# A Semi-Quantitative Approach To Building The Orion Spacecraft Medical Kit

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# Disclosure Statement

*92st Annual Scientific Meeting*

- We have no financial relationships to disclose
- We will not discuss off-label and/or investigational uses


- Lunar orbital mission
- Orion vehicle
- 21 days
- 4 crewmembers
- No extravehicular activities

→**What medical equipment do we need?**



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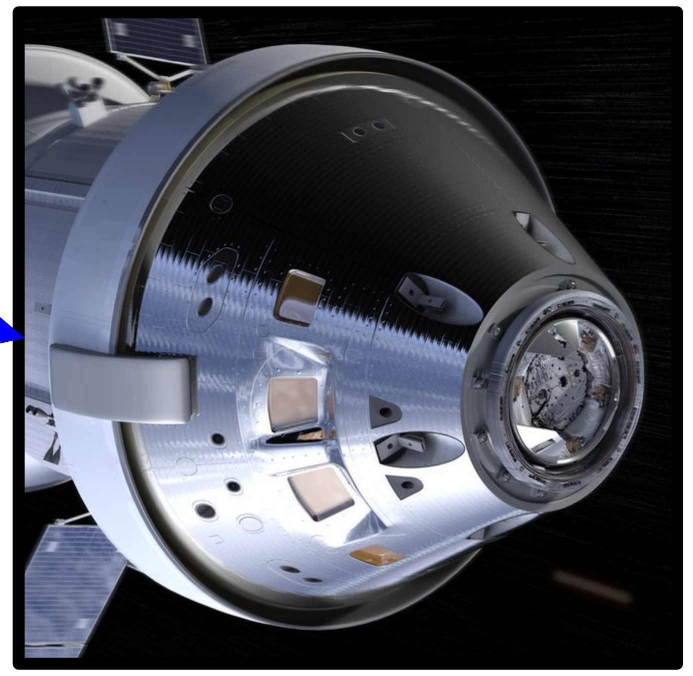
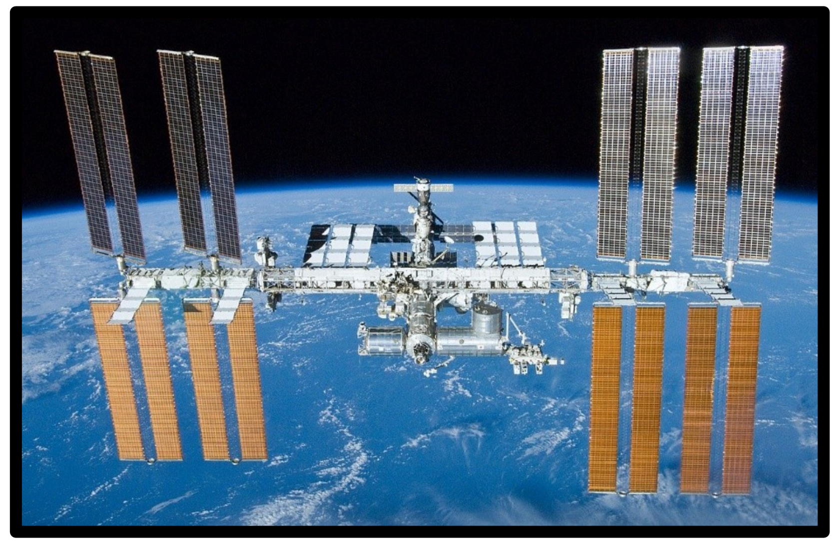
# NASA Medical Care Standards

| Level of Care | Mission | Capability |
|---|---|---|
| I | Leo < 8 Days | Space Motion Sickness, Basic Life Support, First Aid, Private Audio, Anaphylaxis Response, Acoustic Monitor |
| II | LEO < 30 days | Level I + Clinical Diagnostics, Ambulatory Care, Private Video, Private Telemedicine |
| III | Beyond LEO < 30 day | Level II + Limited Advanced Life Support, Trauma Care, Limited Dental Care |
| IV | Lunar > 30 days | Level III + Medical Imaging, Sustainable Advanced Life Support, Limited Surgical, Dental Care |
| V | Mars Expedition | Level IV Autonomous Advanced Life Support and Ambulatory Care, Basic Surgical Care |





# “Medical System” Components

**“PRIME” MEDICAL KIT**

Planned monitoring and unplanned events
- Medical Equipment
- Pharmaceuticals

**POST-LAUNCH RESOURCES**

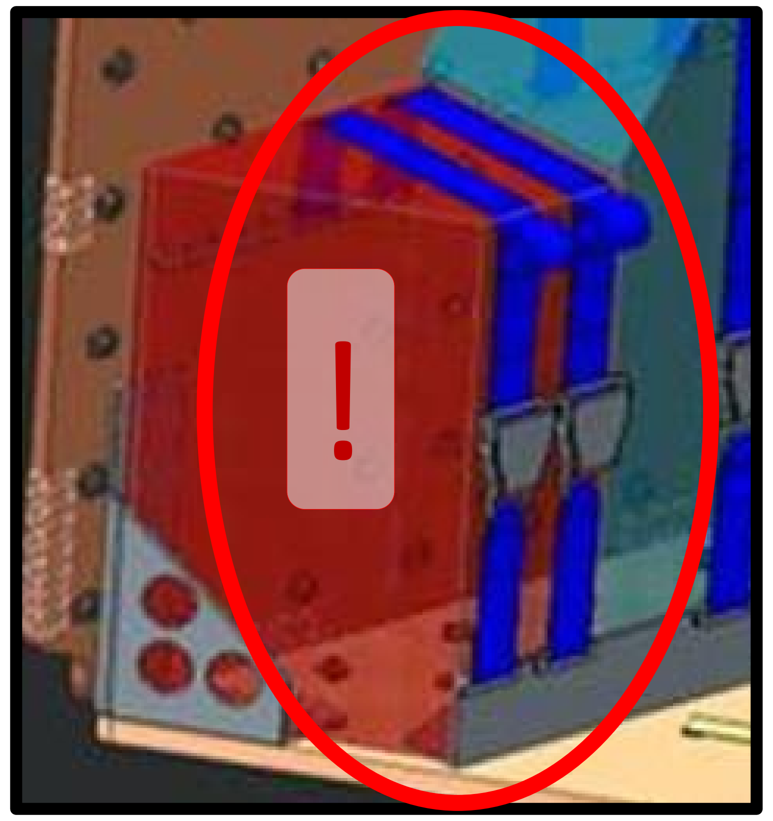
**PERSONAL MEDICAL ITEMS**

**CREW SURVIVAL KIT**
- **Post-landing water ops**
  - **First Aid Subpack**

# Prime Medical Kit Constraints

Open Cabin Constraints

Interference Constraints

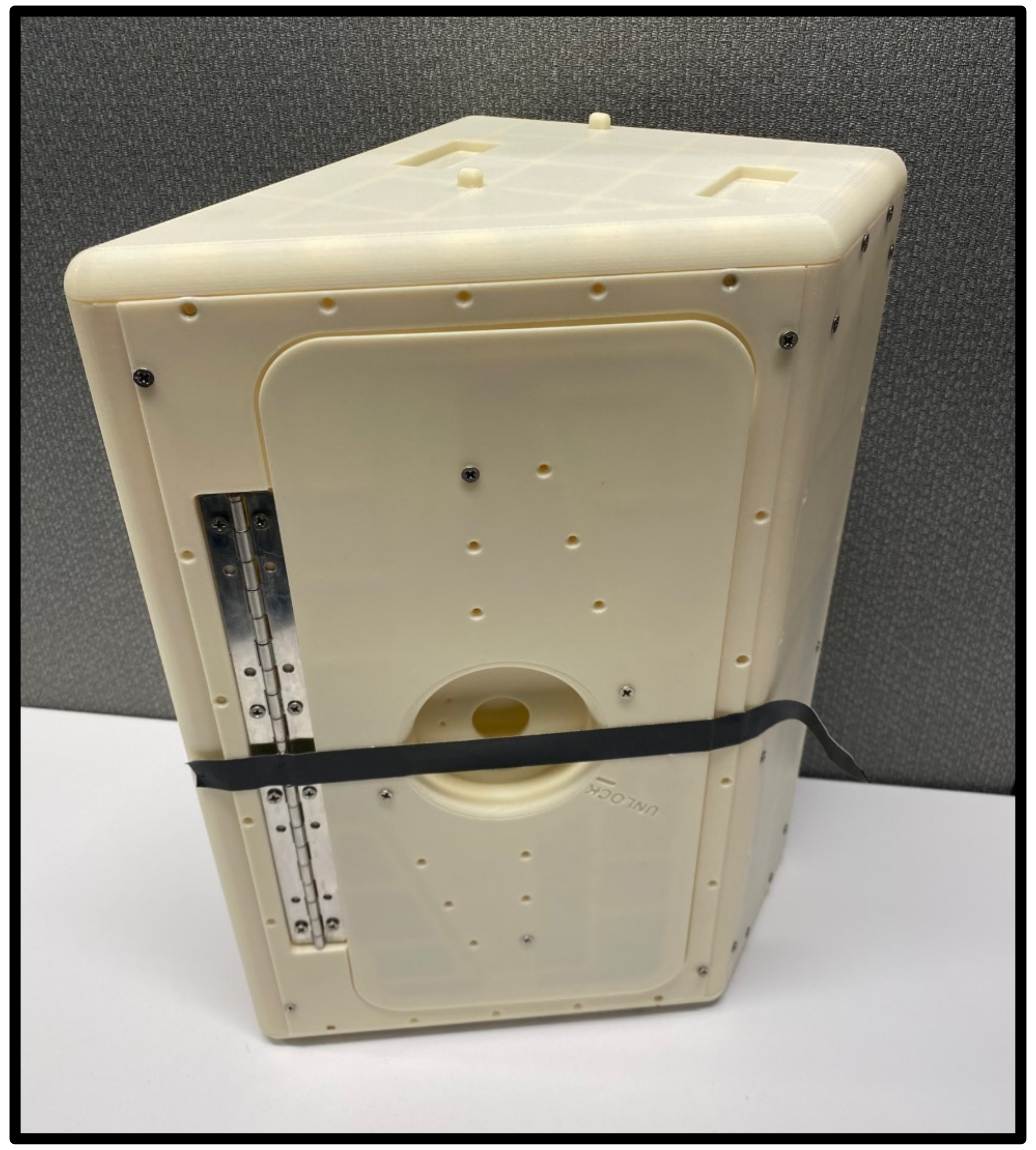


Load Constraints

Mass Allocation: 30 lbs

Volume Allocation: ~1,116 $in^3$

Mass/Volume Constraints



# Deciding What Goes In the Prime Kit

**We needed a process that could:**

- Assist in identifying high priority medical conditions to plan for during deep space missions.
- Drive decisions related to what medical resources/capability will be available aboard future deep space vehicles.
- Drive research related to the development of future spaceflight-related medical technologies.
- Illustrate the rationale behind the decisions made re: kit contents
- Account for our constraints

**We needed a process that was:**

- Quantitative where possible
- Repeatable (without repeating all the work)
- Documented

# Existing Tools

## NASA's "Integrated Medical Model"

Probabilistic Risk Assessment (PRA) using Monte Carlo simulations

Assesses mission risk due to in-flight medical events

Produces "optimized" kit based on:

- Selected risk type
- Mass & volume constraints
- Preset resource list

Limitations:

- Pre-set Conditions List
- Prioritizes mass/volume over resources
- No resource bundling
- Condition likelihood based on small sample size
- Developed for ISS

# Existing Tools

## NASA Human Research Program (HRP) Exploration Medical Capability (ExMC) Element "Accepted Medical Condition List" (AMCL) Process

- Scoping activity for deep space exploration
- Prototype method
- Used the Integrated Medical Model (IMM) to:
  - Generate probability of occurrence
  - Generate "optimized" medical kit
- Used the IMM condition list as a starting point

# ExMC Method

ExMC Accepted Medical Condition List (AMCL) scoping activity for deep space exploration

- Prototype method
- Uses “Futility” and “Complexity” to rank conditions
- Uses the Integrated Medical Model (IMM) to generate probability of occurrence
  - Leverages existing model database and processes

$$Exclusion\ Score = \frac{Complexity * Futility}{Probability}$$

# Method

**GENERATE DATA FROM MODEL** → RANK CONDITIONS → IDENTIFY RESOURCES

**Probability of Occurrence**

Sources from IMM data set

**Resource Mass & Volume**

Used Orion mass allocation

Assumed no volume constraint

**Optimized Kit**

Used as a guideline, not a solution

**Excluded Condition**

Abdominal Injury

Acute Compartment Syndrome

Chest Injury

Elbow Dislocation

Head Injury

Hip/Proximal Femur Fracture

Lower Extremity (LE) Stress Fracture

Lumbar Spine Fracture

Shoulder Dislocation

Neurogenic Shock

Traumatic Hypovolemic Shock

# Method

GENERATE DATA FROM MODEL → **RANK CONDITIONS** → IDENTIFY RESOURCES

**Complexity**

# of resources/skill level

High/Medium/Low

**Futility**

Responsiveness to treatment

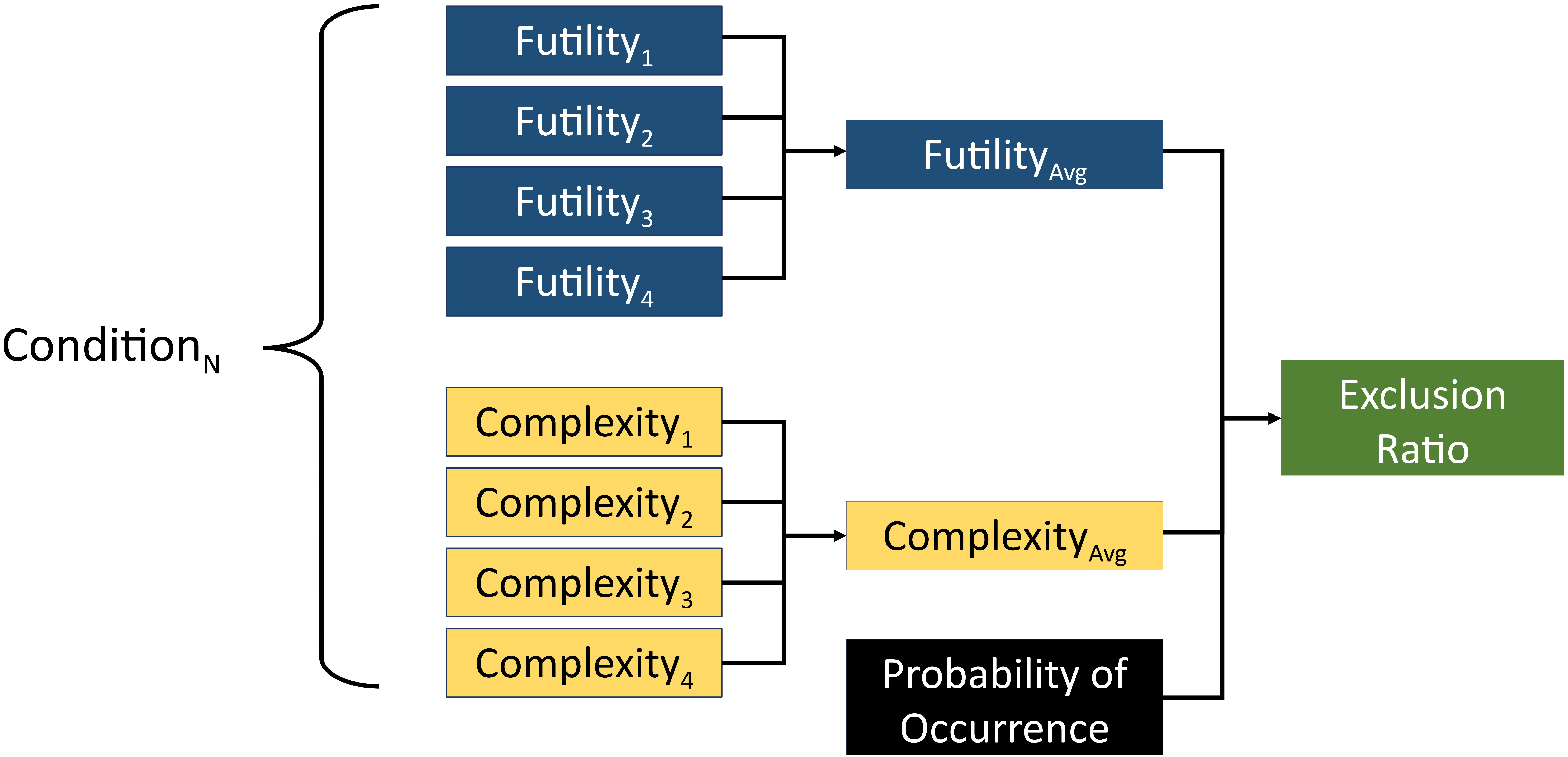
High/Medium/Low

**Exclusion Ratio**

**"Plan to Treat"**

ER ↑, "plan to treat" justification ↓

# Method


Condition$_N$
Futility$_1$
Futility$_2$
Futility$_3$
Futility$_4$
Futility$_{Avg}$
Complexity$_1$
Complexity$_2$
Complexity$_3$
Complexity$_4$
Complexity$_{Avg}$
Probability of Occurrence
Exclusion Ratio

# Method

| | | | | | | |
|---|---|---|---|---|---|---|
| $Condition_1$ | Yes | Yes | Yes | Yes | → | Yes |
| $Condition_3$ | Yes | Yes | Yes | No | → | Maybe-Yes |
| $Condition_4$ | No | No | No | Yes | → | Maybe-No |
| $Condition_2$ | No | No | No | No | → | No |
| ⋮ | | | | | | |
| $Condition_n$ | Yes | Yes | No | No | → | Maybe-Yes/ Maybe-No |

# Method

GENERATE DATA FROM MODEL → RANK CONDITIONS → **IDENTIFY RESOURCES**

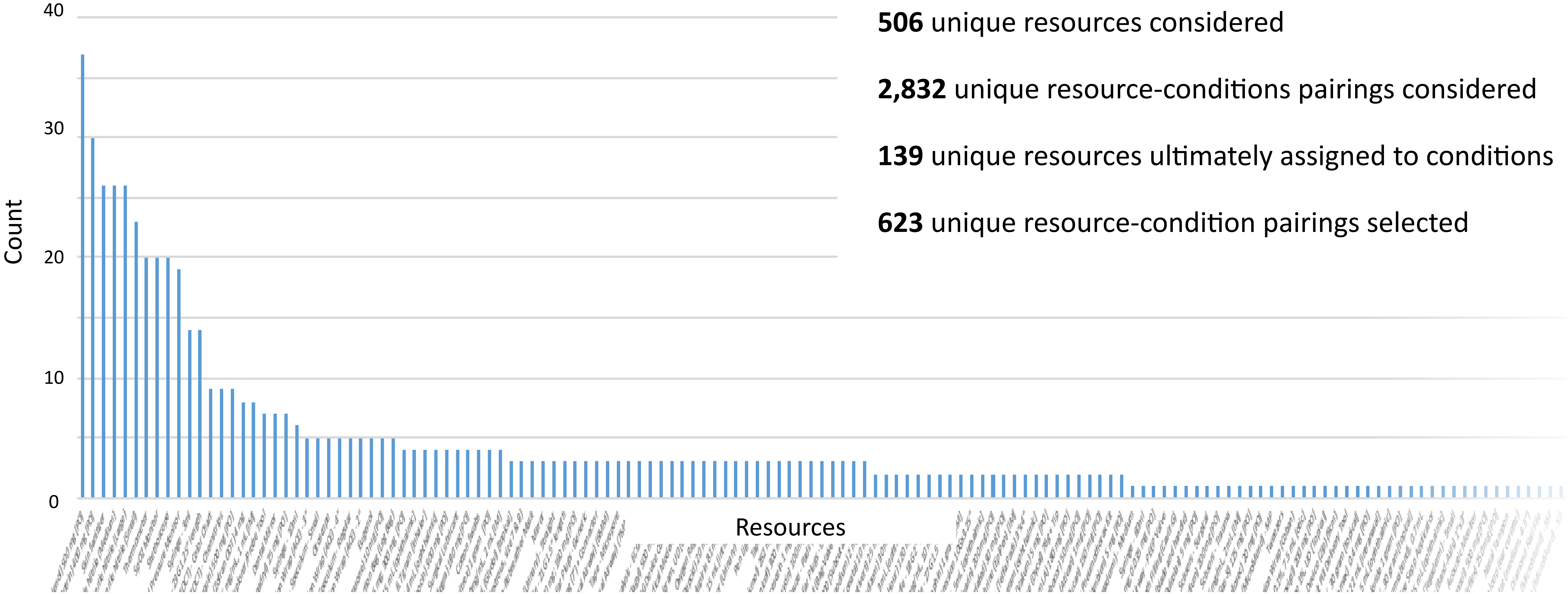
Based on terrestrial and spaceflight experience

Considerations:

- Level of Care / Mission duration
- Mass/volume/power/geometry
- Items that treat a single condition
- PO versus IM/IV
- Complexity of use (skill/training required)
- Treat condition over symptom
- Mandatory resource inclusions

# Results

GENERATE DATA FROM MODEL → RANK CONDITIONS → IDENTIFY RESOURCES




**506** unique resources considered

**2,832** unique resource-conditions pairings considered

**139** unique resources ultimately assigned to conditions

**623** unique resource-condition pairings selected

# Results

**GENERATE DATA FROM MODEL**

- Probability of Occurrence
- Resource Mass & Volume
- Optimized Kit

→

**RANK CONDITIONS**

- Futility
- Complexity
- Exclusion Ratio
- "Plan to Treat"

→

**IDENTIFY RESOURCES**

- What we use terrestrially?
- What do we need for the DRM?
- What fits in the kit?

Of ~200 condition cases:

- Initial "plan to treat":
  - No: 73
  - Yes: 91
  - Maybe: 42
- Final "plan to treat":
  - No: 93
  - Yes: 128

# Summary of Key Findings

## Benefits

Provides a framework for discussion

Provides strong starting point for subject matter experts

Highlights areas of agreement/discussion early in the process

Provides a record of decision making

# Summary of Key Findings

**Limitations**

- "Semi-quantitative", but still subjective
- No external validation
- Baseline condition list is not comprehensive
- Time and effort intensive

Future efforts may rely on more advanced tools