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 resources available?

Yes

Treated case: Decrement medical resources

No

Untreated Case

Best-case Scenario

Medical Event

Worst-case Scenario

No

Untreated Worst-Case

No

Untreated Case

Worst-case resources available?

Yes

Treated case: Decrement medical resources

No

Worst-case Scenario

Calculate End States:

• Evacuation
• Loss of Crew Life
• Quality Time Lost
• Resource Utilization
• Type and number of medical events
Assumptions and limitations

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

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 Externa
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
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<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>2</td>
<td>15</td>
<td>(23%) SK / Pharmacology - SK / Behavioral Hlth</td>
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<td>Exploration Mission Planning</td>
<td>5</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>25</td>
<td>(37%) SF / ExMC - HMTA - GRC Fluids Branch</td>
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<tr>
<td>ISS Program Operations Support</td>
<td>5</td>
<td>11</td>
<td>8</td>
<td>3</td>
<td>27</td>
<td>(40%) - SD /Flight Surgeons</td>
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<td><strong>Total Requests</strong></td>
<td><strong>18</strong></td>
<td><strong>25</strong></td>
<td><strong>14</strong></td>
<td><strong>10</strong></td>
<td><strong>67</strong></td>
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<td><strong>Average Per Quarter</strong></td>
<td><strong>4.50</strong></td>
<td><strong>6.25</strong></td>
<td><strong>3.50</strong></td>
<td><strong>3.33</strong></td>
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<tr>
<td>Requestor</td>
<td>Question</td>
<td>IMM Analysis</td>
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<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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<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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<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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<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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Verification, Validation & Certification

- 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
Service Request Example

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>
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<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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<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?