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Development of an Accepted Medical Condition List for Exploration Medical Capability Scoping

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1.0 INTRODUCTION

Future NASA human spaceflight programs are on the verge of moving beyond Low Earth Orbit (LEO) to implement missions in lunar space and ultimately Mars. The mission constraints for these types of missions are expected to be progressively challenging for integration of Human Systems requirements into the vehicle and mission architectures. Mass and volume allocations are expected to become increasingly restrictive at the same time that mission realities will drive an increasing need for crew self-sufficiency in the maintenance and repair of both vehicle systems and human systems. To meet these challenges, a systematic, traceable, and repeatable approach to identifying, defining, and prioritizing medical capabilities is required.

To provide a systematic and repeatable approach to defining and prioritizing clinical capabilities for spaceflight medicine, a clear process is required for delivering a list of prioritized medical capabilities to the Systems Engineering process that will delineate the mass, power, volume, and similar needs and the trade space analysis for a given space vehicle and mission architecture.

Figure 1 shows the process and products needed to deliver a medical capabilities list to the Systems Engineering team responsible for Human Systems Requirements development.

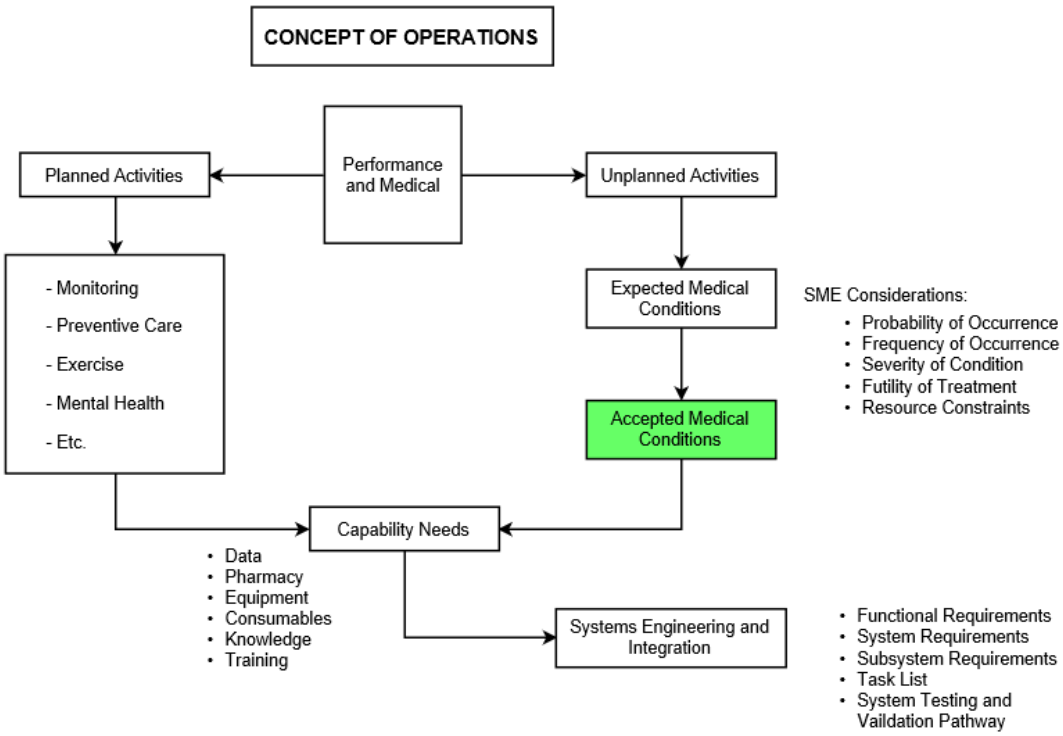

Figure 1: Flow of work from the Concept of Operations to defining clinical capabilities needed for interfacing with Systems Engineering Teams. The Accepted Medical Conditions List, highlighted in green, is used to scope clinically desirable capabilities for inclusion in the Medical System in the exploration vehicle and mission design.

Starting with the Concept of Operations for the medical system, Planned Activities and Unplanned Activities are considered. Planned Activities are those medical crew activities that are expected to be performed throughout a nominal mission. Examples include private medical conferences, periodic dental exams, self-examinations by crew, psychological examinations, exercise sessions, etc. Unplanned activities are those medical conditions that occur and require medical evaluation, diagnosis, monitoring, treatment, or long-term care to be implemented by the crew during the mission. Consideration of which medical conditions may occur in-mission uses a list of the expected medical conditions [1], [2] as the starting point for assessment. It is a given assumption that NASA will not be able to provide a full, Earth-like medical capability in flight to evaluate, monitor, diagnose, treat, or provide long-term management for all of the potential medical conditions that may occur. Since this is the case, it is critical to provide a process that allows for an evidence-based consensus

position on what medical conditions mission planners should prioritize for the vehicle and mission design process.

The Accepted Medical Conditions List (AMCL) is a product designed to provide a traceable, repeatable, evidence-based consensus process for scoping the medical capability needs for future design reference missions (DRMs) and upcoming programs. These include a Mars transit DRM and a shorter duration cis-lunar DRM. The development of a baseline AMCL by the Exploration Medical Capability (ExMC) Element will assist the effort to identify high priority medical capabilities for inclusion in mission and vehicle planning and provide traceable and documented clinical needs to the Systems Engineering teams tasked with requirements development and design work.

The ExMC Clinician's group developed a process to identify and prioritize potential medical conditions that a medical capability should plan to address during these DRMs. This was done in two separate iterations as described below, first as an AMCL Version 1.0 designed around a Mars transit DRM and subsequently as an AMCL Version 2.0 designed around a shorter duration cis-lunar DRM. Defining an AMCL allows the Element to better scope a potential exploration medical capability and identify the necessary resources for inclusion aboard future exploration vehicles within the context of known conditions, desired treatment capabilities, and limitations of vehicle and mission design. This document explores the methodology used in pilot efforts toward development of an AMCL and results of the first and second iterations, as well as lessons learned that can be used for future refinement of these AMCLs, and development of new ones to address future DRMs.

There is a precedent with regard to identifying the medical conditions that pose a sufficient risk due to incidence, severity, morbidity, mortality, futility, or a combination of these factors during spaceflight missions. Previous efforts have led to the development of the Exploration Medical Condition List (EMCL) [3], derived from the International Space Station (ISS) Integrated Medical Group (IMG) Medical Checklist (JSC-48522) [4], the Flight Data File Medical Checklist (JSC-48031) [5], inflight medical incidence data in the Lifetime Surveillance of Astronaut Health (LSAH) repository, and NASA Flight Surgeon subject matter expertise. The EMCL has served as a foundation in determining which medical conditions might affect crewmembers during a given mission profile, helping to define which conditions might be of concern and require treatment and to identify gaps in

knowledge that should be addressed by dedicated research or technological advances for future mission development [6]. Similarly, NASA developed the Integrated Medical Model (IMM) condition list (IMCL), a list of medical conditions considered to be of concern for ISS-specific spaceflight [1], [2]. This list, along with data from the Integrated Medical Evidence Database (iMED) have been used to populate the IMM for probabilistic risk analysis calculations for ISS missions based on the makeup of a given crew and specific mission parameters. Use of the iMED database allows for an evidence-based assessment of medical conditions' probability of occurrence and an estimate of the number of occurrences that may occur throughout a given DRM. The EMCL and IMCL database are closely related.

Knowledge gaps and uncertainty surrounding the probability of medical events during spaceflight are a known challenge faced at this time in human spaceflight. These naturally limit the ability to define an AMCL that will closely match what medical events occur in upcoming missions. This fact will not prevent human spaceflight missions from occurring, and impending timelines for cis-lunar missions and Mars transit missions beyond LEO drive the need for the best available AMCL that can inform vehicle and mission design efforts. This pilot effort attempts to identify the conditions that should, or should not, influence medical system planning for cis-lunar and Mars transit missions in the near-term future. When this process is used correctly, the best available evidence-based information on what medical conditions are likely to occur is considered along with survey-based Subject Matter Expert (SME) interpretation of the complexity and futility involved in dealing with each of those conditions, allowing a prioritization process that is transparent, repeatable, and traceable. The role of the SMEs in this process cannot be understated. In this process, SMEs are defined to include spaceflight support personnel with clinical experience in treating medical conditions such as operational flight surgeons, pharmacists, and nurses.

2.0 METHODS

A pilot effort was developed to generate a logical method for comparative analysis of various medical conditions that might be experienced during Mars exploration spaceflight in an attempt to determine which conditions should or should not be accommodated by the medical system for such a mission. This led to an initial medical list that was subsequently modified to a second list that was appropriate for a shorter duration cis-lunar mission profile. The IMM Condition List was used as a starting point for all discussion of potential medical conditions of concern. To preserve familiarity of language, each condition was considered in two scenarios, as in the iMED [1], [2] – a "Best Case" scenario, where all interventions and treatments are successful and the patient recovers in the best manner possible for a given condition, and a "Worst Case" scenario, where the condition is complicated by poor response to treatment and failed interventions. The definitions for Best Case and Worst Care are taken from the iMED list in the IMM definitions document (IMM Service Request number D-20160815-365) and were not altered for this process. As IMM simulations can be requested and tailored for specific applications and different mission needs, varied mission parameters were implemented for different IMM runs specific to each AMCL effort. The probability of occurrence was identified based upon model output data from the NASA IMM Project at Johnson Space Center, Houston, TX (IMM Service Request number SR-20170306-376), using IMM version 3.0, programmed in MatLab® version 8.3 (2014a, MathWorks, Natick, MA). Model parameters included a four crew (two male, two female) profile for a 16-month DRM with no extra-vehicular (EVA) activity for the Mars transit version. Of 200 Best and Worst Case conditions included in the iMED, six were excluded from consideration in scoring because of their association with EVAs and their probabilities were assumed to be 0 as EVA activity was removed from the DRM. The six conditions excluded from this effort were Best and Worst Case scenarios for Decompression Sickness, Fingernail Delamination, and Paresthesias. With the transition from a Mars transit DRM to a shorter duration cis-lunar DRM, data were extracted from an IMM run previously requested for another task (IMM Service Request number 201710623-384; IMM version 4.1, programmed in MatLab® version 8.3 (2014a, MathWorks, Natick, MA)), which included four crew (all male) and excluded EVA conditions for a cis-lunar mission lasting 42 days. While a mixed-sex crew is preferable, this run was selected to demonstrate the process while limiting cost and schedule impacts and comes with recognized limitations to the outcomes.

2.1 Scoring Variables

The medical conditions were provided to ExMC medical professionals for review. These medical professionals included an Aerospace-trained pharmacist and six physicians with training and certification in Aerospace Medicine, Emergency Medicine, Internal Medicine, Family Medicine, and Physical Medicine and Rehabilitation, as well as familiarity and experience in operational aerospace medicine practice and the exploration mission concept. For the initial version of the medical list, each provider reviewed the conditions and Best/Worst Case scenarios, identifying whether management of each condition or scenario would be feasible for an exploration medical capability specific to the Mars transit Design Reference Mission. Specifically, each provider was asked to score the condition based on complexity (low, medium, high) and futility (low, medium, high) as defined in the tables below. These scores were translated to a logarithmic scale to roughly estimate the likelihood of successful intervention and good clinical outcome. Table 1 shows the definitions and scoring schema assigned to the Complexity category. Table 2 shows the definitions and scoring schema assigned to the Futility category.

Table 1: Complexity variable definition and scoring schema. Clinical subject matter experts assigned scores on a logarithmic scale.

Complexity Key	*Score*	*Clinical Definition*
High	1	Large number of resources required to diagnose and treat, or difficult management. (i.e. Worst Case sepsis)
Medium	0.1	Moderate number of resources required
Low	0.01	Small number of resources required (i.e. Best Case mild headache)

Table 2: Futility variable definition and scoring schema. Clinical subject matter experts assigned scores on a logarithmic scale.

Futility Key	*Score*	*Clinical Definition*
High	1	Highly likely to result in death or disability despite treatment
Medium	0.1	Somewhat likely to result in death or disability despite treatment
Low	0.01	Unlikely to result in death or disability

The logarithmic score for futility was multiplied by the score for complexity, with the product then divided by the probability of occurrence to provide a final comparative ratio, the Exclusion Score (ES).

$$Exclusion\ Score = \frac{Complexity * Futility}{Probability}$$

By this schema, conditions that are unlikely to occur (probability), are unlikely to have a good outcome despite full treatment (futility), and are difficult to accommodate in light of resource and training constraints (complexity) will have a high ES. Those conditions that are likely to occur, have good expected outcomes, and require minimal resources will have a low ES. This allowed for a logical mathematical comparison of the viability of planning for conditions given a resource-limited exploration medical capability. It should be noted that, while the probability of occurrence is an evidence-based output from the IMM, the other two variables are subjective clinical SME assessments and logarithmic scores according to the definitions above. This is an acknowledged limitation to the methodology of this study and is discussed further in the Limitations and the Future Directions sections below. For process purposes, consistent use of the same definition set and scoring algorithm allows for a repeatable process despite these limitations.

2.2 Manual Review

Calculated ESs were reviewed by the Exploration Medical Capability Element Scientist (the individual responsible for guiding the science and research of ExMC) to assess any inconsistencies and determine face validity. The Element Scientist assessed each condition, considering whether to recommend "Should Plan to Treat" or "Should Not Plan to Treat" based upon the variables (probability, complexity, and futility), the ES, and clinical experience. Of note, designation of a condition as "Should Not Plan to Treat" should not be interpreted as an indication that there would be no attempt to help a crewmember experiencing such a condition, but rather that dedicated exploration medical capabilities would not be specifically included in exploration medical planning and scoping for the purpose of anticipating and treating that specific illness or injury. As the methodology for this modeling evolved, a further designation of "Might Plan to Treat" was also incorporated to indicate a condition that might require certain additional resources that could be included in a medical capability if given the additional volume, mass, and training that would be required. Conditions with this designation could then be discussed further by the SMEs regarding the risk/benefit of inclusion within the model, at a later date when vehicle and crew training limitations were better defined. Conditions or scenarios were reordered manually to reflect the likelihood of successful intervention and whether such conditions should be considered treatable during an exploration mission. Following Element Scientist review, the remaining medical experts were asked to agree or disagree with the Element Scientist's assessments and any reorganization by the Element Scientist and to provide

rationale for any disagreement. Where majority consensus was reached, conditions were again manually reordered to reflect SME consensus. Where consensus was not reached, the Element Scientist provided the final designation based upon the interpretation of considerations presented by the SMEs queried.

With transition from a Mars transit DRM to a shorter duration cis-lunar DRM, ExMC further refined the medical condition list by attaching medical resources/capabilities to each of the conditions. Necessary capabilities for the prevention, diagnosis, and treatment for each of the conditions were identified and the resources were determined based on what would be considered terrestrial standards of best practice. However, these "best practices" were modified to account for assumed resource limitations of the flight environment (e.g. future deep space missions are most likely not going to have a robust surgical capability, so conditions requiring the use of such a capability were modified to account for this limitation). Once these resources/capabilities were determined for each of the conditions, this information was used by the SMEs to further order and refine which conditions would and would not be treated, incorporating a dimension of "resource requirements" to previous assessments of complexity, futility, and probability. This was done subjectively, with the medical professionals providing an updated expert opinion on whether to treat or not treat each condition based on the initial exclusion scoring of the condition and the resources identified to manage them.

With the methodology established, a final list of medical conditions that should or should not be treated during an exploration mission was generated. This list represents the consensus views of queried experts.

3.0 RESULTS

The initial pilot project outcomes include lists of 1. conditions that an exploration medical capability "*Should Plan to Treat"* and 2. conditions that an exploration medical capability "*Should Not Plan to Treat*," each subcategorized by Best- and Worst-Case scenario. The third "*Might Plan to Treat*" designation (referred to in the condition list as *"Plan to Treat, with Conditions"*) is included in the first list, identifying medical scenarios that would require dedicated additions to an exploration medical capability that would most likely be beyond the scope of the current medical capability design but could be managed in part using medical capabilities included in the planned medical system that would be used to manage other medical conditions. This third designation could also encompass conditions where treatment would be initiated but may be limited in duration based upon limited quantities of available resources. Lists are provided in Appendix A. Examples of calculations and comparative ratios are provided in Appendix B.

There was general agreement between providers regarding conditions of high probability and low futility and simplicity of intervention; these conditions were nearly universally accepted as "*Should Plan to Treat*" conditions. The conditions that most often generated consensus toward no intent to treat were generally the rarest and most complex (least simple) conditions, and scenarios that, despite gold-standard intervention, would likely progress to poor clinical outcome (most futile).

Of the 194 conditions considered for the initial pilot project design, 135 were listed as "*Should Plan to Treat"* for medical system scoping with no dissent. Twenty-two conditions were listed as "*Plan to Treat, with Conditions,"* with clarification regarding the nature or extent of treatment capability to be provisioned and that additional dedicated resources/capabilities would not be included for these specific conditions. Thirty-four conditions were excluded from consideration for system scoping by consensus, designated as *Should Not Plan to Treat*. Figure 2 shows relevant proportions for condition inclusion and level of disagreement encountered among the SMEs. Disagreement was noted in the recommendation regarding 14 of the conditions; in that subset of cases, the Element Scientist provided final disposition. This accounted for 7% of the total number of conditions.

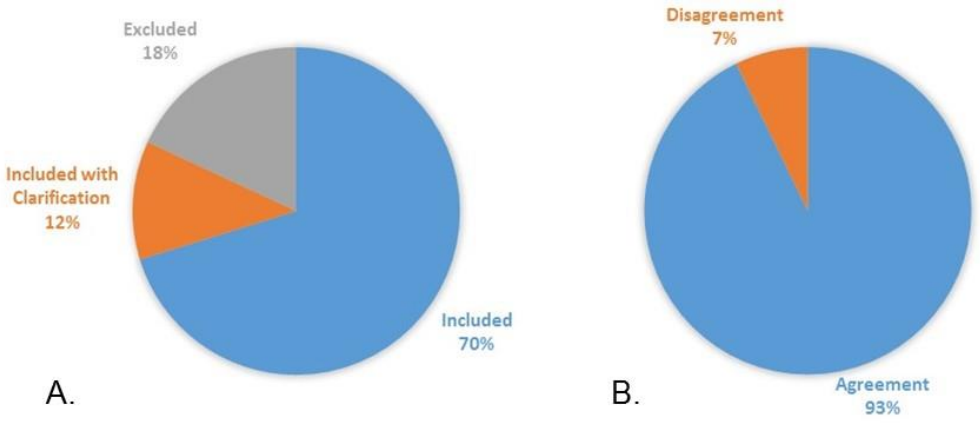

Figure 2: A. relative proportion of conditions recommended for inclusion ("*Should Plan to Treat*"), inclusion with clarification ("*Plan to Treat, with Conditions*"), and exclusion ("*Should Not Plan to Treat*") for medical system scoping from this approach. B. Relative percentage of conditions for which disagreement was encountered; final designations for these conditions required single voice disposition by the Element Scientist.

The follow-on iteration to this model, developed in response to the shift to a shorter duration cis-lunar DRM, consolidated the initial 194 conditions (plus the six EVA conditions) into a 100-condition list by removing the "Best Case" and "Worst Case" definitions and looking at requirements for treating the condition as a whole. This was done by taking the previously developed mathematical calculations of probability, futility, and complexity and incorporating a "resource requirement" dimension, as described previously. Once done, the conditions were re-ranked and again organized into categories of "*Should Plan to Treat,*" "*Might Plan to Treat,*" and "*Should Not Plan to Treat.*" This was again done based on expert opinion of the previously described panel of SMEs.

Given the challenges in reaching consensus in the first iteration of the model, the second iteration utilized an alternative methodology that involved developing a comprehensive approach to spaceflight-specific diagnosis and treatment of each condition. Once this comprehensive approach had been developed, it was simpler to identify futility and complexity and reach consensus regarding "*Should Plan to Treat," "Plan to Treat with Conditions,"* and *"Should not Plan to Treat"* categorization. Finally, after this process was complete, the condition list was re-expanded to include Best Case and Worst Case definitions. Clinicians were asked to reevaluate the cases in light of the determined diagnostic and treatment plan and identify whether either case altered the resources needed or management plans. This expanded the final list back to 200 total conditions considered.

Of the 200 conditions in this second iteration, 92 were listed as "*Should Plan to Treat"* for medical system scoping with no dissent, 89 conditions were listed as "*Plan to Treat, with Conditions,"* and 19 conditions were excluded from consideration for system scoping by consensus, designated as "*Should Not Plan to Treat*." Using this adjusted approach, providers reached 100% consensus for categorization of the medical conditions for a shorter duration cis-lunar DRM. Examples of calculations and comparative ratios are provided in Appendix C.

4.0 DISCUSSION

Classification of medical conditions for comparative review, as well as determining reasonable vs. unreasonable medical management, is complex and difficult. Here, a first pilot effort attempted to provide some framework for approaching the problem with mathematical and logarithmic designations of complexity, futility, and a calculation of probability generated by evidence-based modeling tools. Subsequent revisions of the process attempted to quantify a "resource requirement" dimension for each medical condition, based on terrestrial standards adapted for spaceflight. The intention behind these first process attempts was to find a starting point to generate discussion and then allow for refinement of technique through iteration.

4.1 Sources of Disagreement

Providers identified unresolved disagreement in 7% of conditions for the initial design and no disagreement in the second-round design of the process. As program-level planning and approval processes often require multiple levels of decision-making, limiting the discussion to small areas of SME disagreement may streamline review, deliberation, and the need for dedicated SME time for these approval efforts. Of note, disagreement in the pilot effort most often occurred with conditions where complexity or futility is considered to be high. Most often, providers expressed disagreement or struggled to reach consensus regarding two types of conditions. First were conditions that were considered rare but likely to be successfully managed with the addition of few resources to a medical capability. With these cases, there were at times disagreements over whether a dedication of resources to such low-probability events would be appropriate, regardless of the chance for successful treatment should one of these events occur. Second were conditions that were interpreted differently by providers of differing medical backgrounds regarding the likelihood of

successful intervention, likelihood of poor clinical outcome despite intervention, or definition of what a "Worst Case" scenario might entail. An example of this was the condition, Acute Radiation Syndrome, where there tended to be differences in opinions for the care of this condition between those clinicians with a background in acute-care management (e.g. Emergency Medicine physicians) and those with a background in long-term management (e.g. Internal Medicine physicians). Emergency Medicine-trained physicians tended to approach this condition from a "triage" point of view and often favored not treating given the low success rate, where Internal Medicine-trained physicians more often favored an attempt at treatment. Finally, there was also some disagreement regarding how to classify certain conditions that would be particularly complex to manage, but where providers felt that at least an attempt to manage was warranted. These disagreements often arose over conditions where procedures and interventions would be needed to adequately manage a condition and stemmed from the fact that clinicians with different backgrounds had various comfort levels with administering such procedures and thus had different expectations regarding the ability of future crews to effectively utilize such procedures for the management of these conditions. Examples of each are provided in Appendix D. In the second iteration of this effort, clear definition of resources and treatment requirements provided needed clarification of probability of outcome. This clarification led to universal agreement in classification.

The definition of Best and Worst Case scenarios was another area of disagreement. This effort used the definitions already existing in iMED and IMM. There were a number of clinical definitions of disease that were not captured by the Best or Worst Case definitions, or where definitions were outdated, inappropriate, or do not represent the spectra of clinical sequelae of a given disease. For the purposes of the initial project design, definitions as provided by the iMED were used with the understanding that this is a known limitation for the final AMCLs generated. Following this reasoning, with the shift to a shorter duration cis-lunar DRM, Best and Worst Case definitions were initially eliminated and conditions were assessed based on how they would be managed comprehensively, including prevention, diagnosis, and treatment. While the Case definitions were re-added for the final results, initial classification considered only a single condition definition, including the full potential spectrum of outcome.

Finally, there was disagreement over whether discussions should focus on inclusion or exclusion of medical conditions. The effort described in this paper focused on providing an "exclusion" score and resultant exclusion of the associated condition from mission planning. This decision was made by the Element Scientist and was intended to prompt departmental and agency consideration of the potential consequences of any prioritization process and the value of mass and volume allocated to the medical system. Because of this decision, discussions started from a baseline list of possible conditions with the background and pedigree described in the introduction. It is not an all-encompassing list of medical possibilities in an exploration mission; similarly, the list of "excluded" conditions is not complete but is based on the starting list of conditions considered. While we acknowledge this limitation, this was intentional. Focusing on "inclusion" in an attempt to capture all possible medical conditions that may be relevant for mission planning may provide an easier framework for medical capability scoping. However, this approach could easily overwhelm the process as it has been designed and make its use less practical.

4.2 Future Direction

Future efforts would benefit from more stringent terminology definitions, such as better delineating the difference between intent to treat ("*Might Plan to Treat"*) vs. intent to provide dedicated resources specific to treatment of a given condition ("*Should Plan to Treat"*). Expanded input from more medical providers across disciplines, as well as expert opinion from designated consultants for more complex conditions, could further identify management options, pitfalls, or other considerations for medical capability development. In addition, future efforts should continue to consider the broader range of disease manifestations, as well as clinical sequelae of different conditions. Careful attention to definitions, to ensure that they reflect accurate descriptions of clinical disease and sequelae, would result in more robust input to SME scoring efforts. Consideration of additional mission parameters, such as varied crew makeup (inclusive of male and female members of varied medical history) and inclusion of EVA-specific risks, could better elucidate how such factors alter risk for a given DRM.

Second, despite an attempt at using objective criteria for evaluating clinical conditions, medical condition ranking and cutoffs for treating vs. not treating were still very heavily dependent upon SME opinion. Because of this, the cutoff between treatment and no treatment was poorly defined and there was often disagreement among clinicians as to

which conditions warrant resource allocation during exploration missions. As a result, disagreements often required a tie-breaking decision by an authority willing to accept responsibility, in this case the Element Scientist. In the undesirable circumstance that mission timelines dictate an authority decision in lieu of external validation, in the future these decisions should be relegated to an authority such as the Office of the Chief Health and Medical Officer. To limit the impact of authority-level decision-making, future work to refine the model should include means to better define and objectively determine which conditions warrant resource allocation. For example, this could include objectively defining the required Level of Care for each type of DRM and clearly delineating how these Levels of Care impact complexity, futility, resource availability, and ultimately the decision to treat or not treat a given condition. If subjective opinion continues to play a role in the decision-making process, it may be possible to build in a metric for "strength of agreement" to quantify the level of agreement among SMEs and between SMEs and the decision-making authority.

Third, as described above, medical conditions included in the model were based on available clinical data as well as current and historical expert opinion. This information was compiled into an initial list of conditions that was then scrutinized and conditions from that list were subsequently excluded if resources dedicated to their management could not be justifiably built into a mission architecture. This "exclusion"-based methodology was done intentionally, as it was felt that approaching a condition list from an "inclusion" standpoint and attempting to plan for every potential medical condition during a mission would render the process ineffective. However, it is acknowledged that choosing this methodology introduces limitations to the model by creating the potential for overlooked medical conditions. Future work can address this by building in an uncertainty factor into the medical capabilities for future missions to account for conditions that are missing or unexpected.

Finally, future work should also include weighing the relative risk of various medical conditions from an ethical viewpoint. Potential medical risk must be understood as part of Agency risk early in the process and should impact vehicle and mission planning. Crewmembers should be apprised of all known potential medical conditions and their likelihood of occurrence, the limitations of treatment capabilities, and potential treatment

outcomes to allow reasonable informed consent. These discussions should also include acknowledgment of the uncertainty in risk prediction: there are numerous unknowns that will alter the risk profile of an exploration mission. As a result, detailed understanding of where there is simply not enough information available to identify, or quantify, medical risk should be included in informed consent discussions prior to future exploration spaceflight.

Official use of an AMCL should be reviewed and concurred upon by two key stakeholders: the NASA Chief Health and Medical Officer (CHMO) and the Space Medicine Operations Control Board (SMOCB). CHMO and the Health and Medical Technical Authority have overall responsibility for medical standards and ethical issues associated with the delivery of care. The SMOCB is responsible for the operational implementation of medical capabilities by the Space Medicine Operations Division at NASA Johnson Space Center and should be consulted for the review of proposed capabilities and capability drivers for a cis-lunar or Mars mission.

5.0 CONCLUSION

The AMCL is a critical step in scoping the medical capability needs to inform systems engineering processes for future vehicle and mission planning. Defining AMCLs allows the ExMC Element to better scope a potential exploration medical capability and identify high-value resources for inclusion aboard future exploration vehicles within the context of known conditions, desired treatment capabilities, and limitations of vehicle design. Future work will be needed to further refine the AMCL model process in order to maximize its utility for informing future mission architectures with regard to the prevention, diagnosis, treatment, and long-term management of disease. Despite limitations, this approach should be considered as a transparent, repeatable, and traceable process that can be implemented by space medicine experts responsible for informing the integration of medical capabilities within vehicle and mission architectures for exploration beyond LEO.

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7.0 APPENDICES

Appendix A: Conditions and Case Definitions

Definitions for Best Case and Worst Care are taken from the iMED list in the IMM definitions document (IMM Service Request number D-20160815-365) and were not altered for this process.

Name	Best Case Definition	Worst Case Definition
Abdominal Injury	The best case scenario is defined as a mild or moderate blunt abdominal injury resulting in localized pain/discomfort and/or ecchymosis, with no hollow or solid organ involvement and no evidence of peritonitis or bleeding, requiring only minimal treatment.	The worst case scenario is defined as severe abdominal injury resulting in abdominal cavity injury, which may develop into hemorrhage and/or shock; or a blunt abdominal trauma that causes damage of the internal abdominal organs with secondary complications of shock, peritonitis, and sepsis.
Angina/Myocardial Infarction	Best case scenario definition: Cardiac chest pain that is brief, self-limited, is relieved spontaneously or with sublingual nitroglycerin and does not result in evidence of injury to the heart, e.g. Acute Myocardial Infarction (AMI).	Worst Case scenario definition: Cardiac chest pain associated with persistent chest pain at rest, with evidence of unstable angina (UA) and / or AMI such as dyspnea, cold clammy skin, and ST changes of at least 1 mm elevation or depression.
Pharyngitis	Best case scenario is defined as mild uncomplicated pharyngitis that resolves spontaneously or with symptomatic treatment.	Worst case scenario is defined as severe pharyngitis that may require antibiotic treatment.
Acute Prostatitis	Best case scenario is defined as a mild to moderate prostatitis that responds to treatment with analgesics and antibiotics.	Worst case scenario is defined as a severe prostatitis including development of prostatic abscess.
Acute Radiation Syndrome	The best case scenario is defined as receiving a dose ranging from 1 to less than 2 Gray (Gy) causing a mild course of acute radiation syndrome, e.g. mild constitutional symptoms such as fatigue and weakness, time to emesis of 4 hours after the event, and/or infection and is completely relieved by symptomatic treatment and/or resolves by itself .	The worst case scenario is defined as receiving a dose of 2 Gy or greater causing a moderate to severe course of acute radiation syndrome, e.g. symptoms such as abdominal pain, intractable vomiting and/or diarrhea, dehydration, hemorrhage, skin peels, severe burns, superimposed infection, bone marrow suppression, and cardiovascular or central nervous system involvement. These symptoms are not entirely relieved by symptomatic treatment and may ultimately lead to death. Refer to the CliFF Appendix for more information.
Allergic Reaction (mild to moderate)	The best case scenario describes a crewmember with an allergic reaction that is quickly relieved by one dose of oral medication.	The worst case scenario involves a crewmember with a more severe allergic reaction; able to be treated with oral medication, but requires multiple doses and a longer duration of treatment.

Altitude Sickness	The best case scenario is defined as a mild case of altitude sickness, which resolves with oxygen use and acetazolamide (Diamox), or return to standard environmental conditions.	The worst case scenario is defined as moderate to severe altitude sickness, which may lead to high altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE) which are life-threatening if untreated.
Anxiety	Best case scenario is defined as anxiety that resolves spontaneously or requires minimal pharmacological therapy or psychological counseling.	Worst case scenario is defined as severe anxiety that requires prolonged pharmacologic therapy and/or psychological counseling.
Appendicitis	The best case scenario is defined as an uncomplicated course of appendicitis which responds to conservative medical treatment (antibiotics and symptomatic treatment) and involves relatively minor functional impairment.	The worst case scenario is defined as having a complicated course of appendicitis, that is not responsive to conservative treatment and involves significant systemic symptoms, severe pain, complications (such as ruptured appendix), and a major functional impairment.
Atrial Fibrillation/ Atrial Flutter	The best case scenario is defined as an isolated episode of lone atrial fibrillation or atrial flutter. There is low risk of thrombo-embolic events. The episode is asymptomatic or mildly symptomatic and/or resolves spontaneously. An underlying precipitating factor such as physical stress, infection, etc. may or may not be identified.	The worst case scenario is defined as new onset of atrial fibrillation or atrial flutter that is either symptomatic, sustained, or associated with complications requiring oral or intravenous treatment for rate or rhythm control, as well as prophylaxis for thrombo-embolic complications.
Back Sprain/Strain	Best case scenario is defined a mild or moderate back injury which resolves by itself or causes minimal disturbance requiring only symptomatic treatment.	Worst case scenario is defined as having a severe back injury accompanied by severe pain.
Back Pain (Space Adaptation)	The best case scenario is defined as back awareness to mild back discomfort in the lumbar region.	The worst case scenario moderate to severe back pain also in the lumbar region.
Behavioral Emergency	Best case scenario is defined as a brief behavioral emergency that resolves with a short course of medication.	Worst case scenario is defined as a behavioral emergency that lasts more than 24 hours and requires a course of medication for at least several days.
Burns secondary to Fire	Best Case scenario is defined as first degree burn, or a second degree burn covering less than 9% of total body surface area (TBSA).	Worst Case scenario is defined as second degree burn greater than 9% of TBSA or any third degree burn.
Chest Injury	The best case scenario is defined as a mild or moderate blunt chest injury resulting in localized pain/discomfort and/or ecchymosis, requiring only minimal treatment.	The worst case scenario is defined as severe chest injury resulting in chest cavity penetration, which may develop into hemorrhage and/or shock; or a blunt chest trauma that causes damage of the internal chest organs with secondary complications of hemothorax, pneumothorax, diaphragmatic rupture, ribs fracture, shock or sepsis.

Choking/Obstructed Airway	Best case scenario is defined as choking and cough that resolves spontaneously, or obstructed airway that responds to the Heimlich maneuver.	Worst case scenario is defined as choking and obstructed airway that requires instrument extraction or advanced life support.
Constipation (space adaptation)	Our best case definition is symptomatic complaints of constipation, requiring minimal to no treatment.	Our worst case definition is symptomatic complaints of constipation that do not respond to initial treatment.
Eye Penetration (foreign body)	Best case scenario is defined as a scleral laceration which has minimal effect on vision.	Worst case scenario is defined as a penetrating or perforating foreign body with serious effect on vision.
Eye Corneal Ulcer	Best case scenario is defined as a bacterial corneal ulcer that responds to treatment	Worst case scenario is defined as a fungal or viral corneal ulcer, or a bacterial ulcer, which may or may not respond to treatment
Respiratory Infection	The best case scenario is defined as a respiratory irritation or infection, common cold or mild bronchitis that resolves spontaneously.	The worst case scenario is defined as a respiratory infection, bronchiolitis or pneumonia that requires treatment.
Decompression Sickness Secondary to Extravehicular Activity	Best case definition is Type I DCS with mild to moderate joint pain that resolves spontaneously or with treatment.	Worst case is defined as Type II DCS with severe joint pain and/or symptoms including central neurological, e.g. spotted vision, slurred speech, coordination difficulty, loss of sensation, headache, seizures, unconsciousness, and cardiopulmonary (chest pain, cough, shortness of breath).
Dental: Crown Loss	The best case scenario is the loss of a crown without any pain and can wait until return to earth.	The worst case scenario is loss of a crown which requires re-cementing of the crown.

Depression	Best case scenario is defined as a depression disorder that responds rapidly to pharmacologic and/or psychological counseling. (less than 4 weeks)	Worst case scenario is defined as a depression disorder that requires prolonged pharmacologic and/or psychological counseling. (greater than 4 weeks)
Diarrhea	Best case scenario is defined as mild diarrhea that resolves spontaneously, or with one dose of medication.	Worst case scenario is defined as copious, severe and prolonged diarrhea that may lead to dehydration and electrolyte imbalance, and requires treatment with intravenous fluids.
Elbow Dislocation	Best case scenario is defined as a simple dislocation, without a major injury to the bone that responds to conservative treatment, resolves in less than 2-4 weeks, and does not involve neurovascular compromise.	Worst case scenario is defined as a complex dislocation which may involve ligament or bone injuries, does not resolve in 2-4 weeks, potentially involves neurovascular compromise, and that may require surgery.
Finger Dislocation	Best case scenario is defined as a simple dislocation, without interposed soft tissue.	Worst case scenario is defined as a complex dislocation with interposed soft tissue which may require surgical reduction.
Shoulder Dislocation	Best case scenario is defined as a dislocation with stable capsular tears and no labral ligament lesions that reduces spontaneously or without complication. (Baker Type 1)	Worst case scenario is defined as a dislocation with partial or complete labral detachments, mildly to grossly unstable, and mild to large hemarthrosis (Baker type 2 and 3)
Barotrauma (ear/sinus block)	Best case scenario definition: is mild barotrauma consisting to no or minimal pain, fullness in the ears, that responds to analgesics and decongestants.	Worst Case scenario definition : is moderate to severe barotrauma, including symptoms of significant pain, hearing loss, vertigo, nausea, dizziness, and/or ear canal hemorrhage or epistaxis.
Dental : Exposed Pulp	The best case scenario definition is reversible pulpitis, when pain is controlled by removing the painful stimuli, oral pain reliever, or by topical anesthetic.	The worst case scenario is defined as irreversible pulpitis when pain is not relieved by oral pain reliever or topical anesthetic, and requires injected analgesic.
Eye Irritation/Abrasion	Best case scenario is defined as dry, irritated eyes or a corneal abrasion/foreign body that spontaneously resolves or can be easily treated, and does not affect vision.	Worst case scenario is defined as a corneal abrasion/foreign body that requires treatment, and affects vision or has the potential to result in a permanent impairment of vision.
Eye Infection	Best case scenario is a mild eyelid infection or viral conjunctivitis.	Worst case scenario is defined as a moderate or severe eye infection which requires antibiotic or antiviral treatment.
Fingernail Delamination Secondary to Extravehicular Activity	The best case definition is a mild to moderate nail bed trauma with partial onycholysis that responds to treatment.	The worst case definition is severe nail bed trauma causing onycholysis and/or nail loss despite treatment.

Hip/Proximal Femur Fracture	The best case scenario is defined as an incomplete, non-displaced hip fracture.	The worst case scenario is defined as an unstable, displaced, or intra-articular fracture.
Lumbar Spine Fracture	Best case scenario is defined as an uncomplicated non-displaced fracture of the vertebral body, with no dislocation, and mild to moderate pain that responds to analgesics and conservative treatment.	Worst case scenario is defined as severe fracture that would require surgical procedure and/or is associated with severe or refractory pain.
Wrist Fracture	The best case scenario is defined as a stable, non-displaced wrist fracture.	The worst case scenario is defined as an unstable, displaced, or intra-articular fracture requiring operative intervention.
Gastroenteritis	The best case scenario is defined as having an uncomplicated course of gastroenteritis which resolves spontaneously or causes minimal disturbance; with mild nausea/vomiting, diarrhea, or abdominal pain requiring only symptomatic treatment.	The worst case scenario is defined as having a severe course of gastroenteritis or prolonged symptoms refractory to treatment.
Head Injury	The best case scenario is defined as a mild or moderate blunt head injury resulting in localized pain/discomfort , diffuse headache, and/or ecchymosis, or a brief change in mental status or consciousness, lasting less than 5 minutes, and requiring only minimal treatment.	The worst case scenario is defined as a moderate or severe head or brain injury causing an extended period of unconsciousness, vomiting, diffuse headache or amnesia after the injury. All penetrating injuries are considered severe.
Headache (CO_2 induced)	The best case scenario is defined as having an uncomplicated course of CO_2-induced headache, which resolves spontaneously or with minor symptomatic treatment, and involves minimal functional impairment.	The worst case scenario is defined as a moderate CO_2-induced headache which involves a moderate level of functional impairment. Because CO_2 headaches are promptly treated in-flight, the severity of the headache is not expected to be severe.
Headache (space adaptation)	The best case scenario is defined as having an uncomplicated course of space adaptation syndrome-related headache, which resolves spontaneously or with minor symptomatic treatment.	The worst case scenario is defined as a severe space adaptation related headache poorly responsive to available treatment.
Hemorrhoids	The best case scenario is defined as a mild case of hemorrhoids, which causes minimal symptoms and responds to brief topical treatment, dietary and fluid modification. (Stages I and II)	The worst case scenario is defined as moderate or severe case of hemorrhoids with repeated symptoms requiring prolonged treatment. (Stages III and IV)

Herpes Zoster Reactivation (shingles)	The best case scenario is defined as having an uncomplicated course of herpes zoster which resolves spontaneously over the course of several days and causes minimal disturbance with localized pain.	The worst case scenario is defined as a prolonged course of herpes zoster accompanied by symptoms of either persistent disruptive pain, e.g. post herpetic neuralgia (PHN), or ocular and neurological complications (peripheral motor neuropathy, Ramsay Hunt syndrome, or HZ ophthalmicus).
Indigestion	Best case scenario: Defined as mild indigestion, most likely due to gastro-esophageal reflux (GERD), esophagitis, or gastritis that resolves with minimal or no treatment.	Worst case scenario: Defined as moderate or severe indigestion, including duodenal and/or gastric ulceration, and either requiring prolonged treatment, or leading to complications such as gastrointestinal bleeding.
Sleep Disorder	Best case scenario definition: Sleep disorders include insomnia that is not related to space adaptation and occurs after flight day 5. It can also include sleep shifting and sleep prophylaxis for Extravehicular Activities (EVAs). It is mild in nature. It can be effectively treated with appropriate crew scheduling/sleep-shifting and the available hypnotic medications.	Worst case scenario definition: As in the best case scenario, the criteria for sleep disorders apply. A small percentage of these cases in spaceflight might be severe or refractory to treatment.
Insomnia (space adaptation)	Best case scenario definition: Insomnia occurring within the first 5 days of spaceflight that is mild and is effectively treated with appropriate crew scheduling/sleep-shifting and the available hypnotic medications.	Worst case scenario: Insomnia space adaptation occurs with the first 5 days of spaceflight that is severe or refractory to treatment.
Acute Angle-Closure Glaucoma	Best case scenario is defined as a mild unilateral angle-closure glaucoma that responds to topical and systemic treatment.	Worst case scenario is defined as bilateral angle-closure glaucoma with intraocular pressure that does not respond to topical and systemic treatment. It may present with pain and/or vomiting.
Mouth Ulcer	Best case scenario describes a crewmember with a mouth ulcer and minimal discomfort that may require topical treatment.	Worst case scenario is a mouth ulcer with moderate to severe pain. Discomfort may require topical treatment, oral pain medication or for the crewmember to be on a soft or liquid diet.
Nasal Congestion (space adaptation)	Best case scenario is defined as mild to moderate nasal congestion, partial nasal obstruction	Worst case scenario is defined as severe nasal congestion, complete nasal obstruction

Neck Sprain/Strain	Best case scenario is defined as a mild neck injury that resolves with minimal or no treatment.	Worst case scenario is defined as a moderate or severe neck injury that requires more prolonged treatment, or is refractory to treatment.
Nose bleed (space adaptation)	Best case nosebleed is defined as an anterior nosebleed that resolves with minimal or no treatment.	Worst case nosebleed is defined as a posterior nosebleed that requires nasal packing and possibly surgical treatment.
Otitis Externa	The best case scenario is mild otitis externa resolving in 48 to 72 hours from the start of treatment and controlled of pain by non-narcotic analgesics.	The worst case scenario is severe otitis externa taking an extended time to respond to medication and pain that may require narcotic analgesics. Malignant or necrotizing otitis externa is not considered to be a real threat in this population because it only occurs in immune compromised or diabetic patients, unlikely among the astronaut population.
Otitis Media	The best case scenario is defined as having uncomplicated acute otitis media that is treated with antibiotics and improves rapidly, with any pain easily controlled by Ibuprofen.	The worst case scenario is defined as having severe acute otitis media and treatment failure which prolongs the duration of symptoms, requires the use of a different broad spectrum antibiotic, is accompanied by pain that cannot be controlled with Ibuprofen, and may cause hearing loss.

Paresthesias Secondary to Extravehicular Activity	The best case scenario is defined as having mild paresthesias or local pain from an EVA suit pressure point, with mild tingling, numbness, or pain, which resolve spontaneously.	The worst case scenario is defined as having moderate to severe numbness and or localized pain from an EVA suit hot-spot that may require treatment with analgesics and or steroids.
Nephrolithiasis	Best case scenario is defined as a renal stone that responds to conservative treatment (e.g. analgesics and hydration)	Worst case scenario is defined as a renal stone that does not respond to conservative treatment (e.g. requires lithotripsy or surgical treatment)
Seizures	Best case is defined as a seizure that responds to drug therapy and does not recur.	Worst case is defined as a seizure that does not respond to initial drug therapy and/or recurs.
Anaphylaxis	The best case scenario is defined as an anaphylactic event involving a reaction of the respiratory or cardiovascular systems that responds to initial treatment with epinephrine.	The worst case scenario is defined as an anaphylactic event involving a reaction of the respiratory or cardiovascular systems that does not respond to initial treatment with epinephrine.
Cardiogenic Shock secondary to Myocardial Infarction	Best case scenario describes a crewmember suffering mild cardiogenic shock exhibiting low blood pressures and some minor signs of poor perfusion. The crewmember recovers with minimal interventions.	Worst case scenario is defined as crewmember suffering severe cardiogenic shock. The crewmember suffers altered state of conscious to unconsciousness and exhibits low blood pressure, cyanosis and oliguria. The crewmember is unlikely to survive without significant invasive treatment such as revascularization, intra-aortic balloon pump and appropriate vasopressor and inotropic agents.

Traumatic Hypovolemic Shock	Best Case Scenario: The best case scenario is defined as a crewmember who becomes hypovolemic following a traumatic injury and responds to fluid resuscitation.	Worst Case Scenario: The worst case scenario is defined as a crewmember who goes into hypovolemic shock following a traumatic injury, does not respond to treatment and is experiencing multi-organ failure resulting from the inadequate circulating volume and poor perfusion.
Neurogenic Shock	The best case scenario is defined as mild neurogenic shock that responds to treatment.	The worst case scenario is defined as moderate to severe neurogenic shock that does not respond to treatment, and may result in significant impairment or loss of crew life.
Sepsis	The best case scenario is defined as sepsis, (SIRS and source of infection) without organ dysfunction or hypotension, which responds to the available antibiotic treatment.	The worst case scenario is defined as a case of severe sepsis, involving organ dysfunction or a prolonged course of septic illness with poor response to available antibiotic treatment.
Acute Sinusitis	Best case is defined as uncomplicated viral or bacterial rhinosinusitis that responds to initial treatment.	The worst case scenario is defined as a moderate or severe skin infection that could require oral, intramuscular, or intravenous antibiotics, or could be refractory to treatment.
Skin Infection	The best case scenario is defined as a mild skin infection, bacterial or fungal, that resolves without treatment or minimal treatment with topical or oral antibiotics.	The worst case scenario is defined as a moderate or severe skin infection that could require oral, intramuscular, or intravenous antibiotics, or could be refractory to treatment.
Skin Rash	The best case scenario is defined as mild to moderate and uncomplicated skin rash that responds to treatment.	The worst case scenario is defined as a moderate to severe skin rash, covering an extensive area and that might be refractory to treatment.
Medication Overdose/Adverse Reaction	Best case is defined as a sedative or opioid medication overdose that resolves within 8 hours and does not require treatment.	Worst case is defined as a sedative or opioid medication overdose that requires more than 8 hours to resolve and/or requires treatment.
Smoke Inhalation	The best case scenario is defined a small fire with minimal smoke and the crewmember is conscious, with no breathing difficulty.	The worst case scenario is defined as the crewmember having difficulty breathing or is unconscious and not breathing.

Space Motion Sickness (space adaptation)	Best case scenario definition : SMS including mild to moderate symptoms, e.g. loss of appetite, malaise, stomach awareness, 2 or fewer episodes of emesis, resolves within 72 hours, no or minimal performance decrement.	Worst Case scenario definition: SMS with severe and persistent symptoms, need to keep head from moving, greater than 2 episodes of emesis, significant performance decrement, persists for greater than 72 hours.
Ankle Sprain/Strain	The best case scenario is defined as a mild sprain/strain that will resolve in 2-4 weeks with minimal or no treatment.	The worst case scenario involves a moderate or severe sprain/strain that does not resolve in 2-4 weeks.
Elbow Sprain/Strain	Best case scenario is defined as a mild sprain/strain that will resolve with minimal or no treatment.	Worst case scenario involves a moderate or severe sprain/strain that could result in a ligament, tendon or muscle tear.
Hip Sprain/Strain	The best case scenario is defined as a mild hip sprain or strain that involves minimal or no treatment.	The worst case scenario involves a moderate or severe sprain or strain that could result in a ligament, tendon or muscle tear.
Knee Sprain/Strain	Best case scenario would involve minor knee pain with minimal analgesic needed for discomfort.	Worst case scenario is an injury that does not resolve with conservative treatment and/or may involve significant tearing of the ligament, tendon or cartilage. The crew member would likely require considerable pain management.
Shoulder Sprain/Strain	Best case scenario is defined as a mild sprain/strain that will resolve with minimal or no treatment.	Worst case scenario involves a moderate or severe sprain/strain that could result in a ligament, tendon or muscle tear.
Wrist Sprain/Strain	Best case scenario is defined as a mild sprain/strain that will resolve with minimal or no treatment.	Worst case scenario involves a moderate or severe sprain/strain that could result in a ligament, tendon or muscle tear.
Stroke (cerebrovascular accident)	The best case scenario is defined as a transient ischemic attack (TIA) with no permanent neurologic impairment.	The worst case scenario is defined as a stroke that causes significant impairment or loss of crew life.
Sudden Cardiac Arrest	The best case scenario is defined as a crew member who experiences a sudden cardiac arrest and responds to the ACLS treatment protocol.	The worst case scenario is defined as a crew member who experiences sudden cardiac arrest and does not respond to the ACLS treatment protocol.
Dental: Filling Loss	The best case scenario is the loss of a filling without any pain and can wait until return to earth.	The worst case scenario is loss of a filling which requires pain management with analgesics and/or temporary filling. A cracked tooth without exposed pulp is also included in this scenario.

Dental: Avulsion (Tooth Loss)	The best case scenario is defined as avulsion due to trauma with mild pain and bleeding that is easily controlled.	The worst case scenario is defined as avulsion due to trauma, with moderate to severe pain that may require narcotic analgesics, and/or bleeding is prolonged beyond 20 minutes.
Toxic Exposure: Ammonia	The best case scenario describes, even though the probability is 0% based on ISS PRA Fire and Ammonia Module, a crewmember with mild exposure (ammonia inhalation) that resolves without treatment or is easily treated. The crewmember can resume their duties with no threat to the mission.	The worst case scenario is defined as a significant exposure (Ammonia inhalation), which may result in acute respiratory failure or other significant end-organ dysfunction.
Urinary Incontinence (space adaptation)	The best case scenario is defined as having an uncomplicated course of urinary incontinence which resolves by itself or causes minimal discomfort.	The worst case scenario is defined as having a moderate to severe course of urinary incontinence.
Urinary Retention (space adaptation)	The best case scenario is defined as urinary retention that resolves spontaneously or requires straight catheterization.	The worst case scenario is defined as urinary retention that requires repeated straight catheterization or indwelling catheter. Extended retention puts the crew member at risk for urinary tract infection, which is addressed in the Urinary Tract Infection CliFF. Retention may be caused by urethral stricture, thus preventing the insertion of the catheter and this will require evacuation of the crew member.
Urinary Tract Infection	The best case scenario is Urinary Tract Infection (UTI) with mild symptoms and responds to first line antibiotics.	The worst case scenario is UTI with moderate to severe symptoms, requiring second line antibiotics.
Vaginal Yeast Infection	The best case scenario is defined as uncomplicated vulvovaginal candidiasis (VVC), with mild to moderate, sporadic, or infrequent vulvar irritation, including itching and discomfort of the vulvar skin and vaginal epithelium, vaginal discharge, and discomfort with voiding which responds to all azole treatment regimens including short (3-day) and single-dose oral and vaginal therapy.	The worst case scenario is defined as complicated, severe or recurrent vulvovaginal candidiasis. (RVVC) treated with oral dose of Fluconazole every third day for a total of 3 doses (day 1, 4, 7).

Skin Abrasion	The abrasion best case scenario is defined as skin scrapes that do not fully penetrate the epidermis or the rubbing or scraping of the surface layer of cells or tissue from an area of the skin or mucous membrane. Minor cuts requiring cleaning and Band-Aids are also included in this scenario, as listed in the ISS medical checklist wound care procedures.	The worst case scenario is defined as abrasions covering an extensive area, requiring a dressing, topical antibiotic treatment, and mild non-prescription analgesics. Abrasions are evaluated, cleansed, and debrided similarly to lacerations. After thoroughly removing all debris, antibiotic ointment (e.g., bacitracin) and a non-adherent gauze dressing can be applied. Other wound dressings may be used to keep the wound from drying out, as this interferes with re-epithelialization, and to keep the dressing from adhering.
Skin Laceration	The best case scenario is defined as a laceration that requires skin adhesive or dressing for repair.	The worst case scenario is defined as a laceration requiring sutures or staples for repair.
Dental: Abscess	The best case scenario is an abscess that responds to treatment with pain medication and antibiotics.	The worst case scenario is defined as an abscess that does not respond to oral treatment or topical anesthetic and requires extraction. The development of sepsis secondary to necrosis is addressed in the Sepsis CliFF.
Dental Caries	The best case scenario is asymptomatic or simple caries. Response to a hot or cold stimulus may result in mild non-lingering pain that resolves when stimuli are removed.	The worst case scenario is defined as symptomatic or simple caries that requires oral analgesics.
Acute Cholecystitis/Biliary Colic	The best case scenario is s defined as a course of uncomplicated biliary colic which resolves spontaneously or causes minimal disturbance requiring only symptomatic pain management.	The worst case scenario is defined as acute cholecystitis with likely complications requiring significant pain management, antibiotic administration and likely definitive surgical management.
Headache (Late)	The best case scenario is defined as having an uncomplicated course of a tension type headache, which resolves spontaneously or with minor symptomatic treatment. Late headache includes headaches occurring on or after the 6th flight day.	The worst case scenario is defined as a moderate or severe headache poorly responsive to available treatment.
Hypertension	Best case scenario is defined as Hypertension Stage 1, i.e. Systolic 140-159 and/or Diastolic 90-99 mmHg.	Worst case scenario is defined as Hypertension Stage 2, i.e. Systolic 160 or higher and/or Diastolic 100 mmHg or higher.

Visual Impairment and/or Increased Intracranial Pressure (VIIP)(space adaptation)	The best case scenario is visual acuity changes and/or papilledema grades 0-2.	The worst case scenario is visual acuity changes and papilledema grades 3 or above.
Small Bowel Obstruction	The best case scenario is defined as an uncomplicated course of small bowel obstruction which responds to conservative medical treatment (antibiotics and symptomatic treatment) and involves relatively minor functional impairment.	The worst case scenario is defined as having a complicated course of small bowel obstruction that is not responsive to conservative treatment and involves significant systemic symptoms, such as severe pain, such as fever, leukocytosis, tachycardia, elevated BUN, serum amylase or alkaline phosphatase, metabolic acidosis and a major functional impairment.
Lower Extremity (LE) Stress Fracture	The best case scenario is defined as a Grade 1 to 3 stress fracture, which causes mild to moderate symptoms and does not require casting or surgical treatment.	The worst case scenario is defined as a Grade 4 stress fracture, which causes moderate to severe symptoms and requires casting or surgical treatment.
Influenza	The best case scenario is defined as a mild case of influenza lasting 48 to 72 hours.	The worst case scenario is defined as a moderate to severe case of influenza that lasts 72 hours or longer.
Abnormal Uterine Bleeding	The best case scenario is defined as a mild or moderate abnormal uterine bleeding, requiring only minimal treatment.	The worst case scenario is defined as severe abnormal uterine bleeding which does not respond to treatment and may require surgical management
Acute Arthritis	The best case scenario is defined as non-septic arthritis with mild to moderate symptoms that responds to treatment.	The worst case scenario is defined as septic arthritis requiring antibiotic treatment and with severe symptoms requiring prolonged treatment.
Acute Compartment Syndrome	The best case scenario is defined as compartment syndrome diagnosed less than 1 hour after onset. This scenario is more likely to result in normal limb function after fasciotomy.	The worst case scenario is defined as compartment syndrome diagnosed more than 1 hour after onset. This scenario is more likely to result in abnormalities in limb function after fasciotomy.

Acute Pancreatitis	The best case scenario is defined as a course of an uncomplicated acute pancreatitis which resolves with minimal intervention. Such cases require the patient not be fed and kept NPO (NPO, meaning nothing by mouth). Additional needs include IV fluid hydration and minimal pain management medications; possibly anti-emetics.	The worst case scenario is defined as a complicated acute pancreatitis with severe systemic manifestations (i.e. hemodynamic instability, acute respiratory distress syndrome, acute renal failure, necrotizing pancreatitis, acute cholecystitis). Depending upon the manifestation, multiple resources will be required starting with significant pain management and aggressive IV hydration, and may warrant advanced respiratory support, IV antibiotics, parenteral nutrition, and potentially definitive surgical management.
Acute Diverticulitis	The best case scenario is defined as an uncomplicated case of diverticulitis that is self-limited or responds to available non-surgical treatment.	The worst case scenario is defined as a complicated case of diverticulitis, which may require surgical intervention.
Hearing Loss	The best case scenario is defined as a Mission Significant Threshold Shift (M-STS) that resolves spontaneously after 24-48 hours of avoiding noise exposure.	The worst case scenario is defined as an M-STS that persists after 24-48 hours of avoiding noise exposure.
Retinal Detachment	Best Case Definition: A detached retina without involvement of the macula (central vision and visual acuity are preserved).	Worst Case Definition: A detached retina with involvement of the macula (central vision and visual acuity may be severely reduced).
Abdominal Wall Hernia	Best Case Definition: Asymptomatic or mildly symptomatic hernia not requiring surgery.	Worst Case Definition: Hernia requiring either emergent surgery due to complications, or non-emergent surgery due to severity of symptoms.
Eye Chemical Burn	Best case scenario is a mild eyelid burn or an ocular burn which does not affect vision.	Worst case scenario is defined as a moderate or severe burn that causes corneal scarring or ulceration, or intraocular pressure changes. Treatment for the initial phase may be given on board but this scenario may require surgical debridement, lens implant and other treatments that require surgical care by an ophthalmologist.

Appendix B: Medical Conditions, Scoring, and Intent to Treat – Mars Transit DRM

Representative examples of medical conditions are shown, sorted by Exclusion Score. For full list, please contact ExMC Element Scientist.

Medical Condition	Case	Probability S-20170306-376	Futility	Complexity	Exclusion Score	Plan to Treat	Rationale / Conditions / Comments
TOXIC EXPOSURE (AMMONIA)	Best	0	0.1	1	N/A	Yes, with conditions	Initial ABC treatment only, supportive care
ANAPHYLAXIS	Worst	1.30762E-05	1	1	7.65E+04	No	All anaphylaxis will be approached as Best Case until there is treatment failure.
SUDDEN CARDIAC ARREST	Best	3.57632E-05	1	1	2.80E+04	Yes, with conditions	Limited to bag valve mask ventilation, chest compressions, use of automated external defibrillator, Intraosseous device insertion and epinephrine; treatment lasting <45 minutes
ACUTE ANGLE-CLOSURE GLAUCOMA	Worst	4.46883E-05	1	1	2.24E+04	No	
ACUTE PROSTATITIS	Best	0.01213786	0.1	0.01	8.24E-02	Yes	
LOWER EXTREMITY (LE) STRESS FRACTURE	Worst	0.029007037	0.01	0.1	3.45E-02	Yes	Treatment is limited to supportive care (immobilization, pain meds, etc.),
SMALL BOWEL OBSTRUCTION	Best	0.005582118	0.01	0.01	1.79E-02	Yes	
RESPIRATORY INFECTION	Best	0.983416095	0.01	0.01	1.02E-04	Yes	
SKIN RASH	Best	0.994999989	0.01	0.01	1.01E-04	Yes	

Appendix C: Medical Conditions, Scoring, and Intent to Treat – Cis-Lunar DRM Examples

Representative examples of medical conditions are shown, sorted by Exclusion Score. For full list, please contact ExMC Element Scientist.

Medical_Condition	Best / Worst	Prob_one_or_more S-20170623-384	Futility	Complexity	Exclusion score	Plan to Treat	Characterization of Plan
ANAPHYLAXIS	Worst	1.13E-06	1	1	8.86E+05	Plan to Treat with Conditions	Treat to best case only
NEUROGENIC SHOCK	Worst	1.20E-06	1	1	8.33E+05	Plan to Treat with Conditions	Diagnosis and treatment limited to what is provided for best case only then consider medical evac and/or palliative care
CARDIOGENIC SHOCK SECONDARY TO MYOCARDIAL INFARCTION	Worst	3.00E-06	1	1	3.34E+05	Do Not Plan to Treat	Diagnosis will include interview, physical exam, 12 lead electrocardiogram (ECG), continuous ECG rhythm monitoring and ultrasound (cardiac and lung)
ACUTE RADIATION SYNDROME	Worst	6.03E-06	1	1	1.66E+05	Plan to Treat with Conditions	Treat to best case only, consider medical evac
DENTAL CROWN LOSS	Worst	9.53E-05	0.01	0.01	1.05E+00	Plan to Treat	Diagnosis includes interview and physical exam. Treatment includes dietary adjustment and dental adhesives.
SEIZURES	Best	1.07E-04	0.01	0.01	9.36E-01	Plan to Treat with Conditions	Treatment limited to supportive care to promote open airway, patient safety and medications to control seizing; consider medical evac
EYE CORNEAL ULCER	Best	1.93E-04	0.01	0.01	5.19E-01	Plan to Treat	Diagnosis includes interview, physical exam and eye exams using fluorescein and topical anesthetics. Treatment includes pain medications, antibiotics, eye lubricants and possibly steroids

KNEE SPRAIN/STRAIN	Best	1.12E-01	0.01	0.01	8.90E-04	Plan to Treat	Diagnosis will include interview and physical exam; Treatment will be limited to pain medications and muscle relaxers, splinting, topical temperature therapy and exercise regimen adjustment
SPACE MOTION SICKNESS (SPACE ADAPTATION)	Best	8.46E-01	0.01	0.01	1.18E-04	Plan to Treat	Diagnosis includes interview and physical exam Treatment includes dietary adjustment, oral fluids, antiemetics

Appendix D: Examples of Disagreement for Condition Ranking

Issue: Disagreement between providers of different backgrounds
Example: Compartment Syndrome
Some providers felt that fasciotomy and wound care was a reasonable treatment option in a best-case scenario. However, final consensus was that this condition would be untreatable, given the limited quantities of onboard resources for wound management and the need for the prolonged management of an open wound after fasciotomy. (Again, this should not be interpreted to mean that a compartment syndrome would not prompt any attempt to manage; rather, that addition of significant volume of wound care materials (such as wet-to-dry capabilities requiring gauze, sterile fluid and dressings, petrolatum dressings, etc.) specifically included for the management of the unlikely scenario of a compartment syndrome was not indicated.)

Issue: Disagreement based upon inclusion/exclusion of specific resources
Example: Acute pancreatitis
Some providers felt that dedicated capabilities should be included for the management of this condition; however, others identified concern over the volume or quantity of onboard supplies that could be required. In the case of bowel rest and parenteral hydration, limited resources may not be sufficient for successful management; some providers argued for inclusion of increased resource volume to ensure successful management while others indicated that treatment would be attempted until resources were exhausted (a "plan to treat, with conditions" designation). Final consensus was to identify this condition as "plan to treat, with conditions" given the likelihood of vehicle volume limitations on medical capabilities in exploration missions.

Issue: Complex medical condition
Example: Cardiogenic Shock Secondary to Myocardial Infarction (MI)
Management of cardiogenic shock after MI requires prolonged, complex care and, most often, interventional procedures ranging from cardiac catheterization to open heart surgery, even in best-case scenarios. These resources will be unavailable during exploration flight. Recognizing the complexity of management, some providers felt that a "will not treat" designation was warranted (again, interpreted as management limited to resources available for other medical conditions, without specific resources included in a medical capability *dedicated* to the management of acute MI with cardiogenic shock). Others felt that a "treat, with conditions" designation was warranted, given the likelihood that some degree of treatment would be attempted; others felt that a "will treat" designation was warranted for a best-case scenario, with inclusion of capabilities such as vasopressor medications (epinephrine, norepinephrine) to manage the most responsive scenario imaginable (where treatment leads to rapid clinical improvement, within reason). The final list designates best-case Cardiogenic Shock as a "will treat" scenario; however, a consensus on designation was not reached among providers queried.