Validation of the NASA Integrated Medical Model: A Space Flight Medical Risk Prediction Tool

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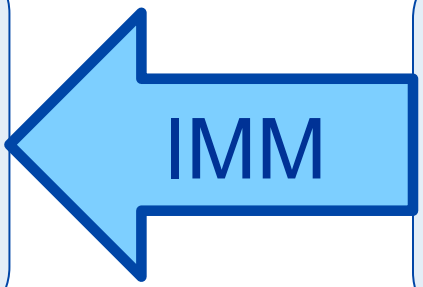
Quantifying Spaceflight Medical Risk

Human Spaceflight Involves Both Engineering and Medical/Health Risks

Mission and Vehicle Engineering and Design

Spaceflight Medical Community

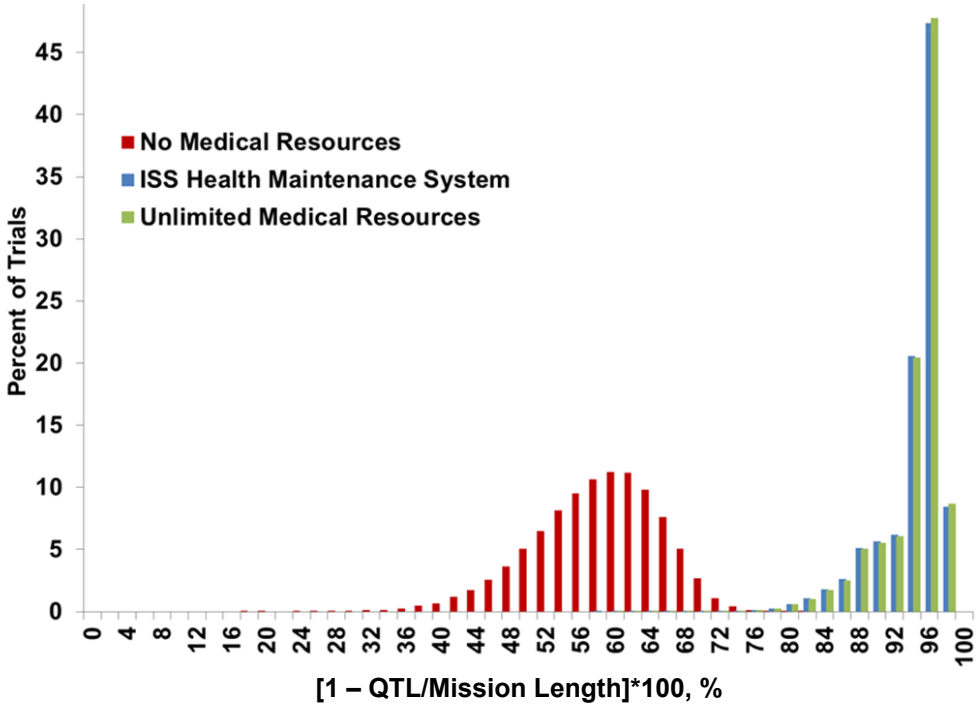
Balance Medical and Vehicle Resource Limitations with Quantitative Medical Risk Information



Quantitative Tools to Assess Medical Risk and Optimize Mission Medical Resources

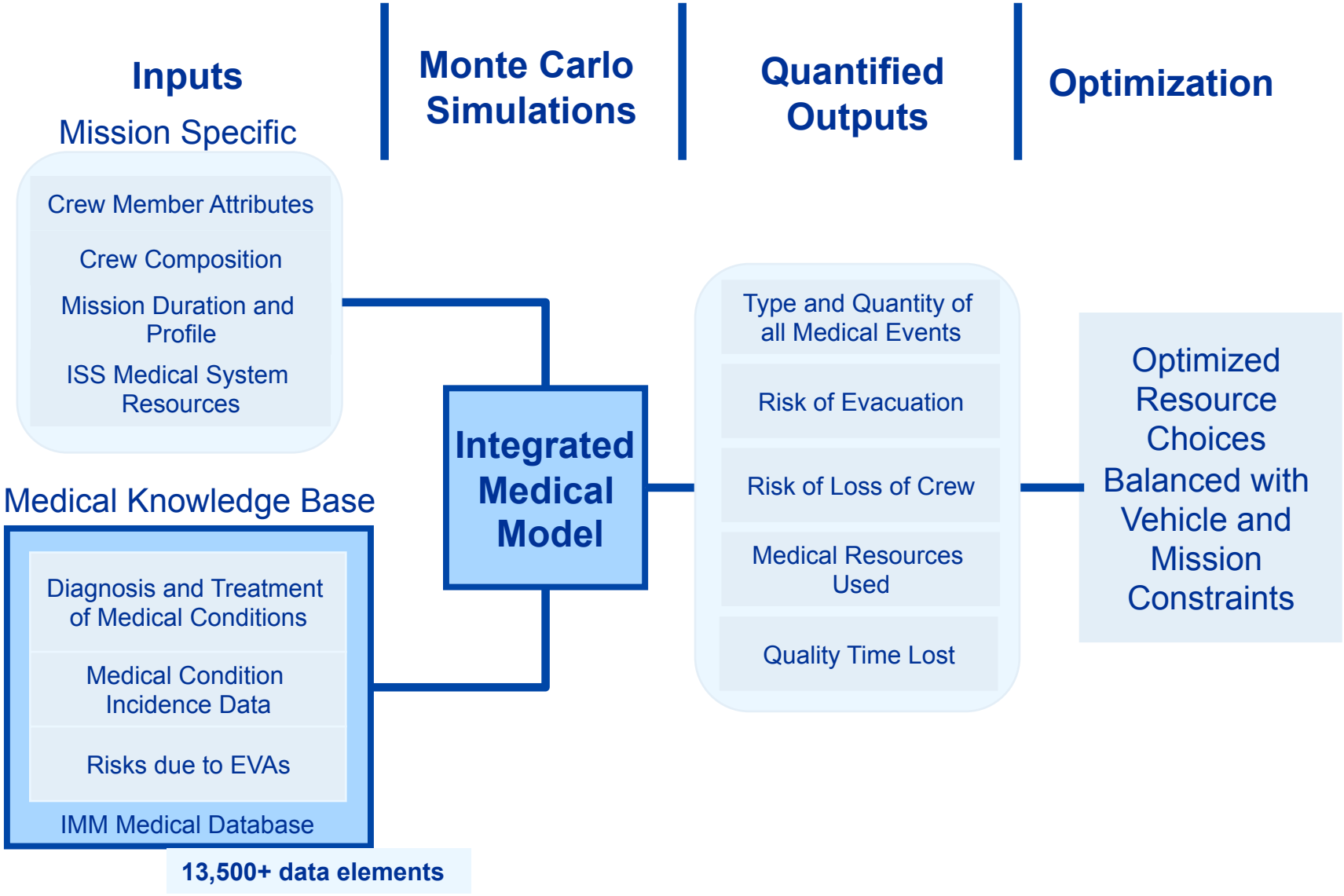
Integrated Medical Model : IMM

Stochastic simulation model that predicts in-flight medical events, the resources required to treat, and approximate impacts to the spaceflight mission.

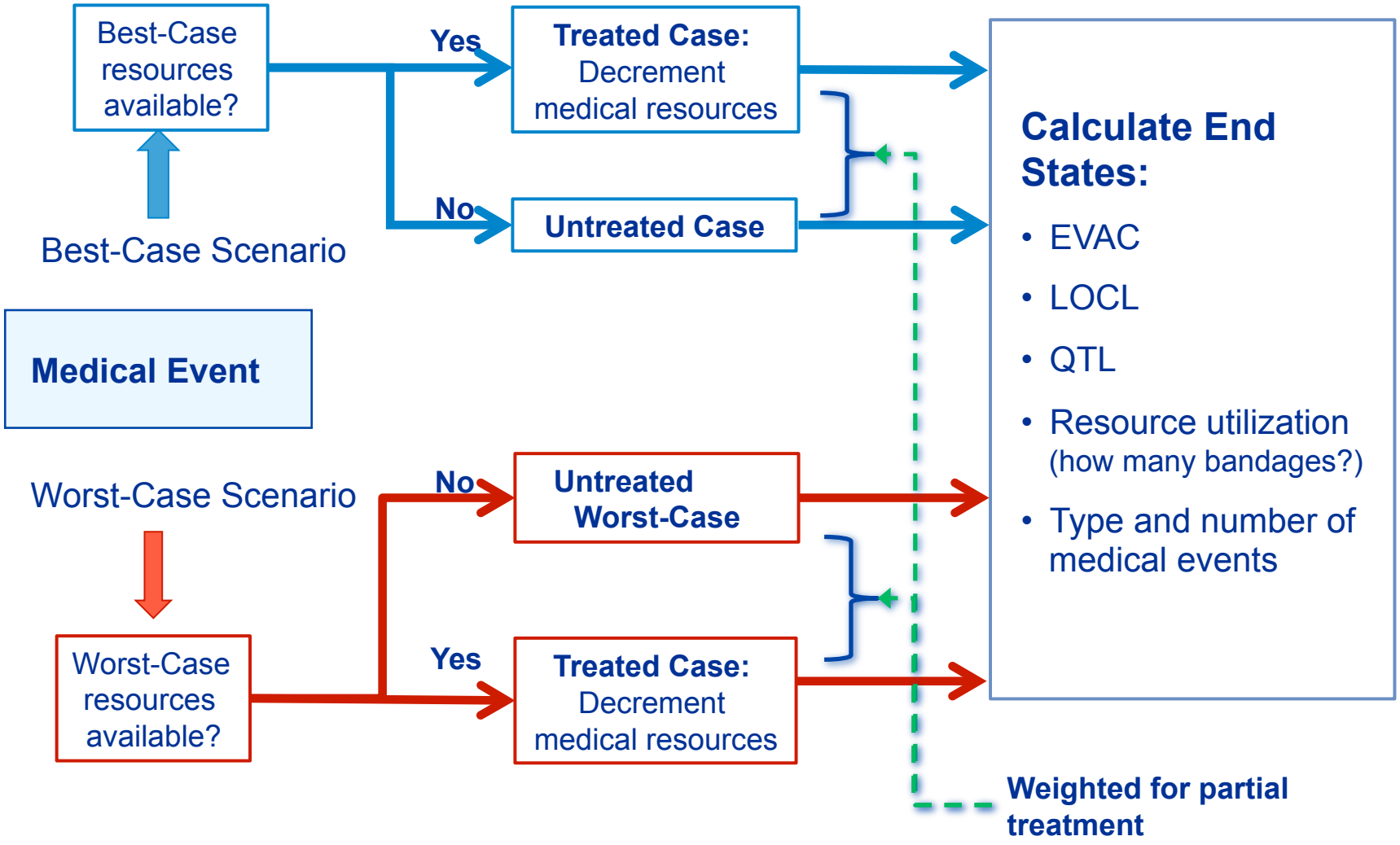


- Mission medical risk
- Medical resource trade studies

IMM Workflow



IMM Methodology



National Aeronautics and Space Administration

The IMM Medical Conditions

SKIN
- Burns secondary to Fire
- Skin Abrasion
- Skin Laceration

EYES
- Acute Angle-Closure Glaucoma
- Eye Corneal Ulcer
- Eye Infection
- Retinal Detachment
- Eye Abrasion
- Eye Chemical Burn
- Eye Penetration

EARS, NOSE, THROAT
- Barotrauma (Ear/Sinus Block)
- Nasal Congestion (SA)
- Nose Bleed (space adaptation)
- Acute Sinusitis
- Hearing Loss
- Otitis Externa
- Otitis Media
- Pharyngitis

DENTAL
- Abscess
- Caries
- Exposed Pulp
- Tooth Loss
- Crown Loss
- Filling Loss

CARDIOVASCULAR
- Angina/Myocardial Infarction
- Atrial Fibrillation / Atrial Flutter
- Cardiogenic Shock secondary to Myocardial Infarction
- Hypertension
- Sudden Cardiac Arrest
- Traumatic Hypovolemic Shock

GASTROINTESTINAL
- Constipation (space adaptation)
- Abdominal Injury
- Acute Cholecystitis/Biliary Colic Acute Diverticulitis
- Acute Pancreatitis
- Appendicitis
- Diarrhea
- Gastroenteritis
- Hemorrhoids
- Indigestion
- Small Bowel Obstruction

LUNG
- Choking/Obstructed Airway
- Respiratory Infection
- Toxic Exposure: Ammonia
- Smoke Inhalation
- Chest Injury

IMMUNE
- Allergic Reaction (mild to moderate)
- Anaphylaxis
- Skin Rash
- Medication Overdose/Adverse Reaction

NEUROLOGIC
- Space Motion Sickness (Space Adaptation)
- Head Injury
- Seizures
- Headache (Late)
- Stroke (cerebrovascular accident)
- Paresthesia Secondary to Extravehicular Activity
- Headache (Space Adaptation) Neurogenic Shock
- VIIP (Space Adaptation)

MUSKULOSKELETAL
- Back Pain (Space Adaptation)
- Abdominal Wall Hernia
- Acute Arthritis
- Back Sprain/Strain
- Ankle Sprain/Strain
- Elbow Dislocation
- Elbow Sprain/Strain
- Finger Dislocation
- Fingernail Delamination Secondary to Extravehicular Activity
- Hip Sprain/Strain
- Hip/Proximal Femur Fracture
- Knee Sprain/Strain
- Lower Extremity (LE) Stress fracture
- Lumbar Spine Fracture
- Shoulder Dislocation
- Shoulder Sprain/Strain
- Acute Compartment Syndrome
- Neck Sprain/Strain
- Wrist Sprain/Strain
- Wrist Fracture

PSYCHIATRIC
- Insomnia (Space Adaptation)
- Sleep Disorder
- Anxiety
- Behavioral Emergency
- Depression

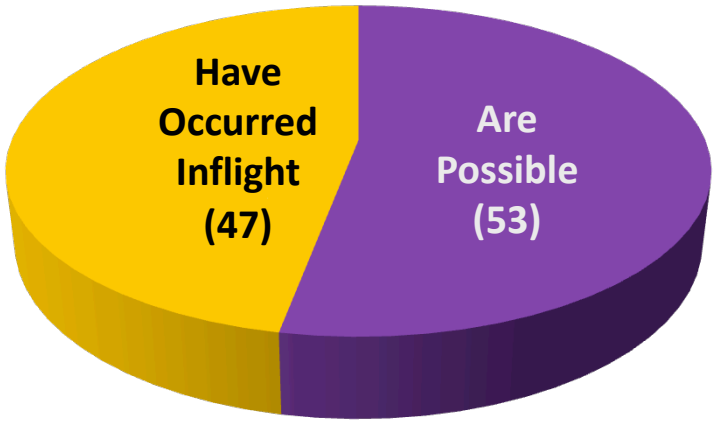
GENITOURINARY
- Abnormal Uterine Bleeding
- Acute Prostatitis
- Nephrolithiasis
- Urinary Incontinence (space adaptation)
- Urinary Retention (space adaptation)
- Vaginal Yeast Infection

INFECTION
- Herpes Zoster Reactivation (shingles)
- Influenza
- Mouth Ulcer
- Sepsis
- Skin Infection
- Urinary Tract Infection

ENVIRONMENT
- Acute Radiation Syndrome
- Altitude Sickness
- Decompression Sickness Secondary to Extravehicular Activity
- Headache (CO_2)

Spaceflight Medical Knowledge Database: iMED*

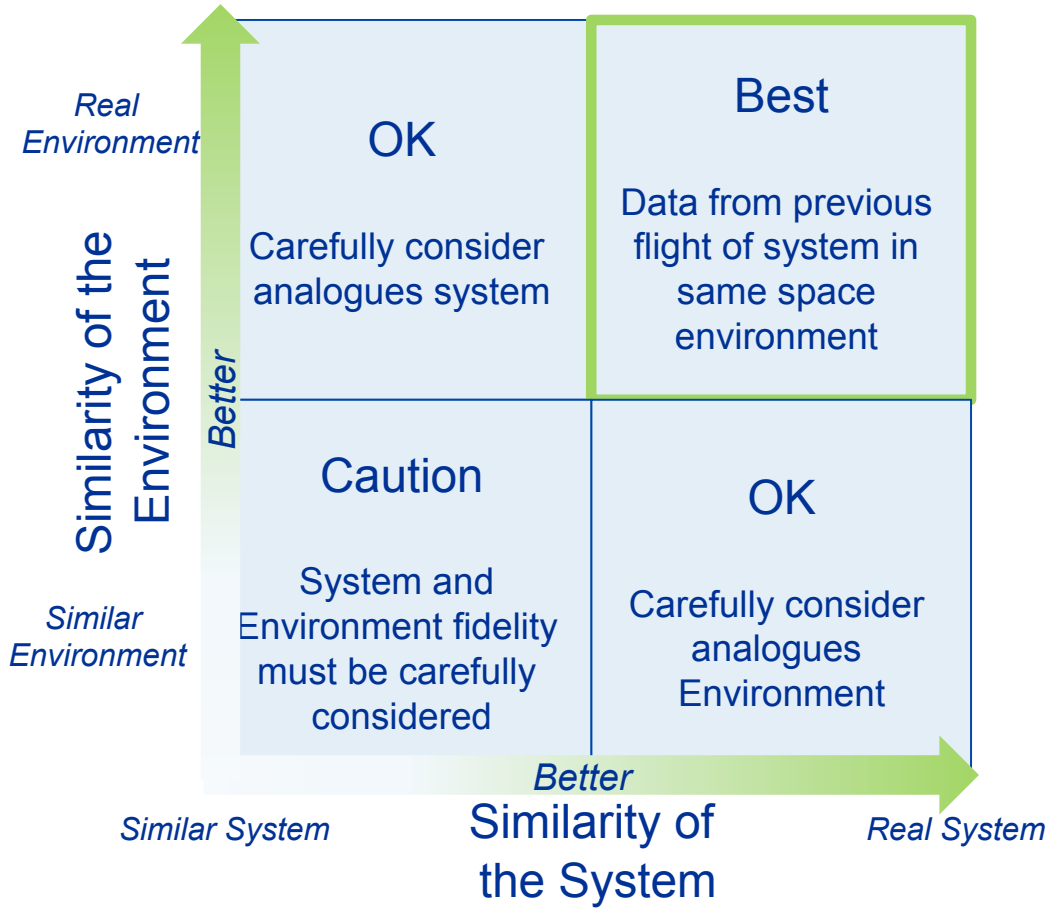
- Categorize astronaut symptomatology into conditions, flight medicine concerns, and resources
- Lifetime Surveillance of Astronaut Health (LSAH)
  - ISS Expeditions 1 thru 13 (2006)*,**
  - STS-01 thru STS-114 (2005)
  - Apollo, Skylab, Mir (U.S. crew only)
- Analog & terrestrial data
  - Bayesian and Independent models analyses
- Flight surgeon Delphi study
  - ***Russian medical data not used***



* Integrated Medical Database, iMED
** More current data used for Spaceflight Associated Neuro-ocular Syndrome, SANS

Validation

Compare IMM predictions to relevant referent :
Real spaceflight observed medical events during real missions



What Data is Used for Comparison?

- Real World System (RWS): 31 ISS and 21 STS missions not previously incorporated into the primary IMM data repository

STS 115 through STS 135 and STS 107

ISS Expedition (Exp) 14 through 39/40 and ISS Exp 9

Image Credits: NASA

IMM Simulations of the RWS Missions

Equivalent simulations performed for each RWS mission profile using IMM v 4.0

- Length of mission
- Mission schedule (EVA)
- Crew complement (sex, limited medical history)
- ISS simulation assumed resupply of medical supplies
- 100 Medical condition set

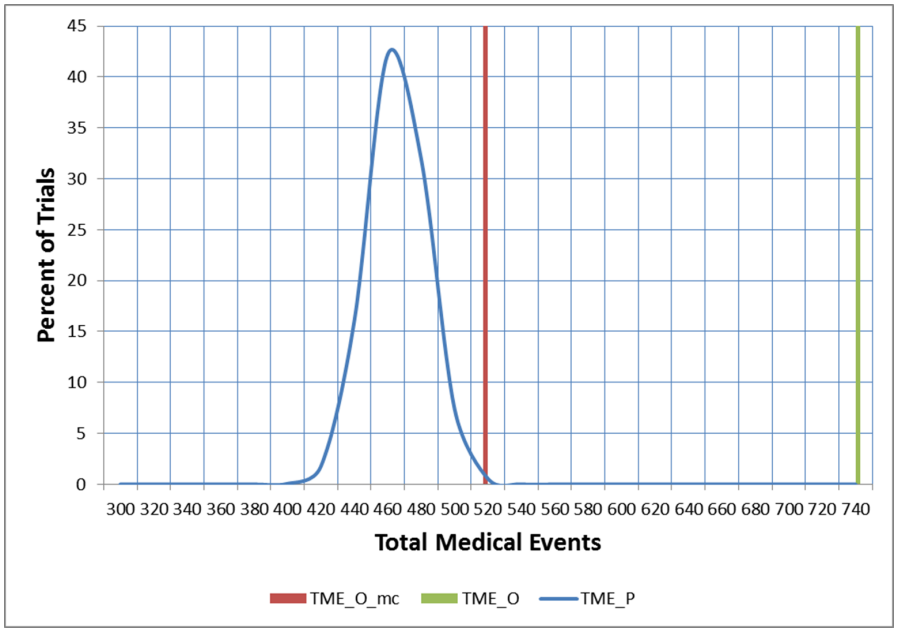
Observed and Predicted Outcomes

- Total medical events (TME)
- Medical consumable utilization
- Loss of crew life (LOCL) and potential need for evacuation (EVAC)*

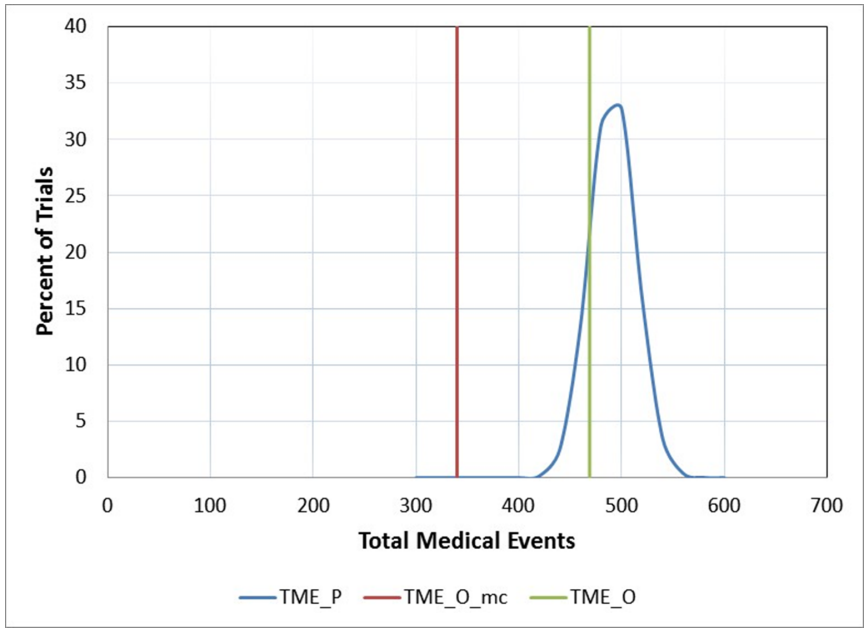
* RWS had zero LOCL and EVAC events

(Cumulative) Total Medical Events

STS

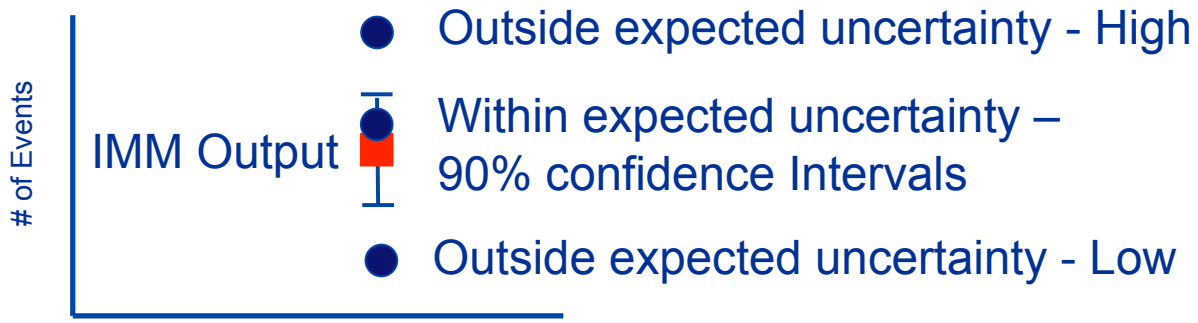


ISS



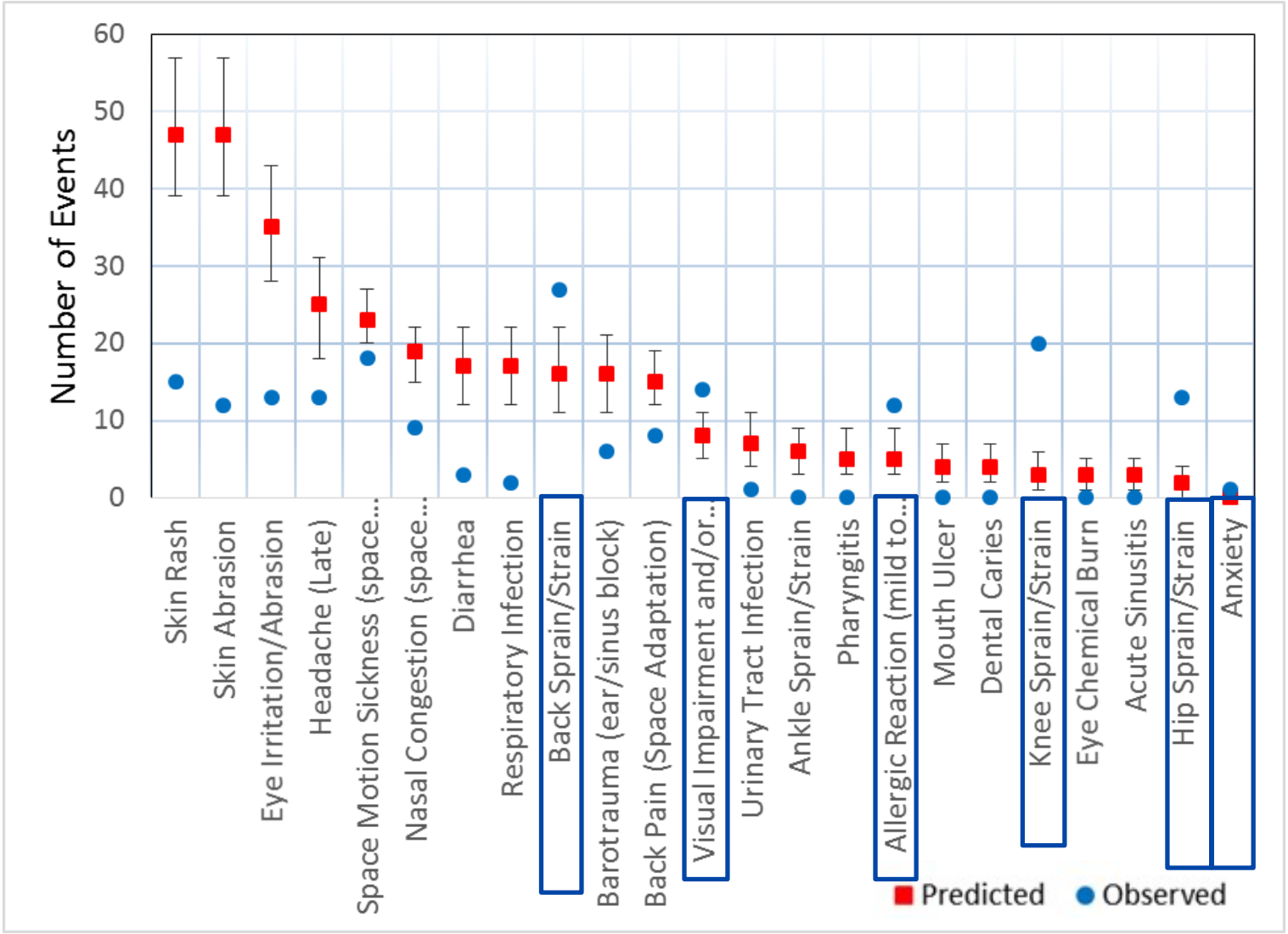
Predicted (P)
Observed (O)
Observed: IMM medical conditions list only (mc)

Per Condition Comparison



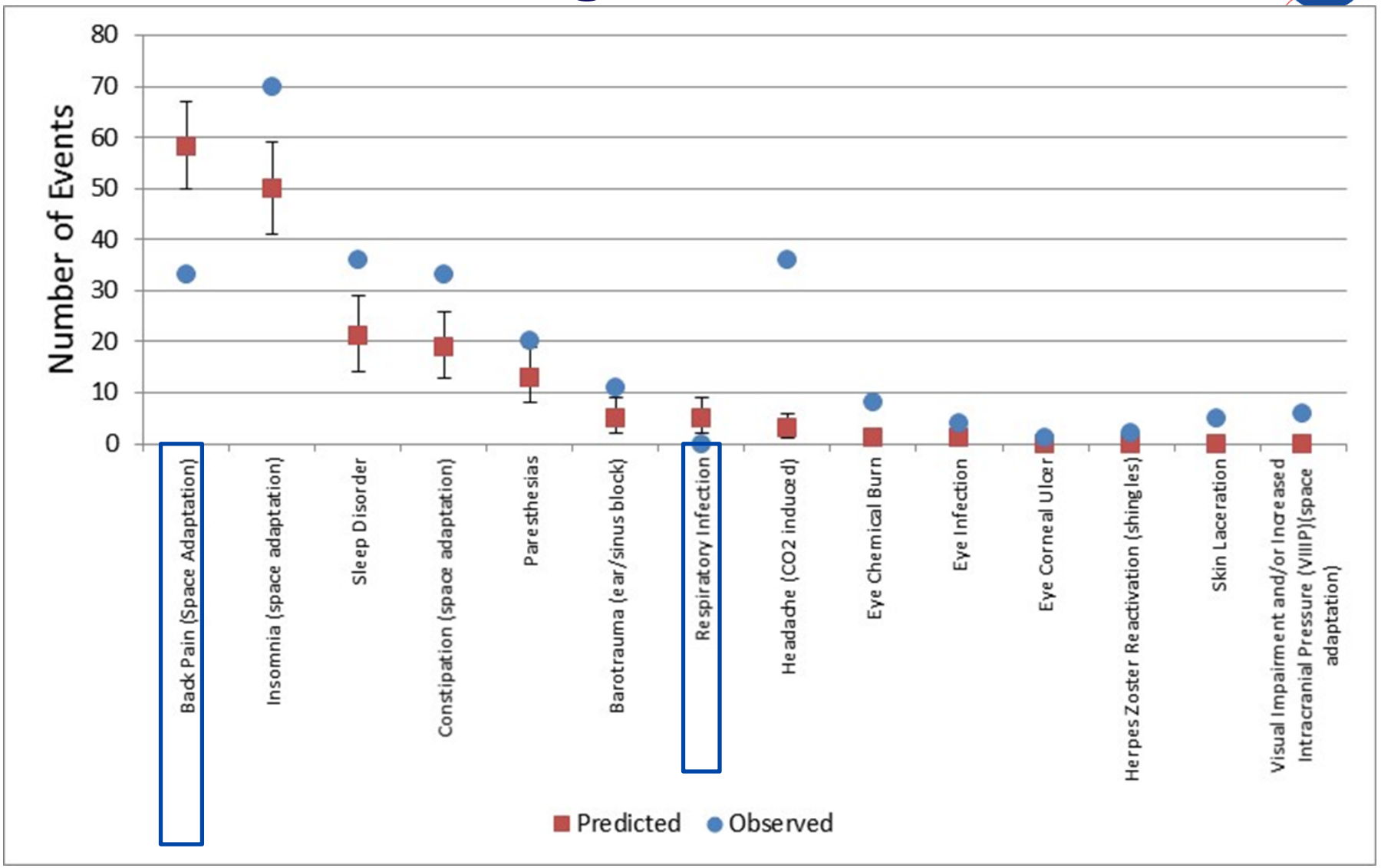
- 20% of the STS and 15% of the ISS medical events within expected uncertainty.
- 14% for STS and 24% for ISS medical events outside of the expected uncertainty.
- The remainder of the events had an indeterminate comparison.

Out of Range ISS Conditions



Over predicted the number of events for all but 6 conditions.

Out of Range STS Conditions



Under predicted the number of events for all but two conditions.

Medical Consumables

	STS			ISS		
Medical Resource Category	Observed	Predicted	Match	Observed	Predicted	Match
Antacids	10	13	Fair	10	12	Excellent
Antibiotics	7	8	Excellent	7	3	Fair
Antidiarrheals	11	7	Fair	11	8	Fair
Antiemetics	3	1	Excellent	3	6	Fair
Antifungals	9	10	Excellent	9	9	Excellent
Antihistamines	4	3	Excellent	4	4	Excellent
Antivirals	13	12	Excellent	13	14	Excellent
Decongestants	6	5	Excellent	6	7	Excellent
Hypnotics	2	2	Excellent	2	2	Excellent
Laxatives	12	11	Excellent	12	10	Excellent
Non-opioid Analgesics	1	4	Fair	1	1	Excellent
Ophthalmic Lubricants	8	9	Excellent	8	5	Fair
Opioid Analgesics	14	14	Excellent	14	11	Fair
Steroids	5	6	Excellent	5	13	Poor

Positive correlation between the IMM predictions with the observed RWS
STS: Kendall Tau-b = 0.76 and ISS: Kendall Tau-b = 0.57

LOCL and EVAC Comparison

STS	Predicted Number	90% Confidence Interval
EVAC RWS = 0	0	0, 1
LOCL RWS = 0	0	0, 0

ISS	Predicted Number	90% Confidence Interval
EVAC RWS = 0	0	0, 1
LOCL RWS = 0	0	0, 0

- Predicted counts are estimated using the median of the simulated distribution.
- A confidence limit of (0, 0) indicates that more than 95% of the generated LOCL counts was 0 as these confidence limits are estimated by the 5^{th} and 95^{th} percentiles of the simulation distribution.

Potential Implications on Decision Making

- Variation exists in IMM predictive power for STS and ISS missions

- Decision should account for information limits
  - Longer mission profile - IMM tends to over predict incidences
  - Shorter mission profiles - IMM tends to under predict incidence.

- Difference in predictions
  - Different ISS and STS reporting conditions.
  - Combining all “mission type” data
  - Constant occurrence rate or fixed proportion.

Future Work (Some Already Done!)

- Incorporation RWS data into the iMED
- Review of Treatment Pathway Data

Acknowledgments

GRC

- Kelly Gilkey
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Questions?