INTEGRATED MEDICAL MODEL (IMM) 4.0
VERIFICATION AND VALIDATION (V&V) TESTING

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2. University of Texas Medical Branch, Galveston, TX
3. MEI Technologies
4. NASA Glenn Research Center
Presentation Overview

• IMM v3 versus IMM 4.0
• V&V Scope
• V&V Objectives
• Methods
• Results
• Summary
**Timeline** – In addition to generating if conditions occur, IMM v4.0 generates when conditions occur.

**Partial Treatment** – IMM v4.0 gives partial credit for partial treatment in generating the outcomes of a condition.

**Alternative Drug** – If a primary drug required for treatment is not available, IMM v4.0 searches for medically appropriate substitutes.
New capabilities were examined in a comparative, stepwise approach as follows:

• comparison of the current operational IMM v3 with the enhanced functionality of timeline (IMM 4.T)
• comparison of IMM 4.T with the enhanced functionalities of timeline and partial treatment capability (IMM 4.TPT)
• comparison of IMM 4.TPT with the enhanced functionalities of timeline, partial treatment and alternative medication capability (IMM 4.0)
Verification Objectives

Confirm that the IMM version undergoing evaluation functioned correctly and that this IMM version performed appropriately when compared to the previous IMM version:

• Events are distributed as specified
  o Incidence rate and proportion
  o Event timing
  o Best and worst case scenarios
  o Evacuation (EVAC) and loss of crew life (LOCL) assignments

• Quality-adjusted mission time lost is being calculated correctly

• Resources are utilized and depleted correctly
Validation Objectives

IMM primary outputs underwent quantitative evaluation and/or face validation to confirm that the IMM version undergoing evaluation functioned correctly:

- Total medical events (TME)
- Crew health index (CHI)
- EVAC
- LOCL
- Resource utilization

- Quantitative: statistical significance assessed using 95% CI to test differences between compared outcomes
- Face validation: assessment of the model and/or its behavior by SMEs to determine whether the model outputs are reasonable
  - understanding directions and magnitudes of differences of the model and the RWS
## Validation Objectives

(Hypothesized Qualitative Trends for Primary Outputs)

<table>
<thead>
<tr>
<th>Enhanced Functionality</th>
<th>TME</th>
<th>CHI</th>
<th>EVAC</th>
<th>LOCL</th>
<th>Resource Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timeline (IMM 4.T)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected effect on IMM 4.T outputs compared to IMM V3</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td><strong>Partial Treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IMM 4.TPT)</td>
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<td></td>
</tr>
<tr>
<td>Expected effect on IMM 4.TPT outputs compared to IMM 4.T</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Alternate Medications</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(IMM 4.0)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Expected effect on IMM 4.0 outputs compared to IMM 4.TPT</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
</tr>
</tbody>
</table>

Qualitative trend directions of the primary IMM outputs were hypothesized for mission scenario comparison of each successive implementation of new IMM capability. IMM version performed as hypothesized when compared with each successive implementation of new IMM capability.
Design Reference Mission Characteristics

<table>
<thead>
<tr>
<th>Mission</th>
<th>Duration</th>
<th>Number of 2-person EVAs*</th>
<th>Total EVAs</th>
<th>EVA Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Sortie</td>
<td>14 (days)</td>
<td>8</td>
<td>16</td>
<td>every day from day 3 to day 10</td>
</tr>
<tr>
<td>ISS6</td>
<td>180 (days)</td>
<td>6</td>
<td>12</td>
<td>day 25, 50, 75, 100, 125, 150</td>
</tr>
<tr>
<td>Mars</td>
<td>2.5 (years)</td>
<td>231</td>
<td>462</td>
<td>every second day starting from day 180</td>
</tr>
</tbody>
</table>

*Only two crew members are EVA eligible, 1 male, 1 female

• Crew characteristics
  o Six- 4 males, 2 females
  o Diverse physiological traits representative of astronaut corps
Results: TME
(ISS6 DRM -MedCap Scenario)
Results: CHI
(IS6 DRMedCap Scenario)

<table>
<thead>
<tr>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.72</td>
<td>97.58</td>
</tr>
<tr>
<td>81.99</td>
<td>98.24</td>
</tr>
<tr>
<td>84.24</td>
<td>98.41</td>
</tr>
<tr>
<td>84.37</td>
<td>98.44</td>
</tr>
</tbody>
</table>

Crew Health Index - ISS6

Percent of Trials

[Graph showing distribution of Crew Health Index values with confidence intervals for v3, v4.T, v4.TPT, and v4.0]
Results: EVAC and LOCL
( ISS6 DRM - MedCap Scenario)
## Results Summary

### Enhanced Functionality

<table>
<thead>
<tr>
<th>Enhanced Functionality</th>
<th>TME</th>
<th>CHI</th>
<th>EVAC</th>
<th>LOCL</th>
<th>Resource Utilization</th>
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</thead>
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<tr>
<td>IMM 4.T outputs compared to IMM V3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timeline (IMM 4.T)</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>V3</td>
<td>106.41</td>
<td>90.36</td>
<td>0.1724</td>
<td>0.0051</td>
<td>739.29</td>
</tr>
<tr>
<td>4.T</td>
<td>105.49</td>
<td>93.96</td>
<td>0.1418</td>
<td>0.0054</td>
<td>720.89</td>
</tr>
<tr>
<td>Partial Treatment (IMM 4.TPT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMM 4.TPT outputs compared to IMM 4.T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.T</td>
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<td>93.96</td>
<td>0.1418</td>
<td>0.0054</td>
<td>720.89</td>
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<tr>
<td>4.TPT</td>
<td>105.97</td>
<td>94.87</td>
<td>0.0594</td>
<td>0.0043</td>
<td>724.09</td>
</tr>
<tr>
<td>Alternate Medications (IMM 4.0)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>94.87</td>
<td>0.0594</td>
<td>0.0043</td>
<td>724.09</td>
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<tr>
<td>4.0</td>
<td>106.02</td>
<td>94.92</td>
<td>0.0550</td>
<td>0.0042</td>
<td>723.41</td>
</tr>
</tbody>
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Summary

- IMM 4.0 functionalities of timeline, partial treatment, and alternative treatments were added to IMM v3 to provide a closer approximation of the baselined real world system (i.e. the International Space Station).

- V&V of these enhanced functionalities indicates that the IMM 4.0 version is functioning correctly and performs as hypothesized based on meeting the proposed verification and validation objectives.

- Analysis confirmed:
  - medical events are distributed as specified by the IMM
  - quality-adjusted mission time lost is being calculated correctly
  - resources are utilized and depleted correctly
  - total medical events, crew health index, probability of evacuation, and probability of loss of crew life were as hypothesized

- Although original resource utilization hypotheses were not tested; subject matter expertise was used to evaluate the resources required. With this consideration, no unacceptable findings were identified.
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Thank you!
INTEGRATED MEDICAL MODEL (IMM) 4.0
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Back up Slides
• **Verification**: “…computational model accurately represents the underlying mathematical model…”

• **Validation**: “…determining the degree to which a model … is an accurate representation of the real world…”

• **Credibility**: “the quality to elicit belief or trust…”

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IMM Project VV&C History

- Scenario Definition (DRM)
- iMED Database

IMM

Probabilistic Risk Analysis / Monte Carlo Simulation

- Medical Events
- Crew Impairment
- Loss of Crew Life
- Evacuation
- Resources Consumed

Resource Optimization!
## Methods: Crew Characteristics

### Table 1: Design Reference Mission Characteristics

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*Only two crew members are EVA eligible, 1 male, 1 female (see Table 2 below)*

### Table 2: Crew Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>CAC</th>
<th>EVA*</th>
<th>Crowns</th>
<th>Contacts</th>
<th>Abdominal</th>
<th>Surgery History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew 1</td>
<td>M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew 2</td>
<td>M</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew 3</td>
<td>M</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew 4</td>
<td>M</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Crew 5</td>
<td>F</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew 6</td>
<td>F</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*EVA schedule described in Table 1
M- male(s); F- female(s); CAC- coronary artery calcium
Programmatics (7/49)

Simulations and analyses (10/49)

Recommended practices: identification and use (1/49)

Credibility assessment of model and simulation (M&S) results (3/49)

Models (13/49)

V&V and uncertainty quantification (9/49)

Training (3/49)

Reporting results to decision makers (3/49)
- 7009 Technical Review
  - Evidence
  - Processes
  - Identify limitations

Credibility assessment of M&S results

- Verification
- Validation
- Input Pedigree
- Results Uncertainty

- Results Robustness
- Use History
- M&S Management
- People Qualifications