Executive Summary

The simulation results from a 10.5 day design reference mission (DRM) with 4 crewmembers and zero EVAs using the optimized medical capability generated from IMM Service Request S-20180815-406 (with CHI priority with a 20 lbs. mass and 13721 cm^3 volume constraint). The contents of the optimized medical capability from S-20180815-406 are presented in Table 2. The capabilities contain some resources that have decimal-valued quantities. For those resources, the decimal values were rounded up to the nearest integer. The optimized capability with a weight constraint of 20 lb. and a volume constraint of 13721 cm^3, generated from the optimization routine, is approximately 17.09 lbs. (7.75 kg) and 13,895.43 cm^3. For this simulation, the optimized medical capability results in a mean CHI of 95.81%, mean probability of evacuation (EVAC) of 0.004 and mean probability of loss of crew life (LOCL) of 0.00015 for the MedCap scenario (ISS medical capability without resupply).

Results for the total number of medical events (TME), CHI, EVAC, and LOCL are shown in Table 3 and Figures 1-4 in the results section of this report. The Top Influential Conditions for EVAC are shown in Table 4, the Top Influential Conditions for LOCL are shown in Table 5, and the Top Influential Conditions for Quality-Adjusted Time Lost (QATL) are shown in Table 6 in the results section of this report.

The CHI may be lower for this shorter DRM than for longer missions since CHI is calculated as a percentage of total mission person-years and, for shorter missions, space adaption medical conditions predominate resulting in a lower CHI due to a lower number of person-years.

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 incidence values and probability distributions. Finally, total crew health and mission impact outcomes are summarized. For this report, the primary outcomes of interest are crew health index (CHI), probability for evacuation (EVAC) and probability for 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 profile 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.

Table 1: 10.5 day DRM crew profile

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

Medical Conditions and Resources

The one hundred medical conditions currently included in the IMM are shown in Appendix B. However, to better approximate the Orion real world system, several conditions were not considered or were modified for this request as described in Appendix C. The incidence of IMM medical events occurring during simulated missions are based on historical mission and cohort data contained within the Integrated Medical Evidence Database (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.

Because Orion design is not yet completed, the fire risk for the vehicle is not yet known. It is known that Orion will have much less volume than the ISS. Therefore, rather than considering the entire ISS for application of Fire Model result input to the IMM, ISS Node 3 was used to approximate the Orion vehicle. The corresponding Node 3 Fire Model results [6] were used to update Burns Secondary to Fire and Smoke Inhalation for this request as follows: Burns Secondary to Fire: incidence 0.00613 (events/person year), worst case scenario likelihood = 0-5%; Smoke Inhalation: incidence 0.00613 (events/person year), worst case scenario likelihood = 0-5%.

Model outcomes can be given for the all-treated (continuous resupply, e.g. ISS in low earth orbit), all-untreated (no Medical Capability) and baseline MedCap (ISS Medkit without resupply). For exploration missions, the MedCap state 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 the number of 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].

$$\textbf{CHI} = (1 - (\textbf{QAMTL} \div \textbf{Mission Length})) \times 100$$

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. Additionally, IMM does not consider time and treatment required from time of EVAC to time the crew returns to definitive care on the ground.

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, the simulation usually assigns each crew member only 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 versions of the model. Catastrophic vehicle failures such as the Challenger and Columbia accidents, and MMOD (micrometeorite and orbital debris) are not considered as possible causes of EVAC and LOCL.

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 (ISS medical capability without resupply) 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 none of the resources are available to treat the event, the event is considered "untreated." The initial quantities for medical resources are baselined to a fully stocked ISS medical capability (MedCap). Note that when an event is partially treated, its outcomes are based on a weighted average of the treated and untreated values. For example, if a condition has a 0% chance of going to EVAC in the best case treated scenario and a 0-100% chance of going to EVAC in the best case untreated scenario, then under best case partial treatment, it is possible the condition will go to EVAC. It should also be noted that packaging mass and volume are not considered in the IMM.

Modeling Approach

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 2 - 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 without resupply. 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, TME, CHI, EVAC and LOCL results are presented. Features, assumptions and limitations pertinent to this report are described in a separate section below.

Optimization Approach

The optimized medical capability from IMM Service Request S-20180815-406 was selected solely by the customer to meet the optimization risk criteria within the specified mass and volume constraints. End user specified mass constraints were 20 lbs. (~9.07 kg) with a 13,721 cm^3 volume constraint to maximize CHI. It is important to note that the IMM v4.1 optimization routine used in this request considers resources at the unit resource level. Because of this, some resource quantities in the generated optimized capabilities have decimal values. Quantities for items in the medical capabilities must be integer-valued (as most resources cannot be fractionalized), therefore these quantities were rounded up to the nearest integer value. The optimization routine only considers resources marked as essential in iMED when generating the capabilities list. It also does not consider resource dependencies when generating capabilities. In other words, even though a set of resources may be required for treatment in reality, the optimization routine may only include a subset of those resources. The entire set of required resources is not bundled together. When generating the optimized capability, the quantity of each resource available to add to the capabilities list is determined by the maximum quantity needed during a simulation trial. It is not restricted to the quantity in the ISS medkit. Therefore it is possible for the generated optimized medical capability to include a higher quantity for a particular resource than is included in the ISS medkit. Packaging mass and volume are **not** considered. The

results of this optimization should only be used as an evidence-based guide to the development of an Orion Medical Capability and should not be used in isolation to design the medical capability without the input of subject matter expertise and operational experience.

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

1. All non-space adaption (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 (triggered by Solar Particle Events) and EVA-linked conditions (triggered by EVA events), 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 generated optimized medical capability is presented below in Table 2. The IMM simulation MedCap results for TME, CHI, EVAC, and LOCL for the simulated DRM are presented in the proceeding tables and figures. (As stated in the executive summary, the CHI may be lower for this shorter DRM than for longer missions since CHI is calculated as a percentage of total mission person-years and, for shorter missions, space adaption medical conditions predominate resulting in a lower CHI due to a lower number of person-years.) Some of the resources in the optimized capability have quantities that are decimal values. With decimal values, the 20lb., 13721 cm^3-constrainted capability is approximately 16.76 lbs. (7.60 kg). When the quantities were rounded up to the nearest integer, the capability is approximately 17.09 lbs. (7.75 kg).

Table 2: (Generated from IMM Service Request S-20180815-406) - optimized medical capability with 20 lbs. (9.07 kg)-infinite volume constraint and 20 lbs.-13721cm^3 constraint with CHI priority. The highlighted individual resources have quantities with decimal values. Those values were rounded up to the nearest integer for the proceeding simulation, shown in parentheses.

Resource	20 lb.-13721cm^3 Quantity
ABILIFY (ARIPIPRAZOLE) 5 MG	0
ABILIFY (ARIPIPRAZOLE) 7.5 MG/ML, 1.3 ML	0
ABSORBABLE SUTURE 3.0	2
ACE BANDAGE 2 INCHES	1
ACE BANDAGE 3 INCHES	1
ACE BANDAGE 4 INCHES	1
ADRENALINE (EPINEPHRINE 1:10000) 10ML	0
AED	0
AFRIN (OXYMETAZOLINE) 0.05% 15ML BOTTLE	1
ALBUTEROL INHALER (PROVENTIL) 90 MCG, 6.7 GM	2
AMBIEN 10MG TABLET	11
AMBU BAG AND MASK	0
AMOXICILLIN 500 MG CAPSULE	22
ANTIVERT (MECLIZINE) 25 MG	0
ASPIRIN 325MG TAB.	1
ATIVAN (LORAZEPAM) 1 MG TABLET	42
ATROPINE 1 MG, 10ML SYRINGE.	0
BACITRACIN 500 UNITS/GM. 28 GM TUBE	0.85 (1)
BACTRIM DS (SULFAMETHOXAZOLE/TRIMETHOPRIM) 800 MG/160 MG TABLET	40
BANDAID (2X3)	0
BANDAID (KNUCKLE)	0
BANDAID DOT	0
BANDAID STRIP	0
BENADRYL 25 MG CAPSULE	26
BENADRYL 50 MG/ML, 1ML INJECTABLE	1
BENZOCAINE SWAB STICK ORAL 20%, 0.15 ML SWAB	0
BIOHAZARD TRASH BAG	0
BLOOD OXIMETER	1
BLOOD PRESSURE /ECG MONITOR	0
BLOOD PRESSURE CUFF - LARGE	0
BLOOD PRESSURE CUFF - SMALL	0

BOUGIE ET TUBE INTRODUCER	0
BURN BANDAGE	0
BZK WIPES	0
CAMERA	0
CIPROFLOXACIN AND DEXAMETHASONE (CIPRODEX) 3%,7%, 7.5 ML BOTTLE	0.52 (1)
CLARITIN (LORATADINE)10MG TABLET	0
CLEAR BANDAGE	0
CLEOCIN (CLINDAMYCIN) 300MG	21
CMRS	0
COTTON BALLS	0
COTTON PELLET	0
COTTON SWABS	0
CYCLOPENTOLATE 2% 15ML BOTTLE.	0.2 (1)
DCS EXAMINATION SCORECARD	0
DEBROX FOR EARWAX (CARBAMIDE PEROXIDE) 6.5% 15ML BOTTLE	0
DENTAL ADHESIVE (76 GRAMS)	0.1 (1)
DENTAL ADHESIVE TIP	1
DENTAL AMALGAM FILE	0
DENTAL CARVER FILE (G)	1
DENTAL CROWN REMOVER	0
DENTAL ELEVATOR - 301 (I)	1
DENTAL ELEVATOR - 34S (J)	1
DENTAL EUGENOL ANESTHETIC 1ML ORAL SYRINGE	2
DENTAL EXPLORER/PROBE (E)	1
DENTAL FORCEPS-10S (A)	1
DENTAL FORCEPS-151A (B)	1
DENTAL FORCEPS-17 (C)	1
DENTAL MIRROR (H)	1
DENTAL SYRINGE (TUBEX)	0
DERMABOND APPLICATOR 0.5ML	1
DEXAMETHASONE (DECADRON) 10MG INJECTABLE	1
DIAMOX (ACETAZOLAMIDE) 250 MG TABLETS	6
DIFLUCAN (FLUCONAZOLE) 150 MG	1
DILANTIN (PHENYTOIN) 300MG CAPSULES	6
DILAUDID (HYDROMORPHONE) 2MG/ML, 1ML SYRINGE	6
DISPOSABLE OTOSCOPE SPECULA	0
DULCOLAX (BISACODYL) TABLET 5MG	16
EAR CURETTE	0
EAR WICK	2
EFFEXOR XR (VENLAFAXINE XR) 75 MG CAPSULES	0

ENDOTRACHEAL STYLET	1
EPIPEN 1:1000	1
EPT	1
ERTAPENEM 1GM	6
ERYTHROMYCIN OINTMENT 0.5%, 3.5 GM TUBE	1
ESTROGEN 1.25 MG TABLETS	7
ETHINYL ESTRADIOL / NORGESTREL 0.05 MG/ 0.5 MG	0
EYE SHIELD	0
EYE SIMULATOR CORNEA	0
EYE WASH GOGGLES & TUBING	1
EYEWASH WASTE WATER BAG	3
FINGER SPLINT	1
FLAGYL (METRONIDAZOLE) 500MG	30
FLUOCINONIDE 0.05%, 30GM TUBE	0.5 (1)
FLUORESCEIN 1MG STRIPS	6
FLUTICASONE 220MCG, 12GM INHALER	0
FOAM ELECTRODES	10
G1 CAMCORDER	0
GAUZE PADS (4X4)	0
HEIMLICH MANEUVER	1
HEMOSTATS	1
HOT AND COLD PAD	0
ILMA CUE CARD	1
ILMA ENDOTRACHEAL TUBE 7.0/7.5 & ENDOTRACHEAL TUBE 7.0/8.0	1
ILMA HARDWARE	0
ILMA STABILIZING ROD	1
ILMA SYRINGE	0
IMODIUM (LOPERAMIDE HCL) 2 MG TABLET	24
INTRAOSSEOUS DEVICE STARTER KIT	1
INTRAOSSEOUS INJECTION DEVICE	1
IODINE SWAB STICK	0
IV ADMINISTRATION SET	2
IV CAP	2
IV CATHETER (14G)	0
IV CATHETER (18G)	2
IV CATHETER (20G)	2
IV CATHETER (22G)	1
IV FLUID 1L (1000ML)	0
IV PRESSURE INFUSER	1
KETAMINE 50 MG/ML, 10 ML MULTI DOSE VIAL	0.3 (1)
LARYNGOSCOPE (BLADE)	0

LARYNGOSCOPE HANDLE	0
LEVAQUIN (LEVOFLOXACIN) 500MG	0
LIDOCAINE (XYLOCAINE) CARDIAC 2% (20MG/ML) 5ML SYRINGE	0
LIDOCAINE (XYLOCAINE) PLAIN 1%, 10ML MULTI DOSE VIAL	1
LIDOCAINE JELLY 2% 30ML TUBE	1.2 (2)
LIDOCAINE W/ EPINEPHRINE (XYLOCAINE) 2 %, 2-ML UNITS 1:100,000 EPI, 20 ML. MULTI DOSE VIALS.	0.1 (1)
LOPRESSOR (METOPROLOL) 50 MG	62
LOTRIMIN AF CREAM (CLOTRIMAZOLE) 1%, 30GM TUBE	1.1 (2)
MAXIMUM ABSORBENCY GARMENT (MAG)	0
MEDICAL TAPE	0
MELATONIN 3 MG	0
MIRROR	0
MOTRIN (IBUPROFEN) 400MG	55
MOXIFLOXACIN (AVELOX) 0.5%, 3ML BOTTLE	0.3 (1)
MUPIROCIN (BACTROBAN) 2%, 22 GM TUBE	1
NASAL AIRWAY 6MM	0
NASAL AIRWAY 7MM	0
NASAL PACKING (POSTERIOR NASAL PACKING)	1
NEEDLE (23G)	0
NEEDLE [25G]	1
NEEDLE DRIVER (AA)	1
NEEDLE PLASTIC	0
NITRILE GLOVES (LARGE, MEDIUM, AND SMALL) (PAIR)	0
NITROGLYCERIN TABLET 0.4MG	10
NONSTICK BANDAGE (TELFA PADS)	0
NYLON SUTURE 2.0	2
NYLON SUTURE 5.0	0
ORAL AIRWAY	0
OTOSCOPE HANDLE	1
OTOSCOPE HEAD	1
OTOSCOPE USB CABLE	1
OXYGEN MASK - RESUSCITATION MASK	0
OXYGEN TUBING	0
PANOPTIC OPHTHALMOSCOPE	1
PENLIGHT	1
PEPTO-BISMOL 262MG CHEWABLE TABS	6
PHENERGAN (PROMETHAZINE TABLET) 25 MG	4
PREDNISONE 20 MG	4
PRILOSEC 20MG	0
PROMETHAZINE INJECTABLE (PHENERGAN) 50MG/ML	1.5 (2)

SINGLE DOSE VIAL	
PROPARACAINE EYE DROPS 0.5%, 15ML BOTTLE	0
PROVIGIL (MODAFINIL) 200 MG TABLETS	0
PSYCHOTHERAPY	1
REFRESH ARTIFICIAL TEARS (CARBOXYMETHYLCELLULOSE) 0.5%, 0.4ML BOTTLE	6
REFRESH EYE OINTMENT (PETROLATUM WHITE AND MINERAL OIL) 42.5%; 57.3%, 3.5GM	0
ROBINUL (GLYCOPYRROLATE) 0.2MG/ML	0
ROCEPHIN (CEFTRIAXONE) 1 GM	1
ROLLED GAUZE	0
SALINE NOSE SPRAY 22ML BOTTLE	0
SAM SPLINT - LEG/ARM SPLINT	0
SCALPEL #11 (SCALPEL BLADE & HANDLE)	1
SCISSORS – TRAUMA	0
SHARPS CONTAINER	0
SILVER NITRATE STICK 75%/25%	0
SKIN STAPLE REMOVER	1
SKIN STAPLER	1
SMOOTH FORCEPS	1
SPACE ANTICIPATION GLASSES	0
SPACE STATION EYE WASH	1
STERILE GLOVES (LARGE, MEDIUM, AND SMALL) (PAIR)	0
STERILE WATER 10 ML VIAL	0
STETHOSCOPE	1
STETHOSCOPE EAR PIECES	0
SUCTION CARTRIDGE	0
SUCTION DEVICE	0
SUCTION DEVICE COLLECTION BAG	0
SUCTION DEVICE SYRINGE	0
SUCTION TIP - MOUTH (CURETTE)	0
SUCTION TUBING - ENDOTRACHEAL TUBE	0
SUCTION TUBING - GASTRIC TUBE	1
SUDAFED (PSEUDOEPHEDRINE) 30MG	0
SUDAFED 12 HOUR (PSEUDOEPHEDRINE) 120 MG	6
SURGICAL LUBRICANT	0
SURGICAL TOOLS KIT	0
SUTURE SCISSORS (BB)	0
SYRINGE (10CC)	3
SYRINGE (35CC)	0
SYRINGE (3CC)	2
SYRINGE (5CC)	0

SYRINGE (60ML)	1
TAMSULOSIN 0.4 MG TABLET	10
TEMPORARY TOOTH FILLING	0
THERMOMETER	0
TOBRAMYCIN AND DEXAMETHASONE 0.3%; 0.1%, 10ML BOTTLE	0
TONGUE DEPRESSOR	0
TONOMETER	0
TONOMETER TIP COVER	0
TOOTHED FORCEPS (EE)	0
TORADOL (KETOROLAC) 30MG/ML, 2ML SINGLE DOSE VIAL	4
TOURNIQUET	1
TROPICAMIDE 1%	0
TYLENOL (ACETAMINOPHEN) 325 MG	96
ULTRASOUND GEL	2
ULTRASOUND MACHINE	0
URINARY COLLECTION BAG (LEG BAG)	1
URINE CATHETER COUDE	0
URINE CATHETER FOLEY	0
URINE CATHETER SHORT	3
URINE CATHETER STRAIGHT	3
URINE CHEMSTRIPS	9
URINE COLOR CHART	0
VALACYCLOVIR 1 GM TABLET	21
VALIUM (DIAZEPAM) 5 MG/ML, 2 ML SYRINGE	1
VARIABLE OXYGEN SYSTEM	0
VICODIN HP (HYDROCODONE/ ACETAMINOPHEN HP) 10 MG/660 MG	36
VOS INTUBATED PATIENT HARDWARE (VENTILATOR/RESPIRATOR)	0
WATER	0
WOUND PACKING	0
ZANTAC (RANITIDINE) 150 MG	4
ZIPRASIDONE (GEODON 20MG/ML)	0
ZITHROMAX (AZITHROMYCIN) 250 MG	12
ZOFRAN (ONDANSETRON) 8 MG TABLET	12
ZOLOFT (SERTRALINE) 50 MG	20
ZYRTEC (CETIRIZINE) 10 MG TABLET	0

The IMM MedCap results for TME, CHI, EVAC, and LOCL for the simulated DRM are presented in Table 3 and in Figures 1-4 below. Note that in the figures “cc” corresponds to cm3.

Table 3: TME, CHI, EVAC, and LOCL

Results for 10.5 day 4 crew DRM with 20 lb.-13721cm3 Optimization			
	Mean or Probability	95 % CI	
TME	14.55	9	20
CHI (%)	95.81	91.53	98.31
Probability of EVAC	0.004	0.0036	0.0044
Probability of LOCL	0.00015	0.00008	0.00023

Figure 1: Average Number of TME

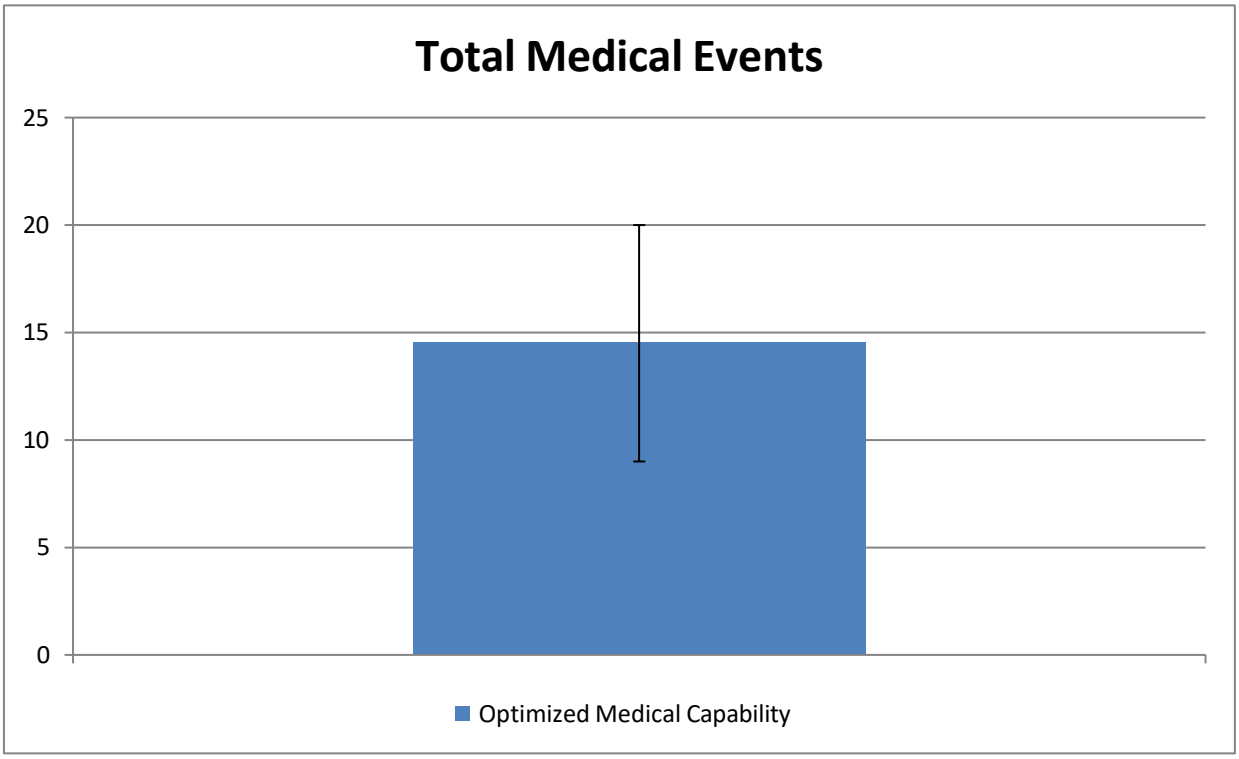


Figure 2: Average CHI

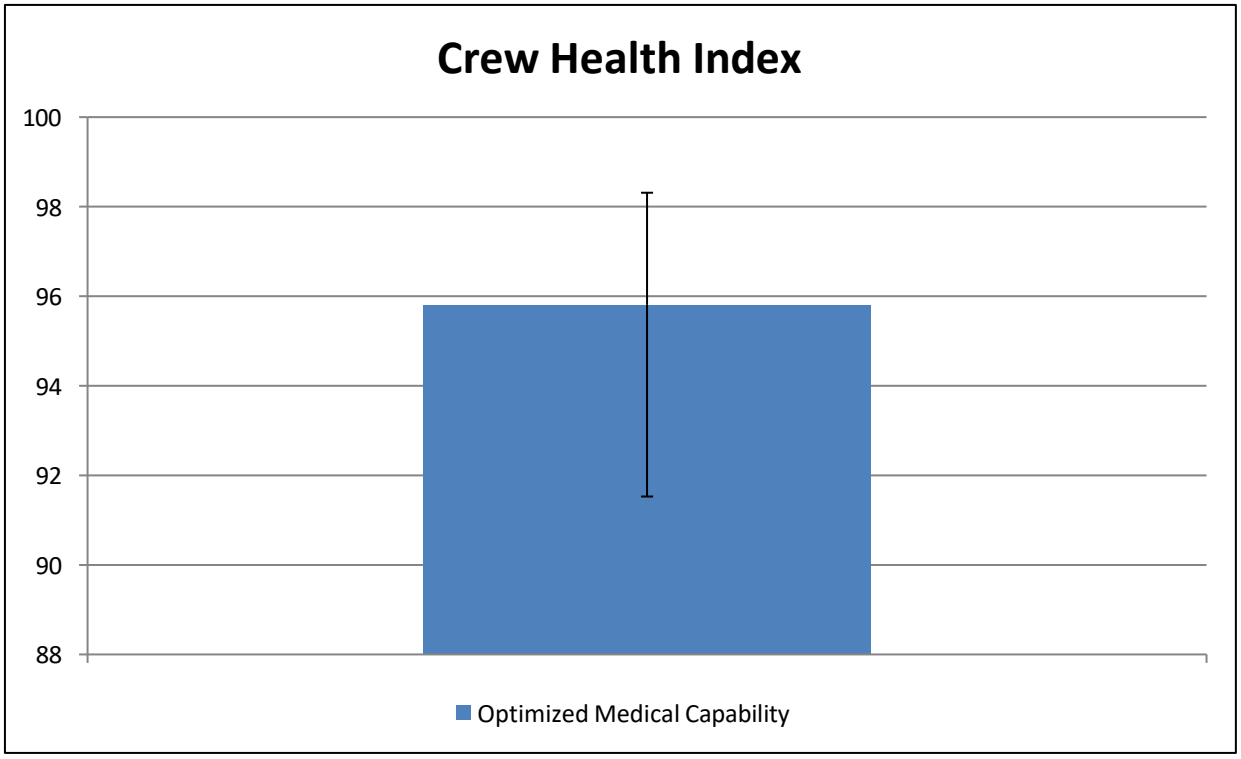


Figure 3: Probability of EVAC

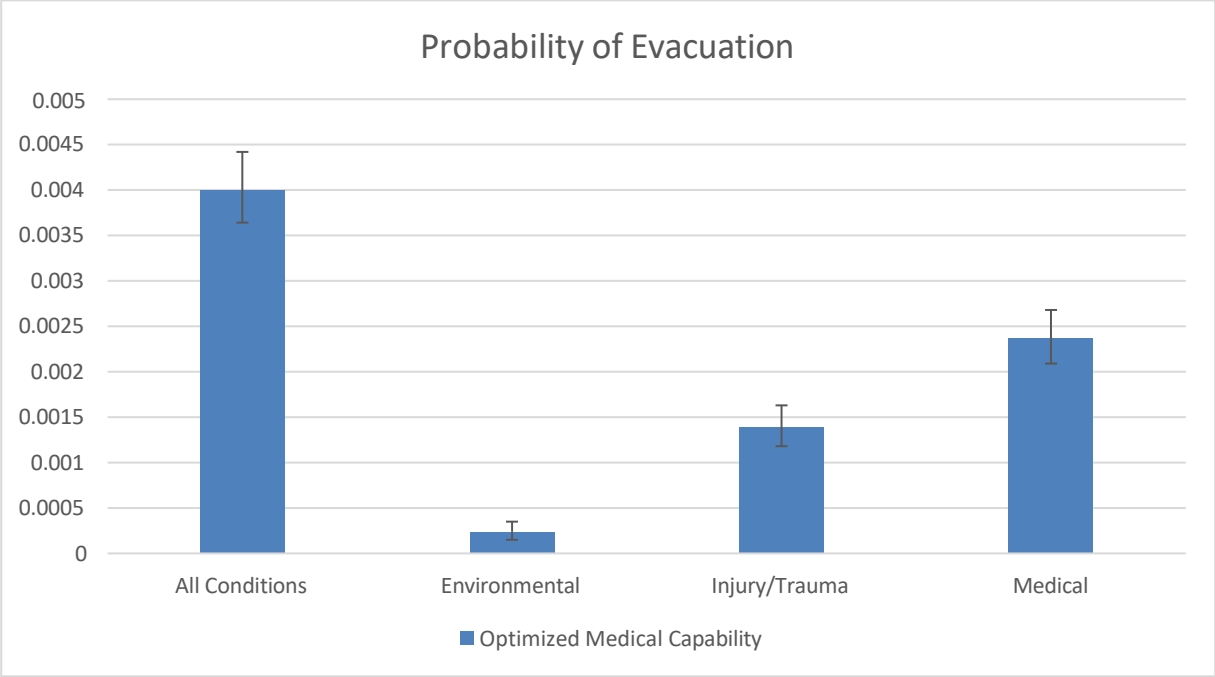
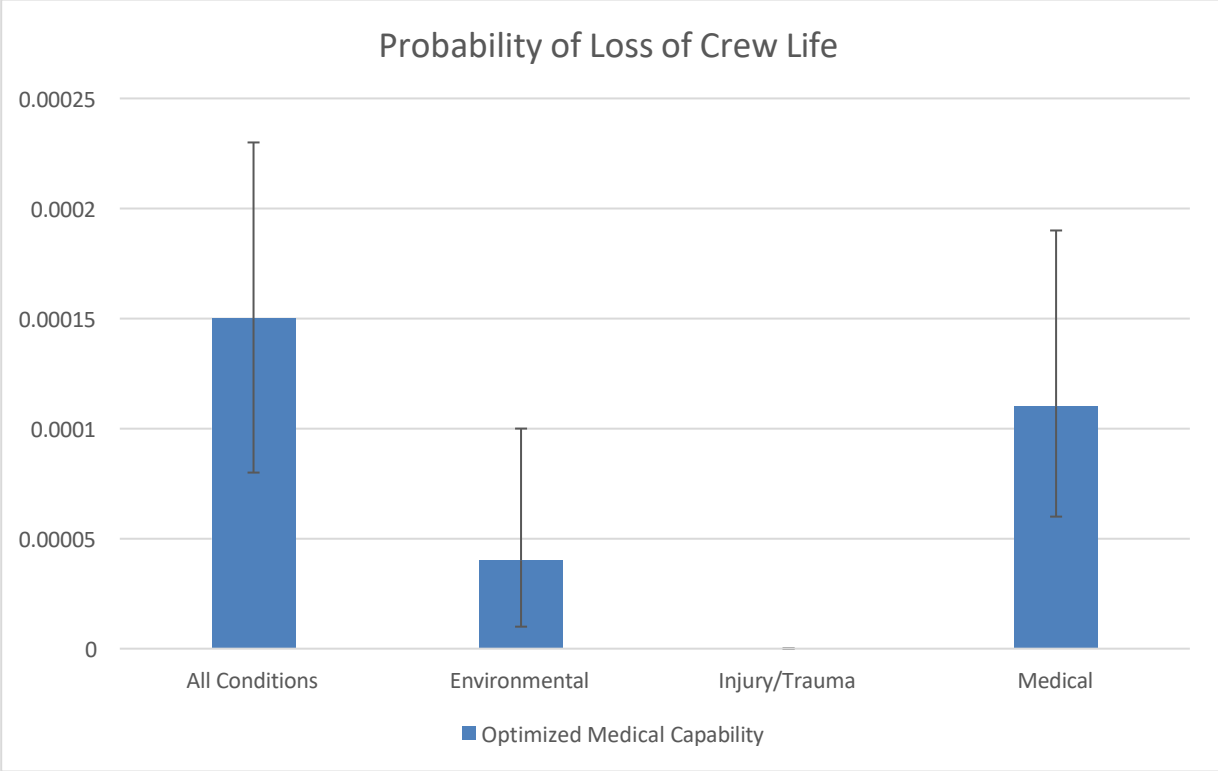


Figure 4: Probability of LOCL



Tables 4-6 present the top ten influential conditions for EVAC, LOCL, and QATL with regards to the 20 lb., 13721 cm^3-constrained Optimized Medical Capability.

Table 4: 20-lb, 13721 cm^3, CHI Optimized Medical Capability Top Ten Influential Conditions for EVAC

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	FINGER DISLOCATION	INJURY/TRAUMA	49	12.22	12.22
WORST CASE	PARTIAL	SKIN INFECTION	MEDICAL	29	7.23	19.45
WORST CASE	PARTIAL	NOSE BLEED (SPACE ADAPTATION)	MEDICAL	27	6.73	26.18
WORST CASE	PARTIAL	HEADACHE (SPACE ADAPTATION)	MEDICAL	25	6.23	32.42
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	19	4.74	37.16
WORST CASE	PARTIAL	GASTROENTERITIS	MEDICAL	18	4.49	41.65
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	18	4.49	46.13
WORST CASE	PARTIAL	SHOULDER SPRAIN/STRAIN	INJURY/TRAUMA	17	4.24	50.37
WORST CASE	PARTIAL	NECK SPRAIN/STRAIN	INJURY/TRAUMA	15	3.74	54.11
WORST CASE	PARTIAL	HEADACHE (CO2 INDUCED)	ENVIRONMENTAL	13	3.24	57.36

Table 5: 20-lb, 13721 cm^3, CHI Optimized Medical Capability Top Influential Conditions for LOCL

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SEPSIS	MEDICAL	5	33.33	33.33
WORST CASE	PARTIAL	BURNS SECONDARY TO FIRE	ENVIRONMENTAL	2	13.33	46.67
WORST CASE	PARTIAL	CHOKING/OBSTRUCTED AIRWAY	MEDICAL	2	13.33	60.00
WORST CASE	PARTIAL	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	2	13.33	73.33
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	1	6.67	80.00
BEST CASE	PARTIAL	SEPSIS	MEDICAL	1	6.67	86.67
WORST CASE	PARTIAL	TOXIC EXPOSURE (AMMONIA)	ENVIRONMENTAL	1	6.67	93.33
WORST CASE	PARTIAL	CARDIOGENIC SHOCK SECONDARY TO MYOCARDIAL INFARCTION	MEDICAL	1	6.67	100.00

Table 6: 20-lb, 13721 cm^3, CHI Optimized Medical Capability Top Ten Influential Conditions for QATL

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SPACE MOTION SICKNESS (SPACE ADAPTATION)	MEDICAL	36985	8.60	20.36
BEST CASE	**PARTIAL**	**SPACE MOTION SICKNESS (SPACE ADAPTATION)**	**MEDICAL**	**95758**	**4.44**	**10.50**
BEST CASE	TREATED	SPACE MOTION SICKNESS (SPACE ADAPTATION)	MEDICAL	152565	4.23	10.01
BEST CASE	**TREATED**	**NASAL CONGESTION (SPACE ADAPTATION)**	**MEDICAL**	**232799**	**4.08**	**9.66**
BEST CASE	TREATED	BACK PAIN (SPACE ADAPTATION)	MEDICAL	203395	3.55	8.41
BEST CASE	**TREATED**	**INSOMNIA (SPACE ADAPTATION)**	**MEDICAL**	**178939**	**2.31**	**5.46**
WORST CASE	TREATED	BACK PAIN (SPACE ADAPTATION)	MEDICAL	6205	1.64	3.87
BEST CASE	**TREATED**	**EYE IRRITATION/ABRASION**	**INJURY/TRAUMA**	**29124**	**1.45**	**3.44**
BEST CASE	TREATED	CONSTIPATION (SPACE ADAPTATION)	MEDICAL	68118	1.20	2.84
BEST CASE	**TREATED**	**SKIN RASH**	**MEDICAL**	**38932**	**1.03**	**2.43**

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*

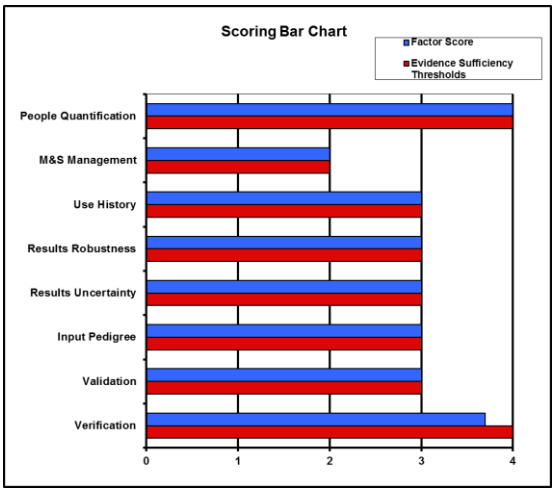
4. NASA-STD-7009: Standard for Models and Simulations (2008). NASA: Washington, DC.

5. ISS Medical Checklist (Med CL), 04 June 2014, NASA Johnson Space Center, Medical Operations Group
6. ISS PRA Model v.3.2.0. ISS PRA Fire and Ammonia Model Contributions to the Integrated Medical Model. 2015. Houston, Texas, NASA Johnson Space Center. *Ref Type: Report*

Appendix A: IMM Status at Time of Service Request Report

Validation status for IMM

IMM V&V Matrix: The following bar chart shows the IMM v4.1 MATLAB status of IMM validation for each IMM element listed.



Compliance with NASA-Standard-7009 requirements

IMM Compliance Matrix: The IMM has no waivers to any of the requirements in the NASA-Standard-7009 for Models and Simulations (6); however there are certain requirements that are not applicable to the IMM and other requirements where IMM compliance has not yet been fully attained.

Compliant	Compliance Incomplete	Not applicable
36	5	5

Current NASA-Standard-7009 credibility assessment score

IMM Credibility Matrix: The following table shows the overall IMM v4.1 MATLAB credibility assessment score (CAS), individual factor CAS, customer-specified sufficiency thresholds, and weighted scores. Legend depicts CAS score designated range and color assignments from NASA-Standard-7009.

Factor	Sufficiency Thresholds	Factor Score	Weighted Scores	Overall Score
Verification	**4**	**3.7**	0.28	
Validation	**3**	**3**	0.45	
Input Pedigree	**3**	**3**	0.53	
Results Uncertainty	**3**	**3**	0.60	**3.06**
Results Robustness	**3**	**3**	0.45	
Use History	**3**	**3**	0.45	
M&S Management	**2**	**2**	0.10	
People Qualification	**4**	**4**	0.20	

Legend from NASA-STD-7009	
	CAS Score > Threshold ***Exceeds credibility requirements***
	Threshold ≥ CAS Score ≥ (Threshold-0.5) ***Ready for use***
	Threshold-0.5 > CAS Score ≥ Threshold-1.0 ***Use with caution***
	CAS Score < Threshold - 1.0 ***Use not recommended or to be used with EXTREME CAUTION by subject matter experts only***

Additional verification and validation information applicable to this analysis

none

Integrated Medical Evidence Database (iMED) code version and date accessed

iMED Lockdown ID: (46), created on (9/11/2018)

IMM version and code version

Data analysis for this report was generated using IMM v4.1 with release 2016a of MATLAB software. MATLAB and all other MathWorks product or service names are registered trademarks or trademarks of MathWorks, Natick, MA, USA.

Modifications made to the code for analysis

None

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

ENVIRONMENTAL
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
Abdominal Injury
Acute Compartment Syndrome
Ankle Sprain/Strain
Back Sprain/Strain
Chest Injury
Dental: Avulsion (tooth loss)
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
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

MEDICAL ILLNESS (continued)
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
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)

Appendix C: Medical Conditions Excluded or Modified for the 10.5 Day DRM

Due to limited vehicle size consisting of a single module and limited movement of crew, the following conditions are judged highly unlikely to occur and were removed before running the simulation:

- Abdominal Injury
- Acute Compartment Syndrome
- Chest Injury
- Elbow Dislocation
- Head Injury
- Hip/Proximal Femur Fracture
- Lower Extremity (LE) Stress Fracture
- Lumbar Spine Fracture
- Shoulder Dislocation
- Neurogenic Shock
- Traumatic Hypovolemic Shock

Due to short duration of mission (10.5 days) plus the above limitations, the following condition is judged highly unlikely to develop and was removed before running the simulation:

- Visual Impairment and/or Increased Intracranial Pressure (VIIP) (Space Adaptation)

Due to absence of any EVAs and a constant cabin pressure of 14.7psi, the following condition is judged highly unlikely to occur and was removed before running the simulation:

- Barotrauma (ear/sinus block)

Since the IMM worst case definition of depression specifies symptoms lasting more than 4 weeks and the DRM of this mission lasting 10.5 days, the following condition was set to follow the best case scenario for 100% of events that occurred for this request:

- Depression

Rather than considering the entire ISS volume for application of Fire Model result input to the IMM, ISS Node 3 was used to approximate the size of the Orion vehicle. The corresponding Node 3 Fire Model results (directly from the ISS PRA Fire Model v3.2) were used to update Burns Secondary to Fire and Smoke Inhalation for this request as follows:

- Burns Secondary to Fire:
  - **incidence 0.00613 (events/person year)** - probability one or more crew exposed to response level event (value same as for likelihood for Fire Sustains (response level event) since modeling for single compartment, i.e. Node 3) (v3.2);
  - **worst case scenario = 0-5%** - EVAC (uncontrollable fire- not vehicle) (value = 0.0486; derived from uncontrolled fire event/probability one or more crew exposed to response level event)
- Smoke Inhalation:
  - **incidence 0.00613 (events/person year)** - Fire Sustains (response level event) (v3.2);
  - **worst case scenario = 0-5%** - EVAC (uncontrollable fire- not vehicle) (value = 0.0486; derived from uncontrolled fire event/Fire Sustains (response level event))