EXPLORATION MEDICAL CAPABILITY

System Levers within IMPACT

Exploration Medical Capability, NASA Human Research Program

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"Expanding the Boundaries of Space Medicine and Technology"

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PANEL OVERVIEW

- **IMPACT** is a quantitative, evidence-based medical system **probabilistic risk assessment (PRA)** and **tradespace analysis** tool for exploration missions
- **IMPACT** = **I**nforming **M**ission **P**lanning via **A**nalysis of **C**omplex **T**radespaces
  - *Tool is still undergoing acceptance reviews within NASA; all data is notional data*
- Our ***SYSTEM LEVERS*** panel today conveys the types of questions and data that you can expect from IMPACT

PANEL AGENDA

ABSTRACT 1 **-** ***Jon G Steller*** – *IMPACT Overview*

ABSTRACT 2 **-** ***Eric Kerstman*** – *RWS Validation*

ABSTRACT 3 **-** ***Arian Anderson*** **-** *How does altering* ***DURATION*** *change the proposed medical system?*

ABSTRACT 4 **-** ***Ariana C Nelson*** **-** *How does altering* ***SIZE*** *change the proposed medical system?*

ABSTRACT 5 **-** ***Prashant Parmar*** **-** *How does prioritizing one* ***OUTCOME*** *target (i.e., LOCL, RTDC, TTL) more than others change the proposed medical system?*

STANDARD LATE-ARTEMIS DRM

- 4 crew – 2M, 2F – 1 with contacts; 1 with dental crowns
- SLS/Orion Launch
- 10 days on Orion outbound to NHRO insertion and Gateway rendezvous
- 10 days on Gateway in NRHO
- 6 hours HLS to Lunar surface
- 168d (24w) on Lunar surface in lunar habitat
  - 2 Lunar surface EVAs of 2 crew per week (48 EVAs which is 24 per person and total of 96 person/EVAs)
    - Corresponding habitat dust exposures for crew who did not go on EVAs still present for each
  - Prolonged expeditions in pressurized rover
- Return on HLS to Gateway
- 10 days on Gateway in NHRO
- 5 days inbound to Earth on Orion
- Re-entry and landing

EXPLORATION MEDICAL CAPABILITY

Thank you to the entire team from ExMC, Med Ops, JSC, GRC, ARC, and LaRC!

Disclosure Information

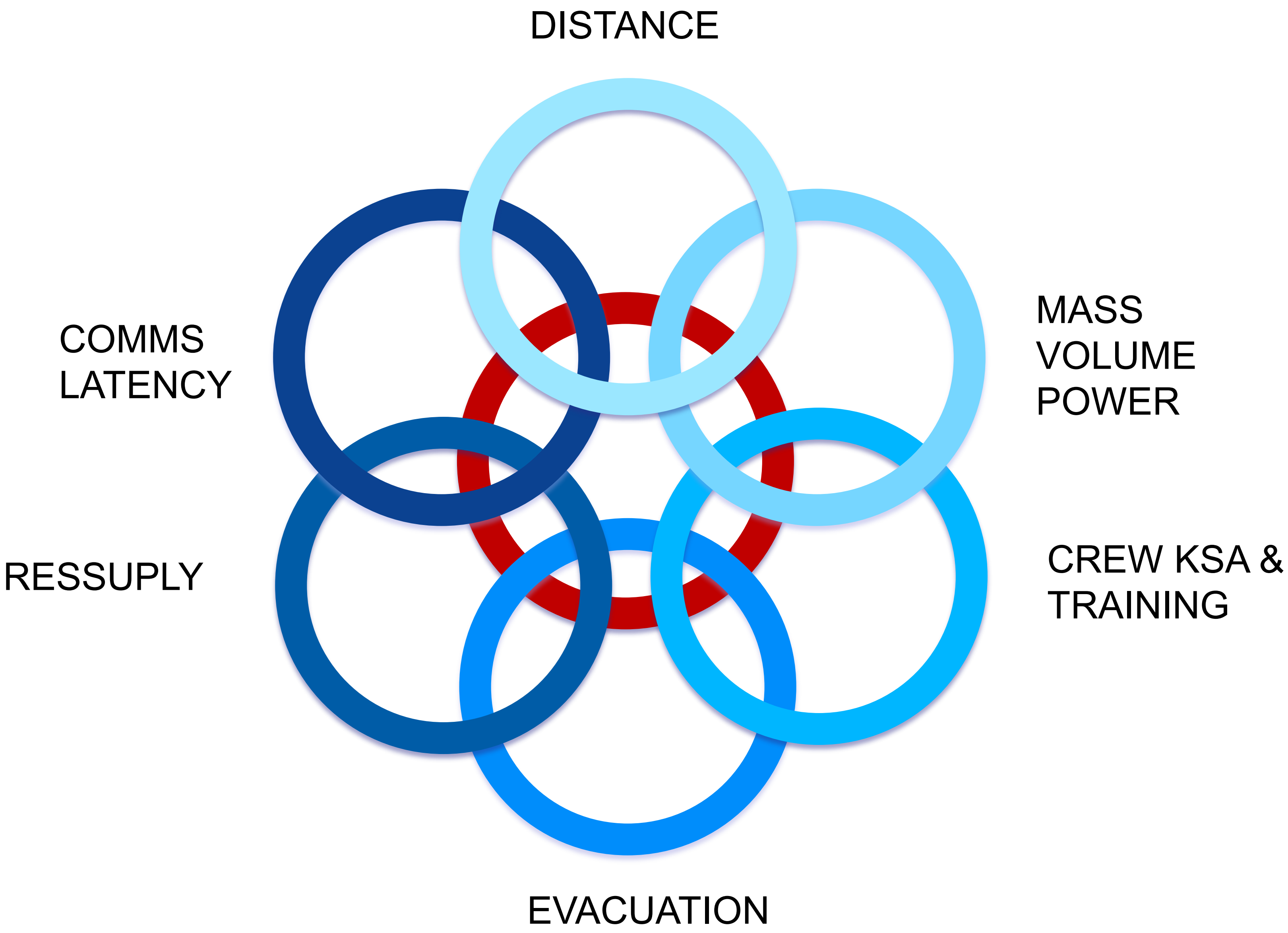
94th Annual Scientific Meeting

We have no financial relationships to disclose.

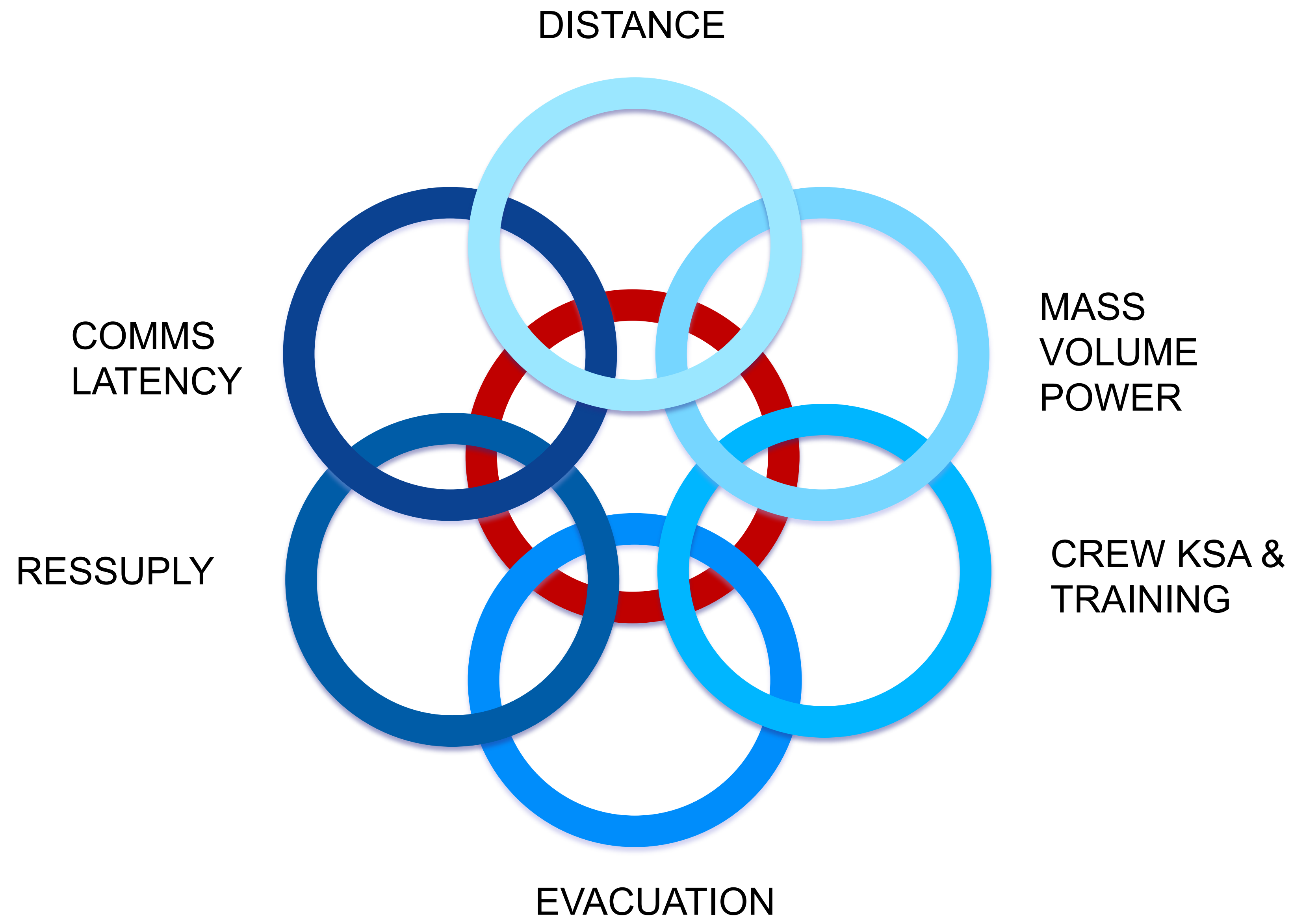
We will not discuss off-label use and/or investigational use in my presentation

Please hold all questions until the end.
Thank you!

MEDICAL SYSTEM PLANNING NEEDS



MEDICAL SYSTEM PLANNING NEEDS



- **Medical system desired features:**
  - Quantitative
  - Systematic
  - Traceable
  - Repeatable
  - Feasible

WHAT IS PROBABILISTIC RISK ANALYSIS?

- PRA identifies, assesses, and aggregates the risks associated with complex technological systems by understanding **each individual component's** unique effect on mission outcomes
- **PRA basic questions**
  - What can go wrong?
  - How frequently?
  - What are the consequences?
- **Probabilistic**
  - Evidence-based, but intentionally incorporates randomness to look at a distribution of outcomes

X 100,000

Integrated Medical Model (IMM)

- **Existing risk analysis tool**
- **Evidence and capabilities baselined to ISS**
- **100 medical conditions**
- **Limitations**
  - Considers only microgravity
  - Not specifically designed for trade space analysis
  - Heavy computational resources
  - Last comprehensive update of evidence base was in 2017

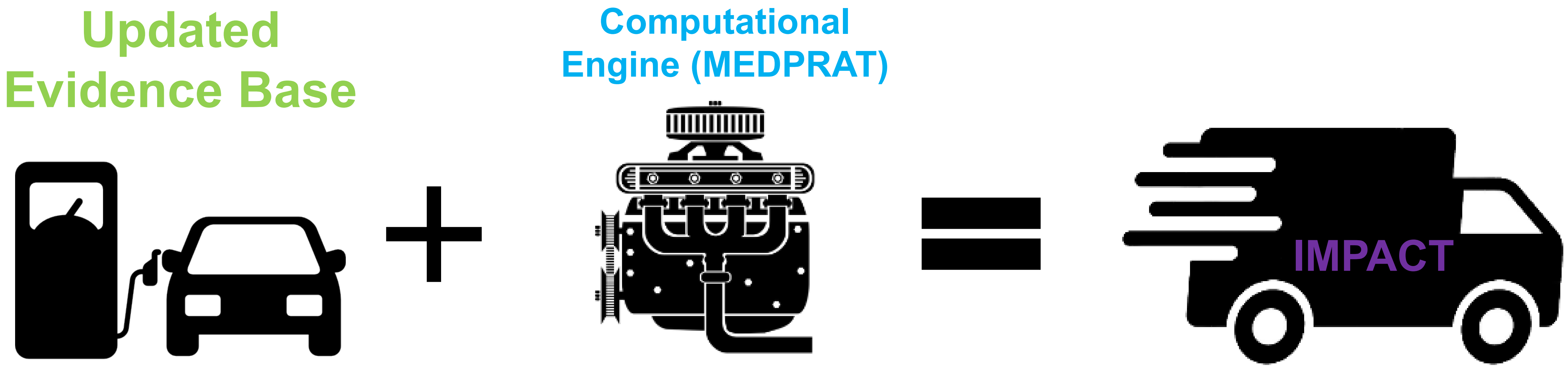
UPDATE MODELING

- **Need for a new model:**
  - Update evidence base
  - Update resource warehouse
  - Baseline to exploration missions
  - Expand condition list
  - Build-in tradespace capability
  - New computational engine

IMPACT

What is IMPACT?

Informing **M**ission **P**lanning via **A**nalysis of **C**omplex **T**radespaces



- Exploration-focused
- Next evolution of Integrated Medical Model (IMM)
- Operational in 2024

MEDICAL SYSTEM PLANNING NEEDS

- **Medical system design:**
  - Define morbidities that may arise during exploration spaceflight
  - Populate with evidence-based incidence (BC/WC) and outcome data
  - Determine clinical capabilities and resources needed for diagnosis and management (M/V/P/KSA)
  - Proposition of optimal medical system given DRM-specific constraints
  - Communication of medical system needs to Medical Operations, engineers, pharmacy

- Quantitative
- Systematic
- Traceable
- Repeatable
- Feasible

STEP 1 - IMPACT CONDITION SELECTION

- Determine medical conditions that are in scope or out of scope for system design (i.e., which conditions to plan around)
- 119 medical conditions of greatest likelihood and consequence for Lunar missions
  - Nothing specific about that number – determined by schedule/resources
  - Will continue to be adding medical conditions to the library

Reference HRP-48036, Rev A

STEP 2 – GATHER BEST AVAILABLE DATA

- **Spaceflight data**
- **Analog data**
- **Modeling predictions** (e.g., ISS fire model)
- **Terrestrial data** - keywords/MeSH terms of databases using Rapid Systematic Review*

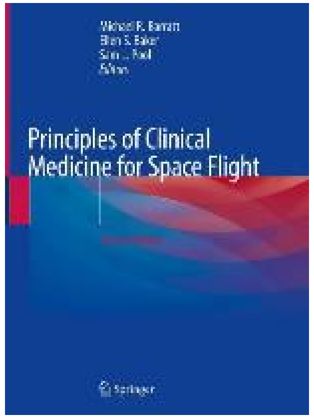
PubMed.gov

Google Scholar

NTRS NASA Technical Reports Server

Cochrane Library

DynaMed®



*Tricco AC, Antony J, Zarin W, et al. A scoping review of rapid review methods. *BMC Med* **13**, 224 (2015). https://doi.org/10.1186/s12916-015-0465-6

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STEP 2 – MEDICAL CONDITION DATA

- **Incidence**
- **Best Case/Worst Case Definitions and probabilities**
- **Clinical Phase Durations**
  - Diagnosis
  - Treatment
  - End State

STEP 2 – OUTCOME METRICS

How does each intervention affect:

Loss of Crew Life (events/mission)

- Likelihood of a crewmember's death during the mission

Medical Evacuation (events/mission)

- Vehicle capabilities insufficient forcing consideration of evacuation to higher level of care

Task Time Affected (crewmember-hours)

- Crew time affected by medical condition

STEP 2 - CAPABILITY RESOURCE TABLES

- CRTs detail the capabilities/resources needed for prevention, diagnosis, stabilization, management, and prevention of recurrence for each condition
- Adapted from evidence-based practice guidelines by space medicine SMEs
- Condition -> Capabilities -> Resources -> Mass/Volume
  - Capability - cognitive/procedural skillset or action (e.g., deliver IV antibiotics)
  - Resource - a piece of equipment, pharmaceutical, or skillset (e.g., 20g IV, interpret physical exam)

STEP 2 – CRT EXAMPLE

Name	Best Case							Worst Case						
	Contribution	Necessity	Equivalence	Rank	Efficacy	Frequency	Quantity	Contribution	Necessity	Equivalence	Rank	Efficacy	Frequency	Quantity
CP1 - Interpretation - Ultrasound - MSK Absolute	100	0	0	0	100	N/A		100	0	0	0	100	N/A	
CP1 - Interpretation - Ultrasound - MSK	100	100	0	0	100	Event	1.00	100	100	0	0	100	Event	1.00
CP1 - Physical Exam - Vital Signs - Periodic Absolute								100	0	0	0	100	N/A	
CP1 - Physical Exam - MSK Absolute	100	0	0	0	100	N/A		100	0	0	0	100	N/A	
CP1 - Physical Exam - MSK	100	100	0	0	100	Event	1.00	100	100	0	0	100	Event	1.00
CP1 - Physical Exam - Neurologic Exam - MSK Absolute	100	0	0	0	100	N/A		100	0	0	0	100	N/A	
Medical Instrument - Reflex Hammer	100	100	0	0	100	Event	1.00	100	100	0	0	100	Event	1.00
CP1 - Physical Exam - Neurological - Focused Exam Absolute	100	0	0	0	100	N/A		100	0	0	0	100	N/A	
CP1 - Physical Exam - Neurological - Focused Exam	100	100	0	0	100	Event	1.00	100	100	0	0	100	Event	1.00

STEP 3 - PROBABILISTIC RISK ANALYSIS

- **Mission-specific inputs**
  - Mission Duration
  - Mission Destination (with segment-specific conditions; e.g., Space Adaptation Syndrome)
  - Crew Characteristics (number, sex, pre-existing medical conditions)
  - EVA number and frequency

EXPLORATION MEDICAL CAPABILITY

IMPACT FLOW

Medical Event Incidence

Best-case Scenario

Best-case resources available?

- Yes → **Treated Case:** Decrement medical resources
- No → **Untreated Case** Decrement medical resources

Worst-case Scenario

Worst-case resources available?

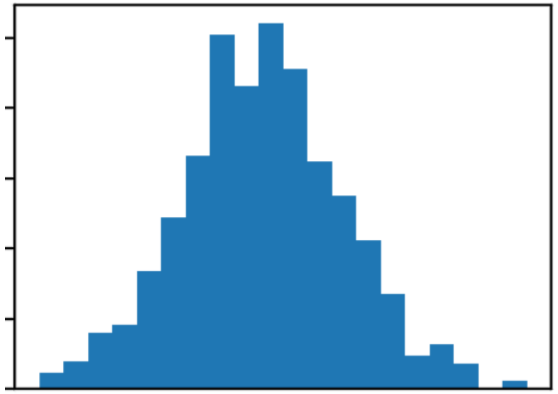
- No → **Untreated Worst-Case** Decrement medical resources
- Yes → **Treated case:** Decrement medical resources

Calculate End States:

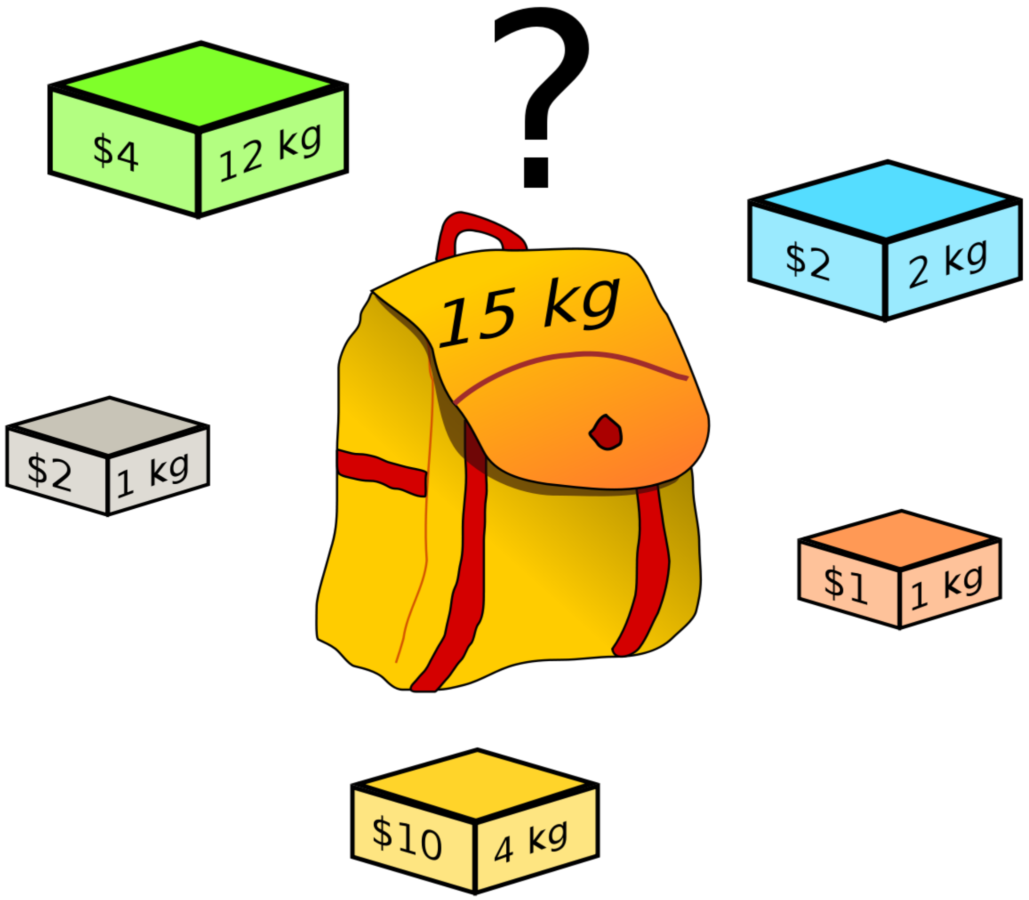
- Loss of Crew Life (LOCL)
- Medical Evacuation
- Task Time Affected
- Resource Utilization

Outputs can adjust with changes in mass/volume

100,000 simulations



STEP 4 - TRADESPACE OPTIMIZATION (THE BACKPACK PROBLEM)



- Optimization problem
- Maximize value subject to constraints
- Question: what combination of blocks yields the most money but does not exceed the weight limit?

MISSION CHARACTERISTICS

Capabilities/Resources

Medical system:
- Mass
- Volume
- Power

Risk Metrics
- Loss of Crew Life
- Medical Evacuation
- Task time affected