Human Research Program

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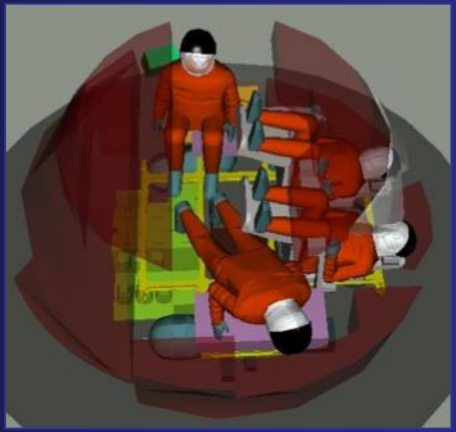
Human Research Program

- The Human Research Program (HRP) focuses on applied research
- Program goals
  - Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
  - Enable development of human spaceflight medical and human performance standards
  - Develop and validate technologies that serve to characterize and reduce medical risks associated with human spaceflight



An Applied Research Program

Characteristics of HRP

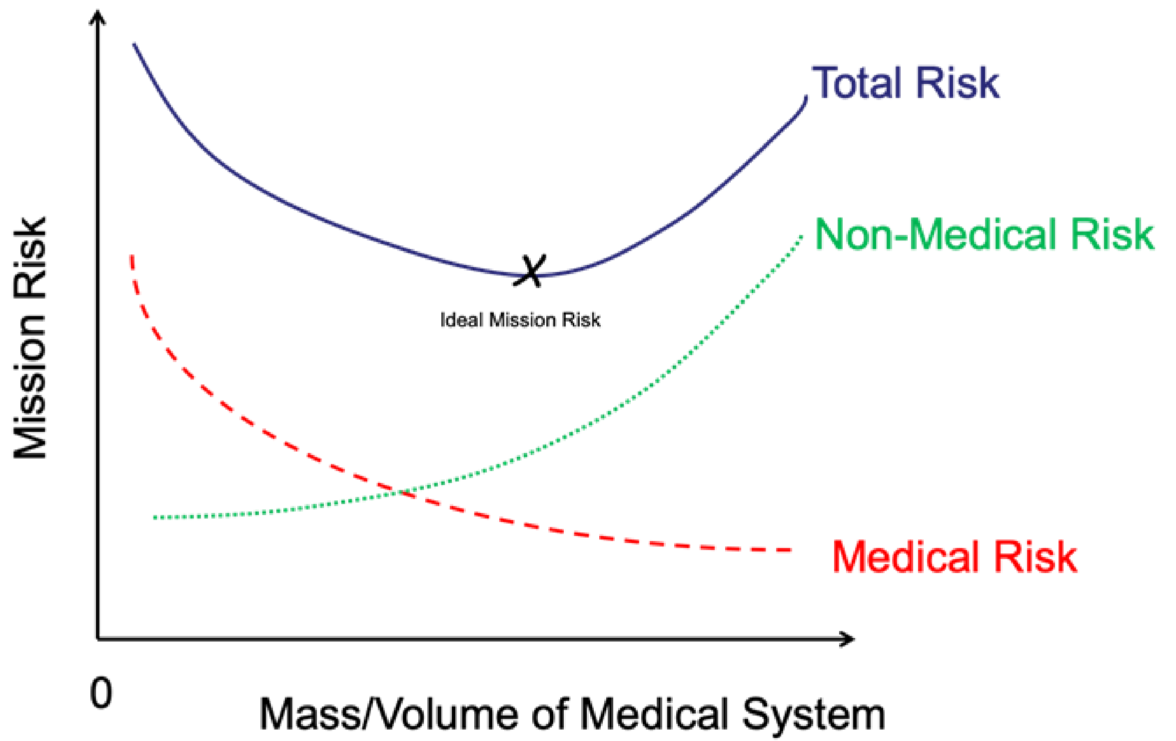
- Composed of five Elements
  - Exploration Medical Capability
    - *Medical care for deep-space missions*
  - Human Factors and Behavioral Performance
    - *Interfaces between humans, vehicles & habitats*
    - *Individual and interpersonal*
  - Human Health Countermeasures
    - *Physiology*
  - ISS Medical Projects
    - *Infrastructure for flight and analog experiments*
  - Space Radiation
    - *Biological effects of radiation exposure*
- Funds Translational Research Institute (TRI) through cooperative agreement to pursue research that complements HRP portfolio

- Collaborates with NASA Space Biology to understand causal cellular and other mechanisms that underlie adaptation to fractional gravity levels in cells, microorganisms, plants, and animals

Goals of the ExMC medical models

- **Inform Research Priorities**
  - The tool suite will help to quantify the risk buy-down of proposed research, allowing HRP to prioritize funding.
    - Example: What would be the added benefit for exploration spaceflight of an x-ray capability and how does this relate to its resource (mass, power, volume) footprint?
    - Evaluations will assess metrics for:
      - Risk: Probabilities of loss of crew and loss of mission
      - Resource characterizations: mass, power, volume, technology readiness level, vehicle integration needs (refrigeration, humidity control, vacuum), trash production, radiation emittance, etc.
      - Requirement satisfaction
  - Informing research priorities will support decision regarding the funding of research, thereby improving future human health and performance capabilities and systems:
    - Reduce footprint of large items
    - Development of newer medical technologies
    - Alternatives to current medical interventions
    - Improving medical evidence base

Medical vs. non-medical risks to a mission



(Values are notional)

Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)

- MEDPRAT is the math model and the math model only

- Dynamic probabilistic risk assessment tool
  - Incorporates chance, probabilities, and event dependencies
  - Incorporates deterministic elements including sub-models, monitoring and control logic, and operating procedures

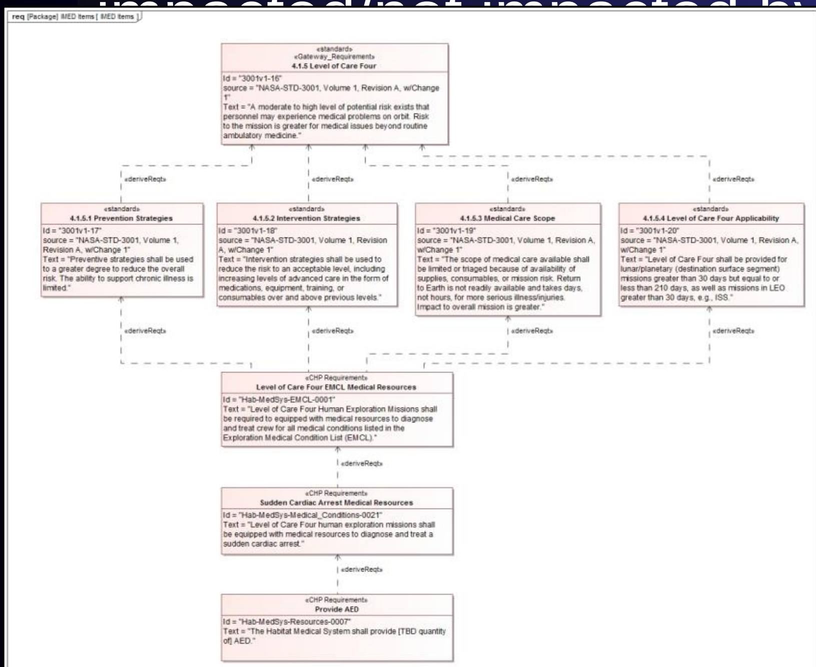
- Supports risk based medical system design by enabling the evaluation of new and existing technologies, procedures, research insights, and mission plans

- Runs Monte Carlo simulations to determine what conditions occur, how frequently, what resources are used to treat those conditions, what the outcomes are, and all associated risk metrics

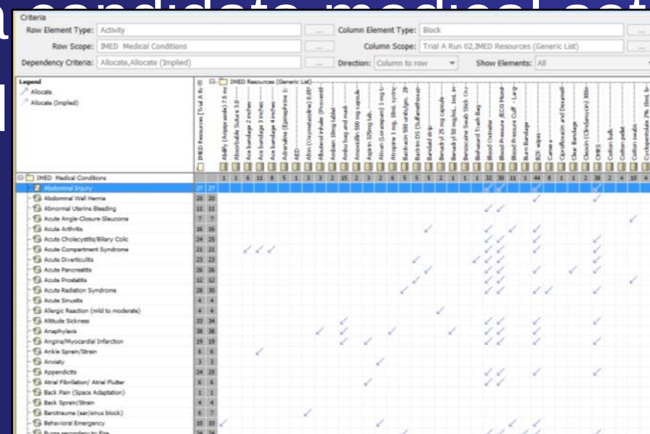
- Determines candidate feasible medical sets that are within target constraints

SysML Model

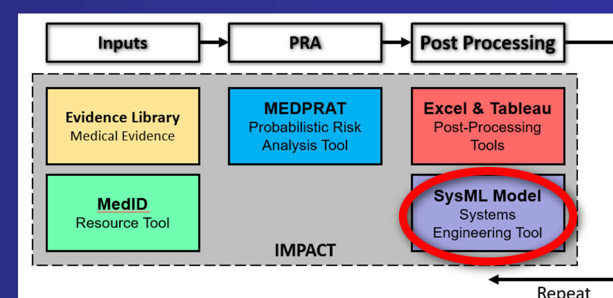
- Houses the medical system requirements and conditions
- Evaluates whether a candidate medical set has met/not met system requirements
- Evaluates whether ability to address conditions has been ... a
- ... util ... e model



Requirements Tracing

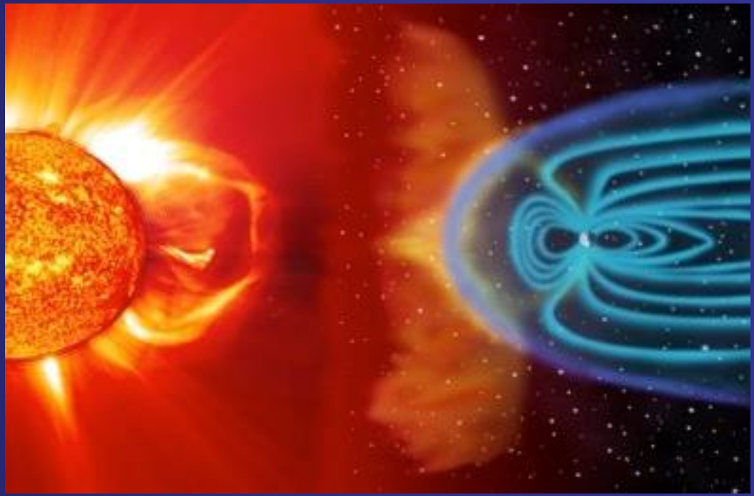


Condition Dependencies



Space Radiation Protection

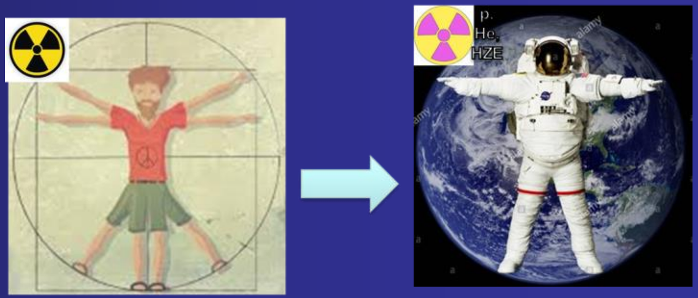
- Radiation in deep space consists of episodic SPE and omni-present GCR
- Current strategy is to
  - build storm shelters to shield from SPE
  - Limit overall exposure by limiting time in space
- Permissible exposure limits limit time is space such that total exposure doesn’t exceed a 3% excess risk of cancer
- The risk is determined using computational models build on a combination of human and animal radiobiology data as well as radiation physics models



Eruption from sun being partially deflected by earths magnetic field

Space Radiation Risk Mitigation

- In order to extend time in space and improve safety HRP has experimental and modeling efforts to extend and improve risk models
  - Include CVD and CNS risks and other spaceflight stressors
  - Personalize risks for individual based estimates
- Improved risk models will allow for an integrated medical management approach that includes spaceflight stressors and ordinary medical risks
- Models can also help prioritize and evaluate new potential medical countermeasures



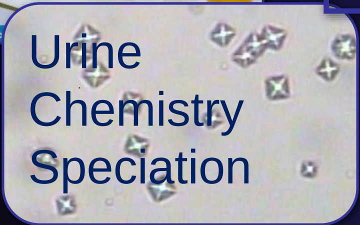
TERRESTRIAL EXPOSURES

EXTRA-TERRESTRIAL EXPOSURES

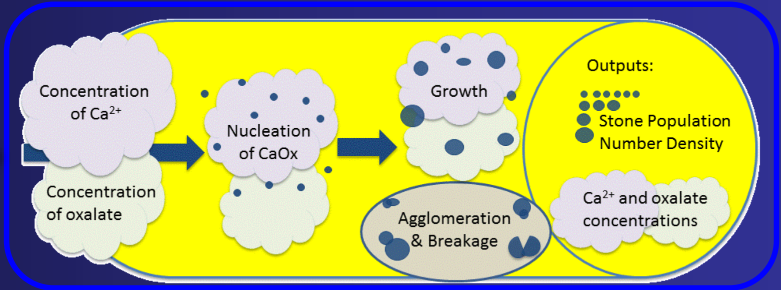
National Aeronautics and Space Administration

Prediction of Relative Renal Stone Risk for Astronauts Using Population Balance Equation (PBE) Model

Human Research Program

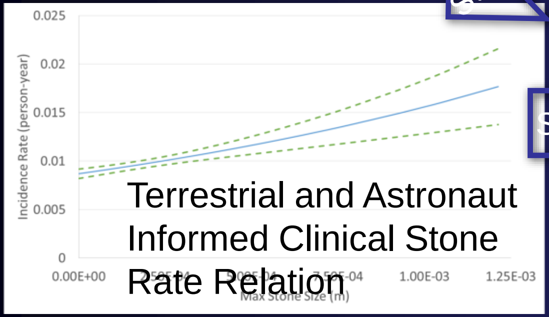


Population Data

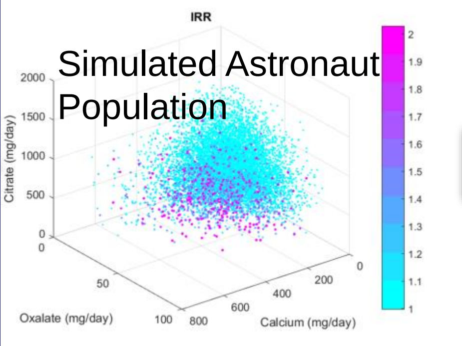


Kassemi, M., and Thompson, D., ***Am J. Physiol. Renal Physiol.***, 311 (3) Part 1 - F520-F530; Part 2 - F531-F538; (2016)

Stone Size Metric

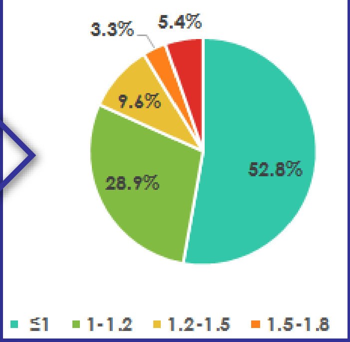


Stochastic Sim



Incidence Risk Ratio (IRR) – Calculated incidence rate / average calculated preflight incidence rate

Analysis



Relative Risk Statistics

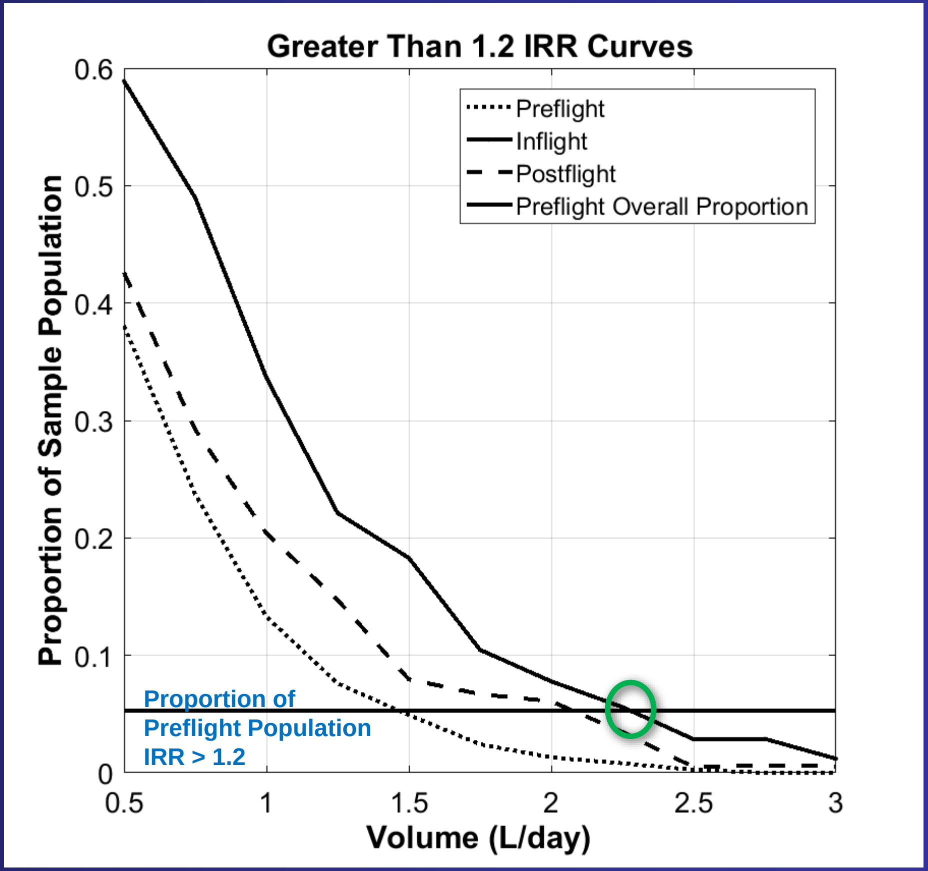
Example Estimate Change in Allowable Water to Maintain Risk Level

Approach to quantify risk of reducing water intake

- Assume
  - Change in intake is proportional to the change in output with +/- 0.125 L/day uncertainty
  - Output range from 0.5 to 3 L/day
  - Clinicians desire to keep 95% of the Astronauts with an IRR < 1.2

- Use Model to generate representation of Proportion of population IRR > 1.2

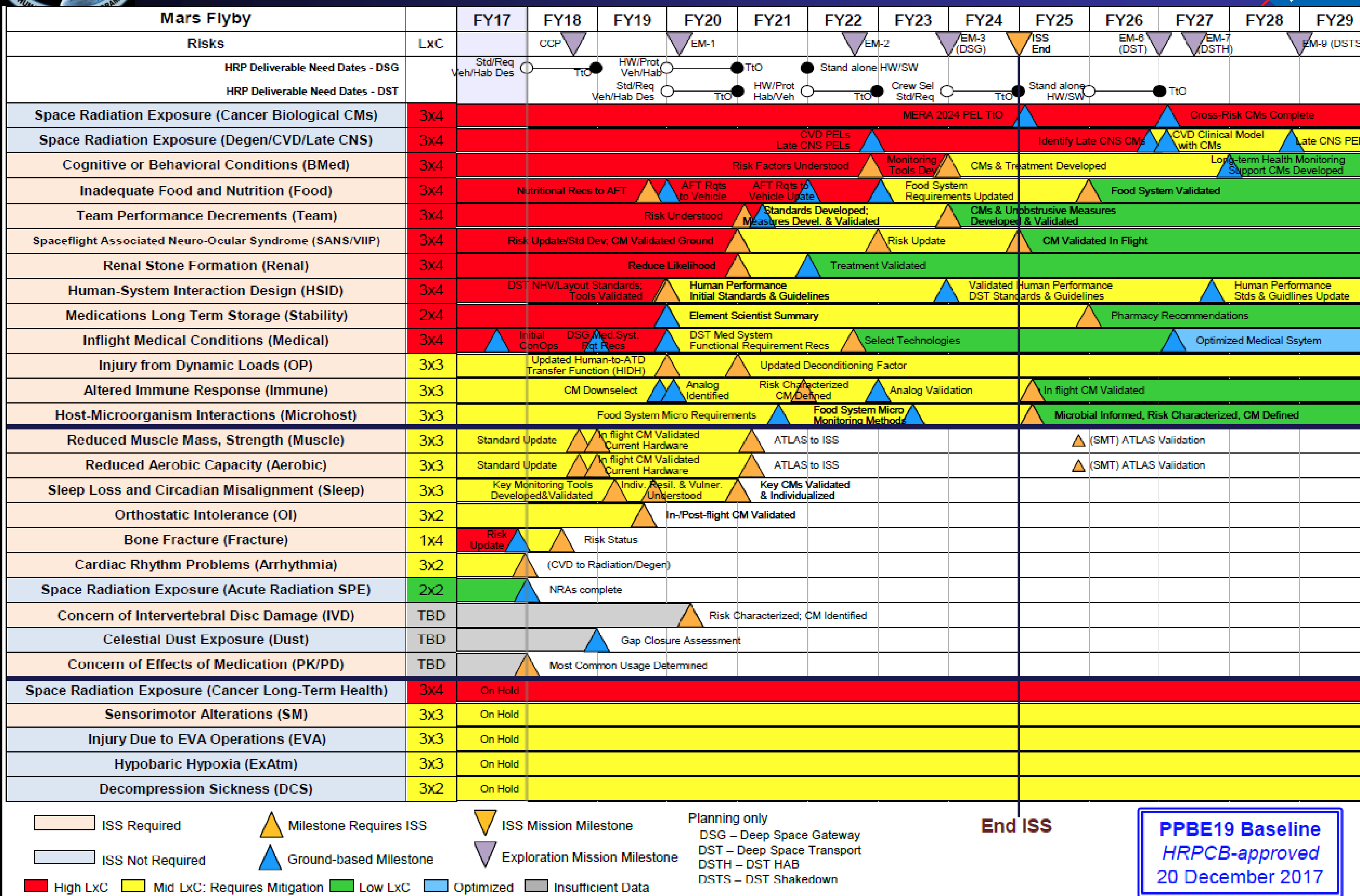
- Example: For a nominal 2.0 L output, a reduction in intake by 0.5 L results in
  - 2.4x the proportion of the represented population would be in the >1.2 IRR sub-population



Back Up Slides

National Aeronautics and Space Administration

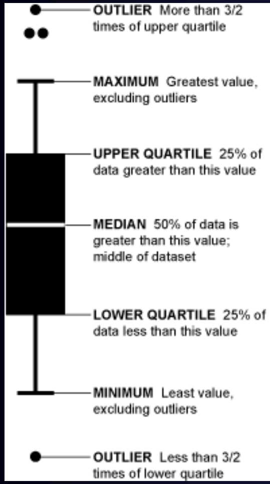
HRP Integrated Path to Risk Reduction

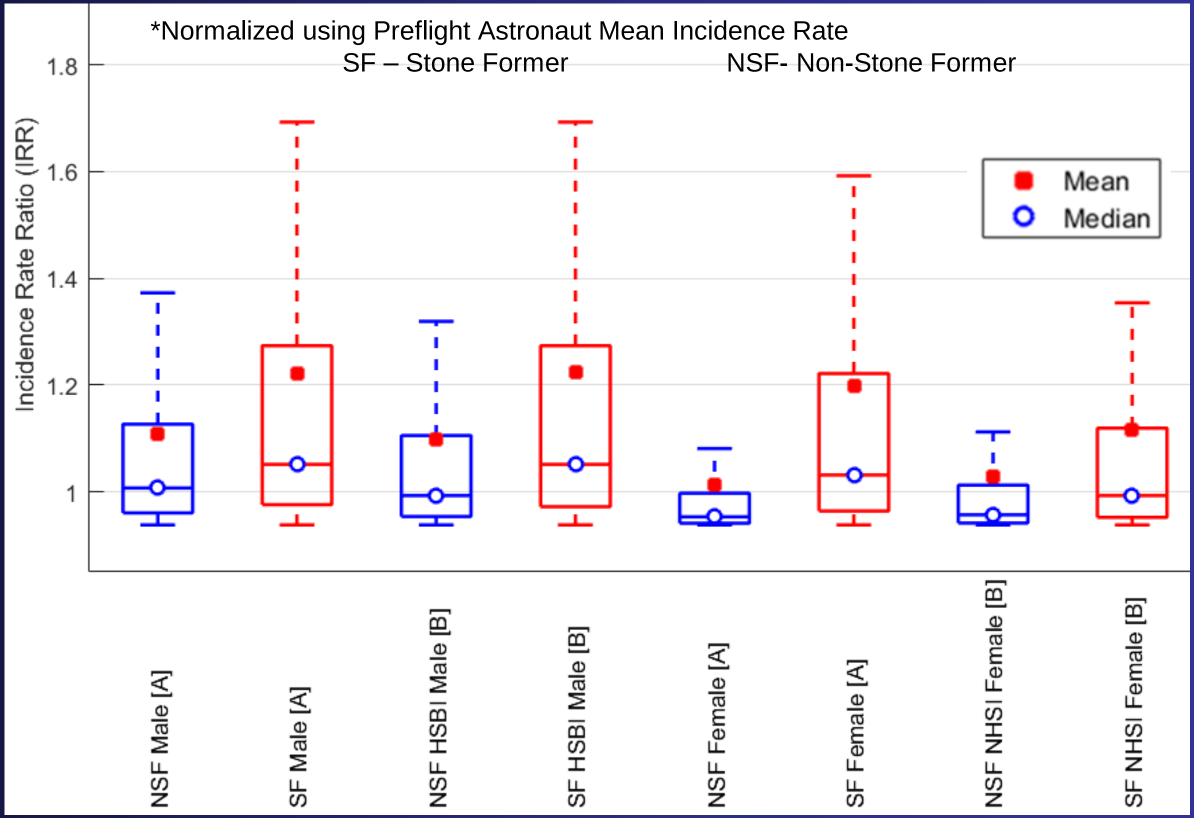


Relative Risk - Terrestrial Prediction Comparison

[A] Stone Formers, Primarily CaOX stones, Sex Specific Parks and Coe (1986)

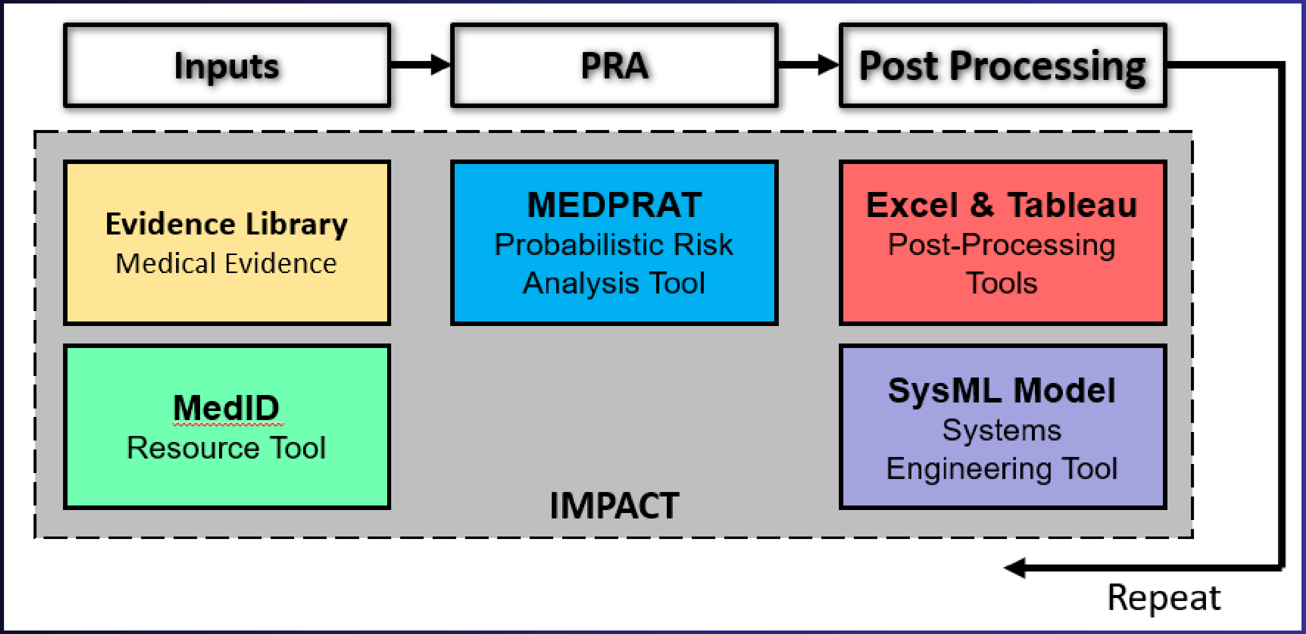
[B] Primarily Incident stones, All Stone Types, Sex Specific Curhan et al. (2001)





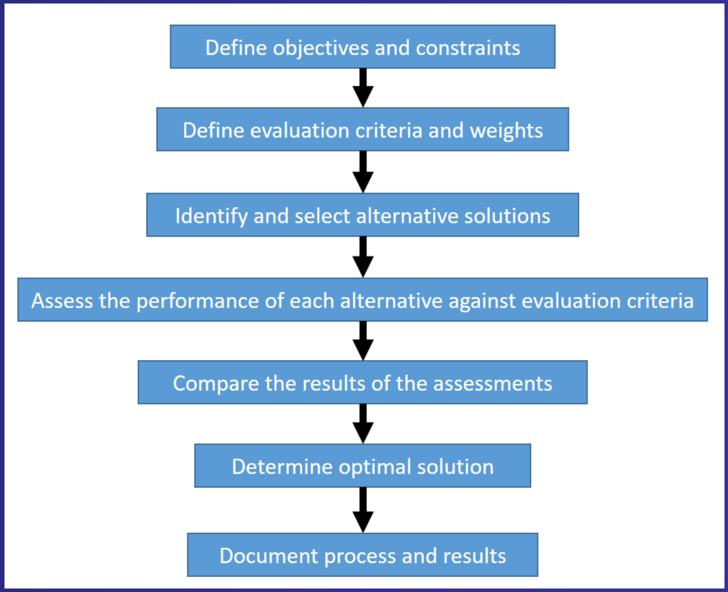
Overview of IMPACT

The tool suite pilot project phase II is the second iteration of implementing the tool suite functions using a set of decision-support tools developed across multiple NASA centers that facilitate trade space analyses for a medical capability based on evidence, risks, and systems engineering principles.



Goals of the tool suite

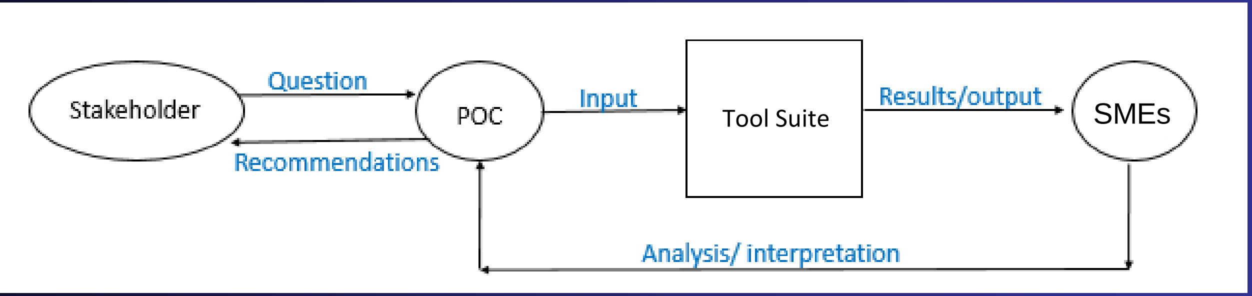
- **Enable systematic trade space evaluations**
  - System designers will make recommendations to mission decision makers.
    - Evaluations will assess metrics for:
      - Risk: Probabilities of loss of crew and loss of mission
      - Resource characterizations: mass, power, volume
      - Requirement satisfaction
    - These recommendations will support decisions regarding the scope and implementation of future human health and performance capabilities and systems
  - What is a trade space?
    - Decision-making activity used to identify the most acceptable solution amongst a set of proposed solutions
    - Effective means for addressing risks by documenting decision-making process to enable traceability and repeatability
    - The traditional steps in a trade space process are shown at right



Purpose of the tool suite

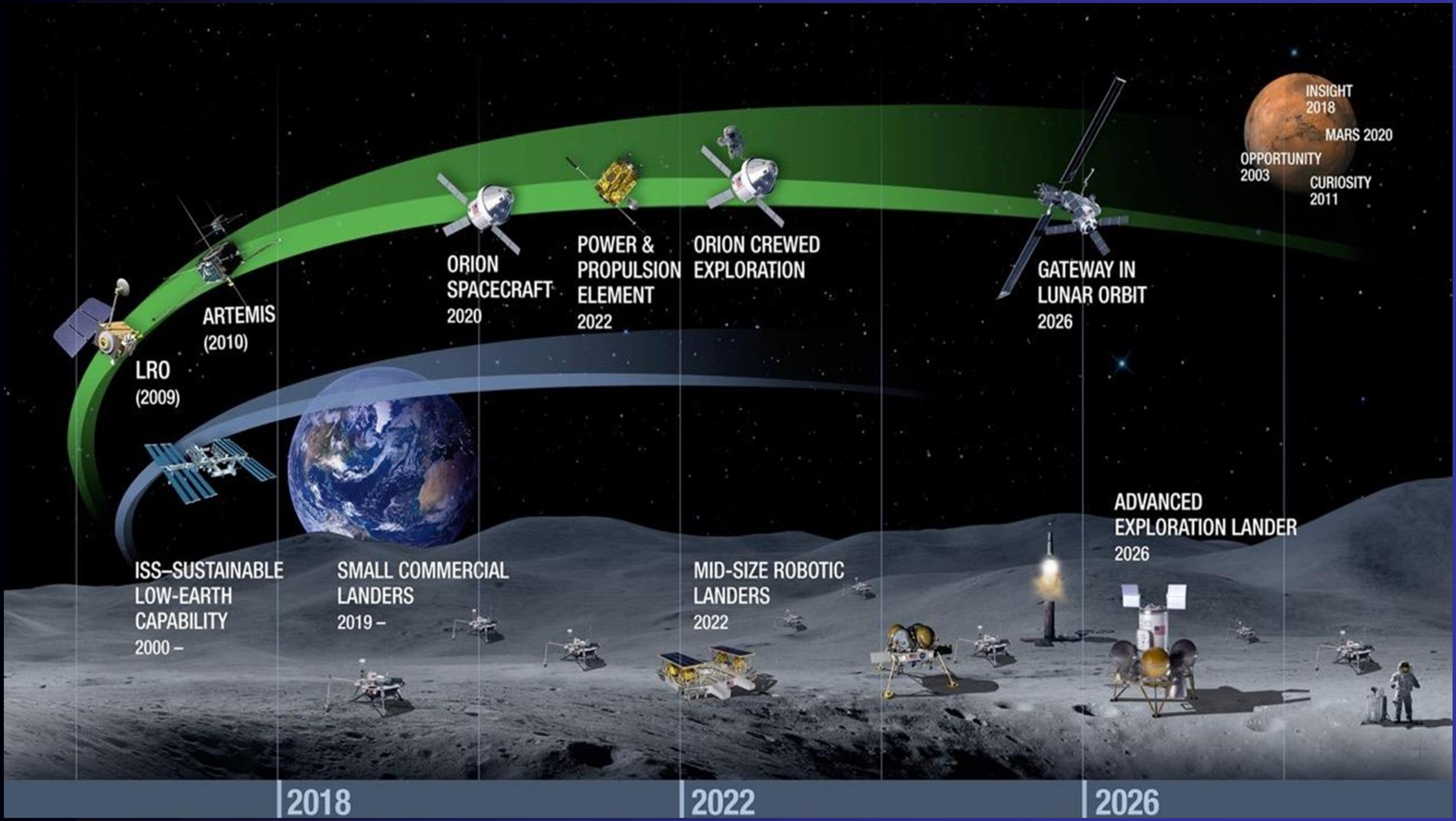
ExMC's Need:

Provide a data-driven means to inform human health and performance risk mitigation interests during resource-constrained exploration mission development.



- Does 1 kg of meds or water or an AED best reduce medical risk?
- What is the benefit of changing crew's water rations from 2 to 3L daily on medical risk?
- If I could reduce the mass or volume of hardware X by 50%, would it be sufficient to manifest?

Planned Exploration Activities



Why do we need a tool suite?

- Stakeholders can determine the effects of:
  - Modifying input parameters and activities on crew health risks
    - What if EVAs were added to the mission parameters?
    - What if the mission were extended?
  - Raising/lowering mass or volume allocations on crew health risks
    - What if mass allocation lowers by 25%?
  - Technology developments on crew health risks
    - What if we funded ultrasound development instead of X-ray development?

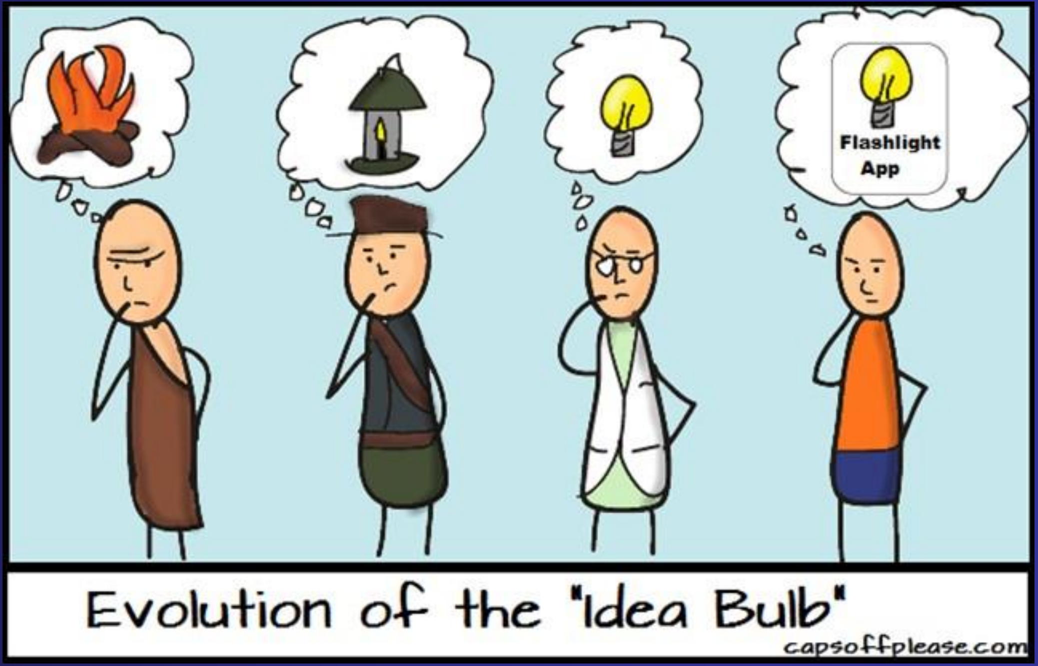
We cannot take everything we might need for a medical system due to mass, volume, and power constraints!

We cannot research the development of every technology that we would like due to time and funding constraints!

Optimization and Research Prioritization are necessary!

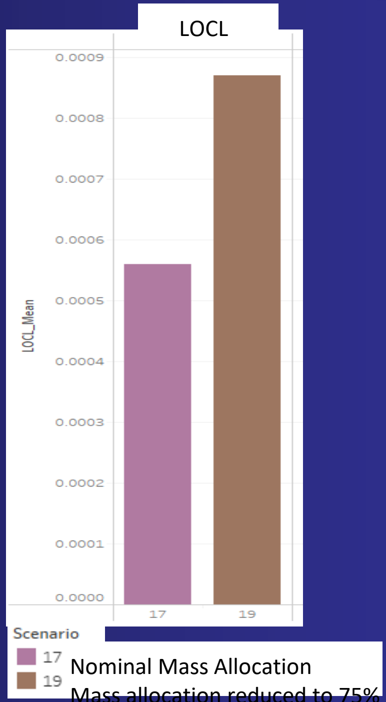
MEDPRAT PRA Advances

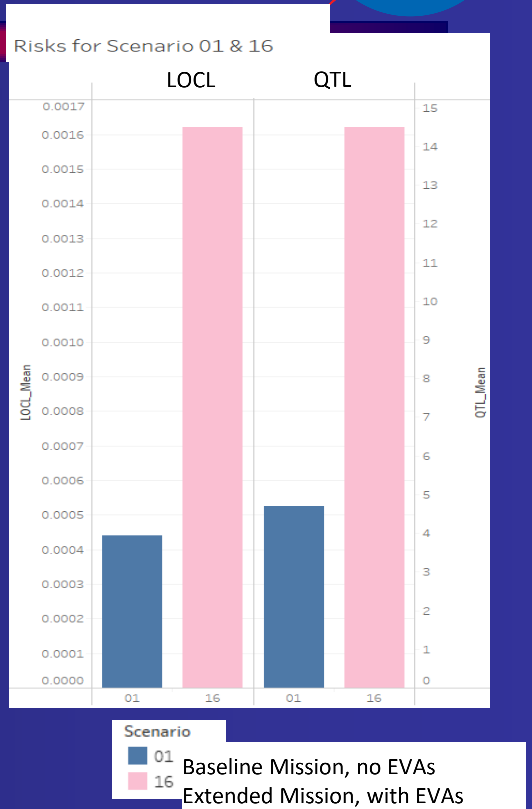
- Integrated Medical Model (IMM)
  - Early successful application of a mission medical PRA
  - Remains a current standard for assessing medical risk
- Advantages of MEDPRAT
  - Works orders of magnitude more quickly than IMM
  - Accounts for linkage of medical conditions to

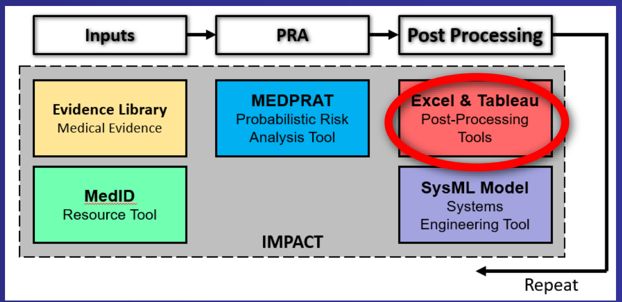


Significance of IMPACT

- Stakeholders can determine the effect of modifying the input parameters and activities on crew health and performance risks using the tools
- Stakeholders can determine the effect of changing constraints on mitigating/exacerbating crew health risks
- Analyses can be performed with weighted combinations of cost factors (mass, volume) and risk factors (LOCL,QTL, RTDC) to emphasize relative weights or importance
- The resulting benefit (risk reduction) from reducing the footprint of heavy medical equipment through technology development can be quantified, given good input data
- By changing optimization parameters, a user can optimize a run to meet a challenging set of cost targets and acceptable risk thresholds simultaneously







Assumptions, Limitations and Applications

Assumptions and Limitations

- Only consider CaOx Stones, 70%+ of all total possible stone risk in general population.
- All urine constituents sampled as independent, may miss some correlative dependencies.
- Influence of the 1-year post flight urine samples tends regression curve toward post flight rates.
- IR prediction capped at the extent of the Poisson Regression, some values may be higher.
- Single, integrative value assessment may not represent more subtle contributions.

Medical PRA Application

- Provide an informed update to prior estimates of renal stone incidence rate assumptions
- Adjust the incidence rate through the mission
- Assess the impact of in mission changes to water or dietary countermeasures
- Potential exists to approach an individualized renal stone incidence rate risk analysis