Head Injury Prediction for NASA's Integrated Medical Model

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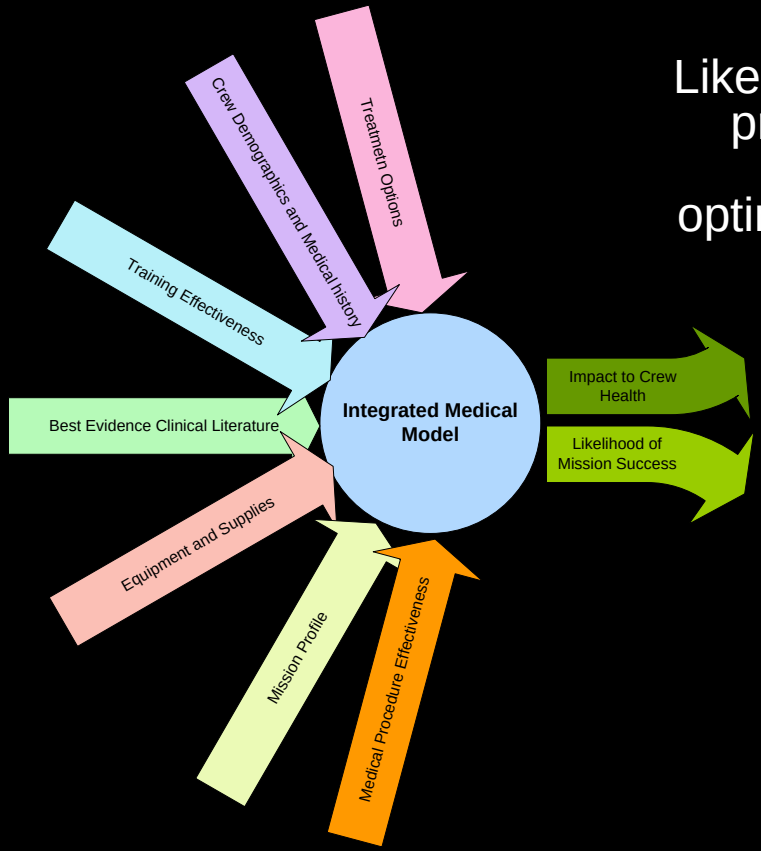
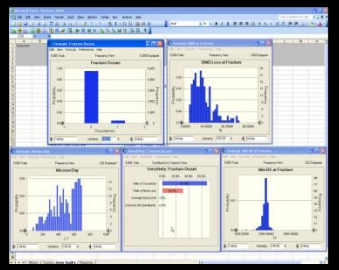
Integrated Medical Model (IMM)

Potential Medical Condition



Likelihood of occurrence, probable severity of occurrence, and optimization of treatment and resources.



Evaluate with IMM

- Probability and consequences of medical risks
- Integrate best evidence in a quantifiable assessment of risk
- Identify medical resources necessary to optimize health and mission success

Probabilistic Modeling

- Why computational modeling?
  - Event has not happened during space flight
    - No incidence rate
    - Many unknowns

- The Head Injury Module examines the likelihood of neurologic injury due to head impacts during standardized ISS increments to crewmembers during IVA activities.

Probabilistic Modeling Overview

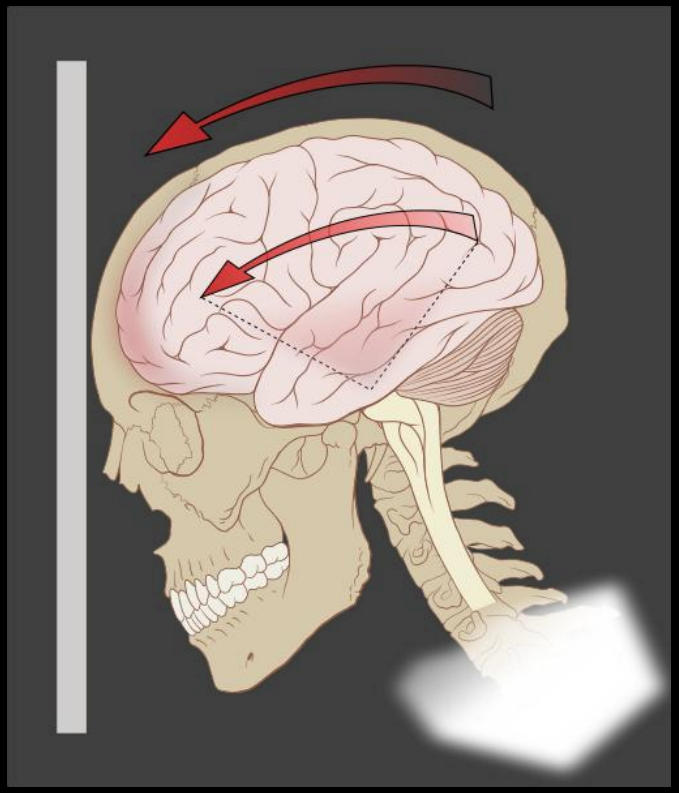
- Construct a computational model
  - Define the initiating event scenario and resulting injury
  - Determine available data and develop parameter distributions
  - Mathematically model the physiological response
  - Perform Verification and Validation
  - Relate the physiological response to probability of injury
  - Determine probability of occurrence
- Use probabilistic risk assessment methodology
  - Monte Carlo simulations
  - Estimate the most likely probability and confidence intervals

Head Injury Mission Scenario

- Head impacts onboard the ISS
- Impact through the center of gravity
- Crewmember without a helmet
- Impacting structure is modeled as a fixed, rigid body

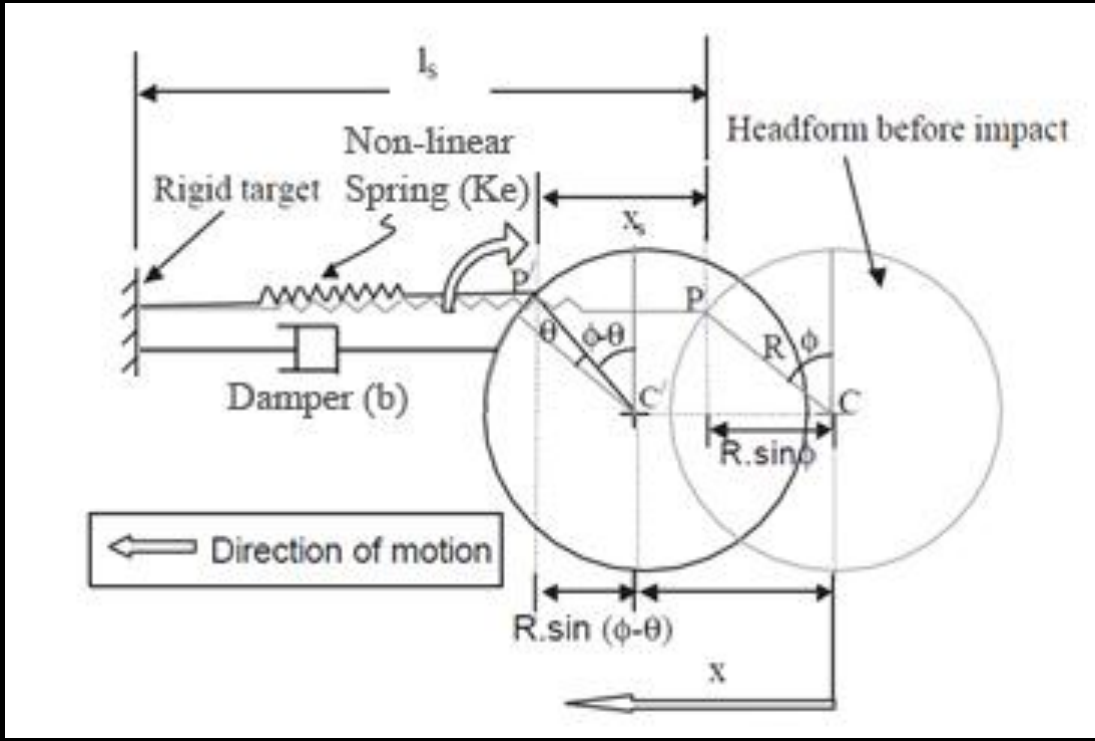
Injury Definition

- Moderate neurological injury
- Anterograde amnesia of 30 min - 24 hrs
- Abbreviated Injury Scale (AIS) score of three and above



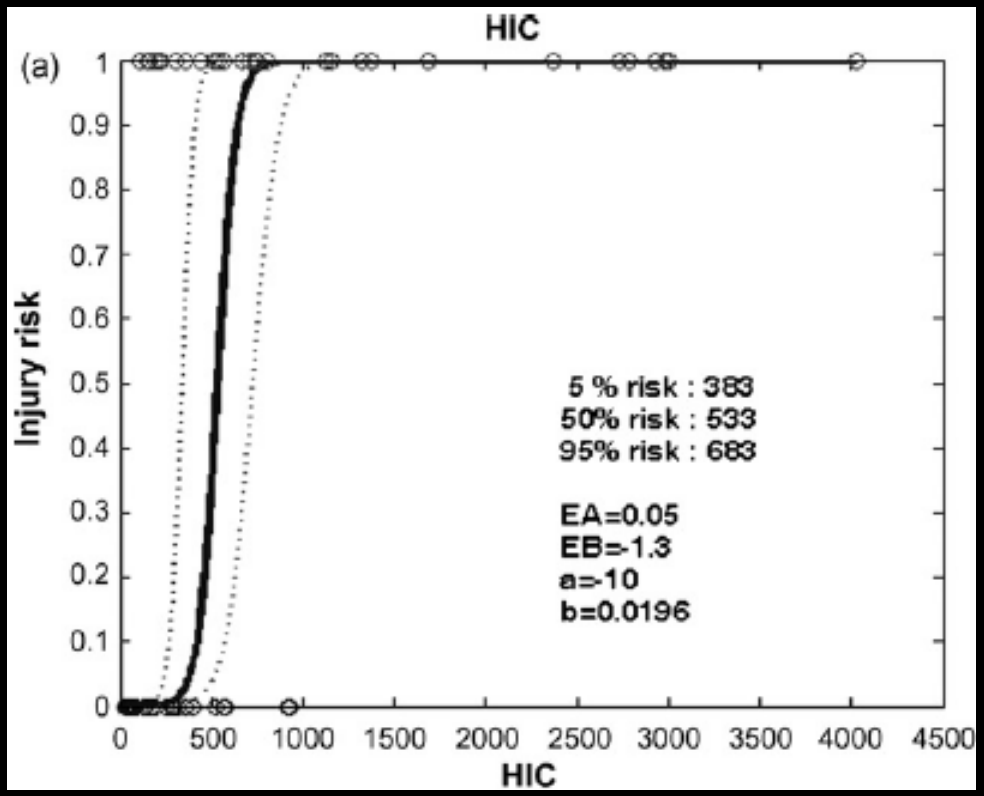
Lumped Parameter Mathematical Model

- A model of head acceleration response developed in [1] was modified for the ISS head impact scenario
- Allows for both head translation and rotation
- Stiffness and damping relationships taken from [2]



[1] Deb and Ali, 2004
[2] Sulzer et. al., 2006

Lumped Parameter Mathematical Model



- The Head Injury Criteria (HIC) score was used to determine risk of injury.
- The relation of HIC to moderate head injury risk was developed from [3].
- The 5^{th}-95^{th} percentile uncertainty bands were used to define the injury corridor.

[3] Marjoux et. al., 2008

Input Distributions

- Head mass
- Head radius
- Moment of inertia
- Neck stiffness
- Impact velocity
- Incidence rate
- Probability of injury coefficients

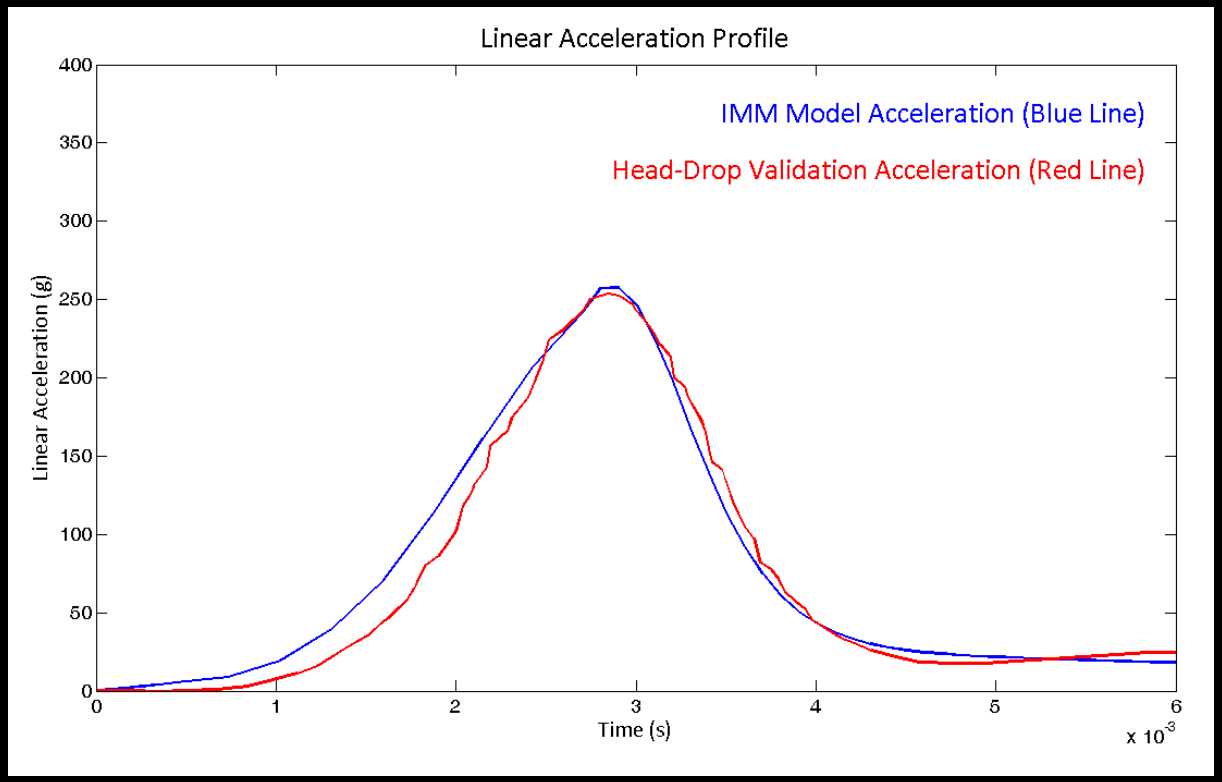
Assumptions on Incidence Rate

- Data from Scheuring et. al. (2009) were used to develop a distribution for the event that an crew member hits his/her head.
- There were 9 total head injuries reported.
  - Created a distribution using only injuries from translation, impacts, and unknown categories

Assumptions on Velocity at Impact

- Velocities are given in NASA-STD-3000 as
  - 0.15-0.30 m/s for moving equipment
  - 0.40-0.60 m/s for translation
  - 1.8 m/s for “gymnastics”
- Percentages and bounds were constructed using injuries from transferring equipment, stowing equipment, translating, impacting structures, and unknown.

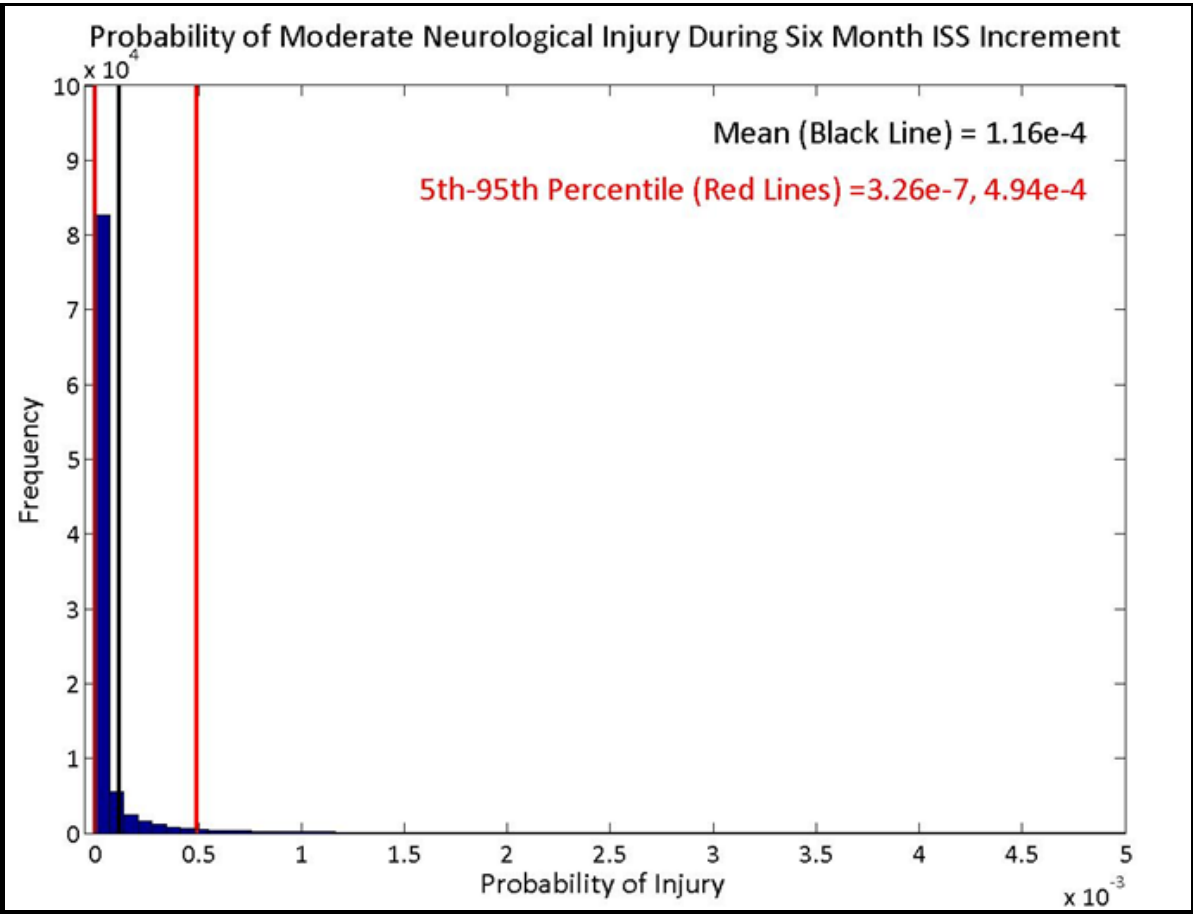
Model Validation



- The output of the current model was compared to data from a head-drop test [2]
  - Model showed a +1.2% error in peak acceleration and -1.0% error in HIC score when compared to experimental data.

Results of Monte Carlo Simulation

	Mean	Standard Deviation	5th Percentile	95th Percentile
Probability of Moderate Neurological Injury per six months (per year)	1.16×10^{-4} (2.32×10^{-4})	5.48×10^{-4} (1.10×10^{-3})	3.26×10^{-7} (6.52×10^{-7})	4.94×10^{-4} (9.88×10^{-4})



Sensitivity Analysis

- Percentage that each input variable accounts for the variability in the probability of injury output

Input Parameter	% Contribution to Variance
Impact Velocity	64.80
Injury Coefficient, b	23.58
Incidence Rate	10.66
Head Mass	0.94
Injury Coefficient, a	0.01
Moment of Inertia	0.00
Neck Stiffness	0.00

Assumptions and Limitations

- Minor injuries that may require med kit items, are not covered by this model.
- HIC score does not take rotation into account. Therefore, in order to obtain a more conservative result, only translation was considered.
- The headform impact model, which is used by the automobile industry to examine the effectiveness of countermeasures is assumed to accurately represent head impact onboard the ISS.

Thank You

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References

- [1] Deb A, Ali T. International Journal of Impact Engineering 2004;30: 521-539.
- [2] Sulzer J et. al. SAE International Conference on Digital Human Modeling. Lyon, France; 2006.
- [3] Marjoux D et. al. Accident Analysis & Prevention 2008;40: 1135-1148.