



# Dynamic Medical Risk Assessment Supported by Inference Networks

L. McIntyre<sup>1</sup>, L. Leinweber<sup>2</sup>, J. Myers<sup>1</sup>

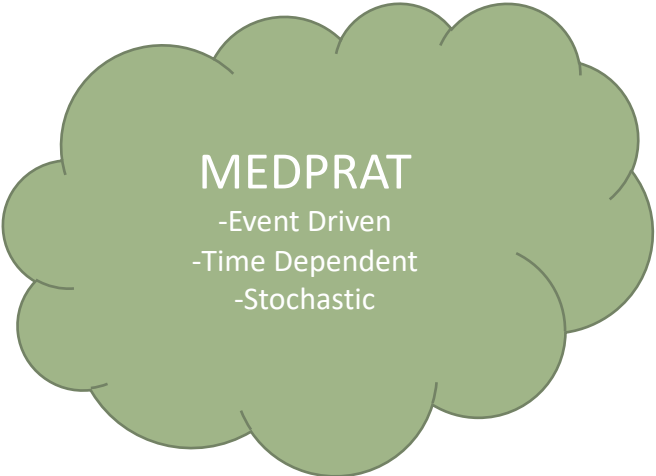
<sup>1</sup>NASA Glenn Research Center

<sup>2</sup>ZIN Technologies, Inc.



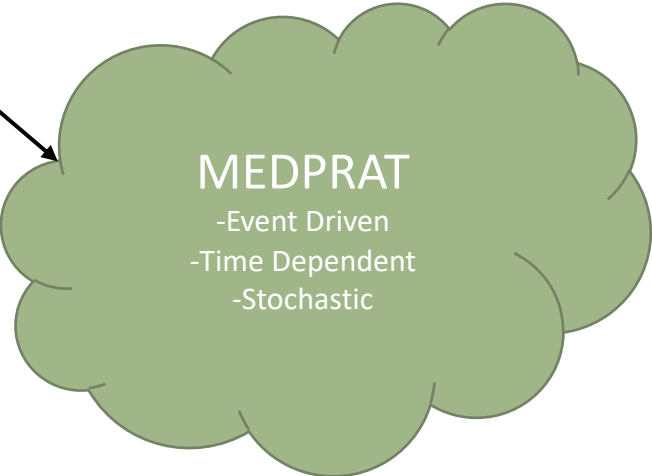
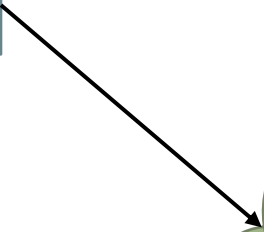


# Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



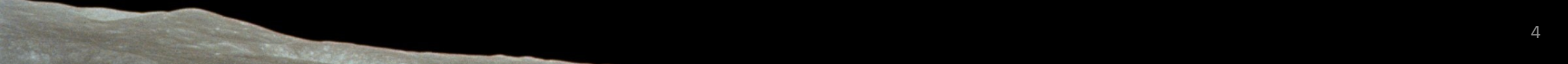


Crew Attributes

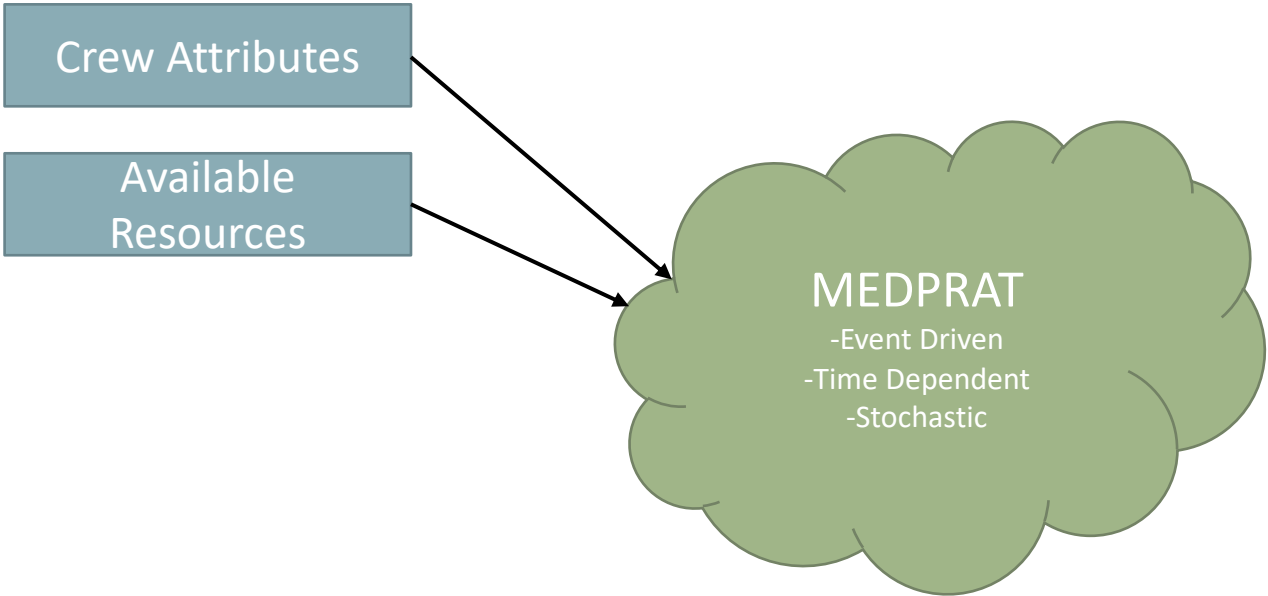


### Crew Attributes

- Gender
- Dental Crowns
- Contacts
- H<sub>x</sub> abdominal surgery
- EVA



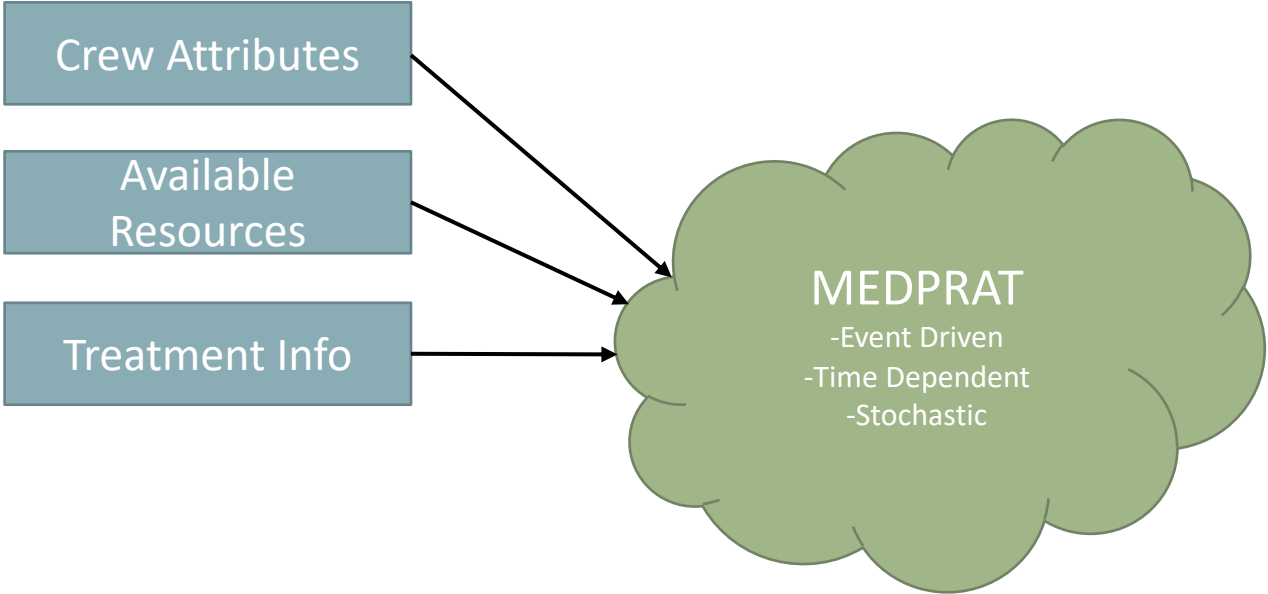
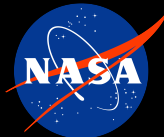
# Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



## Available Resources

- Initial quantity
- Consumable
- Essential
- Mass
- Volume

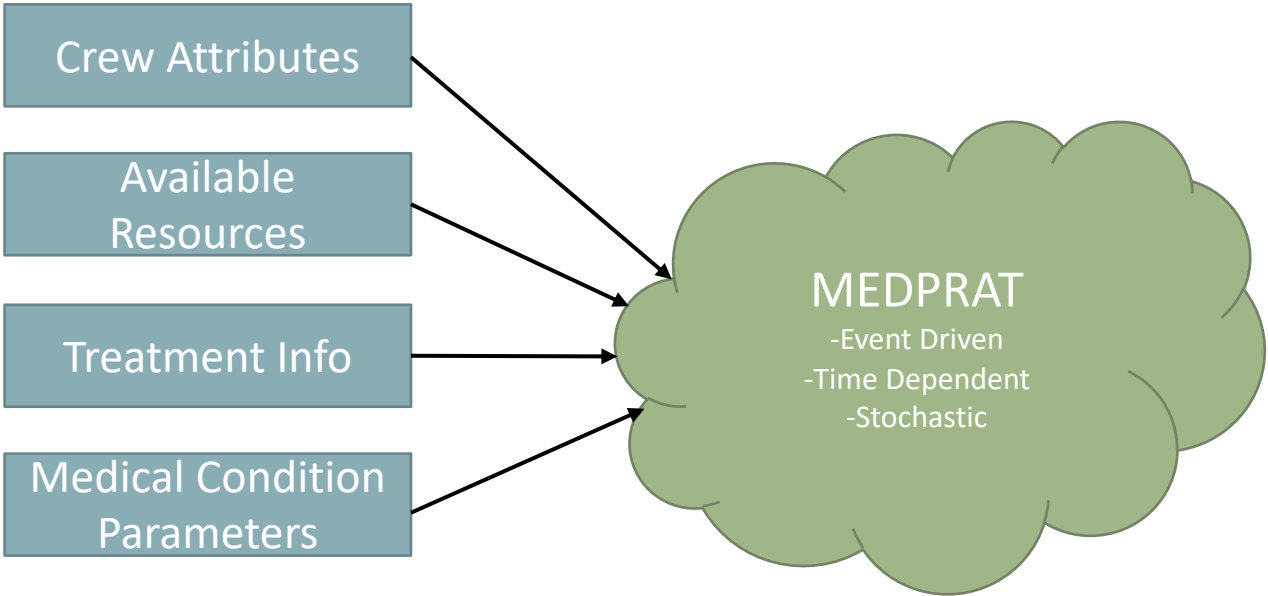
# Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



## Treatment Info

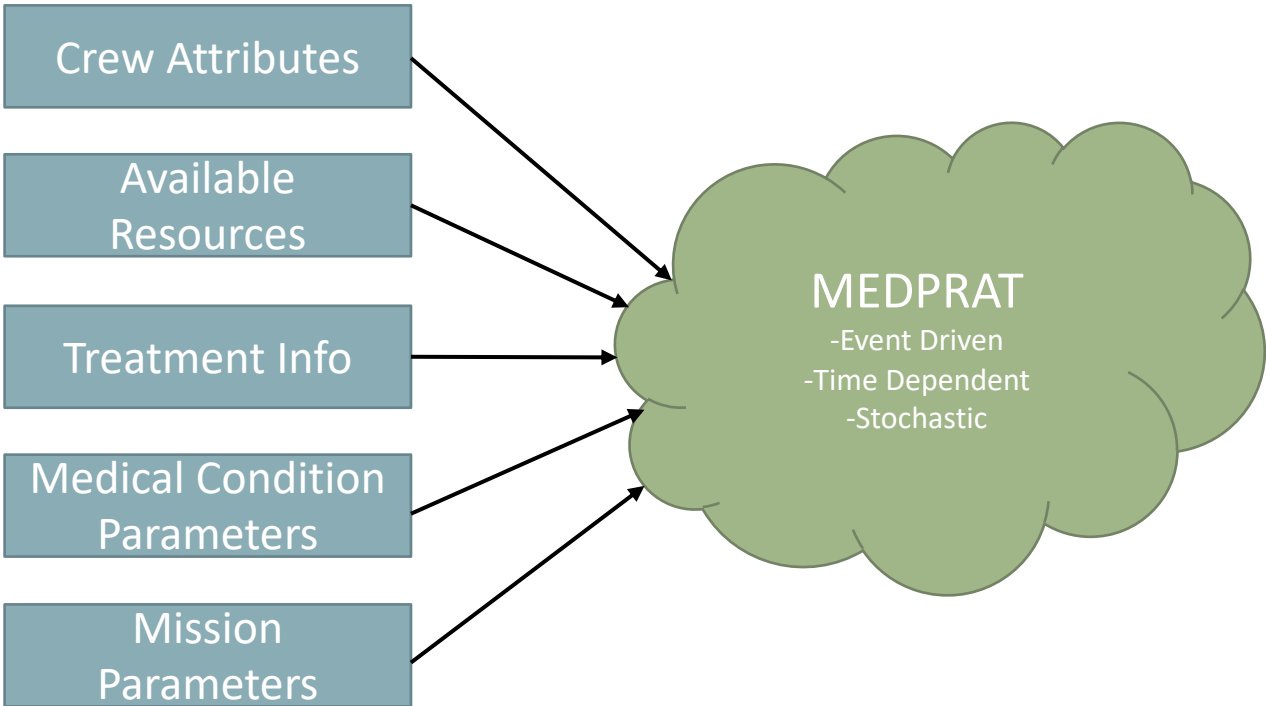
- Condition
- Resource
- Dose

# 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)

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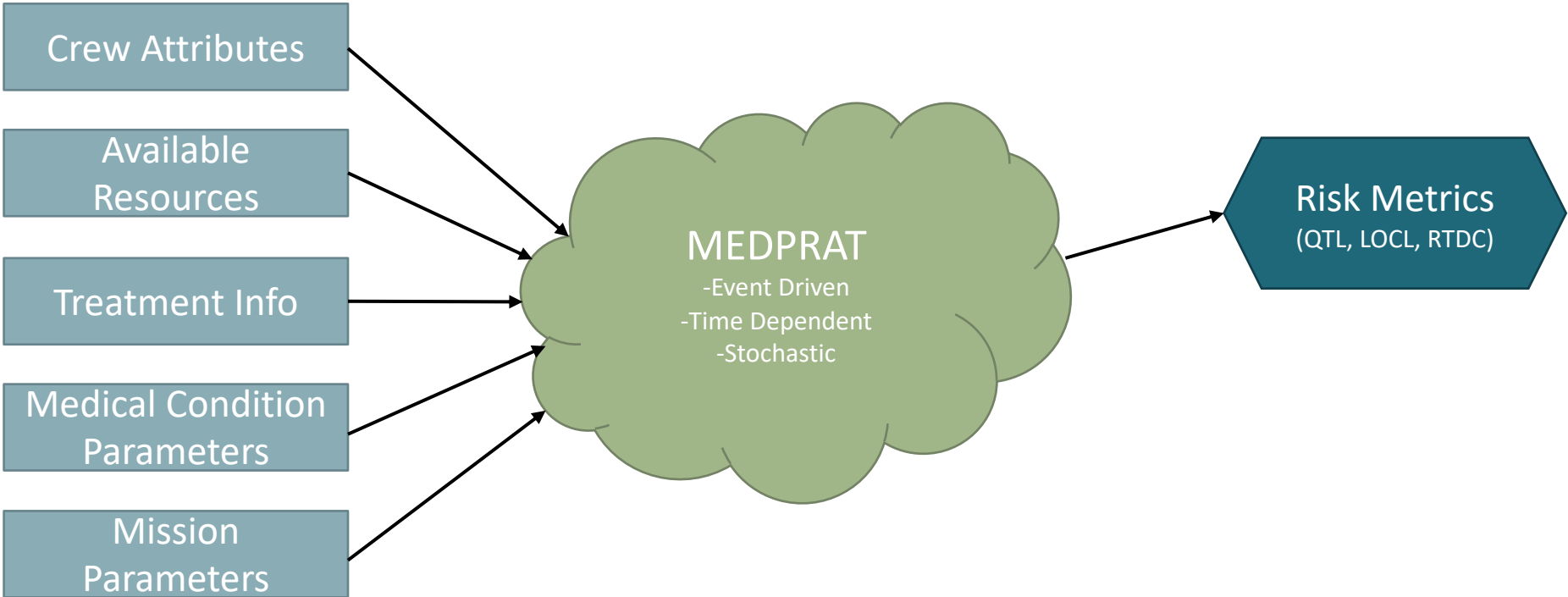


## Mission Parameters

- # Crew
- Mission duration
- EVA schedule



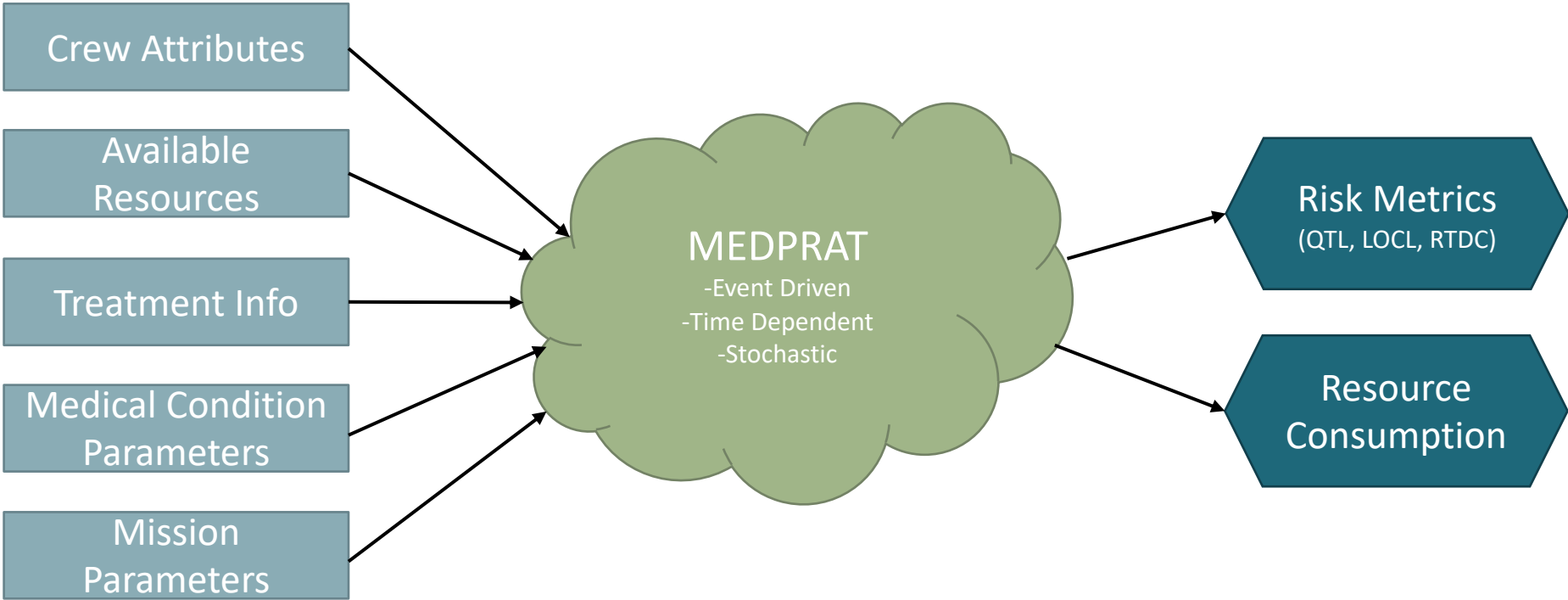
# Medical Extensible Dynamic Probabilistic Risk Assessment Tool (MEDPRAT)



## Risk Metrics

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

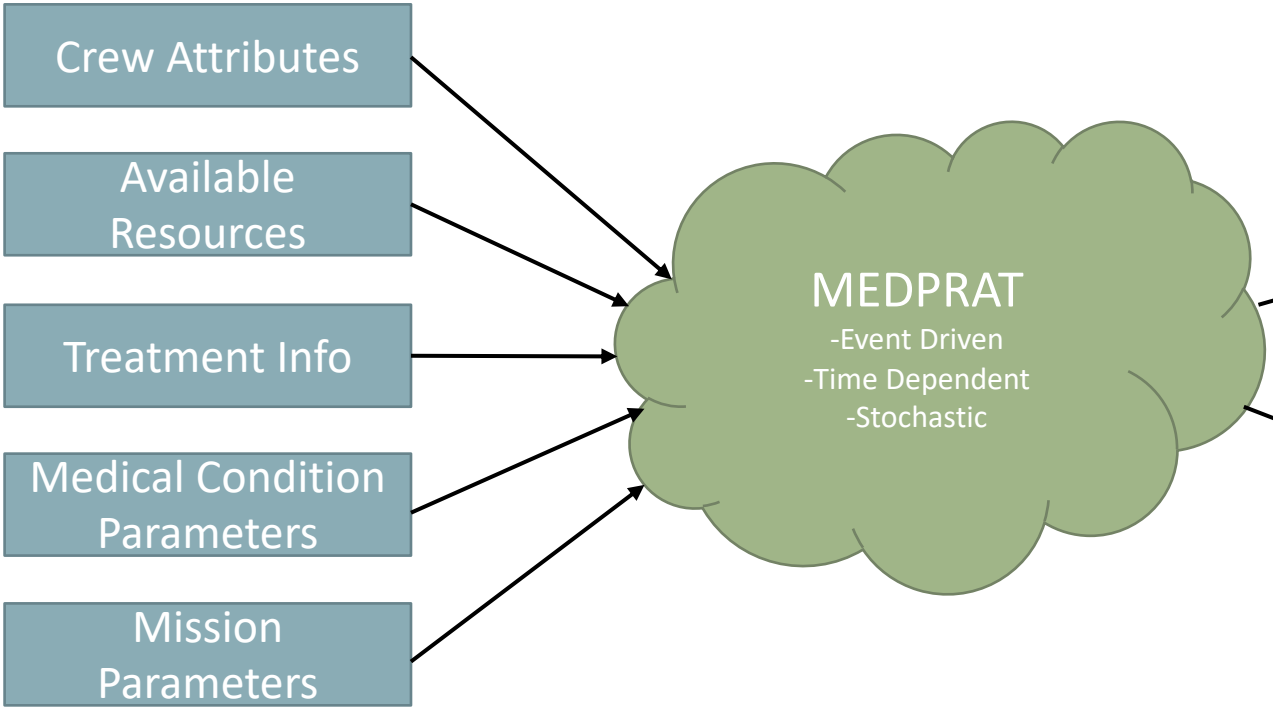
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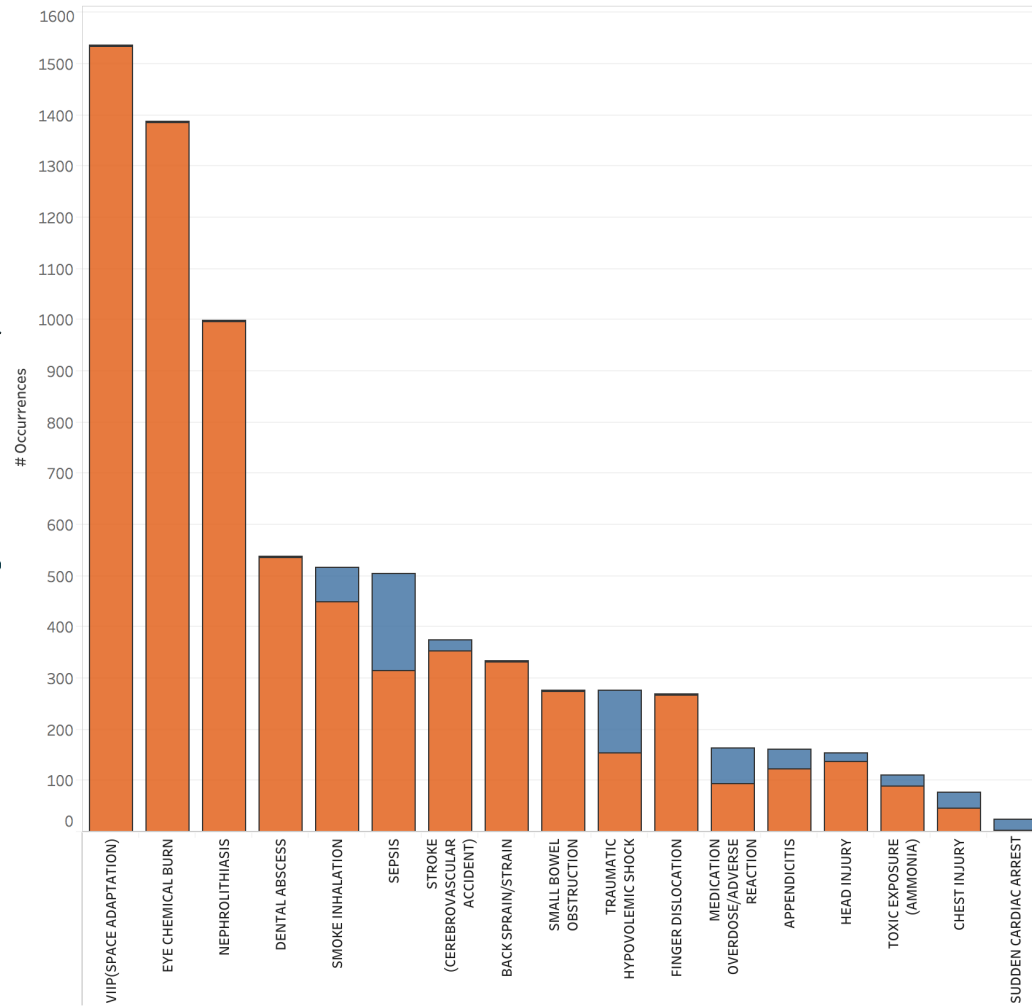
## Resource Consumption

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

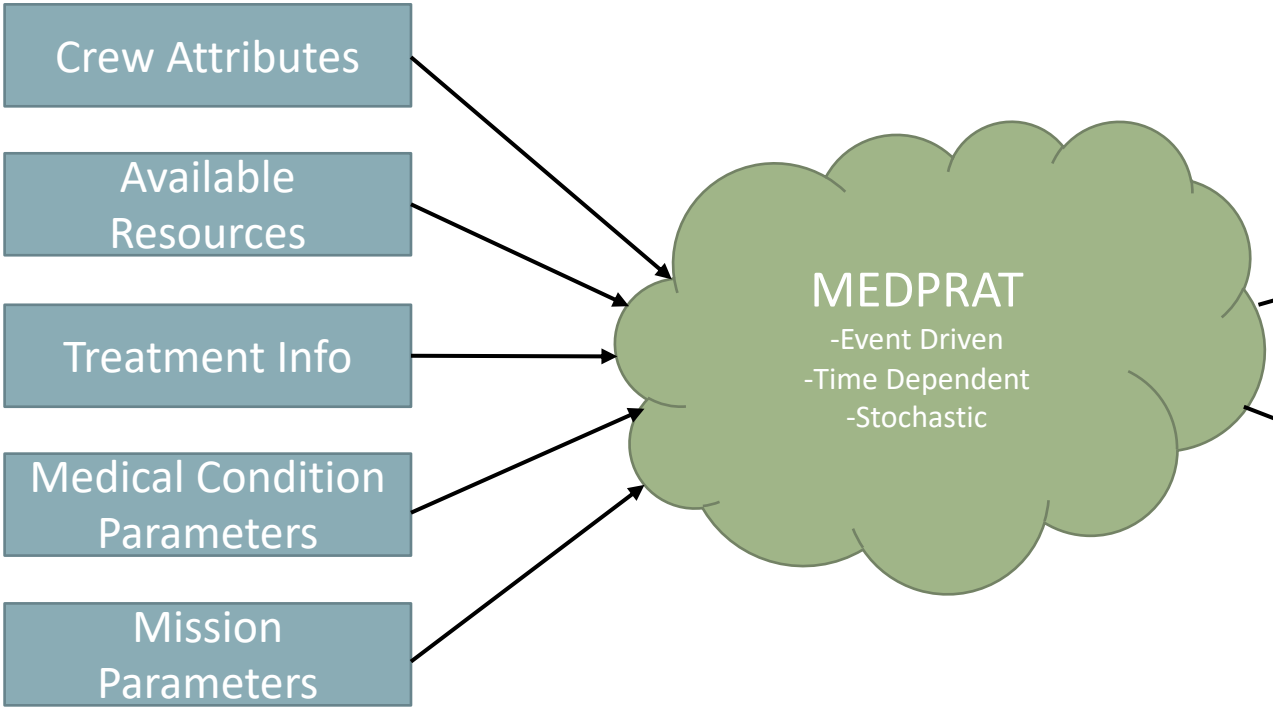
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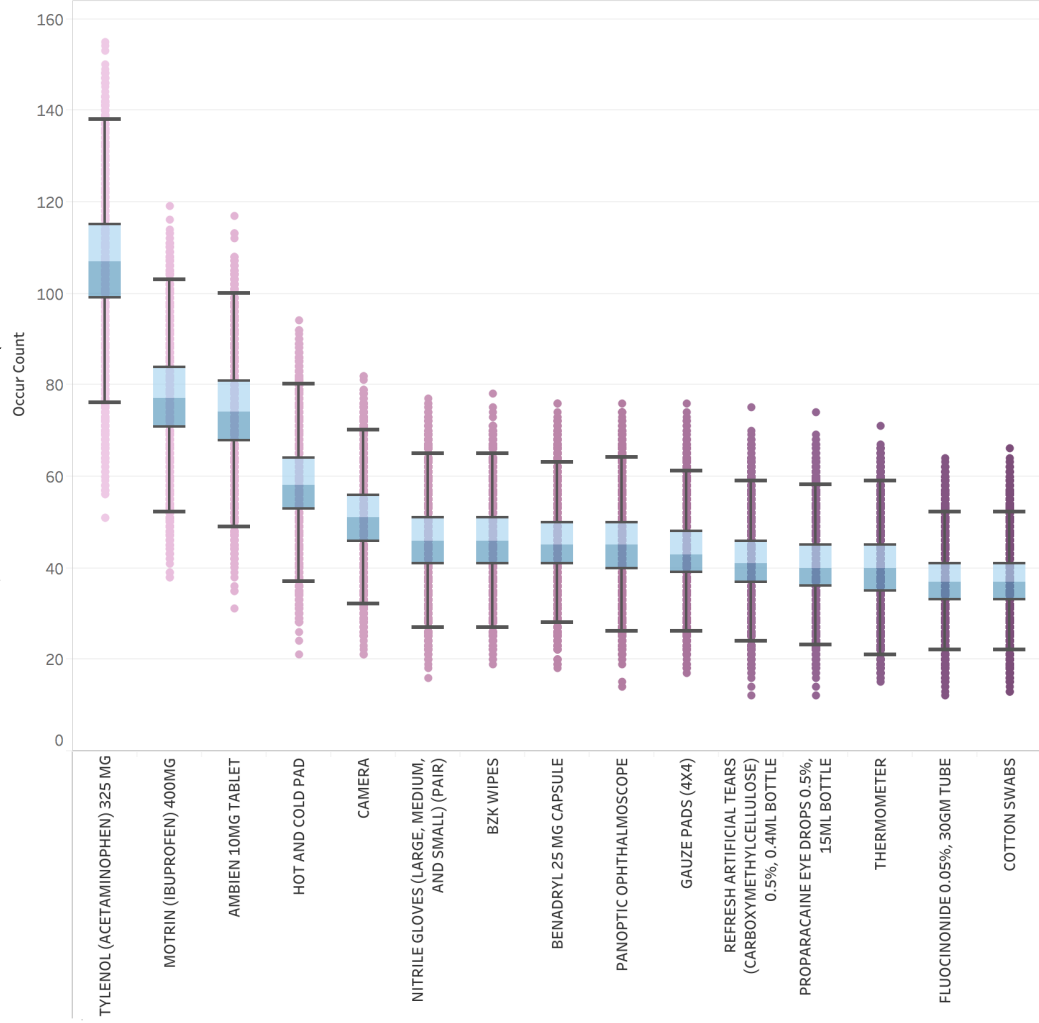
LOCL/EVAC Breakdown for Top 10 Contributing Conditions



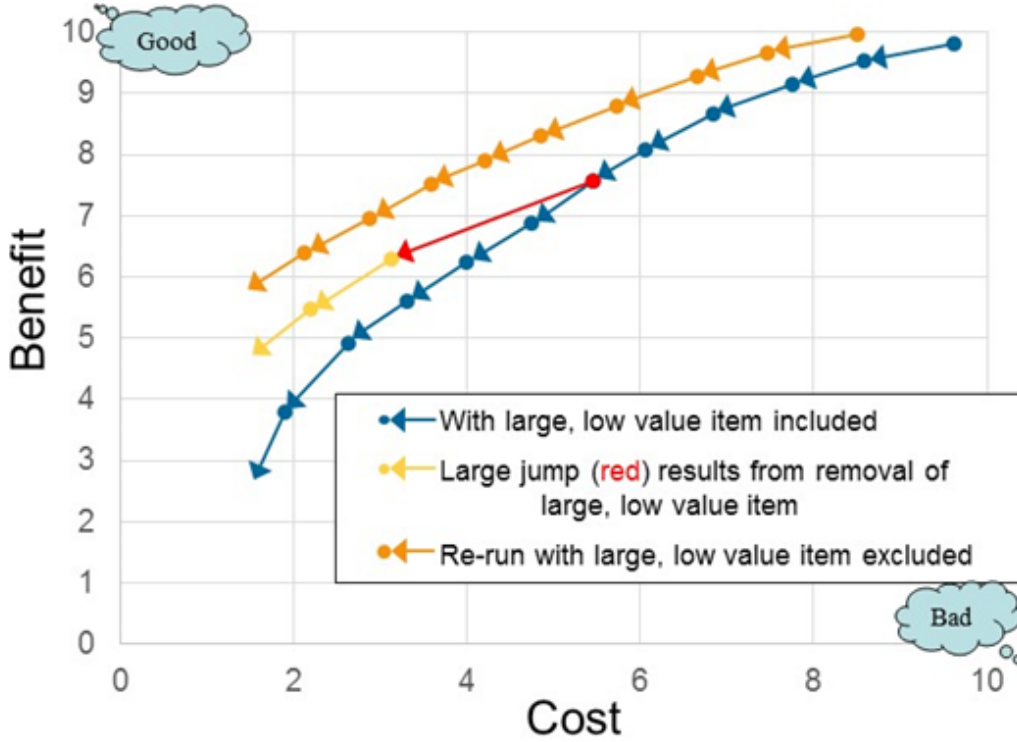
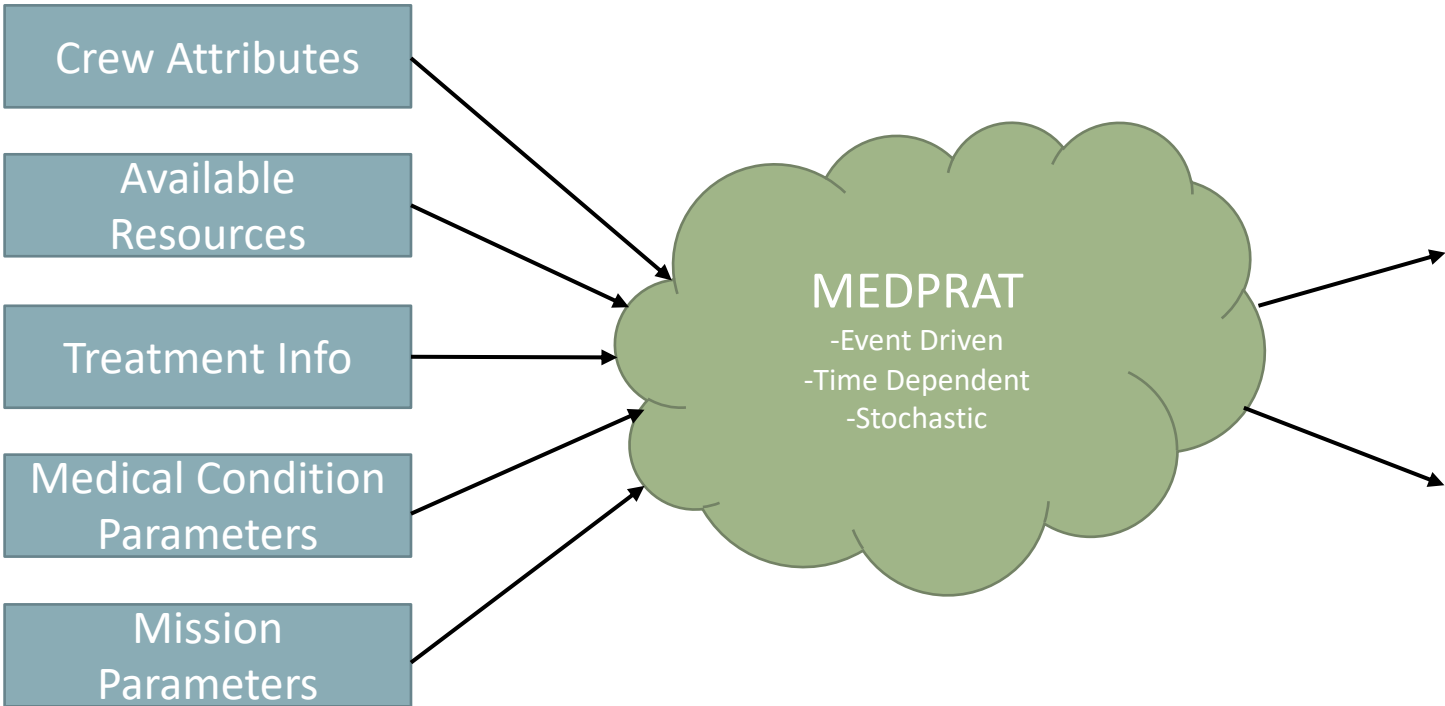
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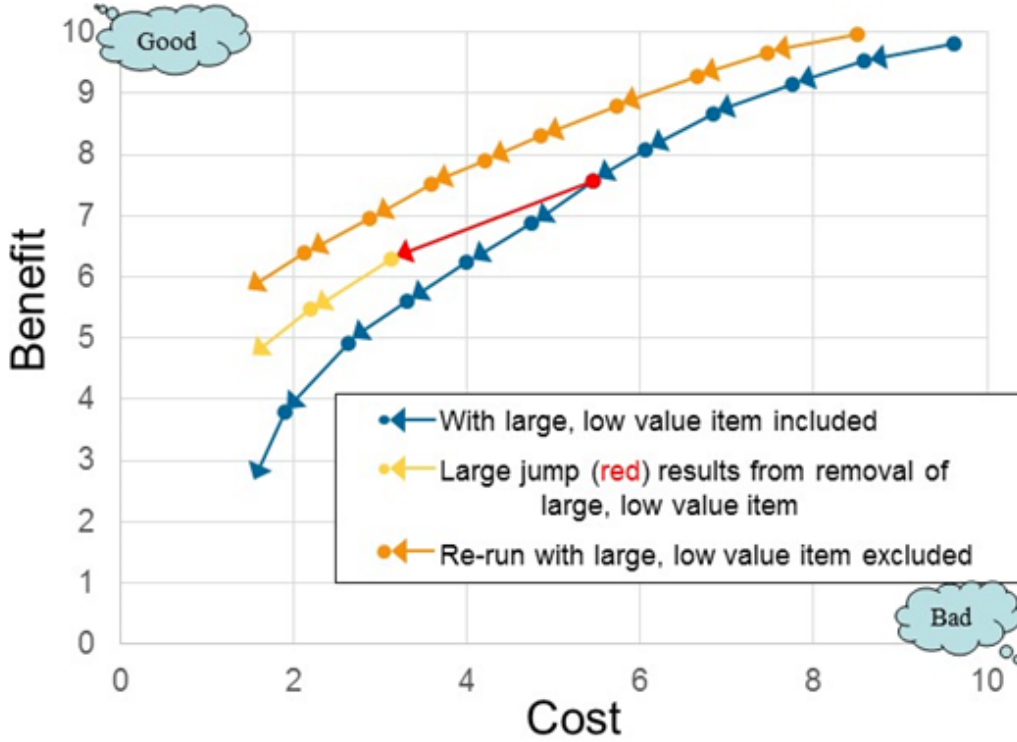
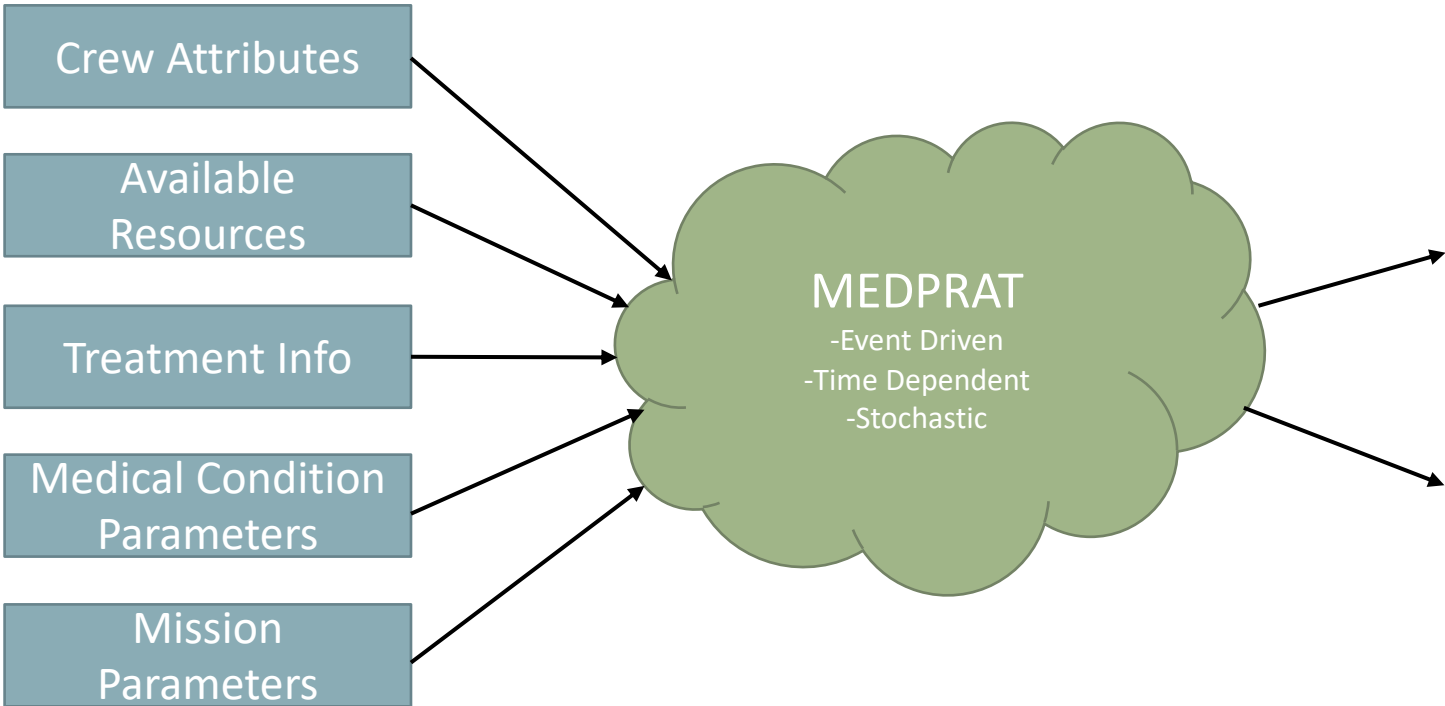
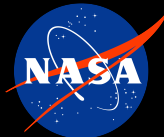
Resources Used per Mission



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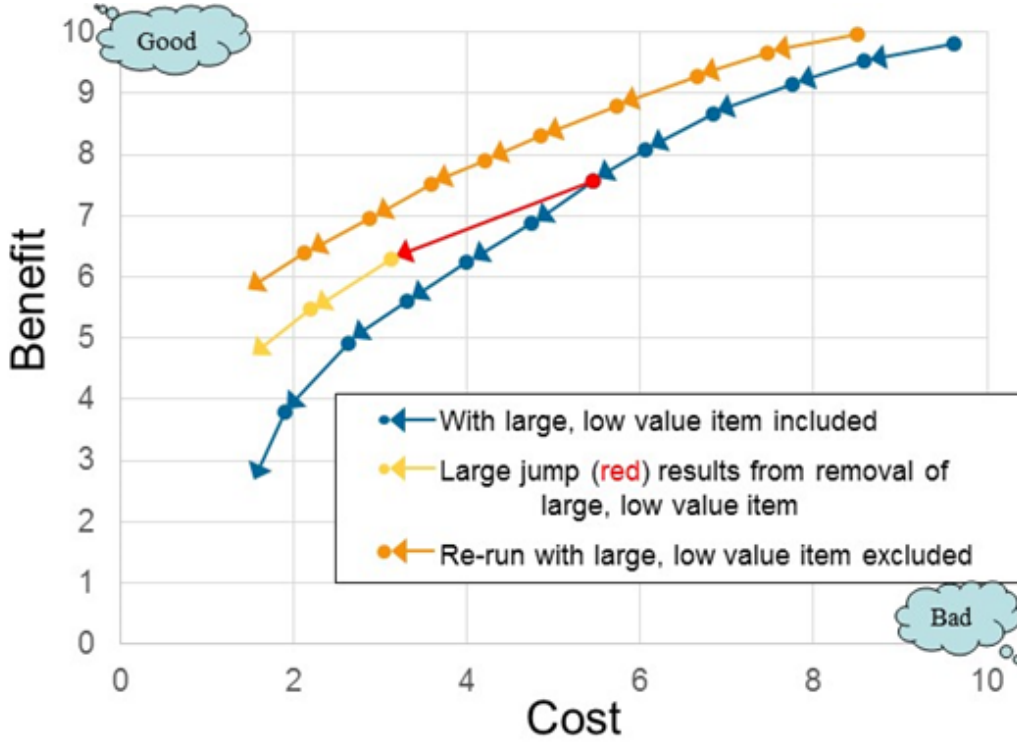
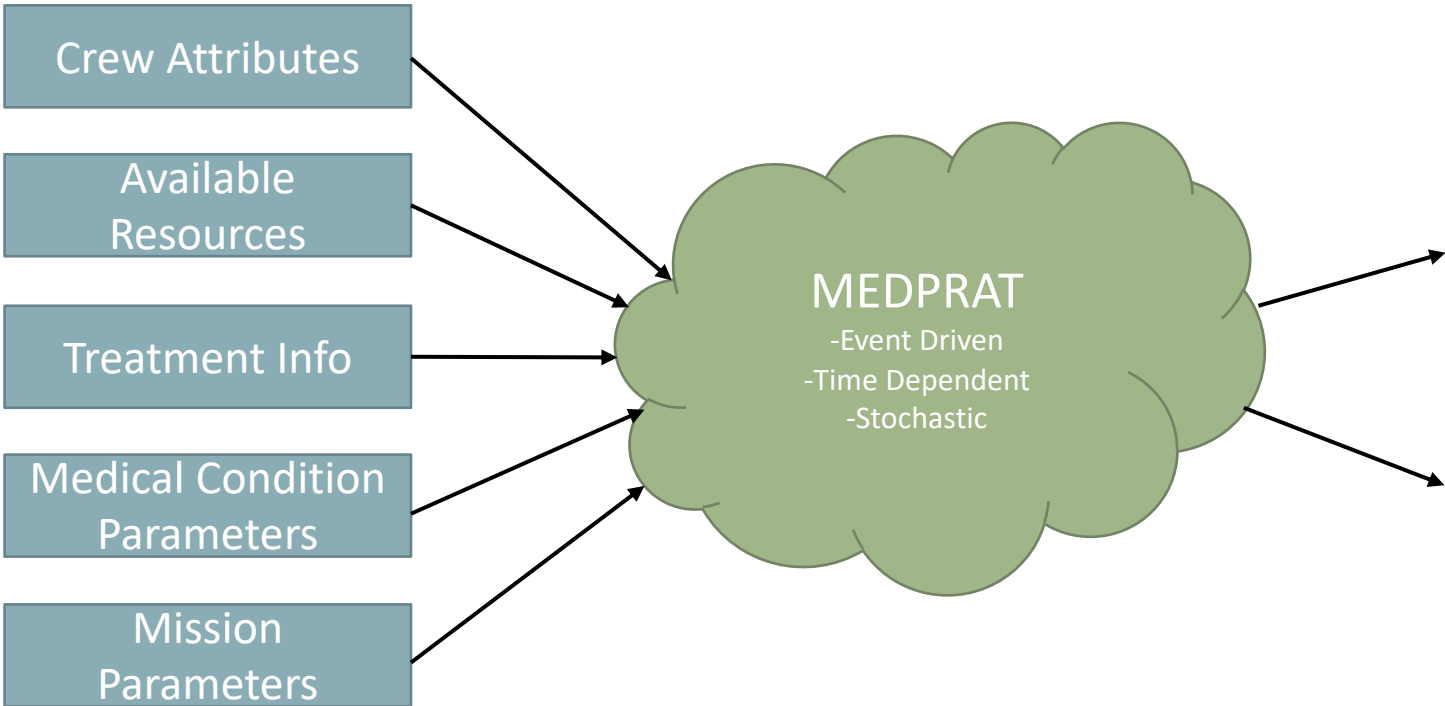


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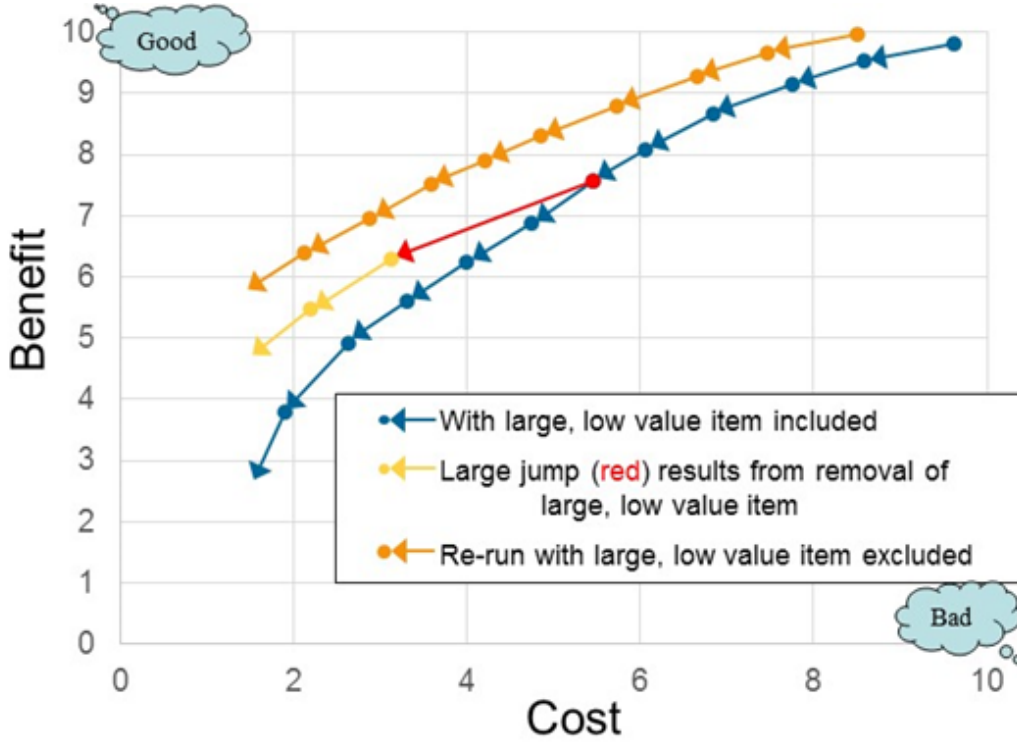
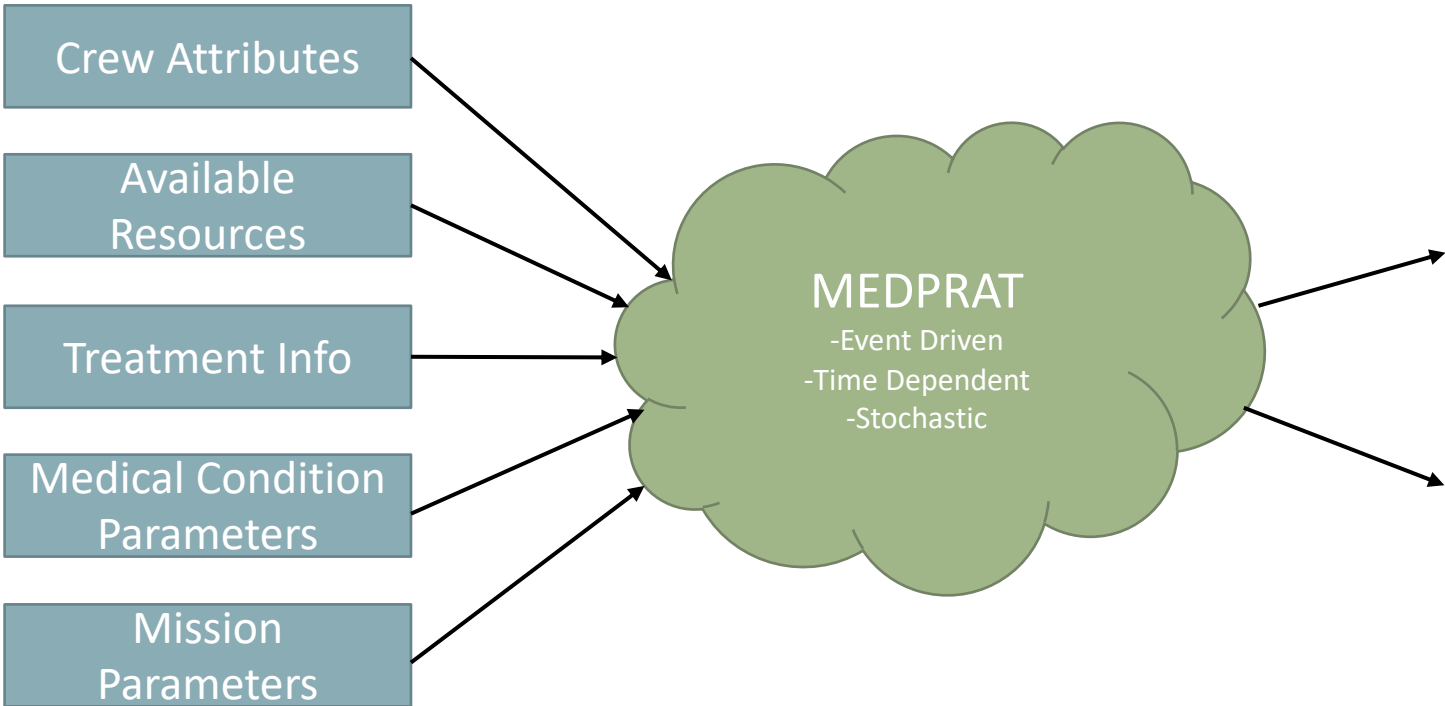
Given any Medical Equipment List (MEL) what is the level of risk?

# 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



HIP/PROXIMAL FEMUR FRACTURE  
MEDICATION OVERDOSE/ADVERSE REACTION  
FINGERNAIL DELAMINATION SEC TO EVA  
HERPES ZOSTER REACTIVATION (SHINGLES)  
ACUTE CHOLECYSTITIS/BILIARY COLIC  
LOWER EXTREMITY STRESS FRACTURE  
DECOMPRESSION SICKNESS SECONDARY TO EVA  
CARDIOGENIC SHOCK SEC TO MYOCARDIAL INFARCTION  
BAROTRAUMA (EAR/SINUS BLOCK)  
EYE PENETRATION (FOREIGN BODY)  
STROKE (CEREBROVASCULAR ACCIDENT)  
ACUTE COMPARTMENT SYNDROME  
ACUTE ANGLE-CLOSURE GLAUCOMA  
ATRIAL FIBRILLATION/ ATRIAL FLUTTER  
ACUTE COMPARTMENT SYNDROME  
ABNORMAL UTERINE BLEEDING  
SMALL BOWEL OBSTRUCTION  
DENTAL AVULSION (TOOTH LOSS)  
TRAUMATIC HYPOVOLEMIC SHOCK  
ANGINA/MYOCARDIAL INFARCTION  
RETINAL DETACHMENT  
RESPIRATORY INFECTION  
DENTAL EXPOSED PULP  
EYE IRRITATION/ABRASION  
FINGER DISLOCATION  
HEADACHE (CO2 INDUCED)  
ACUTE ARTHRITIS  
SMOKE INHALATION  
TOXIC EXPOSURE (AMMONIA)  
BURNS SECONDARY TO FIRE  
NEUROGENIC SHOCK  
SKIN ABRASION  
SKIN LACERATION  
ABDOMINAL INJURY  
CHEST INJURY

NASAL CONGESTION (SAS)  
APPENDICITIS  
DENTAL FILLING LOSS  
SLEEP DISORDER  
PARESTHESIAS SEC TO EVA  
SPACE MOTION SICKNESS (SAS)  
ALTITUDE SICKNESS  
ACUTE PROSTATITIS  
ALLERGIC REACTION  
ANKLE SPRAIN/STRAIN  
ELBOW SPRAIN/STRAIN  
HIP SPRAIN/STRAIN  
KNEE SPRAIN/STRAIN  
SHOULDER SPRAIN/STRAIN  
WRIST SPRAIN/STRAIN  
BACK SPRAIN/STRAIN  
CHOKING/OBSTRUCTED AIRWAY  
CONSTIPATION (SAS)  
URINARY RETENTION (SAS)  
WRIST FRACTURE  
SUDDEN CARDIAC ARREST  
URINARY TRACT INFECTION  
BEHAVIORAL EMERGENCY  
EYE CORNEAL ULCER  
SHOULDER DISLOCATION  
URINARY INCONTINENCE (SAS)  
ACUTE RADIATION SYNDROME  
LUMBAR SPINE FRACTURE  
ABDOMINAL WALL HERNIA  
VAGINAL YEAST INFECTION  
URINARY TRACT INFECTION  
URINARY RETENTION (SAS)  
BACK PAIN (SAS)  
SEIZURES

NECK SPRAIN/STRAIN  
ELBOW DISLOCATION  
INFLUENZA  
VIIP (SAS)  
HEADACHE (LATE)  
HYPERTENSION  
DENTAL CARIES  
DEPRESSION  
ANXIETY  
MOUTH ULCER  
HEARING LOSS  
ANAPHYLAXIS  
DIARRHEA  
INSOMNIA (SAS)  
EYE CHEMICAL BURN  
EYE INFECTION  
GASTROENTERITIS  
HEAD INJURY  
ACUTE DIVERTICULITIS  
DENTAL CROWN LOSS  
ACUTE PANCREATITIS  
HEADACHE (SAS)  
HEMORRHOIDS  
INDIGESTION  
NEPHROLITHIASIS  
NOSE BLEED (SAS)  
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OTITIS MEDIA  
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ACUTE SINUSITIS  
SKIN INFECTION  
SKIN RASH



# Simulated Medical Events



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DECOMPRESSION SICKNESS SECONDARY TO EVA  
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EYE PENETRATION (FOREIGN BODY)  
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SKIN RASH

Approximately 100 conditions



# Simulated Medical Events



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Approximately 100 conditions

IR sampled from specified probability distributions

IR probability parameters may vary given crew attributes

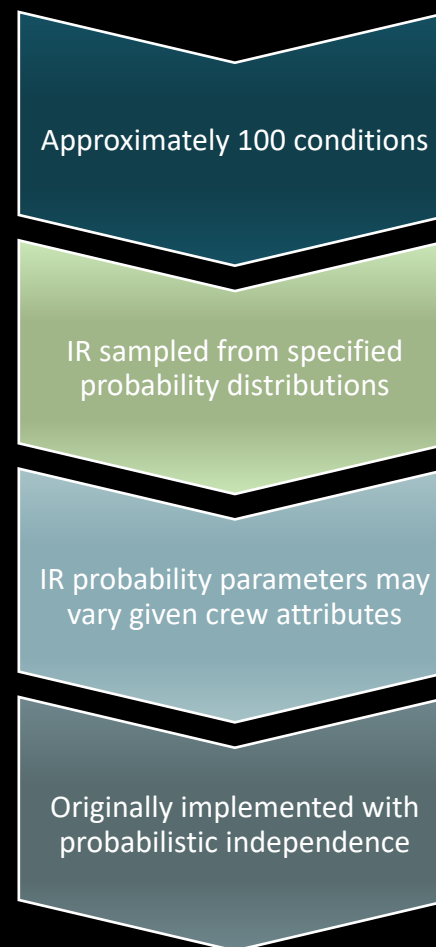
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 ACUTE RADIATION SYNDROME  
 LUMBAR SPINE FRACTURE  
 ABDOMINAL WALL HERNIA  
 VAGINAL YEAST INFECTION  
 URINARY TRACT INFECTION  
 URINARY RETENTION (SAS)  
 BACK PAIN (SAS)  
 SEIZURES

NECK SPRAIN/STRAIN  
 ELBOW DISLOCATION  
 INFLUENZA  
 VIIP (SAS)  
 HEADACHE (LATE)  
 HYPERTENSION  
 DENTAL CARIES  
 DEPRESSION  
 ANXIETY  
 MOUTH ULCER  
 HEARING LOSS  
 ANAPHYLAXIS  
 DIARRHEA  
 INSOMNIA (SAS)  
 EYE CHEMICAL BURN  
 EYE INFECTION  
 GASTROENTERITIS  
 HEAD INJURY  
 ACUTE DIVERTICULITIS  
 DENTAL CROWN LOSS  
 ACUTE PANCREATITIS  
 HEADACHE (SAS)  
 HEMORRHOIDS  
 INDIGESTION  
 NEPHROLITHIASIS  
 NOSE BLEED (SAS)  
 OTITIS EXTERNA  
 OTITIS MEDIA  
 PHARYNGITIS  
 SEPSIS  
 DENTAL ABSCESS  
 ACUTE SINUSITIS  
 SKIN INFECTION  
 SKIN RASH





# 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.

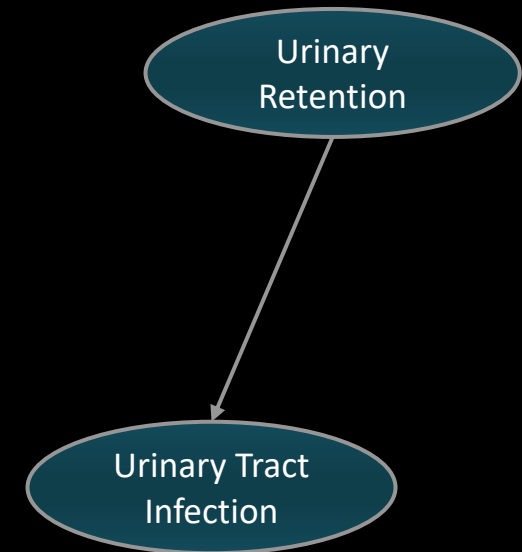


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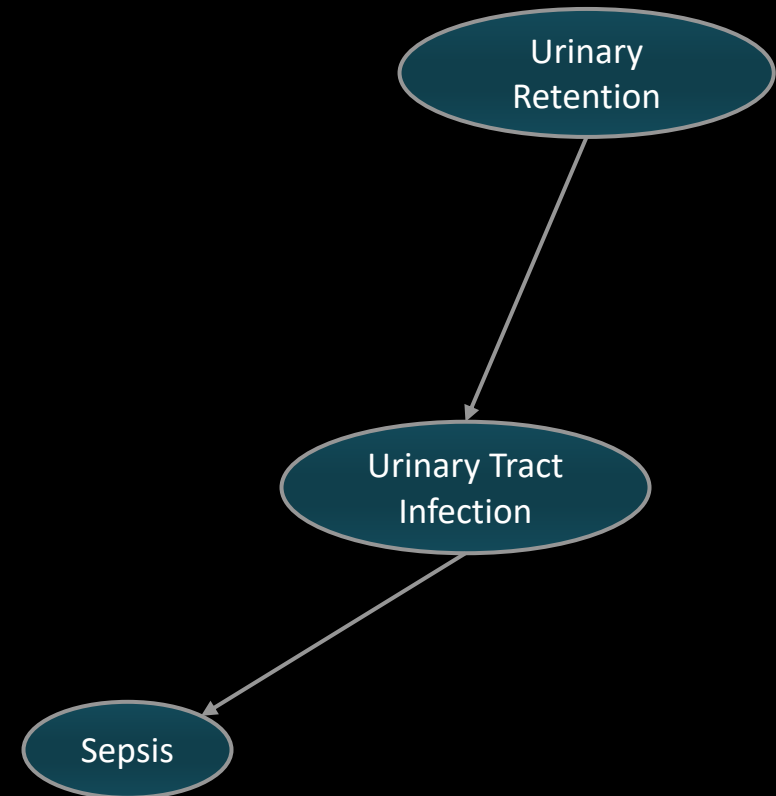


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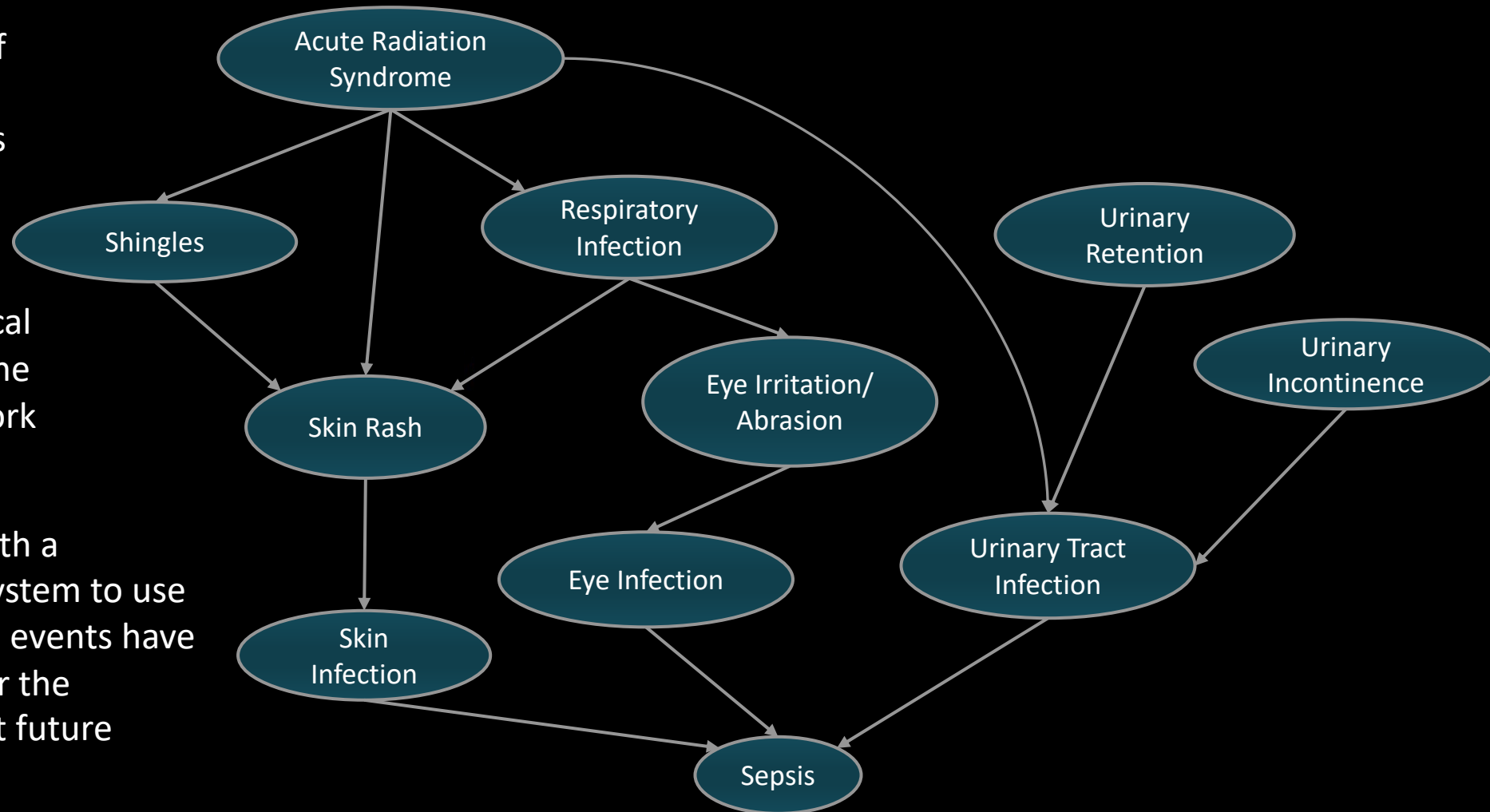


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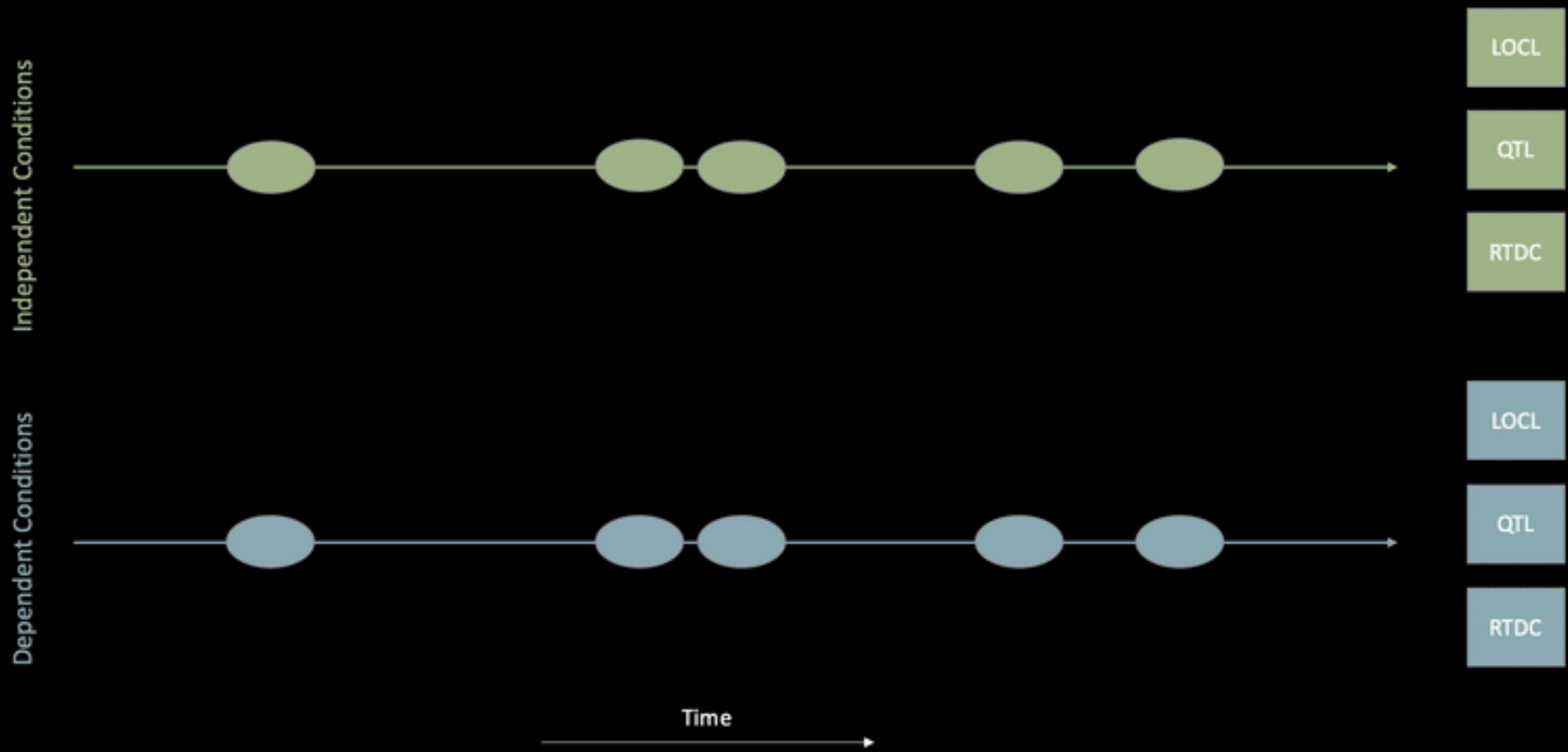
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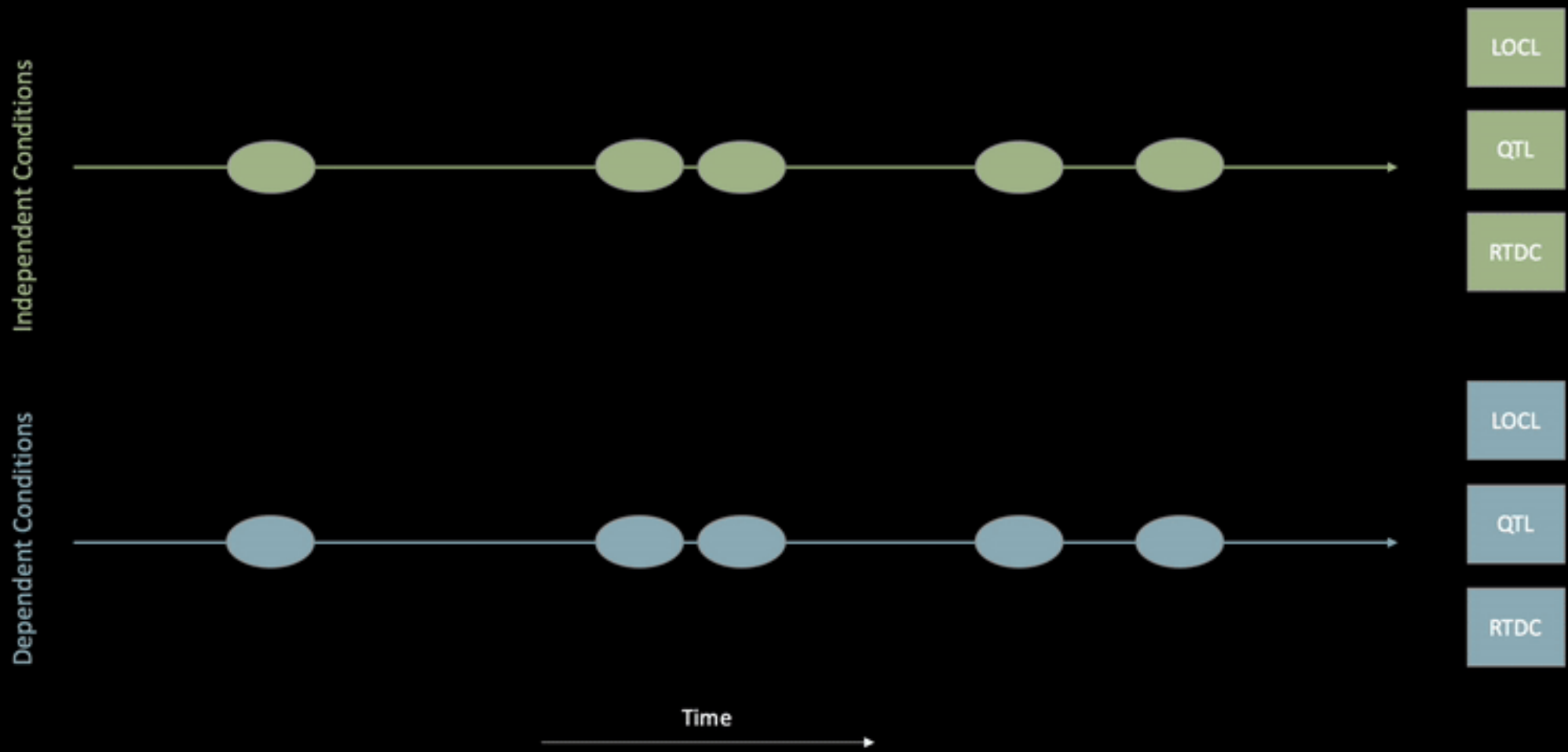
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# Simulation with Independent Events



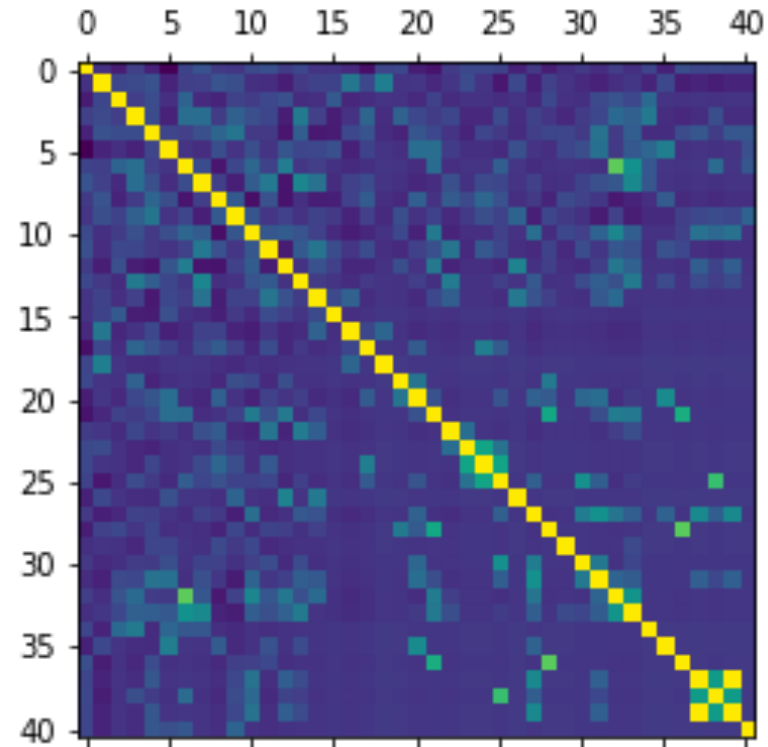
# Simulation with Dependent Events



# 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)

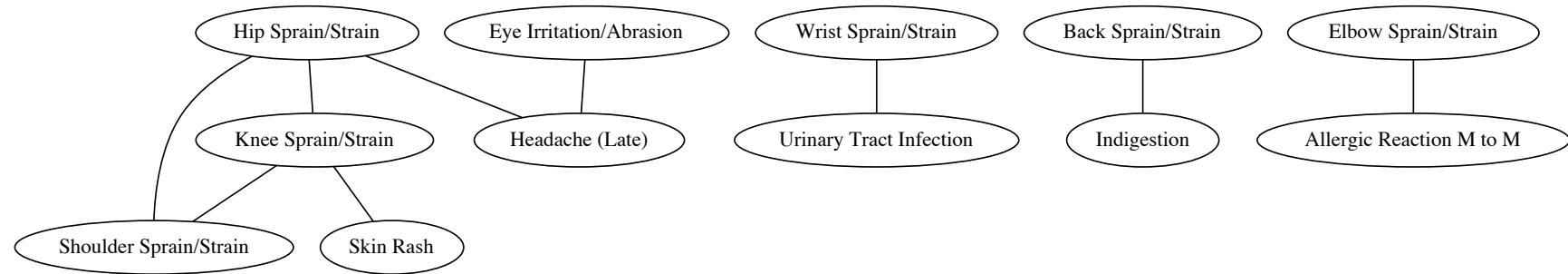
- De-identified
- Shuttle/ISS

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

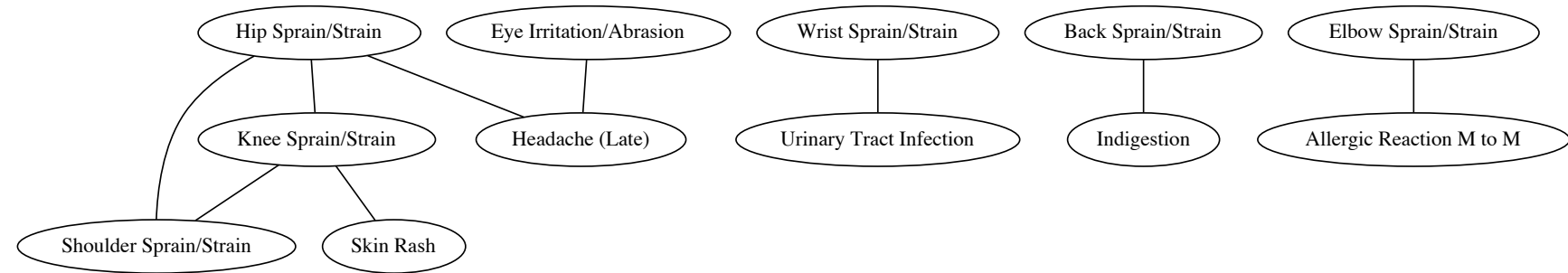


# Spaceflight Data Assessment

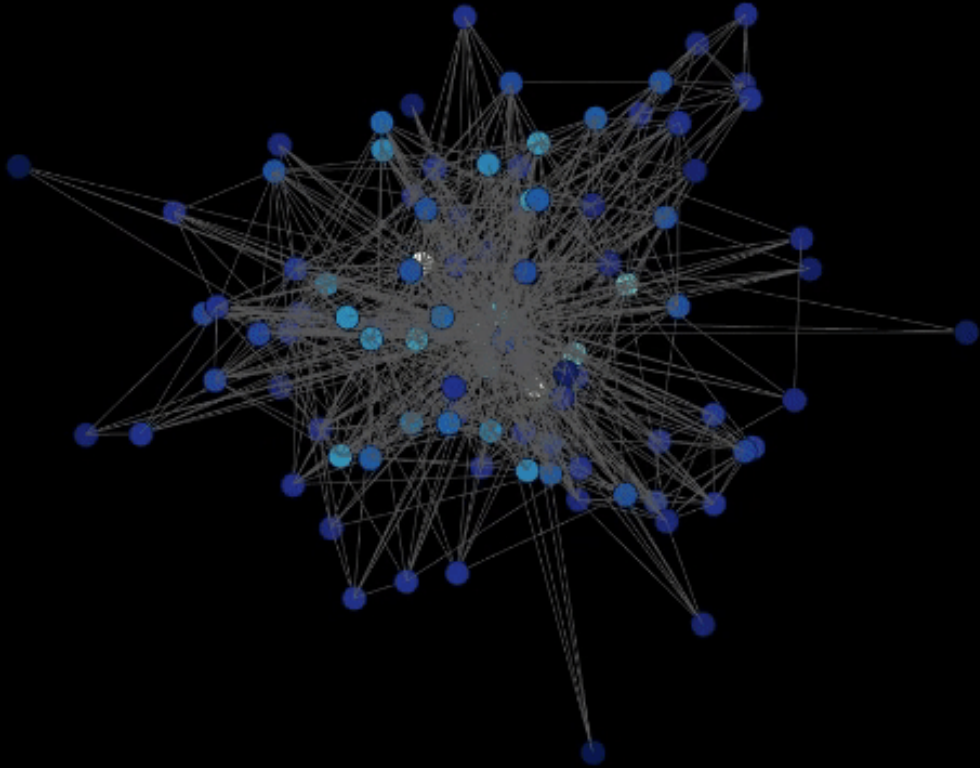
## Conclusion:

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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