Hearing Loss Cliff

Branch Baseline

In the United States, a person is considered to be totally deaf when speech sounds cannot be heard at intensities less than 82 Sound Pressure Level (dB_{SPL}) (the intensity of ordinary speech is around 60 dB_{SPL}). The term hearing impairment, a more inclusive term, refers to any loss in auditory sensitivity relative to the hearing ability of the normal young adult (Blake, 2005)

Hearing impairments can be classified in two categories: conduction and sensorineural loss. Conduction loss can be caused by ear wax, middle ear infection, and/or otosclerosis. Damage to the cochlea or the auditory nerve causes sensorineural loss. Aging and noise exposure may cause sensorineural loss. (Blake, 2005)

The sound frequency or pitch is measured in hertz (Hz), cycles per second. A person with normal hearing range can hear sounds that have frequencies between 20 and 20,000 Hz. The most important sounds we hear every day are in the 250 to 6,000 Hz range. Sound intensity, amplitude or loudness, values are measured in decibels (dB). A person with hearing within the normal range can hear sounds ranging from 0 to 140 dB Sounds that are 120 dB or louder can be painful and can result in temporary or permanent hearing loss. (Centers for Disease Control and Prevention (CDC), 2012)

On the audiogram, these normal thresholds are represented as 0 dB hearing level (HL). The individual's thresholds are plotted, usually in 5-dB increments, as their HL; that is, the HL is the difference between their measured threshold and the normal threshold. Hearing thresholds may be both positive and negative, since a particular individual may be more or less sensitive than the general population at a given frequency. Hearing loss is generally defined by thresholds that are greater than about 25 dB HL, with normal hearing ranging from -10 dB HL to 25 dB HL. (Runco, 2010)

Crewmembers' hearing sensitivity is conventionally monitored with air-conduction, pure-tone audiometry during annual flight physical examinations, which allows comparisons of the results to their initial NASA audiometric test or baseline audiogram. When crewmembers are assigned to space missions, they also receive additional pre-flight and post flight audiometric testing, which is intended to better isolate the effects of the mission on hearing. (Garcia, 2012)

In audiometry, a hearing threshold is defined as the lowest hearing level at which the subject detects a pure-tone stimulus. Hearing thresholds are thus determined for each frequency and each ear. Because the psychophysical audiometric procedure does not use step sizes smaller than 5 dB, and the human ear typically cannot identify differences of less than 2-3 dB, test-retest variability of ±5 dB is considered clinically insignificant in conventional audiometry. In occupational hearing conservation programs, a *Significant Threshold Shift* (STS) is defined as a 10 dB shift or greater (when averaging 2k, 3k, and 4k Hz), seen in either ear when the annual audiogram is compared to the baseline audiogram. (Garcia, 2012)

Crew performance is critical to mission success. The effects of noise can compromise verbal communications and the ability to hear caution-and-warning alarms and monitor air-to-ground communications loops. Noisy environments require individuals to raise their voices, contributing to sore throats and hoarseness. High noise levels can cause headaches, irritation, stress, impaired sleep, fatigue, and tinnitus. Performance degradation depends on the noise intensity, variability, duration, intermittency, periodicity, and type of task. (Alford, 2012)

in summary, hearing impairment or hearing loss in this Clinical Findings Form refers to a Significant Threshold Shift (STS) that occurs during space flight.

Incidence Data Included in the Model

The model imports the following incidence information from the IMM database: incidence data category, space adaption status, incidence data, incidence and occurrence distribution data and incidence data characteristics. Data category defines the type of data available for incidence calculations (i.e. raw data vs. fixed data). Space adaptation identifies medical events that onset occurs in the first 5 days of flight and does not reoccur. Incidence values vary by data category and define the number of medical events per person-year or medical events per person-at-risk for each medical condition. Incidence values can be modified by crew characteristics such as gender. Modifying characteristics are noted below and incidence values are listed individually for each characteristic. Distributions are assigned to medical events incidence values and occurrences in the model. For each crew member in a given trial, the incidence and number of occurrences of each medical condition are randomly selected from these probability distributions. Detailed descriptions of the distributions are included in the IMM Technical Description Document.

Incidence	
Data Category:	Raw Data
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data

Incidence:	Gamma
Occurrence:	Poisson

Data Characteristics

Events:	4
Person Years:	33.48
Space Flight Incidence Rate (Events / Person Years):	4 / 33.48 = 0.1194743130227

Incidence Comments

A NASA-unique "Mission-related Significant Threshold Shift" (M-STS) is defined for the purposes of this analysis, as a 10 decibels (dB) shift or greater, when averaging 2k, 3k, and 4k Hertz (Hz), seen in either ear when the post flight audiogram is compared to the preflight audiogram.

In noise research, a threshold shift that's exhibited after noise exposure may be considered *temporary* (with greatest recovery within a day or

two after the exposure) or *permanent* (if the hearing loss persists for 30 days after the exposure). In order to better link a mission's effects on

resultant hearing loss, this review analyzes only data from those records in which audiometry was performed at least within 90 days preceding

launch (*on-or-after L-90*) and within 30 days after return (*before R+30*) (Garcia, 2012)

Crewmembers on long duration missions on the International Space Station (ISS) have typically received their preflight audiometric test between L-45 and L-60 (before leaving Houston, if their launch site is in Russia) and their post flight test by R+3. Crewmembers on short duration missions on the Space Shuttle Transport (STS) typically received their preflight audiometric test at L-10 and their post flight test at R+3. Some crewmembers on long duration missions, if transported to/from ISS on the Shuttle were also tested at L-10 and/or R+3. In this analysis, audiograms designated to provide "preflight" and "post flight" data came from the hearing test most near the launch date (on-or-after L-90) and return date (on-or-before R+30), as noted above. Tests missing data at 2k, 3k, or 4k Hz were deleted and considered incomplete, and the next chronological test was used. Additionally, some individual astronauts have had both short and long duration missions, and multiple missions, which are not taken into account in this analysis, unless otherwise noted (Garcia, 2012)

One hundred fifty (n=150) astronauts had complete data, 122 males and 28 females. Twenty four long-duration astronauts had no incidence of M-STS. Of the one hundred twenty six short duration astronauts, 3 had M-STS (2.38%), all males. When all astronauts with a long duration mission were excluded from the short duration category, there were 24 long duration and 114 short duration crew members. 3 of the short duration crew members had M-STS (2.63%). Total person-years of space flight years was 15.25 (10.62 person-yrs for long duration and 4.63 person-yrs for short duration). Of the three incident cases of M-STS, only one was persistent, i.e. confirmed in follow up audiogram. The other two cases did not have a shift during follow up audiogram. M-STS was not identified among ISS crew members.

Based on three incident cases of M-STS, the overall **incidence** is 3 events/15.25 person-yrs = **0.20 events/person-year**. The incidence is

0.00 for long duration astronauts and 0.65 (3 events/4.63 person-years) for short duration M-STS per person-flight years. (Garcia, 2012)

For ISS crew members (n=34), flight years are 11.47, using the first on orbit test (OOHA) as baseline, 3 events occurred, all male. OOHA data was also extracted and reviewed from U.S. crewmembers' electronic medical records. Initially, during Expeditions 1-7, no preflight OOHA was performed before the mission, so the "baseline OOHA" was derived from first set of OOHA hearing thresholds that were recorded on orbit (n=6). Beginning with Expedition 8, a preflight OOHA has been obtained in the JSC Audiology Clinic before the mission and available for comparison with subsequent in-flight OOHA results, (n=28). On orbit M-STS do not appear to persist for ISS crew-members. Incidence is 0.26 M-STS per person flight-years. (Garcia, 2012). These data will not go into the model.

This analysis suggests that the incidence of Mission-related Significant Threshold Shifts (M-STS's) among U.S. crewmembers in 2002-2011 is below 1 per person flight year, with long-duration crewmembers demonstrating very few M-STS's during in-flight OOHA's and none in post flight audiometry. While such small numbers of long-duration crewmembers limit the assessment of the statistical significance of these data, it appears that the potential risk of permanent hearing loss to long-duration crewmembers is minimal (Garcia, 2012).

One monaural case is documented in our In-flight Compilation (Walton, 2010). It is a self-reported hearing loss that occurred on ISS flight day 139, in a male crewmember, etiology noisy environment. Duration or audiometry measurements are not recorded. Lacking objective measurements IMM has not counted it as an in-flight event.

Updated incidence data based on RWS missions time frames based updated M-STS (Saile, 2017)

The integrated person years changed person years changed from 33.52 to 33.48 based on the M-STS for the RWS incidence integration (Saile L., 2017)

Information Regarding Prevention

Selection criteria

Disqualifying conditions include: Any diseases of the ear or mastoid that interfere with the auditory or vestibular functions sufficient to interfere with performance of duties; congenital deformation of the external meatus or canal severe enough to interfere with hearing or performance of duties; tumors of the external auditory canal unless benign and surgically removed. Small exostoses are not disqualifying. Also chronic external otitis, mastoiditis or mastoid fistula; otitis media, suppurative or serous; persistent perforation of the tympanic membrane; history of stapedectomy; history of radical or modified radical mastoidectomy; history or presence of abnormal labyrinthine function, unless an isolated, remote episode with full recovery (e.g., vestibular neuronitis). history or presence of Meniere's disease; chronic inability to equalize the pressure of the middle ear (valsalva's maneuver); tinnitus that interferes with hearing or communication (International Space Station Program, 2011)

Hearing standards for selection, on each ear are audiometric thresholds of no worse than 30 decibels hearing level (dB HL) at 500 Hz, 25 dB HL at 1000 Hz, 25 dB HL at 2000 Hz, 35 dB HL at 3000 Hz, and 50 dB HL at 4000 Hz, (International Space Station Program, 2011)

Vehicle requirements

Major contributors to shuttle noise included circulating fans within the environmental control and life support systems, refrigerators, and exercise equipment operations. Acoustic dosimetry measurements on STS-40 revealed peak back ground levels of 72.6 dBA, with a maximum of 80 to 85 dBA during ergometer operations.(Dalton, 1995)

ISS Acoustic Flight Rule B13 152. Currently based on 24 hr noise exposure level (Leq24). Requires use of hearing protection when 24 hour noise dosimetry exceeds 66 dBA. The Multilateral Medical Operations Panel (MMOP) Acoustics subgroup has proposed a change on this Rule. (Danielson, 2011)

Other

In addition to conventional pre-flight and post flight audiometric tests, done in a clinic's audiometric booth, NASA also monitors each ISS crewmember's hearing on board the ISS, with an **On-Orbit Hearing Assessment** (OOHA). The OOHA is done during the actual ISS mission,

using software on a computer that presents pure-tone stimuli via the computer's sound card and custom-made silicone ear monitors. Tests are done approximately every 45 days, and (when reviewed by medical personnel) can reveal temporary changes in hearing sensitivity that may be an early flag for hearing loss, prompting crew surgeons and audiologist to recommend increased use of hearing protection during the mission. (Garcia, 2012)

Incidence Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
Saile, 2017	2	Incidence
Saile L., 2017	1	Incidence

Incidence data not included in the model

The model pulls the incidence information from the IMM database ... the information shown below does not go into the model.

Incidence	
Data Category:	In-flight
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Gamma
Occurrence:	Poisson

Data Characteristics	
Events:	3
Person Years:	15.25
Space Flight Incidence Rate (Events / Person Years):	3 / 15.25 = 0.19672131147541

Incidence Comments

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Incidence Level of Evidence (LOE)

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Citation	LOE Value	LOE Category
Garcia, 2012	1	Incidence

Alternative Incidence Data

Analog Populations

Several authors (Davis, 2008); (Williams, 2011); (Clark, 2007) have reported sudden hearing loss in the astronaut corps. However, the JSC audiologist has reviewed the crewmember medical records and found no instances of “sudden deafness” among U.S. crewmembers during spaceflight, or that could be attributed to spaceflight after the mission. (Garcia, 2012)

A report by the Army Institute of Public Health (AIPH) and the Armed Forces Health Surveillance Center (AFHSC) summarizes medical encounters of U.S. service members(Army, Navy, Air Force or Marine Corps) that were documented with Noise Induced Hearing Injury (NIHI) indicator ICD-9-CM diagnosis codes during calendar years 2007 through 2010. The population included all individuals who served in an active component any time during the surveillance period. Incidence rates were calculated as incident injuries per 1,000 person-years of active component military service. During the four-year surveillance period, 2007-2010, the most frequently diagnosed indicators of noise-induced hearing Injuries in the U.S. Armed Forces were tinnitus, sensorineural hearing loss, and Significant threshold shift (STS). Annual incidence rates in 2010, per 1,000 person-years of active component military service, were 0.0314 (31.4) for the 35-39 cohort and 0.0626 (62.6/1000) for the 40+ cohort. Rates by gender are not stratified by age and were higher for male 0.0273 (27.3/1000) than female 0.0151 (15.1/1000). Rates by occupation among officers ranged from 0.0214 (21.4/1000) for Intelligence to 0.0504 (50.4/1000) for General, Flag rank and Executives. Numbers and rates of noise-induced hearing loss steadily declined from 2007 through 2010; there were approximately 40 percent fewer cases in 2010 (n=2,424) than in 2007 (n=4,113) (Helfer, 2011). These rates are lower than the astronaut population.

Air Force: Query of the Aeromedical Information Management and Waiver Tracking System (AIMWTS) database showed 20 cases of hearing aid usage and all but one were granted a waiver; this person was a pilot training applicant. During the same time period there were 1,977 waivers for some degree of hearing loss; 172 were disqualified (8.7%). Of the 172 disqualified, 105 were reviewed. Of the 105, 79 (75%) were disqualified for the hearing loss and 26 (25%) were disqualified for other medical conditions (TIA, stroke, Meniere’s disease, coronary artery disease, diabetes mellitus, back pain, psych, etc.). Of the 79 disqualified for hearing loss, the majority (~ 95%) were due to non H-1 hearing (H-3>>H-2). (American Society of Aerospace Medicine Specialists, 2011)

Army: The Aeromedical Epidemiological Data Repository (AEDR) catalogs all Army flight physicals since 1960. There have been approximately 160,000 individual aircrew entered in this database. During this period of time, there were 530 requests for waiver among pilot applicants. Of those 354 were granted an exception to policy and retained. During the same period there were 607 aeromedical summaries for rated aviators were submitted, for which 553 waivers were granted. Additionally, there were 477 requests for waiver in non-rated aircrew; 413 were granted waivers and retained in aviation. (American Society of Aerospace Medicine Specialists, 2011)

Comparison of Analog vs. non-analog population

Periodic medical examinations of pilots have revealed threshold shifts. A study investigated the risk of noise induced hearing loss (NIHL) among the Finnish Air Force pilots using the NoiseScan model based on noise exposure data and other risk factors. The population consisted of 274 pilots, average age 31, and range 20-51. The study also compared NIHL to the prediction of the International Organization for Standardization (ISO) 1999 model for industrial workers. The industrial workers had a larger number of risk factors than the pilots. Owing to the small number of risk factors, the hearing of pilots corresponds to approximately the 80th percentile, being 9–13 dB better than the 50th percentile obtained with the industrial population. (Kuronen, 2004)

Treatment and Outcomes

Based on the best evidence available best and worst case percentage ranges are assigned. The medical condition is divided into three clinical phases in all three clinical phases a functional impairment is assigned. The clinical phase I and II's functional impairments remain for the duration for that respective clinical phase. The function impairment in clinical phase III represents final impairment for this medical condition and remains for the rest of the mission. Other mission end states include evacuation and loss of crew life.

The IMM checks medical resource availability once the number of medical events and scenarios has been established. If there is not sufficient essential resources called out in the CliFF, then the medical condition will go down an untreated best or worst case scenario pathway.

The table below summarizes the treated and untreated best and worst case scenarios.

	Clinical Phase I Diagnosis & Initial Treatment[1]		**Clinical Phase II On-going Treatment / Convalescence[2]**		**Clinical Phase III Recovered / Mission End State[3]**		
	FI* (%)	**Duration (hrs)**	**FI* (%)**	**Duration (hrs) (Min - ML - Max)**	**FI* (%)**	**EVAC** (%)**	**LOCL** (%)**
ISS-based Treatment (best case scenario %: 60 - 80)	100	0.25 - 0.5	0 - 9	24 - 36 - 48	0	0	0
ISS-based Treatment (worst case scenario %: 20 - 40)	100	0.25 - 0.5	1 - 17	24 - 36 - 48	1 - 9	0	0
Untreated Best Case	N/A	N/A	0 - 9	24 - 36 - 48	0	0	0
Untreated Worst Case	N/A	N/A	1 - 17	24 - 36 - 48	1 - 9	0	0

[1]Clinical Phase I: Clinical phase I covers only the initial assessment of the affected crew member to define his or her medical condition, and completion of appropriate initial treatment to stabilize the crew member. While the affected crew member is being assessed, he or she is not able to perform any assigned tasks, thus Functional Impairment during this phase is considered 100%. In the untreated case, there is no diagnosis performed or treatment given, therefore Functional Impairment and Duration will always be "not applicable".

[2]Clinical Phase II: On-going Treatment and Convalescence- During clinical phase II, the affected crew member is receiving any appropriate follow-on treatment for his or her medical condition to allow the crew member to recover as much as he or she is able to recover in the ISS environment. Clinical phase II also encompasses relapses or reoccurrences of the same original medical condition in clinical phase I necessitating additional treatment or recovery time due to unsuccessful primary treatment response. The duration in Clinical Phase II is expressed in minimum, most likely (ML) and maximum hours. This was updated for future capabilities in IMM but is currently not being used by the model.

[3]Clinical Phase III: Recovered/Mission End State- Clinical phase III is reached once the affected crew member has recovered from the medical condition as much as he or she is able to recover in the ISS environment. This may or may not be recovery from the given medical condition to the full extent possible. If this "recovered" state results in an evacuation or loss of the crew member, this will be noted in the mission end state results.

*Functional Impairment (FI) is a measure of the affected crew member's health and performance ability.

**Two mission end state results are addressed in the CliFF: 1) Evacuation (EVAC) - crew and patient are evacuated from the spacecraft due to the medical condition, and 2) Loss of crew (LOCL) - death of affected crew member due to medical condition. EVAC is considered as 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. Probability distributions are assigned for each range of values within the Table of Treatments and Outcomes.

Refer to the Integrated Medical Model Technical Document for more information on how risk is reported by the IMM, Crew Health Index (CHI) and Quality Adjusted Mission Time calculations.

Definition and Probability of Best and Worst Case Scenario: (includes definitions of best and worst case scenarios and identifies the probability of those scenarios.)

Scenario Comments

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 a M-STS that persists after 24-48 hours of avoiding noise exposure.

Percentages of how often best versus worst case scenarios occur were determined using in-flight data. Based on the Real World Systems data there were no worst cases so to integrate this data and current iMED data into the BC/WC percentage the algorithm developed with the original data set was used for all the medical events in both data sets. Therefore, if the next case is a worst case we would 2/5 or 40% of cases as worst cases. If the next case is best case, we would have 4/5 or 8%. Thus the percentage for worst case is 20-40% (Saile L., 2017)

Best Case Comments

Mission Significant Threshold Shifts (M-STS) do not constitute disability to perform activities of daily living (ADLs). However, crewmembers performing critical tasks may have significant work disability despite 0% binaural impairment. In order to quantify impairment hearing loss whole person impairment percentages on Table 11-3, page 254, (American Medical Association, 2008)were assigned to classes. Hearing Loss functional impairments (FI) calculation is based on the IMM mild non space adaptation template, except that treated and untreated scenarios are similar to reflect the lack of treatment on board. Furthermore, the worst case scenario may improve, but complete recovery is unlikely, hence for Clinical Phase III, the impairment represents, upper and lower limits of class 1. Refer to the CliFF Appendix for further information.

Clinical phase I: 0.25 to 0.5 hours of 100% functional impairment based on time required for initial evaluation and PMC.

Clinical phase II: 24 to 48 hours is the estimated time to recover from noise exposure. Functional impairment of 0% to 9 % based on the convalescence of mild M-STS, namely using hearing protection to avoid noise exposure.

Clinical Phase III: 0 percent final impairment is based on complete resolution of M-STS. This would be considered a Class I event, no mission impact (Johnston, 2008). Neither EVAC or LOCL is expected.

Worst Case Comments

Mission Significant Threshold Shifts (M-STS) do not constitute disability to perform activities of daily living (ADLs). However, crewmembers performing critical tasks may have significant work disability despite 0% binaural impairment. In order to quantify impairment, classes were assigned to hearing loss whole person impairment percentages on Table 11-3, page 254, (American Medical Association, 2008). Hearing Loss functional impairments (FI) calculation is based on the IMM mild non space adaptation template, except that treated and untreated scenarios are similar to reflect the lack of treatment on board. Furthermore, the worst case scenario may improve, but complete recovery is unlikely, hence for Clinical Phase III, the impairment represents, upper and lower limits of class 1. Refer to the CliFF Appendix for further information.

Clinical phase I: 0.25 to 0.5 hours of 100% functional impairment based on time required for initial evaluation and PMC.

Clinical phase II: 24 to 48 hours is the estimated time to recover from noise exposure. Functional impairment of 1% to 17 % is based on persistent M-STS.

Clinical Phase III: 1 to 9 percent final impairment is based on partial improvement or no resolution of M-STS. Hospitalization due to Significant Threshold Shift has never occurred among the astronaut corps. This would be considered a Class IIa event, manageable with the HMS and not likely to require evacuation or affect mission duration (Johnston, 2008). Neither EVAC or LOCL is expected.

Untreated Best Case Comments

Mission Significant Threshold Shifts (M-STS) do not constitute disability to perform activities of daily living (ADLs). However, crewmembers performing critical tasks may have significant work disability despite 0% binaural impairment. In order to quantify impairment, classes were assigned to hearing loss whole person impairment percentages on Table 11-3, page 254, (American Medical Association, 2008). Hearing Loss functional impairments (FI) calculation is based on the IMM mild non space adaptation template, except that treated and untreated scenarios are similar to reflect the lack of treatment on board. Furthermore, the worst case scenario may improve, but complete recovery is unlikely, hence for Clinical Phase III, the impairment represents, upper and lower limits of class 1. Refer to the CliFF Appendix for further information.

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Clinical Phase III: 0 percent final impairment is based on complete resolution of M-STS. Neither EVAC or LOCL is expected.

Untreated Worst Case Comments

Mission Significant Threshold Shifts (M-STS) do not constitute disability to perform activities of daily living (ADLs). However, crewmembers performing critical tasks may have significant work disability despite 0% binaural impairment. In order to quantify impairment, classes were assigned to hearing loss whole person impairment percentages on Table 11-3, page 254, (American Medical Association, 2008). Hearing Loss functional impairments (FI) calculation is based on the IMM mild non space adaptation template, except that treated and untreated scenarios are similar to reflect the lack of treatment on board. Furthermore, the worst case scenario may improve, but complete recovery is unlikely, hence for Clinical Phase III, the impairment represents, upper and lower limits of class 1. Refer to the CliFF Appendix for further information.

Clinical phase I: 0.25 to 0.5 hours of 100% functional impairment based on time required for initial evaluation and PMC.

Clinical phase II: 24 to 48 hours is the estimated time to recover from noise exposure. Functional impairment of 1% to 17 % is based on persistent M-STS, namely using hearing protection to avoid noise exposure.

Clinical Phase III: 1 to 9 percent final impairment is based on partial improvement or no resolution of M-STS. Hospitalization due to Significant Threshold Shift has never occurred among the astronaut corps. This would be considered a Class IIa event, manageable with the HMS and not likely to require evacuation or affect mission duration (Johnston, 2008). Neither EVAC or LOCL is expected.

Treatment and Options Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
American Medical Association, 2008	3	FI
Johnston, 2008	2	EVAC
Saile L., 2017	1	BCWC

Additional Comments

Searches were conducted in PubMed using the terms hearing loss, hearing impairment, noise induced hearing loss, and noise induced hearing injury.

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Disposable Otoscope Specula (regular, small)	2	10	90	Yes	No	Aural exams
Otoscope (Head, Handle, and USB cable)	1	1	1	No	Yes	Light source for nasal, oral, aural, and eye exams.

Resource Comments

The resource table data was derived from ISS Medical Check List (Mission Operations Directorate (MOD), 2011).

NASA also monitors each ISS crewmember's hearing on board the ISS, with an On-Orbit Hearing Assessment (OOHA). Tests are done approximately every 45 days (Garcia, 2012); thus, 4 during a 6 month mission. The use of Specula were estimated one per ear for the initial exam in the best case, and one per ear for the initial exam plus 4 more per ear for additional evaluations in the worst case.

Hearing protection is used prophylactically and there is no other treatment on board for Significant Threshold Shift.

The Department of Defense Hearing Conservation Program is similar to NASA's, and provides comparable STS measurements; e.g. a significant threshold shift (STS) constitutes a change in hearing threshold relative to the initial reference audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz, in either ear. (Department of Defense (DOD), 2010)

Required Resources Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
NASA Mission Operations Directorate (MOD), 2011	2	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	1.5
Functional Impairment	3
Best Case / Worst Case	1
EVAC / LOCL	2
Resources	2
QUALITY OF EVIDENCE	**1.9**

Description	Range
Excellent	1-2
Good	2.1-3
Fair	3.1-4
Poor	4.1-5

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