AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
PEER REVIEW OF INJURY PREVENTION AND REDUCTION RESEARCH TASK AREA
IMPULSE NOISE INJURY MODELS

November 9, 2010

Review Panel

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INTRODUCTION AND CHARGE TO THE PANEL

On behalf of the US Army Medical Research and Materiel Command (USAMRMC) and Military Operational Medicine Research Program (MOMRP), the American Institute of Biological Sciences (AIBS) convened a panel to conduct an independent scientific peer review of the MOMRP research program on a critical component of the "Protect the Warrior from Neurosensory Injury" task area. The review focused on a comparative analysis of four Impulse Noise Models. The review took place on November 9, 2010 at the Hilton Garden Inn, 7226 Corporate Court in Frederick, Maryland. The panel took into account the following factors in evaluating the merits of each of the competing predictive model of impulse noise injury:

- The scientific quality of the research including its objectives, hypotheses, rationale, methodological rigor, appropriateness of statistical analyses used, adherence to ethical principles of medical research, validity of the research results, and the logic of conclusions drawn from the research data.
- The value and quantity of the science information products, scientific and technical reports, peer-reviewed publications, research product transitions and other reportable outcomes of the research program.
- Deficiencies with the current impulse noise requirement of MIL-STD 1474D that need to be addressed.
- Whether any of the following models/approaches adequately address all of the current MIL-STD deficiencies: LAeq8, AHAAH Model, Chan Approach
- Whether models are sufficiently tested and proven for application.
- The specific deficiencies of the three proposed models.
- Research that needs to be conducted to address the identified deficiencies.
- The panel roster, list of attendees, agenda, and list of acronyms are provided as appendices.

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The panel concluded that there is widespread agreement that immediate action to protect the warfighter by replacing the inaccurate current standard model of impulse noise injury (MIL-STD 1474D) is necessary. The ideal model, in the unanimous view of the panel, will incorporate both damage risk criteria (DRC) and an equipment design standard and will include many aspects of auditory function not currently acknowledged, such as influence of the middle ear reflex. The Auditory Hazard Assessment Algorithm for the Human (AHAAH) model is the only one of the four considered that offers a framework for incorporating aspects of auditory function. However, it is not yet fully developed and verified. Thus, the AIBS panel recommends a blueprint for change that takes the various stages of readiness of competing models into account, with the eventual goal of adopting a standard based on the AHAAH approach.

It is recommended that the LAeq8 model replace the currently used MIL-STD 1474D until the AHAAH is fully vetted, at which time a modified AHAAH will become the final standard. The LAeq8 model will provide a smooth transition to a more meaningful standard as it is relatively easy to implement and should not perform more poorly than the AHAAH at this point in its development. Presently, the LAeq8 can handle multiple exposures to noise better than the AHAAH.

Before the AHAAH model is implemented, there are several critical areas in which research is needed in order to replace anecdotal reports with hard data. These include 1) influence of the middle ear reflex under various conditions; 2) a more quantitative understanding of middle ear function at high levels (linearities, non-linearities); 3) measures of the frequency- dependent performance of hearing protective devices (HPDs) at high levels; and 4) data to justify selection of a particular acoustic test fixture (physical model of the human head and torso) to use for testing HPDs. Also recommended prior to implementing the AHAAH is research to assure the validity of the assumption that summed squared upward displacements of the basilar membrane are the predominant indicator of damage to the auditory system. More research is also needed to determine how AHAAH manages the effects of multiple exposures. At present, only the greatest amount of projected displacement contributes to reported risk, and these peak values are summed across exposures. This approach is problematic because 1) summed displacements at all other basilar membrane locations are ignored, and 2) not all impulses can be expected to produce peak summed displacements at the same location on the basilar membrane, particularly when those impulses come from different sources. Finally, an optimal model should be able to manage simultaneous exposure to continuous and impulsive sources such as would be present on vehicle-mounted weapon systems.

The panel recommends that a well-qualified scientific team be formed to conduct a coordinated research effort with the aim of reducing redundancy and promoting efficient progress toward the goal of a final model. There is some concern that the focus and momentum of the research may be compromised by the departure of the driving force behind development of AHAAH (Dr. Price).

In addition, it is the panel's view that at present the correlation between model predictions and actual hearing damage is weak. Before any new model is adopted it will be important to establish the degree to which the model can predict actual damage in humans, and whether the nature of the damage predicted is actually the damage observed. Implicit in this regard is the recommendation that the applicability of data from animal studies (both chinchilla and cat) to humans be evaluated in detail. The panel recommends that the model predictions of human hearing loss (especially intersubject variability) be studied in at least two ways: 1) measuring noise levels (e.g., with an acoustic test fixture, or ATF) and trainee audiometry before and after exposure in existing live-fire reverberant training settings, such as are known to exist at Ft. Polk; 2) expanding the database of exposures and resulting hearing status obtained from warfighters returning from theater, such as has been published by Dr. Lynne Marshall. This could be accomplished by obtaining more complete audiometry and by conducting extensive verbal debriefings of returning warfighters.

The predictions of any viable model of potential damage due to impulse noise exposure must include the impact of hearing protection. It is unlikely that satisfactory methods for measuring high intensity in-the-ear-canal noise waveforms will be developed in the near future, so assessing the influence of ear protectors must be estimated through use of an ATF. Thus, the panel recommends a program of research with the aim of developing realistic models of hearing protector transfer functions that would be validated on ATFs. The emphasis should be on understanding and modeling the frequency-dependent attenuation (and phase shift) provided by hearing protectors so that a free-field noise impulse can be transformed to an ear-canal equivalent for input into the new standard model of risk.

The panel feels that reliance on measures of temporary threshold shift (TIS) and/or permanent threshold shift (PTS) is ill advised, given the results from studies of newer objective measures. It is recommended that all assessments of damage and/or risk be based not only on measures of TIS and/or PTS, but also on measures of otoacoustic emissions, including, but not limited to, distortion-product otoacoustic emissions. It is now widely believed that these measures are especially sensitive to outer hair cell damage and thus could offer some indication of pre-clinical hearing damage.

PRESENTATION SUMMARIES

Introductory Overview
COL Carl Castro, PhD

COL Castro provided an introductory overview covering the history of impulse noise criteria in the military. The current MIL-STD-1474D is generally thought to be too conservative for large-caliber weapon systems and there have been three major meetings to change the standard or replace it to better protect the warfighter. Compelling evidence is needed to change the standard for impulse noise injury, which in turn changes design standards for weapon development. There is a need to review predictive models of impulse noise injury so that the choice between models becomes clearer. To this end, the Command will evaluate two impulse noise models and one approach, as well as the current standard for impulse noise injury. Recommended changes to the risk criteria standard should take place within the context of providing the best possible protection and conditions for service members.

MIL-STD 1474D
Mr. Chuck Jokel, USAPHC

Mr. Jokel provided a historical perspective and description of the present-day tool for performing health hazard assessment of impulse noises. Graphic depictions of MIL-STD 1474D and Committee on Hearing and Bioacoustics (CHABA) data depict existing health hazard assessments and safe use standards and restrictions that are overly conservative for large-caliber weapon systems with firing restrictions that hamper a soldier's need for self-protection. Soldier survivability not only depends on his or her need to hear well, but also depends on access to high quality weaponry and guidelines for usage that is not overly restrictive. The current standard has been in place for over 40 years and regulators are very familiar with it. However, it ignores known ear behavior; provides a simplistic treatment of hearing protection; treats the ear as a black box; and results in problematic firing restrictions for the noisiest weapons systems (howitzers, shoulder fired weapons, and mortars). It is also too lenient with small arms and does not take the angle of incidence of noise insult into account in its current form. There is widespread agreement that a replacement criterion needs to accommodate both medical standards and design criteria and be applicable to all weapons systems.

AHAAH Model
Mr. Bruce Amrein

Mr. Amrein presented the AHAAH model developed by the Human Research & Engineering Directorate (HRED). The AHAAH model is a theoretically based analog of the ear designed with the aim of predicting hearing loss from exposure to very intense sounds that include high frequencies. It has elements that predict various anatomical components of the ear structure and does not assume that noise impulses will take any particular waveform shape. The AHAAH characterizes basilar membrane displacement in the cochlea and the middle ear transfer function. According to its developers, the AHAAH has the ability to differentiate between different scenarios including warned and unwarned responses. It accounts for non-linear behavior of the ear, predicts the probability of permanent threshold shift reasonably well, and works well with hearing protection.

9.6 dB Variation

Dr. Phil Chan

A statistical comparison of MIL-STD-14740 with three models used by other NATO countries (France, Germany and the Netherlands) alongside a statistical best fit model was presented by Dr. Phil Chan. Rather than using linear correlation, as has been common in past studies, the authors used logistic regression. The data came from walk-up studies funded by the US Army Medical Research and Material Command and conducted in Albuquerque, New Mexico between 1989 and 1995. These tests used perforated plugs and modified Racal muffs to simulate real world conditions under free field and bunker test conditions. Through regression analysis of these data, a statistical model was generated. The analysis indicated that the L(95, 95), the threshold for protecting 95% of the population 95% of the time, is 9.6 dB higher than values derived using the MIL-STD-14740; the other NATO DRC were similarly conservative (range of 9.6 to 21.2 dB) Dr. Chan concluded by enumerating recommendations and conditions that should be met to establish standard datasets and methods to arrive at a corrected noise impulse standard.

LAeq8 Model

CAPT William Murphy

CAPT William Murphy presented the case for adopting the A-weighted Equivalent Energy as a Damage Risk Criteria for Impulse Noise model (the LAeq8 model). He went over the history of damage risk criteria, which has origins based on waveform parameters to equivalent energy DRCs that attempt to describe energy the ear is receiving, to model-based DRCs (such as, those used for the LAeq8 and AHAAH). The LAeq8 model is the A- weighted acoustic energy delivered to the ear for an equivalent 8-hour exposure. The LAeq8 calculates the rate of decay of an impulse and takes into account the acoustic energy criterion developed by Atherly and Martin in 1971 and numerous other published acoustic standards. It can be integrated immediately with the current damage risk criteria used with occupational hearing conservation metrics.

Although it was not originally based on data from studies using an ATF, the LAeq8 model is compatible with the use of an ATF. Thus, this model may accurately represent the influence of hearing protection and can integrate both continuous and impulsive noise. Evaluations of the LAeq8 with the Albuquerque blast overpressure data show a better fit than is seen with the AHAAH. In some instances, the LAeq8 predicts empirical data and TTS better than the AHAAH, although the better fits may be an artifact resulting from adjusting the magnitude of the DRC to the data. However, the LAeq8 model lacks some important features of the AHAAH model. Most notably it does not account for the middle ear reflex, stapes nonlinearity, and intermittent exposures. Improvements in LAeq8s ability to account for the effects of hearing protectors, integrate with traditional ORCs, and account for effects of secondary exposure are areas that need improvement.

EVALUATION OF MODELS

MIL-STD 1474D

Evaluation of the Scientific Quality of MIL-STD 1474D

This standard is based on research conducted 45 years ago, and is known to be seriously flawed. Although the original research represented the "state-of-the-art" at the time, its application to modem weapons design, especially its extrapolation to high sound levels, is inappropriate. The results and the conclusions drawn from them can no longer be considered dependable; much has been learned about the response of the human auditory system to intense impulse noise exposure in the intervening 45 years that indicate the inadequacies of MIL-STD 1474D.

Deficiencies with the Current Impulse Noise Requirement of MIL-STD 1474D that need to be Addressed

There are deficiencies with the current impulse noise requirement, MIL-STD 1474D, serious enough to warrant immediate action to replace the standard.

One serious issue is that the standard is overly conservative for large caliber weapons. In other words, if the development of weapons systems and training scenarios were guided only by the current standard, promising new weapons systems might be abandoned and warfighter training would be limited unnecessarily. Both of these problems raise the very real possibility that warfighter lethality and survivability could be negatively impacted by continued application of the current standard. Another issue is that although the original data were based on human responses to actual exposures, the rule was determined by a limited set of exposure conditions using a predominantly empirical approach. It is argued that a standard based on an ever-evolving understanding of the middle and inner ear will be both more accurate and more accommodating of future modification to apply to new weapons or new battlefield settings. A third weakness is that the standard includes no provision for combining risk of exposure to both impulse and continuous noise. Risk produced by exposure to continuous noise is currently assessed by the Army using an equivalent-energy approach.

Panel Recommendation

The panel is unanimous in its opinion that MIL-STD l474D be replaced as soon as practicable. There does not appear to be any justification for further research on this standard; its weaknesses have been amply demonstrated.

9.6 dB VARIATION

Ability to Address MIL-STD Deficiencies

The analysis of Chan et al. (2001) is not so much a model of hearing hazard from impulsive noise as a demonstration of the weaknesses common to the MIL-STD 1474D and the other three NATO models. Three observations inform the current discussion:

1) The French model, which is based on the 8 hour, A-weighted LAeq8, did no better statistically than MIL-STD 14740.
2) The "best fitting" model described by Chan (2001) differed substantially from MIL-STD-1474D in that it predicted that risk would actually decrease with increasing B-duration and that the accumulation of risk with increasing numbers of exposures would be more gradual than that established in MIL-STD-1474D. However, the generalizability of these predictions beyond the conditions of the blast overpressure study remains uncertain.
3) In the best-fit statistical model the number of impulses is relatively less important than in MIL-STD 1474D and the other three NATO models. In the other three NATO models, hazard increases as a function of 10 log (N), and in MIL-STD 1474D, hazard increases as a function of 5 log (N). For the best-fit model, hazard increases as a function of 3.44 (N).

Sufficiency of Research Conducted on the 9.6 dB Variation

Although this approach is based on well-accepted statistical procedures, its applicability is limited to large-caliber weapon systems producing impulses similar to those used in the blast overpressure (BOP) studies.

Research Needed to Address 9.6 dB Variation Deficiencies

The applicability of the 9.6 dB variation must be assessed against additional data intended to emulate exposures from small-caliber weapon systems in a variety of enclosure conditions (e.g., small and large reverberant environments) and distances.

It would be useful to duplicate the algorithm of the original walk up studies with substitution of a medium-caliber weapon (e.g., 25 mm gun on Bradley Infantry Fighting Vehicle) and a small caliber weapon (e.g., 5.56 mm assault rifle) as the potentially hearing-hazardous sound sources. This panel neither encourages nor discourages such research. It should be noted, however, that Institutional Review Boards have become increasingly cautious over the past twenty years, and there is no certainty that the protocol for the original walk-up studies would be approved in today's environment.

Value and Quantity of 9.6 dB Variation Science Information Products

The "9.6 dB" approach was derived mainly from a single research project, the results of which were published almost 10 years ago in a premier peer-reviewed journal. It does not appear to have been developed further since that time, probably due to the lack of a suitable dataset.

Panel Recommendations

The panel recommends that any consideration of the 9.6 variation be tabled until such time that an appropriate small arms study has been conducted.

AHAAH MODEL

Ability to Address MIL-STD Deficiencies

The AHAAH model in its current form does not adequately address all of the MIL-STD 1474D deficiencies in its current form. However, further refinements and validation of model accuracy (taking physiology into account), predictive power (hearing outcomes), and cross-species transformation could make this a viable substitute for the current standard. This is the only model that is based entirely on knowledge about the response of the mammalian auditory system to impulse noise.

Sufficiency of Research Conducted on the AHAAH Model

There are multiple key features of the AHAAH model that need further study: 1) effects of metabolic exhaustion; 2) stapes non-linearity; 3) acoustical consequences of middle-ear reflex, particularly in the presumed "warned" and "unwarned" states; 4) the translation of results from animal studies to predictions of the response of the human ear; 5) the validity of the assumption that summed squared upward displacements of the basilar membrane are the predominant indicator of damage to the auditory system; 6) the interaction of displacements across basilar membrane length over sequential exposures from different impulsive sources; and 7) how the model might be modified to integrate risk from both continuous and impulsive noise exposures.

The first point needing further study is effects of metabolic exhaustion. Here, cumulative damage is treated as a simple "wear and tear" process. The wear and tear assumption allows the model to provide excellent predictions of the hazards of single, high-intensity impulses, such as the wave shape of the impulse from an automobile airbag. Similarly, the AHAAH model does an excellent job of predicting the amount of permanent hearing loss and cochlear hair cell damage with animals exposed to intense impulses over a short period of time. However, it is not convincing that the AHAAH model can provide a useful simulation of hearing hazard in a complex military environment consisting of continuous noise from diesel engines and impulsive noise from hundreds of rounds reverberating from multiple shooters. From other research showing the effects of fuel and carbon monoxide exposure on NIHL and ongoing research (still inconclusive) on using antioxidants to hasten recovery from NIHL, it is clear that the process of recovery between incidents of “wear and tear" have a role in the prediction of hearing hazard.

On stapes non-linearity, it is the panel’s understanding that the non-linear action of the stapes in the AHAAH model is derived from the behavior of the stapes of domestic cats. Given the importance of stapes non-linearity to the AHAAH model, it is questioned whether the assumption that the human stapes functions in the same way as a cat stapes is reasonable. Empirical measurements with the guinea pig model revealed nonlinearity beginning at approximately 160 dB peak sound pressure level (160 dBSPLpk) and this nonlinearity had an influence below 1 kHz.

As far as the acoustical consequences of middle-ear reflex, (warned and unwarned states), the panel questions whether anyone understands the protective role of the middle ear reflex in sufficient detail to ascertain when an ear is "warned" or "unwarned." It should be noted that the middle ear reflex is not the only protective mechanism observed in the cochlea.

There is also evidence that efferent nerves from the olivo-cochlear bundle to the outer hair cells may modify the functioning of those hair cells. With the uncertainty about the cumulative impact of two protective processes, the boundary between "warned" and "unwarned" ears is likely to be imprecise.

There is little question that the AHAAH is highly successful in explaining why the acoustic signature of an M-16 assault rifle is, decibel-by-decibel, more hazardous than the acoustic signature of a howitzer, however, there are questions concerning the extrapolation from cat to human. Given the fact that most of the published research on peer-reviewed studies of noise-induced hearing loss (NIHL) has involved chinchillas, it will be important that peer-reviewed studies of NIHL in chinchilla far outnumber those in cats. A demonstration is needed to confirm that the cat-based model can be extrapolated to other species with no substantial loss of accuracy; this would lend credence to its adoption.

Research Needed to Address AHAAH Model Deficiencies

Most aspects on the development of this model have been extensively documented in the peer-reviewed literature. The exception is that the concept of the "warned" condition has not been subjected to peer-review. The work is uniformly high in quality, although it has come primarily from one laboratory. However, in its current form, the model is implemented in a somewhat user-unfriendly computer program, and the manner whereby some of the critical parameters are manipulated offers ample room for confusion and error. It would clearly be premature to adopt this model as a standard in its current form. Future work on this model, which is required before it can replace MIL-STD 1474D, must be directed by an active, committed scientific team; that team should be identified and recruited immediately.

It should also be noted that one of the co-developers of the model, Dr. Kalb, has begun to address one of its important deficiencies. That deficiency is the assumption that the hearing hazardous stimulus falls upon unprotected ears. With the exception of unusual events, such as a mortar round detonating inside a protected "green zone" in Iraq or a warfighter deliberately removing his or her helmet during a firefight, there should be no unprotected ears among contemporary US ground forces. At the same time, the Army medical researchers are aware that there is always the potential for errors in the fitting and use of hearing protection. The same acoustical engineering approach used to develop the AHAAH model can be employed to calculate the time history of the acoustic waveform received by the protected ear after the high-intensity impulsive sound is attenuated by a hearing protective device. This addition to the AHAAH model offers an opportunity for more realistic health hazard assessments.

In suggesting that the AHAAH model should be the subject of further research before final adoption, the panel recognizes that research funding within DoD is becoming increasingly limited. With the vast amount of medically relevant issues coming out of operations in Iraq and Afghanistan, further research into NIHL may not be able to obtain further funding within the Army Medical Research and Material Command budget and/or the Army Research Laboratory budget. In view of anticipated, increasingly severe constraints on the funding of Army research, the panel suggests consideration of a "reaching across" within the DoD family of research organizations to the US Navy.

Value and Quantity of AHAAH Model Science Information Products

Work on the AHAAH has progressed for decades, and although there have been some recent peer-reviewed publications describing AHAAH and its relationship with results from humans (e.g., the BOP study), much of the key science information has not been published or has been prepared in the form of non-peer reviewed white papers available on the developer's Website. The recent peer-reviewed publications are of reasonably high quality, but in all cases, one must assume that the model: 1) represents physiological responses to impulses in average adult humans, and 2) estimates risk on the basis of the correct aspect of the modeled physiological response. Looking forward, a high priority should be given to studies that rigorously test each model segment (e.g., outer, middle, and inner ear, and the temporal properties of all active components such as the middle ear muscle contraction).

Panel Recommendations

The panel is unanimous in its recommendation that a temporally based model grounded in mammalian physiology and generalizable to humans become the final standard to guide weapons design and establishment of DRC. However, the AHAAH model needs considerable refinement before this can be accomplished. Research is needed in several areas, as noted above, and this research should be completed before the predictions of the AHAAH model are compared to predictions of the LAeq8 model. In addition to the research noted above, the panel recommends a specific experiment that has the potential to provide leverage on the different predictions of AHAAH and LAeq8. The experiment would involve exposure (presumably of animals) to a train of identical non-overlapping Friedlander impulses, in which the inter-impulse duration is varied. Observed damage would be compared at several different presentation levels. Of particular interest would be cases in which the impulses overlap such that the peak of the lagging waveform occurs in the trough of the leading waveform. AHAAH would predict no impact of separation, but LAeq8 would make specific predictions in this case about the influence of separation. The research on AHAAH should be a focused and comprehensive program, fully supported by the stakeholders, and directed by a dedicated, active, and experienced scientific team.

LAeq8MODEL

Ability to Address MIL-STD Deficiencies

The LAeq8 model does not adequately address all of the MIL-STD 1474D deficiencies, but it has several positive features. First, it does appear to offer the best fit to the data from the Albuquerque BOP study, and it fits the low and moderate level chinchilla data well. Second, it has been widely adopted in other countries as a basis for damage risk criteria for both impulse and continuous noise. Third, it is based on well-understood and widely implemented acoustical parameters (e.g., A-weighting and 8-hour exposure). Finally, it extends upon the Army's current use of an A-weighted energy metric for continuous noise, which could simplify implementation.

Sufficiency of Research Conducted on tile LAeq8 Model

The LAeq8 model is sufficiently tested and proven to the degree that with minimal additional research it could be adopted as an interim standard.

For instance, it is noted that the A-weighting under weights energy above 8 kHz. Sharp pulses, those having rise times shorter than 100 microseconds, have significant energy above 8 kHz. Figure 2 of USAARL Report 94-46 (Patterson and Johnson) shows the spectra of towed artillery blasts. This indicates diminishing energy above 8 kHz, but it's not clear whether that effect is in the blast, in the microphone, or in the sound level meter circuit. Accordingly, the reported impulse energy under A-weighting can be understated. This could be an issue for small arms. However, it is understood that the Laeq8 method provides better protection for sharp pulses from small arms than does the MIL-STD 1474D. Clearly, the frequency response of the measurement system should adequately represent the spectra of impulses in the ear canal.

The final weapons testing sound level meter high frequency response to be required should take into account the hearing protection mandated for each weapon deployment.

Research Needed to Address LAeq8 Model Deficiencies

The revision of MIL-STD-1474D will need to address the required instrumentation for measuring impulses, as was included in the current version of the standard. Current ANSI and IEC standards allow a great deal of error in the high frequencies (e.g., +3/-∞), where impulses from some sources could contain substantial energy. Additionally,the recording systems for impulses might require faster dynamic characteristics than anticipated by device designers. The existing corpus of high-quality recordings of impulses should be subjected to systematic variation in filter responses and dynamic characteristics to determine the minimum specifications for recording systems intended for this purpose.

Value and Quantity of LAeq8 Model Science Information Product

Development of the LAeq8 model has been based on a significant corpus of solid, peer-reviewed research, and has been tested against results from both human and animal studies.

Panel Recommendations

The panel unanimously recommends that after a limited amount of further research, that the low-level and high-level predictions of the model be brought more in line with currently available data, the LAeq8 model be adopted as an interim standard to replace MIL-STD 1474D. This model would represent a step forward, but not a final answer. The most desirable model to guide weapons design and establishment of DRC will be one based on a temporally based physiologically grounded approach.

APPENDIX C: AGENDA

AGENDA AIBS Peer Review Impulse Noise Model
9 November 2010
Hilton Garden Inn, Frederick, MD

0730-0800	Arrival/Sign In
0800-0805	Administrative Information
0805-0845	**Introductory Overview and Charge to Panel** COL Carl Castro Director, Military Operational Medicine Research Program
0845-0915	**MIL-STD-14740-** Mr. Chuck Jokel
0915-0930	Discussion
0930-1000	**AHAAH Model** – Mr. Bruce Amrein
1000-1015	Discussion
1015-1030	Break
1030-1100	**9.6 dB Variation** – Dr. Phil Chan
1100-1115	Discussion
1115-1145	**LAeq Model** – CAPT William Murphy
1145-1200	Discussion
1200-1300	Lunch
1300-1630	Panel Deliberations
1630-1700	Out-brief by the panel
1700	Adjourn

APPENDIX D: LIST OF ABBREVIATIONS

AHAAH	Auditory Hazard Assessment Algorithm for the Human
ATF	Acoustic test fixture
BOP	Blast overpressure
CHABA	Committee on Hearing and Bioacoustics
dBSPLpk	Peak sound pressure level
DRC	Damage risk criteria
HPD	Hearing protective device
HRED	Human Research & Engineering Directorate
LAeq8	A-weighted Equivalent Energy as a Damage Risk Criteria for Impulse Noise
NIHL	Noise-induced hearing loss
PTS	Permanent threshold shift
TTS	Temporary threshold shift