Optimizing Medical Kits for Space Flight

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Introduction

• Space is an inherently hostile environment

• Altered incidence, mitigation and recovery from adverse medical events

• Medical system
  • Physical limitations
  • Limited resupply

Optimization Goal

- Optimize medical kit using IMM results
  - Specific mission profile

- Two scenarios
  1) Best outcome given resource constraints
  2) Minimize resources given desired outcome(s)

IMM Outcomes

• Crew Health Index (CHI)
• Probability of evacuation
• Probability of loss of crew life
• Resources utilization
• Combined metric
Resource Constraints

- Multiple constraints on medical resources
  - Mass
  - Volume
  - Cost
  - Packaging
  - Bandwidth
  - Power
  - Etc.
Consider Scenario 1

- Best outcome given resource constraints
  - Define resource requirements
    - Maximum mass
    - Maximum volume
  - Decide which outcome(s) are of interest
    - Maximize CHI
    - Minimize Pr(evacuation)
  - Fill medical kit with the most efficient set of medical resources
Optimization Scenario 1

• Maximize outcome(s) of interest subject to resource constraints

1. **Identify least influential resource**
2. **Run Simulation** (~50 thousand trials)
3. **Check constraints**
4. **Calculate Outcome(s)**
5. **Determine “maximum” medical kit**
6. **Remove one unit**
Are Constraints Satisfied?

- Identify least influential resource
- Add Resources Back?
- If no:
  - Check constraints
  - If yes:
    - Calculate Outcome(s)
    - If no:
      - Remove one unit
      - If yes:
        - STOP
Additional Considerations

• Essential vs. Nonessential
  • Nonessential resources will be removed first
  • Band-aids, thermometer, etc.

• Consumable vs. Nonconsumables
  • Number of units
  • Frequency of use

• Tie breakers
  • Mass
  • Volume
  • Cost
  • Etc.
Results

• Maximize CHI

• Mission Length
  • 24 days

• Number of crew members
  • 4 (2M, 2F)

• Resource constraints
  • 4.3 kg
  • 6421.7 cm³

http://www.nasa.gov/multimedia/imagegallery/iotd.html#
## Results (24 days, 4 crew)

- **Resource constraints**
  - 4.3 kg
  - 6421.7 cm³

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Optimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>0</td>
<td>3.42</td>
<td>67.3</td>
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<tr>
<td>Volume (cm³)</td>
<td>0</td>
<td>6421.7</td>
<td>191434</td>
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<tr>
<td>Mean CHI (SD)</td>
<td>15.2 (12.3)</td>
<td>94.3 (4.9)</td>
<td>94.9 (3.9)</td>
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<tr>
<td>Median CHI</td>
<td>13.5</td>
<td>96.3</td>
<td>96.4</td>
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</table>
CHI Distribution by Medical Kit

Medical Kit: Minimum, Optimum, Maximum

Percent of Trials vs. Crew Health Index (%)
Optimization Scenario 2

- Minimize resources subject to constraints on the outcome(s)
  - Define outcome requirements
    - Pr(evac) ≤ 10%
    - CHI ≥ 90%
  - Identify the medical kit
Optimization Scenario 2

• Minimize resources subject to constraints on the outcome(s)

Run Simulation
(~50 thousand trials)

Identify all combinations of medical conditions

Randomly select combinations of events to treat

Calculate mass, volume, etc.

Check constraints

Repeat many times.

Lowest mass and volume wins!
Results

• Minimize Mass and Volume

• Mission Length
  • 24 days

• Number of crew members
  • 4 (3M, 1F)

• Evacuation constraints
  • Pr(Evacuation) < 2%

http://www.nasa.gov/multimedia/imagegallery/iotd.html#
Results (24 days, 4 crew)

- Evacuation constraints
  - Pr (Evacuation) < 2%

<table>
<thead>
<tr>
<th>Medical Kit</th>
<th>Parameter</th>
<th>Minimum</th>
<th>Optimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Mass (kg)</td>
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<td>38.66</td>
<td>81.86</td>
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<tr>
<td>Volume (cm³)</td>
<td>0</td>
<td>94,527.73</td>
<td>201,669.01</td>
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<tr>
<td>Mean CHI (SD)</td>
<td>78.27(8.52)</td>
<td>91.38 (3.74)</td>
<td>95.21 (2.35)</td>
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<tr>
<td>Evacuation Probability</td>
<td>16.01%</td>
<td>1.94%</td>
<td>0.37%</td>
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</tbody>
</table>
Additional Considerations

• Goal is to minimize resources

• Some conditions will not satisfy outcome constraints even if treated

• Resources are used to treat medical events
  • Not primary prevention
Flexibility

- Resource inclusion and exclusion criteria
  - Flight surgeons

- Personal medical kits

- Customized metrics
  - Outcomes
Conclusions

- Trade-off
  - Occurrence
  - Impact
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