Integrated Medical Model (IMM) 4.0 – Enhanced Functionalities

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IMM v4.0 Overview

- Consider data for 100 medical conditions from the Integrated Medical Evidence Database (iMED)
- Simulate medical event occurrences over large number of missions via Monte Carlo methodology
- For each medical condition:
  - Incidence Rate
  - Time to occurrence
  - Best Case or Worst Case?
  - Treated or Untreated?
  - FI, duration, EVAC, LOCL
Incidence Rate (IR)

• Fixed, lognormal and gamma distributions defined in iMED
• Generate IR for each medical condition-crewmember combination
• Example: Sepsis

Incidence: Data category: Fixed
Space Adaptation: No
Incidence type: Rate
Model Data Path: Incidence Rate: 0.0024
Distribution Data: Incidence Distribution: Fixed
Occurrence Distribution: Poisson
Characteristics Specific: none
Time to Occurrence

- Given IR and mission length, use exponential distribution to time-to-event(s) for generated IR
- Example: Sepsis
  - IR = 0.0024 (fixed) per person-year
  - Mission Length = 4383 hours (6 months)
  - 6 crew A-F

<table>
<thead>
<tr>
<th>Crew</th>
<th>Condition</th>
<th>Start Time</th>
<th>Worst case</th>
<th>Treated</th>
<th>CP1 FI (%)</th>
<th>CP1 DUR</th>
<th>CP2 FI (%)</th>
<th>CP2 DUR</th>
<th>CP3 FI (%)</th>
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<tbody>
<tr>
<td>B</td>
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Best Case or Worst Case?

- Worst case probability upper bound and lower bound defined in iMED
- \( P_{\text{worst case}} \) drawn from uniform distribution
- Example: Sepsis
  \[ WC_{\text{upper bound}} = 0.38, \ WC_{\text{lower bound}} = 0.38 \quad \rightarrow \quad P_{\text{worst case}} = 0.38 \]

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Treated or Untreated?

• Each medical condition has resources required to treat and possible alternatives defined in iMED.

• Examine contents of medical kit and determine whether sufficient resources exist to treat each medical event occurrence.

• Treatment order determined by start time of each medical event.

• For each occurrence, decrement contents of kit.

• Example: Sepsis

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Incidence Rate  ➔  Time to occurrence  ➔  Best Case or Worst Case?  ➔  Treated or Untreated?  ➔  FI, duration, EVAC, LOCL

National Aeronautics and Space Administration
Outcomes: Functional Impairment and Duration

Upper and lower bounds of beta pert distributions defined in iMED:

<table>
<thead>
<tr>
<th>Sepsis Outcomes</th>
<th>Clinical Phase 1</th>
<th>Clinical Phase 2</th>
<th>Clinical Phase 3</th>
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<tbody>
<tr>
<td></td>
<td>FI</td>
<td>Duration</td>
<td>FI</td>
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<tr>
<td>Treated, Best case</td>
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<td>2-36</td>
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<tr>
<td>Treated, Worst case</td>
<td>100</td>
<td>1-2</td>
<td>16-58</td>
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<tr>
<td>Untreated, Best case</td>
<td>16-58</td>
<td>48-72</td>
<td>16-58</td>
</tr>
<tr>
<td>Untreated, Worst case</td>
<td>38-75</td>
<td>48-72</td>
<td>38-75</td>
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<td>64</td>
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<td>305.6</td>
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National Aeronautics and Space Administration
Summarizing Results

- **Probability of evacuation (pEVAC)**
  - Proportion of simulated missions with one or more evacuations
  - Confidence limits are estimated with bootstrap resampling
- **Probability of loss of crew life (pLOCL)**
  - Proportion of simulated missions with one or more loss of crew life
  - Confidence limits are estimated with bootstrap resampling
- **Crew Health Index (CHI)**
  - Proportion of mission time *not* lost to medical events

\[ 1 - \frac{\sum QTL}{L \times n} = CHI \]

Where \( n = \# \text{ crew}, \ L = \text{mission length}, \ QTL = \text{quality time lost}; \) is a function of functional impairment and duration
Timeline

**IMM v3.0:**
All medical events occur at beginning of mission

*Limitations:*
- Overestimation of quality time lost due to CP3 functional impairment
- Must impose artificial order of treatment

**IMM v4.0:**
- Generate time-to-event for each medical event
- Crewmember cannot have medical events following EVAC or LOCL

*Impacts:*
- Probability of LOCL and EVAC
- CHI
- Resource utilization
Partial Treatment

**IMM v3.0:**
If single resource is not available (e.g. one pill), medical event goes entirely untreated, untreated outcomes used

*Limitations:*
Overestimate negative impact of medical events

**IMM v4.0:**
- Introduce continuum between distributions defined for treated and untreated scenarios
- New distributions defined by proportion of resources available
Alternative Treatment

IMM v3.0:
Only primary resources designated for each medical condition may be used to treat

Limitations:
Does not reflect real-world system.

IMM v4.0:
Alternative resources are designated in iMED and may be used for treatment
Mars (6 crew, 2.5 years)
Total Medical Events

IMM version/ functionality

- **v3** – IMM version 3.0
- **v4.T** – IMM with timeline only
- **v4.TPT** – IMM with timeline and partial treatment
- **v.4.0** – IMM version 4.0 (timeline + partial treatment + alternative treatment)

Percent of Trials

Total Medical Events - Medkit scenario

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Mars (6 crew, 2.5 years)
Crew Health Index

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Mars (6 crew, 2.5 years) Evacuations

% Trials

# of EVACs

- 5
- 4
- 3
- 2
- 1
- 0
Mars (6 crew, 2.5 years)
Loss of Crew Life

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ISS (6 crew, 6 months)
Total Medical Events

IMM version/ functionality
v3 – IMM version 3.0
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v4.TPT – IMM with timeline and partial treatment
v4.0 – IMM version 4.0 (timeline + partial treatment + alternative treatment)
ISS (6 crew, 6 months)
Evacuations

% Trials

# of EVACs
- 5
- 4
- 3
- 2
- 1
- 0

National Aeronautics and Space Administration
ISS (6 crew, 6 months)
Loss of Crew Life
Conclusions

• Total Medical Events
  • Decrease because no events may occur following loss of crew life or evacuation

• Crew Health Index
  • Increase due to:
    • More medical events being treated due to partial treatment and alternative treatment functionalities
    • Timelined medical events causing duration of lingering functional impairment to be shortened

• Probabilities of Evacuation and Loss of Crew Life
  • Decrease due to due to partial treatment and alternative treatment functionalities
Questions?