



INTEGRATED MEDICAL MODEL OVERVIEW

J. Myers³, L. Boley¹, M. Foy¹, D. Goodenow³, D. Griffin³,
A. Keenan¹, E. Kerstman², S. Melton¹, K. McGuire⁴, L.
Saile¹, R. Shah², Y. Garcia¹, B. Sirmons¹, M. Walton¹, D.
Reyes²

1. Wyle Science, Technology & Engineering Group
2. University of Texas Medical Branch, Galveston, TX
3. NASA Glenn Research Center
4. NASA Johnson Space Center



- **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

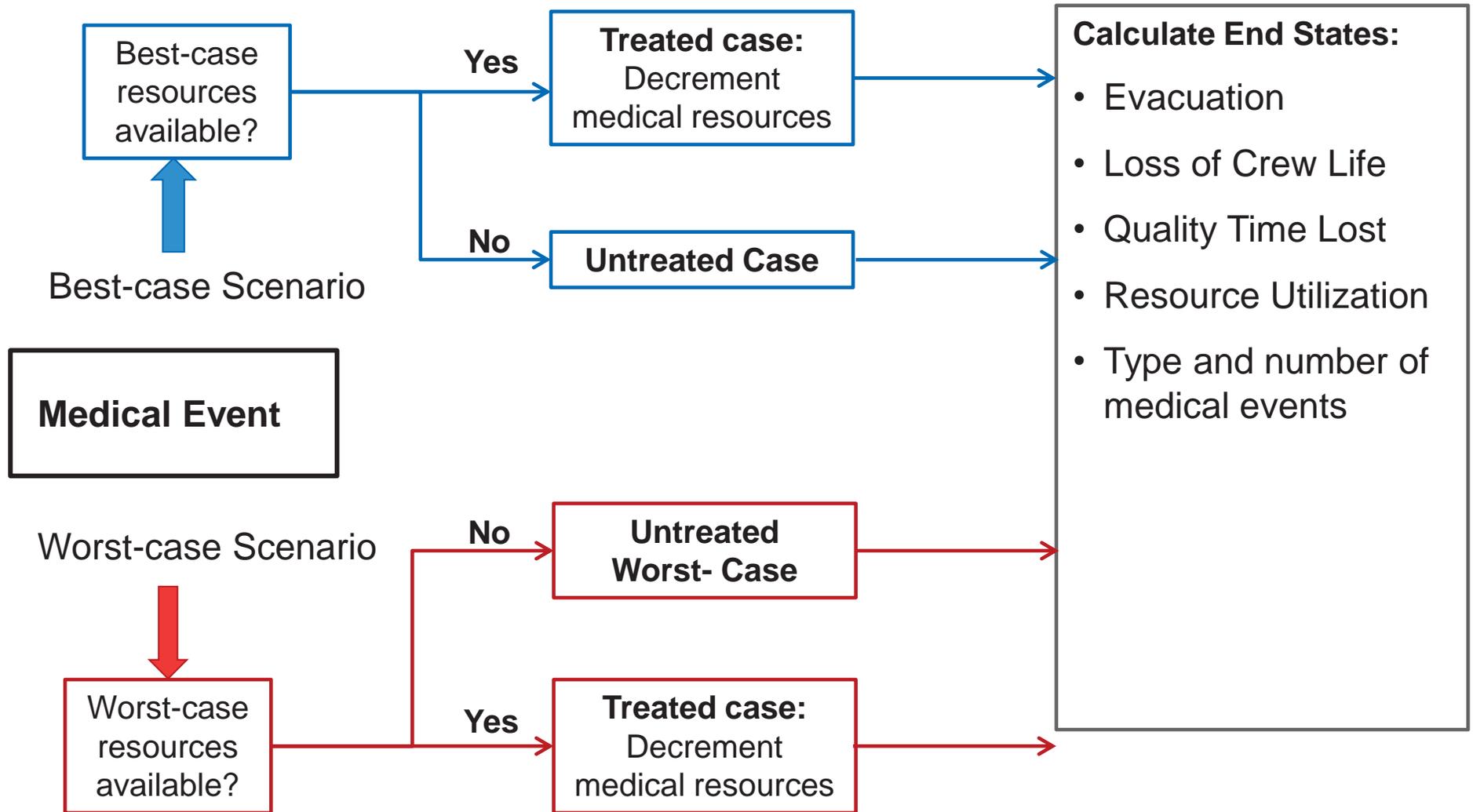
**Resource
Optimization!**

Core Questions



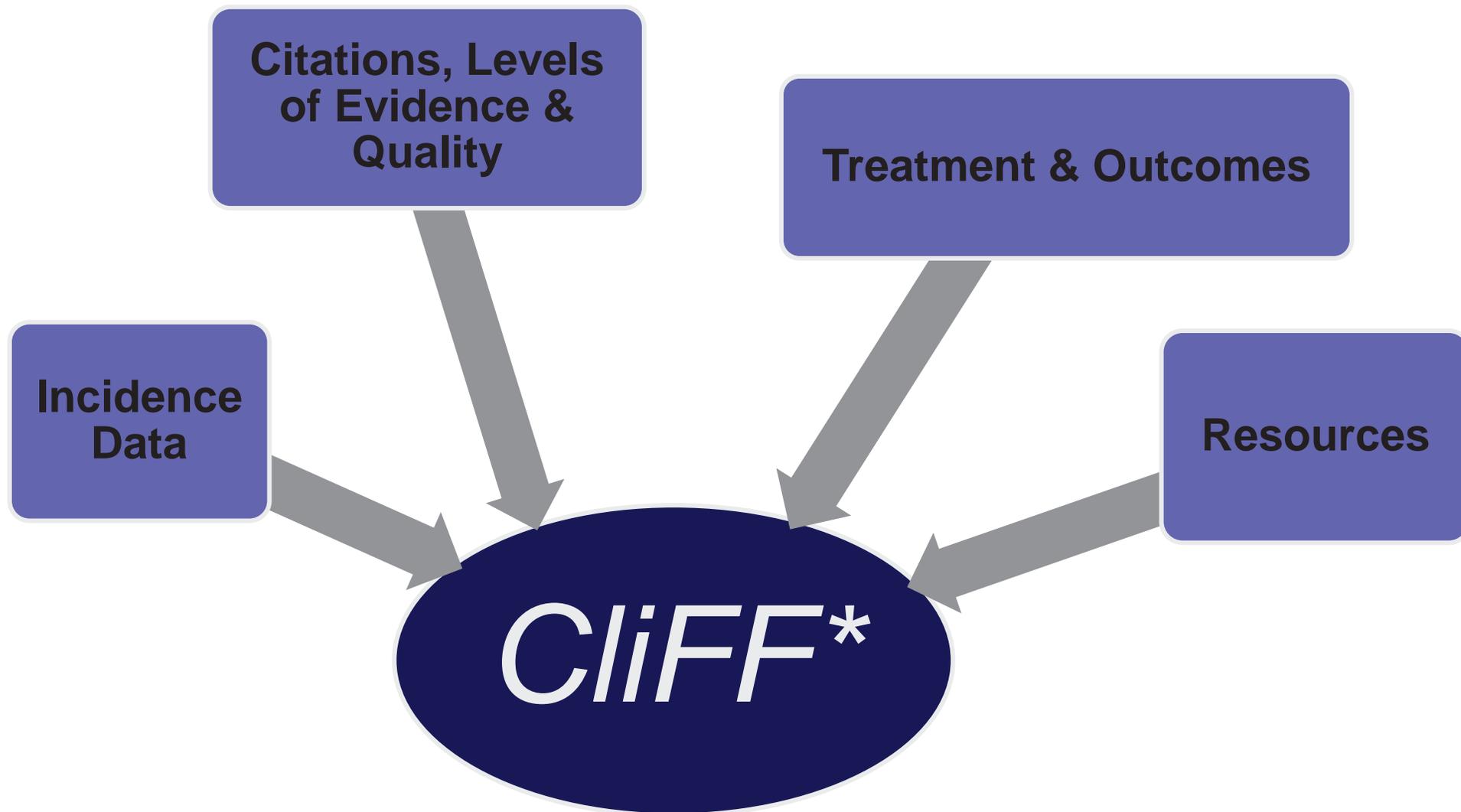
- **What medical conditions will occur most?**
- **What medical resources will be used?**
- **What is the probability of evacuation?**
- **What is the probability of loss of crew life?**
- **What is the range of crew impairment?**
- **What are the optimal medical resources?**

Methodology



Assumptions and limitations

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



**Clinical Finding Form*



- **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

Space Flight Data



1

Anecdotal space flight

Space flight engineering

Validated external models

Terrestrial Analog

ISS Medical Check List

2

3

Non-Validated Models

AMA Impairment Guides

Clinical Practice Guidelines

Standards of Care

4

Terrestrial Data

5

Expert Opinion

Good

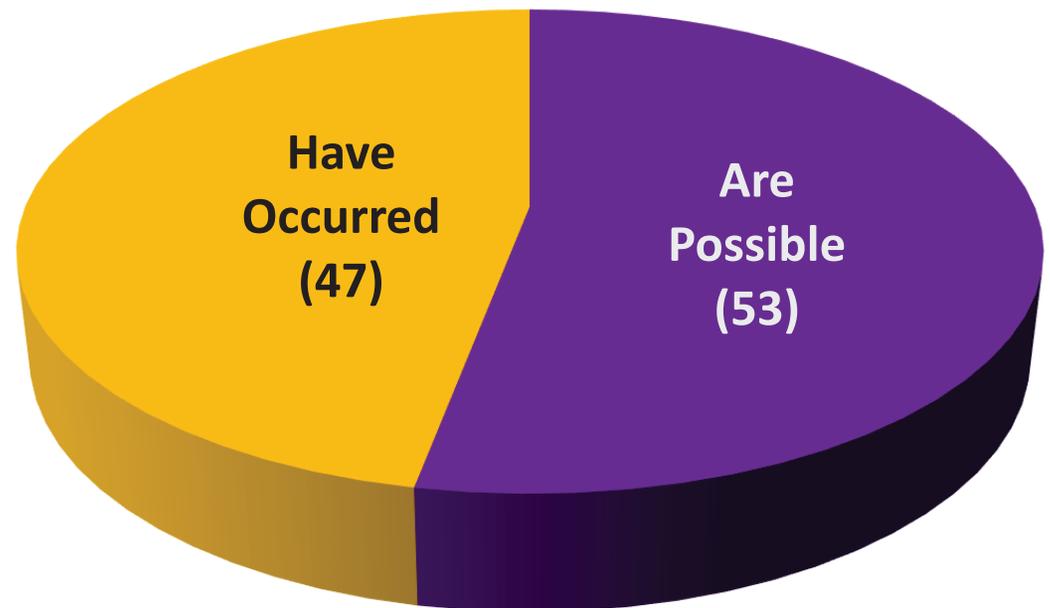
The IMM Medical Condition List



Provides a list of relevant conditions...

- that can result in impairment
- and may be mitigated

The 100 IMM Conditions



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
21. Back Injury
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 Penetration (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. VIIP - Visual Impairment/ Increased Intracranial Pressure (SAS)
99. Wrist Fracture
100. Wrist Sprain/Strain

SAS = Space Adaptation Syndrome

Activity



Support Type	FY 2011 Total	FY 2012 Total	FY 2013 Total	FY2014 Total (to date)	Total Support Requests	Recent Users
Science & Technology Planning	8	5	0	2	15 (23%)	- SK / Pharmacology - SK / Behavioral Hlth
Exploration Mission Planning	5	9	6	5	25 (37%)	- SF / ExMC - HMTA - GRC Fluids Branch
ISS Program Operations Support	5	11	8	3	27 (40%)	- SD /Flight Surgeons
Total Requests	18	25	14	10	67	
Average Per Quarter	4.50	6.25	3.50	3.33		

2014 – Utilization of the IMM



Requestor	Question	IMM Analysis
SD2	Requirement for Oxygen / Ventilator for Commercial Crew Vehicles?	Probability of Oxygen / Ventilator use for ISS DRM
SD2	Is 4-orbit Soyuz docking to ISS safe?	Probability of SMS during docking to ISS
SK	Which medications should be tested for stability?	Most frequently used medications for Mars DRM
HMTA	Loss of Crew Life (LOCL) Analysis	Probability of medical LOCL for EM-2 DRM
ISS Program	Medical Inputs to ISS PRA	Probability of medical EVAC and LOCL for ISS DRM

Verification, Validation & Certification



iMED

Internal
Verification

Internal
Validation

External
Review

External
Review
Disposition

IMM

Internal
Verification

Internal
Validation

External
Review

External
Review
Disposition

- 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



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:

Outcome	Ventilator and Oxygen	Oxygen	No Oxygen No Ventilator
CHI (%)	90.56	90.44	90.45
Evac (%)	12.01	12.67	12.90
LOCL (%)	0.59	1.22	1.39

- **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?