SENSITIVITY ANALYSIS OF THE INTEGRATED MEDICAL MODEL FOR ISS PROGRAMS

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• Consider data for 100 medical conditions from the Integrated Medical Evidence Database (iMED)
• Simulate medical event occurrences over large number of missions via Monte Carlo methodology
• For each medical condition:
Results Robustness

- Best practices with computer modeling includes establishing the robustness of the model

- Robustness is the determination of how thoroughly the sensitivities of the model results to the variables and parameters of the model are known

- Infers an understanding of the sensitivity of the real-world system to potential changes in the variables and parameters of the system
  - Assuming the imitated system behaves like the real-world system

- Understanding the relative importance of variables and parameters, along with the relative ability to affect those variables and parameters, improves decision making
Sensitivity Analysis Methodology

- Saltelli: “Sensitivity Analysis is the study of how variation in the output of a model can be apportioned, qualitatively or quantitatively, to different sources of variation (input) and how the given model depends upon the information fed into it.”

- Partial Rank Correlation Coefficient (PRCC) Analysis
  - Provides the linear relationships between two variables (one input parameter and one output parameter) when all linear effects of other variables are removed after rank transformation
  - Rank Transformation: transforms non-linear monotonic relations to linear

- SRRC – Description goes here
  - Standardized regression-based coefficients measure the sensitivity of each input on each output, adjusted for all the other inputs
  - Rank Transformation: transforms non-linear monotonic relations to linear
Contributing versus a sensitive parameter

• **KEEP IN MIND** the difference between an influential condition and a sensitive condition
  – Many conditions contribute substantially to the mean output of the model
    • Low sensitivity may indicate a “DC-signal effect” over the range of model application and parameter variance
    • Example: VIIP and EVAC
  – Parameter variance affecting model output (magnitude and variance) indicates a sensitive parameter
Using IMM for ISS missions

- IMM Provides probabilistic analysis of 100 medical condition occurrences and impact to mission outcomes
- Context: 32 person-missions representing ISS person-missions of NASA astronauts Expedition 14 and later; also used in RWS validation
- Output:
  - Total Medical Events
  - Crew Health Index (crew available time – time lost due to medical events)
  - Evacuation
  - Loss of crew life

\[
CHI = \left(1 - \frac{QTL}{L}\right) \cdot 100\% 
\]
Consideration of Evacuation
Loss of Crew Life

Sensitivity Estimates - Treated Timeline LOCL

Condition

TRAUMATIC HYPOVOLEMIC...
SEPSIS
CHEST INJURY
HEAD INJURY
STROKE/CEREBROVASCUL...
SUDDEN CARDIAC ARREST
CARDIOGENIC SHOCK SEC...
APPENDICITIS
ABDOMINAL INJURY
TOXIC EXPOSURE/AMMONI...
SMOKE INHALATION
NEUROGENIC SHOCK
MEDICATION OVERDOSE/A...
ELBOW SPRAIN/STRAIN
DEPRESSION
SLEEP DISORDER
HIP SPRAIN/STRAIN
SMALL BOWEL OBSTRUCTI...
HEADACHE-SA
SKIN ABRASION

PRCC

Condition

TRAUMATIC HYPOVOLEMIC...
SEPSIS
CHEST INJURY
HEAD INJURY
STROKE/CEREBROVASCUL...
SUDDEN CARDIAC ARREST
CARDIOGENIC SHOCK SEC...
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MEDICATION OVERDOSE/A...
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DEPRESSION
SLEEP DISORDER
HIP SPRAIN/STRAIN
SMALL BOWEL OBSTRUCTI...
SKIN ABRASION
HEADACHE-SA

SRCC
Conclusions

• Successfully implemented a rigorous quantification of model sensitivity to parameter uncertainty
  – Differs from and augments influential conditions estimate currently used by IMM

• Many sensitive conditions in the CHI, EVAC, and LOCL cases do not appear in the sensitivity estimates of the total number of medical events
  – these conditions having a low incidence rate, so the effect on TME is minimal
  – have a large effect such as prolonged impairment, evacuation, or death
Thank you!

Questions?
Backup- Untreated Total Medical Events

Sensitivity Estimates - Untreated Timeline TME

Condition
- SLEEP DISORDER
- SKIN RASH
- SKIN ABRASION
- EYE IRRITATION/ABRASION
- HEADACHE-LATE
- DIARRHEA
- RESPIRATORY INFECTION
- BACK SPRAIN/STRAIN
- BAROTRAUMA/EAR SINUS...
- SHOULDER SPRAIN/STRAIN
- HEADACHE- CO2 INDUCED
- NASAL CONGESTION-SA
- BACKPAIN-SA
- INSOMNIA-SA
- HEADACHE-SA
- VIB- SA
- URINARY TRACT INFECTION
- SKIN INFECTION
- SPACE MOTION SICKNESS...
- ELBOW SPRAIN/STRAIN

Incidence Dist
- ‘BETA’
- ‘GAMMA’
## Untreated Crew Health Index

<table>
<thead>
<tr>
<th>Condition</th>
<th>Incidence Dist</th>
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<tbody>
<tr>
<td>EYE CHEMICAL BURN</td>
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<tr>
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### Sensitivity Estimates - Untreated Timeline CHI

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Untreated Loss of Crew Life

Sensitivity Estimates - Untreated Timeline LOCL

Condition
- SEPSIS'
- SMOKE INHALATION'
- TRAUMATIC HYPOVOLEMIC..
- 'APPENDICITIS'
- HEAD INJURY'
- 'ANAPHYLAXIS'
- CHEST INJURY'
- STROKE/CEREBROVASCUL..
- SUDDEN CARDIAC ARREST'
- ACUTE DIVERTICULITIS'
- CARDIGENIC SHOCK SEC..
- ABDOMINAL INJURY'
- NEUROGENIC SHOCK'
- TOXIC EXPOSURE/AMMONI..
- SLEEP DISORDER'
- SMALL BOWEL OBSTRUCTI..
- EYE CHEMICAL BURN'
- ABDOMINAL WALL HernIA'
- SKIN RASH'
- URINARY RETENTION-SA'

Condition
- SEPSIS'
- SMOKE INHALATION'
- TRAUMATIC HYPOVOLEMIC..
- 'APPENDICITIS'
- HEAD INJURY'
- 'ANAPHYLAXIS'
- CHEST INJURY'
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- URINARY RETENTION-SA'

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- 'FIXED'
- 'GAMMA'
- 'LOGNORMAL'