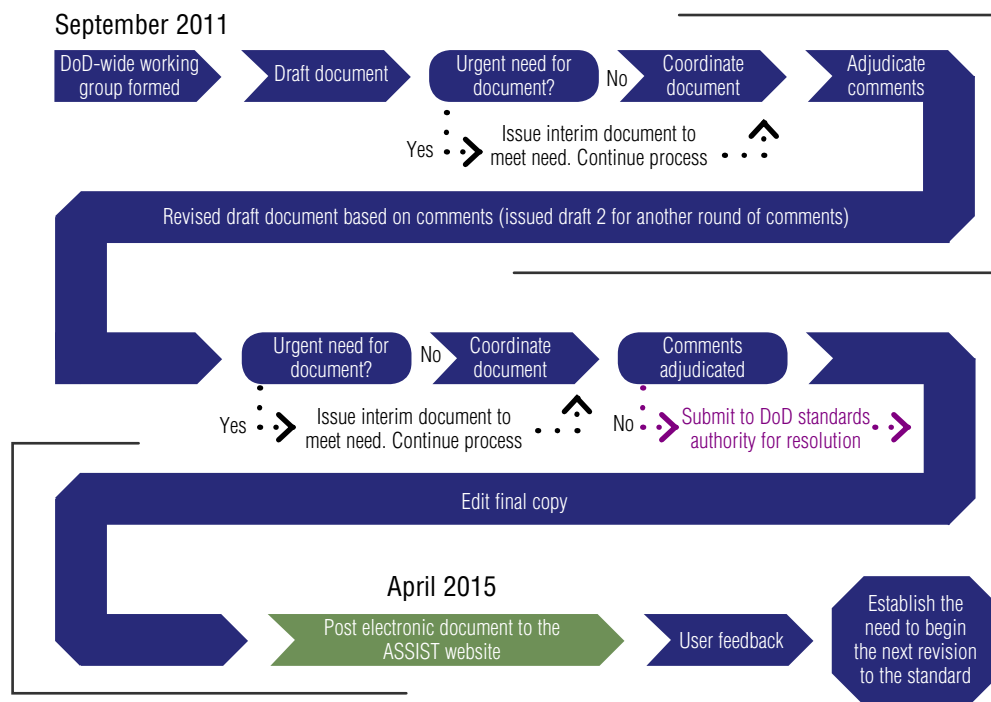


Revision of DoD Design Criteria Standard: Noise Limits (MIL-STD-1474)

Award Winner: ARL Team

An Army Research Laboratory (ARL) team revised and published MIL-STD-1474E, “Design Criteria: Noise Limits,” as much of the information contained in MIL-STD-1474D was out of date. Since 1997, when MIL-STD-1474D was published, the types and levels of military noise sources have changed dramatically, and significant scientific and computational advances have been made in assessing noise-induced hearing loss. Revision E allows designers to produce systems that are at or below required noise levels. The cross-services working group, with representation from the Army, Air Force, Navy, and Marine Corps, produced design requirements and guidance to support the acquisition and sustainment of U.S. military aircraft, land vehicles, ships, and weapon systems, including rockets, missiles, and large and small caliber guns. MIL-STD-1474E establishes acoustic noise limits, prescribes testing requirements, and describes measurement procedures for determining conformance to the noise limits. The standard specifies sound pressure level limits and measurement procedures to promote personnel safety, speech intelligibility, and security from acoustic detection and recognition. In the 2005–06 time frame, DoD began undertaking studies to fully understand the risk of hearing loss among service members. A key issue was that MIL-STD-1474D did not provide scientifically proven methods for reducing or assessing noise. The cross-services working group applied the current science and best practices to establish design requirements for steady-state noise, impulsive noise, aural non-detectability, aircraft noise, shipboard equipment noise, and shipboard compartment noise. (See Figure 1.)

Figure 1. The Process Followed to Revise MIL-STD-1474



Source: Modified from S. Lowell, Defense Standardization Program 101 (retrieved from http://dsp.dla.mil/APP_UIL/content/documents/2007-DSP-conf/Lowell-DSP101.ppt), 2007.

Background

Military operations and training produce pervasive and injurious noise levels. In the 2005–06 time frame, a study revealed that the Department of Veterans Affairs (VA) was spending \$1 billion per year on hearing loss claims. With the number of hearing disability claims continuing to rise, the Office of the Secretary of Defense requested that each of the services investigate ways to reduce the noise of unique military equipment and improve legacy systems to reduce the current injury rate. The U.S. Army had developed a hearing hazard model (Auditory Hazard Assessment Algorithm for Humans) to better quantify impulsive noise to which warfighters are exposed during large- and small-caliber gun firing. The U.S. Navy started an initiative to reduce shipboard equipment noise and define habitability noise limits for shipboard spaces. The U.S. Air Force started an initiative to protect aircraft ground crew from jet engine noise and protect aircrews from impulsive noise. The Army, Air Force, Navy, and Marine Corps came to a similar conclusion that MIL-STD-1474D must be updated as the requirements of the military standard are not adequately protecting soldiers, sailors, airmen, and marines from noise.

Problem/Opportunity

The design criteria for reducing noise levels, the techniques for measuring noise levels, and the means for establishing safe criteria for the firing of large- and small-caliber guns was based on nonscientific data. The update of MIL-STD-1474 provides noise engineers and scientists with the opportunity to establish scientifically based requirements that are achievable and measurable.

The design criteria for setting shipboard equipment noise requirements were outdated and not consistent with Navy and Coast Guard noise criteria for shipboard equipment. The update to the military standard allowed the Navy to codify the noise requirements for shipboard equipment and establish the noise requirements for shipboard spaces. The updated shipboard equipment and ship compartment noise requirements will flow into new ship construction's detailed design specifications to produce quieter ships and reduce the noise-induced injury rate for sailors and marines. Further, the evaluation and mitigation methods outlined in the military standard will allow the operational Navy to better protect personnel deployed on board legacy ships.

Approach

The updated version of MIL-STD-1474 applies to the acquisition and product improvement of all designed or purchased (non-developmental items) facilities, systems, subsystems, and equipment that emit acoustic noise or contain sources of noise. This standard is intended to address noise levels emitted during the full range of typical operational conditions and over the life cycle of the system under consideration. It covers tests for steady-state noise for military vehicles, aircraft, ships, general equipment, and portable shelters, and impulsive noise from weapons and explosive-ordnance materiel.

MIL-STD-1474E (published on April 15, 2015) provides specific noise limits and other requirements to equipment designers and manufacturers. It is intended to cover typical operational conditions. Required noise limits shall not be exceeded if the materiel is to be acceptable to the procuring activity.

MIL-STD-1474E specifies the maximum permissible noise levels produced by military systems and the test requirements for measuring these levels. This standard is neither a hearing damage risk criterion nor a hearing conservation criterion. It is a set of design criteria.

Due to the possibility of unpredictable interactions of various noise sources during military operations, MIL-STD-1474E requires that all new equipment, whether newly designed or purchased, emit the lowest feasible noise level.

Outcome

Below is an overview of resulting outcomes:

- **Cost avoidance.** Over the next few years, the VA will begin seeing reduced numbers of claims relating to hearing loss. The current estimate is a 5 percent reduction in hearing-loss claims starting in 2020 or \$50,000,000/year and continuing each year until 2025. Although legacy equipment will continue to emit high levels of noise, better measurement and mitigation techniques outlined in MIL-STD-1474E will lower the overall numbers of VA claims.
- **Improved performance.** Reduced noise levels and scientifically accurate measurement allows for improved man-machine interface performance.
 - Noise is a form of energy. Reduced noise levels produced by equipment greatly improve their efficacy and allow for increased performance.
 - Noise causes operator fatigue. Reduced noise levels greatly improve the performance of operators, reducing human error and improving readiness.
- **Quality.** The operator/user perceived quality of DoD equipment procured or upgraded using the MIL-STD-1474E requirements and design criteria will be greatly improved by producing quieter equipment and reduced operator fatigue.
- **Sustainability.** Equipment sustainability is projected to be improved as less noise will also result in less vibrations that cause premature failures.
- **Operational improvement.** Operational equipment upgraded to meet the design requirements or equipment procured that used the MIL-STD-1474E design criteria will be improved over legacy equipment.

The operating environments on flight lines, on ships, and inside land vehicles currently in inventory are excessively loud. Operators will now be better able to communicate, to understand hearing protection requirements, and to be provided with quieter equipment, thereby improving situational awareness.

- **Breadth of applicability.** MIL-STD-1474E has been approved for use by all departments and agencies of the Department of Defense. This military standard applies to the acquisition and product improvement of all designed or purchased facilities, systems, subsystems, and equipment that emit acoustic noise or contain sources of noise. MIL-STD-1474E is applicable to all DoD acquisition programs, legacy equipment, and planned upgrades for the Army, Air Force, Navy, and Marine Corps.
- **Cost of development.** The cost to update and develop the MIL-STD was kept to a minimum by setting up ground rules for each service to self-fund working group meetings and scientific studies. Excluding research costs to establish the means to best protect service members from noise and to measure noise correctly, the cost of revising MIL-STD-1474 was approximately \$150,000 (excluding the labor costs of the working group members who all volunteered their participation in addition to their regularly assigned duties).

Current Status

MIL-STD-1474E is published (2015) and will be invoked in all new system acquisitions and major legacy system upgrades. This is a profound improvement over MIL-STD-1474D (1997) and will significantly improve warfighter situational awareness, lethality, and survivability, ultimately enhancing mission success. (See Table 1.)

Table 1. Organization of MIL-STD-1474E Compared to Organization of MIL-STD-1474D

MIL-STD-1474D (1997)			MIL-STD-1474E (2015)		
Foreword and Main Body			Foreword and Main Body		
Requirement			Appendix		
1	Steady-State Noise, Personnel Occupied Areas		A	Steady-State Noise in Personnel Occupied Areas	
2	Aural Non-Detectability		B	Impulsive Noise in Personnel Occupied Areas	
3	Community Annoyance	DELETED	C	Aural Non-Detectability	
4	Impulsive Noise in Personnel Occupied Areas		D	Aircraft Noise	
5	Shipboard Equipment Noise		E	Shipboard Equipment Noise	
6	Aircraft Noise	COMBINED	F	Shipboard Compartment Noise	
7	Rotary-Wing Aircraft Noise			NEW	
Appendix			Note 1: Includes Annex A describing the Auditory Hazard Assessment Algorithm for Humans		
A	Guidance for Requirement 6	NO LONGER NEEDED			
B	Hearing Protector Noise Attenuation	NO LONGER NEEDED			

Challenges

Members of the DoD working group initially operated very parochially (e.g., Army members were only interested in land vehicles and weapons; the Navy was interested in ships and aircraft; and the Air Force was only interested in aircraft). Over time, this changed and all members of the working group began to think globally. This change in attitude opened the doors to an excellent collaboration and technical discussions with the common goal of developing the best solution for our warfighters (soldiers, sailors, airmen, and marines).

There were two important issues, each requiring significant discussion and compromise. Both were successfully resolved and incorporated in the final published version of MIL-STD-1474E. Both of these issues, described below, will provide significant payoff in the future:

- Establishing two shipboard requirements for equipment noise and for noise in shipboard compartments was critical for the Navy to begin to address the overall shipboard noise hazard that has affected the Navy for 40 years. The introduction of both equipment and compartment noise requirements allows the Navy to establish firm requirements for the shipbuilders to meet. Further, the establishment of shipboard noise requirements allows for the Navy to assess noise levels in a common way.
- Establishing two methods to assess impulsive noise allows the individual services to apply the best model for their use. Cancelling MIL-STD-1474D and implementing MIL-STD-1474E provides the designers of large- and small-caliber guns with a scientific model for assessing how many rounds may be fired per day. The MIL-STD-1474D model was a non-scientific table that did not provide guidance for implementation and caused overexposure to noise during training and exercises.

About the Award Winner

The ARL team consisted of Bruce E. Amrein, John Mallino III, Charles R. Jokel, Richard L. McKinley, and Kurt Yankaskas.

Bruce E. Amrein, of the Army Research Laboratory, was the U.S. Army lead and co-chair of the DoD MIL-STD-1474E working group. (He became chair of the working group in early 2015 upon the departure of Mr. Mallino.) Along with Mr. Mallino, Mr. Amrein coordinated initial in-person meetings, developed Draft 1 of MIL-STD-1474E, and arranged for contract support to assist the working group in soliciting comments from interested parties and adjudicating comments. Mr. Amrein arranged for Army funding of the support contractor and coordinated award of the task orders in conjunction with personnel at the U.S. Army Aviation and Missile Research Development and Engineering Center. During year 2 of this 3.5-year effort, travel restrictions made in-person meetings difficult to attend. Mr. Amrein established weekly tele-

conferences to keep the work moving forward to the common goal of publishing MIL-STD-1474E. These teleconferences and weekly deadlines for action items enabled the working group to develop draft 2 of MIL-STD-1474E. Mr. Amrein retired from federal service in October 2014, but at that time MIL-STD-1474E was not ready for publication. As an unpaid, guest researcher, Mr. Amrein continued to lead the working group until all issues requiring adjudication were complete and a final version of MIL-STD-1474E was approved by representatives of the Army, Navy, and Air Force. In April 2015, he submitted the final draft to the proponent at the U.S. Army Aviation and Missile Research Development and Engineering Center.

John Mallino III, representing the Naval Sea Systems Command, was the co-chair of the DoD MIL-STD-1474 working group from its inception until early in 2015 when he left government service. During his time as co-chair, Mr. Mallino established the tri-services (Army, Air Force, Navy [Marine Corps]) MIL-STD-1474E working group, coordinated initial comments to the first draft of MIL-STD-1474E, and coordinated initial working group meetings. He coordinated action items highlighting critical errors in MIL-STD-1474D that required an update, and he adjudicated critical disagreements between the services on the proper way to measure and analyze noise. He ensured that all Navy stakeholders were cognizant of the MIL-STD-1474 update and solicited input from critical personnel. Mr. Mallino led the effort to establish requirements for both shipboard equipment noise and shipboard space noise requirements, a significant change from MIL-STD-1474D. He initiated the effort to remove the impulse noise daily exposure limits table, which allowed the Army and Navy to find common ground with the Air Force to apply the latest scientific models to better protect against hearing damage during use.

Charles R. Jokel, representing the U.S. Army Public Health Center, was responsible for preparing the requirements for steady-state noise, which involved intense technical discussion and coordination with subject matter experts (SMEs) from the Navy and Air Force members of the working group before finalization. He was also an active participant in developing the basic portion of the standard (that portion that is applicable to aspects of all types of noise in all locations). Additionally, Mr. Jokel served as an SME for the impulsive noise requirements appendix. The crafting of specific requirements to enable the addressing of the diverse possible applications across all services was a challenging task, to which he made significant contributions. Without his dedicated participation in more than 3.5 years of discussion, it is doubtful that MIL-STD-1474E would have been published.

Richard L. McKinley, of the Air Force Research Laboratory, was the Air Force lead and chief proponent for aircraft noise. His standing in the DoD, national, and international scientific communities aided significantly in the development and consensus building of updated requirements for aircraft noise. The new standard includes ANSI standard measurement techniques to verify compliance with the MIL-STD requirements. Including the new ANSI standard puts DoD in a legally defensible position relative to measurement techniques. The details of the measurement methods have been publically vetted and represent the consensus of the U.S. scientific community. This levels the playing field for contractors attempting to comply with the military standard and will result in repeatable, reliable, and accurate data. The updated requirements and measurement techniques will apply to the acquisition of all aircraft and will affect the aircrews operating the aircraft, the maintainers servicing the aircraft, and the communities overflown by the aircraft. Mr. McKinley coordinated inputs on aircraft noise from the Army, Navy, and Air Force into the revised standard. He also provided substantial input into the impulsive noise exposure section describing one of the two metrics for impulsive noise exposure detailed in the military standard.

Kurt Yankaskas, of the Office of Naval Research, was the Navy lead and chief proponent for shipboard compartment and equipment noise. His extensive expertise in shipboard noise control provided critical technical

input to the shipboard noise section. He extensively rebuilt the habitability section and acoustic modeling sections, providing the necessary design tools. He coordinated inputs from the Navy's ship design community and provided Navy resources to supplement the working group effort. Mr. Yankaskas provided access to international-level ship designers to provide end-user input to ensure a usable product. He marshaled Navy resources to support the effort and canvassed and adjudicated numerous comments to complete the standard. His contributions apply to a broad scope of naval platforms, including from small to large ships, and provide vibration guidance for submarines. Additionally, he collaborated enthusiastically with other service colleagues representing Navy interests in flight and vehicle requirements to produce a reliable requirement.



Team members (left to right) John Mallino (Naval Sea Systems Command), Charles Jokel (Army Public Health Center), Bruce Amrein (team lead, Army Research Laboratory), Richard McKinley (Air Force Research Laboratory), and Kurt Yankaskas (Office of Naval Research).