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

- Check constraints
- Satisfied?
  - Yes
    - Add Resources Back?
      - Yes
        - Calculate Outcome(s)
      - No
        - Identify least influential resource
        - Remove one unit
        - STOP
  - No
    - Add Resources Back?
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>
</tr>
<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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</tbody>
</table>
CHI Distribution by Medical Kit

- Medical Kit: Minimum
- Optimum
- Maximum

Crew Health Index (%) vs. Percent of Trials
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)

1. **Randomly select combinations of events to treat**
2. **Run Simulation (~50 thousand trials)**
3. **Identify all combinations of medical conditions**
4. **Calculate mass, volume, etc.**
5. **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
  • \( \text{Pr(Evacuation)} < 2\% \)

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

- Evacuation constraints
  - Pr (Evacuation) < 2%

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<th>Maximum</th>
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<tr>
<td>Mass (kg)</td>
<td>0</td>
<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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