Mars Propulsion Transit Times

IMPORTANT SERVICE REQUEST NOTICE (S-20170724-390)

This service report should not be used for diagnostic or treatment decisions, which are outside the scope of the model. Please include the service request number (S-20170724-390) on any presentations or documentation referencing this service request.

Executive Summary

In order to compare medical outcomes for different round trip transit times to Mars that are associated with various propulsion methods, 6 different mission duration times (150 days, 204 days, 335 days, 517 days, 746 days, and 1103 days) with no EVAs were modeled using a 4 person crew (2 males, 2 females). Simulation results shown are based on ISS Medical Capability (MedCap) resources without resupply.

Results show generally linear relationships between transit time and medical outcomes.

Background

The IMM is a stochastic model that uses Monte Carlo methodology to simulate medical outcomes during spaceflight missions. The IMM consists of a three-step process. First, mission and crew member characteristics are specified to define a particular mission profile, or design reference mission (DRM). Next, medical events and outcomes during the space flight mission are randomly generated based on pre-defined values and probability distributions. Finally, total crew health and mission impact outcomes are summarized. For this report, the primary outcomes of interest are total medical events (TME), crew health index (CHI), need for evacuation (EVAC) and loss of crew life (LOCL).

The IMM is most useful for comparing risks across multiple mission profiles based on probable events and resource availability. Biased results may be incurred due to limitations of the model, but the bias will be consistent across mission profiles within the same service request.

Methods

Crew and Mission Parameters

The DRMs were configured using the crew profiles shown in Table 1. The outcomes of certain IMM medical conditions are influenced by pre-existing medical history, including: coronary artery calcium score (CAC), dental crowns, contact lenses, and history of prior abdominal surgery. Pre-existing conditions, as defined here, are consistent with historical U.S. crew data. CAC was specified as positive in one male, and in no female crew members, which is also consistent with historical crew data. EVA conditions were excluded from this report, which focuses on medical events during transit only.

Table 1: Crew Profile Used for All DRMs

Crew Member	Sex	CAC	Crowns	Contacts	Prior Abdominal Surgery	EVA
Crew 1	Male	Yes	Yes	No	No	No
Crew 2	Male	No	No	Yes	Yes	No
Crew 3	Female	No	Yes	No	No	No
Crew 4	Female	No	No	Yes	No	No

Propulsion method and associated round-trip transit time are shown in Table 2. Estimated propulsion transit times were provided by ExMC and were taken from the engineering literature. Please note that the IMM does not model the medical sequelae specifically associated with propulsion methods.

Table 2: Propulsion Transit Times for Each DRM

DRM #	Propulsion Method	Round Trip Transit Time (days)
1	Nuclear electric propulsion (RFIT-45 engine)	1103
2	Solar Electric	746
3	NASA DRM-5	517
4	Nuclear thermal propulsion (Bimodal nuclear thermal electric propulsion)	335
5	VASIMR	204
6	Fusion propulsion (Inertial confinement)	150

Medical Conditions and Resources

The one hundred medical conditions currently included in the IMM are shown in Appendix A (and detailed in Appendix B). The incidence of IMM medical events occurring during simulated missions are based on historical mission and cohort data, contained within the iMED. For each condition, the percentage of “best case” and “worst case” scenarios are specified, as well as a defined set of medical resources that are used to treat the condition. The iMED entry for each condition details the specific medical resources and quantity, necessary for treatment in both the best and worst-case scenarios. In-flight medical treatment is assumed to follow a specified protocol [5] or clinical practice guidelines for each medical condition and is constrained by resource availability on the ISS (i.e. the ISS medical capabilities (MedCap)). Model outcomes can be given for the all-treated (continuous resupply, e.g. ISS in low earth orbit), all-untreated (no Medkit) and baseline MedCap (ISS Medkit without resupply). For this

service request only the MedCap state was utilized, because this should most closely resemble a real world deep space mission where resupply is not possible, but where utilization of partial and alternative treatment can occur.

Main Outcomes

The IMM primary medical outcomes include: total medical events (TME), crew health index (CHI), probability of Evacuation (EVAC), probability of Loss of Crew Life (LOCL), and required resources.

CHI is a calculated percentage using the quality-adjusted mission time lost (QAMTL) due to in-flight medical events and resources available to treat those conditions [2].

$$\text{CHI (\%)} = [\ 1 - (\ \text{QAMTL} \div \text{Mission Length}\ )\ ] \times 100$$

For a given condition, QAMTL is determined by summing the product of functional impairment and duration for all three clinical phases of that condition: i) diagnosis and initial treatment, ii) ongoing treatment, and iii) end-state. CHI percent values range from 0-100, where zero represents complete crew impairment and one hundred represents a completely functional crew.

EVAC in the context of IMM means that medical evacuation from the ISS would be considered for definitive treatment of the afflicted crew member(s). EVAC is considered an end state result if any of the following criteria are met: 1) potential LOCL; 2) potential significant permanent impairment; or 3) potential intractable pain. When EVAC is calculated by the IMM, no consideration has been given to the availability of a return vehicle or the likelihood of a successful clinical outcome should a return vehicle be available.

LOCL in the context of IMM should be interpreted to mean that the clinical scenario resulted in death of the affected crew member(s). In version 4.1 of the IMM, crew members are usually only assigned one end state of EVAC or LOCL. In rare instances a crewmember can get a condition that will go to EVAC or LOCL, and then develop another condition that will also go to EVAC or LOCL in the time between the onset of first condition and the EVAC or LOCL time. Both events are recorded as EVAC or LOCL outcomes. These assumptions should result in more accurate IMM forecasts for the occurrence of EVAC and LOCL as compared to the prior version of the model.

Required resources for treatment are tracked for each simulated mission trial. The number of each resource that is used to treat a given condition is decremented from available resources. If more of any particular resource is used than is available, then that resource is considered “depleted” in the MedCap scenario. Events that require a “depleted” resource are considered “partially treated” if only a portion of the required resources are available. If there are sufficient available alternate resources in the MedCap, the event is considered "fully treated." If there are not enough resources available to treat the event, the event is considered "untreated." The initial quantities for medical resources are baselined to a fully stocked ISS medical kit (MedCap).

Modeling Approach

Simulations were run for the different transit times, as seen in Table 2, using the crew profile in Table 1. One hundred thousand (100,000) trials were run for each DRM, where each trial can be considered an individual "mission". This ensures that the distribution of outcomes meet convergence criteria. Convergence criteria are met when there is less than, or equal to a 5% change in the average standard deviation of the CHI, EVAC, and LOCL primary model outcomes in the last two - 1,000 mission increments. This last step is performed manually by the modelers using the IMMV4ConvergenceReport.

IMM outcomes were determined for the DRMs using the ISS MedCap scenario where all conditions are treated, partially treated or untreated based on the available resources of the ISS MedCap. CHI is calculated as a percentage, with 95% confidence intervals (CIs) for the associated distributions. EVAC and LOCL are probabilities, with 95% CI for EVAC and LOCL obtained using bootstrap resampling of the simulation output [3]. In this report, CHI, EVAC and LOCL results, as well as pertinent influential conditions, are described. IMM version 4.1 has certain features, assumptions and limitations that impact modeled outcomes. IMM 4.1 represents a significant advance over IMM 3.0. Improvements in IMM 4.1 include inclusion of a timeline, and alternate or partial treatment capability. Features, assumptions and limitations pertinent to this report are described below.

Features, Assumptions and Limitations of IMM Version 4.1 [3]

1. All non-SA and non-extravehicular activity (EVA) related conditions have a uniform likelihood of occurring throughout the mission duration. Space Adaptation Syndrome conditions occur in the first 5 days of the mission, with a peak occurrence at 48 hours.

2. Individuals cannot get the same condition for which they are currently being treated (i.e. during Clinical Phase (CP) I and II).

3. EVAC and LOCL are generated for each medical event, and then the timing of the EVAC or LOCL is generated according to a specified distribution.

4. Individuals are no longer at risk for further conditions once their status changes to either EVAC or LOCL. From the start time of the EVAC or LOCL, the functional impairment of the crew member is assumed to be 100%.

5. When the status of a crew member changes to EVAC, only one crew member is evacuated.

6. The IMM assumes that, per crew member, the first condition requiring a specific therapy utilizes all resources required for treating that condition before a second condition has access to those resources.

7. Most medical conditions, with exceptions including acute radiation syndrome and EVA-linked conditions, occur independently of the occurrence of mission events and other medical conditions. Currently there is no correlation or association within or between crew members for most medical conditions.

8. The model assumes another crew member is available to act as caregiver but does not track the time impact of providing this care.

9. Medical procedures are accurately followed and successful; no mistakes occur in executing medical procedures.

10. Crew medical skill level and preflight/inflight training is not modeled.

11. All diagnoses are 100% accurate.

12. All pharmaceuticals maintain maximum efficacy.

13. All medical events receive the appropriate treatment.

14. All medical events respond to the treatment as expected terrestrially.

15. All medical equipment is 100% reliable.

16. For each of the medical conditions specified in iMED, all crew members with the same characteristics (sex, presence of CAC, crowns, contacts, history of abdominal surgery) have the same likelihood distribution of experiencing the condition.

17. All crew members are assumed to have all intrinsic body parts intact (i.e. appendix, gall bladder, and uterus or prostate, etc.).

18. IMM assumes ISS power, potable water and oxygen resources are always available in unlimited supply.

19. No Russian medical capabilities aboard the ISS are available to US crew members in this model.

20. Medical capabilities do not include the use of personal crew carry-on items contained in the Individual Medical Accessories Kit, (IMAK).

21. If a crew member is undergoing treatment for concurrent medical conditions requiring the same consumable resource, the crew member will only utilize resources at the level required by the condition that requires the most resources.

22. If the primary resource required for treating a medical condition is unavailable, one or more alternative resources are considered, if appropriate. One example might be using acetaminophen in place of ibuprofen.

23. Total quantities of a consumable medical resource requiring a daily dose will be adjusted if a dosage schedule runs past the end of the mission.

24. If a solar particle event causes acute radiation sickness in one or more crew members, IMM assumes the condition begins identically in all affected crew members at the beginning of the solar particle event.

25. The IMM does not decrement non-consumable items and allows all non-consumable items to be used simultaneously by multiple astronauts (e.g. blood pressure cuff).

Results

The IMM results for TME, CHI, EVAC and LOCL are presented in the figures and tables below.

TME Results

Figure 1 shows TME across all DRMs. TME increases in a linear fashion with mission length.

Figure 1: Total Medical Events (TME), All DRMs

Error bars represent the 95% confidence interval. (Shows linear increase from ~40 events for DRM6 to ~320 events for DRM1)

CHI Results

CHI is seen in Figure 2. Although CHI declines with longer missions, confidence intervals are overlapping. Influential conditions for CHI, for DRM 6 (150 days) and DRM1 (1103 days) are seen in Tables 3 and 4.

Figure 2: Crew Health Index (CHI), All DRMs

Error bars represent the 95% confidence interval. (Declines gradually with transit time from ~98% for DRM6 to ~91% for DRM1 with overlapping CIs)

Table 3. Top Fifteen Influential Conditions, Crew Health Index (CHI), DRM6 (150 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	22.11	22.11
2	BEST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	17.84	39.95
3	WORST CASE	TREATED	SKIN ABRASION	TRAUMA	5.11	45.05
4	BEST CASE	TREATED	EYE IRRITATION/ABRASION	TRAUMA	3.27	48.32
5	WORST CASE	TREATED	SKIN LACERATION	TRAUMA	2.74	51.06
6	WORST CASE	TREATED	EYE CHEMICAL BURN	ENVIRON	2.54	53.60
7	BEST CASE	TREATED	SKIN RASH	MEDICAL	2.42	56.02
8	BEST CASE	TREATED	SLEEP DISORDER	MEDICAL	1.92	57.94
9	BEST CASE	TREATED	SKIN ABRASION	TRAUMA	1.92	59.86
10	WORST CASE	TREATED	SPACE MOTION SICKNESS (SPACE ADAPTATION)	MEDICAL	1.81	61.67
11	BEST CASE	TREATED	BAROTRAUMA (EAR/SINUS BLOCK)	ENVIRON	1.81	63.48
12	BEST CASE	TREATED	RESPIRATORY INFECTION	MEDICAL	1.71	65.19
13	WORST CASE	TREATED	HEARING LOSS	MEDICAL	1.61	66.80
14	WORST CASE	TREATED	BACK SPRAIN/STRAIN	TRAUMA	1.40	68.20
15	WORST CASE	TREATED	BAROTRAUMA (EAR/SINUS BLOCK)	ENVIRON	1.26	69.46

Table 4. Top Fifteen Influential Conditions, Crew Health Index (CHI), DRM1 (1,103 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	BEST CASE	UNTREATED	SKIN RASH	MEDICAL	17.01	17.01
2	BEST CASE	PARTIAL	SKIN RASH	MEDICAL	6.53	23.54
3	BEST CASE	PARTIAL	EYE IRRITATION/ABRASION	TRAUMA	6.31	29.85
4	BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRON	5.91	35.76
5	WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	5.37	41.12
6	WORST CASE	TREATED	SKIN ABRASION	TRAUMA	4.47	45.59
7	BEST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	4.16	49.75
8	BEST CASE	PARTIAL	BACK SPRAIN/STRAIN	TRAUMA	2.78	52.52
9	WORST CASE	TREATED	SKIN LACERATION	TRAUMA	2.54	55.06
10	WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRON	2.27	57.33
11	BEST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	2.25	59.58
12	WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	2.02	61.59
13	BEST CASE	UNTREATED	URINARY TRACT INFECTION	MEDICAL	2.01	63.60
14	WORST CASE	TREATED	HEARING LOSS	MEDICAL	1.86	65.46
15	BEST CASE	PARTIAL	ALLERGIC REACTION (MILD TO MODERATE)	MEDICAL	1.62	67.08

EVAC Results

EVAC is seen in Figure 3. EVAC increases with longer missions. Confidence intervals are not overlapping. Influential conditions for DRM 6 (150 days) and DRM1 (1103 days) are seen in Tables 5 and 6.

Figure 3: Need for One or More Evacuation (EVAC), All DRMs

Error bars represent the 95% confidence interval. (Increases from ~0.06 for DRM6 to ~0.40 for DRM1 with non-overlapping CIs)

Table 5. Top Fifteen Influential Conditions, Need for Evacuation (EVAC), DRM6 (150 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	31.93	31.93
2	WORST CASE	TREATED	NEPHROLITHIASIS	MEDICAL	7.32	39.26
3	WORST CASE	TREATED	SMOKE INHALATION	ENVIRON	4.10	43.36
4	WORST CASE	TREATED	SEPSIS	MEDICAL	3.81	47.17
5	WORST CASE	TREATED	DENTAL ABSCESS	MEDICAL	3.74	50.91
6	BEST CASE	TREATED	SMALL BOWEL OBSTRUCTION	MEDICAL	2.96	53.87
7	WORST CASE	TREATED	WRIST FRACTURE	TRAUMA	2.28	56.15
8	BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRON	1.99	58.14
9	WORST CASE	PARTIAL	LOWER EXTREMITY (LE) STRESS FRACTURE	TRAUMA	1.86	59.99
10	WORST CASE	PARTIAL	HIP/PROXIMAL FEMUR FRACTURE	TRAUMA	1.69	61.69
11	WORST CASE	TREATED	BACK SPRAIN/STRAIN	TRAUMA	1.53	63.22
12	BEST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	1.39	64.58
13	BEST CASE	TREATED	SEIZURES	MEDICAL	1.39	65.95
14	WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	TRAUMA	1.30	67.25
15	WORST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	1.27	68.52

Table 6. Top Fifteen Influential Conditions, Need for Evacuation (EVAC), DRM1 (1,103 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRON	27.84	27.84

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
				MENTAL		
2	WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	9.82	37.66
3	WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	6.39	44.05
4	BEST CASE	PARTIAL	FINGER DISLOCATION	INJURY/TRAUMA	5.29	49.34
5	WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	5.09	54.43
6	WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	2.85	57.29
7	WORST CASE	PARTIAL	EYE INFECTION	MEDICAL	2.44	59.72
8	WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	2.17	61.89
9	WORST CASE	PARTIAL	EYE IRRITATION/ABRASION	INJURY/TRAUMA	1.64	63.53
10	WORST CASE	TREATED	SMOKE INHALATION	ENVIRONMENTAL	1.60	65.13
11	WORST CASE	PARTIAL	NECK SPRAIN/STRAIN	INJURY/TRAUMA	1.52	66.65
12	WORST CASE	PARTIAL	DENTAL ABSCESS	MEDICAL	1.51	68.16
13	WORST CASE	PARTIAL	ELBOW SPRAIN/STRAIN	INJURY/TRAUMA	1.42	69.58
14	WORST CASE	PARTIAL	HERPES ZOSTER REACTIVATION (SHINGLES)	MEDICAL	1.26	70.85
15	WORST CASE	PARTIAL	ANKLE SPRAIN/STRAIN	INJURY/TRAUMA	1.15	72.00

LOCL Results

LOCL is seen in Figure 4. LOCL increases with longer missions. Confidence intervals are not overlapping. Influential conditions for LOCL, for DRM 6 (150 days) and DRM1 (1103 days) are seen in Tables 7 and 8.

Figure 4: Loss of Crew Life (LOCL), All DRMs

Error bars represent the 95% confidence interval. (Increases from ~0.003 for DRM6 to ~0.022 for DRM1 with non-overlapping CIs)

Table 7. Top Fifteen Influential Conditions, Loss of Crew Life (LOCL), DRM6 (150 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	WORST CASE	TREATED	SEPSIS	MEDICAL	18.91	18.91
2	WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	TRAUMA	16.81	35.71
3	WORST CASE	TREATED	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	13.87	49.58
4	WORST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	9.24	58.82
5	WORST CASE	TREATED	SMOKE INHALATION	ENVIRON	8.82	67.65
6	WORST CASE	TREATED	HEAD INJURY	TRAUMA	5.46	73.11
7	WORST CASE	TREATED	TOXIC EXPOSURE (AMMONIA)	ENVIRON	5.04	78.15
8	WORST CASE	TREATED	APPENDICITIS	MEDICAL	5.04	83.19
9	WORST CASE	TREATED	CHEST INJURY	TRAUMA	4.62	87.82
10	WORST CASE	TREATED	SUDDEN CARDIAC ARREST	MEDICAL	2.52	90.34
11	WORST CASE	PARTIAL	SEPSIS	MEDICAL	2.10	92.44
12	WORST CASE	PARTIAL	APPENDICITIS	MEDICAL	1.68	94.12
13	WORST CASE	TREATED	ACUTE DIVERTICULITIS	MEDICAL	1.26	95.38
14	WORST CASE	TREATED	ABDOMINAL INJURY	TRAUMA	1.26	96.64
15	WORST CASE	TREATED	CHOKING/OBSTRUCTED AIRWAY	MEDICAL	0.42	97.06

Table 8. Top Fifteen Influential Conditions, Loss of Crew Life (LOCL), DRM1 (1,103 days)

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
1	WORST CASE	PARTIAL	SEPSIS	MEDICAL	12.56	12.56

Rank	Scenario	Treated	Medical Condition	Category	% Contrib.	Cum. %
2	WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	TRAUMA	11.72	24.27
3	WORST CASE	TREATED	SEPSIS	MEDICAL	11.45	35.73
4	WORST CASE	TREATED	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	9.92	45.65
5	WORST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	8.71	54.35
6	WORST CASE	TREATED	SMOKE INHALATION	ENVIRONM	8.23	62.59
7	WORST CASE	TREATED	HEAD INJURY	TRAUMA	5.81	68.39
8	WORST CASE	TREATED	CHEST INJURY	TRAUMA	5.70	74.09
9	WORST CASE	TREATED	APPENDICITIS	MEDICAL	3.64	77.73
10	WORST CASE	TREATED	TOXIC EXPOSURE (AMMONIA)	ENVIRON	3.38	81.11
11	WORST CASE	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	TRAUMA	2.85	83.96
12	BEST CASE	PARTIAL	APPENDICITIS	MEDICAL	2.16	86.12
13	BEST CASE	PARTIAL	SEPSIS	MEDICAL	1.85	87.97
14	WORST CASE	TREATED	SUDDEN CARDIAC ARREST	MEDICAL	1.53	89.50
15	WORST CASE	PARTIAL	TOXIC EXPOSURE (AMMONIA)	ENVIRON	1.27	90.77

Summary

Medical outcomes for round trip transit times for different propulsion systems were determined using the IMM. Results show generally linear relationships between transit time and medical outcomes. Some variations are seen that merit subject matter expert interpretation.

References

[1] Integrated Medical Model Project. Integrated Medical Model Operations Plan. JSC-66114. 2011. Houston, TX, NASA, Johnson Space Center. Ref Type: Report

[2] Integrated Medical Model Project. Integrated Medical Model Software Requirements Specification. IMM-SFTWR-008. 2017. Houston, Texas, KBRwyle Integrated Science, Technology and Engineering. Ref Type: Report

[3] Integrated Medical Model Project. Integrated Medical Model version 4 Assumptions and Limitations. IMM-GEN-300. 2017. Houston, Texas, KBRwyle Integrated Science and Engineering Space Medicine Information Technology. Ref Type: Report

[4] NASA-STD-7009: Standard for Models and Simulations (2008). NASA: Washington, DC.

[5] ISS Medical Checklist (Med CL), 04 June 2014, NASA Johnson Space Center, Medical Operations Group.

Appendix A: IMM Status at Time of Service Request Report

Validation status for IMM: IMM V&V Matrix shows full MATLAB validation status for each IMM element.

Compliance with NASA-Standard-7009 Requirements

Compliance Category	Number of Requirements
Compliant	36
Compliance Incomplete	5
Not Applicable	5

Current NASA-Standard-7009 Credibility Assessment Score (CAS)

Factor	Sufficiency Threshold	Factor Score	Weighted Score
Verification	4	3.7	0.28
Validation	3	3.0	0.45
Input Pedigree	3	3.0	0.53
Results Uncertainty	3	3.0	0.60
Results Robustness	3	3.0	0.45
Use History	3	3.0	0.45
M&S Management	2	2.0	0.10
People Qualification	4	4.0	0.20
Overall Credibility Score	-	-	3.06

Model & Database Metadata

Item	Details
Additional V&V Information	None
Integrated Medical Evidence Database (iMED)	iMED Lockdown ID: (26), created on (02/21/2017)
IMM Version & Platform	IMM v4.1 with release 2016a of MATLAB software
Modifications to Code	None

Appendix B: Medical Conditions in iMED by Category (iMED_20170221)

The following table details all 100 medical conditions included in the iMED database categorized by type.

Environmental Conditions (9)

Condition Name
Acute Radiation Syndrome
Altitude Sickness
Barotrauma (ear/sinus block)
Burns secondary to Fire
Decompression Sickness Secondary to EVA
Eye Chemical Burn
Headache (CO_2 induced)
Smoke Inhalation
Toxic Exposure: Ammonia

Injury / Trauma Conditions (28)

Condition Name (Col 1)	Condition Name (Col 2)
Abdominal Injury	Acute Compartment Syndrome
Ankle Sprain/Strain	Back Sprain/Strain
Chest Injury	Dental: Avulsion (tooth loss)

Condition Name (Col 1)	Condition Name (Col 2)
Elbow Dislocation	Elbow Sprain/Strain
Eye Irritation/Abrasion	Eye Penetration (foreign body)
Finger Dislocation	Fingernail Delamination Secondary to EVA
Head Injury	Hip Sprain/Strain
Hip/Proximal Femur Fracture	Knee Sprain/Strain
Lower Extremity Stress Fracture	Lumbar Spine Fracture
Neck Sprain/Strain	Neurogenic Shock
Paresthesias Secondary to EVA	Shoulder Dislocation
Shoulder Sprain/Strain	Skin Abrasion
Skin Laceration	Traumatic Hypovolemic Shock
Wrist Fracture	Wrist Sprain/Strain

Medical Illness Conditions (63)

Condition Name (Col 1)	Condition Name (Col 2)
Abdominal Wall Hernia	Abnormal Uterine Bleeding
Acute Angle-Closure Glaucoma	Acute Arthritis
Acute Cholecystitis/Biliary Colic	Acute Diverticulitis
Acute Pancreatitis	Acute Prostatitis
Acute Sinusitis	Allergic Reaction (mild to moderate)
Anaphylaxis	Angina/Myocardial Infarction
Anxiety	Appendicitis
Atrial Fibrillation/Atrial Flutter	Back Pain (space adaptation)
Behavioral Emergency	Cardiogenic Shock Secondary to Myocardial infarction
Choking/Obstructed Airway	Constipation (space adaptation)
Dental: Exposed Pulp	Dental Caries
Dental: Abscess	Dental: Crown Loss
Dental: Filling Loss	Depression

Mars Propulsion Transit Times

Condition Name (Col 1)	Condition Name (Col 2)
Diarrhea	Eye Corneal Ulcer
Eye Infection	Gastroenteritis
Headache (Late)	Headache (space adaptation)
Hearing Loss	Hemorrhoids
Herpes Zoster Reactivation (shingles)	Hypertension
Indigestion	Influenza
Insomnia (space adaptation)	Medication Overdose/Adverse Reaction
Mouth Ulcer	Nasal Congestion (space adaptation)
Nephrolithiasis	Nose bleed (space adaptation)
Otitis Externa	Otitis Media
Pharyngitis	Respiratory Infection
Retinal Detachment	Seizures
Sepsis	Skin Infection
Skin Rash	Sleep Disorder
Small Bowel Obstruction	Space Motion Sickness (space adaptation)
Stroke (Cerebrovascular Accident)	Sudden Cardiac Arrest
Urinary Incontinence (space adaption)	Urinary Retention (space adaptation)
Urinary Tract Infection	Vaginal Yeast Infection
Visual Impairment and Increased Intracranial Pressure (VIIP) (space adaptation)	