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# Integrating Spaceflight Human System Risk Research

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Jennifer Mindock, KBRwyle, NASA JSC

Sarah Lumpkins, MEI Technologies, NASA JSC

Wilma Anton, KBRwyle, NASA JSC

Maria Havenhill, NASA GRC

Mark Shelhamer, Johns Hopkins University School of Medicine/NASA JSC

Michael Canga, NASA JSC

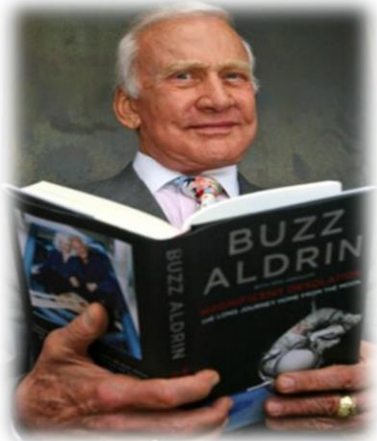
# Background

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*Healthy crew  
in-flight*

*...and  
long-term*



- The NASA Human System Risk Board (HSRB) manages the in-flight and long-term health and performance Risks to crew to enable exploration missions.
- Various entities within HSRB implement plans to address the Risks. Risks requiring research as a significant part of their mitigation are assigned to the Human Research Program (HRP).
- Risks are clearly interrelated. However, at this time, we still lack a systematic approach to understand these linkages to form a basis for better integration of work and resources.

# Relevant Motivation for this Exercise

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- Relevant motivation

- Recent Office of the Inspector General (OIG) and Institute of Medicine (IOM) reports

- OIG: “NASA’s management of crew health risks could benefit from increased efforts to integrate expertise from all related disciplines. While many life science specialists attempt to utilize the range of available expertise both inside and outside the Agency, NASA lacks a clear path for maximizing expertise and data at both the organizational and Agency level. For example, NASA has no formalized requirements for integrating human health and research among life sciences subject matter experts nor does it maintain a centralized point of coordination to **identify key integration points for human health**. Moreover, integrating the experiences of NASA’s engineering and safety efforts would benefit the outside life sciences community. The lack of a coordinated, integrated, and strategic approach may result in more time consuming and costly efforts to develop countermeasures to the numerous human health and performance risks associated with deep space missions.”

"NASA's Efforts to Manage Health and Human Performance Risks for Space Exploration" Office of the Inspector General. Report No. IG-16-003. October 29, 2015.

- IOM: “The reports ...struggle with **establishing the connections and interactions among risks that are related**, but a bit more tangential (e.g., altered immune response and inadequate nutrition).

"Review of NASA's Evidence Reports on Human Health Risks: 2014 Letter Report." Institute of Medicine. Review of NASA's Evidence Reports on Human Health Risks: 2014 Letter Report. Washington, DC: The National Academies Press, 2015. doi:10.17226/18983

- HSRB drive toward integrating Risk management

# Purpose and Scope of this Exercise

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- Purpose: Demonstrate techniques to systematically identify, organize, and manage interfaces among Risks
- Why?
  - Interfaces are where many challenges appear
  - HRP does 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

- Scope : Data currently captured in HSRB Risk records
  - Current content is at varying levels of completeness
  - Noted observations to support future systematic completeness analysis if needed

# Approach

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- 1) Normalized Risk record content using an existing framework
  - Treated all terms in framework as system variables that can be contributing factors, mitigations, or both
  - 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 planned research (“Tasks”) in HRP’s online research plan, the Human Research Roadmap (HRR)
- 4) Visualized options for collaborations and their status



# Methods – Normalize Content

## Renal Risk Record Information Example

### Risk record terms

#### Hazards and Contributing Factors

Primary hazard: microgravity (excess calcium excretion, low urine volume, urinary super-saturation)

Secondary hazards: closed environment – (limited H<sub>2</sub>O resource), distance from Earth

Contributing factors: Increased urinary calcium excretion, decreased urine volume, increased urinary super-saturation, dietary factors, mission duration, mission resources, hypercapnia

#### Mitigations

Preventative: screening, crew education, diet, potassium citrate/bisphosphonates

Treatment – return to Earth

#### Metrics

Metric: Renal stone occurrences

### Framework terms

#### Hazards and Contributing Factors

- Acceleration or Gravity
- Distance From Earth
- Food System
- Genitourinary Function
- Mission Duration
- CO<sub>2</sub>

#### Mitigations

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

#### Metrics

- Genitourinary (Systemic Clinical Outcome)

*Risk record  
info  
binned in  
common  
term  
framework*



# Methods: Identify Risk Interfaces

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



# Framework and Example of Risk's Scope of Work

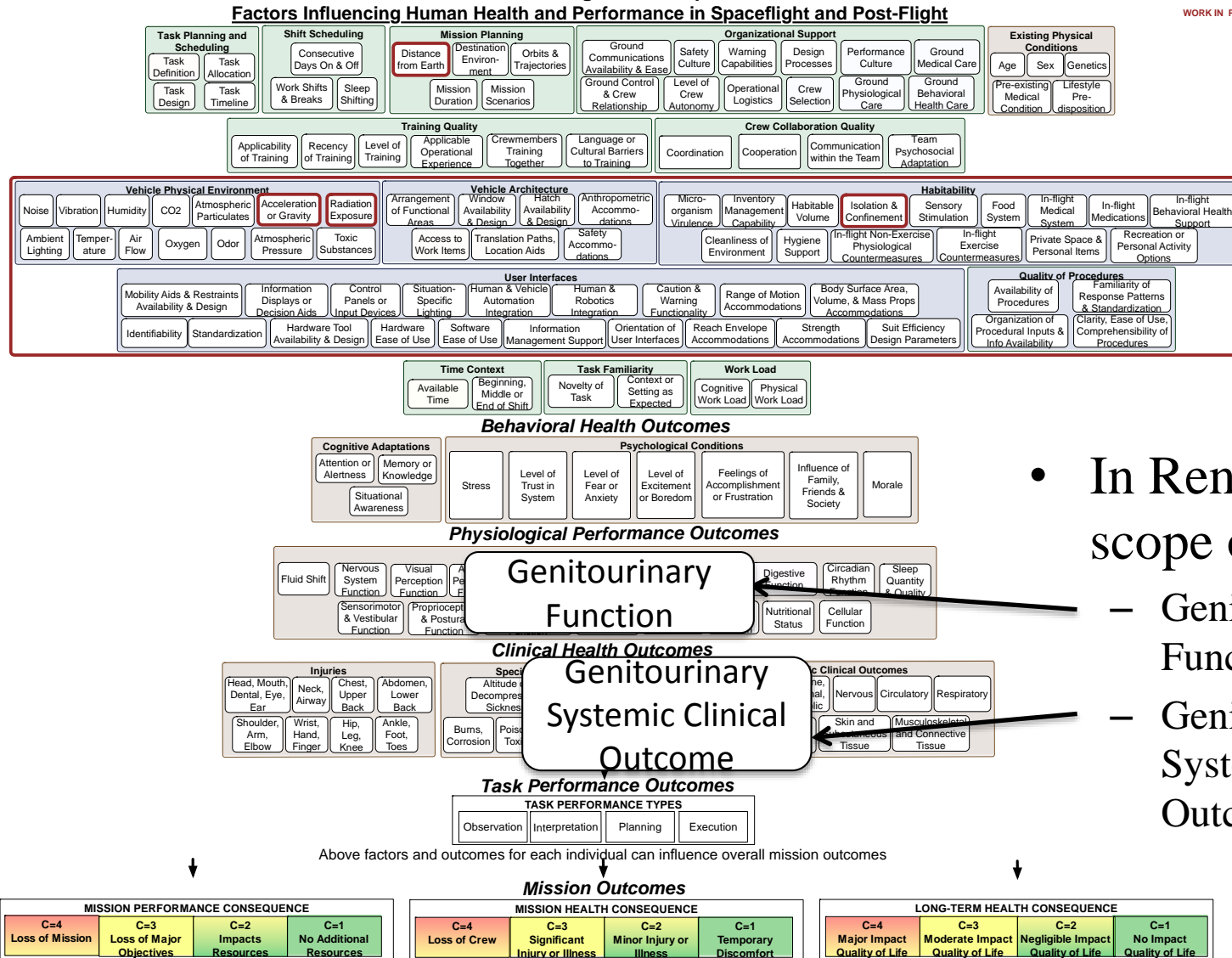
Factor Domain  
Color Key:

- Operations
- Vehicle Design
- Human

HSRB Hazard:

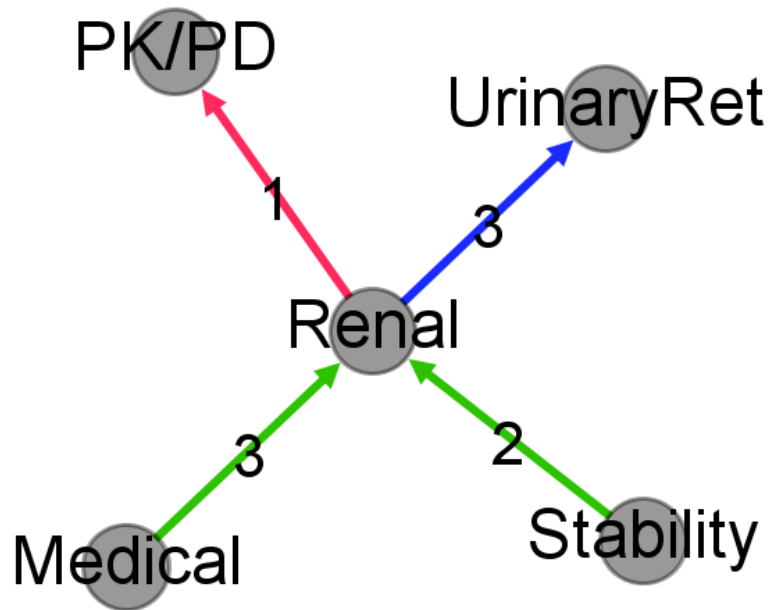
## Contributing Factor Map

12/15/15  
WORK IN PROGRESS





# Interface Visualization



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

- Nodes are HSRB Risks
- Line is drawn (interface is indicated) based on information in HSRB Risk records
- Color is given based on research plan information

Line Color	Do Risks Share Tasks in research plan?
Red	No
Green	Yes
Blue	N/A (not HRP Risks)

## 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

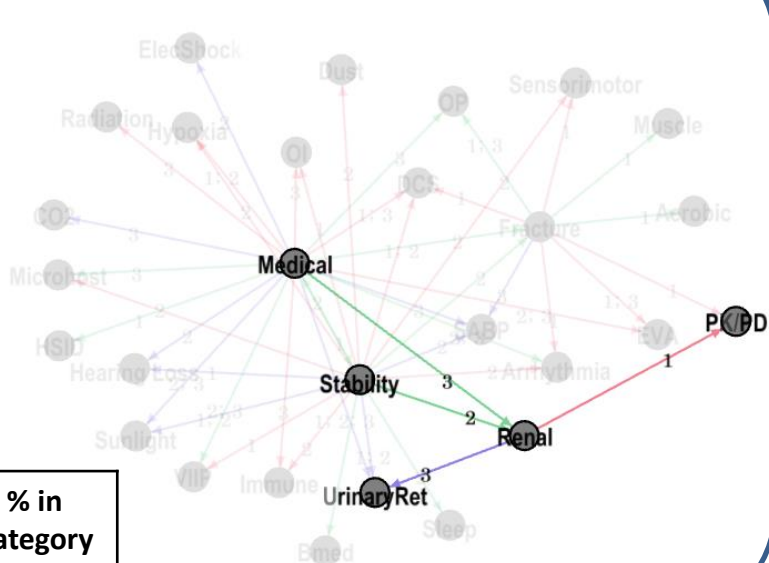
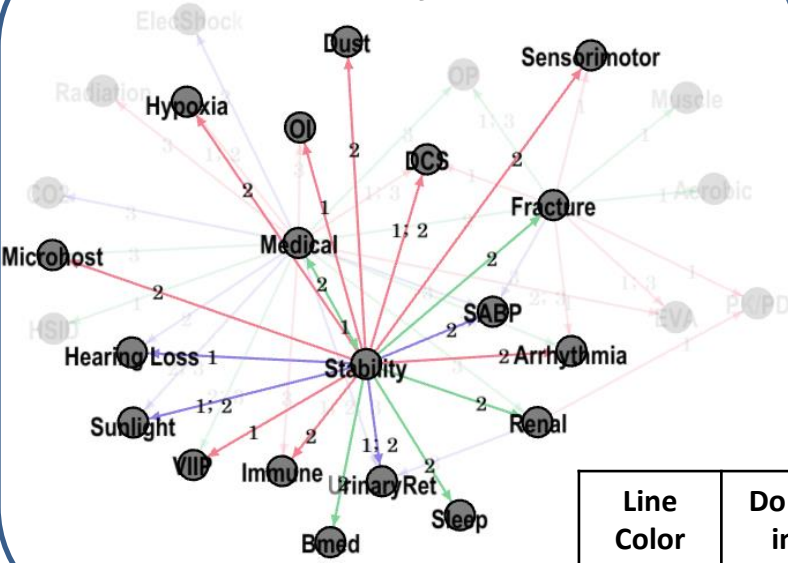
## Stability

# ExMC Element

## Renal

## Risks:

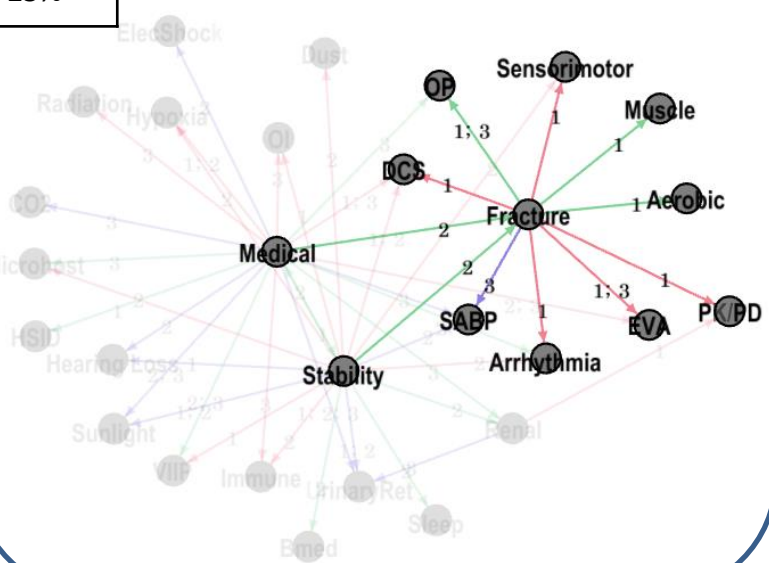
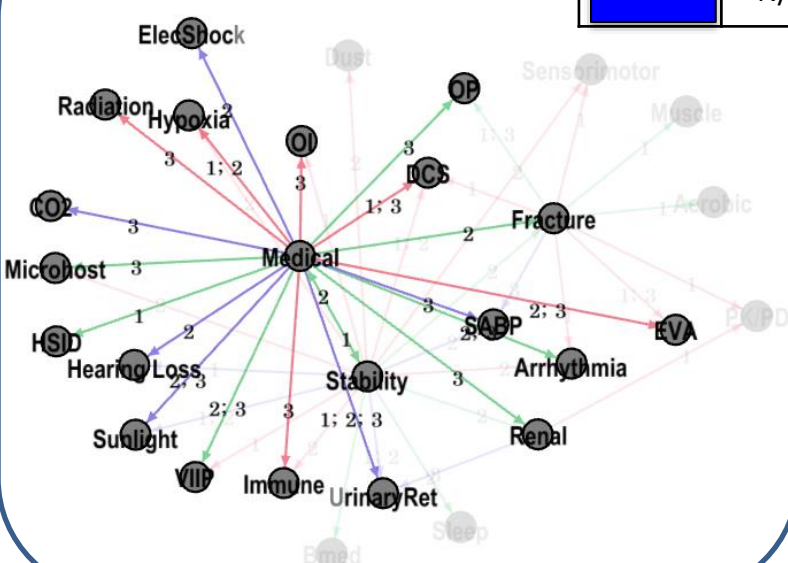
*Work taking place in a Risk at an arrow start influences the state of a Risk at the arrow head.*



Line Color	Do Risks Share Tasks in research plan?	% in Category
	No	44%
	Yes	31%
	N/A (not HRP Risks)	25%

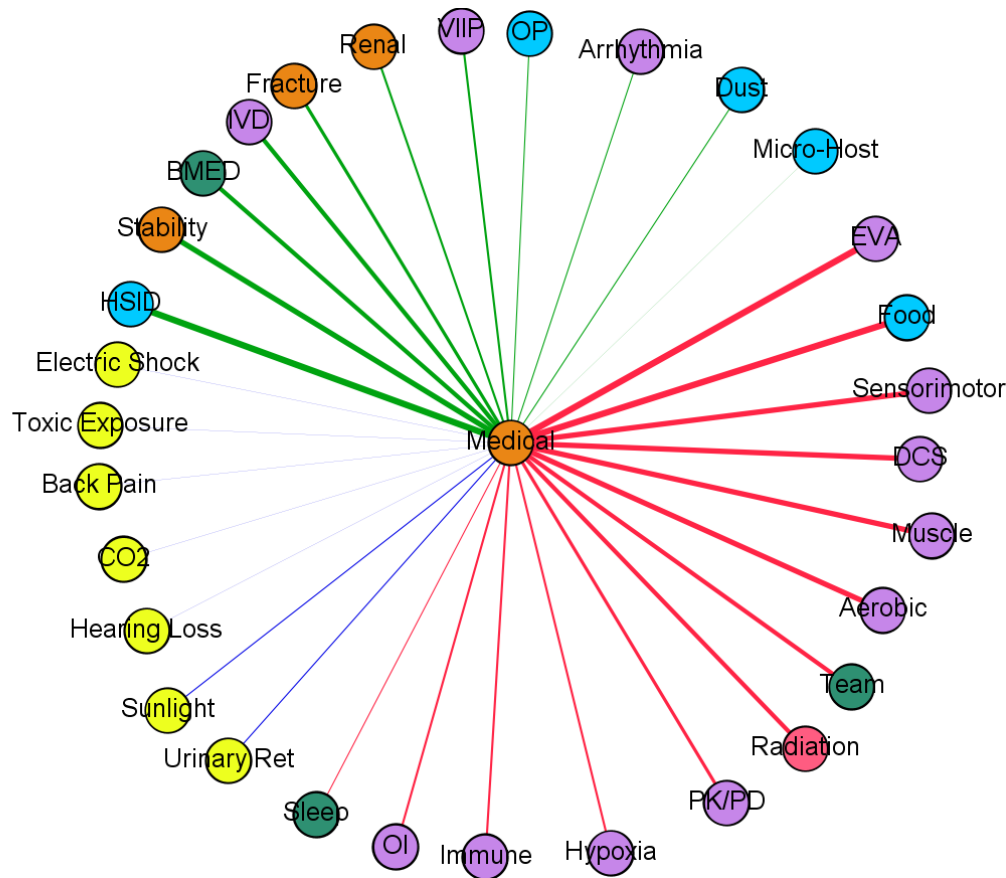
## Medical

## Fracture



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

# ExMC Risk Interfaces Based on Common Contributing Factors (Interface Type 4)



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

## Line Color

- No shared tasks
- Shared tasks
- N/A (not an HRP Risk)

## Node Color

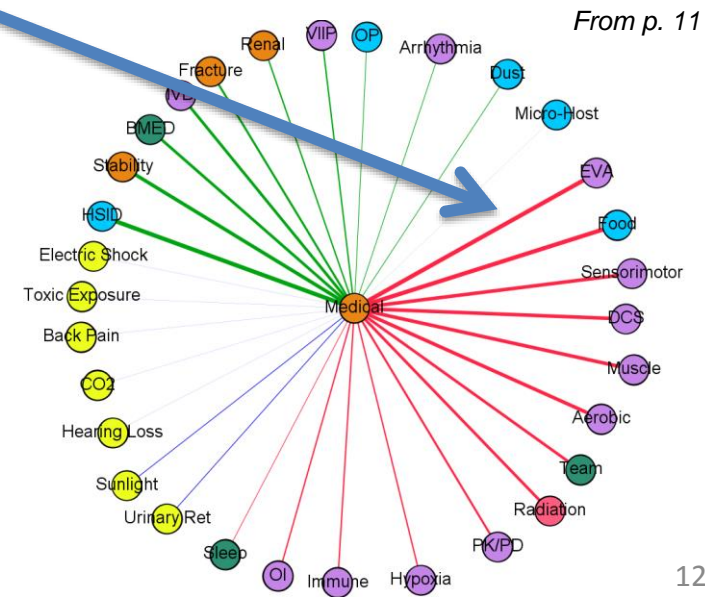
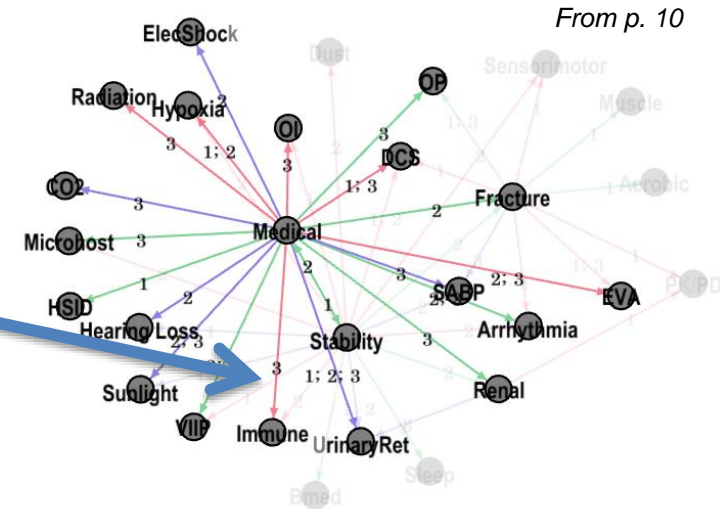
- HHC
- SHFH
- SR
- BHP
- ExMC
- N/A

- Different HRP Elements manage different Risks

- HHC = Human Health and Countermeasures
- SHFH = Space Human Factors and Habitability
- SR = Space Radiation
- BHP = Behavioral Health and Performance
- ExMC = Exploration Medical Capability

# Insights on Interfaces

- ExMC examples (red lines)
  - Many considerations with Human Health and Countermeasures (HHC) Element
  - 5 of 6 red lines connect to Risks managed by HHC
    - Immune, EVA, Decompression Sickness, Hypoxia, Orthostatic Intolerance
  - 9 of 13 red lines connect to HHC Risks
    - EVA shows most common contributing factors, e.g.,
      - Pre-existing Medical Condition
      - Nutritional Status
      - Radiation Exposure
      - Acceleration or Gravity
      - Destination Environment
      - Distance From Earth
      - Food System
      - Mission Scenarios



# Outcomes of this Exercise

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- HRP Management requested approach be applied to improve integration of research solicitation topic development
  - In past, HRP Elements developed topics independently without much coordination of research topic aims or descriptions
  - Tools described in this work were applied to generate cross-Element collaboration ideas for solicitation topics
  - Ideas discussed in open, collegial manner across Elements in HRP meetings
  - Additional cross-Risk and cross-Element coordination occurred
- Results
  - Improved formulation of solicitation topics and their content integration across Risks and Elements
  - Streamlining of overall group of topics, allowing for maximizing use of HRP resources

OMB Approval No. 2700-0087



National Aeronautics and Space Administration  
Johnson Space Center  
Human Exploration and Operations Mission Directorate  
Human Research Program  
Houston, TX 77058

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## Human Exploration Research Opportunities (HERO)

National Aeronautics and Space Administration

NASA Research Announcement

Catalog of Federal Domestic Assistance (CFDA) Number: 43.003

NNJ16ZSA001N

NRA Issued: July 28, 2016

### OVERVIEW

Proposals Due

Starting no earlier than September 6, 2016

Through no later than September 4, 2017

REFER TO APPENDICES FOR EXACT DUE DATES

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# Future Work

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- Continued application of global data set and network tools to identify integration ideas for research solicitation topic development
- Potential areas
  - Reduce assumptions – confirm term binning, scope definitions with discipline experts
  - Evaluate link status, for example:

No new action	New action
Shared Tasks in place, and adequate integration is in place	Shared Tasks in place, but additional integration is needed
Shared Tasks not in place, but adequate integration is in place	Shared Tasks not in place, and additional integration is needed

- Tracking progress of cross-Element integration
  - Expect line color changes and improved summary statistics over time



# Summary

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- Output of this exercise:
  - Used a taxonomy as a common framework across Risks
  - Applied information from HSRB Risk records and HRP research plans
  - Visualized connections for ease of analysis and communication
  - Identified linkages as a basis for discussion of whether further integration efforts are needed
  - Created an approach to track and communicate status of collaborations
- Demonstrated techniques to systematically identify, organize, and manage interfaces among Risks

