

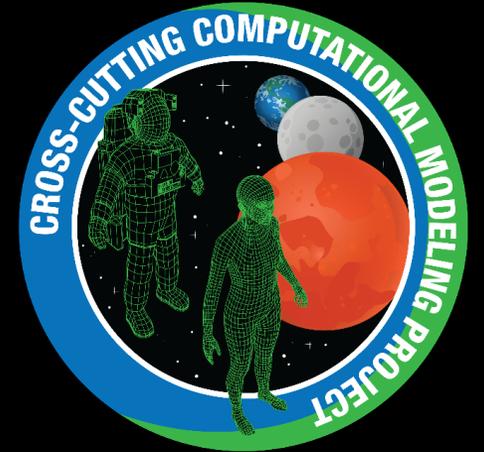


Dynamic Medical Risk Assessment Supported by Inference Networks

L. McIntyre¹, L. Leinweber², J. Myers¹

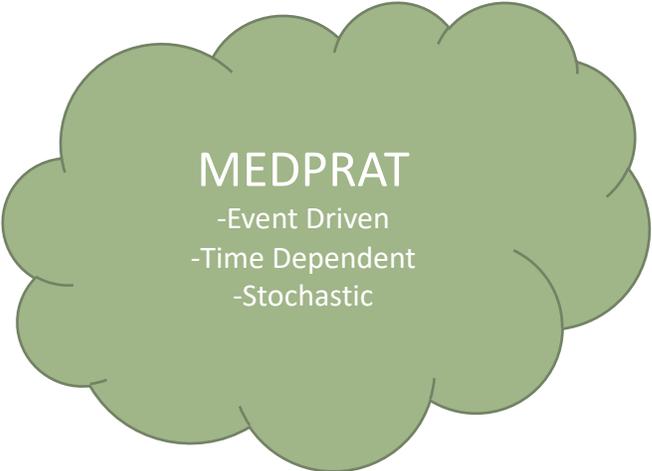
¹NASA Glenn Research Center

²ZIN Technologies, Inc.



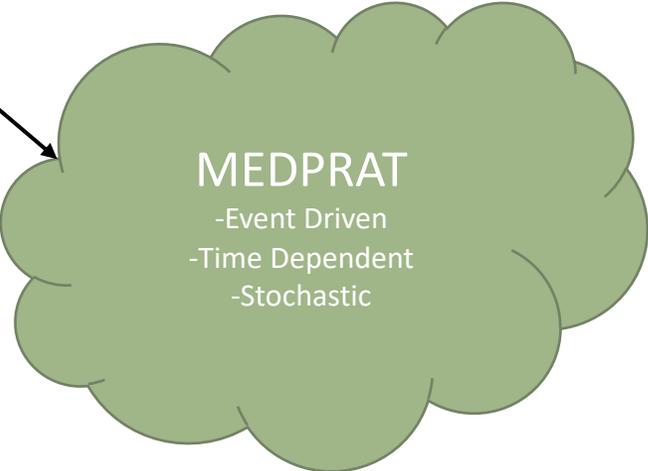
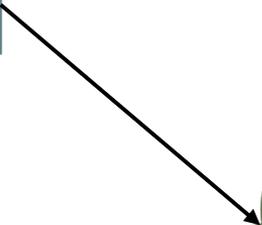


Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



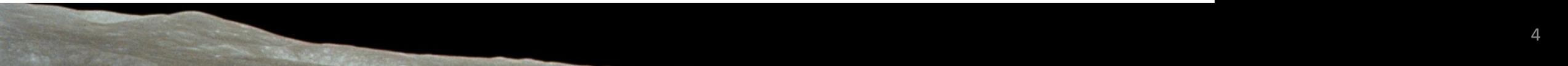


Crew Attributes

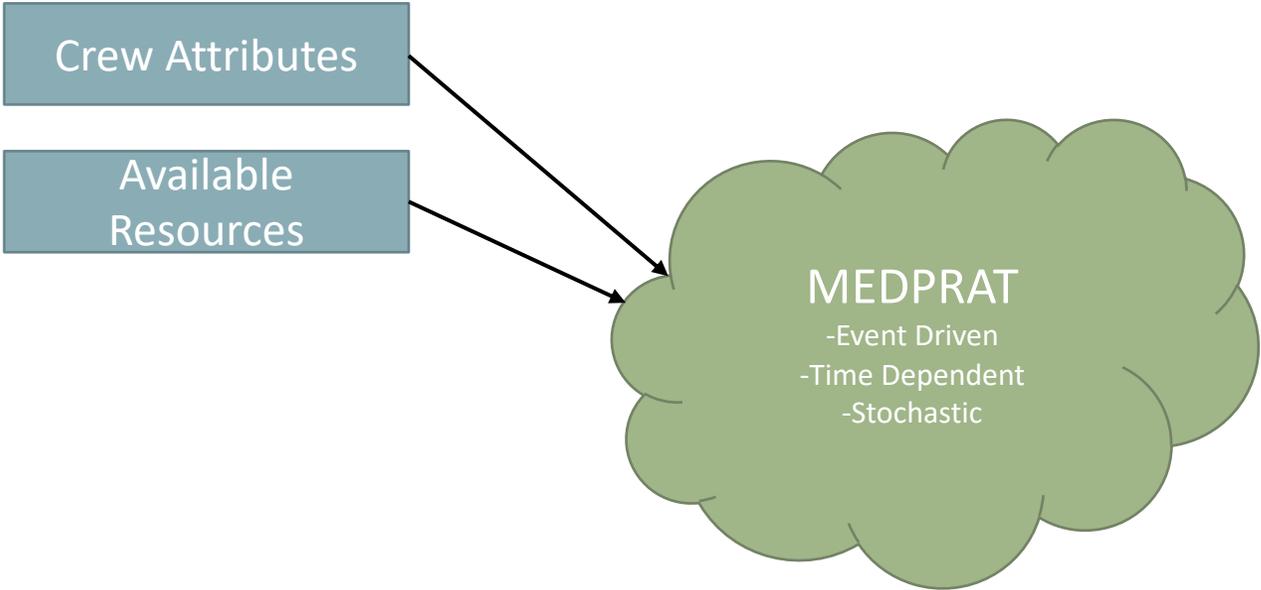


Crew Attributes

- Gender
- Dental Crowns
- Contacts
- H_x abdominal surgery
- EVA



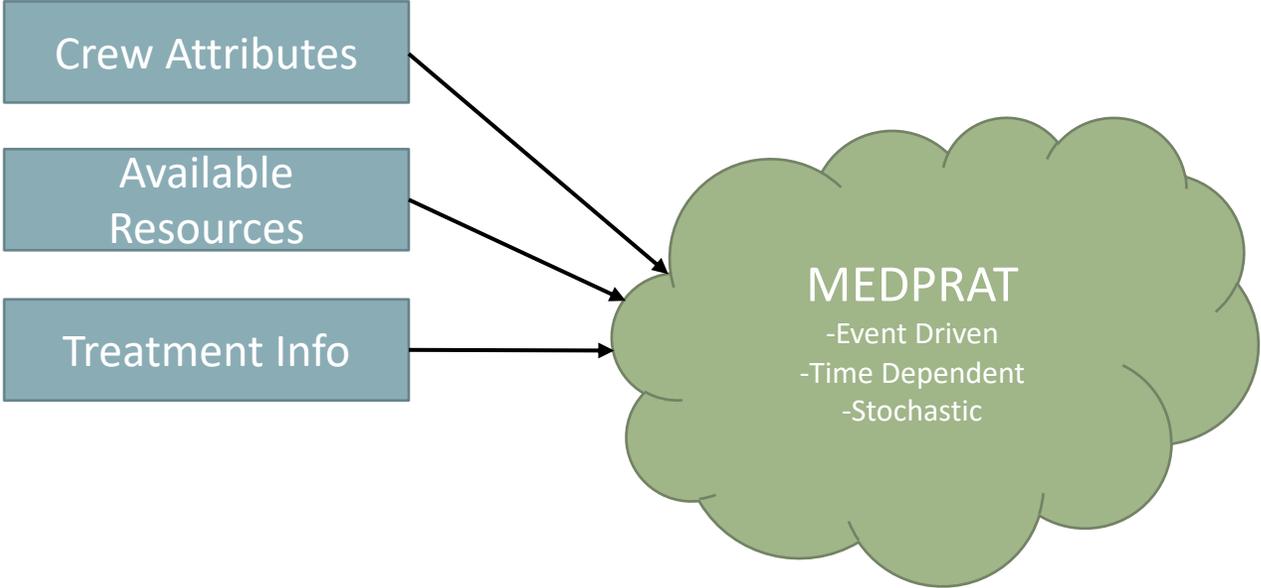
Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



Available Resources

- Initial quantity
- Consumable
- Essential
- Mass
- Volume

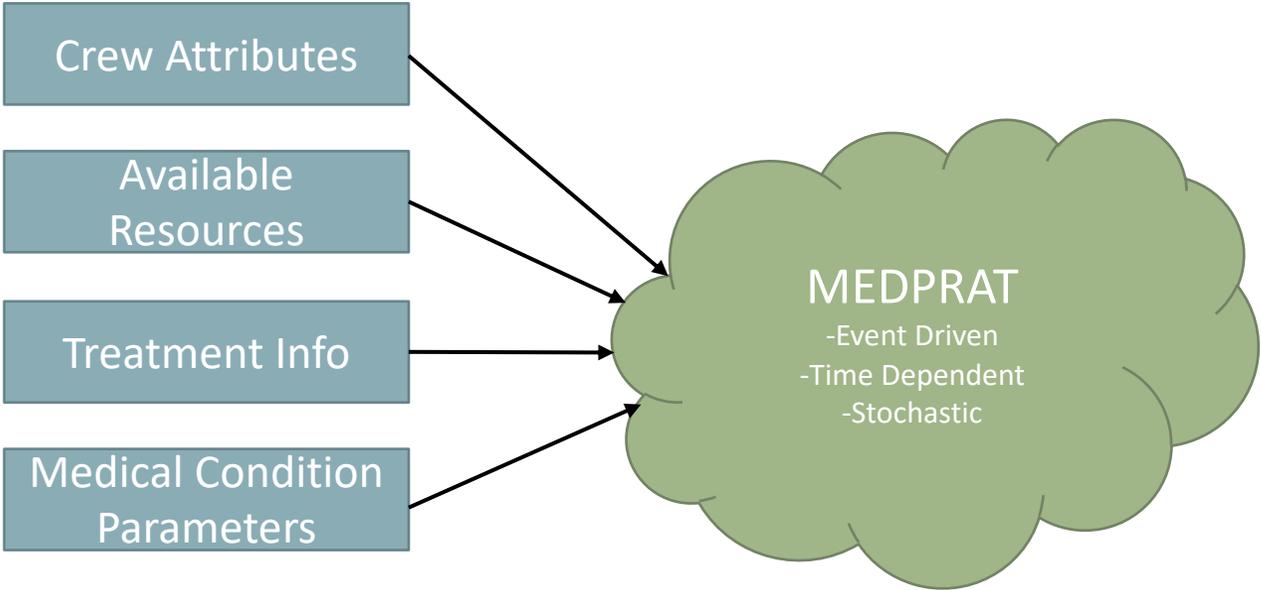
Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



Treatment Info

- Condition
- Resource
- Dose

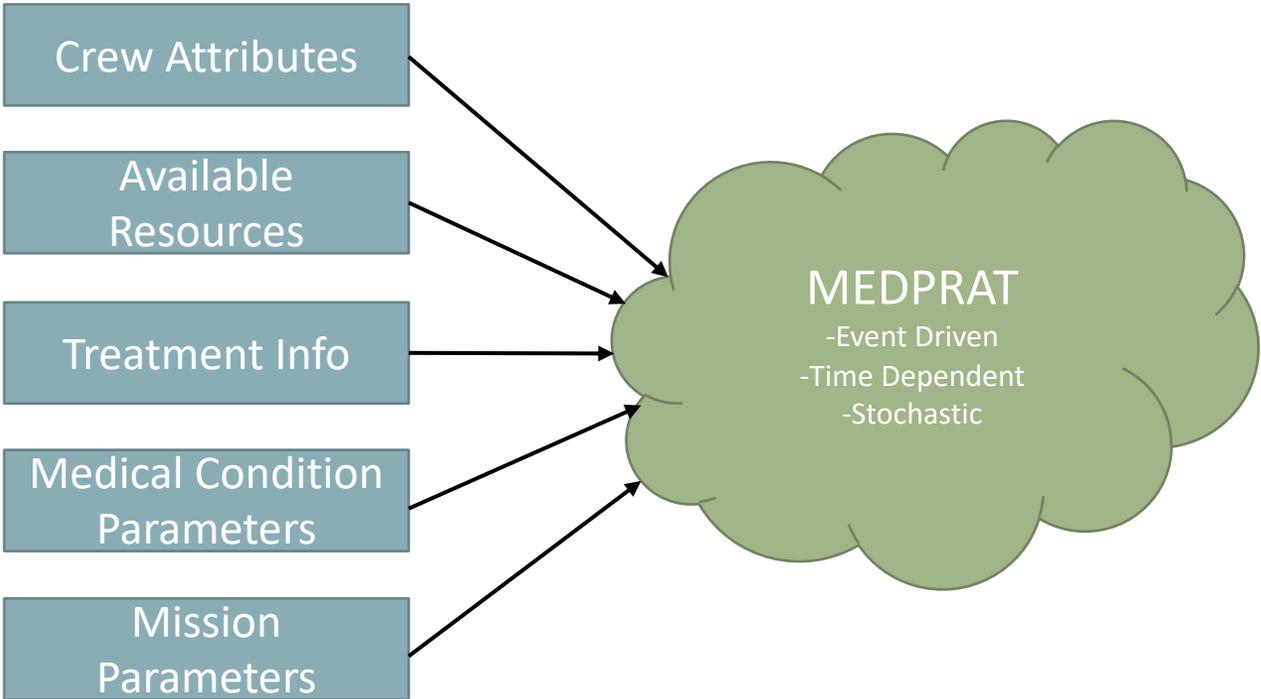
Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



Medical Condition Parameters (RV's)

- Incidence rate (IR)
- Clinical phases
- Best/Worst case
- Functional Impairment
- Loss of Crew Life (LOCL)
- Removed To Definitive Care (RTDC)

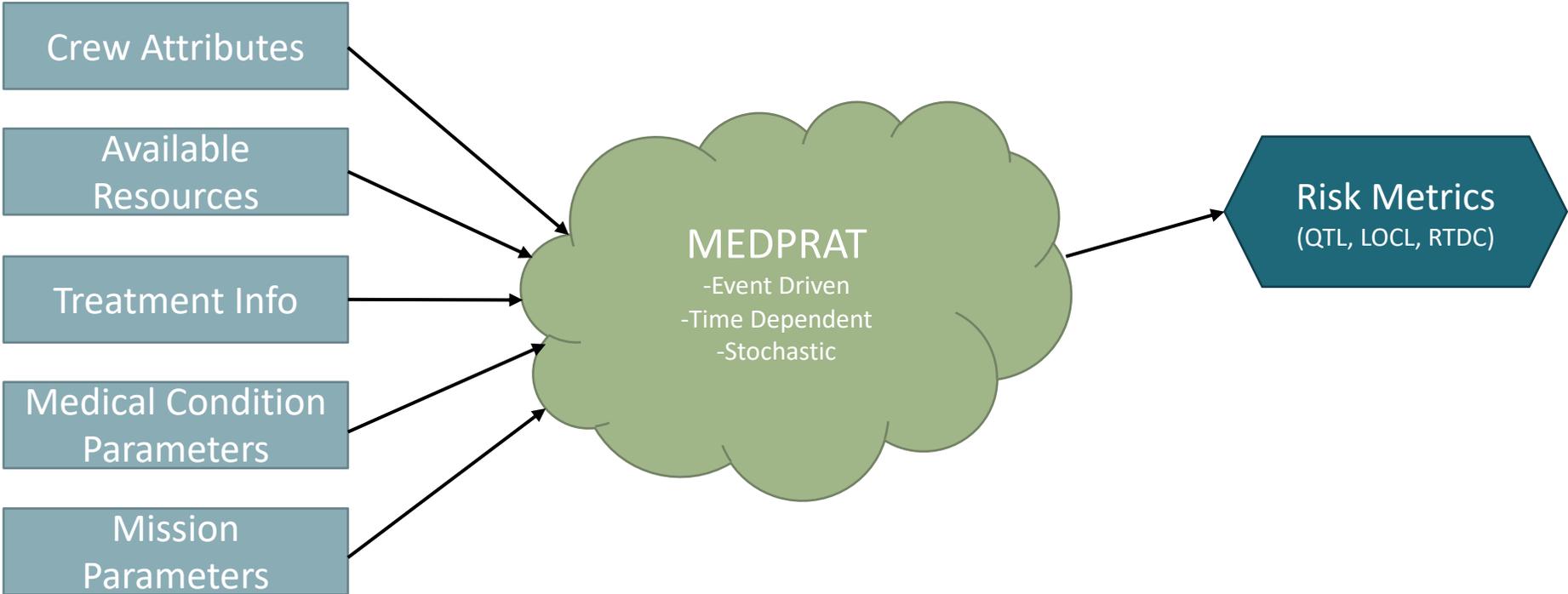
Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



Mission Parameters

- # Crew
- Mission duration
- EVA schedule

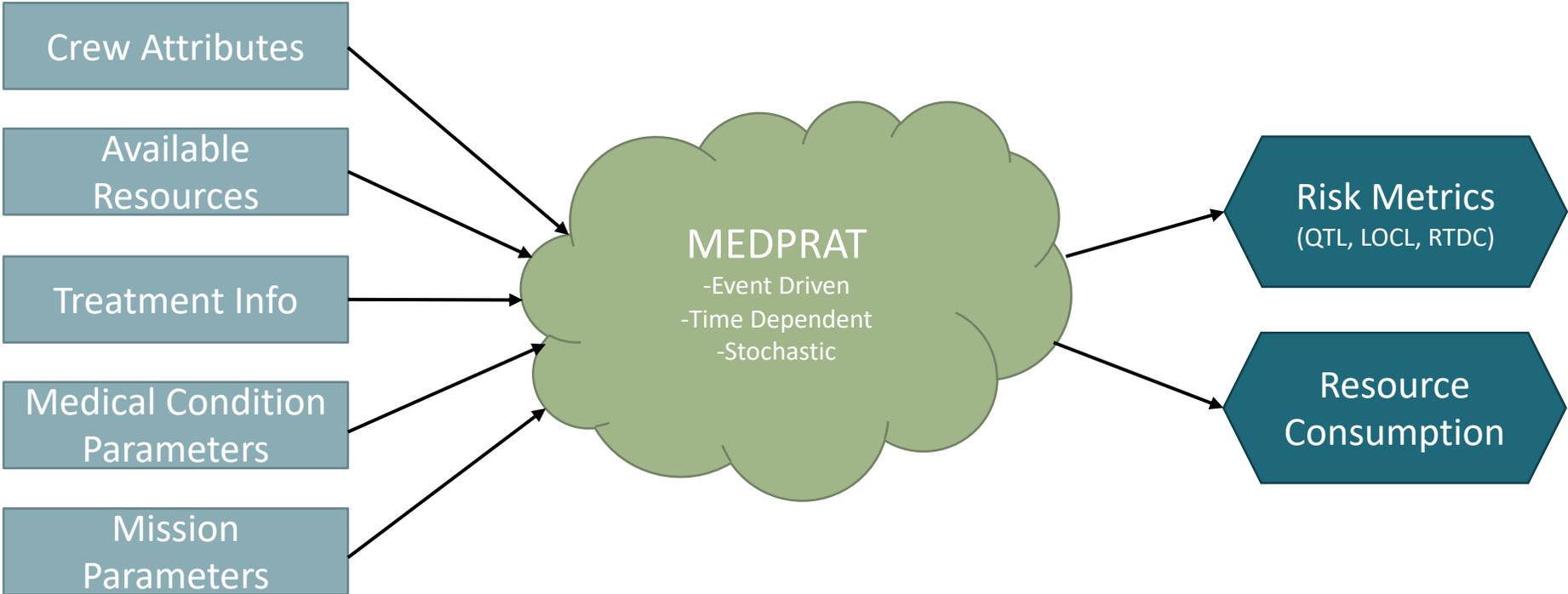
Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



Risk Metrics

- Occurrence
- Condition
- Crew
- Trial
- Sum, mean, std deviation
- Best/Worst case
- Treated/Untreated

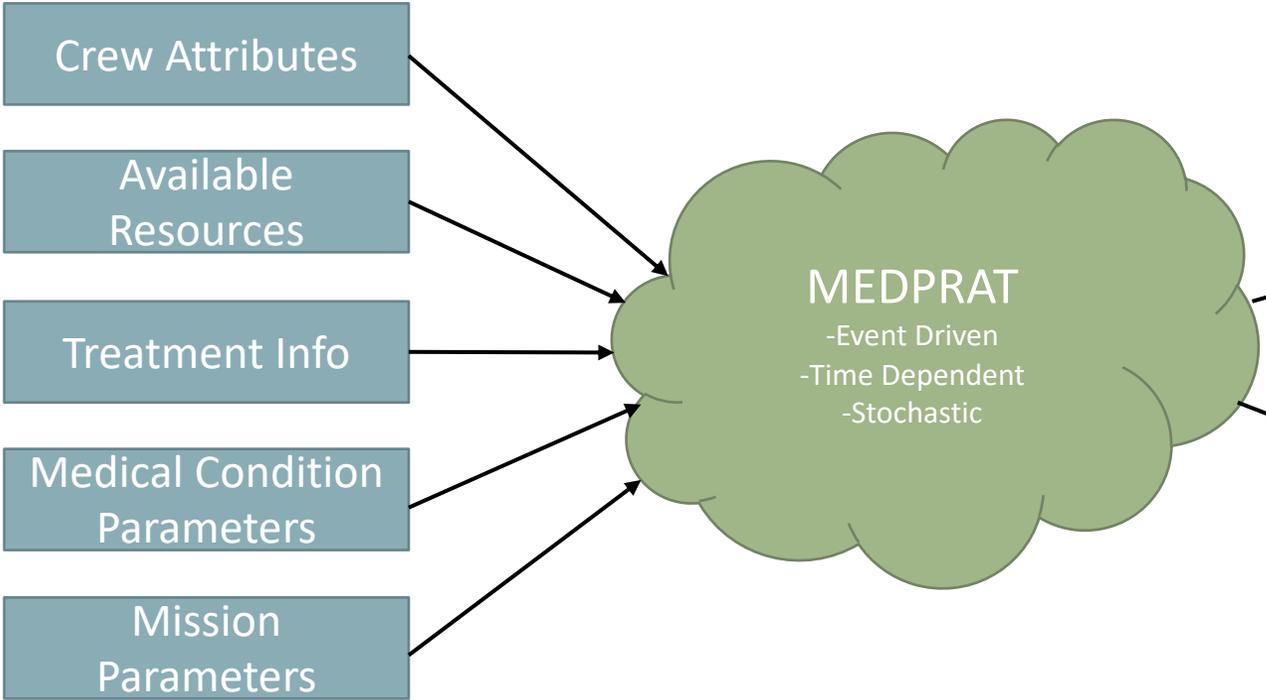
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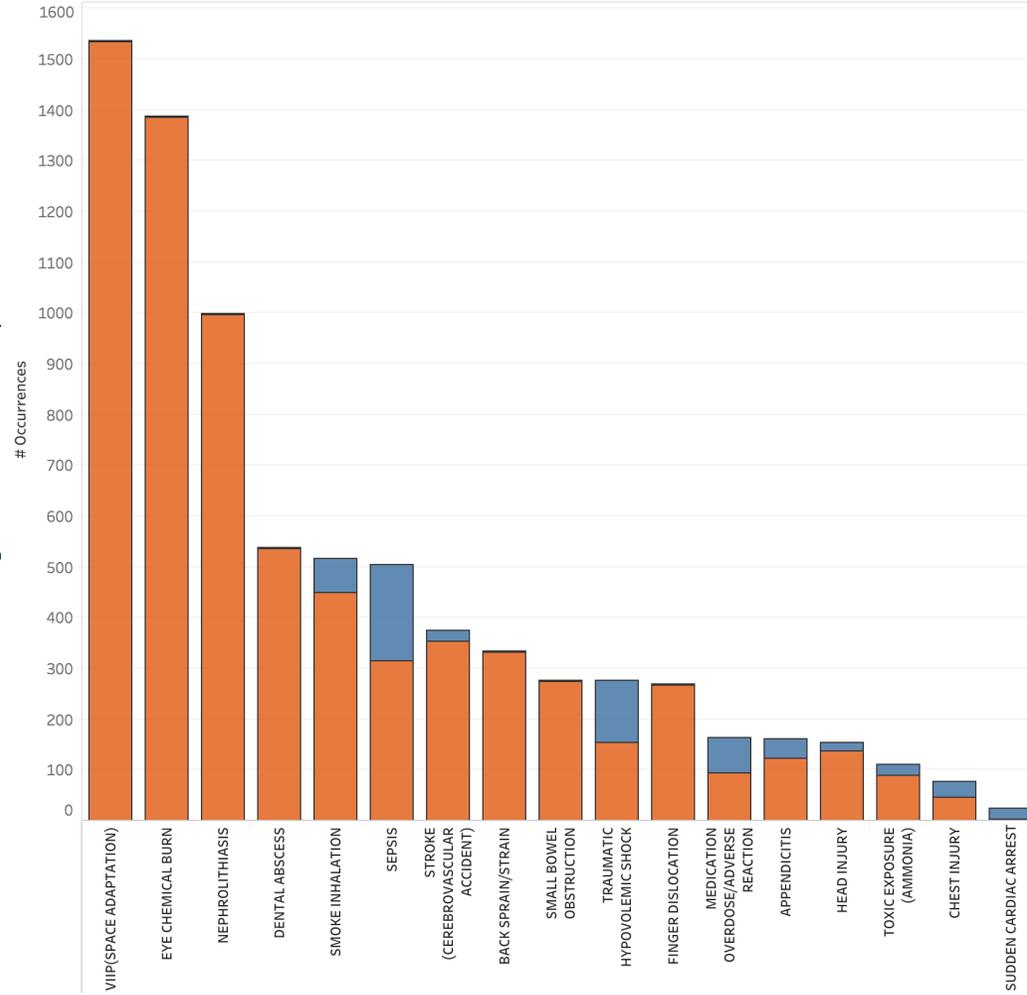
Resource Consumption

- Required quantity
- Resource exhausted
- Peak rate
- Min, max, sum, mean, sd
- Primary vs alternate

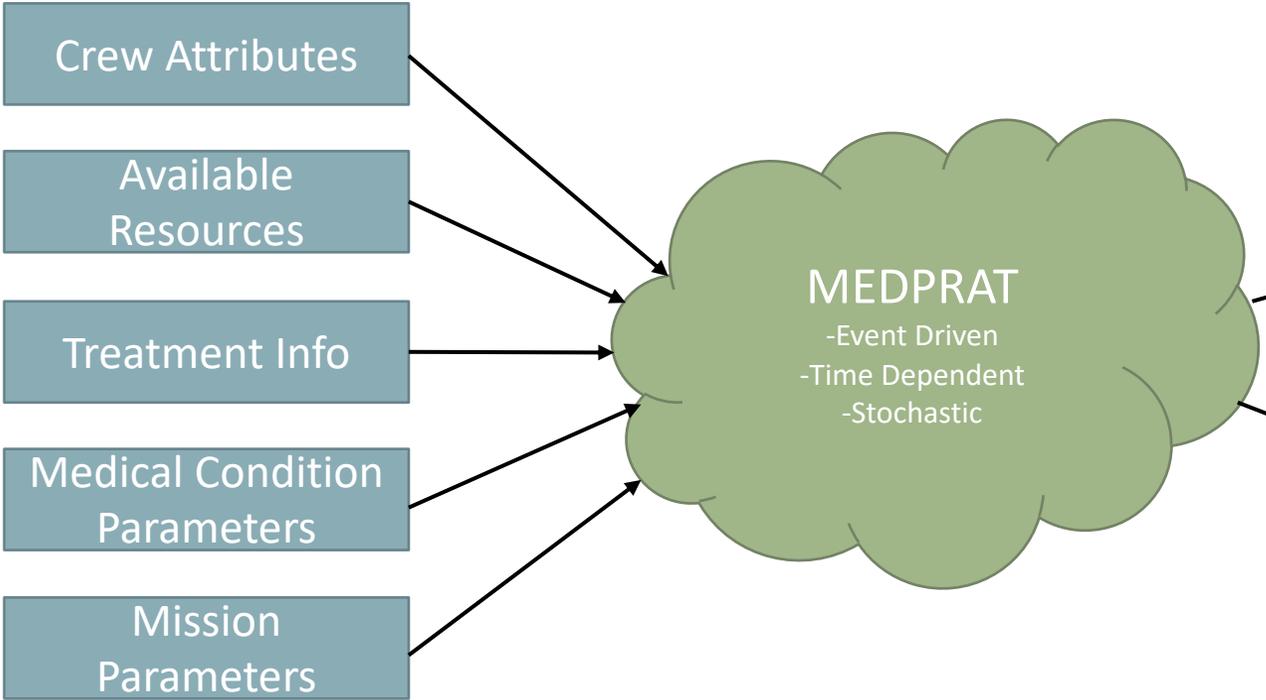
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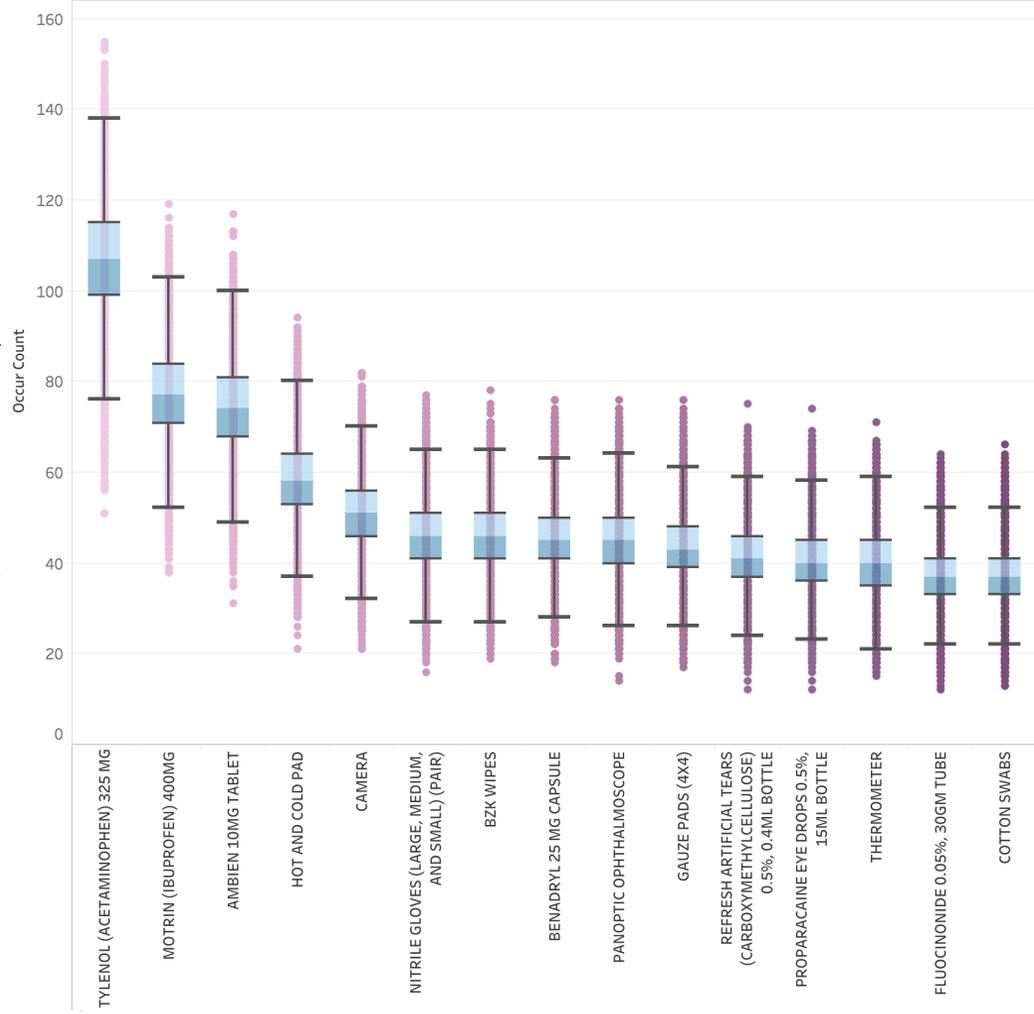
LOCL/EVAC Breakdown for Top 10 Contributing Conditions



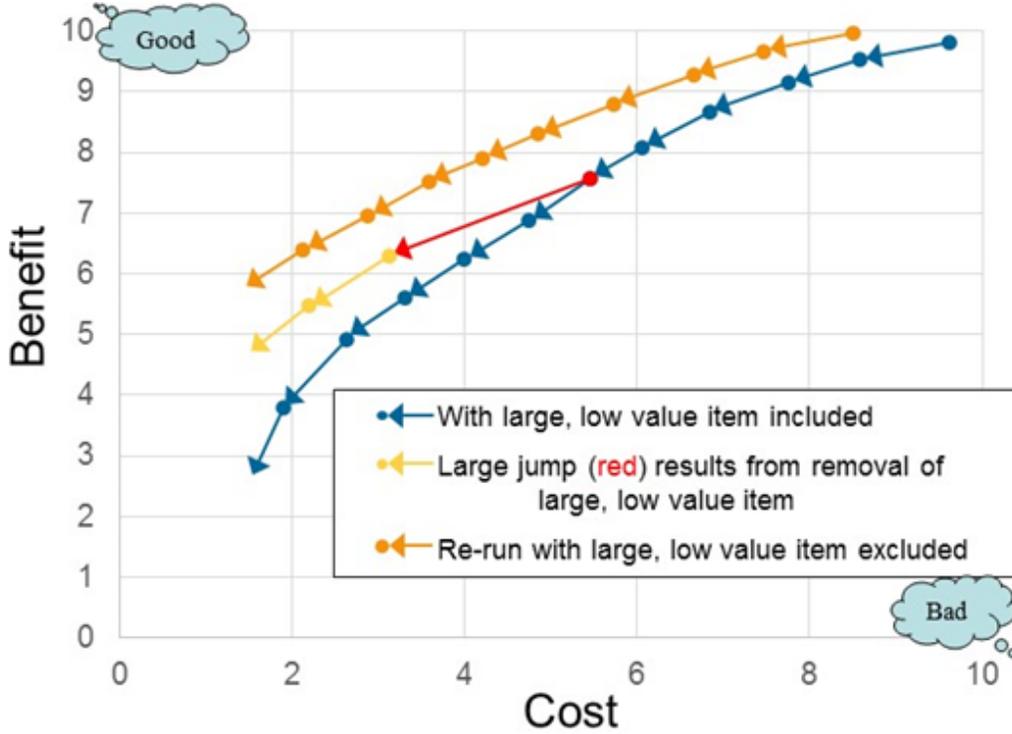
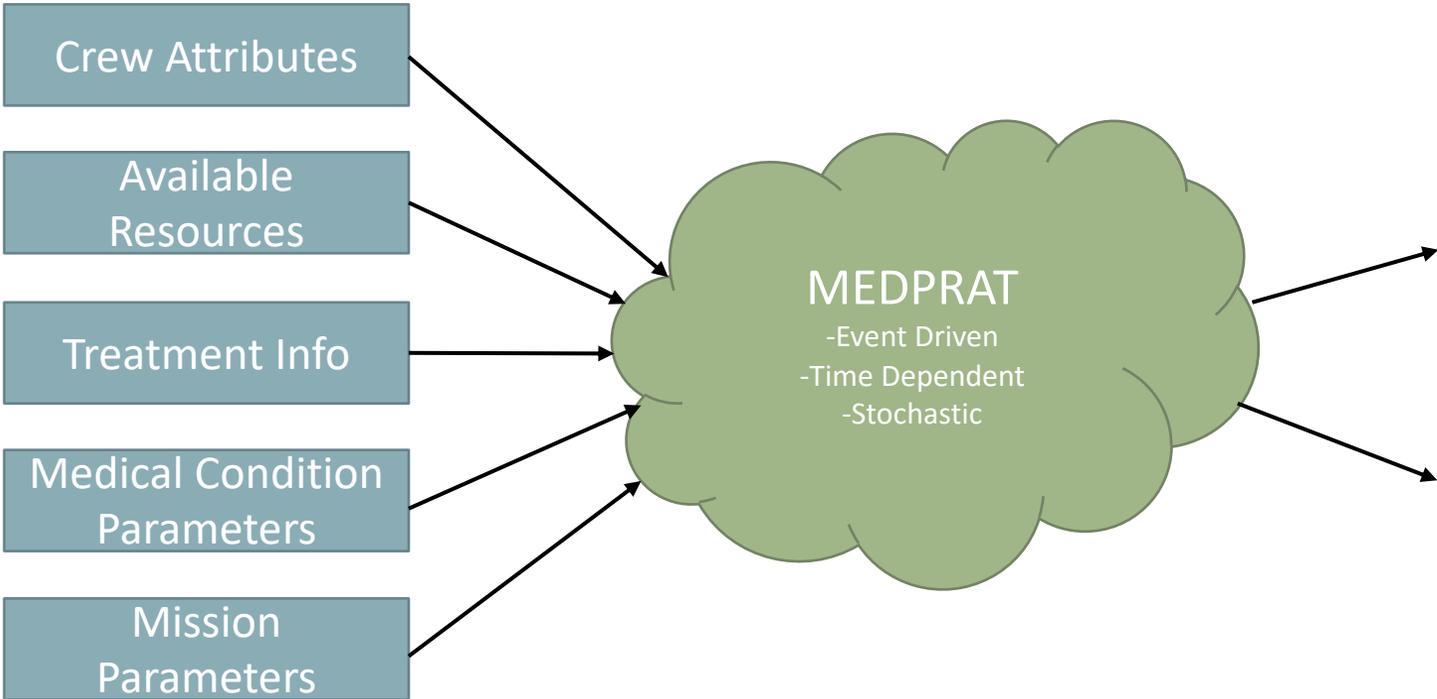
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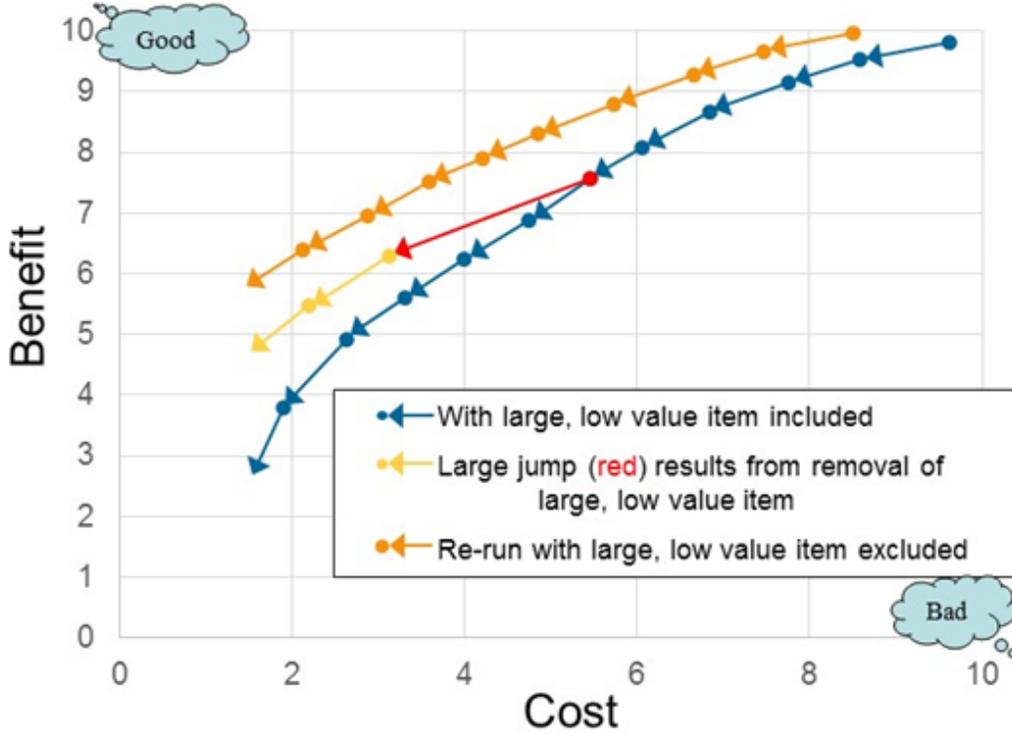
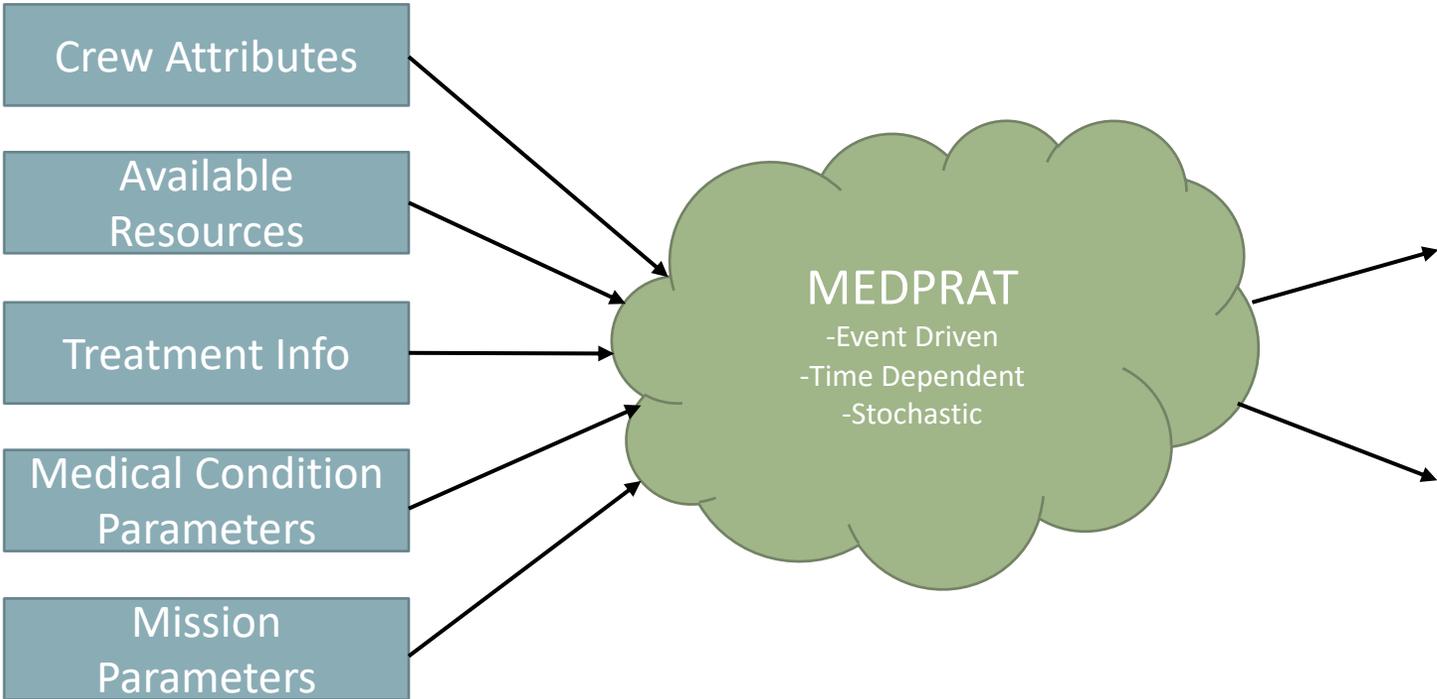
Resources Used per Mission



Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)

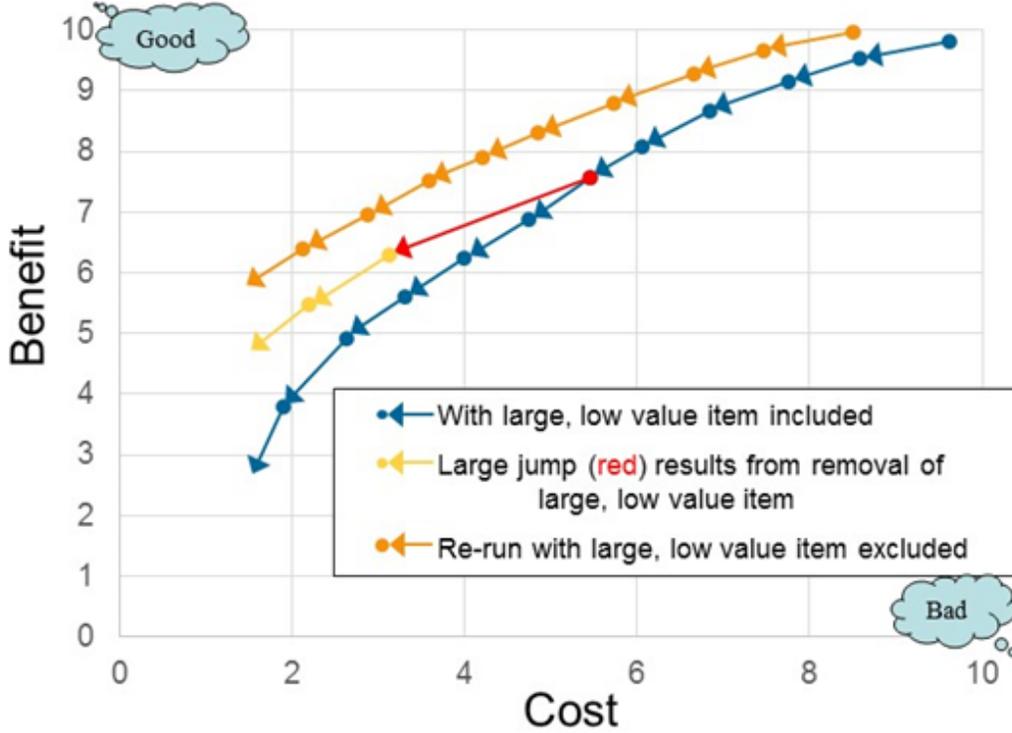
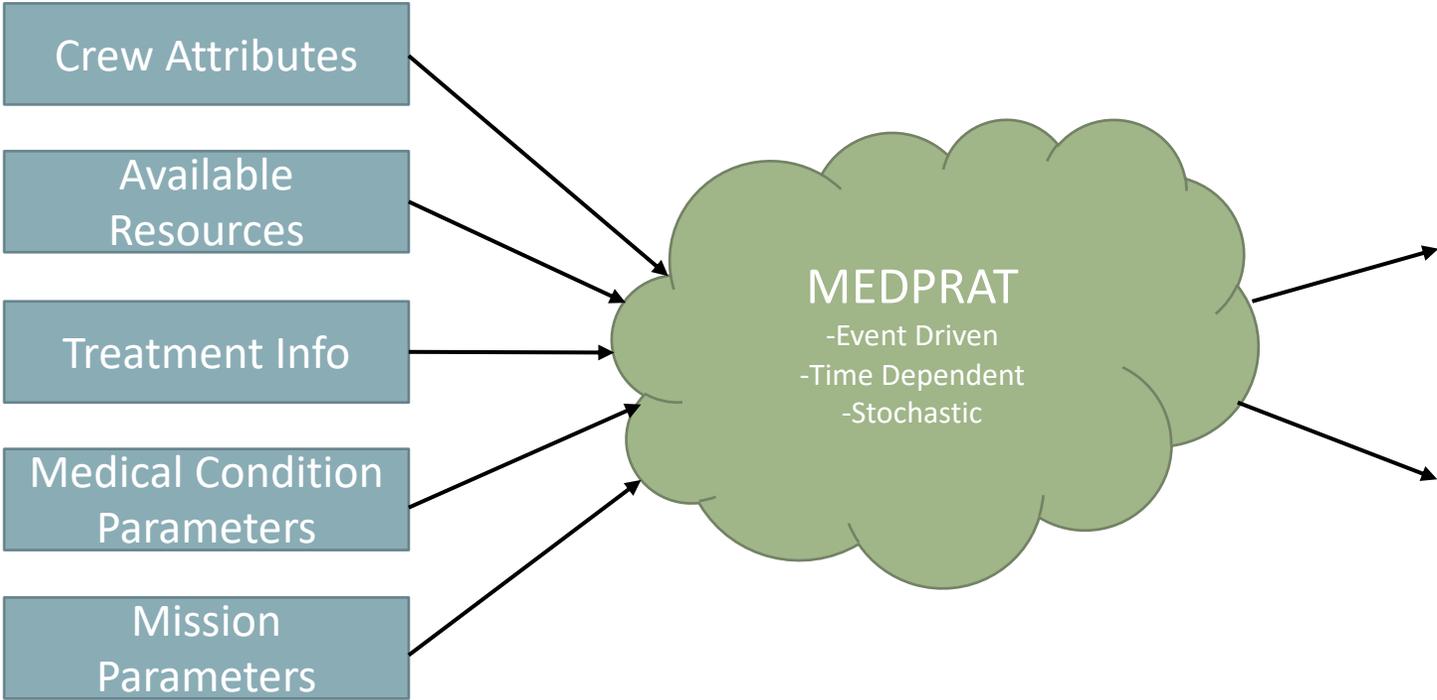


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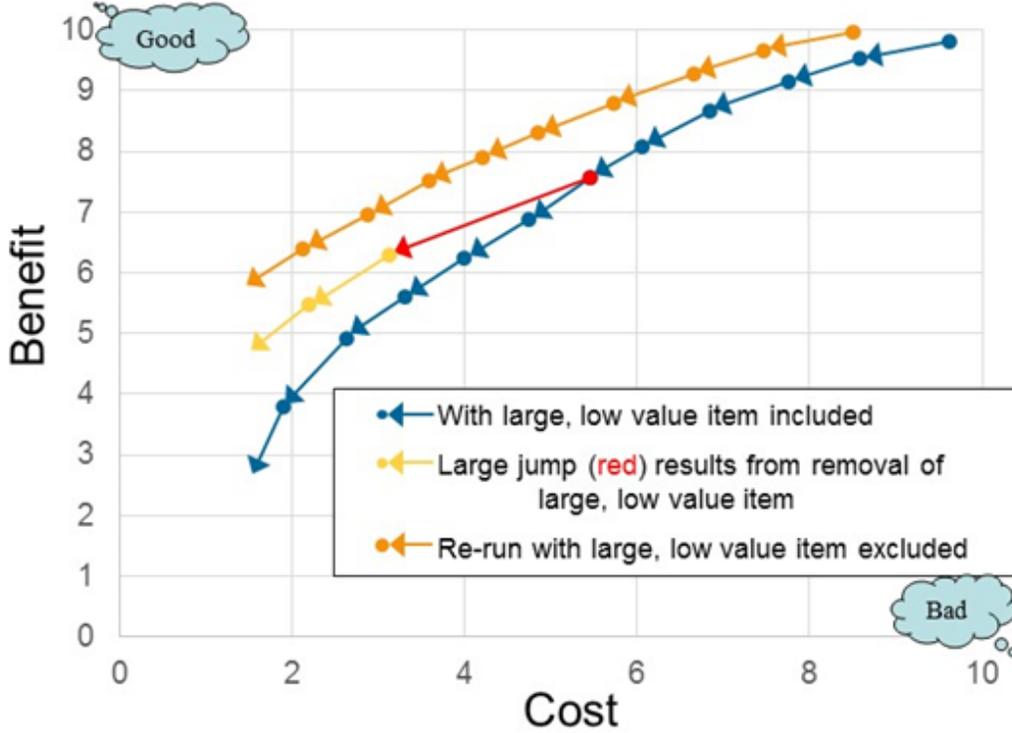
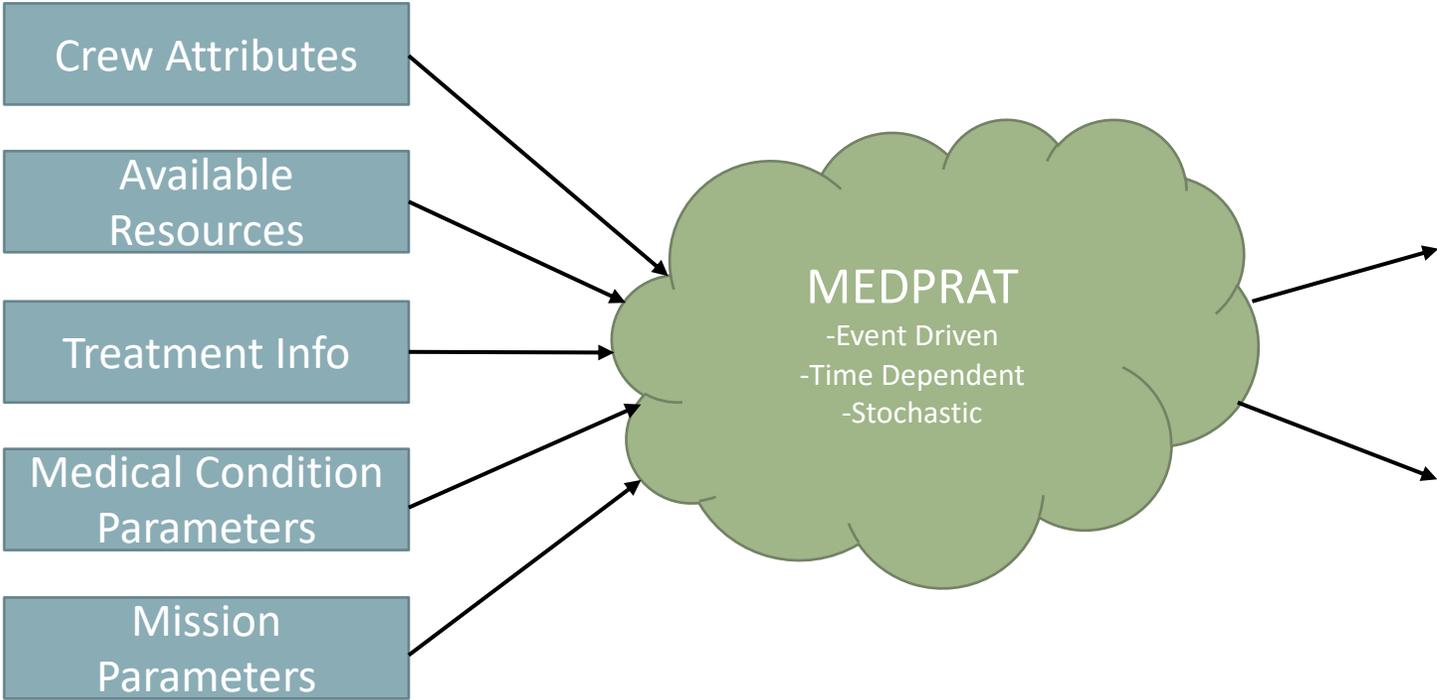
Given any Medical Equipment List (MEL) what is the level of risk?

Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



How is my risk impacted if I reduce the overall mass of a capability/resource?

Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



For a particular “allowable risk”, what is the optimal MEL, given power, mass, and volume requirements?

Simulated Medical Events



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EYE IRRITATION/ABRASION
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HEADACHE (CO2 INDUCED)
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SMOKE INHALATION
TOXIC EXPOSURE (AMMONIA)
BURNS SECONDARY TO FIRE
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SKIN ABRASION
SKIN LACERATION
ABDOMINAL INJURY
CHEST INJURY

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Approximately 100 conditions



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SKIN RASH



Approximately 100 conditions

IR sampled from specified probability distributions

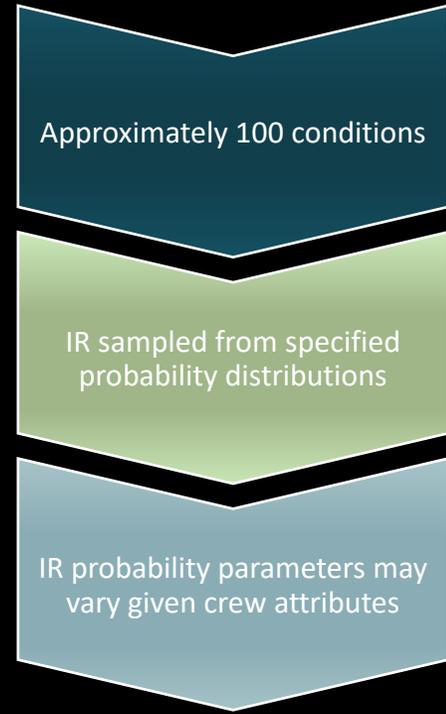
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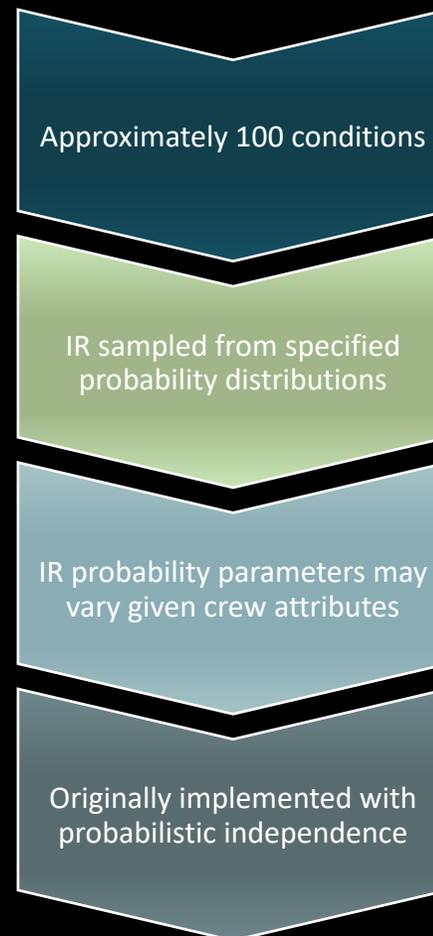
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Introducing Dependent Conditions

MEDPRAT provides a means of capturing relationships and dependencies between events being modeled.

These relationships are quantified using a mathematical data structure referred to as the Susceptibility Inference Network (SIN).

The SIN provides MEDPRAT with a “memory” which allows the system to use knowledge of what simulation events have occurred to appropriately alter the representative probability that future simulation events will occur.

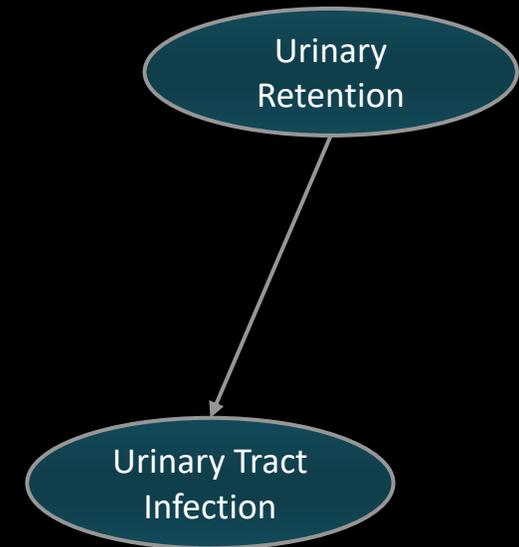


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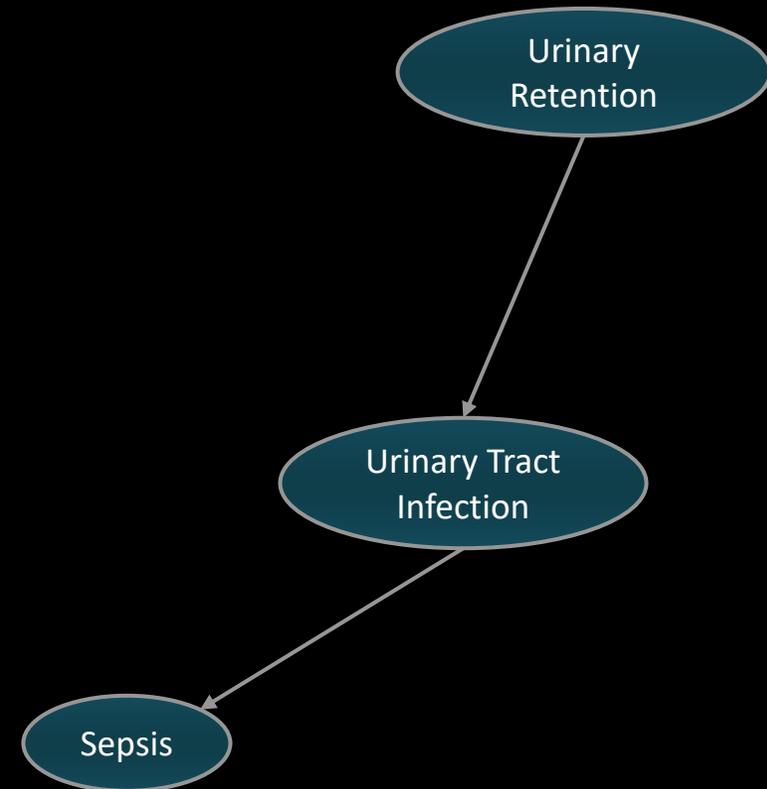


Introducing Dependent Conditions

MEDPRAT provides a means of capturing relationships and dependencies between events being modeled.

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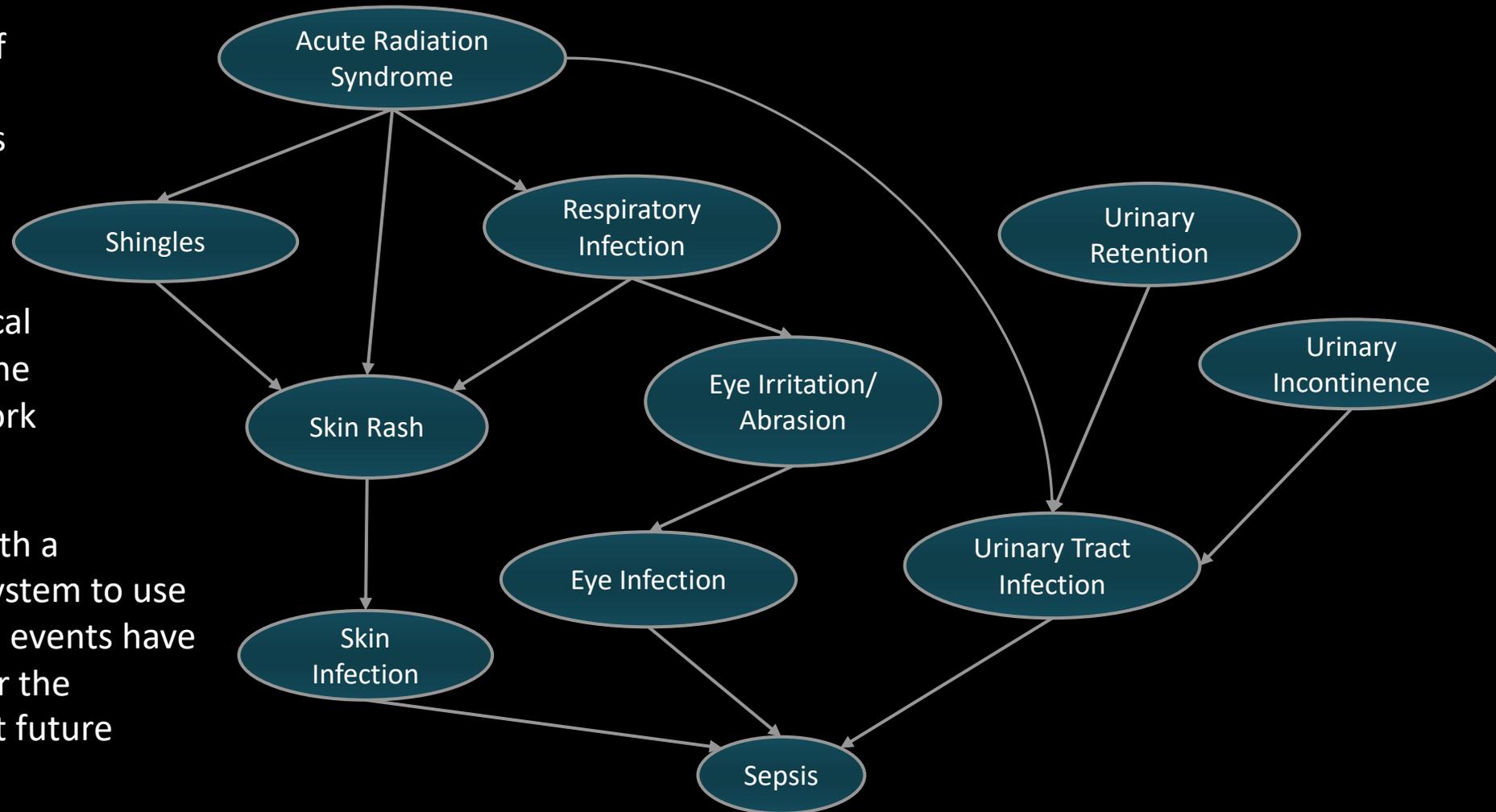


Introducing Dependent Conditions

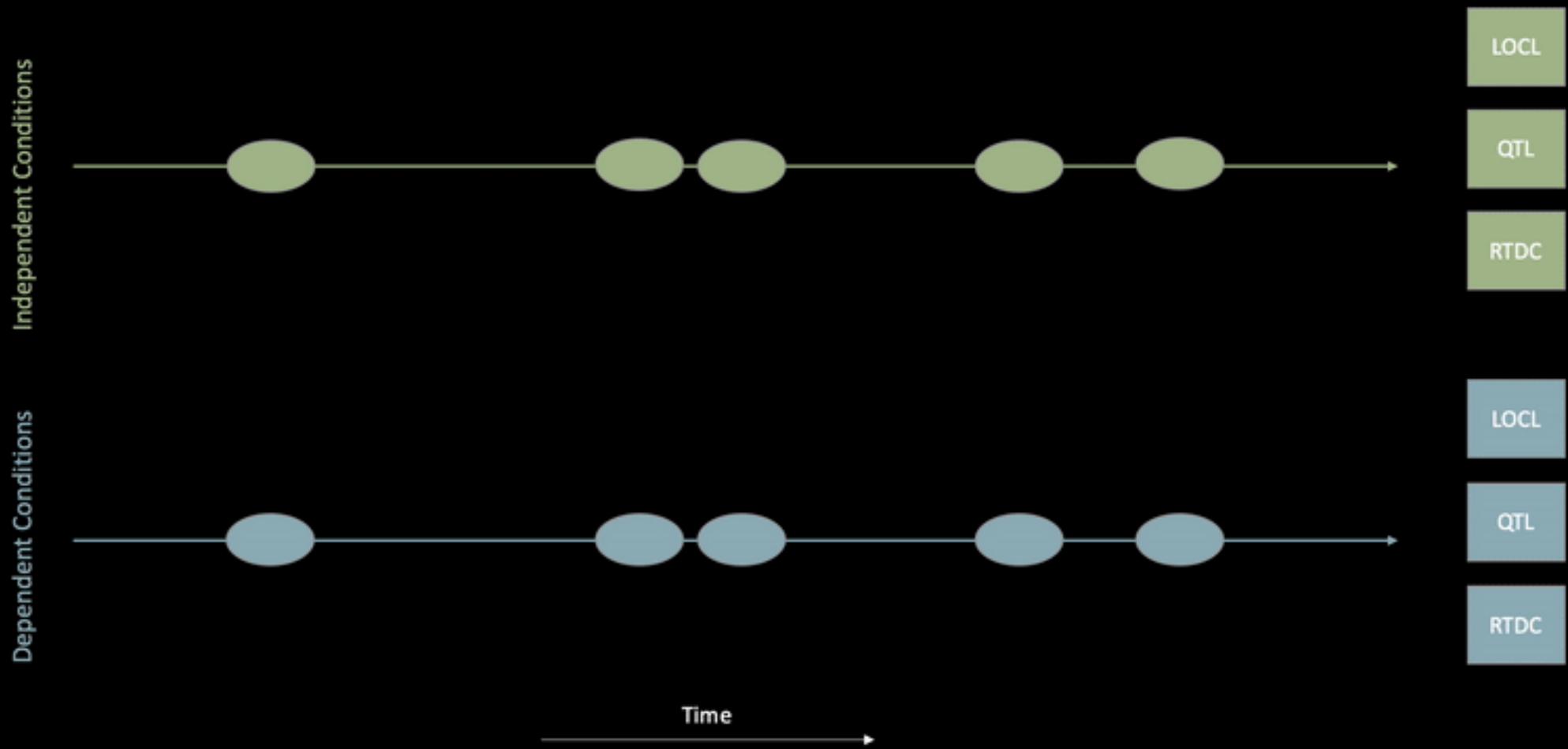
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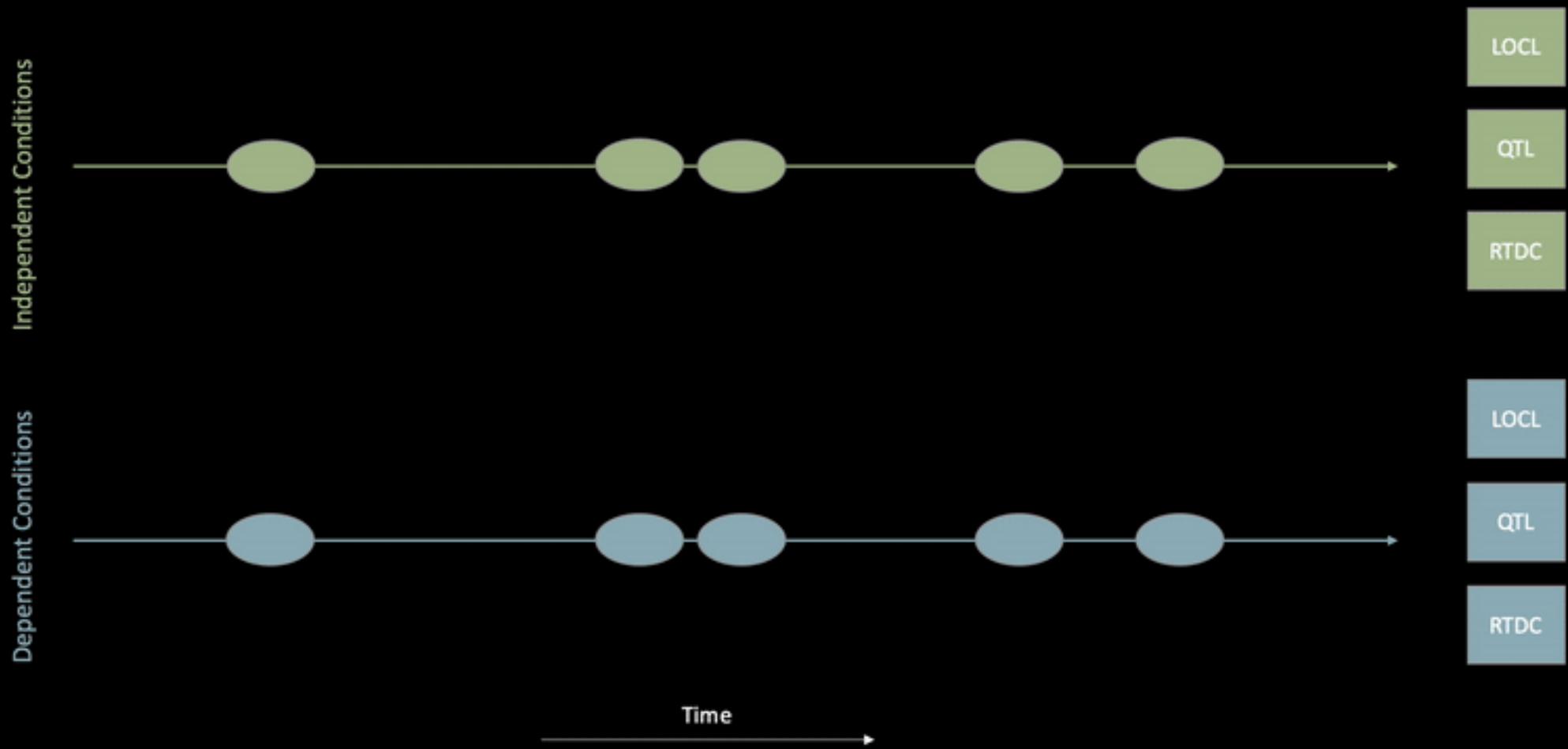
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Simulation with Independent Events



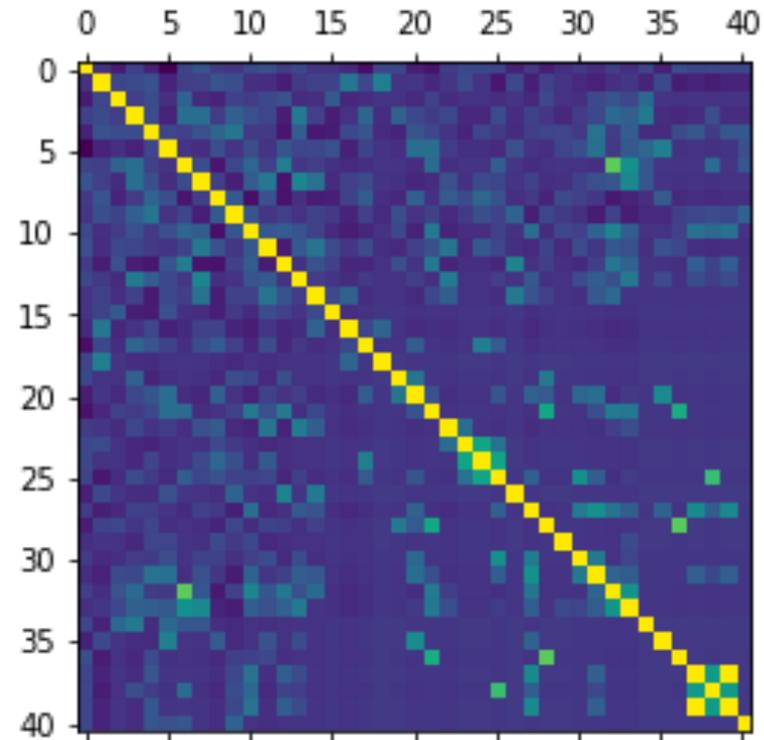
Simulation with Dependent Events



Spaceflight Data Assessment

Data request made to and fulfilled by
Lifetime Surveillance of Astronaut
Health (LSAH)

- De-identified
- Shuttle/ISS



Pearson Correlation

A number between $[-1,1]$ that indicates the extent to which two variables are linearly related.



Spaceflight Data Assessment

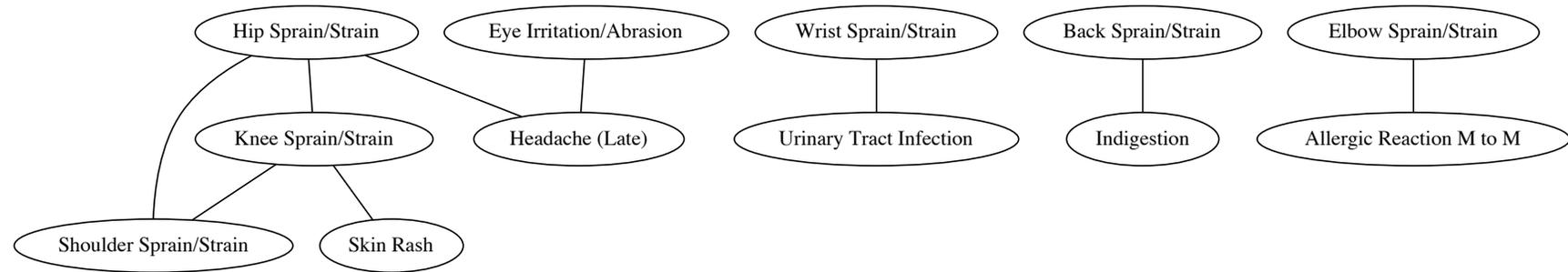
Data request made to and fulfilled by Lifetime Surveillance of Astronaut Health (LSAH)

- De-identified
- Shuttle/ISS

Condition	Condition	Correlation	P Value	Significant? (0.1)		
Knee Sprain/Strain	Shoulder Sprain/Strain	0.701	0.00001	TRUE		
Wrist Sprain/Strain	UTI	0.7	0.0799	TRUE		
Wrist Sprain/Strain	Skin Infection	0.534	0.1728	FALSE		
Respiratory Infection	Indigestion	0.626	0.1326	FALSE		
UTI	Skin Infection	0.506	0.2465	FALSE		
Gastroenteritis	Insomnia (SA)	0.304	0.0049	TRUE	Insomnia = 84	Gastroenteritis = 1
Hip Sprain/Strain	Headache (Late)	0.339	0.0401	TRUE		
Hip Sprain/Strain	Shoulder Sprain/Strain	0.403	0.0973	TRUE		
Eye Irritation/Abrasion	Headache (Late)	0.339	0.016	TRUE		
Knee Sprain/Strain	Skin Rash	0.341	0.0203	TRUE		
Eye Corneal Ulcer	Paresthesias	0.318	0.0991	TRUE	Paresthesias = 27	Eye Corneal Ulcer = 1
Neck Sprain/Strain	Skin Laceration	0.302	0.3964	FALSE		
Neck Sprain/Strain	HZR (Shingles)	0.492	0.262	FALSE		
Indigestion	Neck Sprain/Strain	0.49	0.2177	FALSE		
Back Sprain/Strain	Indigestion	0.392	0.0002	TRUE	Back S/S = 30	Indigestion = 5
Elbow Sprain/Strain	Allergic Reaction (M to M)	0.394	0.0464	TRUE		
Anxiety	Allergic Reaction (M to M)	0.357	0.1746	FALSE		
VIIP	Allergic Reaction (M to M)	0.357	0.1746	FALSE		
Hip Sprain/Strain	Knee Sprain/Strain	0.411	0.0174	TRUE		
Respiratory Infection	Anxiety	0.442	0.7085	FALSE		
VIIP	Respiratory Infection	0.442	0.558	FALSE		

Spaceflight Data Assessment

- 40 out of ~100 conditions are observed
- 15 conditions observed 20 or more times
- Of those, 6 are space adaptation conditions

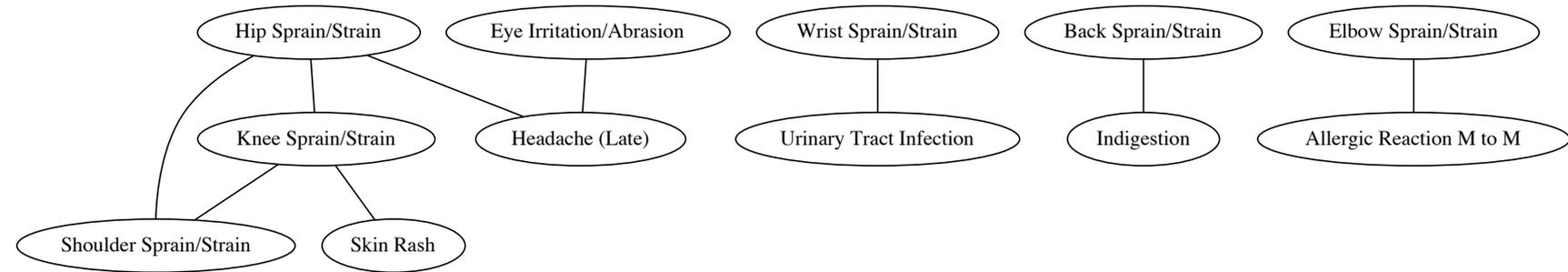


Spaceflight Data Assessment

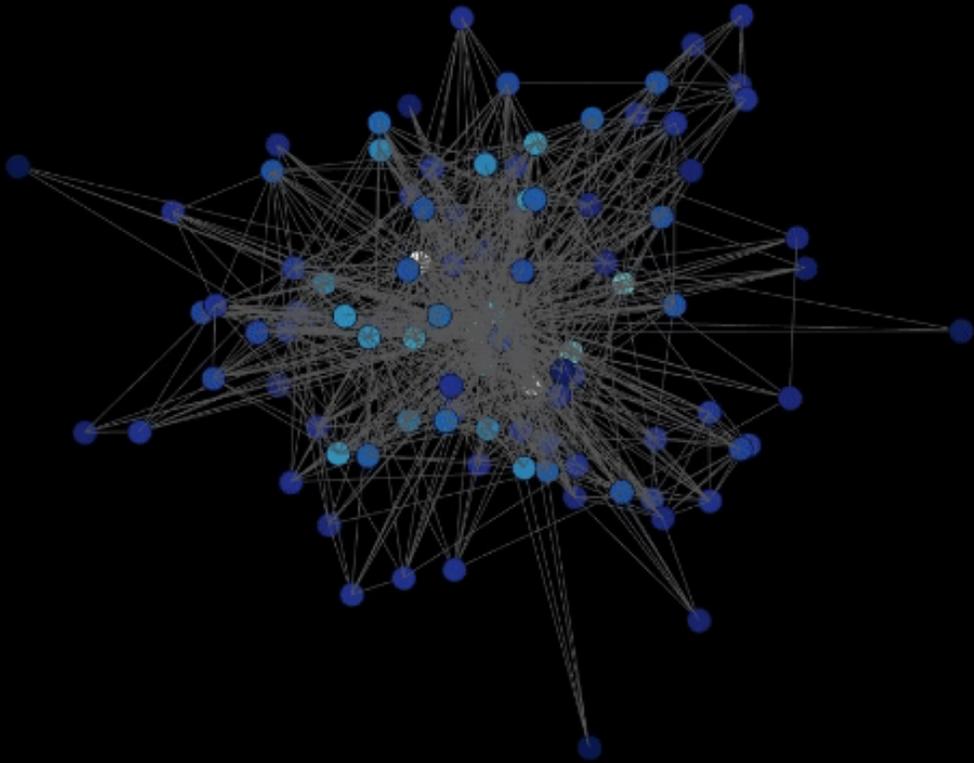
Conclusion:

This data set is not robust enough to inform the SIN. Even with more spaceflight data, we cannot accurately capture the associated risk, particularly to LOCL, without data for high impact conditions such as sepsis, shock, and myocardial infarction.

In order to obtain a data-driven model, we will need significantly more data, likely in the form of spaceflight data, terrestrial data, and medical literature.



Result of Clinician Specified SIN



- 1078 connections identified
- 275 connections as a result of
 - Anxiety
 - Atrial Fibrillation/Atrial Flutter
 - Medication Overdose/Adverse Reaction
- Median of 7 connections per condition
- Maximum number of parents 97 (Anxiety)
- Maximum number of children 43 (Acute Radiation Syndrome)

- Sufficiently complex to require change in MEDPRAT architecture
- May provide roadmap for data acquisition in highly connected or high impact areas

- MEDPRRAT V1.0 Delivery 3/2020
 - Architecture update: calculate incidence rate updates as needed as opposed to during pre-processing to accommodate potentially large numbers of parent conditions
 - Finalize documentation
 - Review and deliver to ExMC
- MEDPRAT V2.0
 - Expand to integrate risks across HRP Elements
 - Proposed 2 to 3-year development plan
 - Within 6 Months -Identify and prioritize capabilities to characterize (iPRR) discipline risk
 - Likely supply intermediate development versions for discipline testing



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