Executive Summary

The objective of this IMM support request is to provide a medical risk assessment for Artemis 7.5 day and 27.5 day Design Reference Missions (DRM).The simulation results are as follows:

- **Average number of Total of Medical Events (TME):**
  - **For the 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 Capabilities was 2.65 events.**
  - **For the 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm3 was 21.66 events.**

- **Average Crew Health Index (CHI):**
  - **For the 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 Capabilities was 97.63.**
  - **For the 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm3 was 96.87.**

- **Probability of consideration for Evacuation (EVAC):**
  - **For the 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 Capabilities was 0.0037.**
  - **For the 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm3 was 0.0094.**

- **Probability of Loss of Crew Life (LOCL):**
  - **For the 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 Capabilities was 0.0002.**
  - **For the 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm3 Capabilities was 0.0005.**

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), 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 Tables 1 and 2. The 27.5 day crew profile is consistent with that of the previous Orion DRM from the IMM Service Request (SR) # S-201808-406 with the exception of 4 additional EVAs each by 2 crew members for this request. 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: 7.5 day DRM crew profile

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

Table 2: 27.5 day DRM crew profile

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

For this request, the 7.5 day DRM assumes that the 7.5 days correspond to the 7.5 days in the middle of the 27.5 day DRM. For the 7.5 day DRM, it is assumed that the 2 crew members have not sustained any medical events, and have therefore not utilized any resources from a 5 lb. set of medical resources. This 5 lb. constraint on the resources was provided by the customer as a possible weight constraint given the mission parameters and is subject to change. More details on the 5 lb. set of resources is provided in the next section.

Medical Conditions and Resources

The one hundred medical conditions currently included in the IMM are shown in Appendix B. However, to better approximate Artemis real world system, the set of conditions was modified for this request as described in Appendix C. Note, that because the days in 7.5 day simulation corresponds to the middle 7.5 days in the 27.5 DRM, it is assumed that conditions related to Space Adaptation would not occur and are therefore removed from the 7.5 day DRM. Other conditions were removed or modified for both the 7.5 day and the 27.5 day DRM (as explained 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.

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 (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.

For this service request, the 5lb. set of resources used for the 7.5 day DRM was generated using the IMM 4.1 Optimization module. Although the optimization module can generate sets of resources with some non-integer quantities, all resource quantities were rounded up to the nearest integer to be used by the IMM during succeeding simulations. Therefore, the actual total weight of the resources used may be slightly larger than 5 lb. The "MedCap" results for the 7.5 day DRM correspond to the above mentioned set of resources. The "MedCap" results for the 27.5 day DRM correspond to the summation of the above mentioned 5 lb. set of resources and the 20 lb. set of resources generated from S-201808-406. This summation process did generate some possible unnecessary resource redundancies. Adding the contents of one set of resources to another set of resources results in a list where some items have a greater total quantity than would actually be flown. For example, if one resource set contained a blood oximeter and the second resource set also contained a blood oximeter, the summation of those two sets would contain two blood oximeters when, in reality, it is possible that only one might be flown. The final decision concerning whether those resources are redundant would be made by the program involved. These redundancies are highlighted in Table *3*.

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].

CHI = (1- (QAMTL ÷ Mission Length)) x 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, 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 (no 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 kit (MedCap) for one simulation, a 5 lb.-constrained set of resources generated for this service request for the second simulation, and the summation of the optimized medical kit from IMM SR-201808-406 and the previously mentioned 5 lb.-constrained set of resources for the third simulation. 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.

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 two optimized medical kits were selected solely to meet the optimization risk criteria within the specified mass and volume constraints for this request and SR-20180815-406. The DRM for the aforementioned request was a 21 day DRM with end user specified mass constraint of 20 lbs. (~9.07 kg) and a volume constraint of 13,721 cm^3, optimized to maximize CHI. For this request, the end user specified a constraint of 5 lbs. (2.27 kg) and no volume constraint for the optimization 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 kit have decimal values. Quantities for items in the medical kit must be integer-valued (as most resources cannot be fractionalized), therefore these quantities were rounded up to the nearest integer value. It should also be noted that packaging mass and volume are not considered in the IMM and therefore have no effect on optimization of a medical kit. The optimization routine only considers resources marked as essential in iMED when generating the kit. It also does not consider resource dependencies when generating the kit. 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 kit, the quantity of each resource available to add to the kit 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 kit to include a higher quantity for a particular resource than is included in the ISS medkit. The results of this optimization should only be used as an evidence-based guide to the development of medical capability and should not be used in isolation to design a medical kit 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. With the exception of VIIP, 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).

Additional Assumptions and Limitations for This Request

1. Although the 7.5 day mission would occur in the middle of the 27.5 day mission, it is assumed that no medical conditions have occurred (and thus no resources have been decremented) at the beginning of the 7.5 day mission.

2. The IMM does not consider medical conditions that are specific to Lunar operations in a partial gravity environment.

3. The IMM is incapable of modeling a 'mission within a mission' where the medical capabilities and the number of crew differ for each.

Results

The generated optimized medical kits are presented below in Table 3. The IMM simulation MedCap results for TME, CHI, EVAC, LOCL and the top ten influential conditions for EVAC/LOCL for the simulated DRMs.

Table 3: The ISS medical kit, and the generated optimized medical kits [from S-20180815-406 with 17.09 lbs. (7.75 kg.) - 13896cm^3] and [for the 7.5 day Lunar with 5.22 lbs. (2.37 kg.) – 6429.53cm^3] respectively. The yellow highlighted individual resources have quantities with decimal values. Those values were rounded up to the nearest integer for the proceeding simulation, shown in parentheses. The orange highlighted resources are those which result in possible unnecessary redundancy when the 7.75 kg. set is added to the 2.37 kg. set.

Resource	ISS Quantity (Reference)	S-406 Optimized Quantity	7.5 day Lunar Optimized Quantity
ABILIFY (ARIPIPRAZOLE) 5 MG	60	0	0
ABILIFY (ARIPIPRAZOLE) 7.5 MG/ML, 1.3 ML	2	0	0
ABSORBABLE SUTURE 3.0	2	2	1
ACE BANDAGE 2 INCHES	1	1	0

ACE BANDAGE 3 INCHES	1	1	1
ACE BANDAGE 4 INCHES	1	1	0
ADRENALINE (EPINEPHRINE 1:10000) 10ML	2	0	0
AED	1	0	0
AFRIN (OXYMETAZOLINE) 0.05% 15ML BOTTLE	12	1	1.2 (2)
ALBUTEROL INHALER (PROVENTIL) 90 MCG, 6.7 GM	3	2	0
AMBIEN 10MG TABLET	250	11	4
AMBU BAG AND MASK	1	0	0
AMOXICILLIN 500 MG CAPSULE	60	22	14
ANTIVERT (MECLIZINE) 25 MG	20	0	0
ASPIRIN 325MG TAB.	120	1	3
ATIVAN (LORAZEPAM) 1 MG TABLET	60	42	6
ATROPINE 1 MG, 10ML SYRINGE.	2	0	0
BACITRACIN 500 UNITS/GM. 28 GM TUBE	1	0.85 (1)	0.8 (1)
BACTRIM DS (SULFAMETHOXAZOLE/TRIMETHOPRIM) 800 MG/160 MG TABLET	40	40	26
BANDAID (2X3)	5	0	0
BANDAID (KNUCKLE)	5	0	0
BANDAID DOT	10	0	0
BANDAID STRIP	10	0	0
BENADRYL 25 MG CAPSULE	60	26	12
BENADRYL 50 MG/ML, 1ML INJECTABLE	3	1	0
BENZOCAINE SWAB STICK ORAL 20%, 0.15 ML SWAB	24	0	0
BIOHAZARD TRASH BAG	15	0	0
BLOOD OXIMETER	1	1	1
BLOOD PRESSURE /ECG MONITOR	1	0	0
BLOOD PRESSURE CUFF - LARGE	1	0	0
BLOOD PRESSURE CUFF – SMALL	1	0	0
BOUGIE ET TUBE INTRODUCER	1	0	0
BURN BANDAGE	10	0	0
BZK WIPES	60	0	0
CAMERA	1	0	0
CIPROFLOXACIN AND DEXAMETHASONE (CIPRODEX) 3%,7%, 7.5 ML BOTTLE	2	0.52 (1)	0.26 (1)
CLARITIN (LORATADINE)10MG TABLET	75	0	0
CLEAR BANDAGE	9	0	0
CLEOCIN (CLINDAMYCIN) 300MG	60	21	14
CMRS	1	0	0
COTTON BALLS	40	0	0

COTTON PELLET	6	0	0
COTTON SWABS	6	0	0
CYCLOPENTOLATE 2% 15ML BOTTLE.	1	0.2 (1)	0.1 (1)
DCS EXAMINATION SCORECARD	1	0	0
DEBROX FOR EARWAX (CARBAMIDE PEROXIDE) 6.5% 15ML BOTTLE	4	0	0
DENTAL ADHESIVE (76 GRAMS)	1	0.1 (1)	0
DENTAL ADHESIVE TIP	1	1	0
DENTAL AMALGAM FILE	1	0	0
DENTAL CARVER FILE (G)	1	1	0
DENTAL CROWN REMOVER	1	0	0
DENTAL ELEVATOR - 301 (I)	1	1	0
DENTAL ELEVATOR - 34S (J)	1	1	0
DENTAL EUGENOL ANESTHETIC 1ML ORAL SYRINGE	2	2	1
DENTAL EXPLORER/PROBE (E)	1	1	0
DENTAL FORCEPS-10S (A)	1	1	0
DENTAL FORCEPS-151A (B)	1	1	0
DENTAL FORCEPS-17 (C)	1	1	0
DENTAL MIRROR (H)	1	1	1
DENTAL SYRINGE (TUBEX)	1	0	0
DERMABOND APPLICATOR 0.5ML	2	1	0
DEXAMETHASONE (DECADRON) 10MG INJECTABLE	20	1	0
DIAMOX (ACETAZOLAMIDE) 250 MG TABLETS	100	6	0
DIFLUCAN (FLUCONAZOLE) 150 MG	150	1	1
DILANTIN (PHENYTOIN) 300MG CAPSULES	30	6	0
DILAUDID (HYDROMORPHONE) 2MG/ML, 1ML SYRINGE	18	6	0
DISPOSABLE OTOSCOPE SPECULA	80	0	0
DULCOLAX (BISACODYL) TABLET 5MG	40	16	2
EAR CURETTE	2	0	0
EAR WICK	6	2	1
EFFEXOR XR (VENLAFAXINE XR) 75 MG CAPSULES	60	0	0
ENDOTRACHEAL STYLET	1	1	0
EPIPEN 1:1000	3	1	0
EPT	2	1	0
ERTAPENEM 1GM	6	6	0
ERYTHROMYCIN OINTMENT 0.5%, 3.5 GM TUBE	1	1	0
ESTROGEN 1.25 MG TABLETS	100	7	7

ETHINYL ESTRADIOL / NORGESTREL 0.05 MG/ 0.5 MG	42	0	0
EYE SHIELD	1	0	0
EYE SIMULATOR CORNEA	2	0	0
EYE WASH GOGGLES & TUBING	1	1	1
EYEWASH WASTE WATER BAG	6	3	1
FINGER SPLINT	1	1	1
FLAGYL (METRONIDAZOLE) 500MG	60	30	21
FLUOCINONIDE 0.05%, 30GM TUBE	2	0.5 (1)	0.2 (1)
FLURESCEIN 1MG STRIPS	20	6	3
FLUTICASONE 220MCG, 12GM INHALER	2	0	0
FOAM ELECTRODES	20	10	1
G1 CAMCORDER	1	0	0
GAUZE PADS (4X4)	50	0	0
HEIMLICH MANEUVER	1	1	1
HEMOSTATS	1	1	0
HOT AND COLD PAD	1	0	0
ILMA CUE CARD	1	1	0
ILMA ENDOTRACHEAL TUBE 7.0/7.5 & ENDOTRACHEAL TUBE 7.0/8.0	4	1	0
ILMA HARDWARE	1	0	0
ILMA STABILIZING ROD	1	1	0
ILMA SYRINGE	2	0	0
IMODIUM (LOPERAMIDE HCL) 2 MG TABLET	40	24	8
INTRAOSSEOUS DEVICE STARTER KIT	1	1	0
INTRAOSSEOUS INJECTION DEVICE	2	1	0
IODINE SWAB STICK	14	0	0
IV ADMINISTRATION SET	3	2	0
IV CAP	5	2	0
IV CATHETER (14G)	2	0	0
IV CATHETER (18G)	4	2	0
IV CATHETER (20G)	4	2	1
IV CATHETER (22G)	4	1	0
IV FLUID 1L (1000ML)	4	0	0
IV PRESSURE INFUSER	1	1	0
KETAMINE 50 MG/ML, 10 ML MULTI DOSE VIAL	4	0.3 (1)	0
LARYNGOSCOPE (BLADE)	1	0	0
LARYNGOSCOPE HANDLE	1	0	0
LEVAQUIN (LEVOFLOXACIN) 500MG	30	0	0
LIDOCAINE (XYLOCAINE) CARDIAC 2% (20MG/ML) 5ML SYRINGE	2	0	0
LIDOCAINE (XYLOCAINE) PLAIN 1%, 10ML	3	1	0

MULTI DOSE VIAL			
LIDOCAINE JELLY 2% 30ML TUBE	3	1.2 (2)	0.3 (1)
LIDOCAINE W/ EPINEPHRINE (XYLOCAINE) 2 %, 2-ML UNITS 1:100,000 EPI, 20 ML. MULTI DOSE VIALS.	2	0.1 (1)	0
LOPRESSOR (METOPROLOL) 50 MG	100	62	0
LOTRIMIN AF CREAM (CLOTRIMAZOLE) 1%, 30GM TUBE	2	1.1 (2)	0.1 (1)
MAXIMUM ABSORBENCY GARMENT (MAG)	1	0	0
MEDICAL TAPE	5	0	0
MELATONIN 3 MG	200	0	0
MIRROR	1	0	0
MOTRIN (IBUPROFEN) 400MG	500	55	15
MOXIFLOXACIN (AVELOX) 0.5%, 3ML BOTTLE	4	0.3 (1)	0.1 (1)
MUPIROCIN (BACTROBAN) 2%, 22 GM TUBE	2	1	0.1
NASAL AIRWAY 6MM	1	0	0
NASAL AIRWAY 7MM	1	0	0
NASAL PACKING (POSTERIOR NASAL PACKING)	10	1	0
NEEDLE (23G)	20	0	0
NEEDLE [25G]	4	1	0
NEEDLE DRIVER (AA)	1	1	0
NEEDLE PLASTIC	10	0	0
NITRILE GLOVES (LARGE, MEDIUM, AND SMALL) (PAIR)	30	0	0
NITROGLYCERIN TABLET 0.4MG	25	10	1
NONSTICK BANDAGE (TELFA PADS)	20	0	0
NYLON SUTURE 2.0	2	2	1
NYLON SUTURE 5.0	2	0	0
ORAL AIRWAY	2	0	0
OTOSCOPE HANDLE	1	1	1
OTOSCOPE HEAD	1	1	1
OTOSCOPE USB CABLE	1	1	1
OXYGEN MASK - RESUSCITATION MASK	1	0	0
OXYGEN TUBING	1	0	0
PANOPTIC OPHTHALMOSCOPE	1	1	1
PENLIGHT	2	1	1
PEPTO-BISMOL 262MG CHEWABLE TABS	80	6	4
PHENERGAN (PROMETHAZINE TABLET) 25 MG	30	4	0
PREDNISONE 20 MG	40	4	0
PRILOSEC 20MG	90	0	0
PROMETHAZINE INJECTABLE (PHENERGAN) 50MG/ML SINGLE DOSE VIAL	12	1.5 (2)	0

PROPARACAINE EYE DROPS 0.5%, 15ML BOTTLE	1	0	0
PROVIGIL (MODAFINIL) 200 MG TABLETS	30	0	0
PSYCHOTHERAPY	1	1	1
REFRESH ARTIFICIAL TEARS (CARBOXYMETHYLCELLULOSE) 0.5%, 0.4ML BOTTLE	40	6	3
REFRESH EYE OINTMENT (PETROLATUM WHITE AND MINERAL OIL) 42.5%; 57.3%, 3.5GM	4	0	0
ROBINUL (GLYCOPYRROLATE) 0.2MG/ML	5	0	0
ROCEPHIN (CEFTRIAXONE) 1 GM	3	1	0
ROLLED GAUZE	2	0	0
SALINE NOSE SPRAY 22ML BOTTLE	1	0	0
SAM SPLINT - LEG/ARM SPLINT	1	0	0
SCALPEL #11 (SCALPEL BLADE & HANDLE)	1	1	0
SCISSORS – TRAUMA	1	0	0
SHARPS CONTAINER	40	0	0
SILVER NITRATE STICK 75%/25%	10	0	0
SKIN STAPLE REMOVER	1	1	0
SKIN STAPLER	2	1	0
SMOOTH FORCEPS	1	1	1
SPACE ANTICIPATION GLASSES	6	0	0
SPACE STATION EYE WASH	1	1	0
STERILE GLOVES (LARGE, MEDIUM, AND SMALL) (PAIR)	6	0	0
STERILE WATER 10 ML VIAL	2	0	0
STETHOSCOPE	2	1	1
STETHOSCOPE EAR PIECES	15	0	0
SUCTION CARTRIDGE	1	0	0
SUCTION DEVICE	1	0	0
SUCTION DEVICE COLLECTION BAG	2	0	0
SUCTION DEVICE SYRINGE	1	0	0
SUCTION TIP - MOUTH (CURETTE)	1	0	0
SUCTION TUBING - ENDOTRACHEAL TUBE	1	0	0
SUCTION TUBING - GASTRIC TUBE	1	1	0
SUDAFED (PSEUDOEPHEDRINE) 30MG	100	0	0
SUDAFED 12 HOUR (PSEUDOEPHEDRINE) 120 MG	125	6	7
SURGICAL LUBRICANT	6	0	0
SURGICAL TOOLS KIT	1	0	0
SUTURE SCISSORS (BB)	1	0	0
SYRINGE (10CC)	6	3	0

SYRINGE (35CC)	1	0	0
SYRINGE (3CC)	20	2	0
SYRINGE (5CC)	6	0	0
SYRINGE (60ML)	1	1	0
TAMSULOSIN 0.4 MG TABLET	10	10	0
TEMPORARY TOOTH FILLING	1	0	0
THERMOMETER	1	0	0
TOBRAMYCIN AND DEXAMETHASONE 0.3%; 0.1%, 10ML BOTTLE	1	0	0
TONGUE DEPRESSOR	20	0	0
TONOMETER	1	0	0
TONOMETER TIP COVER	150	0	0
TOOTHED FORCEPS (EE)	1	0	0
TORADOL (KETOROLAC) 30MG/ML, 2ML SINGLE DOSE VIAL	3	4	1
TOURNIQUET	1	1	1
TROPICAMIDE 1%	6	0	0
TYLENOL (ACETAMINOPHEN) 325 MG	250	96	4
ULTRASOUND GEL	17	2	1
ULTRASOUND MACHINE	1	0	0
URINARY COLLECTION BAG (LEG BAG)	250	1	0
URINE CATHETER COUDE	2	0	0
URINE CATHETER FOLEY	2	0	0
URINE CATHETER SHORT	10	3	0
URINE CATHETER STRAIGHT	2	3	0
URINE CHEMSTRIPS	10	9	5
URINE COLOR CHART	1	0	0
VALACYCLOVIR 1 GM TABLET	60	21	21
VALIUM (DIAZEPAM) 5 MG/ML, 2 ML SYRINGE	2	1	0
VARIABLE OXYGEN SYSTEM	1	0	0
VICODIN HP (HYDROCODONE/ ACETAMINOPHEN HP) 10 MG/660 MG	30	36	6
VOS INTUBATED PATIENT HARDWARE (VENTILATOR/RESPIRATOR)	1	0	0
WATER	1	0	0
WOUND PACKING	3	0	0
ZANTAC (RANITIDINE) 150 MG	60	4	4
ZIPRASIDONE (GEODON 20MG/ML)	2	0	0
ZITHROMAX (AZITHROMYCIN) 250 MG	18	12	6
ZOFRAN (ONDANSETRON) 8 MG TABLET	30	12	2
ZOLOFT (SERTRALINE) 50 MG	60	20	0
ZYRTEC (CETIRIZINE) 10 MG TABLET	30	0	0

The IMM MedCap results for TME, CHI, EVAC, and LOCL for the simulated DRMs are presented in the tables below. Table 4 and figure 1 show the average number of total medical events (TME) during the mission across all of the DRMs. Table 5 and figure 2 show the average CHI across all of the DRMs. Table 6 along with figures 3 and 4 show the probability of EVAC and LOCL across all of the DRMs. Note that in the figures cc corresponds to cm^3.

Table 4: Average Number of TME for the DRMs

		TME	95% CI	
7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 Capabilities	MedCap	2.65	0	6
27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm^3	MedCap	21.66	14	30

Figure 1: Average Number of TME for the DRMs

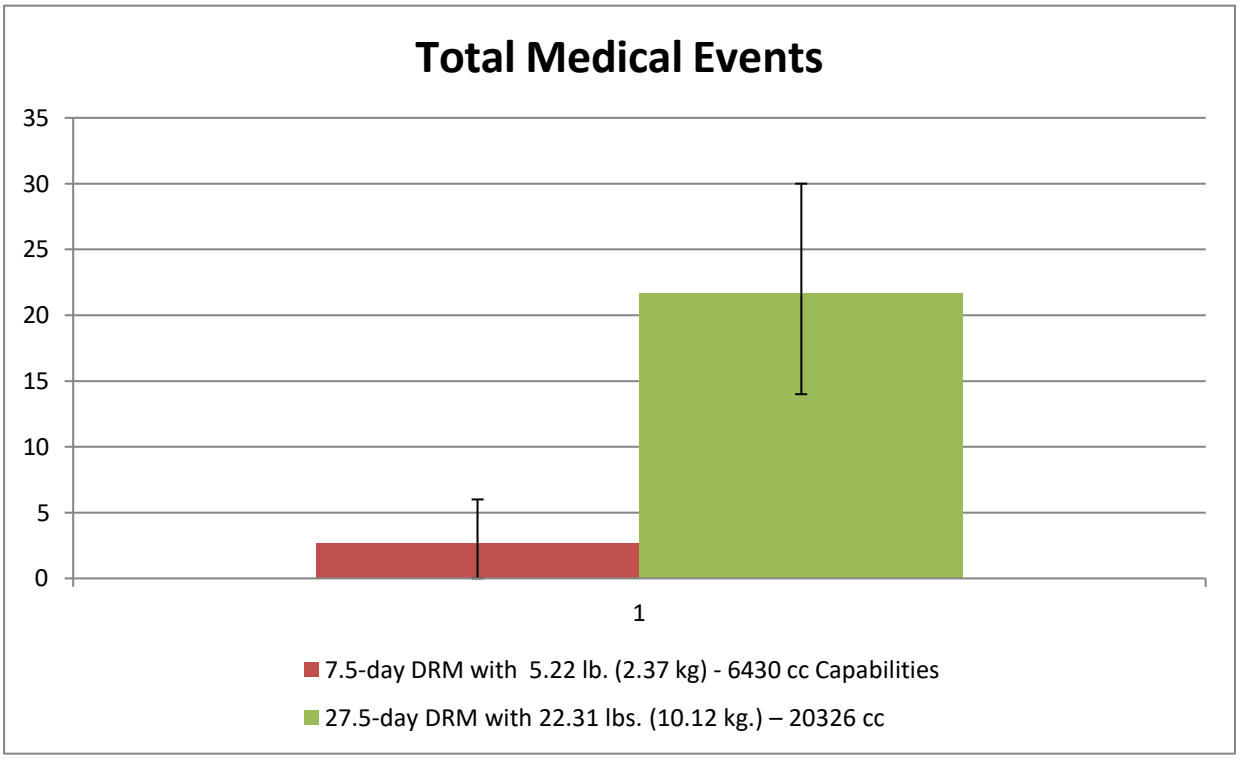


Table 5: Average CHI for the DRMs

		CHI	95% CI	
7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cc Capabilities	MedCap	97.63	89.76	100
27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cc	MedCap	96.87	92.43	98.80

Figure 2: Average CHI for the DRMs

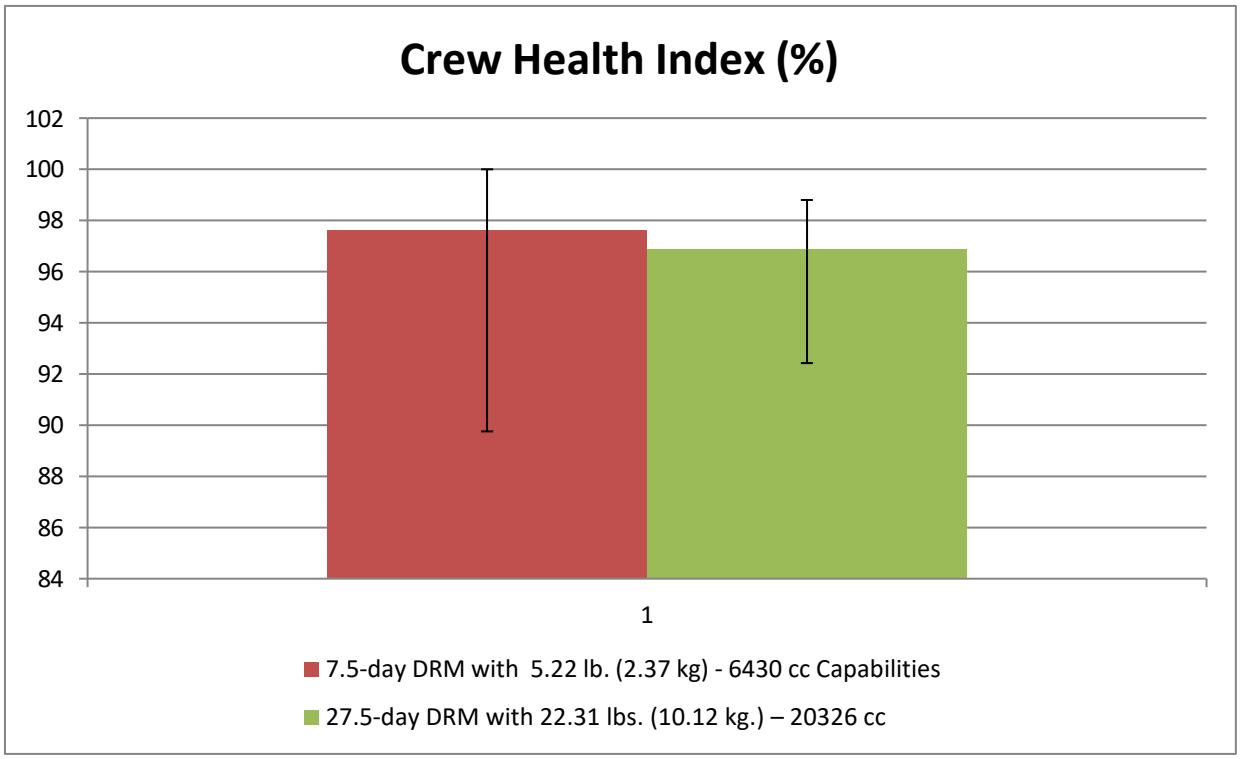


Table 6: Probability of EVAC and LOCL for the DRMs

		EVAC			LOCL		
		Probability	95% CI		Probability	95% CI	
7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cc Capabilities	MedCap	0.0037	0.0033	0.0041	0.0002	0.0001	0.0003
27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cc	MedCap	0.0094	0.0088	0.0100	0.0005	0.0003	0.0006

Figure 3: Probability of EVAC for the DRMs

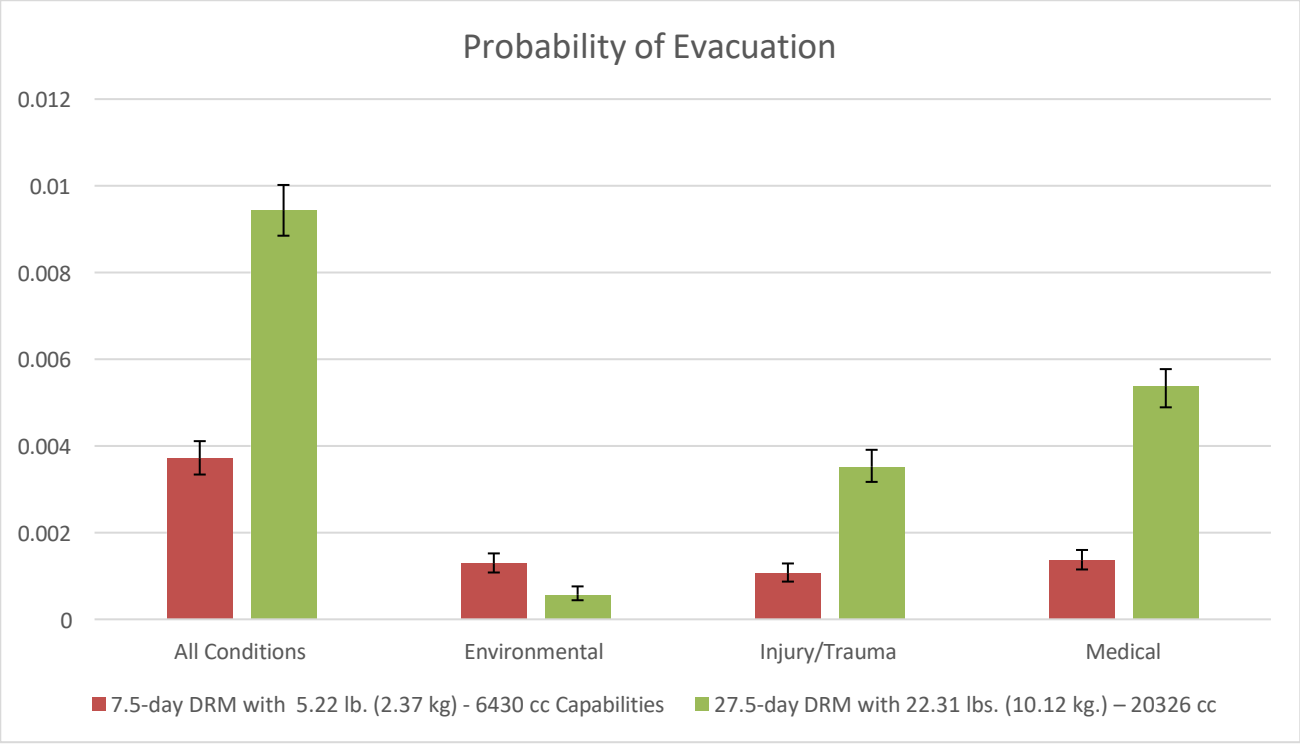
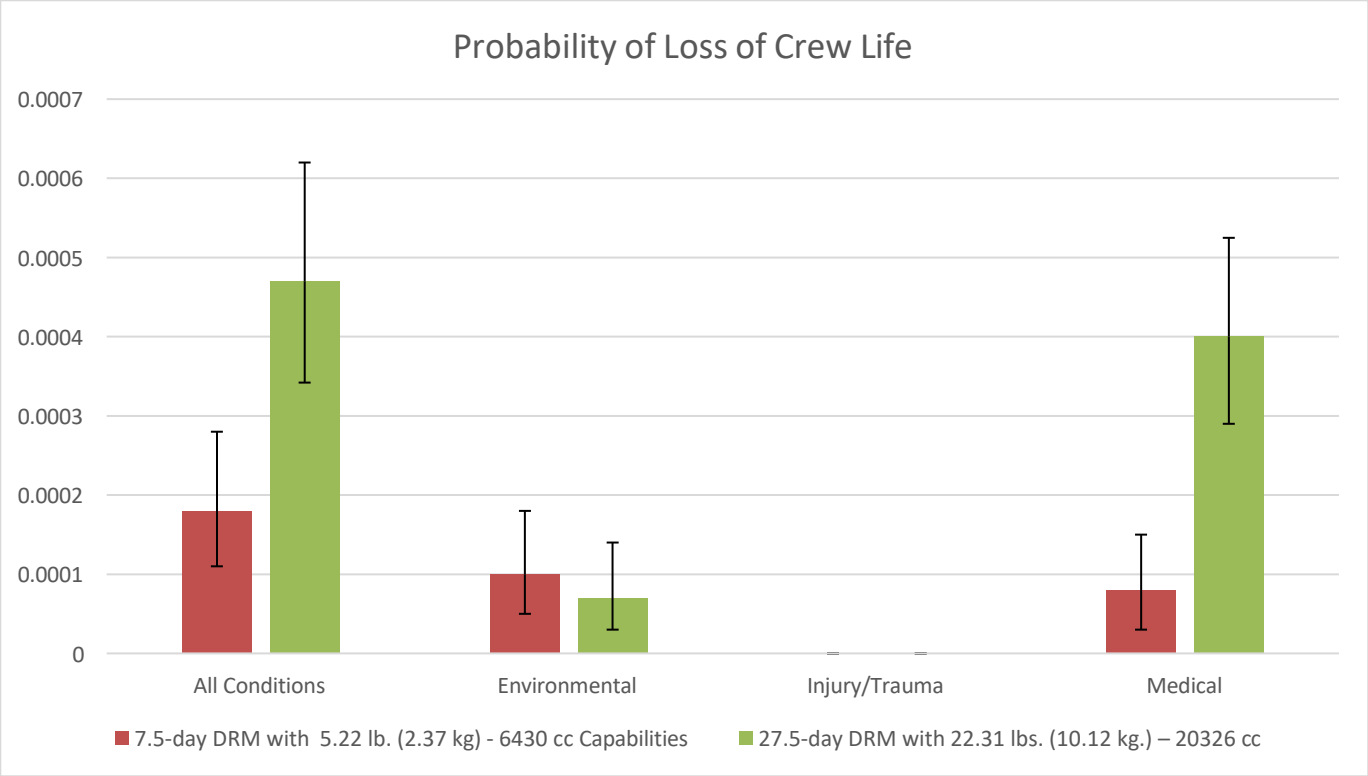


Figure 4: Probability of LOCL for the DRMs



Tables 7 and 8 show the top ten influential conditions for EVAC for the 7.5 day mission with ~5 lb. capabilities, and 27.5 day mission with ~20 lb. capabilities sets Tables 9 and 10 present the top ten influential conditions for LOCL for those same two missions.

Table 7: 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 CHI Optimized Medical Capabilities; Top Ten Influential Conditions for EVAC

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	65	17.52	17.52
WORST CASE	PARTIAL	DECOMPRESSION SICKNESS SECONDARY TO EXTRAVEHICULAR ACTIVITY	ENVIRONMENTAL	31	8.36	25.88
BEST CASE	PARTIAL	FINGER DISLOCATION[1]	INJURY/TRAUMA	28	7.55	33.42
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	25	6.74	40.16
WORST CASE	PARTIAL	SHOULDER SPRAIN/STRAIN	INJURY/TRAUMA	22	5.93	46.09
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	22	5.93	52.02
WORST CASE	PARTIAL	SKIN LACERATION	INJURY/TRAUMA	21	5.66	57.68
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	16	4.31	61.99
WORST CASE	PARTIAL	GASTROENTERITIS	MEDICAL	15	4.04	66.04
WORST CASE	PARTIAL	SKIN INFECTION	MEDICAL	13	3.50	69.54

Table 8: 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm^3 CHI Optimized Medical Capabilities; Top Ten Influential Conditions for EVAC

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	FINGER DISLOCATION[1]	INJURY/TRAUMA	98	10.35	10.35
WORST CASE	PARTIAL	SKIN INFECTION	MEDICAL	76	8.03	18.37
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	69	7.29	25.66
WORST CASE	PARTIAL	SHOULDER SPRAIN/STRAIN	INJURY/TRAUMA	50	5.28	30.94
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	46	4.86	35.80
WORST CASE	PARTIAL	GASTROENTERITIS	MEDICAL	43	4.54	40.34
WORST CASE	PARTIAL	SKIN LACERATION	INJURY/TRAUMA	39	4.12	44.46
WORST CASE	PARTIAL	HEADACHE (SPACE ADAPTATION)	MEDICAL	30	3.17	47.62
WORST CASE	PARTIAL	ANKLE SPRAIN/STRAIN	INJURY/TRAUMA	29	3.06	50.69
WORST CASE	PARTIAL	ELBOW SPRAIN/STRAIN	INJURY/TRAUMA	26	2.75	53.43

[1] Best case finger dislocation is not expected to contribute to EVAC. This EVAC output is due to iMED input data for untreated best case finger dislocation of 0-100% instead of 0%.

Table 9: 7.5 day DRM with 5.22 lb. (2.37 kg) - 6430 cm^3 CHI Optimized Medical Capabilities, Top Ten Influential Conditions for LOCL

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	DECOMPRESSION SICKNESS SECONDARY TO EXTRAVEHICULAR ACTIVITY	ENVIRONMENTAL	9	50.00	50.00
WORST CASE	PARTIAL	SEPSIS	MEDICAL	3	16.67	66.67
BEST CASE	PARTIAL	SEPSIS	MEDICAL	2	11.11	77.78
WORST CASE	PARTIAL	BURNS SECONDARY TO FIRE	ENVIRONMENTAL	1	5.56	83.33
WORST CASE	PARTIAL	ACUTE DIVERTICULITIS	MEDICAL	1	5.56	88.89
BEST CASE	PARTIAL	ANAPHYLAXIS	MEDICAL	1	5.56	94.44
WORST CASE	PARTIAL	SUDDEN CARDIAC ARREST	MEDICAL	1	5.56	100.00

Table 10: 27.5 day DRM with 22.31 lbs. (10.12 kg.) – 20326 cm^3 CHI Optimized Medical Capabilities; Top Ten Influential Conditions for LOCL

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SEPSIS	MEDICAL	19	40.43	40.43
BEST CASE	PARTIAL	SEPSIS	MEDICAL	7	14.89	55.32
WORST CASE	PARTIAL	DECOMPRESSION SICKNESS SECONDARY TO EXTRAVEHICULAR ACTIVITY	ENVIRONMENTAL	5	10.64	65.96
WORST CASE	PARTIAL	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	3	6.38	72.34
WORST CASE	PARTIAL	BURNS SECONDARY TO FIRE	ENVIRONMENTAL	2	4.26	76.60
WORST CASE	PARTIAL	ACUTE DIVERTICULITIS	MEDICAL	2	4.26	80.85
WORST CASE	PARTIAL	APPENDICITIS	MEDICAL	2	4.26	85.11
WORST CASE	PARTIAL	SUDDEN CARDIAC ARREST	MEDICAL	2	4.26	89.36
WORST CASE	PARTIAL	CHOKING/OBSTRUCTED AIRWAY	MEDICAL	1	2.13	91.49
WORST CASE	PARTIAL	SMALL BOWEL OBSTRUCTION	MEDICAL	1	2.13	93.62

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*

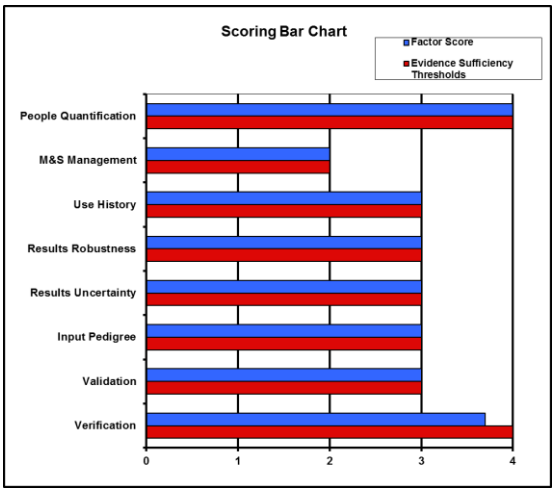
4. NASA-STD-7009: Standard for Models and Simulations (2008). NASA: Washington, DC.

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 IDs: (53), created on (7/30/2019); and (57), created on (8/2/2019)

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 Modified for the 30 Day DRM

Due to limited vehicle size consisting of a single module and limited movement of crew the following major traumatic injury conditions are judged highly unlikely to occur during a 7.5 day DRM (and were removed prior to 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 mission duration, the following condition was removed prior to running the simulation:

- Depression

Because ammonia is not planned to be used in the vehicles, the following condition was also removed prior to running the simulation:

- Toxic Exposure - Ammonia

Due to the assumption that the 7.5 days are to occur during the middle of a 27.5 day mission, all space adaptation conditions (listed below) were also judged unlikely to occur (and removed before running the 7.5 day simulation) with the exception of Visual Impairment and/or Increased Intracranial Pressure (VIIP) (Space Adaptation). For the 27.5 day DRM, the space adaptation conditions were assumed to possibly occur, and so were included as possible for the 27.5 day DRM.

- Back Pain (Space Adaptation)
- Constipation (space adaptation)
- Headache (space adaptation)
- Insomnia (space adaptation)
- Nasal Congestion (space adaptation)
- Nose bleed (space adaptation)
- Space Motion Sickness (space adaptation)
- Urinary Incontinence (space adaptation)
- Urinary Retention (space adaptation)

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

- The probability of EVAC and probability of LOCL were set to zero for VIIP.

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))