Risk of Adverse Health Outcomes & Decrements in Performance due to In-Flight Medical Conditions

DAVID R. WILLIAMS  OC OOnt MSc MD CM FCFP FRCP LLD (HON) DSC (HON)

PRESIDENT & CHIEF EXECUTIVE OFFICER EXPLORATION INCORPORATED

CANADIAN ASTRONAUT (RET.) STS-90, STS-118 (3 EVAS), NEEMO 1, NEEMO 9 (CDR)
IN THE EXPLORATION OF SPACE WE DON’T TAKE CHANCES, WE MITIGATE RISKS TO A LEVEL AS LOW AS REASONABLY ACHIEVABLE.
Exploration Mission Operational Caveats

Fail Ops - Fail Safe Architecture
Balanced Mitigation Strategies for Engineering & Biomedical Risks
Operational Categorization of Mission Specific Risk & Mitigation Strategies
Definition of Standard of Care – Exploration Medicine
Task Based – Skills Based – Proficiency – JIT training
To Err is Human – Acceptance & Mitigation of Error
Acceptance of Uncertainty
Exploration Mission Operational Scenarios

Report reviews the constraints, associated risks & stressors for Exploration Missions including broad issues related to habitat design, communication, telemetry & evacuation capability.

- **RECOMMEND**: Determination of clinical approaches to optimize physiologic transition(s) to mission phase G.
- **RECOMMEND**: Evaluation of the potentially protective effect of sustained partial-G in return to & maintenance of optimum physiologic function. Lunar surface Category III and IV data may be available.
- **RECOMMEND**: Delineation of minimum planetary habitability capacity prior to human launch. Will there be redundant ACRV, redundant habitat, primary & backup inventory?
Exploration Mission Pharmaceutical Considerations

Report reviews the shelf life, impact of space radiation on preservation of pharmaceuticals, need for seamless technology to track medication use & inventory as well as personalized medicine.

- **RECOMMEND**: Development of resupply plan to create redundancy & mitigate risk of limited inventory. Lapsed inventory retained based on 3-year (min) shelf life provides additional supply.
- **RECOMMEND**: Development of protocols for use of controlled substances.
- **RECOMMEND**: Utilization of state-of-the-art technology to track inventory, medication use & incorporation into EMR.
- **RECOMMEND**: Review on board pharmacy & provide evidence based recommendations for micro-G, partial-G dosage.
- **RECOMMEND**: Evaluate redundant options for route(s) of administration of pharmaceuticals.
Exploration Mission Clinical Considerations


• **RECOMMEND**: Delineation of scope of micro-G & partial-G clinical procedures.
• **RECOMMEND**: Development of an atlas of micro-G & partial-G clinical procedures based on Shuttle/Mir/ISS clinical experience. CMOs & FS to be trained & demonstrate proficiency with clinical procedures in parabolic flight.
• **RECOMMEND**: Develop balanced first aid/medical training for non-CMO crew in micro-G & partial-G clinical procedures. 25% of current CMO training is in cardiac resuscitation.
• **RECOMMEND**: MOCOMP program for physician-astronauts similar to flight proficiency requirements for CDR/PLTs.
• **RECOMMEND**: Development of clinical “standing” protocols to manage minor/major trauma, ischemic & dysrhythmic cardiac emergencies, burns & common medical emergencies.
• **RECOMMEND**: Development of response to toxic exposures related to onboard systems including assessment of need for antidotes in medical kit.
Exploration Mission Clinical Considerations

- **RECOMMEND**: Development of local, regional block & general anesthetic capacity for micro-G & partial-G clinical procedures.
- **RECOMMEND**: Continue to develop personalized medicine protocols.
- **RECOMMEND**: Development of suite of countermeasure equipment amenable to volume/weight constraints of transit vehicle for transit duration > X.
- **RECOMMEND**: Development of computerized clinical knowledge systems and decision support tools appropriate for micro-G & partial-G phases of mission profile.
- **RECOMMEND**: Development of on-board EMR with capability for real-time integration of physiologic data from body area network (BAN) – worn, ingested, other sensors.
- **RECOMMEND**: Continued evaluation/development of POC diagnostic tools including imaging modalities.
- **RECOMMEND**: Continued analogue environment studies to evaluate novel medical technologies to support clinical care in space.
- **RECOMMEND**: Continued development of on board CME/SIM to maintain CMO JSK
Exploration Mission Spacewalk Risk Mitigation

Mission architecture suggests need for micro-G & partial-G spacewalks. Medical risks following lunar dust exposure described in report, other risks require mitigation strategies.

• RECOMMEND: Determination of clinical risk of overuse injury, DCS 2⁰ to pre-breathe, suit penetration, trauma.
• RECOMMEND: Determination of spacecraft, habitat & suit operating pressures to mitigate risk of DCS and optimize suited performance.
• RECOMMEND: Delineation of lessons learned from Apollo & POGO partial-G spacewalks for suit & tool design.
• RECOMMEND: Development of airlock capacity for managing suit dust contamination.
• RECOMMEND: Requirement definition & integration of real-time physiologic monitoring system with habitat telemetry for spacewalks.
• RECOMMEND: Develop approach to managing suited trauma.
Exploration Mission Gaps

Report summarizes 13 identified gaps for adverse health outcomes in BEO missions.

• **RECOMMEND**: Utilize ISS to conduct clinically focused DTO/DSOs to provide further evidence to mitigate medical risks of BEO missions.

• **RECOMMEND**: Develop decadal plan with associated resources to “close the gap” in knowledge/capacity to manage BEO mission medical conditions.

• **RECOMMEND**: Increase radiation shielding R&D for spacecraft & habitat, including R&D on active, passive and neutron dosimeters.
Human Health Risk Questions

1. How well is the risk understood? What, if any, are major sources of disagreement in the literature pertaining to the risk?
   • The nature of the health risks in a number of areas is reasonably well understood in micro-G. There is little data/discussion about the prevalence of similar risks and mitigation strategies in partial-G environments.

2. Does the evidence report provide sufficient evidence, as well as sufficient risk context, that the risk is of concern for long duration spaceflight?
   • The report provides an overview and evidence of a number of relevant risks for BEO missions but there are operational risks that have not been included that are of clinical relevance.
   • In the absence of a defined mission architecture it is more difficult to discuss risk context and mitigation strategies.

3. Does the evidence report provide evidence that the named gaps are the most critical presented?
   • Section VIII of the report addresses 13 gaps identified evidence-informed gaps in the report. The resolution of the existing gaps is not articulated nor is the desired end state/requirement clearly stated.
   • Portrayal of existing gaps on a risk matrix assessing probability of occurrence and mission impact would be helpful.
Human Health Risk Questions

4. Does the evidence report address relevant interactions among the risks?
   • The constellation of physiologic changes associated with the adaptation to space has been well described. There is an opportunity given the prolonged micro-G transit phase for BEO missions to Mars to understand how this affects the pathophysiology of disease. The report addresses renal stone formation, fractures and rehabilitation from the perspective of altered physiology yet there are many more clinical conditions where altered physiology may affect the pathophysiology of disease. Further understanding of the pathophysiology of illness and injury is warranted.

5. Is the breadth of the cited literature sufficient?
   • The cited literature in the report is broad and reflective of more recent Shuttle/ISS experience. There is a breadth of NASA technical material from Gemini, Apollo, Skylab and US MIR missions that is worthy of review in the context of mitigating health risks of BEO missions. The literature pertaining to critical care, surgery and anesthesia in space based on parabolic flight, Shuttle animal research and analogue environments could also be included.
THE DESIRE TO EXPLORE IS INHERENT IN HUMANS. WE HAVE THE CAPACITY TO BECOME A SPACE FARING SPECIES REACHING BEYOND EARTH ORBIT TO OTHER DESTINATIONS IN OUR SOLAR SYSTEM. WHAT WE STRUGGLE WITH IS THE IMPERATIVE.