INTEGRATED MEDICAL MODEL (IMM) 4.0 VERIFICATION AND VALIDATION (V&V) TESTING
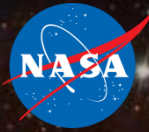
M. Walton[1], E. Kerstman[2], J. Arellano[3], L. Boley[1], D. Reyes[2], M. Young[1], Y. Garcia[1], L. Saile[1], J. Myers[4]

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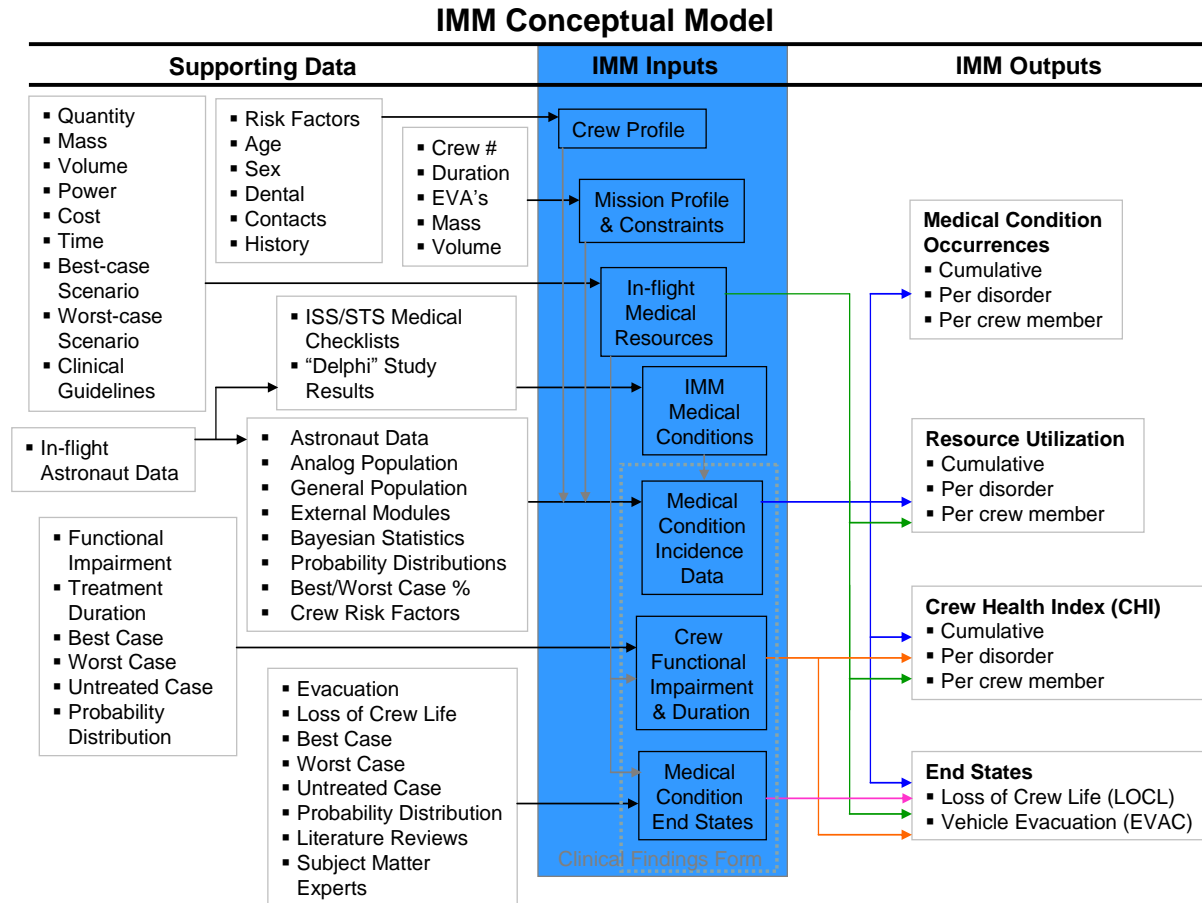3. MEI Technologies
4. NASA Glenn Research Center

- **IMM v3 versus IMM 4.0**
- **V&V Scope**
- **V&V Objectives**
- **Methods**
- **Results**
- **Summary**

IMM v3 versus IMM 4.0

- **Timeline** – In addition to generating if conditions occur, IMM v4.0 generates when conditions occur.
- **Partial Treatment** – IMM v4.0 gives partial credit for partial treatment in generating the outcomes of a condition
- **Alternative Drug** – If a primary drug required for treatment is not available, IMM v4.0 searches for medically appropriate substitutes.

IMM Conceptual Model

Supporting Data	IMM Inputs	IMM Outputs

- Quantity
- Mass
- Volume
- Power
- Cost
- Time
- Best-case Scenario
- Worst-case Scenario
- Clinical Guidelines

- Risk Factors
- Age
- Sex
- Dental
- Contacts
- History

- Crew #
- Duration
- EVA's
- Mass
- Volume

Crew Profile

Mission Profile & Constraints

- ISS/STS Medical Checklists
- "Delphi" Study Results

In-flight Medical Resources

IMM Medical Conditions

- In-flight Astronaut Data

- Astronaut Data
- Analog Population
- General Population
- External Modules
- Bayesian Statistics
- Probability Distributions
- Best/Worst Case %
- Crew Risk Factors

Medical Condition Incidence Data

- Functional Impairment
- Treatment Duration
- Best Case
- Worst Case
- Untreated Case
- Probability Distribution

Crew Functional Impairment & Duration

- Evacuation
- Loss of Crew Life
- Best Case
- Worst Case
- Untreated Case
- Probability Distribution
- Literature Reviews
- Subject Matter Experts

Medical Condition End States

Clinical Findings Form

Medical Condition Occurrences
- Cumulative
- Per disorder
- Per crew member

Resource Utilization
- Cumulative
- Per disorder
- Per crew member

Crew Health Index (CHI)
- Cumulative
- Per disorder
- Per crew member

End States
- Loss of Crew Life (LOCL)
- Vehicle Evacuation (EVAC)

New capabilities were examined in a comparative, stepwise approach as follows:

- comparison of the current operational IMM v3 with the enhanced functionality of timeline (IMM 4.T)

- comparison of IMM 4.T with the enhanced functionalities of timeline and partial treatment capability (IMM 4.TPT)

- comparison of IMM 4.TPT with the enhanced functionalities of timeline, partial treatment and alternative medication capability (IMM 4.0)
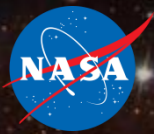
Confirm that the IMM version undergoing evaluation functioned correctly and that this IMM version performed appropriately when compared to the previous IMM version.

- **Events are distributed as specified by the IMM.**
  - Incidence rate and proportion
  - Event timing
  - Best and worst case scenarios
  - Evacuation (EVAC) and loss of crew life (LOCL) assignments
- **Quality-adjusted mission time lost is being calculated correctly.**
- **Resources are utilized and depleted correctly.**

Validation Objectives

- **Qualitative trend directions of the primary IMM outputs were hypothesized for mission scenario comparison of each successive implementation of new IMM capability. The following IMM primary outputs underwent quantitative evaluation and/or face validation to confirm that the IMM version undergoing evaluation functioned correctly, and that this IMM version performed as hypothesized when compared with each successive implementation of new IMM capability:**

- **Total medical events (TME)**

- **Crew health index (CHI)**

- **EVAC**

- **LOCL**

- **Resource utilization**

- **Face validation involves assessment of the model and/or its behavior by knowledgeable individuals to determine whether the model outputs are reasonable. Reasonable is defined as SME understanding of the directions and magnitudes of differences of the model and the RWS.**

Validation Objectives
(Hypothesized Qualitative Trends for Primary Outputs)

Enhanced Functionality	TME	CHI	EVAC	LOCL	Resource Utilization
	Expected effect on IMM 4.T outputs compared to IMM V3				
Timeline (IMM 4.T)	↓	↑	↓	↓	↓
	Expected effect on IMM 4.TPT outputs compared to IMM 4.T				
Partial Treatment (IMM 4.TPT)	↑	↑	↓	↓	↑
	Expected effect on IMM 4.0 outputs compared to IMM 4.TPT				
Alternate Medications (IMM 4.0)	↑	↑	↓	↓	↑

Methods

Table 1: Design Reference Mission Characteristics

Mission	Duration	Number of 2-person EVAs*	Total EVAs	EVA Schedule
Lunar Sortie	14 (days)	8	16	every day from day 3 to day 10
ISS6	180 (days)	6	12	day 25, 50, 75, 100, 125, 150
Mars	2.5 (years)	231	462	every second day starting from day 180

*Only two crew members are EVA eligible, 1 male, 1female (see Table 2 below)

Table 2: Crew Characteristics

	Sex	CAC	EVA*	Crowns	Contacts	Abdominal Surgery History
Crew 1	M	Yes	No	Yes	No	No
Crew 2	M	No	Yes	No	No	No
Crew 3	M	No	No	No	Yes	No
Crew 4	M	No	No	No	Yes	Yes
Crew 5	F	No	Yes	Yes	No	No
Crew 6	F	No	No	No	Yes	No

*EVA schedule described in Table 1
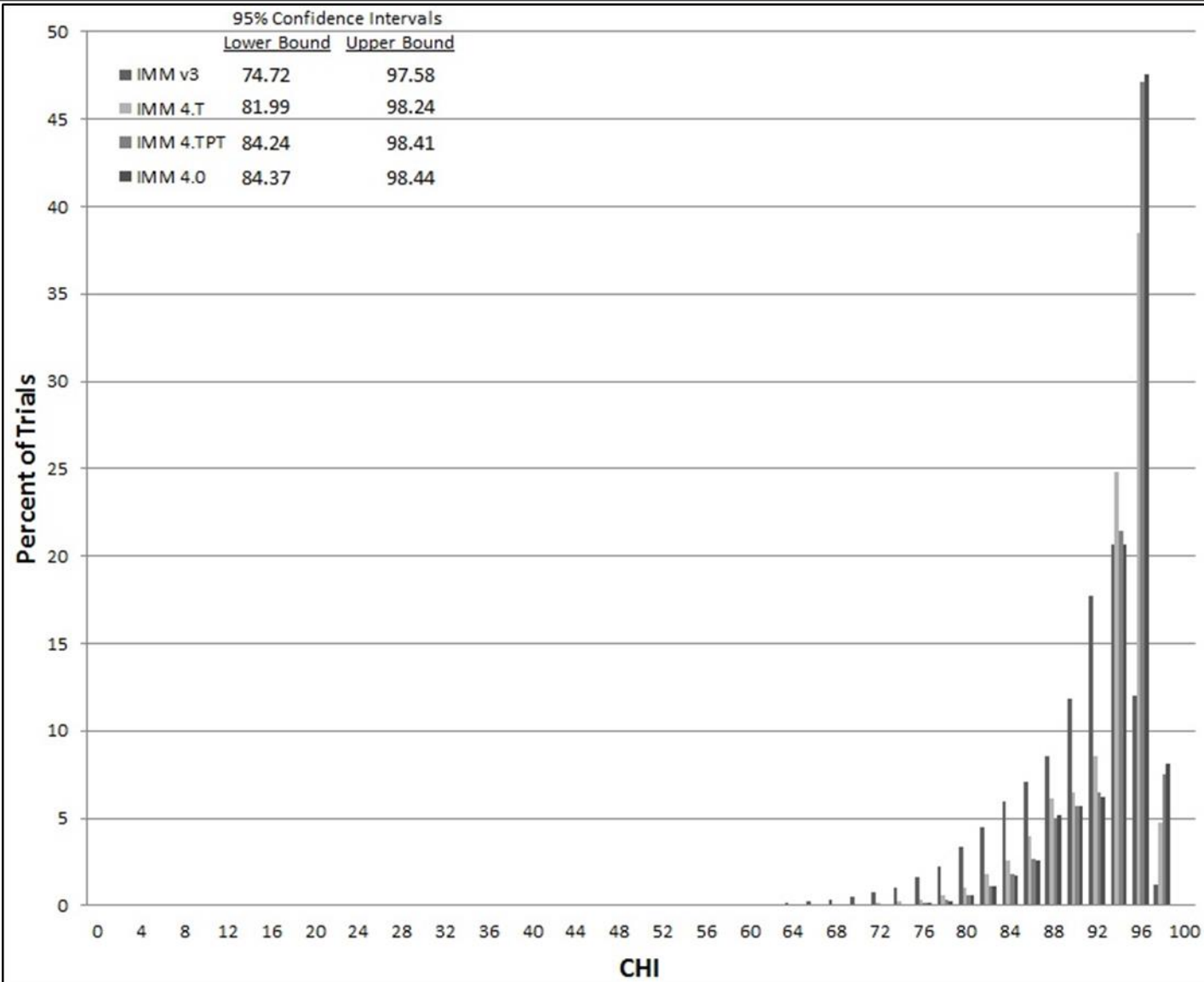
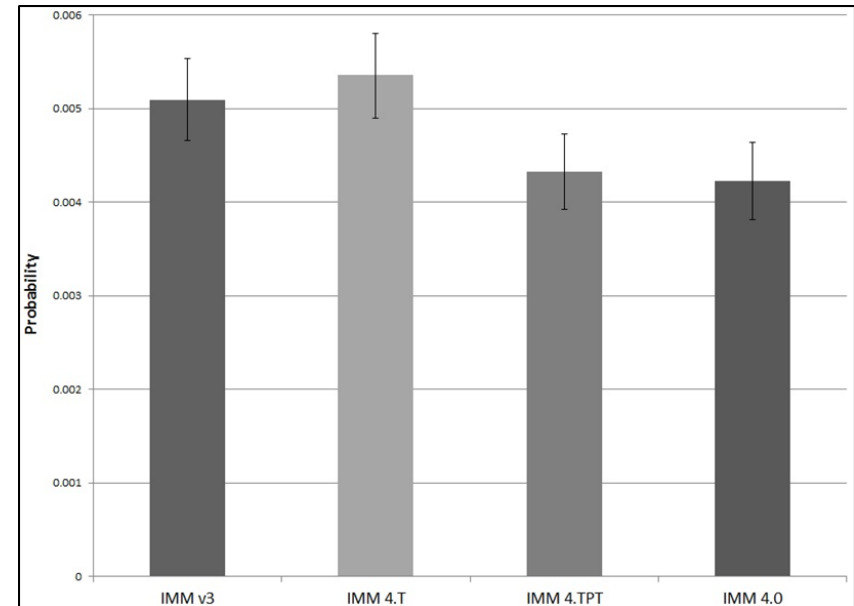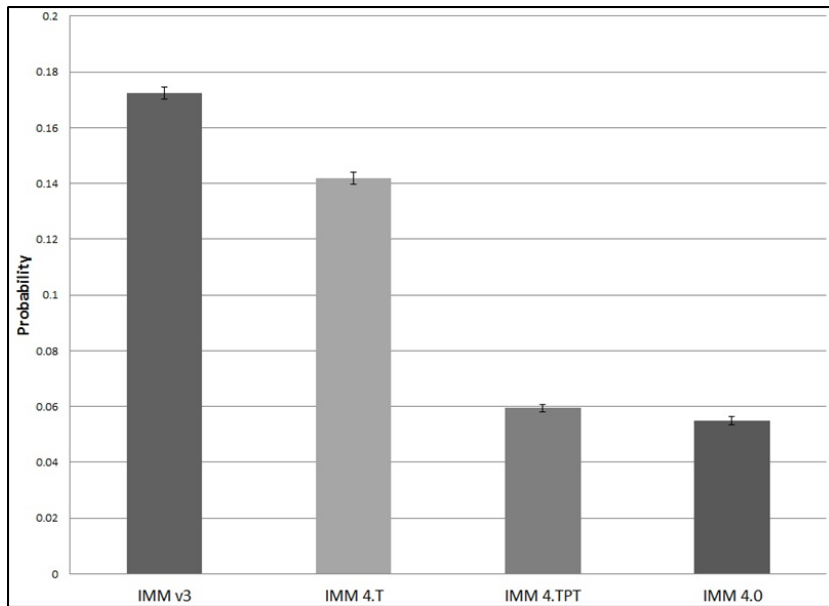M- male(s); F- female(s); CAC- coronary artery calcium
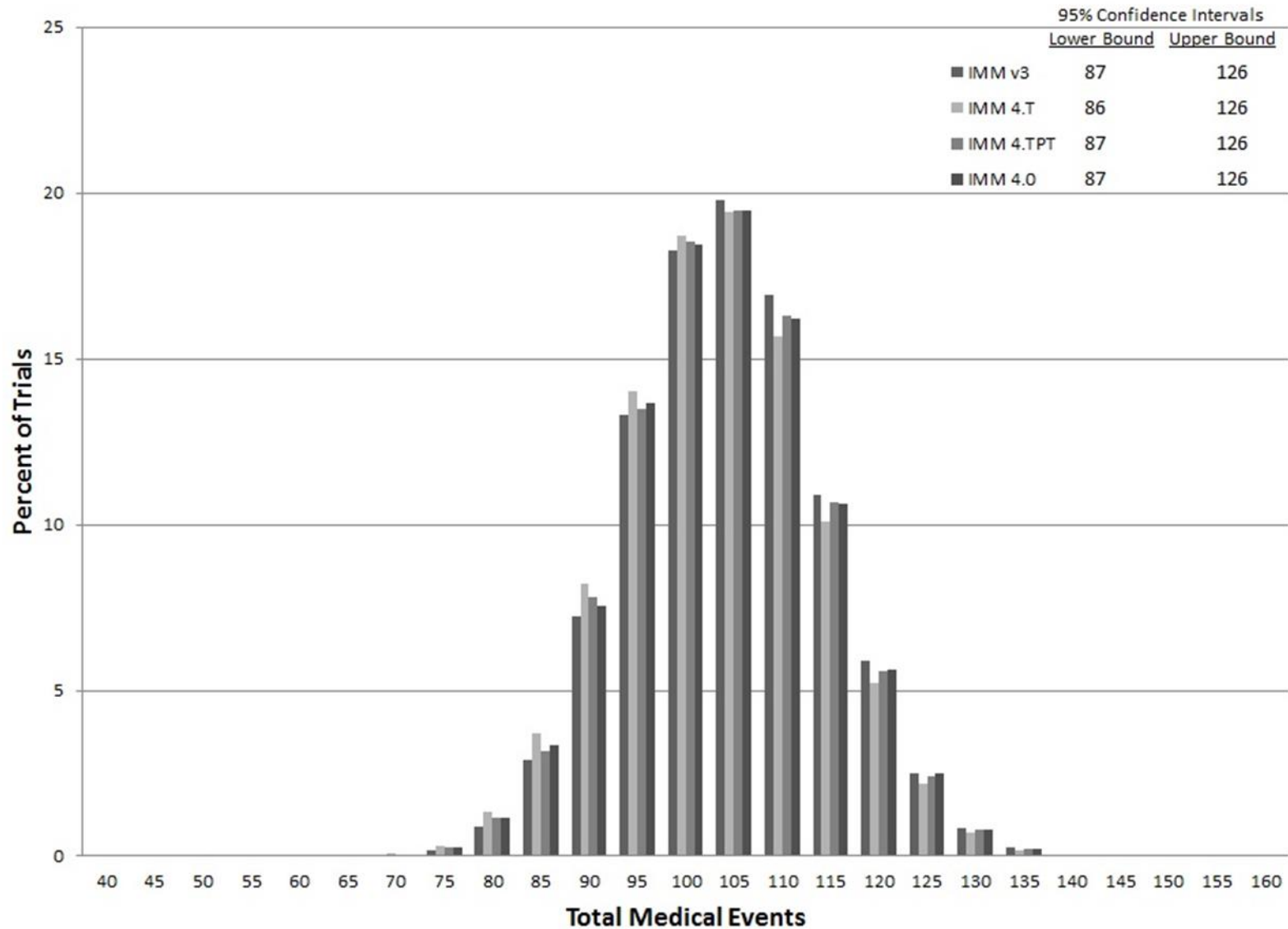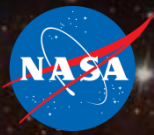
Results Summary

Enhanced Functionality	TME	CHI	EVAC	LOCL	Resource Utilization
	IMM 4.T outputs compared to IMM V3				
Timeline (IMM 4.T)	↓	↑	↓	↓	↓
V3	106.41	90.36	0.1724	0.0051	739.29
4.T	105.49	93.96	0.1418	0.0054	720.89
	IMM 4.TPT outputs compared to IMM 4.T				
Partial Treatment (IMM 4.TPT)	↑	↑	↓	↓	↑
4.T	105.49	93.96	0.1418	0.0054	720.89
4.TPT	105.97	94.87	0.0594	0.0043	724.09
	IMM 4.0 outputs compared to IMM 4.TPT				
Alternate Medications (IMM 4.0)	↑	↑	↓	↓	↑
4.TPT	105.97	94.87	0.0594	0.0043	724.09
4.0	106.02	94.92	0.0550	0.0042	723.41

Summary

- IMM 4.0 functionalities of timeline, partial treatment, and alternative treatments were added to IMM v3 to provide a closer approximation of the baselined real world system (*i.e.* the International Space Station).

- V&V of these enhanced functionalities indicates that the IMM 4.0 version is functioning correctly and performs as hypothesized based on meeting the proposed verification and validation objectives

- Analysis confirmed:
  - medical events are distributed as specified by the IMM
  - quality-adjusted mission time lost is being calculated correctly
  - resources are utilized and depleted correctly
  - total medical events, crew health index, probability of evacuation, and probability of loss of crew life were as hypothesized

- Although original resource utilization hypotheses were not tested; subject matter expertise was used to evaluate the resources required- with this consideration, no unacceptable findings were identified.

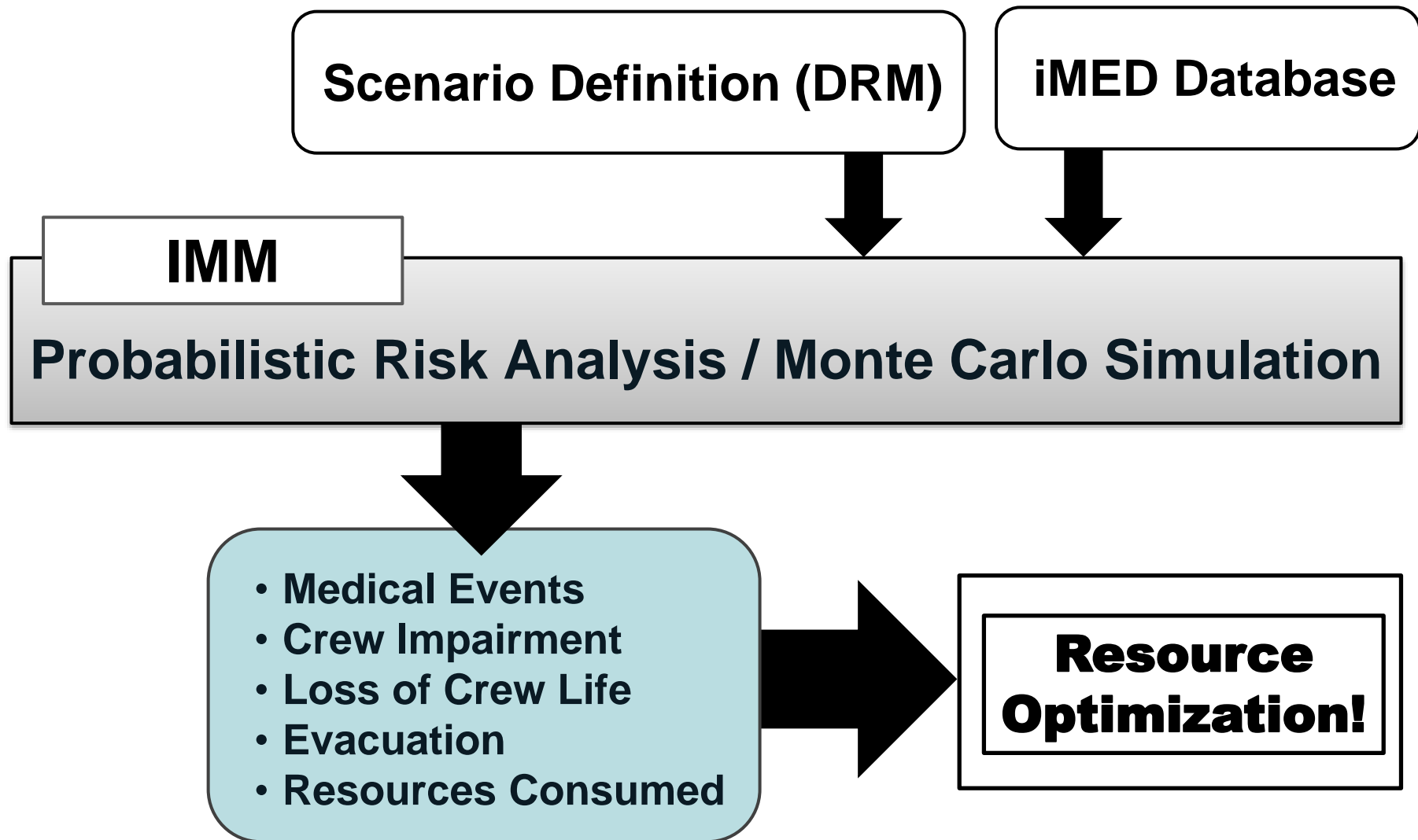# INTEGRATED MEDICAL MODEL (IMM) 4.0 VERIFICATION AND VALIDATION (V&V) TESTING

Back up Slides

- **Verification:** "…computational model accurately represents the underlying mathematical model…"

- **Validation:** "…determining the degree to which a model … is an accurate representation of the real world…"

- **Credibility:** "the quality to elicit belief or trust…"

Programmatics (7/49)

Models (13/49)

Simulations and analyses (10/49)

V&V and uncertainty quantification (9/49)

Recommended practices: identification and use (1/49)

Training (3/49)

Credibility assessment of model and simulation (M&S) results (3/49)

Reporting results to decision makers (3/49)

- **7009 Technical Review**
  - Evidence
  - Processes
  - Identify limitations

Credibility assessment of M&S results

Verification	Validation	Input Pedigree	Results Uncertainty
Results Robustness	Use History	M&S Management	People Qualifications