Human Health and Performance Architectural Drivers
Human System Risks

Radiation
- Non-Ionizing Radiation
- Ionizing Radiation
- Radiation Carcinogenesis – Bone Marrow
- Radiation Carcinogenesis – Brain

Isolation & Confinement
- Isolation
- Confinement
- Psychological Adaptation
- Behavioral Conditions
- Cognitive and Behavioral Conditions

Distance from Earth
- Radiation
- Isolation
- Confinement
- Distance Independent Operations
- Human Systems Architecture

Gravity Fields
- Bone Fracture
- Reduced Muscle Size
- Reduced Aerobic Capacity
- Cardiac Rhythm Problems
- Cardiovascular Adaptations
- Sensor/motor Alterations
- Renal Stone Formation
- Urinary Retention
- Orthostatic Intolerance
- Host/Microbial Interactions

Environments
- Reduced EVA Performance
- Decompression Sickness
- Hypoxia
- Carbon Dioxide Exposure
- Celestial Dust Exposure
- Toxic Exposure
- Electrical Shock
- Hearing Loss
- Injury from Dynamic Loads
- Altered Immune Response
- Sleep Loss
Human System Risks Cross Interaction

Radiation
- Non-Ionizing Radiation
  - Radiation Carcinogenesis – Long Mission
  - Radiation Cataractogenesis

Isolation & Confinement
- Radiation Risk Cross Interaction
- Excessive Risk Cross Interaction
- Inadequate Medical Conditions
- Radiological Adaptation within a Team
- Radiation Risk Cross Interaction
- Excessive Risk Cross Interaction
- Inadequate Medical Conditions
- Environmental Risk Cross Interaction
- Excessive Risk Cross Interaction
- Inadequate Medical Conditions

Distance from Earth
- Human Systems Architecture
  - Earth Independent Operations
  - Human Systems Architecture
  - Earth Independent Operations
- Inadequate Food and Nutrition
  - Cardiac Rhythm Problems
  - Cardiac Vascular Adaptation
  - Urinary Retention
  - Orthostatic Intolerance
- Space Micro-organism Interactions
  - Venous Thromboembolism
  - Inflamed Thrombosis

Gravity Fields
- Bone Fracture
  - Reduced Muscle Size
  - Reduced Aerobic Capacity
  - Reduced EVA Performance
  - Decompression Sickness

Environments
- Carbon Dioxide Exposure
  - Celestial Dust Exposure
  - Toxic Exposure
  - Radiation Risk Cross Interaction
  - Excessive Risk Cross Interaction
  - Inadequate Medical Conditions
  - Environmental Risk Cross Interaction
  - Excessive Risk Cross Interaction
  - Inadequate Medical Conditions

Cross Risk Interaction
Human System Risks and Mission Architecture

Medical/Health

- Integrated Autonomous Medical Systems (processing, data, storage etc.) will be required to prevent, assess and treat medical conditions (illness, injury & environmental exposure)
- Resources and capabilities will be required to ensure behavioral health and performance and effective team dynamics
- Food systems (of minimum mass and volume) will be required to provide proper nutrition for crews
- Proper hydration system will be required to ensure crew health
- Communications will be required for medical operations and behavioral health.
- The ability to train crews in flight will be needed to maintain crew competencies for operations and with comm delay
- Exercise hardware will be required to maintain crew bone, muscle, aerobic and behavioral health
Vehicle Design and Operations

- Adequate vehicle shielding and solar system monitoring will be required to prevent acute radiation sickness and to minimize long term health consequences
- Vehicle design needs to incorporate human system interaction design to minimize performance losses
- Private sleep quarters will be needed to provide space for sleeping, privacy and maintaining behavioral health
- Effective engineering design of systems is required to minimize acoustic levels to provide an adequate environment and minimize damage to crew hearing
- For launch, entry, descent and landing the proper dynamic loads will be required to minimize crew injury
- Automated entry, descent and landing will be required to compensate for the crew’s sensorimotor deficits during re-entry to partial gravity from microgravity
- Window design must minimize sunlight/UV exposure
ECLSS

- Environmental systems are needed to provide an appropriate atmosphere (O₂, CO₂ etc).
- ECLSS filtration systems will be required to prevent crew exposure to celestial dust.
- Microbial health effect must be minimized with vehicle design (materials, filtration, cleanliness etc.)
- Vehicle systems design must minimize toxic exposure to the crew.
- Automated monitoring, logging and warning systems are needed for the vehicle environmental (including acoustics, radiation etc.)
- ECLSS design will be required to provide the resources/capabilities to minimize/mitigate decompression sickness related to EVAs.
Human System Risks and Mission Architecture

EVA Suit Design

- Space Suit design must minimize crew injury and maximize crew performance
- Space suits must provide an appropriate atmosphere ($O_2$, $CO_2$ etc.) and environment (temperature)
- Space suits must provide the ability to provide hydration and nutrition for long duration EVAs
- Space Suit Design should minimize resources required to mitigate the occurrence of decompression sickness
- Proper lighting at South Pole - Lunar
Human Health and Performance: Keeping Astronauts Safe & Productive On a Mission to Mars

NASA has been sending humans to space for more than 50 years, continuously improving the conditions of spaceflight and making it possible for humans to live and work in space. As we prepare to return humans to the Moon and eventually to Mars, health and performance are key to the success of these missions. This paper will highlight the latest research and trends in human health and performance for missions to the Moon and beyond. The paper will cover topics such as spaceflight-induced physiological changes, sleep and circadian rhythm, exercise physiology, and psychological well-being. The paper will also discuss the importance of maintaining a healthy environment for astronauts to ensure their well-being and productivity. The paper concludes with a discussion of the future directions for research and development in human health and performance for future space missions.