Risk Interfaces to Support Integrated Systems Analysis and Development

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Objectives for Systems Analysis Capability

- Develop integrated understanding of how complex human physiological-socio-technical mission system behaves in spaceflight

- Why?
  - Support development of **integrated solutions** that prevent unwanted outcomes
    - Implementable approaches to minimize mission resources
      - (mass, power, crew time, etc.)
  - Support development of tools for autonomy (need for exploration)
    - Assess and maintain resilience – individuals, teams, **integrated system**

*Thrive, not just survive, during long-duration missions*
Purpose of this Limited-Scope Exercise

- Demonstrate techniques to systematically identify, organize, and manage interfaces among Risks

- Why?
  - Interfaces are where many challenges appear
  - We do not currently have a systematic way to manage interfaces and ensure that appropriate work is addressed

- In spacecraft engineering, subsystem scopes (e.g., structures, avionics, power, propulsion) are well-defined in a common conceptual model
- This enables management of interfaces to build an effective system
- Our Risk scope and interfaces would benefit from similar approach
Output of this Exercise

• Output of this exercise:

  – Representation of interfaces based on Human System Risk Board (HSRB) Risk Summary information and simple status based on Human Research Roadmap

  – Consolidated HSRB information applied to support communication

  – Point-of-Departure for HRP Element planning

  – Ability to track and communicate status of collaborations
Approach

1) Normalized HSRB Risk Summary content using an existing framework
   – Created combined data set

2) Identified Risk interfaces
   – Defined types of interfaces
   – Applied HSRB data to identify related Risks

3) Performed first pass comparison to plans
   – Determined if related Risks share Tasks in Human Research Roadmap

4) Visualized options for collaborations and their status
Methods – Normalize Content

- **Hazards and Contributing Factors**
  - Acceleration or Gravity
  - Distance From Earth
  - Food System
  - Genitourinary Function
  - Mission Duration
  - CO₂

- **Countermeasures**
  - Ground Medical Care
  - Crew Selection
  - Food System
  - In-Flight Medications
  - Mission Scenarios

- **Metrics**
  - Genitourinary (Systemic Clinical Outcome)
Methods: Identify Risk Interfaces

• 6 types of interfaces defined for this exercise

1) Risks whose scope of work addresses contributing factors of other Risks
2) Risks whose scope of work addresses mitigations of other Risks
3) Risks whose scope of work addresses metrics of other Risks

Example “scope of work” assumed for Renal Risk:
• Physiological adaptations of the genitourinary system
• Clinical outcomes such as renal stones

4) Risks that share common contributing factors
5) Risks that share common mitigation factors
6) Risks that share common metrics
Interface Visualization

- Nodes are HSRB Risks
- Line is drawn (interface is indicated) based on information in HSRB Risk Summaries
- Color is given based on HRR information

<table>
<thead>
<tr>
<th>Line Color</th>
<th>Do Risks Share Tasks in HRR?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>N/A (not HRP Risks)</td>
</tr>
</tbody>
</table>

Types of interfaces:
1 = Risk at arrow head has contributing factor(s) in scope of Risk at arrow start
2 = Risk at arrow head has mitigation(s) in scope of Risk at arrow start
3 = Risk at arrow head has metric(s) in scope of Risk at arrow start

Work taking place in a Risk at an arrow start influences the state of a Risk at the arrow head.
ExMC Element Risks:

*Work taking place in a Risk at an arrow start influences the state of a Risk at the arrow head.*

Types of interfaces:
1. Risk at arrow head has contributing factor(s) in scope of Risk at arrow start
2. Risk at arrow head has mitigation(s) in scope of Risk at arrow start
3. Risk at arrow head has metric(s) in scope of Risk at arrow start

<table>
<thead>
<tr>
<th>Line Color</th>
<th>Do Risks Share Tasks in HRR?</th>
<th>% in Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>44%</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>31%</td>
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<td>N/A (not HRP Risks)</td>
<td>25%</td>
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</table>
ExMC Risk Interfaces Based on Common Contributing Factors (Interface Type 4)

- Nodes are HSRB Risks
- Line is drawn based on info in HSRB Risk Summaries
- Line thickness indicates # of shared contributing factors
- Line color indicates if Risks share Tasks in HRR

<table>
<thead>
<tr>
<th>Line Color</th>
<th>Do Risks Share Tasks in HRR?</th>
<th>% in Category</th>
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<tbody>
<tr>
<td>Red</td>
<td>No</td>
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</tr>
<tr>
<td>Green</td>
<td>Yes</td>
<td>35%</td>
</tr>
<tr>
<td>Blue</td>
<td>N/A (not HRP Risks)</td>
<td>23%</td>
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</table>

Node colors:
Insights on Interfaces

- Red lines are example candidates for cross-Element work
  - Green lines can also be candidates, depending on details of existing work

<table>
<thead>
<tr>
<th>No new action</th>
<th>New action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared Tasks in place, and adequate integration is in place</td>
<td>Shared Tasks in place, but additional integration is needed</td>
</tr>
<tr>
<td>Shared Tasks not in place, but adequate integration is in place</td>
<td>Shared Tasks not in place, and additional integration is needed</td>
</tr>
</tbody>
</table>

- ExMC examples for candidates with other Elements:
  - Many considerations with HHC: Immune, EVA, DCS, Exploration Atmosphere, OI, Arrhythmia, Sensorimotor, VIIP, PK/PD (details in backup)
  - SHFH: Microhost, Dust (details in backup)
  - SR: Radiation (details in backup)
Forward Work

• Solicitation planning using Human Research Roadmap content

• Element interface identification, planning, management
  • Reduce assumptions
  • Evaluate link status
  • Define additional types of interfaces if necessary (e.g., flow of information, consulting, deliverables)
Summary

• Demonstrated techniques to systematically identify, organize, and manage interfaces among Risks

• Output of this exercise:
  – Representation of interfaces based on HSRB Risk Summary information and simple status based on Human Research Roadmap
  – Consolidated HSRB information applied to support communication
  – Point-of-Departure for Element planning
  – Ability to track and communicate status of collaborations

THANK YOU
Backup
# ExMC Type 1,2,3 Interfaces

<table>
<thead>
<tr>
<th>ExMC Risk of Interest</th>
<th>Related Risk</th>
<th>Contributing Factors of Related Risk in ExMC Risk's Scope</th>
<th>Mitigations of Related Risk in ExMC Risk's Scope</th>
<th>Metrics of Related Risk in ExMC Risk's Scope</th>
<th>Shared task in HRR?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExMC Fracture</td>
<td>N/A</td>
<td>In-flight Medical System</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
</tr>
<tr>
<td>ExMC Arrhythmia</td>
<td>N/A</td>
<td>In-flight Medical System</td>
<td>Circulatory</td>
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<td>ExMC Hearing Loss</td>
<td>N/A</td>
<td>In-flight Medical System</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
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<tr>
<td>ExMC EVA</td>
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<td>In-flight Medical System</td>
<td>Shoulder, Arm, Elbow</td>
<td>N/A</td>
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<tr>
<td>ExMC Sunlight</td>
<td>N/A</td>
<td>In-flight Medical System</td>
<td>Head, Mouth, Dental, Eye, Ear; Skin and Subcutaneous Tissue</td>
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<tr>
<td>ExMC Hypoxia</td>
<td>Altitude or Decompression Sickness</td>
<td>In-flight Medical System</td>
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<td>ExMC DCS</td>
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<td>Altitude or Decompression Sickness</td>
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<td>No</td>
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<tr>
<td>ExMC Stability</td>
<td>In-flight Medical System</td>
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<td>N/A</td>
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<tr>
<td>ExMC HSID</td>
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<td>ExMC OP</td>
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<td>Head, Mouth, Dental, Eye, Ear; Neck, Airway; Chest, Upper Back; Abdomen, Lower Back; Shoulder, Arm, Elbow; Wrist, Hand, Finger; Hip, Leg, Knee; Ankle, Foot, Toes</td>
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<td>ExMC SABP</td>
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<td>Chest, Upper Back; Abdomen, Lower Back</td>
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<td>ExMC Microhost</td>
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<td>ExMC Immune</td>
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<td>Blood, Blood-Forming Organs, Immune; Digestive; Skin and Subcutaneous Tissue</td>
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<td>Circulatory; Malignancy, Tumor</td>
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<td>ExMC Renal</td>
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## ExMC Type 1,2,3 Interfaces Cont.

<table>
<thead>
<tr>
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<th>Mitigations of Related Risk in ExMC Risk's Scope</th>
<th>Metrics of Related Risk in ExMC Risk's Scope</th>
<th>Shared task in HRR?</th>
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<tbody>
<tr>
<td>Stability</td>
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<td>BMed</td>
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<td>Stability</td>
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<td>In-Flight Medications</td>
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<td>Stability</td>
<td>Sunlight</td>
<td>In-Flight Medications</td>
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<tr>
<td>Stability</td>
<td>OI</td>
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</table>
## ExMC Type 1,2,3 Interfaces Cont.

<table>
<thead>
<tr>
<th>ExMC Risk of Interest</th>
<th>Related Risk</th>
<th>Contributing Factors of Related Risk in ExMC Risk’s Scope</th>
<th>Mitigations of Related Risk in ExMC Risk’s Scope</th>
<th>Metrics of Related Risk in ExMC Risk’s Scope</th>
<th>Shared task in HRR?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture</td>
<td>PK/PD</td>
<td>Bone Strength</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
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<td>Fracture</td>
<td>EVA</td>
<td>Bone Strength</td>
<td>N/A</td>
<td>Shoulder, Arm, Elbow</td>
<td>No</td>
</tr>
<tr>
<td>Fracture</td>
<td>OP</td>
<td>Bone Strength</td>
<td>N/A</td>
<td>Head, Mouth, Dental, Eye, Ear; Neck, Airway; Chest, Upper Back; Abdomen, Lower Back; Shoulder, Arm, Elbow; Wrist, Hand, Finger; Hip, Leg, Knee; Ankle, Foot, Toes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fracture</td>
<td>Arrhythmia</td>
<td>Physical Work Load</td>
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<td>N/A</td>
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<tr>
<td>Fracture</td>
<td>DCS</td>
<td>Physical Work Load</td>
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<td>Fracture</td>
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<tr>
<td>Fracture</td>
<td>SABP</td>
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<td>N/A</td>
<td>Chest, Upper Back; Abdomen, Lower Back</td>
<td>N/A</td>
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<tr>
<td>Renal</td>
<td>PK/PD</td>
<td>Genitourinary Function</td>
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<td>N/A</td>
<td>No</td>
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<tr>
<td>Renal</td>
<td>UrinaryRet</td>
<td>N/A</td>
<td>N/A</td>
<td>Genitourinary</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Left off relationships between Fracture and CO2, Microhost, Sunlight, VIIP that would appear due to those 4 having metrics within Head, etc. injury.
ExMC Risk Scope Assumptions

<table>
<thead>
<tr>
<th>RISK</th>
<th>FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExMC</td>
<td>Head, Mouth, Dental, Eye, Ear</td>
</tr>
<tr>
<td></td>
<td>Neck, Airway</td>
</tr>
<tr>
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<td>Chest, Upper Back</td>
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<td>Abdomen, Lower Back</td>
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<td>Shoulder, Arm, Elbow</td>
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<td></td>
<td>Wrist, Hand, Finger</td>
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<tr>
<td></td>
<td>Hip, Leg, Knee</td>
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<td>Ankle, Foot, Toes</td>
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<td></td>
<td>Blood, Blood-Forming Organs, Immune</td>
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<tr>
<td></td>
<td>Endocrine, Nutritional, Metabolic</td>
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<td></td>
<td>Nervous</td>
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<tr>
<td></td>
<td>Circulatory</td>
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<td></td>
<td>Respiratory</td>
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<td>Digestive</td>
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<td></td>
<td>Genitourinary</td>
</tr>
<tr>
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<td>Skin and Subcutaneous Tissue</td>
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<tr>
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<td>Musculoskeletal and Connective Tissue</td>
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<td>Altitude or Decompression Sickness</td>
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<td>Space Motion Sickness</td>
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<td>Acute Radiation Syndrome</td>
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<td>Burns, Corrosion</td>
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<td>Poison, Toxin</td>
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<td>Malignancy, Tumor</td>
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<td></td>
<td>Complications of Medical or Surgical Care</td>
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<tr>
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<td>In-flight Medical System</td>
</tr>
<tr>
<td>Stability</td>
<td>In-flight Medications</td>
</tr>
<tr>
<td>Fracture</td>
<td>Bone Strength</td>
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<tr>
<td></td>
<td>Head, Mouth, Dental, Eye, Ear</td>
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<td>Genitourinary function</td>
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## SHFE Type 1,2,3 Interfaces

<table>
<thead>
<tr>
<th>SHFE Risk</th>
<th>Non-SHFE Risk</th>
<th>Contributing Factors of Non-SHFE in SHFE’s Scope (Type 1)</th>
<th>Mitigations of Non-SHFE in SHFE’s Scope (Type 2)</th>
<th>Metrics of Non-SHFE in SHFE’s Scope (Type 3)</th>
<th>Shared task in HRR?</th>
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<tbody>
<tr>
<td>HARI</td>
<td>Team</td>
<td>Coordination; Cooperation; Communication within the Team; Team Psychosocial Adaptation</td>
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<td>Coordination; Cooperation; Communication within the Team</td>
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<td>HARI</td>
<td>BMed</td>
<td>Coordination; Cooperation; Communication within the Team; Team Psychosocial Adaptation</td>
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<td>Cooperation</td>
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<td>HARI</td>
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<td>Body Surface Area, Volume, &amp; Mass</td>
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<td>Hardware Tool Availability &amp; Design</td>
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<td>Strength Accommodations</td>
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System Risk-Reduction Questions (1/2)

1) What aspects of the integrated system influence the state of other aspects (i.e., what relationships exist)?

2) What are the strengths of those influences?

3) What are the integrated constraints on controlling aspects of the system (e.g., resources such as mass, power, volume, crew time)?

4) What are the most influential aspects we can control (in sets or individually) over appropriate time scales? This will lead to integrated countermeasures and identification of new countermeasure options. It will inform what countermeasures to pursue.

5) How does the state of the integrated system change during and after a mission? This addresses adaptation processes and emergent behavior. This supports identification of risks.
System Risk-Reduction Questions (2/2)

6) How can we gain insight into trends to prevent undesired outcomes (e.g., for medical or psychological health)?

7) How can we identify and describe preferential states (e.g., states such as “healthy” or “space-normal” for an individual)? This identifies acceptable levels of risk.

8) How can we direct the trajectory of the system state toward preferential states while minimizing resource use? This addresses identifying effective and efficient countermeasures. This leads to increasing the likelihood of health and performance success.

9) How can we enhance the system’s resilience in the presence of perturbations (e.g., triggers to the individual such as increased CO₂, mold, or stress; or to the team such as operational stressors)? This leads to increasing the likelihood of health and performance success.