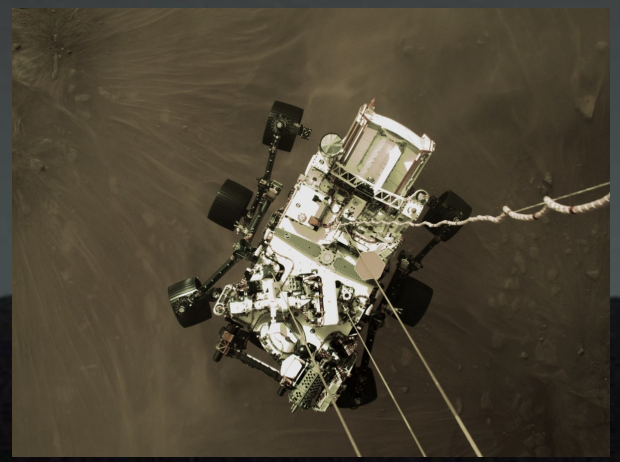


A MODEL BASED APPROACH TO ESTIMATING HUMAN SPACEFLIGHT MEDICAL RISK

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COSPAR 2022
07/22/2022

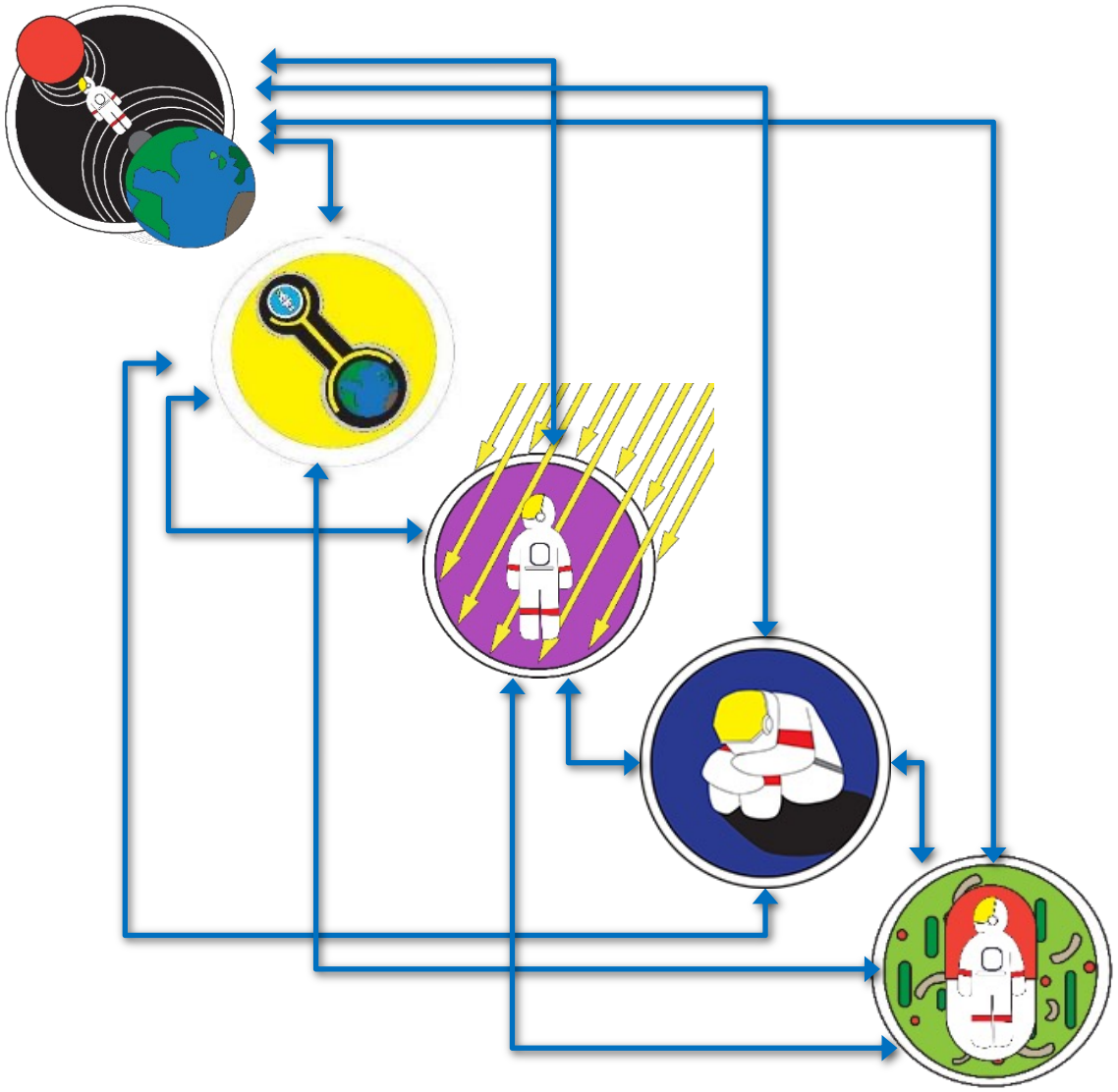
Deep Space Stressors to Human Health & Performance



Earth

- ***Altered Gravity Fields***
- ***Hostile Closed Environment***
- ***Radiation***
- ***Isolation/Confinement***
- ***Distance from Earth***

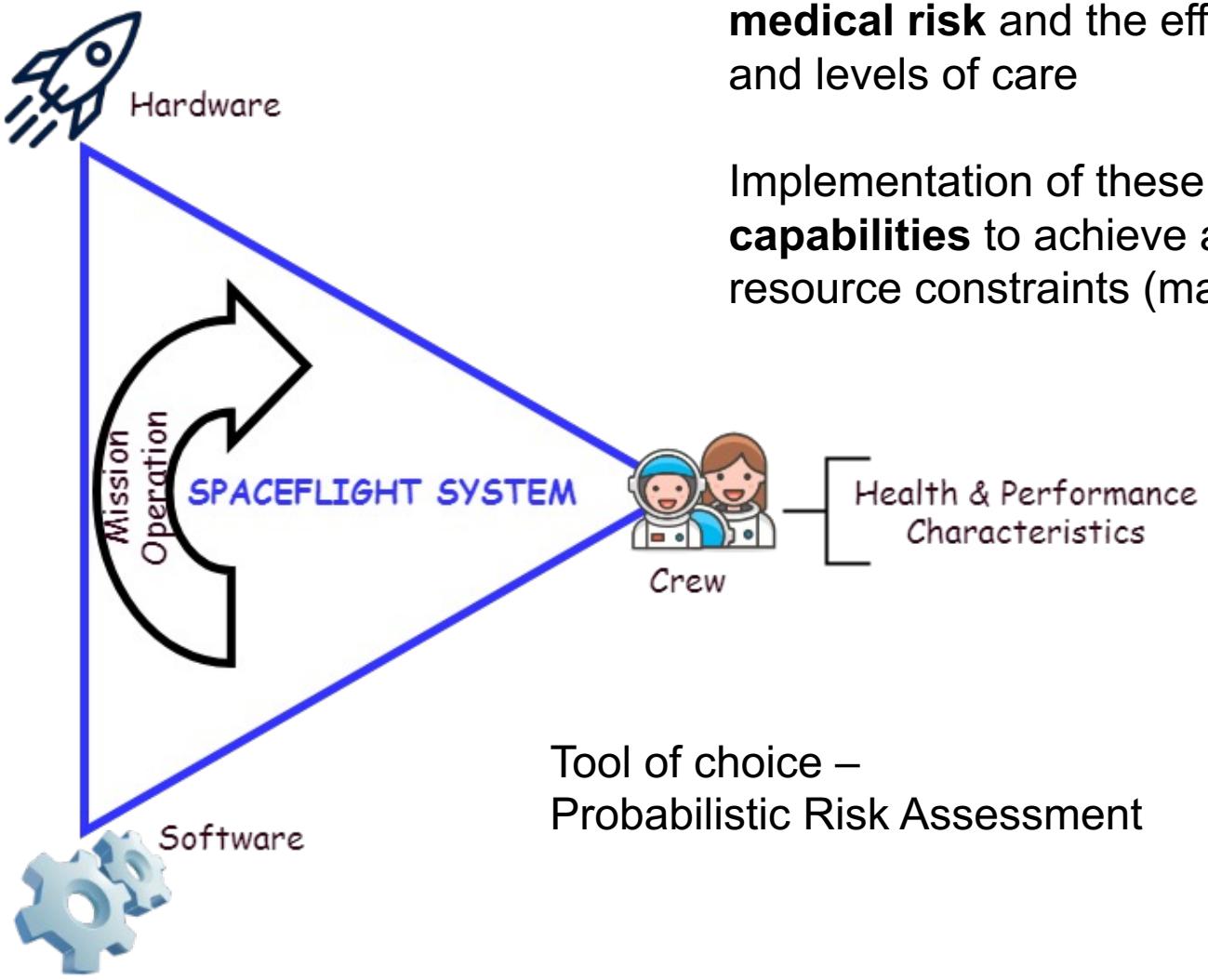
Hazards Interconnected



The hazards
may **synergistically interact**, resulting in a
significantly increased risk
to operationally-relevant crew
health and performance.

This can be especially true when
considering medical capabilities.

Model Based Medical Risk



Intent: Utilize computational systems to assess the **space mission medical risk** and the effect of medical interventions, standard of practice, and levels of care

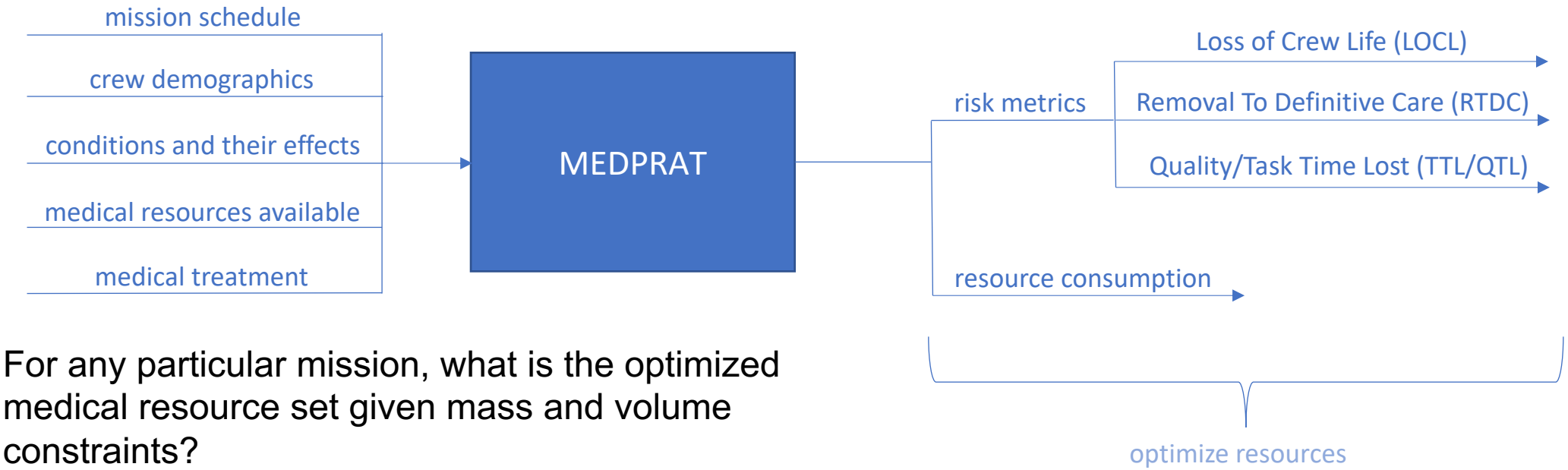
Implementation of these tools leads to the ability to **optimize medical capabilities** to achieve a minimum space medical risk for a set of mission resource constraints (mass, power, volume) or astronaut capability.

Tool of choice –
Probabilistic Risk Assessment



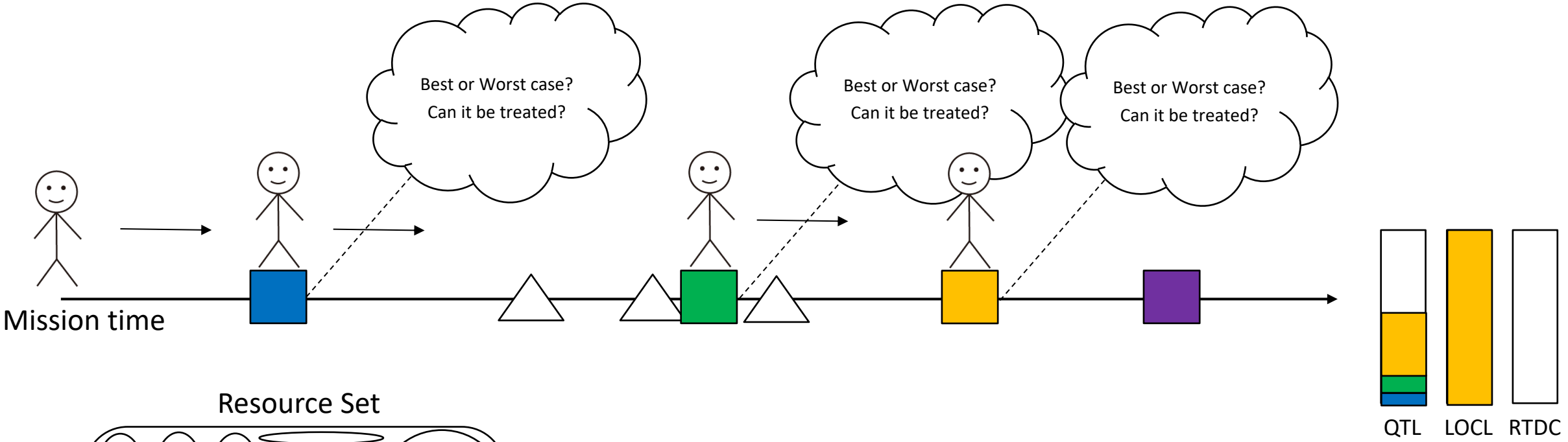
What is MEDPRAT?

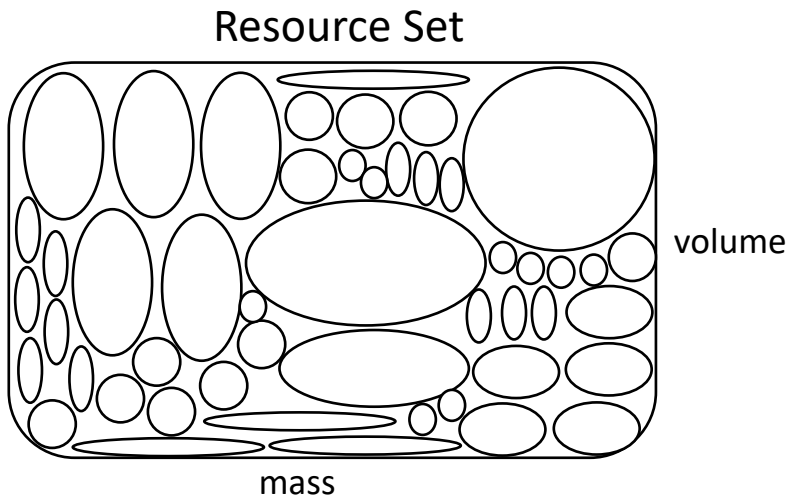
The Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT) is a computational model used to help quantify the medical component of spaceflight medical risk.

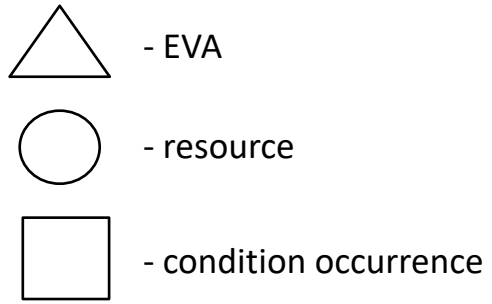


- For any particular mission, what is the optimized medical resource set given mass and volume constraints?
- Given a particular medical resource set what is the level of risk?
- What are the driving conditions and capabilities with respect to risk?
- How is my risk impacted if the overall mass of a capability is decreased?

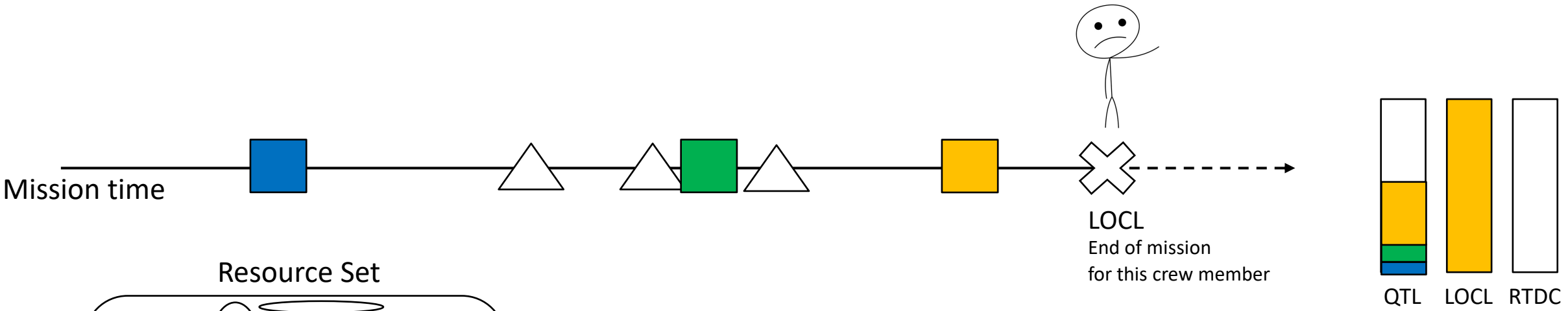
Mission Timeline Illustration

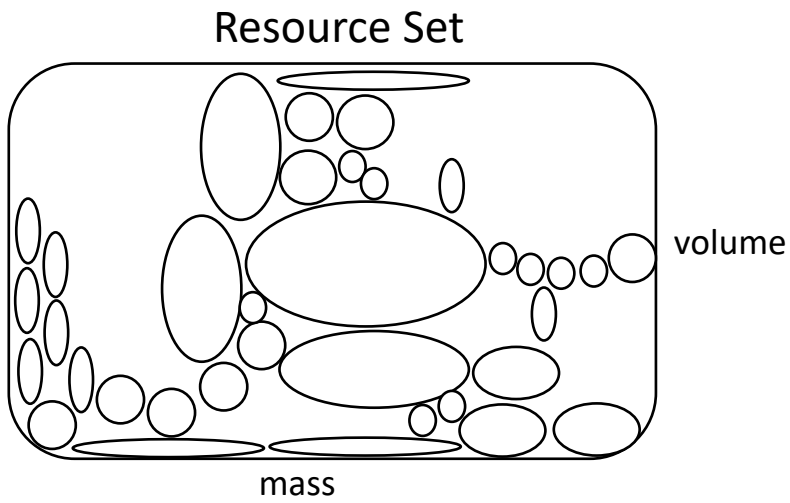


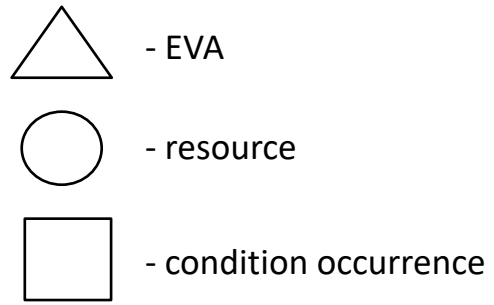




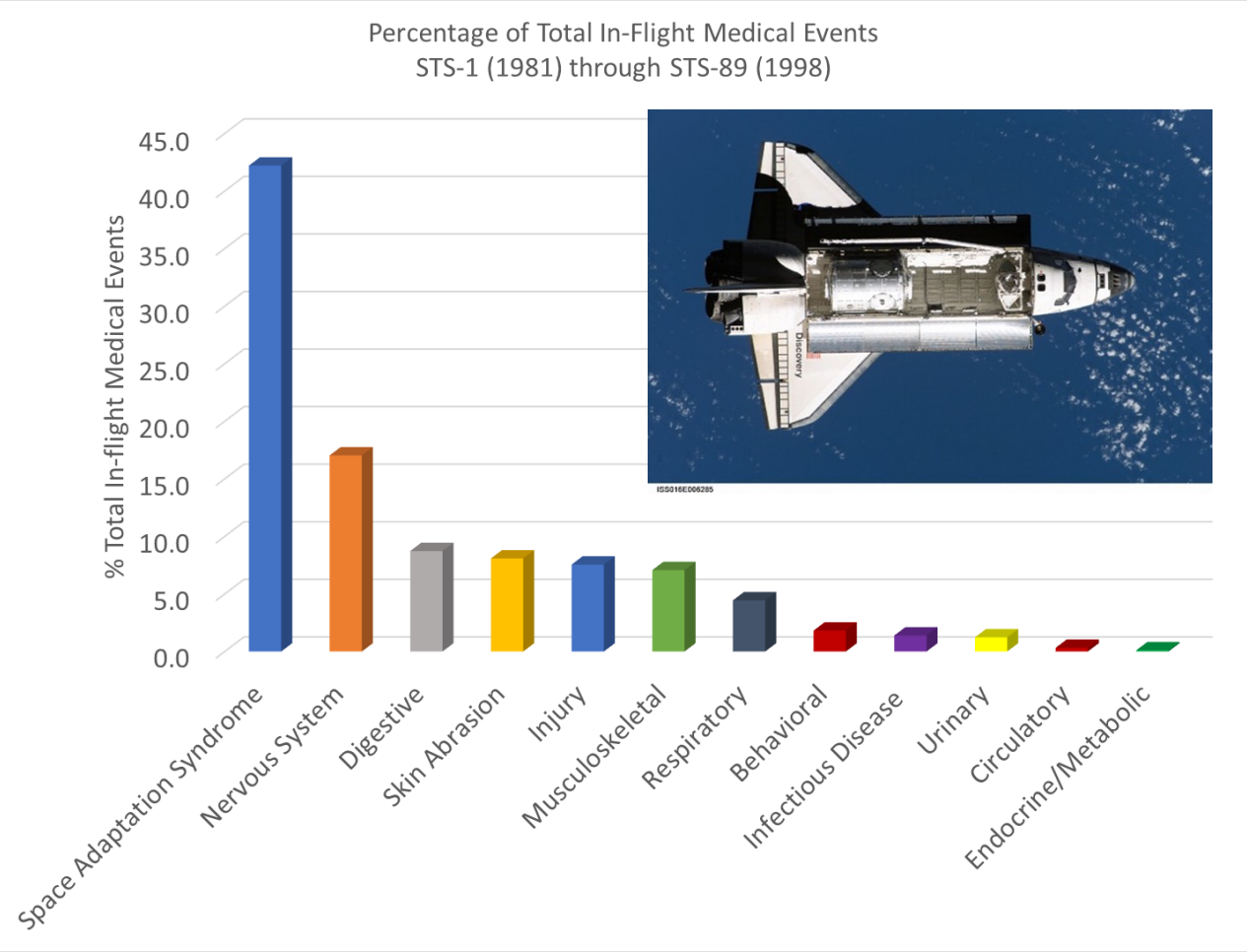
Mission Timeline Illustration







Stochastic Parameters for Conditions

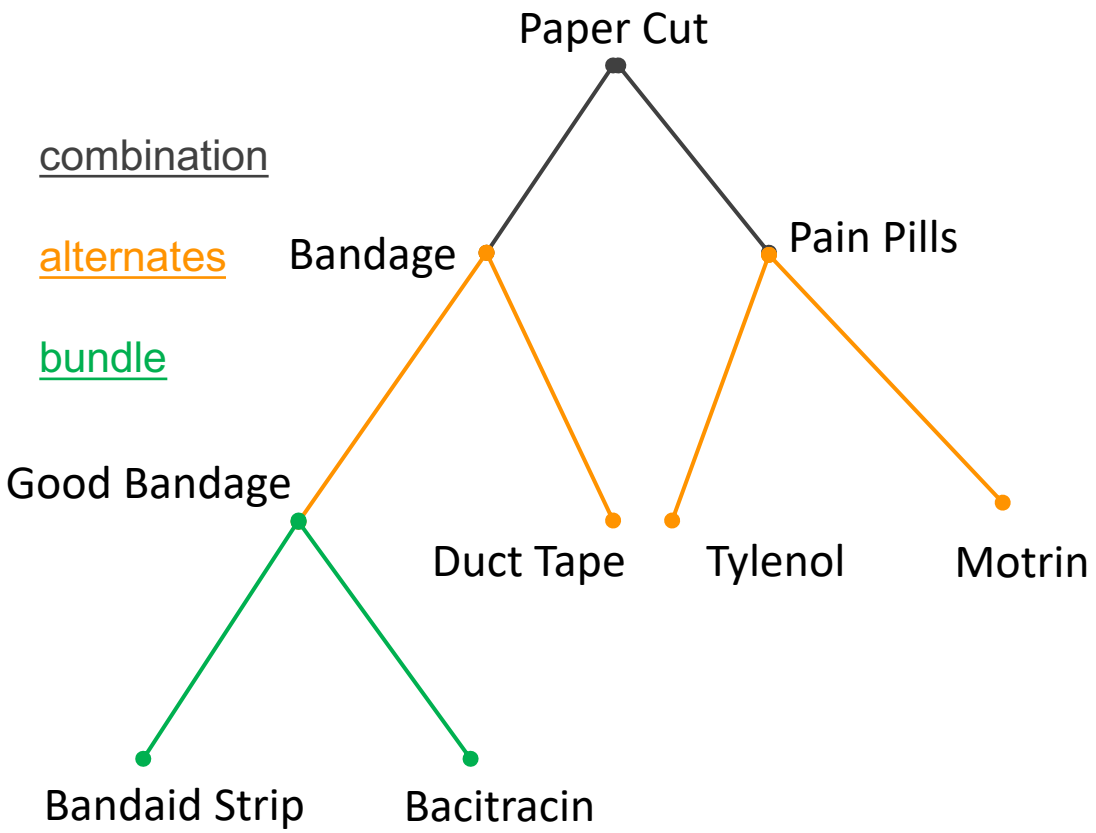


Derived from Data Published at
https://www.spacesafetymagazine.com/spaceflight/space-medicine/

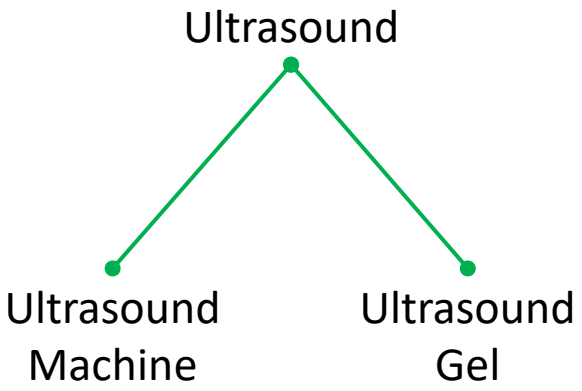
- Incidence rate
- Occurrence onset
- Best/Worst-case condition
- Clinical Phases (CP) and duration
- Functional Impairment (FI) per CP leading to “Quality Time Lost” (QTL) to perform mission activities
- Removal To Definitive Care (RTDC)
- Loss of Crew Life (LOCL)

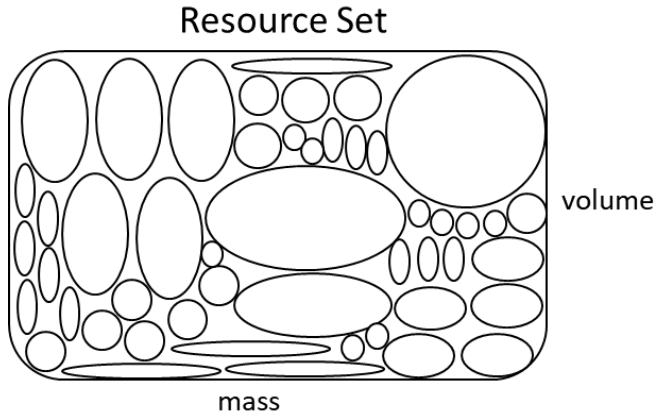
Treatment Clusters

Provide a flexible structure for defining condition treatment with the ability to define different types of relationships between resources



All dependent resources needed for effective resource (bundle)





Bundled resources allow the ability to define capabilities

- Intravenous capability: Air filter, Cap, Admin set, IV Catheter, Pressure Infuser, Tourniquet, IVF

Resources combine into clusters to treat conditions (Directed Acyclic Graph, DAG)

Susceptibility Inference Network

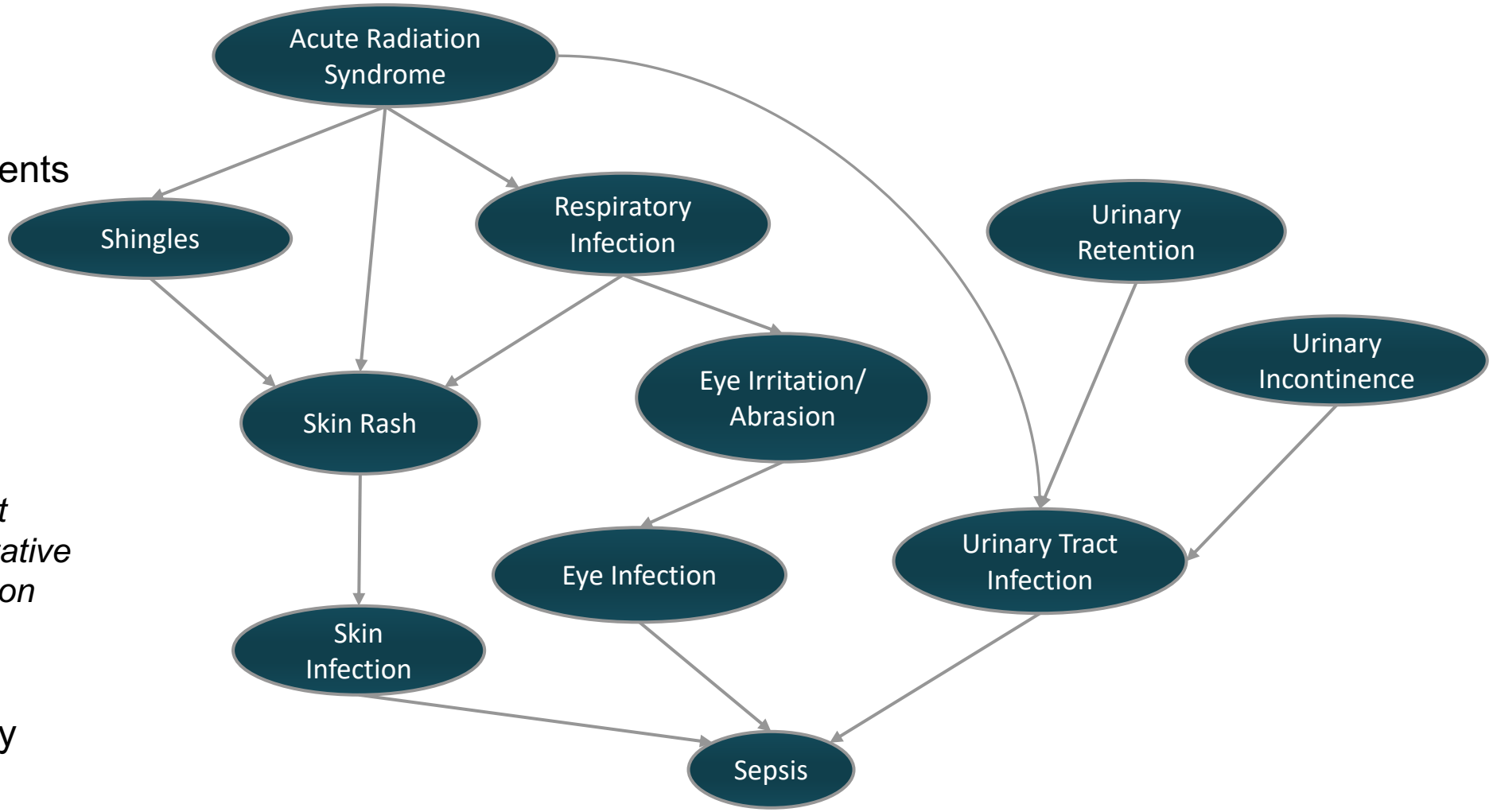
- Modified Acyclic Graph
- A means of capturing relationships and dependencies between events being modeled.



- Provides a “memory”

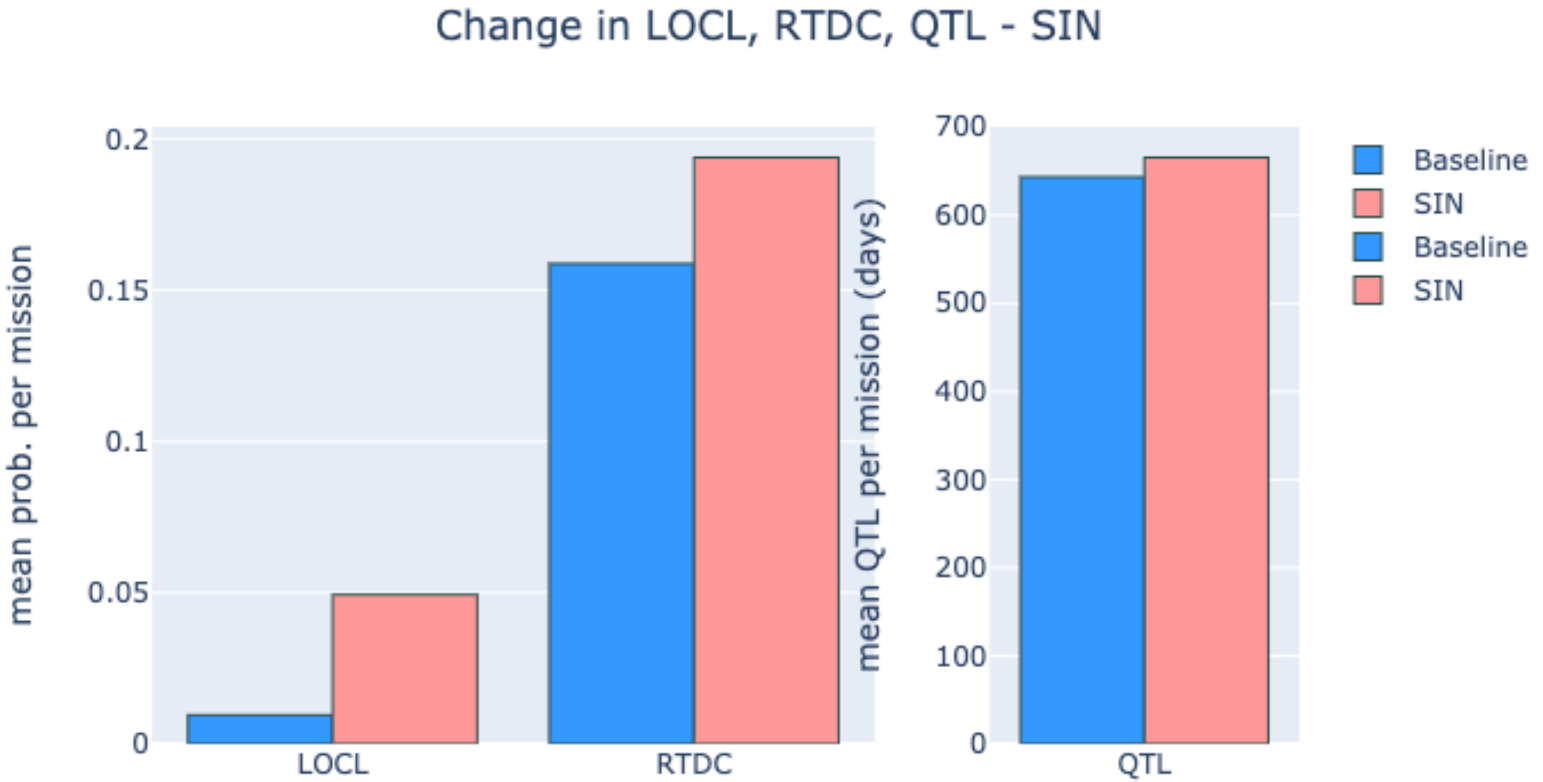
  System simulation events that have occurred alter representative probability that future simulation events will occur

- Acts as dynamic probability field

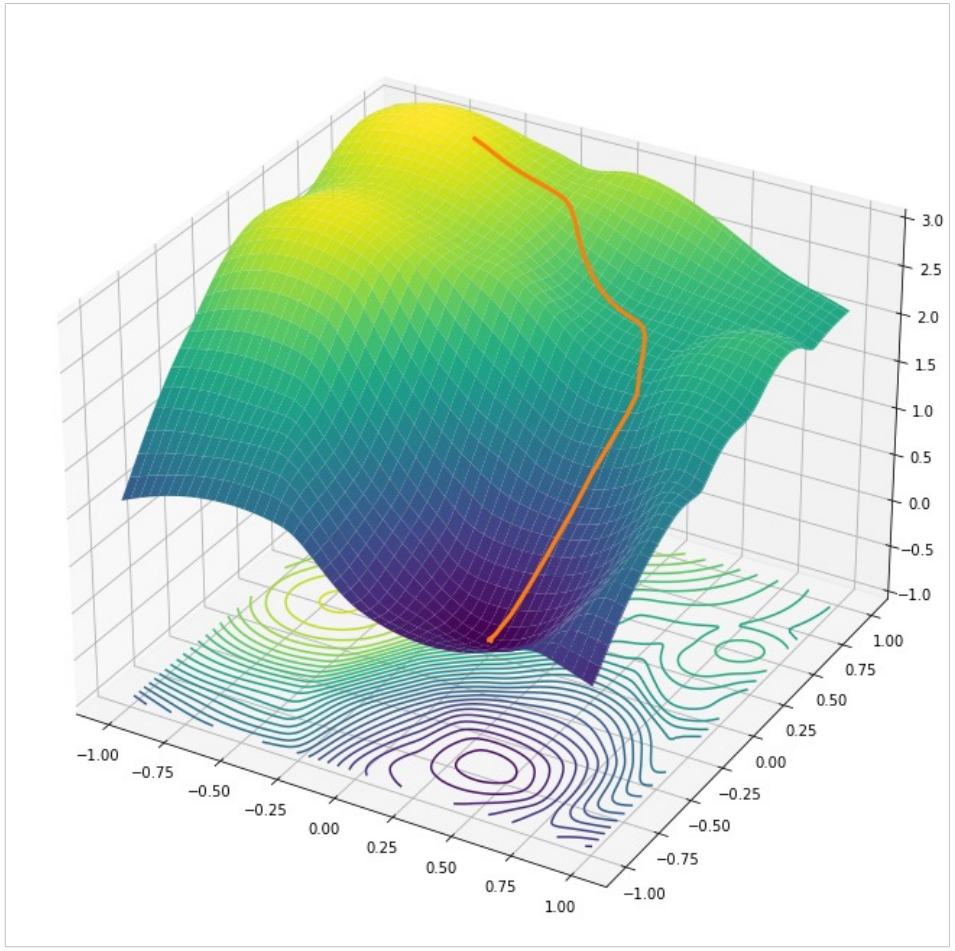


Risk Metrics – SIN Included

Notional Mission length 1000 days
Notional crew size - 4

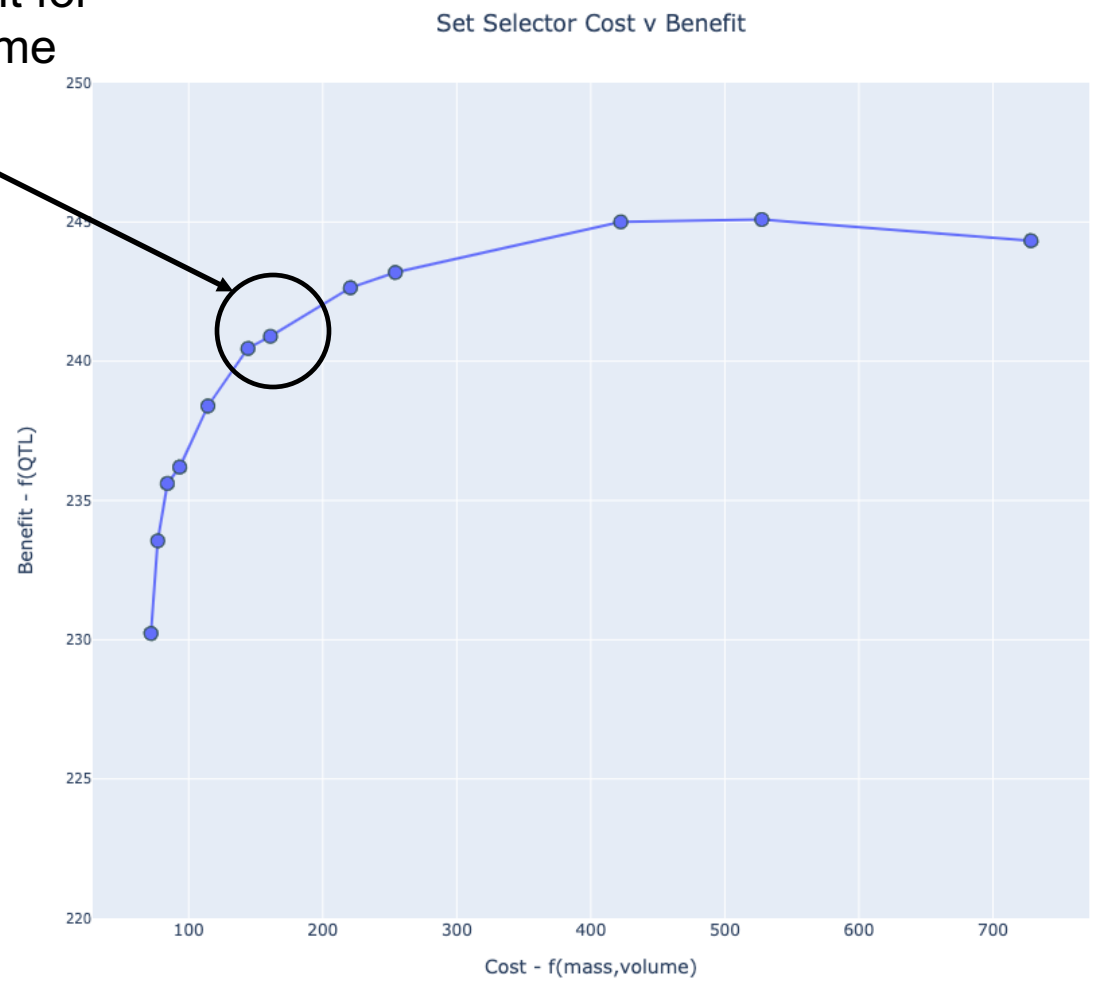


Resource Set Selector



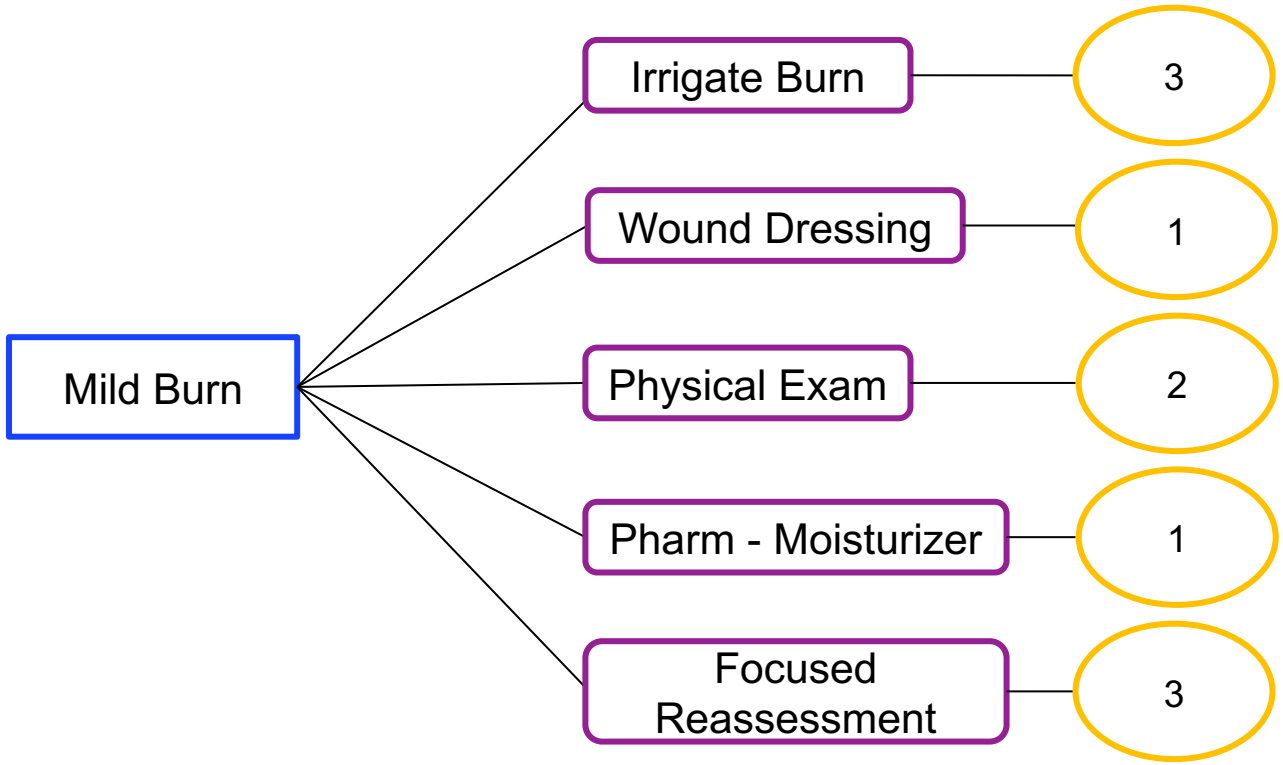
Gradient Descent

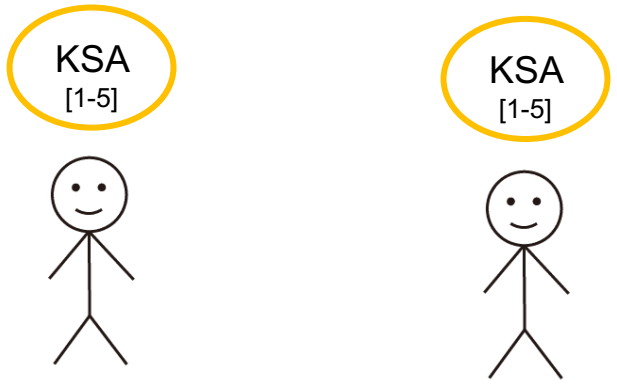
Max Benefit for Mass/Volume Conditions



In the works - Extending Application with KSAs

- Capabilities are mapped to the appropriate condition by best and worst case
- Each capability and condition receives a KSA (Knowledge Skill and Ability) rating, representing the cognitive or procedure execution KSA required in order for the capability to be available
- Each crew member receives a cognitive and procedure execution KSA Rating
- If a capability is required that exceeds the highest KSA level of the crew, the capability is unavailable for treatment

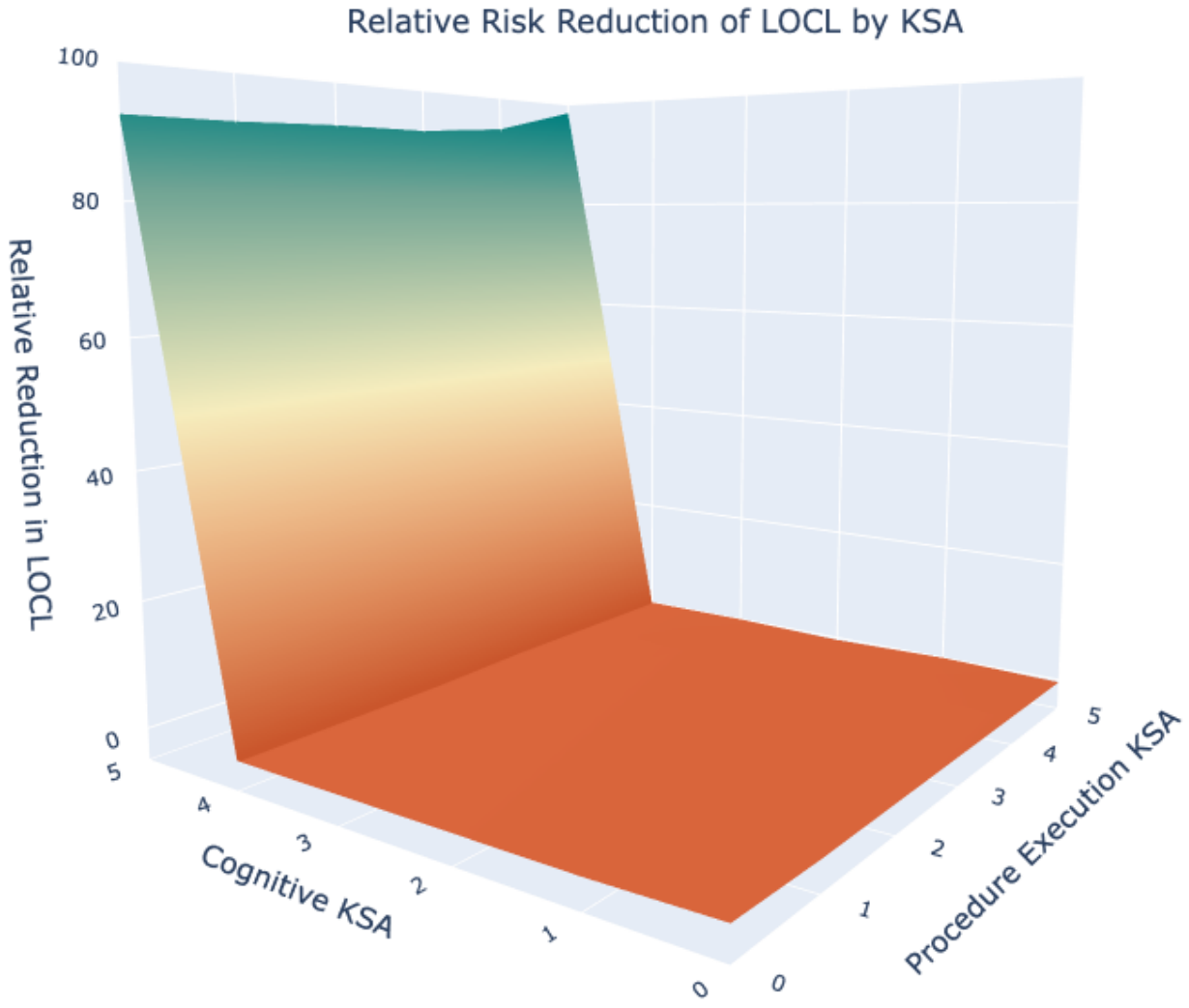




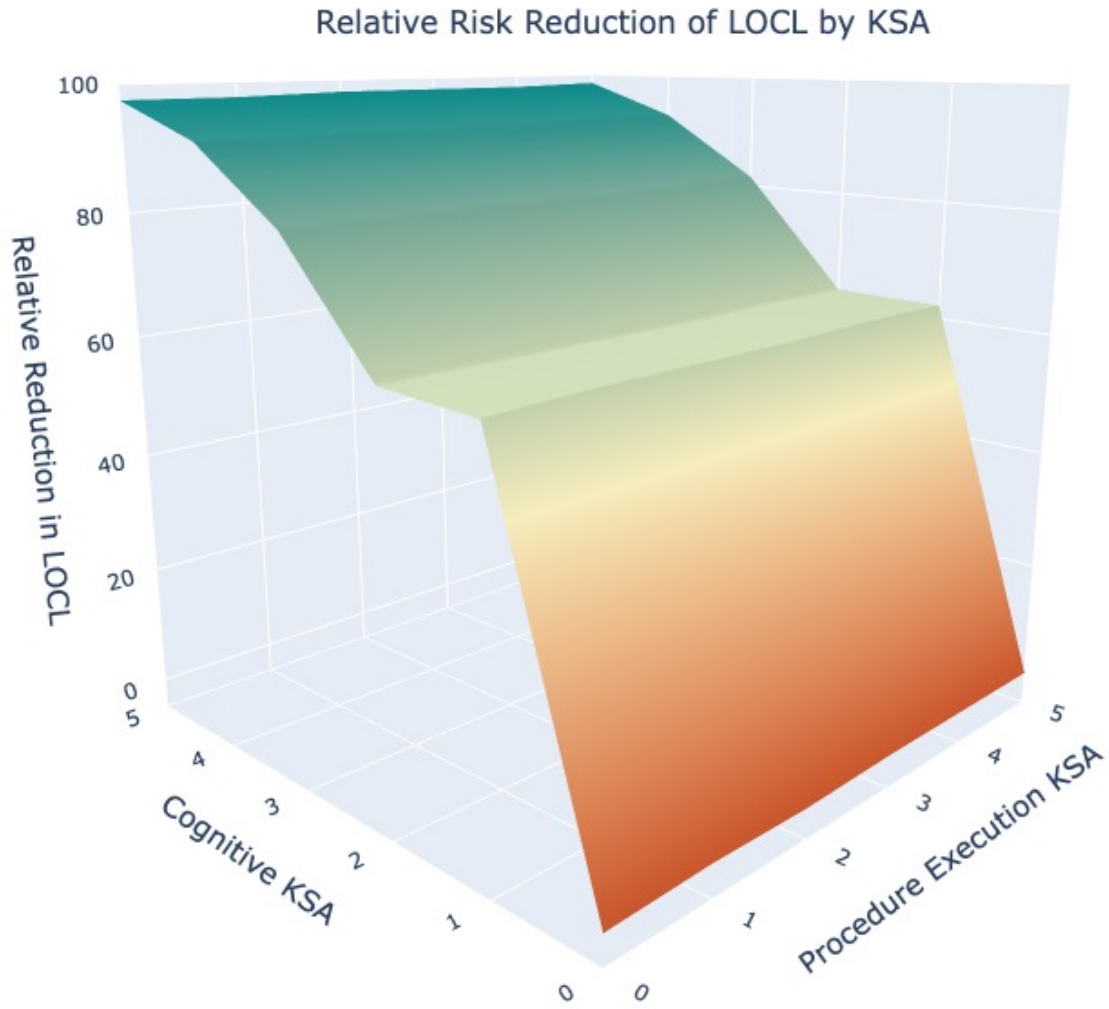
KSA	Description
1	National Registry Emergency Medicine Technician (EMT) - Basic
2	National Registry Paramedic
3	Certified Emergency Registered Nurse
4	First Year Resident Medical Doctor (Intern)
5	Attending Physician (not specialty specific)

Estimating Effect on Loss of Crew Life

Resources require full bundle



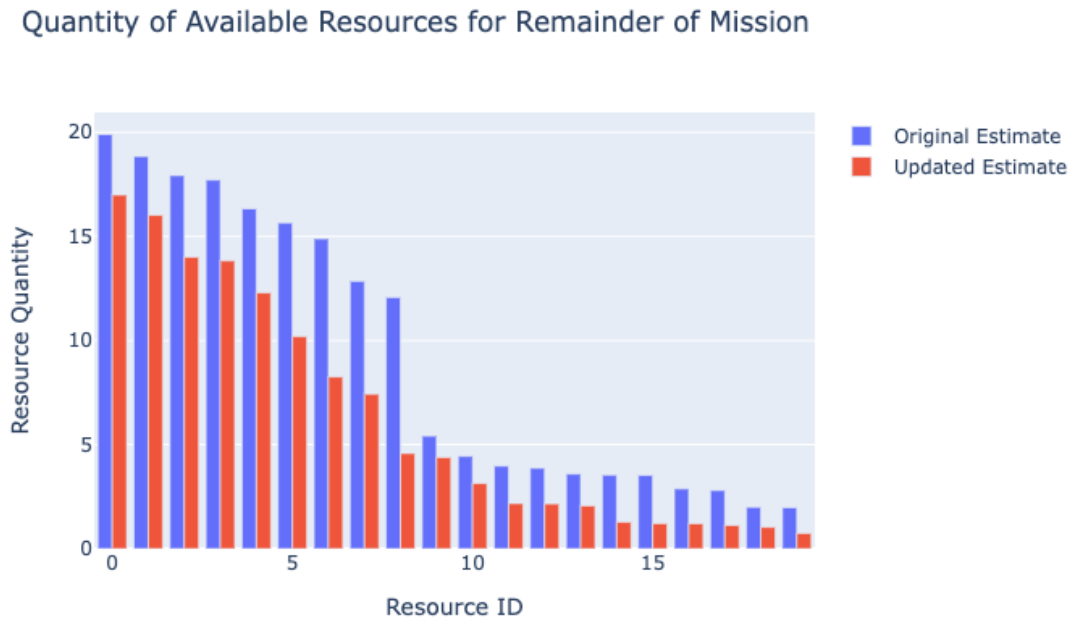
Partial treatment credit allowed



*The Evidence Library data set has not yet been reviewed therefore these results are preliminary

Conclusions

- Model based approaches via MEDPRAT - represents the latest application of PRA techniques to establish the Space medical risk
- MEDPRAT extends ability to assess condition progression and treatment combinations.
- Model based Medical Resource optimization - minimize known risk at a very high fidelity and evaluate risk changes for changes in resource allocations
- Model based risk assessments can establish crew skill contributions to the medical risk posture
- In the future this could be extended to near-real time updates by simulations of the remaining mission from known medical consumables and resource consumptions.



	TTL	LOCL	RTDC
Original Estimate	1155 days	0.017	.96
Updated Estimate	1216 days	0.2	1.3

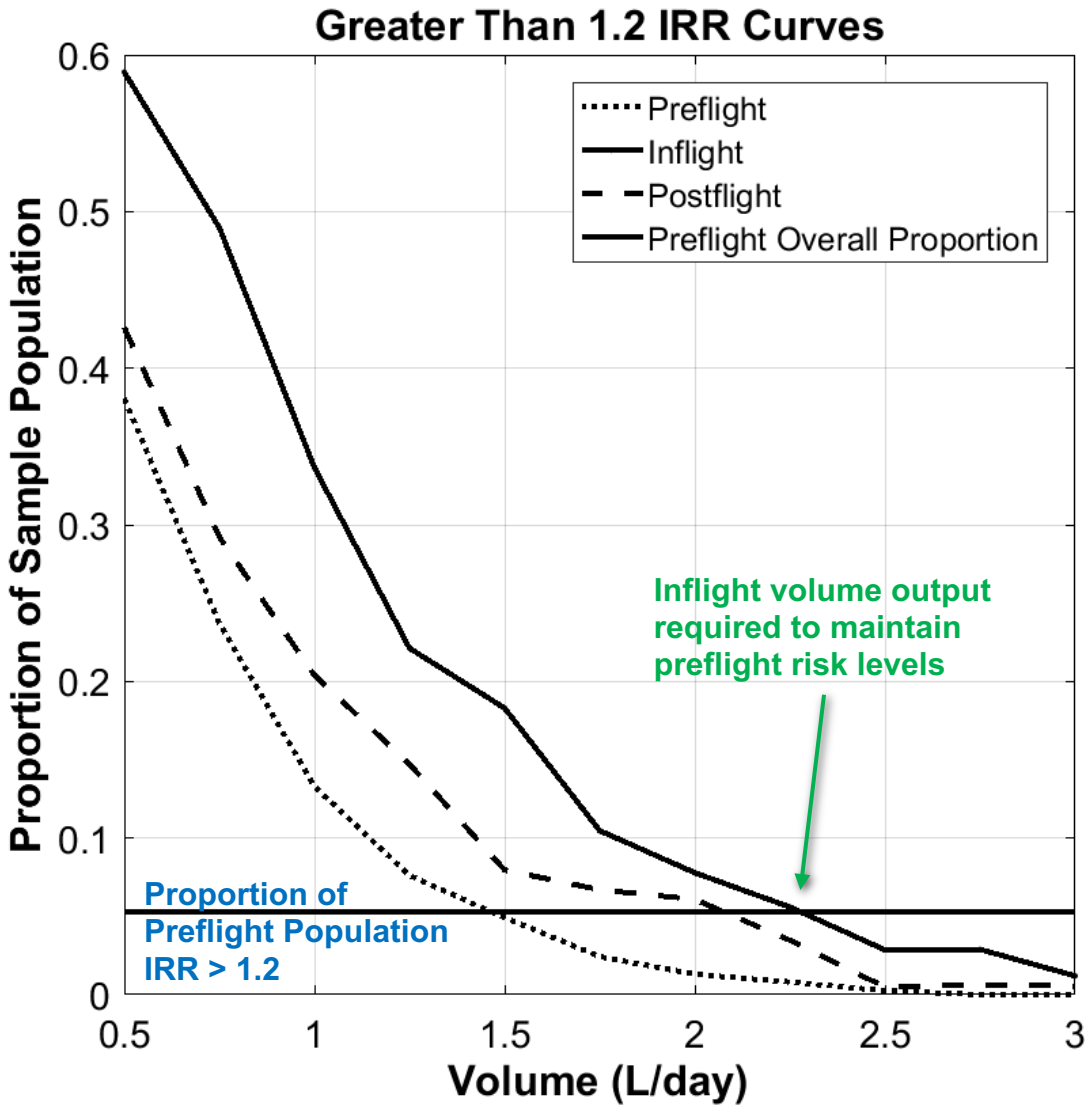


Email: jerry.g.myers@nasa.gov

Example: Engineering Trades - Drinking Water "Volume Reduction"

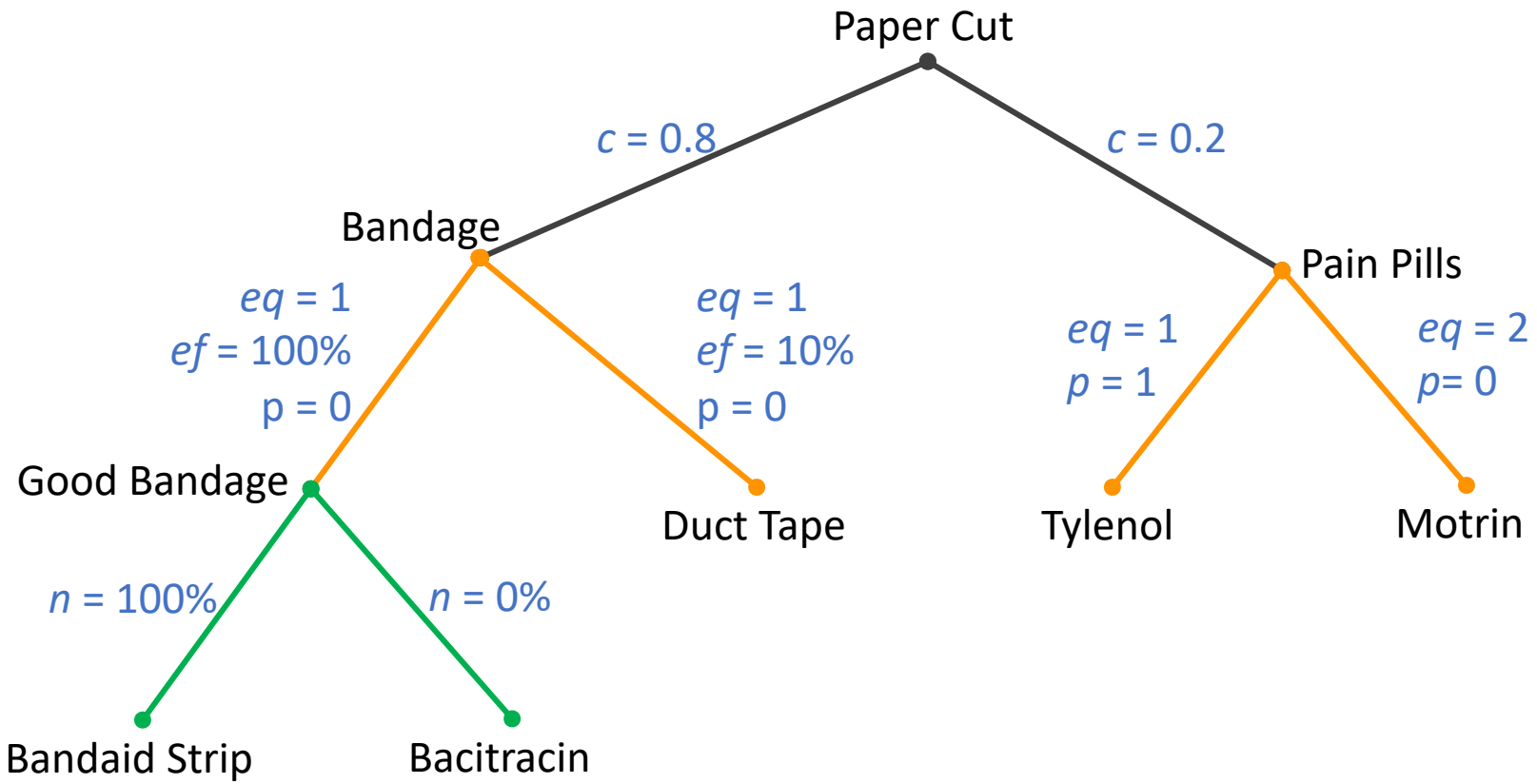
Quantify change in risk of a symptomatic renal stone from reducing water intake standards:

- Example: For a nominal 2.0 L *output*, a reduction in intake by 0.5 L results in:
  - 2.4x the proportion of the astronaut population would be in the >1.2 IRR sub-population
- Note:
  - Insensible Water Losses on a spacecraft tend to be high (assume 0.7 to 0.9 L/day).
  - Must account for this as ***INTAKE*** for providing countermeasure recommendations.



D. Goodenow-Messman, S. Gokoglu, M. Kassemi, and J. Myers, Numerical Characterization of Astronaut CaOx Renal Stone Incidence Rates to Quantify In-flight and Post-flight Relative Risk, Submitted to NPJ Microgravity 1/8/2021.

Resource Cluster Example



Alternate:
- *eq = equivalence*
- *p = primacy*

Non-alternate:
- *c = contribution*
- *n = necessity*

All:
- *ef = efficacy*

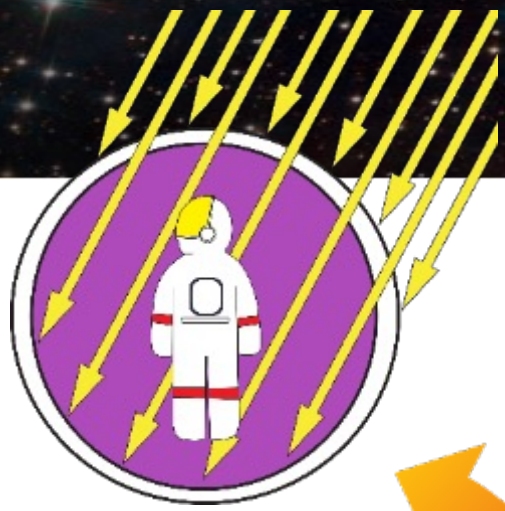
combination

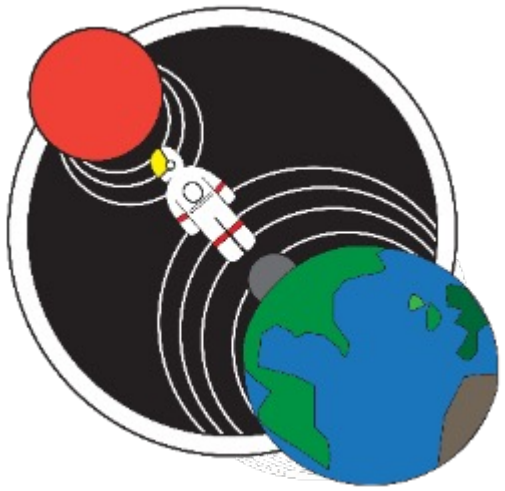
alternates

bundle

Hazards Interconnected











The hazards
may **synergistically interact**, resulting in a
significantly increased risk
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health and performance.

This can be especially true when
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Conclusions

