

Executive Summary

The IMM was used to determine the impact on subsequent mission medical outcomes of using “heroic measures” to treat a severely ill crewmember that would then deplete medical resources. The catastrophic event was triggered at 1, 135, 270 and 405 days into a 540 day mission. Results show that there was no significant effect on the crew health index (CHI) when comparing the control, a nominal run with no depleting event, to the test DRMs. Evacuation (EVAC) rates compared between the control and the test DRMs were significantly different, with decreasing impact the later in the mission that the triggering event occurred. A similar trend is noted for loss of crew life (LOCL), although much smaller in magnitude. Significance is defined as non-overlapping confidence intervals between compared indices. Influential conditions in the test cases are dominated by partially treated conditions, as compared to the control, reflecting depletion of resources; however, this effect diminishes the later in the mission the depleting event occurs.

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 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: Crew 1 for DRM 1 – No Extravehicular Activity (EVA)

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

Table 2: Crew 2 for DRMs 2 – 5. EVA to occur at (1, 135, 270, and 405 days)

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

Medical Conditions and Resources

The one hundred medical conditions currently included in the IMM are shown in Appendix A. 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), except as outlined below. 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 Medical Kit (Medkit)) and baseline MedCap (ISS Medkit without resupply). For longer duration 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.

This work focuses on the baseline MedCap state.

Resource Depleting Event

The goal of this work is to determine what happens to subsequent medical outcomes if a crew member becomes severely ill and, in treating that crew member, a large part of the medical resources are consumed. In an attempt to model this, we used a combination of Worst Case Urinary Tract Obstruction (UTO), Worst Case Urinary Tract Infection (UTI), and Worst Case Sepsis (e.g. a crewperson gets a urinary tract obstruction which progresses to urinary tract infection which leads to urosepsis) as the depleting illness. We chose this urosepsis disease path because sepsis has occurred in spaceflight, and is potentially a severe medical condition. We then named this illness “EVA_Deplete”. The resources used to treat the worst case of each of these conditions (UTO, UTI, and Sepsis) over a period of about 72 hours was deducted from the baseline Medical Capability when the depleting event was triggered.

Ideally, we want to gauge impacts on outcomes at different time points during a mission. Although we have a timeline in IMM 4.1, we cannot specify when an event occurs, because this would require coding changes to the model. However, the timing of EVA events can be set in the model. Therefore, EVA_Deplete was set as an EVA-dependent condition in order to dictate the occurrence timing of the event. The heroic measures are not EVA-related. The name of the condition pertains to the use of EVAs in the simulation to determine when depletion of resources related to UTO, UTI, and Sepsis will occur.

The following methods were used to generate a depleting event: 1) Create an EVA-dependent condition (EVA_Deplete) with a defined set of required resources to deplete medical supplies inventory, which occurs at an incidence rate of 100%, but with no contribution to CHI, EVAC and LOCL (to make the estimation of subsequent impacts straightforward). 2) The Best Case probability is set to 0%, and Worst Case set to 100%. 3) This event is triggered one time in each DRM, as specified below. All other EVA dependent conditions are removed from consideration.

- DRM1 – control, no initial resource depleting event (EVA_Deplete does NOT occur), EVA = 0
- DRM2 – EVA_Deplete occurs once at mission start (Day 1 of 540), EVA = 1 (Crew #2)
- DRM3 – EVA_Deplete occurs once at end of first quarter of mission timeline (Day 135 of 540), EVA = 1 (Crew #2)
- DRM4 – EVA_Deplete occurs once at mid-mission (Day 270 of 540), EVA = 1 (Crew #2)
- DRM5 – EVA_Deplete occurs once at the beginning of last quarter of mission (Day 405 of 540), EVA = 1 (Crew #2)

EVA_Deplete simulates a resource-depleting event where a seriously ill crewmember is treated without regard to future mission outcomes thereby consuming a large portion of the medical resources and impacting subsequent medical outcomes on the other crew. The impact on subsequent outcomes is the

result of primary interest for this request.

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 versions 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). 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

Simulations were run for a 540 day mission. 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 IMM4ConvergenceReport.

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 one ISS Medkit. 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, as well as pertinent influential conditions, are described. IMM version 4.1 has certain features, assumptions and limitations that impact modeled outcomes. Improvements in IMM 4.1 from previous versions 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, LOCL and influential conditions for the simulated DRMs are presented in the tables below. Table 3 and figure 1 show the average number of total medical events (TME) during the mission across all of the DRMs.

Table 3: TME for the DRMs

		TME	95% CI	
DRM 1	MedCap	180.32	147	209
	Treated	181.11	149	210
	Untreated	146.22	84	197
DRM 2	MedCap	179.87	143	210
	Treated	182.08	149	211
	Untreated	147.49	85	198
DRM 3	MedCap	180.29	145	210
	Treated	182.15	150	211
	Untreated	147.28	85	198
DRM 4	MedCap	180.86	147	210
	Treated	182.09	149	211
	Untreated	147.19	84	198
DRM 5	MedCap	181.14	147	210
	Treated	182.03	149	211
	Untreated	146.97	84	197

Figure 1: TME for the DRMS

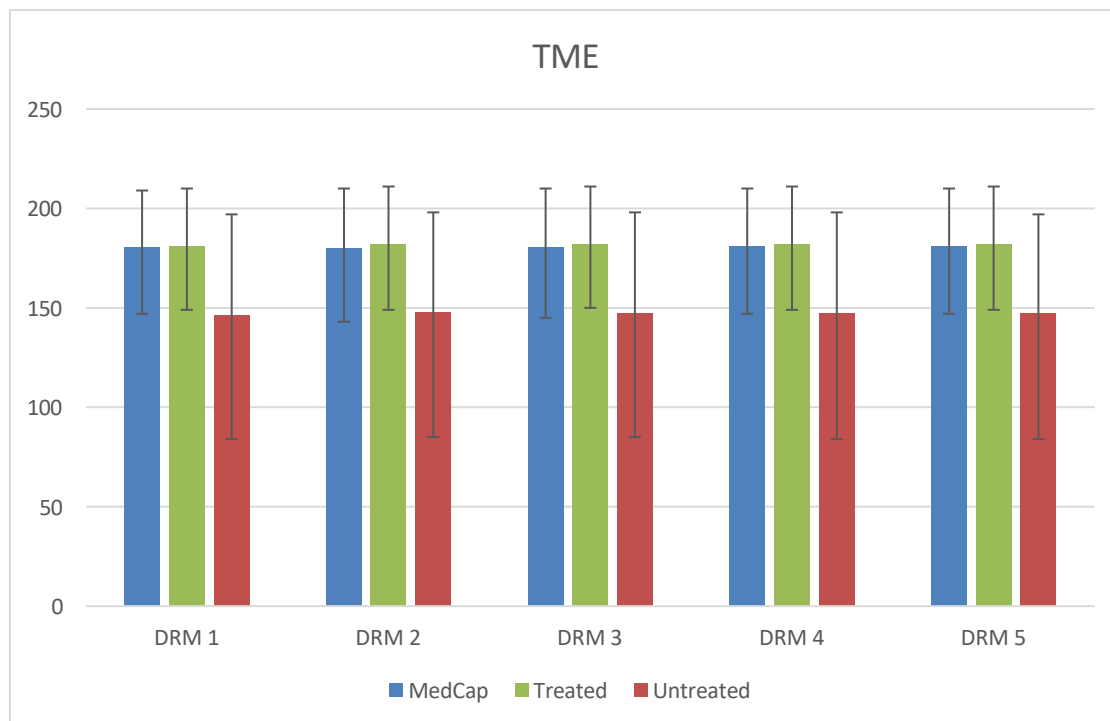


Table 4 and figure 2 show the average CHI across all of the DRMs.

Table 4: CHI for the DRMs

		CHI	95% CI	
DRM 1	MedCap	90.28	72.70	97.24
	Treated	91.88	74.18	97.96
	Untreated	30.86	18.46	41.73
DRM 2	MedCap	88.80	70.47	96.72
	Treated	91.88	74.18	97.95
	Untreated	30.88	18.53	41.76
DRM 3	MedCap	89.18	71.49	96.79
	Treated	91.89	74.27	97.95
	Untreated	30.88	18.53	41.73
DRM 4	MedCap	89.73	72.24	96.97
	Treated	91.87	74.05	97.96
	Untreated	30.90	18.48	41.78
DRM 5	MedCap	90.11	72.56	97.12
	Treated	91.86	74.08	97.96
	Untreated	30.86	18.38	41.75

Figure 2: CHI for the DRMs

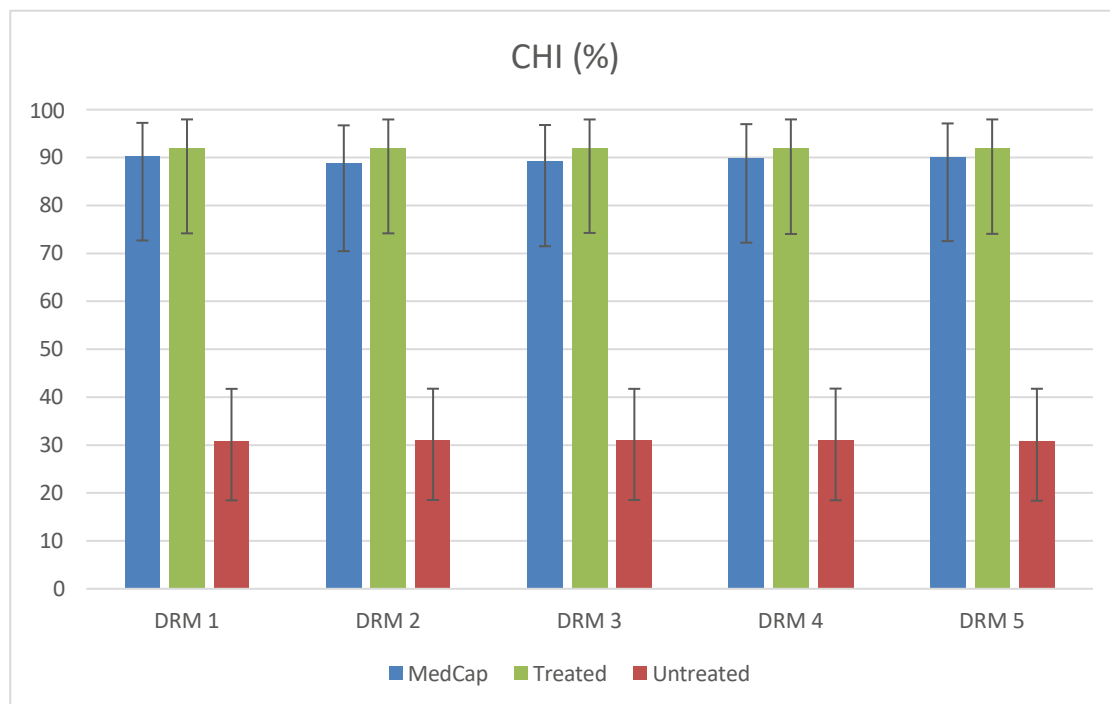


Table 5 along with figures 3 and 4 show the probability of EVAC and LOCL across all of the DRMs.

Table 5: EVAC and LOCL for the DRMs

		EVAC			LOCL		
		Probability	95% CI		Probability	95% CI	
DRM 1	MedCap	0.1333	0.1314	0.1354	0.0095	0.0088	0.0100
	Treated	0.0728	0.0712	0.0743	0.0093	0.0087	0.0099
	Untreated	0.8568	0.8547	0.8589	0.0333	0.0323	0.0344
DRM 2	MedCap	0.2000	0.1975	0.2024	0.0139	0.0132	0.0147
	Treated	0.0716	0.0702	0.0734	0.0092	0.0086	0.0098
	Untreated	0.8573	0.8551	0.8594	0.0325	0.0314	0.0336
DRM 3	MedCap	0.1904	0.1881	0.1932	0.0131	0.0125	0.0139
	Treated	0.0703	0.0686	0.0718	0.0092	0.0086	0.0097
	Untreated	0.8572	0.8548	0.8593	0.0319	0.0308	0.0329
DRM 4	MedCap	0.1731	0.1707	0.1753	0.0119	0.0113	0.0126
	Treated	0.0729	0.0710	0.0744	0.0098	0.0092	0.0104
	Untreated	0.8572	0.8550	0.8592	0.0327	0.0314	0.0336
DRM 5	MedCap	0.1539	0.1516	0.1562	0.0109	0.0102	0.0115
	Treated	0.0737	0.0720	0.0753	0.0093	0.0087	0.0099
	Untreated	0.8577	0.8555	0.8599	0.0329	0.0317	0.0340

Figure 3: Probability of EVAC for the DRMs

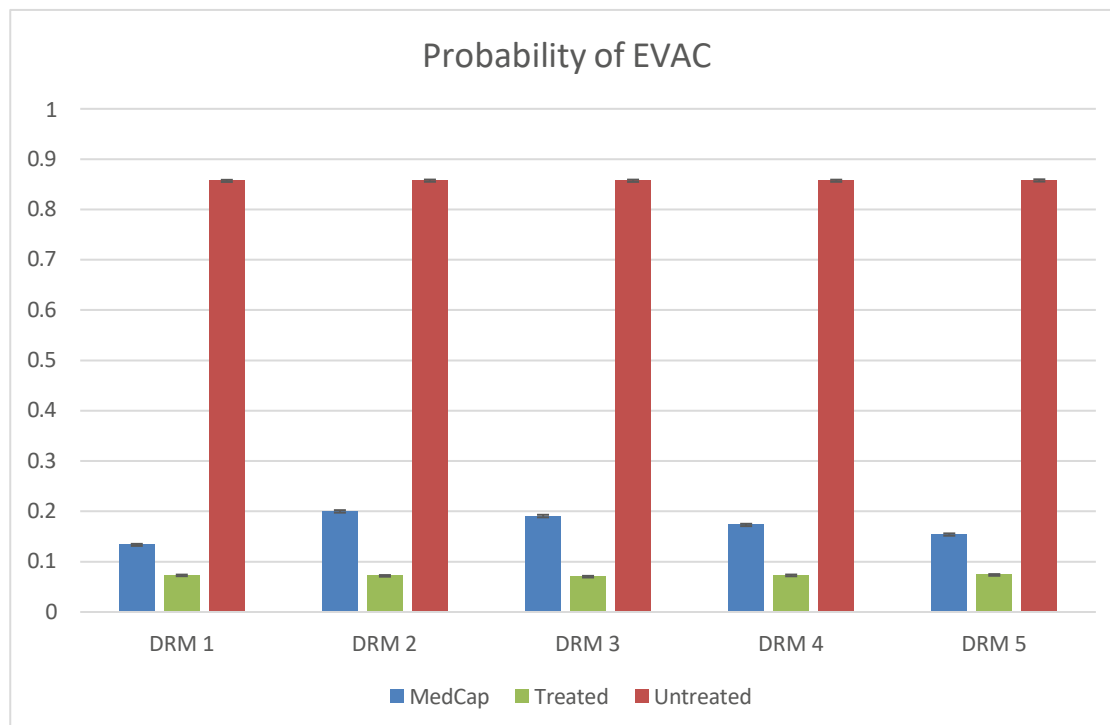
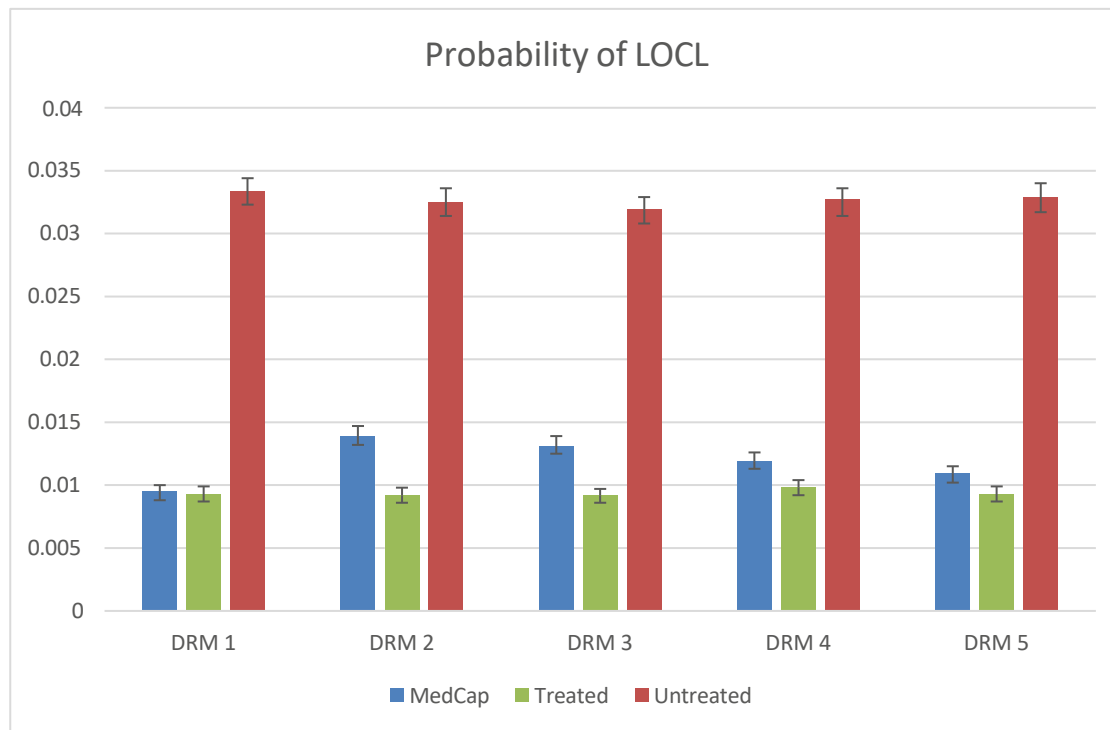


Figure 4: Probability of LOCL for the DRMs



Recall that DRM 1 did not have any EVAs. The list of top 10 influential conditions for all the DRMs are presented in tables 6-15.

Table 6: DRM 1 Medcap EVAC top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	3272	23.10	23.10
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	1127	7.96	31.05
WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	936	6.61	37.66
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	516	3.64	41.30
WORST CASE	TREATED	SMOKE INHALATION	ENVIRONMENTAL	478	3.37	44.68
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	478	3.37	48.05
WORST CASE	TREATED	NEPHROLITHIASIS	MEDICAL	453	3.20	51.25
WORST CASE	TREATED	SEPSIS	MEDICAL	410	2.89	54.14
WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	406	2.87	57.01
WORST CASE	TREATED	WRIST FRACTURE	INJURY/TRAUMA	306	2.16	59.17

Table 7: DRM 1 Medcap LOCL top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	TREATED	SEPSIS	MEDICAL	195	20.57	20.57
WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	135	14.24	34.81
WORST CASE	TREATED	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	91	9.60	44.41
WORST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	79	8.33	52.74
WORST CASE	TREATED	SMOKE INHALATION	ENVIRONMENTAL	77	8.12	60.86
WORST CASE	TREATED	HEAD INJURY	INJURY/TRAUMA	74	7.81	68.67
WORST CASE	TREATED	CHEST INJURY	INJURY/TRAUMA	58	6.12	74.79
WORST CASE	TREATED	TOXIC EXPOSURE (AMMONIA)	ENVIRONMENTAL	46	4.85	79.64
WORST CASE	TREATED	APPENDICITIS	MEDICAL	41	4.32	83.97
WORST CASE	PARTIAL	SEPSIS	MEDICAL	32	3.38	87.34

Table 8: DRM 2 Medcap EVAC top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	6390	29.32	29.32
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	2938	13.48	42.80
WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	971	4.46	47.25
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	927	4.25	51.51
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	879	4.03	55.54
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	719	3.30	58.84
WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	710	3.26	62.10
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	623	2.86	64.96
WORST CASE	PARTIAL	SEPSIS	MEDICAL	457	2.10	67.05
WORST CASE	PARTIAL	DENTAL ABSCESS	MEDICAL	452	2.07	69.13

Table 9: DRM 2 Medcap LOCL top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	302	21.62	21.62
WORST CASE	PARTIAL	SEPSIS	MEDICAL	275	19.69	41.30
WORST CASE	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	135	9.66	50.97
WORST CASE	PARTIAL	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	96	6.87	57.84
WORST CASE	PARTIAL	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	86	6.16	63.99
WORST CASE	PARTIAL	HEAD INJURY	INJURY/TRAUMA	80	5.73	69.72
BEST CASE	PARTIAL	SEPSIS	MEDICAL	78	5.58	75.30
WORST CASE	PARTIAL	CHEST INJURY	INJURY/TRAUMA	75	5.37	80.67
WORST CASE	PARTIAL	TOXIC EXPOSURE (AMMONIA)	ENVIRONMENTAL	54	3.87	84.54
WORST CASE	PARTIAL	APPENDICITIS	MEDICAL	53	3.79	88.33

Table 10: DRM 3 Medcap EVAC top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	5858	28.27	28.27
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	2802	13.52	41.79
WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	983	4.74	46.53
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	841	4.06	50.59
WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	694	3.35	53.94
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	685	3.31	57.25
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	585	2.82	60.07
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	475	2.29	62.36
BEST CASE	PARTIAL	FINGER DISLOCATION	INJURY/TRAUMA	444	2.14	64.50
WORST CASE	PARTIAL	DENTAL ABSCESS	MEDICAL	384	1.85	66.36

Table 11: DRM 3 Medcap LOCL top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	277	21.02	21.02
WORST CASE	PARTIAL	SEPSIS	MEDICAL	228	17.30	38.32
WORST CASE	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	103	7.81	46.13
WORST CASE	PARTIAL	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	70	5.31	51.44
WORST CASE	PARTIAL	HEAD INJURY	INJURY/TRAUMA	65	4.93	56.37
WORST CASE	PARTIAL	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	62	4.70	61.08
WORST CASE	TREATED	SEPSIS	MEDICAL	54	4.10	65.17
WORST CASE	PARTIAL	CHEST INJURY	INJURY/TRAUMA	45	3.41	68.59
BEST CASE	PARTIAL	SEPSIS	MEDICAL	42	3.19	71.78
WORST CASE	PARTIAL	TOXIC EXPOSURE (AMMONIA)	ENVIRONMENTAL	42	3.19	74.96

Table 12: DRM 4 Medcap EVAC top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	4735	25.39	25.39
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	2235	11.99	37.38
WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	1009	5.41	42.79
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	723	3.88	46.66
WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	681	3.65	50.32
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	562	3.01	53.33
BEST CASE	PARTIAL	FINGER DISLOCATION	INJURY/TRAUMA	482	2.58	55.91
WORST CASE	PARTIAL	DIARRHEA	MEDICAL	375	2.01	57.93
WORST CASE	TREATED	NEPHROLITHIASIS	MEDICAL	370	1.98	59.91
WORST CASE	PARTIAL	DENTAL ABSCESS	MEDICAL	311	1.67	61.58

Table 13: DRM 4 Medcap LOCL top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	PARTIAL	SEPSIS	MEDICAL	153	12.81	12.81
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	144	12.06	24.87
WORST CASE	TREATED	SEPSIS	MEDICAL	112	9.38	34.25
WORST CASE	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	85	7.12	41.37
WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	82	6.87	48.24
WORST CASE	TREATED	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	55	4.61	52.85
WORST CASE	PARTIAL	HEAD INJURY	INJURY/TRAUMA	51	4.27	57.12
WORST CASE	PARTIAL	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	46	3.85	60.97
WORST CASE	PARTIAL	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	43	3.60	64.57
BEST CASE	PARTIAL	SEPSIS	MEDICAL	41	3.43	68.01

Table 14: DRM 5 Medcap EVAC top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total EVAC	Percent Contribution	Cumulative Percent
BEST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	3747	22.82	22.82
WORST CASE	PARTIAL	URINARY TRACT INFECTION	MEDICAL	1657	10.09	32.91
WORST CASE	TREATED	VISUAL IMPAIRMENT AND/OR INCREASED INTRACRANIAL PRESSURE (VIIP)(SPACE ADAPTATION)	MEDICAL	1012	6.16	39.07
WORST CASE	PARTIAL	BACK SPRAIN/STRAIN	INJURY/TRAUMA	629	3.83	42.90
WORST CASE	PARTIAL	EYE CHEMICAL BURN	ENVIRONMENTAL	601	3.66	46.56
WORST CASE	PARTIAL	NEPHROLITHIASIS	MEDICAL	476	2.90	49.46
BEST CASE	PARTIAL	FINGER DISLOCATION	INJURY/TRAUMA	455	2.77	52.23
WORST CASE	TREATED	NEPHROLITHIASIS	MEDICAL	391	2.38	54.61
WORST CASE	TREATED	SMOKE INHALATION	ENVIRONMENTAL	323	1.97	56.57
WORST CASE	TREATED	SEPSIS	MEDICAL	304	1.85	58.42

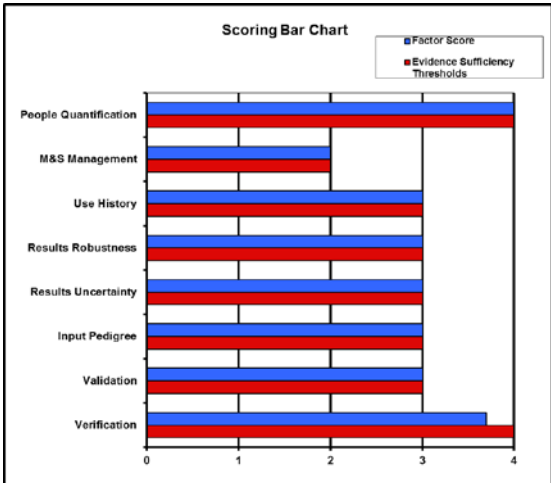
Table 15: DRM 5 Medcap LOCL top 10 Influential Conditions

Scenario	Treated	Medical Condition	Category	Total LOCL	Percent Contribution	Cumulative Percent
WORST CASE	TREATED	SEPSIS	MEDICAL	146	13.39	13.39
WORST CASE	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	97	8.90	22.29
WORST CASE	PARTIAL	SEPSIS	MEDICAL	88	8.07	30.37
WORST CASE	TREATED	MEDICATION OVERDOSE/ADVERSE REACTION	MEDICAL	82	7.52	37.89
WORST CASE	PARTIAL	SMOKE INHALATION	ENVIRONMENTAL	82	7.52	45.41
WORST CASE	TREATED	SMOKE INHALATION	ENVIRONMENTAL	67	6.15	51.56
WORST CASE	TREATED	STROKE (CEREBROVASCULAR ACCIDENT)	MEDICAL	61	5.60	57.16
WORST CASE	TREATED	HEAD INJURY	INJURY/TRAUMA	57	5.23	62.39
WORST CASE	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	INJURY/TRAUMA	48	4.40	66.79
WORST CASE	TREATED	CHEST INJURY	INJURY/TRAUMA	48	4.40	71.19

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: The following bar chart shows the IMM v4.1 MATLAB status of IMM validation for each IMM element listed. Scoring Bar Chart 																																																										
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. <table><tr><th>Factor</th><th>Sufficiency Thresholds</th><th>Factor Score</th><th>Weighted Scores</th><th>Overall Score</th></tr><tr><td>Verification</td><td>4</td><td>3.7</td><td>0.28</td><td></td></tr><tr><td>Validation</td><td>3</td><td>3</td><td>0.45</td><td></td></tr><tr><td>Input Pedigree</td><td>3</td><td>3</td><td>0.53</td><td></td></tr><tr><td>Results Uncertainty</td><td>3</td><td>3</td><td>0.60</td><td>3.06</td></tr><tr><td>Results Robustness</td><td>3</td><td>3</td><td>0.45</td><td></td></tr><tr><td>Use History</td><td>3</td><td>3</td><td>0.45</td><td></td></tr><tr><td>M&S Management</td><td>2</td><td>2</td><td>0.10</td><td></td></tr><tr><td>People Qualification</td><td>4</td><td>4</td><td>0.20</td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table> Legend from NASA-STD-7009 <table><tr><td></td><td>CAS Score > Threshold Exceeds credibility requirements</td></tr><tr><td></td><td>Threshold ≥ CAS Score ≥ (Threshold-0.5) Ready for use</td></tr><tr><td></td><td>Threshold-0.5 > CAS Score ≥ Threshold-1.0 Use with caution</td></tr><tr><td></td><td>CAS Score < Threshold - 1.0 Use not recommended or to be used with EXTREME CAUTION by subject matter experts only</td></tr></table>	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								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
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Additional verification and validation information applicable to this analysis	none																																																										
Integrated Medical Evidence Database (iMED) code version and date accessed	iMED Lockdown ID: For DRM 1: ID 39 (created on 4/30/2018; For DRMs 2-5: ID 40 (created on 6/5/2018)																																																										
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
(removed from this simulation)
Eye Chemical Burn
Headache (CO₂ 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
(removed from this simulation)
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
(removed from this simulation)
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
EVA_Deplete (added for this simulation)
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)