize medical system resource utilization during exploration missions.</td>
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<tr>
<td>Med12</td>
<td>We do not have the capability to mitigate select medical conditions</td>
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<tr>
<td>Med13</td>
<td>We do not have the capability to implement medical resources that enhance operational innovation for medical needs</td>
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The Concept of Operations Drives System Design
Gap Restructuring Enables System Creation

- Safe and Effective Pharmacy
- Oxygen Delivery
- Medical Suction
- Ultrasound Imaging
- Laboratory Analysis
- Biosensors/EKG

Risk

1. Concept of operations
2. Pharmacy recommendation
3. Select technologies
4. Integrated medical system
5. Optimized medical system

Capability

Risk

FY15 FY16 FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24

Pharm – Med02
Risk Est. – Med08
InFlight Risk – Med09

ConOps – Med01
Ethics – Med06

Data Arch – Med07
Training – Med05

Decision Support – Med10

Optimization – Med11

PerMed – Med03
How to decompose the work

Incremental and Iterative Approach

Operations Research
- Identify Medical Needs
- Conceptualize Operations
- Analog Testing

Information Resources
- Medical Systems
- Data Architecture
- Intelligence Augmentation
- Environmental Data

Technology Development
- Medical Appliances
- Element Collaboration
- Environmental Data API Integration

System Resource Interfaces
- Communication Standards
- Contingency Plans

Vehicle Interface Standards
- Medical Appliance Standards
- Technology Constraints
- Guidance on Optimal User-Interfaces

Technology Options
- Optimization
- Drawbacks/Risks

System Performance
- Integrated System Added Value
- Domain Knowledge

Pedigree: DoD AF
The HHP Goal

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

HHP System?
Medical Data Architecture

Ground Based and Vehicle Data Architectures:
- Clinical Operational Needs
- Research Data Capture
- Long Term Health Information

Vehicle Exploration Medical System
- Crew Medical Officer
- Crew Medical Support

Mirrored Delayed Data Presentation for situational awareness/support

Real-Time Data Processing for Crew
ExMC Data Architecture (ARC)

Data Sources Layer
- Structured
  - Health Records
  - Medical Records
  - Clinical Trials
  - Other
- Unstructured
  - Medical devices
  - Monitoring System
  - Images
  - Logs & Notes
  - Exercise Machine
  - Other
- Streams
  - Bio Sensors
  - Env. Sensors
  - Other

Data Storage Layer
- Data Assets
  - Knowledge Models
    - EHR
    - Documents
    - Sensor
    - Vitals
  - Other
- Integrated Data Platform
  - Data Service
  - Annotate
  - Correlate
  - Classify
- Data Models

Analytical Layer
- Clinical Decision Support System
- Analytics Data Mart
- Knowledge Base
- API, Information Services
- Data Mining
  - Text Classification
  - Computational Statistics
- Modeling & Analytics
  - Diagnostic
  - Predictive
- Discovery
  - Ontological Search
- Real Time Apps
  - Alerts
- Cognitive Computing
  - Adaptive, Interactive, Contextual

Discovery & Analytics
- Reports
  - Dashboard
- Data Mining
- Modeling & Analytics
- Discovery
- Real Time Apps
- Cognitive Computing

User Interface
- Applications & Prototypes
- User Interface & Visualization

Data Virtualization
- Metadata & Data Standards
- Federated Access & Delivery Infrastructure (FADI)
# Ground-based Data Architecture (JSC)

## Identify
- EMR
  - Extract, Transform & Load Data
- LSAH
  - Cleanse Data
- SMOT
  - Data Profile & Verification
- PMC
  - Exception Handling
- LSDA
  - Workflow & Rules Management
- Other
  - Batch Processing
  - Realtime Stream Processing

## Acquire
- EMR
- LSAH
- SMOT
- PMC
- LSDA
- Other
- Ad-hoc Datasets
- CO2
- Cardio
- VIIP
- Scheduled Datasets

## Organize
- Processed Data sources
  - EMR
  - LSAH
  - SMOT
  - PMC
  - LSDA
  - Other
- Contextual Datasets
  - Operational & Transactional Data
  - Historical & Trend Data
  - Reference & Meta Data
  - Audit & Exception Data

## Analyze
- Querying, Mining & Exploration
- Controlled Data Modification
- De-Identification
- Data sharing & Consent Workflow
- Exporting to multiple formats
- Scheduling Batch Jobs

## Decide
- Exploration & Discovery
- Reports & Dashboards
- Analytics & Visualization
- Content Analytics
- Machine Learning

## Applications
- MASH Report
- Flight Surgeon Dashboard
- Data Catalog & Search
- Portfolio Analytics

## Current Processes & Protocols
- Data Governance & Stewardship
- Security & Access Control
Long Term Health Directions

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?
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

Science Focus  Engineering Focus  System Integration

SHFH  BHP  HHC  ExMC  SR

ISS Testing  Orion  Proving Ground  Mars
Systems Testing and Development

Exploration Medical System Analog Testing and Evaluation

Time

EMSD

Analog 1

Version 1

Analog 2

Version 2

Analog 3

Version 3

Flight

Feedback and Improvement

Notional
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

- **Benchtop**
- **Integrated System**
- **Analog**

**Iterate**

**Medical Appliances** (H/W and S/W products)

**NASA Internal**

**External**

**IPAS**
- Integrated Sims
- Ground System

**Hestia**
- HERA
- Aquarius

**Proving Ground Vehicle**

**Smart Pods**

**DOD**

**Antarctica**

**Independent Evaluation of System** ( Likely tied to IPAS)
Backup
Human Health and Performance System Block Diagram

Flight System

In-Flight Human Health and Performance System

FSW  Telecom  Avionics  Power  Structures  ECLSS  EVA Systems  Robotic Assets  GNC

Ground System

Ground Human Health and Performance System

Researcher  Analyst  MCC  ASCR  FOD Trainer  Flight Surgeon

Crew as Caregiver

Crew as Explorer or Medical Patient
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.
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
Medical Decision Support Module

Medical Decision Support Module

Knowledge base & Inference engine

Data Integration and Transformation

Information Interpretation

Machine learning & Patterns

Health Assessment & Predictions

Medical & health records

Bio & Env. sensors

Images

Test results

Training

References

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