Medical System Trade Space Evaluation Tool for Exploration Missions

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2018 Human Research Program Investigators’ Workshop
Outline

• Introduction
• Motivation for Tool
• Purpose of Tool
• Conceptual Model
• Logical Model
• Schedule
• Benefits
• Future Plans
• Acknowledgments
Introduction

• Ensuring crew health is of paramount importance as NASA takes the next steps – space exploration beyond low Earth orbit
  – The Deep Space Gateway (DSG) and Deep Space Transport (DST) vehicle designs need to integrate the medical system alongside traditional subsystems to make best use of limited mass, power, and volume
  – Determining how to accommodate human crews requires using historical experience coupled with risk assessments for the particular missions DSG and DST represent

• Trade Space Evaluation Tools
  – ExMC leadership needs to participate in trade studies
    • With medical community (medical conditions, capabilities, risks)
      – FY18 focus is on “Loss of Crew Life” risk metric
      – Support identification of technology gaps
    • With vehicle design community (mass, volume, power)
      – Need timely turnaround to keep up with vehicle design process
Motivation for Developing Medical System Tool

<table>
<thead>
<tr>
<th>Category</th>
<th>ISS</th>
<th>Gateway – Lunar</th>
<th>Transport – Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to Acute Symptoms</td>
<td>Stabilize and Evacuate</td>
<td></td>
<td>Stand and Fight</td>
</tr>
<tr>
<td>Primary Caregiver</td>
<td>Earth Medical Ops</td>
<td></td>
<td>Physician Astronaut</td>
</tr>
<tr>
<td>Level of Care</td>
<td>4: trauma care, diagnostics, private audio/video</td>
<td>5: 4 + basic surgical care</td>
<td></td>
</tr>
<tr>
<td>Mission Length</td>
<td>180 days</td>
<td>6 to 42 days</td>
<td>2 to 3 Years</td>
</tr>
<tr>
<td>Time to Definitive Care</td>
<td>Less than 24 hours</td>
<td>Days</td>
<td>Months to Years</td>
</tr>
<tr>
<td>Crew Communication</td>
<td>Real-time</td>
<td>Less than 3 seconds</td>
<td>Up to 42 minutes round-trip</td>
</tr>
<tr>
<td>Delays with Earth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Resupply Time</td>
<td>Months</td>
<td>No resupply</td>
<td>No resupply</td>
</tr>
</tbody>
</table>

Exploration Missions Require Paradigm Shift in Medical Care
- Lunar – no resupply
- Mars – crew autonomy from Earth, physician astronaut primary caregiver
Purpose of Trade Space Evaluation Tool

- ExMC is leveraging prior efforts to produce an Integrated Risk Analysis tool to
  - Inform the design of Medical Systems for Deep Space Exploration Missions
  - Enable “what if” scenarios to be done quickly in response to varied risk postures, missions, and/or mass, power, and volume constraints
  - “What if medical system mass were cut by 50%? How would risk be affected?”
  - Identify “gaps” in capability that require research or technology development
  - Establish infrastructure to coordinate with other crew health and performance tools
  - Provide a quick turnaround in answering queries (days, not months)
  - Provide consistent results across the set of tools

Trade Option Characterization
- Medical conditions addressed
- Medical Standards met
- Master equipment list
- Mission characteristics (trajectory, communications, duration)

Parameter \( x \)
Risk (metric \( y \))

Option A
Option B
Option C
Option \( n \)
Conceptual Model: Phase I

Phase I: Assemble Data

Knowledge
Medical Research
Spaceflight Medicine

- Apollo, Space Shuttle, ISS, Twins study, bed rest studies
- Spaceflight effects on physiology
- Countermeasures

Doctors and Clinicians
- Medical Conditions
  - Probabilities, Durations
- Medical Capabilities
  - Means to Monitor, Diagnose, Treat
- Resources
  - Hardware, Software, Skillsets, Drugs
  - Mass, Power, Volume

Medical Item Database
- Captures clinician-defined data and relationships

<table>
<thead>
<tr>
<th>Condition</th>
<th>Probability</th>
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<tbody>
<tr>
<td>SKIN ABRASION / LACERATION</td>
<td>Best/worst</td>
</tr>
<tr>
<td>DENTAL: TOOTHACHE</td>
<td>Best/worst</td>
</tr>
<tr>
<td>ALTITUDE SICKNESS</td>
<td>Best/worst</td>
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<table>
<thead>
<tr>
<th>Capability</th>
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<tbody>
<tr>
<td>Perform Physical Exam and Conduct Screening exams/tests</td>
</tr>
<tr>
<td>Physical Exam - Abdomen</td>
</tr>
<tr>
<td>Physical Exam - Trauma</td>
</tr>
<tr>
<td>Perform Imaging</td>
</tr>
<tr>
<td>Imaging- Ultrasound, Linear probe</td>
</tr>
<tr>
<td>Imaging - still/ video photography, external</td>
</tr>
<tr>
<td>Assess and monitor vital signs</td>
</tr>
<tr>
<td>Vital Signs - Heart Rate</td>
</tr>
<tr>
<td>Vital Signs - SpO2</td>
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<thead>
<tr>
<th>Resource</th>
<th>Mass</th>
<th>Power</th>
<th>Volume</th>
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<tbody>
<tr>
<td>ANALGESIC_ORAL_WEAK ASPIRIN</td>
<td>kg</td>
<td>watts</td>
<td>cm³</td>
</tr>
<tr>
<td>FLEX_ULTRASOUND</td>
<td>kg</td>
<td>watts</td>
<td>cm³</td>
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Conceptual Model: Phase II

Phase II: Analysis, Trade Studies

- **Medical Item Database**
  - Medical Conditions
  - Medical Capabilities
  - Resources

- **Design Reference Mission Parameters**
  - Crew
    - Number of crew, gender
    - Mission Parameters
    - Mission length
    - EVA in ConOps (yes/no)
    - Mass/Power/Volume allocations
    - Halo Orbit @ Moon: 6 to 400 days
    - Mars Rendezvous: 2 years
    - Mars Landing: 3 years

- **Dynamic Probabilistic Risk Assessment**

- **Doctors and Clinicians**
  - Risk of Loss of Crew

- **Vehicle Designers**
  - Mass, Power, Volume required

- **Deep Space Gateway Model (SysML)**
  - **Deep Space Gateway Medical System Model**
  - Represents human health standards for spaceflight and medical system requirements
  - Mass and power constraints

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**MEDPRAT – Medical Extensible Dynamic Probabilistic Risk Analysis Tool**

Models a customer-defined mission to produce risk of Loss of Crew Life

- Iterate until physical constraints met, and risk level is acceptable
### Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Tasks</th>
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<tbody>
<tr>
<td>2017</td>
<td>Dec</td>
<td>Define Goals and Objectives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Identify gaps between goals and existing component capabilities</td>
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<tr>
<td></td>
<td>Jan</td>
<td>Baseline Design</td>
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<td></td>
<td>Feb</td>
<td>Baseline Components</td>
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<tr>
<td></td>
<td>Mar</td>
<td>Integrate, Test, Validate</td>
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<tr>
<td>2018</td>
<td>Apr</td>
<td>Demo Dry Run</td>
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<tr>
<td></td>
<td>May</td>
<td>Demo for Stakeholders</td>
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<td></td>
<td>Jun</td>
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<td>Jul</td>
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<td>Sep</td>
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<td>Oct</td>
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Note: The schedule includes key milestones from December 2017 to October 2018, with tasks such as defining goals and objectives, identifying gaps, designing baselines, integrating and testing, and demonstrating for stakeholders.
**Benefits**

Enable medical system to inform vehicle design up front
   Enable trades between risk, mass, power, and volume

Integrate medical system model in vehicle model
   Model captures medical requirements and architecture to integrate into vehicle model

Identify medical technology and method gaps
   Identify areas of medical technology that need further research and development
Future Plans

Demonstration of capabilities in FY2018

Integrate support tool
   Ensure tool is evolvable to integrate with future tools
      SOLV, workstation evaluation, decision support

Identify gaps in medical capabilities
   Identify medical health monitoring, diagnosis, and/or treatments without spaceflight heritage

Optimize software
   Auto-select resources to mitigate risk based on pre-set parameters
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