



Exploration Medical Capability (ExMC) Science and Research Overview and Update

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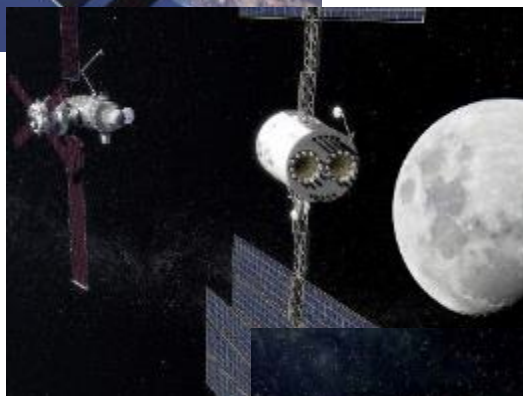
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“Expanding the Boundaries of Space Medicine and Technology”

Challenges to medical care during human space exploration



- Real Time Communications
- Evacuation Capability (1.5 – 36 hrs)
- 'Strong' Consumables Resupply
- Large internal volume



- Near Real Time Communications
- Evacuation Capability (**3-11 days**)
- **Limited** Consumables Resupply
- Significant mass and volume constraints



- **No** Real Time Communications
- **No** Evacuation Capability
- **No** Consumables Resupply
- Very small spacecraft



Increasing exposure to Hazards



Advance **medical system design** and **risk-informed decision-making** for exploration beyond low Earth orbit to promote human health and performance in space

Altered Gravity Field

1. Spaceflight-Associated Neuro-ocular Syndrome (SANS)
2. Renal Stone Formation
3. Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
4. Bone Fracture due to spaceflight Induced changes to bone
5. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
6. Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
7. Adverse Health Effects Due to Host-Microorganism Interactions
8. Urinary Retention
9. Orthostatic Intolerance During Re-Exposure to Gravity

Concerns

1. Concern of Clinically Relevant Unpredicted Effects of Medication
2. Concern of Intervertebral Disc Damage upon and immediately after re-exposure to Gravity

Radiation

1. Risk of Space Radiation Exposure on Human Health:
 - Acute solar events
 - Cancer
 - CNS impairment
 - Tissue degeneration (cardio)

Distance from Earth

1. Adverse Health Outcomes & Decrements in Performance due to inflight Medical Conditions
2. Ineffective or Toxic Medications due to Long Term Storage

Isolation/Confinement

1. Adverse Cognitive or Behavioral Conditions & Psychiatric Disorders
2. Performance & Behavioral health Decrements Due to Inadequate Cooperation, Coordination, Communication, & Psychosocial Adaptation within a Team

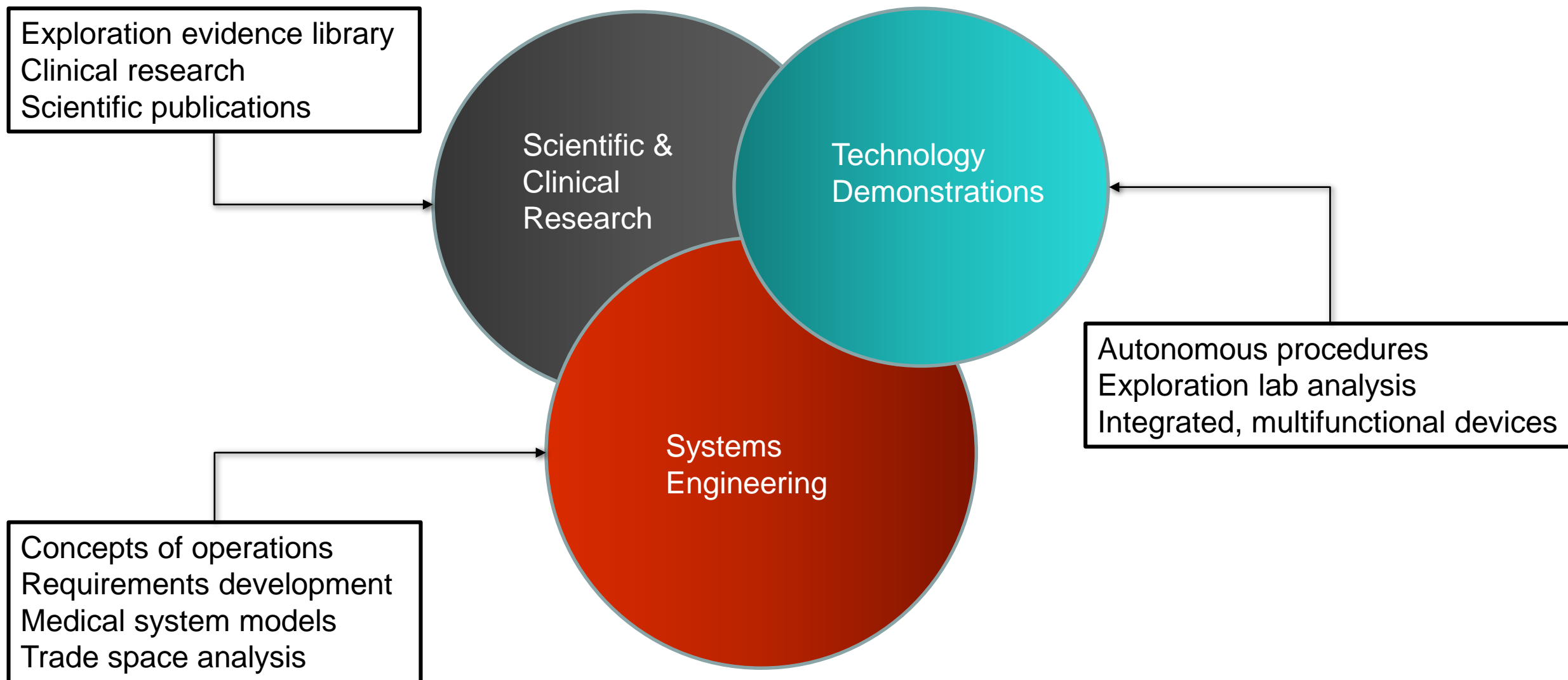
Hostile Closed Environment

1. Acute and Chronic Carbon Dioxide Exposure
2. Performance decrement and crew illness due to inadequate food and nutrition
3. Injury from Dynamic Loads
4. Injury and Compromised Performance due to EVA Operations
5. Adverse Health & Performance Effects of Celestial Dust Exposure
6. Adverse Health Event Due to Altered Immune Response
7. Reduced Crew Performance Due to Hypobaric Hypoxia
8. Performance Decrements & Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, & Work Overload
9. Reduced Crew Performance Due to Inadequate Human-System Interaction Design
10. Decompression Sickness
11. Toxic Exposure
12. Hearing Loss Related to Spaceflight

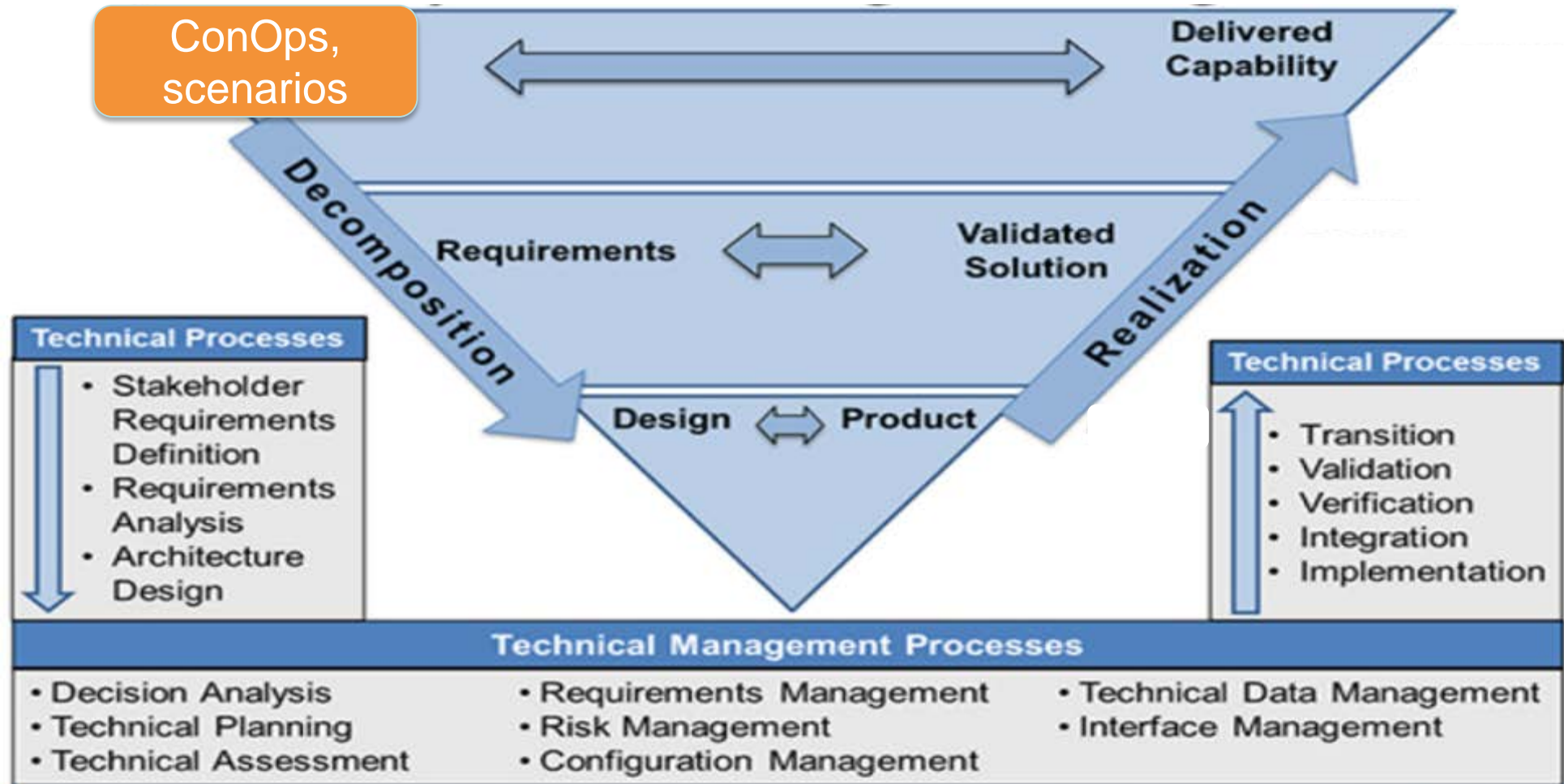
Key: High LxC Medium LxC Low LxC TBD LxC

Likelihood and Consequence (LxC) linked to potential NASA Mars mission

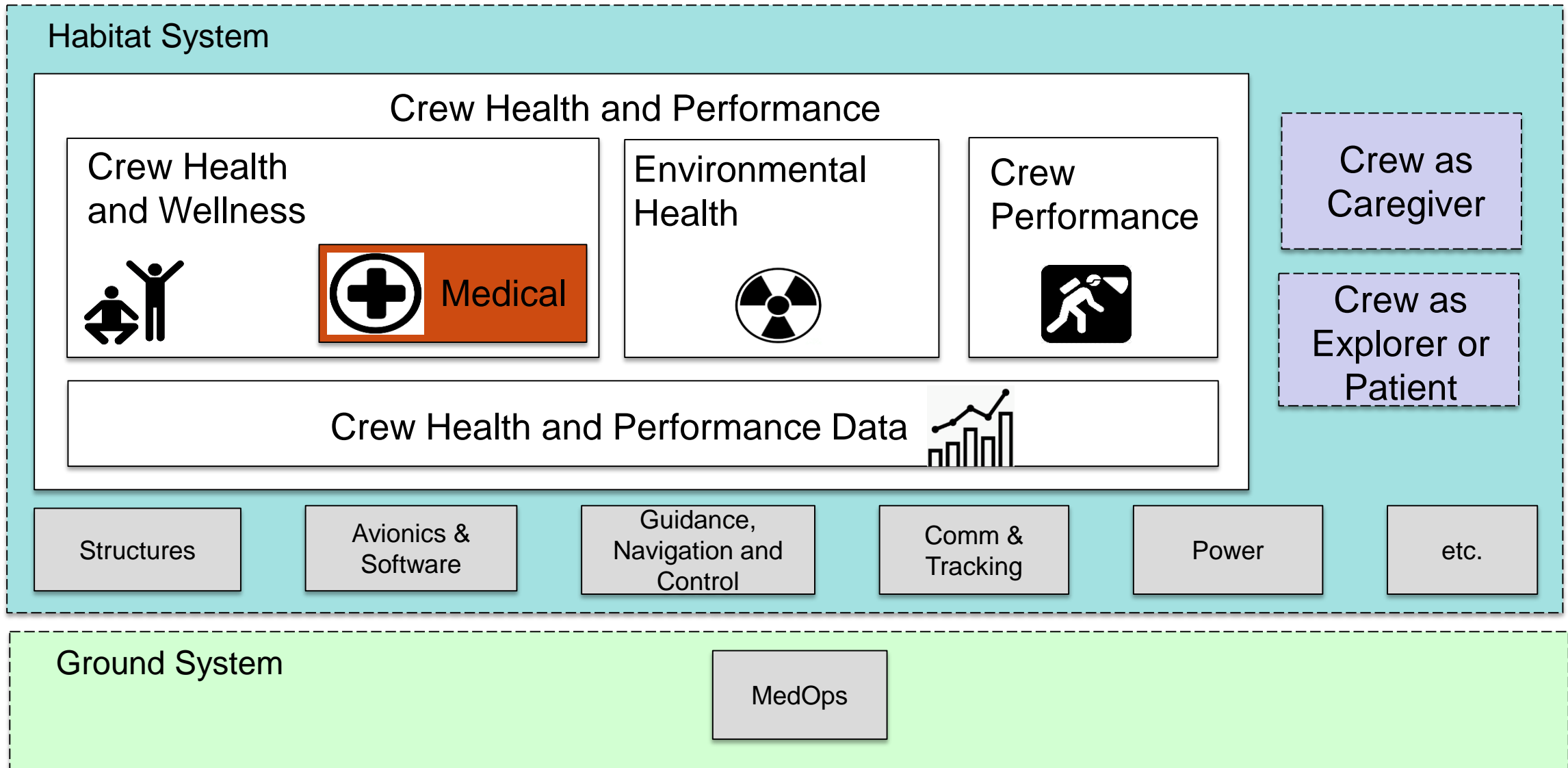
ExMC's Areas of Focus



Translate medicine into engineering to enable medicine



Integrating medical into a broader crew health and performance system



What is a “trade space analysis”?



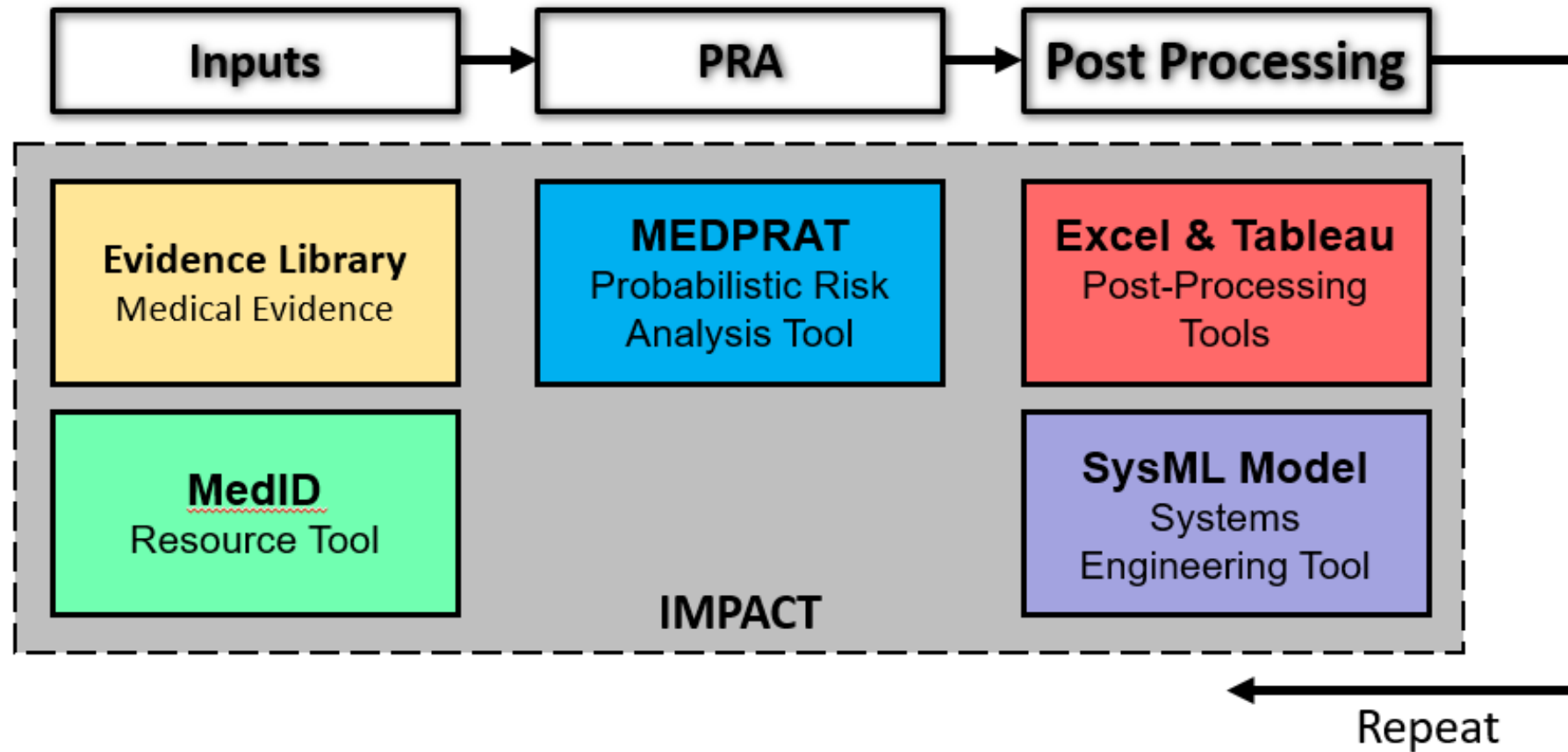
ExMC's Need:

Provide a data-driven means to inform human health and performance risk mitigation for resource-constrained exploration missions

- What if spacewalks are added to the mission parameters?
- What if the mission were extended?
- What if mass allocation lowers by 25%?
- Which imaging technology is most useful?
Ultrasound or X-ray?
- What is the medical risk of reducing crew's water rations from 3L to 2L daily?

- Rigorous exercise to identify the most *acceptable* solution amongst a set of alternative solutions
- Enables a traceable and repeatable process
- Evaluations will assess metrics for:
 - Risk: Probabilities of loss of crew and loss of mission
 - Resource characterizations: mass, power, volume, etc.

IMPACT – trade space analysis tool suite



Key ExMC 2019 Accomplishments



Pharmacy Stability Technical Interchange Meeting

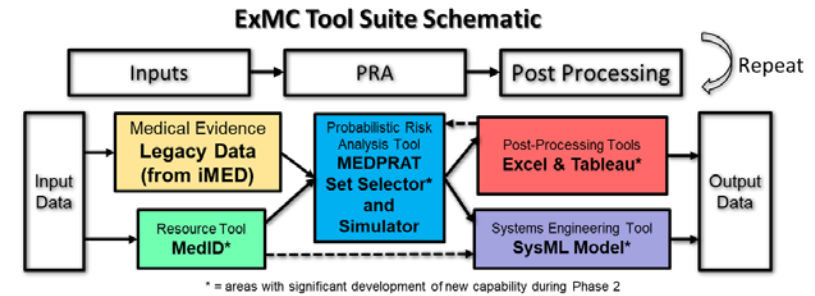
ExMC held a Pharmacy Stability TIM in June 2019. The TIM:

- Uncovered a gap about potential impact of CO2
- Recommended prioritization scheme for medication study
- Kick started a collaboration with the FDA for stability data
- Created a path to a stability flight study



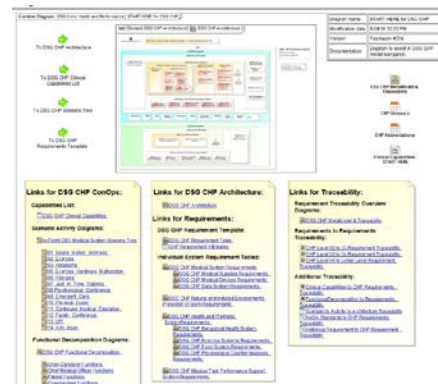
Trade Study Evaluation Tool Suite (TSETS)

- Completed all pilot studies
- Further integration of individual tools that make up the tool suite
- Developed post-processing tools to improve visualization
- Demonstrated the ability to perform medical system trades
- TSETS will now become IMPACT, adding additional capability



Cis-lunar Medical System Requirements

ExMC delivered medical system functional requirements recommendations that can be applied to future Gateway vehicles/missions.



MDA Participation in NASA Gateway Habitat Evaluations

ExMC Medical Data Architecture team successfully deployed MDA software in the Gateway Habitat Test Environment in support of engineering and crewed assessments of prototype habitats which were developed by multiple commercial companies. The integration of the medical data system into the habitat network helps NASA evaluate habitat prototypes through system tests which map to relevant mission scenarios and test objectives.



Selected ExMC current efforts



- Continuing to use systems engineering principles and models to develop crew health and performance (includes medical system) functional requirements to enable full vehicle and mission integration, especially for Mars missions
- Initial assessment of potential clinical decision support tools for inclusion in the Medical Data Architecture (MDA)
- Refining the trade space analysis tools suite (IMPACT) that will allow for evidence-based, risk-informed decision making (with respect to human health and performance) when participating in the engineering system design process of new space vehicles and missions
- Complete assessment of potential medications to include in an exploration formulary using previously published information and new access to FDA data
- Technology demonstrations of medical capabilities that have the potential for inclusion in future exploration medical systems (blood analysis devices, autonomous ultrasound procedures, integrated multifunctional devices)
- Expanding and updated the evidence library that will be used by the next generation medical probabilistic risk analysis tool (MEDPRAT) and IMPACT



- **Exploration pharmacy:**
 - Designing and executing a flight study to assess pharmaceutical stability of selected high-yield exploration medications
 - Development of the Element strategy to evaluate the role of pharmacokinetics and pharmacodynamics in medication effectiveness during long-duration, long-distance spaceflight
- **Clinical decision support tools to be used by astronauts autonomously:**
 - Determination of medical treatment/management plans
 - Automated image/data analysis
 - Differential diagnosis generation
- **Deep space exploration medical system model:**
 - Refine Concept of Operations for medical care during Mars missions
 - Develop evidence-based functional requirements and incorporate into system model
 - Incorporate new medical technologies and capabilities into system model for trade space analysis

Questions?



Credit: Phil Smith

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