INTEGRATED MEDICAL MODEL OVERVIEW

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3. NASA Glenn Research Center
4. NASA Johnson Space Center
Presentation Overview

• Brief History
• Core Questions
• Concept and Implementation
• Application
• Verification, Validation & Certification (V,V&C)
• Future Endeavors
Integrated Medical Model Project

• Simulation for medical resource planning

• Useful to quantify risk!

• Utilizes space flight community knowledge
IMM Framework

Scenario Definition (DRM) ➔ iMED Database

Integrated Medical Model

Probabilistic Risk Analysis / Monte Carlo Simulation

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

Resource Optimization!
Core Questions

• What medical conditions will occur most?
• What medical resources will be used?
• What is the probability of evacuation?
• What is the probability of loss of crew life?
• What is the range of crew impairment?
• What are the optimal medical resources?
**Methodology**

**Best-case Scenario**

- **Resources available?**
  - Yes → **Treated case:** Decrement medical resources
  - No → **Untreated Case**

**Medical Event**

**Worst-case Scenario**

- **Resources available?**
  - Yes → **Treated case:** Decrement medical resources
  - No → **Untreated Worst-Case**

**Calculate End States:**
- Evacuation
- Loss of Crew Life
- Quality Time Lost
- Resource Utilization
- Type and number of medical events
Methodology

Assumptions and limitations
– no mistakes are made
– all treatments 100% reliable
– only SAS and EVA are dependent
– no crew carry on items
– other
iMed Database

Citations, Levels of Evidence & Quality

Treatment & Outcomes

Incidence Data

Resources

Cliff*

*Clinical Finding Form
Data Sources

• ISS Expeditions 1 thru 13
• STS-01 thru STS-114
• US Crew - Apollo, Skylab, Mir
• Analog, terrestrial data
• Bayesian Analyses
• Independent Predictive Models
Levels of Evidence

Better

1. Anecdotal space flight
2. Space flight engineering
3. Validated external models
4. Terrestrial Analog
5. ISS Medical Check List

Non-Validated Models
AMA Impairment Guides
Clinical Practice Guidelines
Standards of Care

Good

Terrestrial Data
Expert Opinion
The IMM Medical Condition List

Provides a list of relevant conditions...

– that can result in impairment
– and may be mitigated

The 100 IMM Conditions

- Have Occurred (47)
- Are Possible (53)
## The IMM Medical Conditions

1. Abdominal Injury  
2. Abdominal Wall Hernia  
3. Abnormal Uterine Bleeding  
4. Acute Arthritis  
5. Acute Cholecystitis / Biliary Colic  
6. Acute Compartment Syndrome  
7. Acute Diverticulitis  
8. Acute Glaucoma  
9. Acute Pancreatitis  
10. Acute Prostatitis  
11. Acute Radiation Syndrome  
12. Acute Sinusitis  
13. Allergic Reaction (mild to moderate)  
14. Altitude Sickness  
15. Angina/ Myocardial Infarction  
16. Anaphylaxis  
17. Ankle Sprain/Strain  
18. Anxiety  
19. Appendicitis  
20. Atrial Fibrillation/ Flutter  
22. Back Pain (SAS)  
23. Barotrauma (sinus block)  
24. Behavioral Emergency  
25. Burns secondary to Fire  
26. Cardiogenic Shock secondary to Infarction  
27. Chest Injury  
28. Choking/Obstructed Airway  
29. Constipation (SAS)  
30. Decompression Sickness Secondary to EVA  
31. Dental : Exposed Pulp  
32. Dental Caries  
33. Dental: Abscess  
34. Dental: Avulsion (Tooth Loss)  
35. Dental: Crown Loss  
36. Dental: Filling Loss  
37. Dental: Toothache  
38. Depression  
39. Diarrhea  
40. Elbow Dislocation  
41. Elbow Sprain/Strain  
42. Eye Abrasion (foreign body)  
43. Eye Chemical Burn  
44. Eye Corneal Ulcer  
45. Eye Infection  
46. Eye Infection (foreign body)  
47. Finger Dislocation  
48. Fingernail Delamination (EVA)  
49. Gastroenteritis  
50. Head Injury  
51. Headache (CO2 induced)  
52. Headache (Late)  
53. Headache (SAS)  
54. Hearing Loss  
55. Hemorrhoids  
56. Herpes Zoster  
57. Hip Sprain/Strain  
58. Hip/Proximal Femur Fracture  
59. Hypertension  
60. Indigestion  
61. Influenza  
62. Insomnia (SAS)  
63. Knee Sprain/Strain  
64. Late Insomnia  
65. Lower Extremity Stress Fracture  
66. Lumbar Spine Fracture  
67. Medication Overdose / Reaction  
68. Mouth Ulcer  
69. Nasal Congestion (SAS)  
70. Nephrolithiasis  
71. Neurogenic Shock  
72. Nose bleed (SAS)  
73. Otitis Exerna  
74. Otitis Media  
75. Paresthesias  
76. Pharyngitis  
77. Respiratory Infection  
78. Retinal Detachment  
79. Seizures  
80. Sepsis  
81. Shoulder Dislocation  
82. Shoulder Sprain/Strain  
83. Skin Abrasion  
84. Skin Infection  
85. Skin Laceration  
86. Skin Rash  
87. Small Bowel Obstruction  
88. Smoke Inhalation  
89. Space Motion Sickness (SAS)  
90. Stroke (CVA)  
91. Sudden Cardiac Arrest  
92. Toxic Exposure: Ammonia  
93. Traumatic Hypovolemic Shock  
94. Urinary Incontinence (SAS)  
95. Urinary Retention (SAS)  
96. Urinary Tract Infection  
97. Vaginal Yeast Infection  
98. VIIIP – Visual Impairment/ Increased Intracranial Pressure (SAS)  
99. Wrist Fracture  
100. Wrist Sprain/Strain

SAS = Space Adaptation Syndrome
<table>
<thead>
<tr>
<th>Support Type</th>
<th>FY 2011 Total</th>
<th>FY 2012 Total</th>
<th>FY 2013 Total</th>
<th>FY2014 Total (to date)</th>
<th>Total Support Requests</th>
<th>Recent Users</th>
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<tbody>
<tr>
<td>Science &amp; Technology Planning</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td></td>
<td>2</td>
<td>15 (23%) SK / Pharmacology SK / Behavioral Hlth</td>
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<tr>
<td>Exploration Mission Planning</td>
<td>5</td>
<td>9</td>
<td>6</td>
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<td>5</td>
<td>25 (37%) SF / ExMC HMTA GRC Fluids Branch</td>
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<td>ISS Program Operations Support</td>
<td>5</td>
<td>11</td>
<td>8</td>
<td></td>
<td>3</td>
<td>27 (40%) SD /Flight Surgeons</td>
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<tr>
<td>Total Requests</td>
<td>18</td>
<td>25</td>
<td>14</td>
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<td>10</td>
<td>67</td>
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<tr>
<td>Average Per Quarter</td>
<td>4.50</td>
<td>6.25</td>
<td>3.50</td>
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<td>3.33</td>
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# 2014 – Utilization of the IMM

<table>
<thead>
<tr>
<th>Requestor</th>
<th>Question</th>
<th>IMM Analysis</th>
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<tbody>
<tr>
<td>SD2</td>
<td>Requirement for Oxygen / Ventilator for Commercial Crew Vehicles?</td>
<td>Probability of Oxygen / Ventilator use for ISS DRM</td>
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<tr>
<td>SD2</td>
<td>Is 4-orbit Soyuz docking to ISS safe?</td>
<td>Probability of SMS during docking to ISS</td>
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<tr>
<td>SK</td>
<td>Which medications should be tested for stability?</td>
<td>Most frequently used medications for Mars DRM</td>
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<td>HMTA</td>
<td>Loss of Crew Life (LOCL) Analysis</td>
<td>Probability of medical LOCL for EM-2 DRM</td>
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<tr>
<td>ISS Program</td>
<td>Medical Inputs to ISS PRA</td>
<td>Probability of medical EVAC and LOCL for ISS DRM</td>
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</table>
• Version 3.0 in use since 2011

• Following NASA Standard 7009

• Service caution statements
  – current model V, V & C status
  – care in using IMM information
S-20130607-100. Ventilator and Oxygen Quantitative Risk Analysis
What is the requirement for O²/Ventilator Capability for Commercial Vehicles?

1. Meet with customer to review goals, methods, & limitations
2. Run IMM to Compare outputs under different scenarios
3. Report results to customer

Results:

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Ventilator and Oxygen</th>
<th>Oxygen</th>
<th>No Oxygen No Ventilator</th>
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<tr>
<td>CHI (%)</td>
<td>90.56</td>
<td>90.44</td>
<td>90.45</td>
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<tr>
<td>Evac (%)</td>
<td>12.01</td>
<td>12.67</td>
<td>12.90</td>
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<tr>
<td>LOCL (%)</td>
<td>0.59</td>
<td>1.22</td>
<td>1.39</td>
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Way Forward

• Version 4.0 FY2015  
  (Foy et al – IMM Enhanced Functionalities)

• Include a more event driven scheme
  – Dynamic PRA
    • Environmental and mission specific influences (countermeasures)
    • Enhanced "what if-able" scenario capability
  – Crew Medical Officer contribution to risk reduction

• IMM “Under the Hood” roadshow
INTEGRATED MEDICAL MODEL

OVERVIEW

Thank you!

Questions?