2013-09

Tailoring MIL-STD-1472G: developing a systemlevel MANPRINT requirements document for contract use in the acquisition of military ground combat vehicles

Swain, Deborah L.

Monterey, California. Naval Postgraduate School

https://hdl.handle.net/10945/37053

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

HUMAN SYSTEMS INTEGRATION CAPSTONE

TAILORING MIL-STD-1472G: DEVELOPING A SYSTEM–LEVEL MANPRINT REQUIREMENTS DOCUMENT FOR CONTRACT USE IN THE ACQUISITION OF MILITARY GROUND COMBAT VEHICLES

by

Deborah L. Swain

September 2013

Unlimited Distribution

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB no 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** September 2013		**3. REPORT TYPE AND DATES COVERED** HSI Capstone
4. TITLE AND SUBTITLE TAILORING MIL-STD-1472G: DEVELOPING A SYSTEM–LEVEL MANPRINT REQUIREMENTS DOCUMENT FOR CONTRACT USE IN THE ACQUISITION OF MILITARY GROUND COMBAT VEHICLES			**5. FUNDING NUMBERS**
6. AUTHOR(S) Deborah L. Swain			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School, Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Unlimited Distribution			**12b. DISTRIBUTION CODE**
13. ABSTRACT (maximum 200 words) This document has been created to initiate an artifact which can be further developed into a hard contract requirements document that will mandate human design requirements as critical and requiring accountability on programs. By quantifying high-level HSI requirements, human engineers are able to provide the pass/fail criteria sought by hardware engineers. The battle now is to review those documents which we use on a daily basis and tailor out those that fall under systems design and sub-systems design. Currently, human engineering documents are organized to cover general design and detailed design all in one paragraph. The intention of tailoring these requirements out and breaking them down by domain is to increase the ease of reviewing these documents and only provide the up-front information that's most critical for design of a specific system.			
14. SUBJECT TERMS Human Systems Integration, Requirements, MANPRINT, Human Factors Engineering, Soldier Survivability, System Safety, Health Hazards, Manpower, Personnel, Training, MIL-STD-1472G			**15. NUMBER OF PAGES** 88
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This document has been created to initiate an artifact which can be further developed into a hard contract requirements document that will mandate human design requirements as critical and requiring accountability on programs. By quantifying high-level HSI requirements, human engineers are able to provide the pass/fail criteria sought by hardware engineers. The battle now is to review those documents which we use on a daily basis and tailor out those that fall under systems design and sub-systems design. Currently, human engineering documents are organized to cover general design and detailed design all in one paragraph. The intention of tailoring these requirements out and breaking them down by domain is to increase the ease of reviewing these documents and only provide the up-front information that's most critical for design of a specific system.

THIS PAGE INTENTIONALLY LEFT BLANK

OVERVIEW

Requirements involving human engineering are continuously evolving as technology permits for further exploration into human capabilities and physical traits. Studies are being conducted to better understand and model human strength and flexibility, evolving physical characteristics, the brain's functions, and limitations of survival in extreme environments. As the battle field continues to evolve into an electronic war zone, our interfaces are requiring soldiers to multi-task beyond what their primary mission tasks entailed in prior wars. Soldier anthropometrics are continuously changing as the U.S. diet evolves and the number of minorities entering the service increase. Threats to our soldiers are also changing as the enemy continues to increase its capabilities in the war zone; Improvised Explosive Devices (IEDs) seen in the Iraq and Afghanistan wars have required engineers to rethink system requirements to increase the survivability factor for personnel.

Experts in the field of HSI strive to include human engineering requirements and principles into the acquisition of military materials; however, it is an uphill battle. Many times, traditional engineering fields do not understand the purpose for their systems beyond the hardware. They develop hardware solutions based on a hardware performance requirements and in many cases fail to consider the soldier-in-the-loop. Government contracts do little in mandating HSI requirements as critical aspects of the design; rather, human engineering specification documents, such as MIL-STD-1472 are considered "guidelines" and hold little weight when considered in hardware performance specifications. Many times, human engineers are brought into the design when it's too late for modifications and this is accepted because the human requirements are only considered "guidelines" or a "nice to have".

For this work, emphasis is placed on the development of a systems-level HSI requirements document for U.S. Army acquisition programs, which use the HSI Directorate MANPRINT as a means of optimizing system performance for soldier use and safety. MANPRINT is broken down into five domains: Manpower, Personnel, Training, Human Factors Engineering, System Safety, Health Hazards and Soldier Survivability. MIL-STD-1472G was used as a basis for all requirements included. The areas covered by MIL-STD-1472G include Human Factors Engineering, System Safety and Health Hazards. Future review of additional documents and artifacts would help to fill in the areas of Manpower, Personnel, Training, and Soldier Survivability.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

1. Human Factors Engineering

Description: The integration of human characteristics into system definition, design, development and evaluation to optimize human-machine performance under operational conditions.

1.1 Anthropometric Accommodations

1.1.1. Physical Accommodation. The system shall provide physical accommodation, compatibility, operability and maintainability by the central 90 percent of the target user population as specified by the procuring organization. The system shall accommodate human capability requirements for size, weight, reach, strength and endurance to ensure that the crew is capable of performing all physical tasks. (5.8.1)

1.1.1.1 Crew Comfort. The system shall provide adequate clearance for crew comfort, ingress and egress, performance of all operational and maintenance tasks.

1.1.1.2 Crew External Visibility. The system shall provide adequate internal and external visibility to perform all required operations.

1.1.2 **Crewstations.** The system shall provide crewstations capable of accommodating all operational and maintenance tasks by the central 90 percent accommodation for the range and type of user population as specified by the procuring organization while wearing the appropriate Personnel Protective Equipment (PPE), clothing and required tools. (5.10.2.1)

1.1.2.1 Personnel Specifications. The system shall consider the number of personnel required to perform work and the body positions required to do the work in the design of workspaces. (5.10.2.2)

1.1.2.2 Storage Space. The system shall ensure that adequate space is provided on consoles or immediate workspace for storing manuals and other required materials to include basic operational equipment. (5.10.2.8)

1.1.2.3 Eliminate Interference. The system workplace shall be designed to eliminate interference among crewmembers during operations or maintenance. (5.10.2.12.1)

1.1.3 **Target Populations.**

1.1.3.1 Regular Populations. The population(s) to be accommodated shall include both genders of applicable service and foreign military personnel. (5.8.2.1)

1.1.3.2 Special Populations. Male only populations. Systems, equipment, and facilities intended for use by males only may limit the population to males only in lieu of the requirements specifying otherwise. (5.8.2.2)

1.1.4 **Anthropometric Modeling.** The system shall be designed using human figure modeling and three-dimensional body scanning to obtain new data to meet requirements of 3.1.

1.1.4.1 Additional anthropometric dimensions for the standing body, seated body, depth and breadth, circumferences and surfaces, hands and feet, and head and face, and extensive additional data can be found in NATICK TR-91/040, and NATICK TR 89/044. (5.8.4)

1.1.5 **Use of Anthropometric Data.** The system's use of anthropometric data as design criteria shall consider all of the following: (5.8.4.1)

1.1.5.1 Tasks. The nature, frequency, safety, and difficulty of the related tasks to be performed by the user or wearer of the equipment.

1.1.5.2 Body Position. The position of the body during performance of these tasks.

1.1.5.3 Mobility or Flexibility. Mobility or flexibility requirements imposed by these tasks.

1.1.5.4 Obstacles and Projections. Increments in the design-critical dimensions imposed by the need to compensate for obstacles and projections.

1.1.5.5 Adjustments. Because the above-cited anthropometric data represent nude body measurements, suitable adjustments in design-critical dimensions shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, hydration packs, and other worn or carried items. Additional appropriate factors to be added to dimensions can be found in NATICK/TR 99/012, available through the Defense Technical Information Center. If the appropriate factor is not available in NATICK/TR 99/012, designers shall derive it empirically. (5.8.4.1.2)

1.1.6 Reach/Lift Requirements

1.1.6.1 Reach Limitations. The system shall be designed so that the maximum effective forward reach (i.e., able to grasp and turn/push/pull) shall be 610 millimeters (24 inches) from the front of the user's body. (5.10.2.12.4)

1.1.6.2 Lifting Forward Reach. The system shall be designed so that jobs requiring the user to lift more than 3.0 kilograms (7.0 pounds), or produce torque (e.g., turning a wrench), shall be kept within 305 millimeters (12 inches) of the front of the user's body. If a hazard (e.g., hot surface, electrical contact) exists within these reach envelopes, it must be guarded, removed, or moved beyond the maximum reach of the user. (5.10.2.12.5)

1.2 Controls

1.2.1 **User Accommodation**

1.2.1.1 Control Design. System handles, levers, pedals, knobs, and workspace dimensions shall be designed to enhance effective vehicle operation by suitably clothed and equipped users with relevant body dimensions varying between the central 90 percent of the anticipated user population. (5.6.1)

1.2.1.2 Motion Envelopes. The system shall be designed so that the type of control selected and the location of the motion envelopes accommodate the central 90 percent of the anticipated user population suitably clothed and suitably equipped user personnel body dimensions for three-dimensional design elements (i.e., crewstations).

1.2.1.3 Strength. Fifth percentile strength values and 5th or 95th percentile physical dimension values shall be used for two-dimensional design elements (see Figure 22 and Figure 23).

1.2.1.4 Right and Left Handed Use. The system design shall accommodate both right- and left-handed users when possible; if constraints permit only one group of users (right- or left-handed) to be accommodated, the majority of the user population shall receive priority.

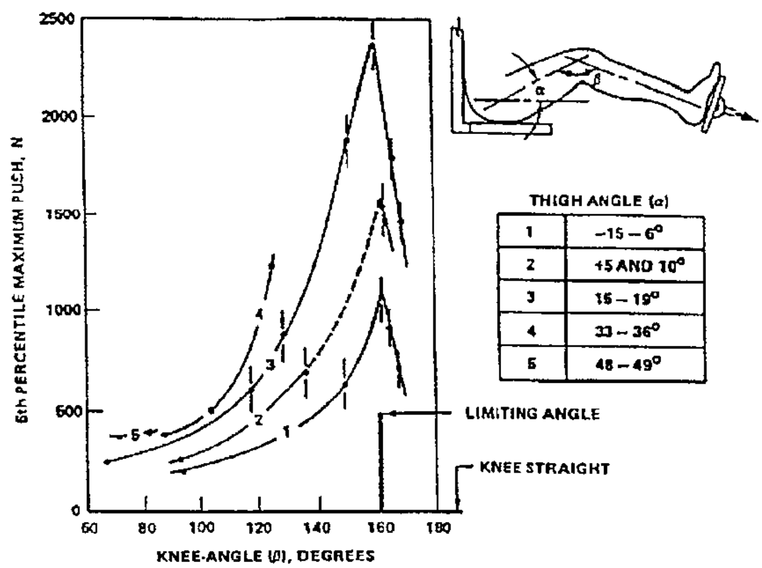
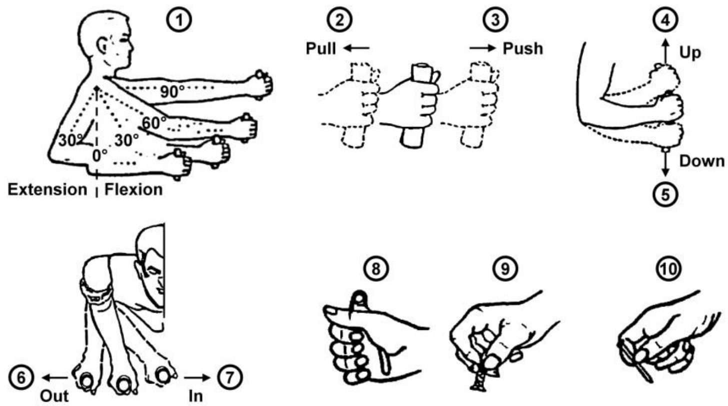


FIGURE 22. Leg Strength at Various Knee and Thigh Angles (5th Percentile Male Data)



Arm Strength in Newtons (pounds of force)														
(1)	**(2)**		**(3)**		**(4)**		**(5)**		**(6)**		**(7)**	
Degree of shoulder flexion/extension	**Pull**		**Push**		**Up**		**Down**		**Out**		**In**	
	L	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**
90 deg (flexion)	222 (50)	231 (52)	187 (42)	222 (50)	40 (9.0)	62 (14)	58 (13)	76 (17)	36 (8.0)	62 (14)	58 (13)	89 (20)
60 deg (flexion)	187 (42)	249 (56)	133 (30)	187 (42)	67 (15)	80 (18)	80 (18)	89 (20)	36 (8.0)	67 (15)	67 (15)	89 (20)
30 deg (flexion)	151 (34)	187 (42)	116 (26)	160 (36)	76 (17)	107 (24)	93 (21)	116 (26)	45 (10)	67 (15)	89 (20)	98 (22)
0 deg (neutral)	142 (32)	165 (37)	98 (22)	160 (36)	76 (17)	89 (20)	93 (21)	116 (26)	45 (10)	71 (16)	71 (16)	80 (18)
30 deg (extension)	116 (26)	107 (24)	98 (22)	151 (34)	67 (15)	89 (20)	80 (18)	89 (20)	53 (12)	76 (17)	76 (17)	89 (20)

Hand and pinch strength Newtons (pounds of force)				
	(8)		**(9)**	**(10)**
	Hand grip		**Palmer pinch grip**	**Tip pinch grip**
	L	**R**	**(Thumb pad to index & middle finger pads)**	**(Thumb tip to index finger)**
Momentary hold	250 (56)	260 (59)	60 (13)	60 (13)
Sustained hold	145 (33)	155 (35)	35 (8.0)	35 (8.0)

FIGURE 23. Arm, Hand and Thumb-Finger Strength (5th Percentile Male Data)

1.2.2 Selection and Placement

1.2.2.1 Control Selection. The system shall meet the criteria in Table I to determine the type of control to be used on control panels. Table II shows recommended controls in relation to control function and actuation force required.

TABLE I. Control Criteria

Function	Control									
	Selector Switch	**Round Knob**	**Discrete Thumb Wheel**	**Cont. Thumb Wheel**	**Crank**	**Push Button**	**Toggle Switch**	**Rocker Switch**	**Lever**	**Joystick, Lever, Ball, Mouse**
Select power state ON-OFF	3					1	2	2	la	
3-state (OFF-STBY-ON)	1	2					2	3		
Select between OFF/Prime Mode/Secondary Mode(s)	1					2	3	3	la	
Select one or more of N-related functions						1	2	2		
Select one of N mutually exclusive functions of any order						1				
Select one of 3 to 24 discrete alternatives – sequential order	1									
Select digit – discrete	2b		2b			lc				
Set value on – continuous scale		1		2	3				3	
Select value in – discrete steps	1		1			1				
Select operating condition	2					1	1	1	2	
Enter alphanumeric data						lc				
Initiate test subfunction (momentary)	3					1	1	2		
Initiate directional function	3			3		2d	1	1d	1	2
Generate stepping impulse (momentary hold)						1	1	2		
Slew counters or other numeric readout		le			1f	1	1			
Reset mechanical counter, manual		1	3	1						
Interrupt sequence, “hold”						1	2	2		
Engage – disengage mechanical function									1	
Adjust light level, continuous		1	3	1				2	3	
Adjust sound level, continuous		1	3	1				2	3	
Coarse adjustment		1g		2h	2i				2j	2
Fine adjustment		lk		2l	2m				3n	2
Adjust to null position		1		2	3				3	2

TABLE I. Control Criteria – Continued

Function	Control									
	Selector Switch	Round Knob	Discrete Thumb Wheel	Cont. Thumb Wheel	Crank	Push Button	Toggle Switch	Rocker Switch	Lever	Joystick, Lever, Ball, Mouse
Single-coordinate tracking		3			2				1	
Two-coordinate tracking					3					1

NOTES:

1 = most preferred 2 = secondary preference 3 = least preferred

a – Lever for heavy duty power circuits
b – Only if sequential selection is acceptable
c – Keyboard
d – Multiple controls
e – Rate control
f – Manual only
g – Small diameter
h – Small motion
i – Few turns
j – Short throw
k – Large diameter
l – Large motion
m – Many turns
n – Long throw

TABLE II. Recommended Manual Controls

Control Function	Control Type
Small actuation force required:	
2 discrete positions	Keylock Legend Switch Push Button Slide Switch Toggle Switch
3 discrete positions	Push button Rotary selector switch Toggle switch
4 to 24 discrete positions	Rotary selector switch
Continuous setting (linear and less than 360 degrees)	Continuous rotary knob Joystick or lever
Continuous slewing and fine adjustment	Continuous rotary knob Crank Joystick or lever
Large actuation force required:	
2 discrete positions	Detent lever Foot push button Hand push button
3 to 24 discrete positions	Detent lever Rotary selector switch
Continuous setting (linear and less than 360 degrees)	Crank Handwheel Joystick or lever Two-axis grip handle
Continuous setting (more than 360 degrees)	Crank Handwheel Two-axis grip handle Valve

1.2.2.2 Spacing Between Controls. The system shall be designed so that the minimum spacing between controls comply with Table III.

1.2.2.3 Spacing Between Control and Adjacent Obstruction. The system shall be designed so that the minimum spacing between a control and any adjacent obstruction complies with Table III. (Note: Minimum spacing shown in Table III shall be increased for operation with gloves, mittens, or CBRNE-protective hand-wear when such operation is a system requirement.)

TABLE III. Minimum, Edge-to-Edge Separation Distances for Controls

	Toggle Switches	Push buttons [2/]	Continuous Rotary Controls	Rotary Selector Switches	Discrete Thumbwheel Controls
Toggle Switches	See Figure 16	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	13 mm (0.5 in)
Push Buttons [2/]	13 mm (0.5 in)	See Figure 14	13 mm (0.5 in)	13 mm (0.5 in)	13 mm (0.5 in)
Continuous Rotary Controls	19 mm (0.75 in)	13 mm (0.5in)	See Figure 12	25 mm (1 in)	19 mm (0.75 in)
Rotary Selector Switches	19 mm (0.75 in)	13 mm (0.5 in)	25 mm (1.0 in)	See Figure 6	19 mm (0.75 in)
Discrete Thumbwheel Controls	13 mm (0.5 in)	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	See Figure 8

NOTES:

[1/] All values are for one-hand operation. All values are for bare-handed operation.

[2/] For push buttons not separated by barriers.

1.2.2.4 Accessibility. All controls shall be reachable and readable from the normal work body postures or positions without having to assume awkward or uncomfortable postures. (5.10.2.11)

1.2.2.4.1 *Seated Overhead Reach*. Where overhead reach is required for a seated user to operate a control (i.e., pushing a button), the maximum extended reach shall be 1321 millimeters (52 inches) above the seated surface for males, 1245 millimeters (49 inches) for females.

1.2.2.4.2 *Maximum Overhead Reach*. Maximum overhead reach for gripping reach (i.e., grasping a knob or turning a handle) shall be 1270 millimeters (50 inches) above the seated surface for males, 1168 millimeters (46 inches) for females. (5.10.3.4.9)

1.2.2.5 Control Placement, Normal. Controls mounted on a vertical surface and used in normal equipment operation shall be located 20 to 86 centimeters (8.0 to 34 inches) above the sitting surface. Where exclusive use by male personnel is specified (see 6.2), the controls shall be located 20 to 89 centimeters (8.0 to 35 inches) above the sitting surface. (5.10.3.2.18)

1.2.2.6 Control Placement, Special. Controls that require precise or frequent operation shall be located 20 to 74 centimeters (8.0 to 29 inches) above the sitting surface. Where exclusive use by male personnel is specified (see 6.2), the controls shall be located 20 to 76 centimeters (8.0 to 30 inches) above the sitting surface. (5.10.3.2.19)

1.2.2.7 User Orientation. System controls shall be oriented with respect to the user. Where a vehicle user may use two or more stations, the controls shall cause movement oriented to the user at the effecting station, unless remote visual reference is used.

1.2.2.8 Emergency Controls. Emergency controls shall be located where they can be seen and reached without delay (within a 30-degree cone about the user's normal line of sight (see Figure 2); an emergency control close to its related warning display, or use of the nearest available hand in its nominal operating position).

1.2.2.9 Control Arrangement. The system's controls shall be arranged on a console in accordance with the following provisions: (5.10.3.7.2)

1.2.2.9.1 *Primary Controls.* The system's primary controls shall be located between shoulder level and waist height.

1.2.2.9.2 *Simultaneous Operation.* System controls shall be located so that simultaneous operation of two controls will not necessitate crossing or interchanging hands.

1.2.2.9.3 *Frequently Used Controls.* System controls that are operated frequently shall be located to the left front or right front of the user.

1.2.2.9.4 *Grouping Frequently Used Controls*. System controls that are frequently used shall be grouped together, unless there are overriding reasons for separating them.

1.2.2.9.5 *Right-Hand Operations.* The system shall located frequently used controls for right-hand operation.

1.2.2.9.6 *Frequently Use Control Radius.* System controls frequently used shall be within a radius of 40 centimeters (15.7 inches) from the normal working position.

1.2.2.9.7 *Occasionally Used Control Radius.* System controls which are occasionally used shall be within a radius of 50 centimeters (19.6 inches).

1.2.2.9.8 *Infrequently Used Control Radius*. System controls that are infrequently used shall be within a radius of 70 centimeters (27.5 inches).

1.2.2.9.9 *Viewability*. System controls shall be located where the user can see them to check their positions, regardless of the viewing angle.

1.2.2.9.10 *Reach*. System controls shall be within the maximum reach of the seated user (see Figure 74).

1.2.2.9.11 *Fine Adjustments.* System controls requiring fine adjustments shall be located closer to the user's line of sight than controls requiring gross positioning.

1.2.3 **Functional Grouping**

1.2.3.1 Operational Sequence. The system shall be designed such that functional groups of controls and displays are located to provide for left-to-right (preferred) or top-to-bottom order of use, or both. Arrangement of controls by operational sequence when not within the same functional group (e.g., location, time/date, and mission designations) shall be permitted when it is more efficient. (5.1.2.2.1)

1.2.3.2 Control Action Commonality. The system shall be designed so that the arrangement of functionally similar, or identical, primary controls is consistent from panel to panel throughout the system, equipment, vehicle, and other systems expected to be operated by the user (e.g., a movement of a control to the right or left shall result in a corresponding movement of a displayed element to the right or left).

1.2.3.3 Control-Display Relationship. The system shall be designed so that the relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the user. A control shall be located adjacent to (normally below or to the right of) it's associated display and positioned so that neither the control nor the hand normally used for setting the control will obscure the display. (5.1.2.1.1)

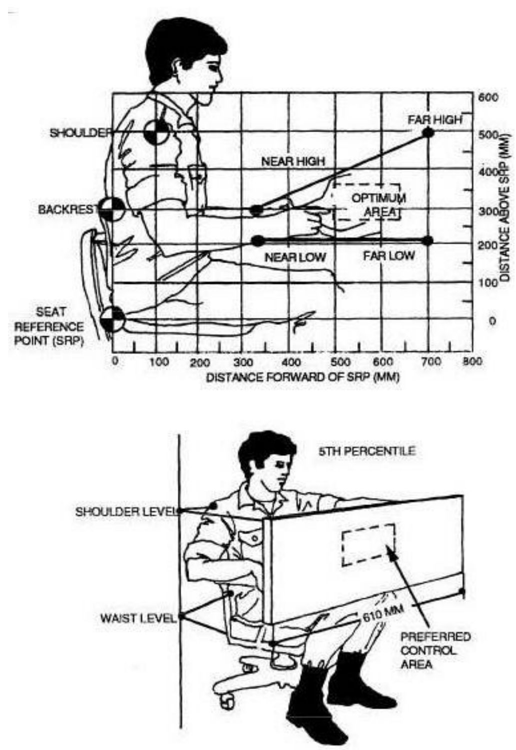


FIGURE 74. Seated Optimum Manual Control Space

1.2.4 **Inadvertent Activation**

1.2.4.1 Vehicle Ingress/Egress. System controls shall be located so they are not accidentally operated or blocked for by personnel who are entering or leaving the vehicle. (5.11.2.1.2)

1.2.4.2 Accidental Movement. The system's controls shall be designed and located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, personnel injury, system performance degradation, or system shutdown of mission critical equipment where a reboot period is necessary to restart the equipment. (5.1.1.8.1)

1.2.4.3 Inadvertent Activation of Infrequently Used Controls. System controls that are used infrequently shall be placed to one side to prevent inadvertent activation.

1.2.4.4 Location of Controls Used Occasionally. System controls that are occasionally used may be mounted behind hinged doors or recessed into the panel to reduce distraction and prevent inadvertent operation.

1.2.5 Response Times

1.2.5.1 Response Time. The system shall be designed so that there is no discernible time lag between a change in a system condition being controlled or monitored and its indication on a display. If a time lag between control actuation and ultimate system state is unavoidable, the system shall provide immediate feedback to the user of the process and direction of parameter change.

1.2.5.2 Feedback. System feedback of lag shall indicate to the user that the control is properly actuated, that the desired response is achieved, and when the desired response is complete.

1.2.5.3 Critical Control Functions. System control functions that are critical, such as those entered by keyboard, shall provide feedback to the user prior to entry to ensure that the keyed entry is errorless and is the one that the user desires to enter. (5.1.1.9)

1.2.5.4 Real-Time and Non-Real-Time Systems. The system shall be designed so that the maximum response times for real-time systems (e.g., fire control systems, command, and control systems) shall not exceed the values of Table V. Non-real-time systems may permit relaxed response times.

1.2.5.5 Predecessor Response Times. The system shall be designs so that response times for real-time and non-real-time systems shall not exceed the response time of the equivalent existing or predecessor system. If computer response time will exceed 1.0 second, the user shall be given a message indicating that the system is processing. (5.1.2.1.4)

1.2.5.6 Task Performance Time. The system's performance shall not exceed the time required to accurately complete a standard time sensitive action or sequence of actions (including system response time) when compared to the time to complete the same action(s) on the equivalent existing or predecessor system. The system shall give warning information when a command is invoked which will be time consuming or resource-intensive to process.

1.2.5.7 Common Format for Multiple Displays. The system design shall maintain commonality of nomenclature and symbology all displays when multiple displays and multiple display formats are used. Text or readout fields, common to all displays, (e.g., system advisories) shall be in a standard location on all display panels and formats.

TABLE V. Acceptable System Response Times

System Interpretation	Response Time Definition	Time (seconds)
Key response	Key depression until positive response, e.g., "click"	0.1
Key print	Key depression until appearance of character	0.2
Page turn	End of request until first few lines are visible	1.0
Page scan	End of request until text begins to scroll	0.5
XY entry	From selection of field until visual verification	0.2
Pointing	From input of point to display point	0.2
Sketching	From input of point to display of line	0.2
Local update	Change to image using local data base, e.g., new menu list from display buffer	0.5
Host update	Change where data is at host in readily accessible form, e.g., a scale change of existing image	2.0
File update	Image update requires an access to a host file	10
Inquiry (simple)	From command until display of a commonly used message	2.0
Inquiry (complex)	Response message requires seldom used calculations in graphic form	10
Error feedback	From entry of input until error message appears	0.2

1.2.6 Touch Screens

1.2.6.1 When to Use. The system shall incorporate touch-screen control when the display interface design includes providing an overlaying control functions to a data display where direct visual reference access and optimum direct control access are desired. Touch-screens are appropriate for interactions involving the selection of devices or targets on position displays (e.g., radars), arrangement diagrams, piping diagrams, discrete-function controls, or opening/closing valves. (5.1.3.1.1)

1.2.6.2 When Not to Use. The system shall not utilize a touch-screen if the interface will be used to enter large amounts of data frequently. A touch-screen shall not be the sole input means if system movement or vibration degrades user performance below the level required for mission accomplishment.

1.2.6.3 Response Time. The system's touch screen display response time shall be not more than 100 milliseconds. (5.1.3.1.4)

1.2.6.4 Touch-Screen Viewing Angle. The system's touch screens shall be positioned perpendicular to the user's line of sight while the user is in a normal operating position when possible. (Note: A reduced viewing angle, less than 90 degrees from horizontal, may reduce arm fatigue for frequent actions; however, changes to viewing angle shall be evaluated in relation to the negative impact on parallax, specular glare and readability.) (5.1.3.1.10)

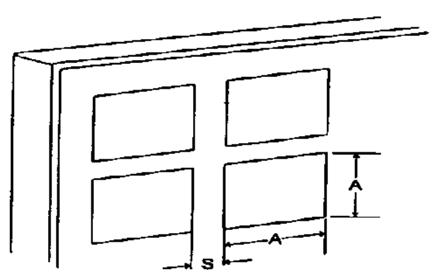
1.2.6.5 Mounting Location. The system's touch screens shall be mounted to ensure the central 90 percent of the anticipated user population can reach and actuate all areas of the screen including corners of the display. (5.1.3.1.11 a)

1.2.6.5.1 The system's touch screens shall be located so as to avoid full arm extension

1.2.6.5.2 The system's touch screens shall be located so as to avoid upward reach

1.2.6.5.3 The system shall provide elbow support where possible to minimize arm fatigue during touch screen use

1.2.6.5.4 Dimensions, Resistance and Separation. The dimensions, resistance, and separation of responsive areas shall conform to Figure 3. (5.1.3.1.15)



	Alphanumeric/numeric keyboards [1/]		
	A (Actuation area) [2/]	**S (Separation) [3/]**	**Resistance**
Minimum	—	0	250 mN (0.9 oz)
Preferred	13 by 13 mm (0.5 by 0.5 in)	—	—
Maximum	—	6.0 mm (0.25 in)	1.5 N (5.3 oz)

FIGURE 3. Touch-Screen

	Other applications		
	A (Actuation area) [2/]	S (Separation) [3/]	Resistance
Minimum	15 by 15 mm (0.6 by 0.6 in)	3.0 mm (0.12 in)	250 mN (0.9 oz)
Maximum	38 by 38 mm (1.5 by 1.5 in)	6.0 mm (0.25 in)	1.5 N (5.3 oz)

NOTES:

[1/] The dimensions specified apply to ungloved finger touch unless otherwise noted.

[2/] For standard cotton flame resistant anti-flash gloves (i.e., Navy flash gloves (as defined in MIL-G-2874E)) use, add 5.0 mm (0.2 in) to each dimension of the actuation area (A).

[3/] For touch-screens that use a "first contact" actuation strategy, separation between targets shall be not less than 5.0 mm (0.2 in). For touch-screens that use a "last contact" strategy, separation between targets may be less than 5.0 mm (0.2 in), but not less than 3.0 mm (0.12 in) for applications other than alphanumeric/numeric keyboards.

FIGURE 3. Touch-Screen - Continued

1.2.7 Keyboards

1.2.7.1 When to Use. The system shall use keyboards when alphabetic, numeric, or special function information is to be entered into the system. (5.1.3.2.1)

1.2.7.2 Design. The system's alphanumeric keyboards and numeric keypads shall be in accordance with ANSI/HFES 100. (5.1.3.2.2)

1.2.7.3 Dimensions, Resistance, Displacement and Separation. The pushbuttons of the system's keyboard shall meet the dimensions, resistance, displacement, and separation between adjacent edges of the push buttons specified in Table VII. For a given keyboard, Table VII criteria shall be uniformly met for all individual keys. (5.1.3.2.3)

1.2.7.4 Slope. The system shall be designed so that the slope of non-portable keyboards is 0 to 25 degrees above the horizontal. The preferred keyboard slope is 0 to 15 degrees. The slope of a portable device shall be capable of being varied according to the preference of the user. (5.1.3.2.4)

1.2.7.5 Lighted Keys for Use in Dark Environments. The system shall incorporate keyboards with lighted keys that are dimmable to a minimum of 30 incremental positions from the full on to off position for operations in darkened environments. Individual key characters/symbols shall be backlit to ensure readability in darkened conditions.

1.2.7.5.1 Low-level white light shall be used for keyboard backlighting in accordance with SAE-AS25050. (5.1.3.2.7)

1.2.7.5.2 System input requiring substantial numeric input shall be equipped with a numeric keypad.

TABLE VII. Keyboards

	Dimensions (Square)			Resistance		
	Bare hand	Arctic mittens [1/]	[2/]	Numeric	Alphanumeric	Dual function
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	15 mm (0.6 in)	1.0 N (3.5 oz)	0.25 N (0.9 oz)	0.25 N (0.9 oz)
Preferred	13 mm (0.5 in)	19 mm (0.75 in)	18 mm (0.7 in)	--	0.5 – 0.6 N (1.8 – 2.2 oz)	--
Maximum	19 mm (0.75 in)	--	--	4.0 N (14.0 oz)	1.5 N (5.3 oz)	1.5 N (5.3 oz)

	Displacement [3/]			Separation (between adjacent key tops)
	Numeric	Alphanumer	Dual function	
Minimum	0.8 mm (0.03 in)	1.3 mm (0.05 in	0.8 mm (0.03 in)	6.4 mm (0.25 in)
Preferred	--	--	--	6.4 mm (0.25 in)
Maximum	4.8 mm (0.19 in)	6.3 mm (0.25 in	4.8 mm (0.19 in)	--

Vehicle Applications				
	Dimensions		Resistance	Separation
	Bare hand	Gloved hand	Numeric Input	
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	2.8 N (9.9 oz)	--
Preferred	--	--	--	13 mm (0.5 in)
Maximum	25 mm (1.0 in)	25 mm (1.0 in)	6.7 N (23.7 oz)	--

NOTES:

[1/] Trigger finger type; other parameters are unchanged from those of bare-handed operation.

[2/] Standard cotton flame resistant anti-flash gloves (i.e., Navy flash gloves (as defined in MIL-G-2874E)).

[3/] For membrane keys, preferred displacement is 0.7 mm (0.03 in) and resistance shall be not less than 2.0 N (7.2 oz). Membrane keys shall also incorporate positive tactile feedback (e.g., “snap” action).

1.3 Visual Displays

1.3.1 Displays General

1.3.1.1 Content. The system shall be designed so that computer programs and equipment interfaces provide a functional interface between the system for which they are designed and users (operators/maintainers) of that system. This interface shall optimize compatibility with personnel and shall minimize conditions which can degrade human performance or contribute to human error. (5.2.2)

1.3.1.2 Accurate Reading. The system's displays shall be located so that they may be read to the required degree of accuracy by personnel in ergonomic operating or servicing positions. (5.2.1.2)

1.3.1.3 Stacked Displays. The system shall be designed so that where direct forward vision over the top of the console is not required by a seated user, and when lateral space is limited, the display panel is divided into three vertical/stacked segments. The surfaces of the panels shall be perpendicular to the user's line of sight with little or no head movement. (5.10.4.2.1)

1.3.1.3.1 The center of the central segment shall be 80 centimeters (31.5 inches) above the seat reference point. The height of this segment shall be not more than 53 centimeters (2l inches). (5.10.4.2.2)

1.3.1.4 *Primary Display Surface*. The system shall be designed such that the primary visual surface on consoles or instrument panels are be reserved for displays which are used frequently or are critical to successful operation. Special cases, where controls and displays are combined, or control and display compatibility is important (even though the displays are of secondary importance), may warrant placing them on this surface. (5.10.3.6.4)

1.3.1.5 Secondary Display Surface. The system shall be designed such that the secondary display surfaces are be located above or to the side of the primary display surfaces. These surfaces shall be used for displays that are used infrequently during operations (e.g., setup, adjustment, or operationally noncritical functions).

1.3.1.6 Design Principles. The system shall incorporate the following principles in laying out displays on the console or instrument panel:

1.3.1.6.1 *Preferred Distance to Display.* The preferred distance to displays is 63.5 centimeters (25 inches).

1.3.1.6.2 *Short Viewing Period Distance*. The viewing distance to displays shall not be less than 25 to 30 centimeters (9.8 to 11.8 inches) for short viewing periods, and preferably not less than 40 centimeters (15.7 inches).

1.3.1.6.3 *Display Requiring Accurate Readout*. Displays requiring accurate readout shall be located closer to the user's line of sight than displays requiring only gross monitoring.

1.3.1.6.4 *Angular Deviation*. Displays shall be mounted perpendicular to the line of sight. Angular deviation from the line of sight up to 45 degrees may be acceptable, provided accurate instrument reading is not essential and parallax is not too great.

1.3.1.6.5 *Readability of Instruments and Legends*. All instruments and legends shall be readable from the user's normal head position, allowing for normal head rotation and for restrictions imposed by helmets or other head gear.

1.3.1.6.6 *Grouping of Displays for Task Sequencing*. All displays necessary to support a user activity or sequence of activities shall be grouped together.

1.3.1.6.7 *Infrequently Viewed Displays*. Infrequently used displays can be in the periphery (maximum viewing angle) of the visual field.

1.3.1.7 Provide Clear Indication of Equipment, System and Environmental Conditions. The system shall incorporate visual displays that provide the user with a clear indication of equipment, system, or environmental conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design. (5.2.1.1)

1.3.1.8 Display Face Flush with Panel. The system shall be designed so that the face of a display is flush with the surface of the panel in which it is installed.

1.3.1.9 Preventing Distortion. The system shall be designs so that the combined effects of all geometric distortion does not displace any point on the display from its correct position by more than 5.0 percent of the picture height.

1.3.1.10 Preventing Flicker of Electronic Visual Displays. The system shall be designed so that the display refresh rate and other parameters (e.g., duty cycle, brightness, contrast, color, and motion) are adjustable to provide a flicker free display.

1.3.1.10.1 Over a period of 1.0 second, the movement of a picture element shall not be greater than 0.2 milliradians (41 seconds) of visual angle.

1.3.1.11 Vibration. The system shall be designed so that the vibration of visual displays or of observers does not degrade user performance below the level required for mission accomplishment (see 5.5.5).

1.3.2 Display Placement

1.3.2.1 Normal Line of Sight. The system shall be designed so that display faces are perpendicular to the user's normal line of sight. Display faces shall be not less than 45 degrees (0.79 radians) from the normal line of sight (see Figure 2). (5.2.1.2.3)

1.3.2.2 Parallax. The system shall be designed such that the orientation of displays minimize parallax. (5.2.1.2.4)

1.3.2.3 Display Placement, Normal. The system shall be designed such that visual displays mounted on vertical panels and used in normal equipment operation are located 15 to 117 centimeters (6.0 to 46 inches) above the sitting surface.

1.3.2.3.1 Where exclusive use by male personnel is specified, the equipment shall be located 15 to 122 centimeters (6.0 to 48 inches) above the sitting surface. (5.10.3.2.15)

1.3.2.4 Display Placement, Special. The system shall be designed so that displays that must be read precisely and frequently are located in an area 36 to 89 centimeters (14 to 35 inches) above the sitting surface, and no farther than 53 centimeters (21 inches) laterally from the centerline. (5.10.3.2.16)

1.3.2.4.1 Where exclusive use by male personnel is specified (see 6.2), the display shall be located 36 to 94 centimeters (14 to 37 inches) above the sitting surface and no farther than 56 centimeters (22 inches).

1.3.2.5 Warning Displays. The system shall be designed so that critical visual warning displays are mounted not less than 57 centimeters (22.5 inches) above the sitting surface when horizontal vision over the top of the console is required. (5.10.3.2.17)

1.3.2.6 Display Mounting Heights. Mounting heights for displays on a vertical flat surface such as a panel or bulkhead for use by a seated person shall be as shown on Figure 68. (5.10.3.4.11)

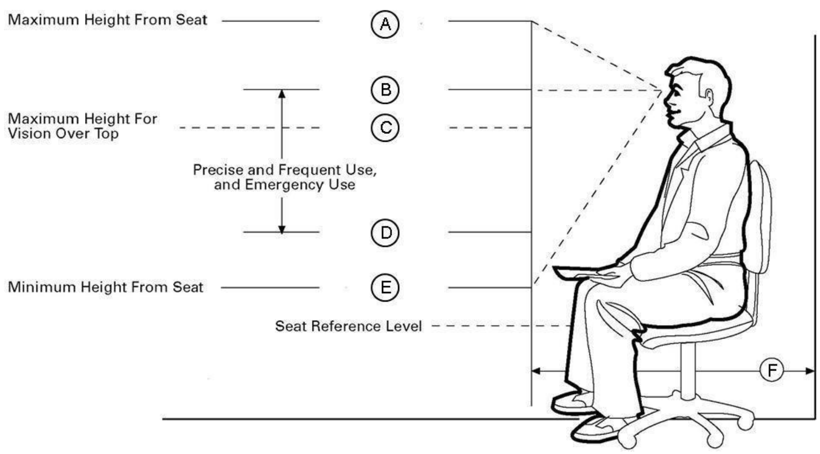
1.3.2.7 Display/Control Viewing Distance. The viewing distance from the eye reference point of the seated user to displays located close to their associated controls shall not exceed 70 centimeters (28 inches).

1.3.2.8 Grouping. All displays necessary to support an user activity or sequence of activities, shall be grouped together. (5.2.2.2.5)

1.3.2.8.1 Displays used most frequently shall be grouped together and placed in the optimum visual zone (see Figure 25)

1.3.2.8.2 Important or critical displays shall be located in the optimum projected visual zone or otherwise highlighted.

1.3.2.8.3 Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent such that order in functional groups provide a viewing flow from left-to-right or top-to-bottom. This requirement does not apply to master warning, caution, or advisory indicators (see 5.2.3.13.9)



Dimension [1/]	Value
Maximum height (A)	111.8 cm (44 in)
Preferred max. height [2/] (B)	90.0 cm (35 in)
Max. height for vision over top (C)	68.6 cm (27 in)
Preferred minimum height (D)	35.6 cm (14 in)
Minimum height, (E)	15.2 cm (6.0 in)
Min. workspace depth (F)	106.7 cm (42 in)

NOTES:

1/ The dimensions listed accommodate the central 90 percent of the anticipated user population.

2/ Preferred dimensions are for those controls that require precise, frequent, or emergency use.

FIGURE 68. Display Mounting Heights for Seated Personnel

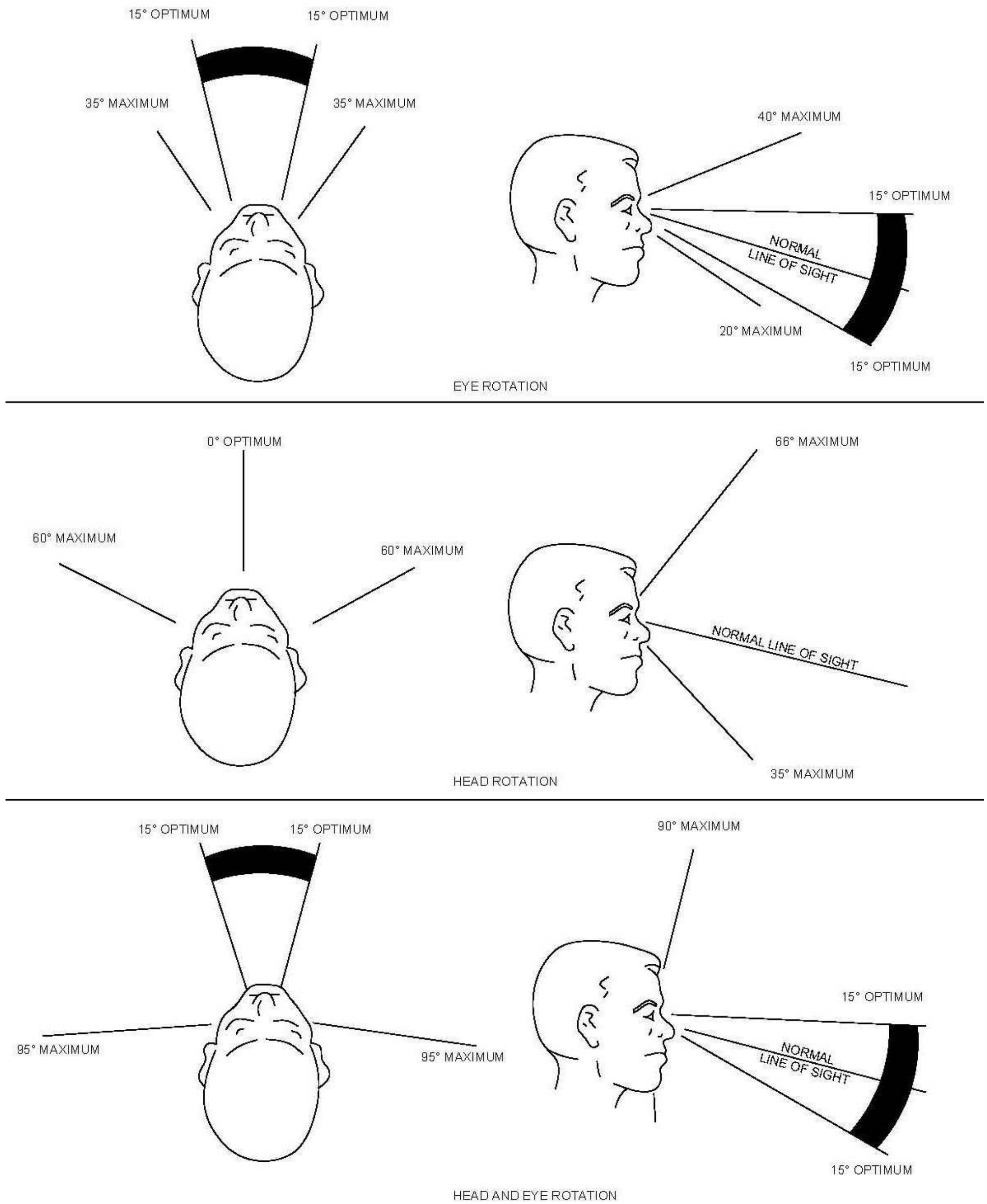


FIGURE 25. Vertical and Horizontal Visual Fields

1.3.3. **Viewing Distance**

1.3.3.1 Effective Viewing Distance. The system shall be designed so that the effective viewing distance to displays is not less than 33 centimeters (13 inches) and preferably not less than 51 centimeters (20 inches).

1.3.3.1.1 When periods of display observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 25 centimeters (10 inches).

1.3.3.1.2 The design shall permit the observer to view the display from as close as desired.

1.3.3.2 Viewing Distances Greater than 20 Inches. Displays which must be placed at viewing distances greater than 50 centimeters (20 inches) due to other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, and resolution.

1.3.4 Text Presentation

1.3.4.1 Alphanumeric Character and Symbol Sizes. For dynamic environments, the height of alphanumeric characters and pictorial symbols, when measured from the greatest anticipated viewing distance, shall subtend not less than 7.0 milliradians (24 minutes) of visual angle. (5.2.2.4)

1.3.4.2 Character Stroke. Character stroke width shall be not less than 0.0834 nor greater than 0.1667 the number of pixels used for character height.

1.3.4.3 Character Width. Character width shall be approximately 0.6 of the height.

1.3.4.4 Symbology. The system shall be designed so that symbology meets MIL-STD-2525 and guidance of JSSG-2010.

1.3.4.4.1 *Automotive Symbols*. Symbols for automotive equipment shall be in accordance with 49 CFR 571.101. (5.6.4.6)

1.3.4.4.2 Pictorial symbols may be used in place of word labels or in addition to a word label when the pictorial provides faster user response. (5.4.6.4.1)

1.3.4.4.3 Pictorial symbols shall be completely unambiguous in the expected visual operating environments. (5.4.6.4.2)

1.3.4.5 Symbol/Graphics Size. The size of a symbol or graphic shall be such that all text or graphics embedded within the symbol (e.g., label within symbol) shall subtend not less than 5.8 milliradians (20 minutes) of visual angle from the greatest anticipated viewing distance to be compatible with viewing while wearing a CBRNE protective mask.

1.3.4.6 Font Style. Font style shall allow discrimination of similar characters (e.g., letter l/number 1, letter Z/number 2). A common, standard font shall be used (e.g., Arial, Times New Roman, Courier, Verdana).

1.3.4.6.1 Where users must read quickly under adverse conditions (e.g., poor lighting), a sans serif style shall be used (e.g., Arial, Verdana, Helvetica).

1.3.4.6.2 *Graphical User Interfaces*. See ANSI/HFES 200 for additional Graphical User Interface guidance. (5.2.2.5.1)

1.3.5 **Presentation of Information**

1.3.5.1 Information Architecture. The system design shall be ensure that information displayed complies with the following: (5.2.2.2.1)

1.3.5.1.1 Information displayed to a user shall be sufficient to allow the user to perform the intended mission and shall be limited to information necessary to perform specific actions or to make decisions. The information requirements shall be traceable to a task analysis.

1.3.5.1.2 Information shall be displayed only within the limits and precision required for specific user actions or decisions. The information requirements shall be traceable to a task analysis.

1.3.5.1.3 The user shall not have to rely on memory to interpret new data. Each data display shall provide needed context, including recapitulating prior data from prior displays as necessary.

1.3.5.1.4 Operator and maintainer information shall not be combined in a single display unless the information content, format, and timeliness support the needs of both users, as defined by the results of the task analysis.

1.3.5.1.5 Information shall be presented to the user in a directly usable form that does not require the user to transpose, compute, interpolate, or mentally translate the information into other units, number bases, or languages.

1.3.5.2 Abbreviations and Acronyms. The system shall be designs so that abbreviations and acronyms are in accordance with current standards MIL-STD-2525 and MIL-STD-1787 while,using the guidance of JSSG-2010.

1.3.5.2.1 New acronyms, if required, shall be developed using logical rules of abbreviation. Abbreviations shall be distinctive to avoid confusion. Words shall have only one consistent abbreviation. No punctuation shall be used in abbreviations. Definitions of all abbreviations, mnemonics, and codes shall be provided at the user’s request. (5.2.2.2.3)

1.3.6 **Caution and Warning Signals**

1.3.6.1 General. Visual displays shall be used to provide the user with a clear indication of warning for off-normal equipment or system conditions. (5.7.3.1)

1.3.6.1.1 Visual danger signals (i.e., warnings and cautions) shall be used to alert the user that a specific condition exists and to inform the user about the nature and priority of the condition. (5.7.3.2.1)

1.3.6.1.2 Danger signal displays shall be clearly noticeable under all anticipated lighting conditions. Displays shall be conspicuously different from general area lighting. Displays shall have specific meaning within the operational area in which they are used. Visual warnings, cautions, and advisories shall be in accordance with MIL-STD-411. (5.7.3.2.2)

1.3.6.1.3 Visual warnings, cautions, and advisories shall be integrated with those presented in other sensory modalities (e.g., auditory, tactile). (5.7.3.2.3)

1.3.6.2 Priority Coding. To establish the priority of visual signals, discriminatory characteristics such as flashing, color, shape, symbols, color contrast, size, luminance contrast, and location shall be used. (5.7.3.2.4)

1.3.6.2.1 *Warning Signals*. Visual warning signals shall be presented using flashing red with flash frequency between 3.0 and 5.0 Hertz with a 50 percent duty cycle. The flash rate for all such warning signals shall be synchronized. If used in conjunction with caution signals, warning signals shall be coded to be easily distinguished from caution signals.

1.3.6.2.2 *Caution Signals*. If cautions take the form of flashing text, the text shall flash at a rate not greater than 2.0 Hertz with ON/OFF interval of about 70 percent on. Visual caution signals shall be yellow. A minimum of two discriminatory characteristics shall be employed to ensure rapid identification and interpretation of caution signals. If used in conjunction with warning signals, caution signals shall be not more than half the intensity of the warning signal.

1.3.6.2.3 *Text Height*. Text for visual warning and caution signals shall be presented using characters between 8.7 and 17.4 milliradians (30 and 60 minutes of subtended arc) as measured from the longest anticipated viewing distance, with the larger size used where conditions may be adverse. (5.7.3.2.5)

1.3.7 **Display Luminance**

1.3.7.1 Display Lighting. Display luminance shall be in accordance with the values in Table XXIII. (5.5.3.1.11)

TABLE XXIII. Recommendations for Display Luminance

Condition of use	Lighting technique [1/]	Brightness of markings cd/m^2 (fL)	Brightness adjustment
Indicator reading, dark adaptation necessary	White flood, indirect, or both with operator choice	0.07 – 0.35 (0.02 – 0.1)	Continuous throughout range
Indicator reading, dark adaptation not necessary but desirable	White flood, indirect, or both with operator choice	0.07 – 3.5 (0.02 – 0.1)	Continuous throughout range
Indicator reading, dark adaptation not necessary	White flood	3.5 – 70 (1.0 – 20)	Fixed or continuous
Panel monitoring, dark adaptation necessary	White flood, indirect, or both with operator choice	0.07 – 0.35 (0.02 – 0.1)	Continuous throughout range
Panel monitoring, dark adaptation not necessary	White flood	35 – 70 (10 – 20)	Fixed or continuous
Possible exposure to bright flashes, restricted daylight	White flood	35 – 70 (10 – 20)	Fixed
Chart reading, dark adaptation necessary	White flood	0.35 – 3.5 (0.1 – 1.0)	Continuous throughout range
Chart reading, dark adaptation not necessary	White flood	17 – 70 (5.0 – 20)	Fixed or continuous

FOOTNOTE:

[1/] Where detection of ground vehicles or other protected assets by image intensifier night vision devices must be minimized, NVIS green shall be used in lieu of low-level cool temperature white light.

NOTE:

1. Under scotopic conditions, character contrast, stroke width, and character size must be assessed for readability under the expected operational conditions.

1.3.7.1.1 The display luminance adjustability (highest to lowest) range shall be not less than 50:1.

1.3.7.1.2 A control shall be provided to vary the electronic display luminance from 10 percent of minimum ambient luminance to full luminance.

1.3.7.1.3 The brighter of characters or their background shall have a luminance of not less than 35 cd/m². Where military applications or survivability require, the luminance shall be adjustable to zero.

1.3.7.1.4 The contrast ratios between the lightest and darkest areas or between a task area and its surroundings shall be no less than the ratios specified in Table XII.

1.3.7.1.5 All reflections of the display that may disrupt operations, such shall be prevented.

TABLE XII. Contrast Ratios

Comparisons	Environmental Classification		
	A [1/]	**B** [2/]	**C** [3/]
Between lighter surfaces and darker surfaces within the task	5:1	5:1	5:1
Between tasks and adjacent surroundings	3:1	3:1	5:1
Between tasks and more remote surfaces	10:1	20:1	[4/]
Between luminaries and adjacent surfaces	20:1	[4/]	[4/]
Between the immediate work area and the rest of the environment	40:1	[4/]	[4/]

NOTES:

[1/] A = Interior areas where reflection off entire space can be controlled for optimum visual conditions.

[2/] B = Areas where reflection off immediate work area can be controlled, but there is only limited control over remote surroundings.

[3/] C = Areas (indoor and outdoor) where it is impractical to control reflection and difficult to alter environmental conditions.

[4/] Contrast ratio control not practical.

1.3.7.2 Avoiding Glare on Display Surfaces. The system shall be designed so that lighting is located to avoid glare from working and display surfaces as viewed from the normal working position.

1.3.7.2.1 The maximum luminance ratio between any two different sources of luminance light within an operator or maintainer's field of view shall not exceed 5:1.

1.3.7.2.2 To reduce glare, non-reflective or matte finished surfaces shall be provided on consoles, panels, and other work surfaces.

1.3.7.2.3 Avoid placing smooth, highly polished surfaces within 60 degrees of a person's normal visual field shall be avoided.

1.3.8 Display Illumination

1.3.8.1 Instrument Panel Illumination. The system's design shall include instrument panel lights to illuminate the instruments. (5.6.5.7.6)

1.3.8.2 Characters and Symbols. If the ambient illumination in the vicinity of the display is 540 lux or greater, dark characters and symbols on a light background shall be used rather than light characters on a dark background.

1.3.8.3 External Illumination. External illumination of a group of displays shall not vary more than 3:1 between the brightest and the darkest area.

1.3.8.4 Character-Background Contrast. Contrast between characters and a background shall be 6:1 or greater. The preferred contrast shall be 10:1 or greater. (5.2.1.5.1)

1.3.8.5 Night Vision. Where night vision device compatibility is required, displays shall be in accordance with MIL-STD-3009. (5.2.1.6)

1.3.8.6 Backlighting. Low-level blue-filtered white color light shall be used for panel, display, task, and backlit keyboard lighting in accordance with SAE-AS25050. (5.2.1.6.8)

1.3.8.7 General Night Operation. Indicators required by the vehicle operator during night operation shall be illuminated. The display luminance shall be adjustable from 0.1 to 3.5 cd/m² (0.03 to 1.0 footlamberts). (5.6.5.8.1)

1.3.8.7.1 When night vision is required, low-level white lighting (with the capability to dim to zero) shall be used.

1.3.8.7.2 Where night vision imaging devices are anticipated to be used in the proximity, night vision imaging system (NVIS) green shall be used.

1.3.8.7.3 Red lighting shall not be used in areas where color recognition, readability of maps and color symbology, or dark adaptation is required. (5.5.3.1.6)

1.3.8.8 Dark Adaptation. The system shall be designed so that where dark adaptation is required (e.g., crew stations), all displays and light-emitting sources are variably dimmable to at least a low luminance level of 0.000035 cd/m² (0.00001 fL).

1.4 Audio and Speech Systems

1.4.1 Audio Alarms

1.4.1.1 Optimum Signal Presentation. The system shall design in accordance with Table XIX when an audio presentation is required. (5.3.1.1.2)

1.4.1.1.1 *Audio Signal Interference*. Audio signals shall not interfere with other sound sources, including verbal communication.

TABLE XIX. Functional Evaluation of Audio Signals

Function	Type of signal		
	Tones (periodic)	**Complex sounds (non-periodic)**	**Speech**
Quantitative indication	Poor, maximum of 5 to 6 tones absolutely recognizable.	Poor, interpolation between signals inaccurate.	Good, minimum time and error in obtaining exact value in terms compatible with response.
Qualitative indication	Poor-to-fair, difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	Poor, difficult to judge approximate deviation from desired value.	Good, information concerning displacement, direction, and rate presented in form compatible with required response.
Status indication	Good, start and stop timing. Continuous information where rate of change of input is low.	Good, especially suitable for irregularly occurring signals (e.g., alarm signals).	Poor, inefficient; more easily masked; problem of repeatability.
Tracking	Fair, null position easily monitored; problem of signal-response compatibility.	Poor, required qualitative indications difficult to provide.	Good, meaning intrinsic in signal.
General	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multi-dimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

1.4.1.2 Silent Operations. The system shall be designed so that the sound level at the ear under an earphone shall be not greater than 50 decibels on the A weighted scale (dBA) during silent operations. (5.3.1.1.7)

1.4.1.3 Warning Signals. The system shall provide Warning that warn personnel of impending danger, to alert the user to a critical change in system or equipment status, and to remind the user of a critical action or actions that must be taken. (5.3.1.2.1)

1.4.1.3.1 Warning signals shall consist of distinctive complex sounds of exceptional attention-getting value and be presented at a level of at least 15 dBA above the noise environment.

1.4.1.3.2 Audio warning signals shall be either a two-element or single-element signal as appropriate to the situation in consideration of the total acoustic signal environment.

1.4.1.3.3 When reaction time is critical and a two-element signal is necessary, an alerting signal of 0.5 second duration shall be provided. All essential information shall be transmitted in the first 2 seconds of the identifying or action signal.

1.4.1.3.4 A single-element signal is permissible (i.e., when reaction time is critical) and all essential information shall be transmitted in the first 0.5 second.

1.4.1.4 <u>Caution Signals</u>. The system shall provide Caution signals that indicate conditions requiring awareness, but not necessarily immediate action. Caution signals shall be readily distinguishable from Warning signals. (5.3.1.2.2)

1.4.1.4.1 Caution signals shall consist of distinctive complex sounds at least 15 dBA above the noise environment.

1.4.1.4.2 Caution signals shall persist intermittently until restoration of normal conditions or manual shut off..

1.4.1.5 <u>Alerting Signals</u>. The system shall provide Alerting signals whenever there is a requirement for immediate response to a situation outside of the user's normal task sequence, or some system function needs attention on an irregular basis, or there may be a minor component failure. (5.3.1.2.3)

1.4.1.5.1 Alerting signals may be momentary or continuous in nature as appropriate, but if momentary, the alerting signals shall be repeated periodically until either proper action is taken or the signal is turned off.

1.4.1.5.2 Alerting signals shall exceed the noise level in the critical band for all major signal components by at least 20 decibels.

1.4.1.6 <u>Advisory Signals</u>. Audio signals may be provided to transmit information of an advisory nature which does not require specific user response or acknowledgment. (5.3.1.2.4)

1.4.1.6.1 In quiet areas (below 45 dBA), advisory signals shall be presented at a level of 50 to 70 dBA.

1.4.1.6.2 When there is a noisy background, advisory signals shall be at least 20 dB above the noise level in the critical band centered on each major component frequency of the advisory signal.

1.4.1.7 Message Priority. The system shall provide a message priority system that presents the most critical message overrides for initial presentation of any messages occurring lower on the priority list. Following initial presentation of the top-priority message, other messages shall be presented in the priority order except that no caution messages shall be presented until all warning messages are terminated. (5.3.1.2.5)

1.4.1.8 Warning Recognition Time. The system shall be designed so that Warning signals are sufficiently distinctive and can be unambiguously recognized as warning signals within 0.5 second of initiation. Single-element signals shall, in addition, convey full meaning of the signal within that initial 0.5-second period. In the worst case, two-element signals shall convey full meaning of the signal within 2.5 seconds of initiation. (5.3.1.3.1)

1.4.1.9 Frequency Range. The system shall be designed such that the frequency range of Warning signals falls between 250 and 8000 Hertz and, if possible, between 500 and 2000 Hertz. (5.3.1.3.3)

1.4.1.10 Maximum Decibels Permissible. The system shall be designed so that audio warning signals levels do not exceed 115 decibels measured at the ear of the listener as to avoid discomfort or "ringing" in the ears.

1.4.1.11 Signal-to-Signal Ratio. A signal-to-noise ratio of at least 10 decibels shall be provided in at least one octave band between 200 and 5000 Hertz at the operating position of the intended receiver. Signal to noise ratios can be greater as long as the levels do not exceed 115 decibels at the ear of the listener. (5.3.1.4.1)

1.4.1.12 Verbal Alarm Speech Interference. Verbal alarms for critical functions shall be not less than 20 decibels above the speech interference level at the operating position of the intended receiver.

1.4.1.12.1 The duration of an audio warning signal shall be at least 0.5 seconds, and may continue until the appropriate response is made. The completion of a corrective action by the user or by other means shall automatically terminate the signal.

1.4.1.12.2 The alerting signal shall fall within the range from 250 and 8000 Hertz. (5.3.1.5)

1.4.2 Speech Transmission Equipment

1.4.2.1 Speech-Transmission Equipment. The system shall be designed such that microphones and associated system-input devices shall respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6300 Hertz). (5.3.1.6)

1.4.2.1.1 Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6300 Hertz, the minimum acceptable frequency range shall be 250 to 4000 Hertz.

1.4.2.1.2 The dynamic range of a microphone used with a selected amplifier shall be wide enough to admit variations in signal input of at least 50 decibels.

1.4.2.2 <u>Cut-Off in Low-Frequency Noise</u>. The system shall be designed such that a high-pass filtering shall be used to cut off environments with predominantly low-frequency noise, at 300 Hertz.

1.4.2.2.1 In very loud, low-frequency noise environments (100 decibels overall), the following shall be applicable:

1.4.2.2.1.1 Use of noise-canceling microphones. Noise canceling microphones shall be used.

1.4.2.2.1.2 Noise canceling microphones shall be capable of achieving an improvement of not less than 10 decibels peak-speech to root-mean-square noise ratio as compared with non-noise-canceling microphones of equivalent transmission characteristics.

1.5 Crew Physical Attributes

1.5.1 **Clearance Dimensions.** The system shall be designed such that clearance dimensions (e.g., minimum dimensions for passageways and accesses) accommodate or allow passage of the body or parts of the body to include applicable clothing equipment and must be related to performance of tasks before being substituted for performance criteria. Clearance dimensions shall include adjustments for the task-appropriate clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items. (5.8.4.1.3)

1.5.1.1 Multiple Dimension Accommodation. The system shall be designed such that anthropometric dimension percentiles are not additive. To accommodate size, reach and vision, design parameters shall be defined by either using jointed distributions of all design relevant size, reach, and mass variables; or by using appropriate anthropometric models (5.8.4.1.6)

1.5.1.2 Whole Body. The system shall that all operating positions permit for enough space to move the trunk of the target user's body. When large forces (more than 13.6 kilograms (30 pounds)) or large control displacements (more than 380 millimeters (15 inches) in a fore-aft direction) are required, the target user shall have enough space to move his entire body. (5.8.4.2)

1.5.1.3 Soldier Equipment List. The system's design shall accommodate soldier equipment specified by contract (see Table XXXVII)

TABLE XXXVII. Typical Fighting and Existence Loads (Temperate Zones)

Fighting load	Approximate weight	
	kg	**lbs**
Clothing		
Personal Armor System for Ground Troops (PASGT) helmet	1.5	3.3
Battle dress uniform	1.73	3.8
PASGT vest	3.86	8.5
Underwear and socks	0.22	0.48
Belt with buckle	0.2	0.44
Boots, leather (Direct Molded Sole (DMS))	1.52	3.36
Clothing subtotal	9.03	19.88
Equipment		
Rifle M16A1 with 30-round magazine and sling	3.59	7.91
Ammunition pouches (2 each) with 180 rounds in 6 magazines	3.21	7.07
Hand grenades (2 each)	0.91	2.0
Light Anti-tank Weapon (LAW) (2 each) or Improved Light Anti-tank Weapon (ILAW) (1 each)	3.86	8.5
Canteen (1.0 quart filled) with cup and cover	1.63	3.6
Water purification tablets	0.03	0.06
Individual equipment belt, first aid packet with case and suspenders	0.72	1.59
Entrenching tool with carrier	1.14	2.52
Bayonet M7 with scabbard	0.59	1.3
Mask, chemical/biological (CB) protective, with hood	1.35	2.97
Poncho	0.77	1.7
Equipment subtotal	17.8	39.22
Existence Load		
All-purpose Lightweight Individual Carrying Equipment (ALICE) pack medium with straps	1.12	2.46
Chemical protective overgarment with gloves and boots	2.61	5.75
Canteen (1.0 quart filled) with cup and cover (additional)	1.63	3.6
Cap, utility	0.1	0.22
Underwear and socks	0.22	0.48
Personal hygiene kit	1.2	2.64
Rations MRE (3 each)	1.33	2.94
Bag, sleeping, intermediate cold	3.4	7.5
Mattress, pneumatic insulated	1.59	3.5
Jacket, field (1 each), with gloves, leather with wool insert, 1 pair	1.94	4.28
Bag, waterproof (1 each)	0.34	0.75
Existence load subtotal	15.48	34.12

1.5.2 **Range of Motion**. The system shall be designed in accordance with Table XXXVI which gives the ranges, in angular degrees, for all voluntary movements the joints of the body can make, as illustrated on Figure 54. These are maximum values and do not reflect the restrictions clothing would impose. The lower limit shall be used when personnel must operate or maintain a component. The upper limit shall be used in designing for freedom of movement. (5.8.4.1.8)

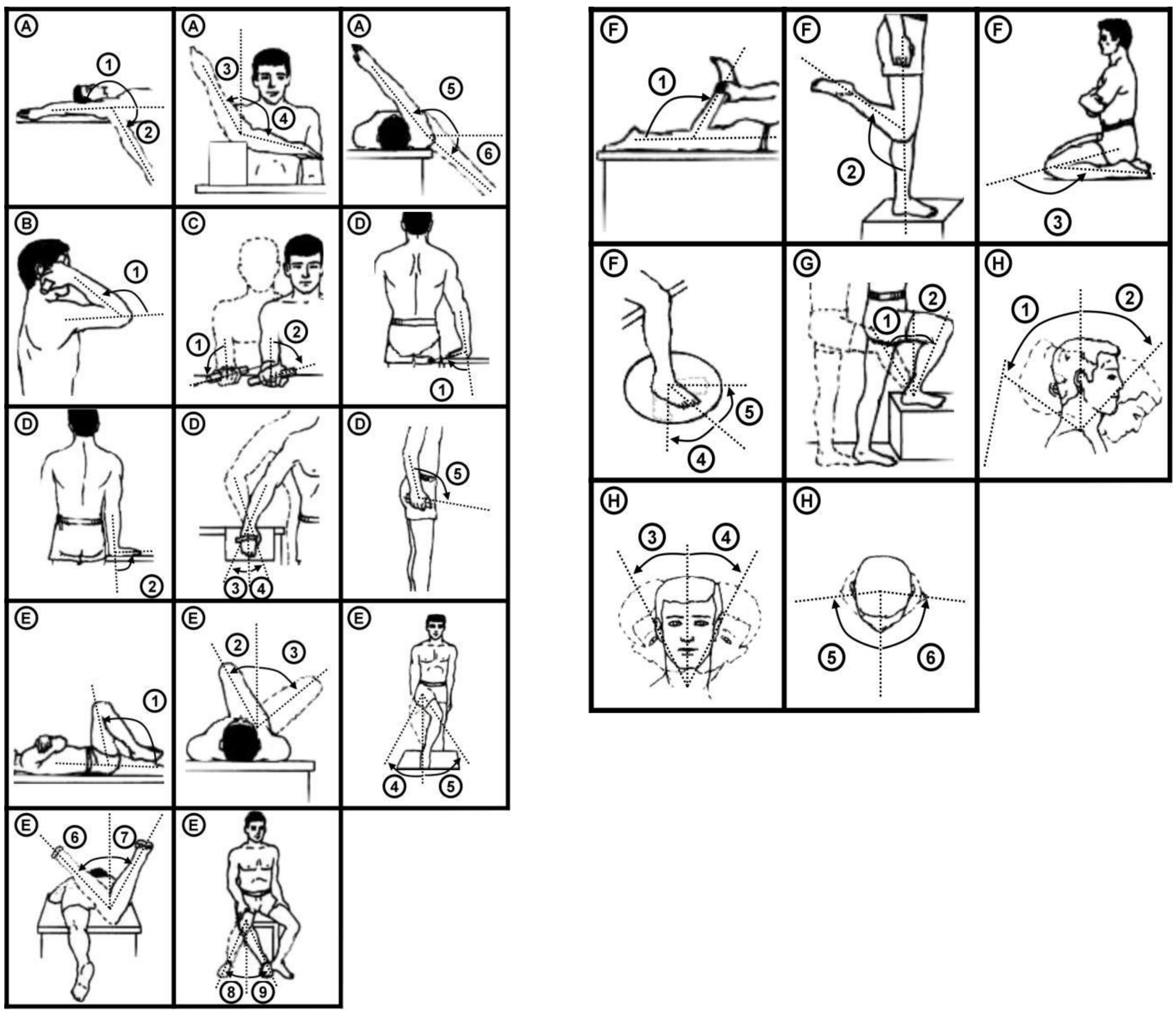


FIGURE 54. Range of Human Motion

TABLE XXXVI. Range of Human Motion

Body member movement		Lower limit (degrees)	Average (degrees)	Upper limit (degrees)
A. Shoulder	1. Flexion	176	188	190
	2. Extension	47	61	75
	3. Lateral rotation	21	34	47
	4. Medial rotation	75	97	119
	5. Horizontal adduction	39	48	57
	6. Horizontal abduction	117	134	151
B. Elbow	1. Flexion	132	142	152
C. Forearm	1. Supination	91	113	135
	2. Pronation	53	77	101
D. Wrist	1. Flexion	78	90	102
	2. Extension	86	99	112
	3. Ulnar deviation	40	47	54
	4. Radial deviation	18	27	36
	5. Wrist carry angle	95	102	109
E. Hip	1. Flexion	100	113	126
	2. Adduction (supine)	19	31	43
	3. Abduction (supine)	41	53	65
	4. Abduction (standing)	16	23	30
	5. Adduction (standing)	15	24	33
	6. Lateral rotation (prone)	24	34	44
	7. Medial rotation (prone)	29	39	49
	8. Medial rotation (sitting)	22	31	40
	9. Lateral rotation (sitting)	21	30	39
F. Knee	1. Flexion (prone)	115	125	135
	2. Flexion (standing)	100	113	126
	3. Flexion (kneeling)	150	159	168
	4. Lateral rotation	31	43	55

TABLE XXXVI. Range of Human Motion – Continued

Body member movement		Lower limit (degrees)	Average (degrees)	Upper limit (degrees)
H. Neck	1. Extension (backward)	44	61	88
	2. Flexion (forward)	48	60	72
	3. Lateral flexion (right)	34	41	48
	4. Lateral flexion (left)	34	41	48
	5. Rotation (right)	65	79	93
	6. Rotation (left)	65	79	93

NOTES:

1. These values are based on the nude body. The ranges are larger than they would be for clothed and mission equipped personnel.
2. Flexion: Bending or decreasing the angle between parts of the body.
3. Extension: Straightening or increasing the angle between parts of the body.
4. Adduction: Moving toward the midline of the body.
5. Abduction: Moving away from the midline of the body.
6. Medial rotation: Turning toward the midplane of the body.
7. Lateral Rotation: Turning away from the midplane of the body.
8. Pronation: Rotation of the palm of the hand downward.
9. Supination: Rotation of the palm of the hand upward.
10. Radialdeviation: Hand moving toward radius (bone).
11. Ulnar deviation: Hand moving toward ulna (bone).
12. Plantarflexion: Movement that increases angle between the foot and leg.
13. Dorsiflexion: Movement that decreases the angle between the foot and leg.

1.5.3 Lifting Limits

1.5.3.1 Lifting Limits. The system shall be designed to avoid lifting limits that exceed user capabilities. The weight limits in Table XXXVIII show the maximum design weight limits for loads lifted, lowered, or carried while being grasped by two hands. These values were derived from performance capacity data from a young, healthy population and do not necessarily represent thresholds for injury risk. (5.8.6.3.1)

1.5.3.1.1 *Maximum Values for One Lifter*. The weight limits in Table XXXVIII shall be used as maximum values in determining the design weight of items requiring one person lifting with one or two hands.

1.5.3.1.2 *Maximum Values for Two Lifters*. Double the weight limits in Table XXXVIII shall be used as the maximum values in determining the design weight of items requiring two-person lifting, provided the load is uniformly distributed between the two lifters.

1.5.3.1.3 *Non-Uniform Weight Distribution*. If the weight of the load is not uniformly distributed, the weight limit applies to the heavier lift point. Where three or more persons are lifting simultaneously, not more than 75 percent of the one-person value may be added for each additional lifter, provided that the object lifted is sufficiently large that the lifters do not interfere with one another while lifting and that adequate grip can be attained by each person.

1.5.3.1.4 *Lifting Height Limits*. Where it is not possible to define the height to which an object will be lifted in operational use, the limit wherein the object is lifted to shoulder height (1.5 meters (5.0 feet) above floor) shall be used rather than the more permissive bench-height (0.9 meter (3.0 feet) above floor) value or the less permissive above-shoulder-height (1.5 meters (5.0 feet) above floor) value. The values in Table XXXVIII are applicable to objects with or without handles.

TABLE XXXVIII. Maximum Design Weight Limits

Handling Function	**Population**	
	Male and female	**Male only**
Lift an object from the floor and place it on a surface equal to or greater than 152 cm (5.0 ft) above the floor	14 kg (31 lb)	21.9 kg (48 lb)
Lift an object from the floor and place it on a surface not greater than 152 cm (5.0 ft) above the floor	16.8 kg (37 lb)	25.4 kg (56 lb)
Lift an object from the floor and place it on a surface not greater than 91 cm (3.0 ft) above the floor	20 kg (44 lb)	39.5 kg (87 lb)
Carry an object 10 m (33 ft) or less	19 kg (42 lb)	37.2 kg (82 lb)

1.5.3.2 Lifting Frequency. The equipment weight limits in Table XXXVIII are not for repetitive lifting as found, for example, in loading or unloading transport vehicles. If the frequency of lift exceeds one lift in 5.0 minutes or 20 lifts per 8 hours, the permissible weight limits shall be reduced by (8.33 x LF) percent, where LF is the lift frequency in lifts per minute. For example, if the lift frequency is 6 lifts per minute, then the maximum permissible weight is reduced by 50 percent (8.33 x 6.0 = 50). To calculate the Frequent Lift Limit use the following equation: Frequent Lift Limit = (Table XXXVIII Lift Limit) * (1 – (8.33 * Lifts Per Minute)/100). (5.8.6.3.2)

1.5.3.3 Load Size. The maximum permissible weight lift limits in Table XXXVIII apply to an object with uniform mass distribution and a compact size not exceeding 46 centimeters (18 inches) high, 46 centimeters (18 inches) wide, and 30 centimeters (12 inches) deep (away from the lifter). (5.8.6.3.3)

1.5.3.3.1 Exceeds by 30 Centimeters (12 inches). If the depth of the object exceeds 30 centimeters (12 inches), the permissible weight shall be reduced by 33 percent.

1.5.3.3.2 Exceeds by 91 Centimeters (36 inches). If the depth of the object exceeds 91 centimeters (36 inches), the permissible weight shall be reduced by 50 percent.

1.5.3.3.3 Exceeds by 122 centimeters (48 inches). If the depth of the object exceeds 122 centimeters (48 inches), the permissible weight shall be reduced by 66 percent.

1.5.3.4 Twisting. Lifting tasks shall minimize or eliminate twisting of the body during the lifting task. If twisting motion is required, it shall be limited to a maximum of 30 degrees left or right of body centerline. If the body has to twist through more than 15 degrees and up to 45 degrees, the recommended acceptable loads shall be reduced by 20 percent. However, twisting while lifting, lowering, or supporting a load is not recommended. (5.8.6.3.4)

1.5.3.5 Obstacles. Where a lower protruding shelf or other obstacle limits the lifter's approach to the desired surface, the weight limit of the object shall be reduced by 33 percent. (5.8.6.3.5)

1.5.3.6 Lifting Team Designations. The number of lifters assigned to a handle a load shall not exceed the object's capacity to support the team. (5.8.6.3.6)

1.5.3.6.1 *Calculation*. Maximum permissible number of lifters assignable to a lifting team for either one-handed or two-handed lifts shall be calculated by rounding to the nearest whole number the result of dividing the size of the perimeter in inches by 24. For example, the maximum permissible number of lifters that could be assigned to lift an object with length 25 inches and width 35 inches would be: (2 x 25 + 2 x 35) / 24 = 5 lifters.

1.5.3.7 User Population. The "male and female" population values in Table XXXIX shall apply to any object to be lifted or carried manually; the "male only" population values apply only as specified by the procuring activity. (5.8.6.3.11)

1.5.3.8 Removable Components. Removable components should weigh less than 13.6 kilograms (30 pounds) preferred, and shall weigh less than 20.5 kilograms (45 pounds) maximum. (5.9.12.10.1)

1.5.3.9 Difficult to Reach Items. Difficult to reach items shall weigh less than 11.3 kilograms (25 pounds). (5.9.12.10.3)

1.5.3.10 Two-Person Lift. Items weighing over 20.5 kilograms (45 pounds) shall be placed for two-person handling. (5.9.12.10.4)

TABLE XXXIX. Carrying Limits for Distances over 10 Meters (33 Feet)

	Weight limits, kg (lb) male and female
Package carried at side with one hand (tool chest, container with handles, and so forth).	13.6 (30)
Package with irregular sides (electronic equipment chassis and so forth).	11.4 (25)
Box or other item with two hands.	14 (35)

1.5.4 Push and Pull Force Limits

1.5.4.1 Horizontal Force. The system shall be designed such that manual horizontal push and pull forces required, to be applied initially to an object to set it in motion or to be sustained over a short period of time, do not exceed the values of Table XL, as applicable, or those given in Table XLI, if more appropriate to the force and movement characteristics of the task. The values shown in Table XL apply to males only and shall be modified for females. (5.8.6.5.1)

1.5.4.2 Vertical. Manual vertical push and pull forces required shall not exceed the applicable 5th percentile peak or mean force values of Table XL, or those given in Table XLI if more appropriate to the force and movement characteristics of the task. (5.8.6.5.2)

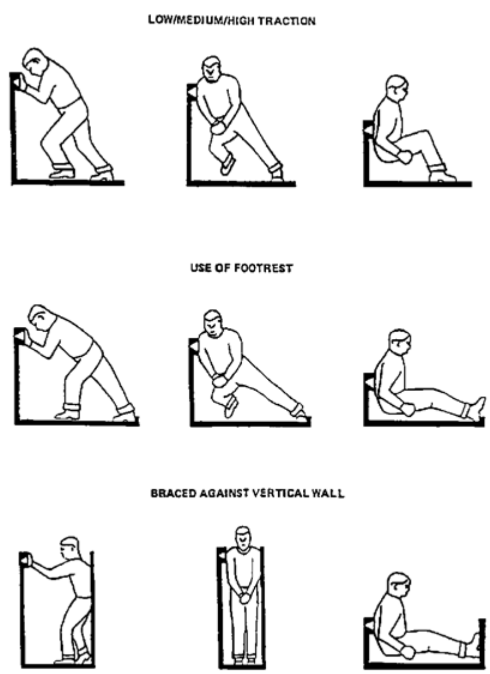


FIGURE 55. Examples of Push Forces

TABLE XL. Horizontal Push and Pull Forces Exertable Intermittently or for Short Periods of Time (Male Personnel)

Horizontal force [1/]	**Applied with** [2/]	**Condition (m = coefficient of friction)**
100 N (25 lb) push or pull	both hands or one shoulder or the back	low traction: $0.2 < \mu < 0.3$
200 N (45 lb) push or pull	both hands or one shoulder or the back	medium traction: $\mu \sim 0.6$
250 N (55 lb) push	one hand	if braced against a vertical wall 51 – 152 cm (20 - 60 in) from and parallel to the push panel
300 N (70 lb) push or pull	both hands or one shoulder or the back	high traction: $\mu > 0.9$
500 N (110 lb) push or pull	both hands or one shoulder or the back	if braced against a vertical wall 51 – 178 cm (20 - 70 in) from and parallel to the panel or if anchoring the feet on a perfectly nonslip ground (like a footrest)
750 N (165 lb) push	the back	if braced against a vertical wall 51 – 178 cm (20 - 70 in) from and parallel to the panel or if anchoring the feet on a perfectly nonslip ground (like a footrest)

FOOTNOTES:

1/ May be doubled for two and tripled for three users pushing simultaneously. For the fourth and each additional user, not more than 75% of their push capability shall be added.

2/ See Figure 55 for examples.

NOTES

1. Values are predicated upon a suitable surface for force exertion, i.e., a vertical, rough surface, approximately 40 cm (16 in) wide, and 510 – 127 cm (20 – 50 in) above the floor to allow force application with the hands, the shoulder, or the back.
2. Where applicable, force requirements shall be modified for females. Two-thirds of each value shown is considered to be a reasonable adjustment.

TABLE XLI. Static Muscle Strength

Strength measurements (see figure 56)			Values in N (lbs)			
			5th Percentile		95th Percentile	
			Male	Female	Male	Female
A. Standing two-handed pull	38 cm level	Mean force	738 (166)	331 (74)	1354 (304)	818 (184)
		Peak force	845 (190)	397 (89)	1437 (323)	888 (200)
B. Standing two-handed pull	50 cm level	Mean force	758 (170)	326 (73)	1342 (302)	841 (189)
		Peak force	831 (187)	374 (84)	1442 (324)	905 (203)
C. Standing two-handed pull	100 cm level	Mean force	444 (100)	185 (42)	921 (209)	443 (100)
		Peak force	504 (113)	218 (49)	988 (222)	493 (111)
D. Standing two-handed push	150 cm level	Mean force	409 (92)	153 (34)	1017 (229)	380 (85)
		Peak force	473 (106)	188 (42)	1094 (246)	430 (97)
E. Standing one-handed pull	100 cm level	Mean force	215 (48)	103 (23)	628 (141)	284 (64)
		Peak force	259 (58)	132 (30)	724 (163)	322 (72)
F. Seated one-handed pull	Centerline, 45 cm level	Mean force	227 (51)	106 (24)	678 (152)	392 (88)
		Peak force	273 (61)	126 (29)	758 (170)	451 (101)
G. Seated one-handed pull	Side, 45 cm level	Mean force	240 (54)	109 (25)	604 (136)	337 (76)
		Peak force	273 (61)	134 (30)	659 (148)	395 (89)
H. Seated two-handed pull	Centerline, 38 cm level	Mean force	595 (134)	242 (54)	1221 (274)	770 (173)
		Peak force	699 (157)	285 (64)	1324 (298)	842 (189)
I. Seated two-handed pull	Centerline, 50 cm level	Mean force	525 (118)	204 (46)	1052 (237)	632 (142)
		Peak force	596 (134)	237 (53)	1189 (267)	697 (157)

1.6 Hardware Integration Design – Handles and Access Covers

1.6.1 **Handles and Grasp Areas.** The system shall be designed such that all items designed to be carried or removed and replaced include handles or other suitable means for grasping, handling, and carrying (where appropriate, by gloved or mittened hand). Items requiring handling shall be provided with not less than two handles or one handle and one grasp area. Items weighing less than 4.5 kilograms (10 pounds) whose form factor permits them to be handled easily shall be exempt from this requirement unless otherwise specified by the procuring activity. (5.8.6.5.3)

1.6.1.1 Handle Location. Handles, grasp areas, or hoist points shall be located above the center of gravity and in a manner to preclude uncontrolled swinging or tilting when lifted. Handles, grasp areas, or hoist points shall be located to provide at least 5.0 centimeters (2.0 inches) of clearance from obstructions during handling. The location of handles shall not interfere with installing, removing, operating, or maintaining the equipment.

1.6.1.2 Non-Fixed Handles. Non-fixed handles (e.g., hinged or foldout) shall have a stop position for holding the handle perpendicular to the surface on which it is mounted.

Non-fixed handles shall be capable of being placed into carrying position by one hand (where appropriate, by a gloved or mittened hand).

1.6.1.3 Grasp Surface. Where an item's installation requires that its bottom surface be used as a handhold during removal or installation, a nonslip grasp surface (e.g., grooved, knurled, or frictional) shall be provided.

1.6.1.4 Handle Dimensions. Handles which are to be used with mittened, gloved, or ungloved hands shall equal or exceed the minimum applicable dimensions shown on Figure 57.

1.6.1.5 Handle and Grasp Area Force Requirements. Force requirements to operate handle and grasp areas other than the controls covered by 5.1.4.3 shall not exceed the values in Figure 23.

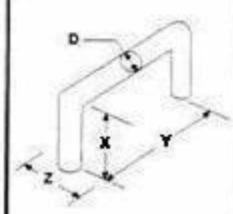
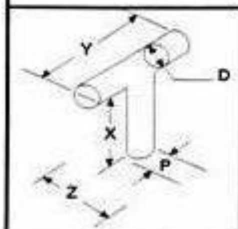
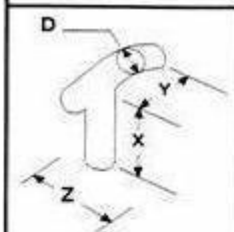
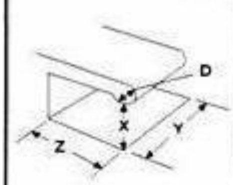
1.6.2 **Access Covers.** The system shall be designed such that equipment access covers are equipped with grasp areas or other means for opening them. Covers shall accommodate hand-wear or special clothing that may be worn by the maintainer. When hinged doors are adjacent, they shall open in the opposite directions to maximize accessibility. Hinged caps shall be used over test or service points so they will not interfere with inserting or attaching test or service equipment. Stops or retainers shall be used as necessary to keep doors from swinging into adjacent controls or fragile components, and so they will not spring their hinges. (5.9.8.6)

1.6.2.1 Ventilation Holes. If a cover or shield requires ventilation holes, the holes shall be no larger than 13 millimeters (0.5 inch) in diameter. Any component which rotates, oscillates, or carries high voltage shall be spaced back from the ventilation holes so personnel cannot accidently contact the hazard. (5.9.8.3)

1.6.2.2 Prevent Attachment in Any Other Orientation. A removable access cover that requires a particular orientation shall be designed to prevent attachment in any other orientation. (5.9.8.4)

1.6.2.3 Stops and Retainers. Covers, cases, and shields shall have adequate stops and retainers to keep them from swinging against, or being dropped on, fragile equipment or personnel, and have locking devices or retaining bars to hold them open if they might otherwise fall shut and cause damage, injury, or inconvenience. (5.9.6.4)

1.6.2.4 Reduce Handling and Stowage of Covers. Hinges, latches, and catches shall be used wherever possible to reduce handling and stowing of covers and cases. (5.9.6.5.1)

ILLUSTRATION	TYPE OF HANDLE	DIMENSIONS IN mm (inches)								
		(Bare Hand)			(Gloved Hand)			(Mittened Hand)		
		X	Y	Z	X	Y	Z	X	Y	Z
	Two-finger bar	32 (1 1/4)	65 (2 1/2)	75 (3)	38 (1 1/2)	75 (3)	75 (3)	Not applicable		
	One-hand bar	48 (1 7/8)	111 (4 3/8)	75 (3)	50 (2)	125 (5)	100 (4)	75 (3)	135 (5 1/4)	150 (6)
	Two-hand bar	48 (1 7/8)	215 (8 1/2)	75 (3)	50 (2)	270 (10 1/2)	100 (4)	75 (3)	280 (11)	150 (6)
	T-bar	38 (1 1/2)	100 (4)	75 (3)	50 (2)	115 (4 1/2)	100 (4)	Not applicable		
	J-bar	50 (2)	100 (4)	75 (3)	50 (2)	115 (4 1/2)	100 (4)	75 (3)	125 (5)	150 (6)
	Two-finger recess	32 (1 1/4)	65 (2 1/2)	50 (2)	38 (1 1/3)	75 (3)	50 (2)	Not applicable		
	One-hand recess	50 (2)	110 (4 1/4)	90 (3 1/2)	90 (3 1/2)	135 (5 1/4)	100 (4)	90 (3 1/2)	135 (5 1/4)	125 (5)

Curvature of Handle or Edge	Weight of item	Minimum Diameter	Gripping efficiency is best if finger can curl around handle or edge to any angle of 2/3 π rad 120°) or more.
(DOES NOT PRECLUDE USE OF OVAL HANDLES)	Up to 15 lbs (6.8 kg)	D - 6 mm (1/4 in.)	
	15 to 20 lbs (6.8 to 9.0 kg)	D - 13 mm (1/2 in.)	
	20 to 40 lbs (9.0 to 18 kg)	D - 19 mm (3/4 in.)	
	Over 40 lbs (over 18 kg)	D - 25 mm (1 in.)	
	T-bar Post	T - 13 mm (1/2 in.)	

FIGURE 57. Minimum Handle Dimensions

1.7 Maintainability

1.7.1 **Tools.** The system shall be designed such that equipment minimizes the numbers, types, and complexity of tools required for maintenance. T he design shall provide for effective use of tools through their full range of motion. Special tools shall be used only when common hand tools cannot be used, when they provide significant advantage over common hand tools, or where required by security considerations.. (5.9.1.3)

1.7.1.1 Grip Span. Grip span for tools requiring exertion of high force should be approximately 75 millimeters (3.0 inches) and shall be not greater than 100 millimeters (4.0 inches). (5.9.1.5)

1.7.1.2 Ease of Access. Equipment design and installation shall provide the maintainer with complete visual and physical access and a favorable working level for all parts of a system on which maintenance is performed, including work-stand interfaces, support equipment interfaces, access openings, adjustment points, test points, servicing points, and connections. (5.9.1.12)

1.7.2 **Accessibility of Components**. The system shall be designed such that all components are accessible with the emphasis for easy access placed on items that require frequent inspection and maintenance. (5.9.2.1.1)

1.7.2.1 Frequent Access. Components that require frequent visual inspection, check points, adjustment points, cable-end connectors, and labels shall be located in positions that can be easily viewed. (5.9.2.1.4)

1.7.2.2 Relative Accessibility. Mission critical items that require rapid maintenance shall be most accessible. When relative criticality is not a factor, items that require the most frequent access shall be most accessible. (5.9.4.5)

1.7.2.3 High-Failure-Rate Items. High-failure-rate items shall be accessible for replacement without moving non-failed items. (5.9.4.6)

1.7.2.4 Access Openings. Access openings shall be provided to all equipment or components that require testing, calibrating, adjusting, removing, replacing, or repairing. Access openings shall be large enough to accommodate hands, arms, tools, and provide full visual access to the task area. The type, size, shape, and location of accesses (see Figure 58) shall be based on a thorough understanding of the considerations listed below. (5.9.4.9.2)

1.7.2.4.1 Operational location, setting, and environment of the unit

1.7.2.4.2 Frequency of use

1.7.2.4.3 Maintenance tasks performed through the access and the intricacy of the tasks

1.7.2.4.4 Time required to perform maintenance functions

1.7.2.4.5 Types of tools and accessories required

1.7.2.4.6 Workspace required

1.7.2.4.7 Type of clothing likely to be worn by personnel

1.7.2.4.8 Necessary access reach

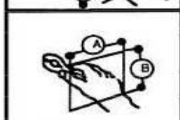
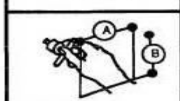
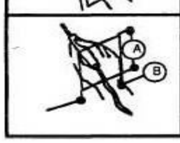
1.7.2.4.9 Visual requirements and the intricacy of the tasks

1.7.2.4.10 Packaging of items and elements behind the access

1.7.2.4.11 Mounting of items, units, and elements behind the access

1.7.2.4.12 Hazards in using the access

1.7.2.4.13 Size, shape, weight, and clearance requirements for logical combinations of human appendages, tools, and units that will enter the access

OPENING DIMENSIONS	DIMENSIONS (IN MM) A	B	TASK
	110	120	USING COMMON SCREWDRIVER, WITH FREEDOM TO TURN HAND THROUGH 180°.
	130	115	USING PLIERS AND SIMILAR TOOLS.
	135	155	USING "T" HANDLE WRENCH, WITH FREEDOM TO TURN HAND THROUGH 180°
	270	200	USING OPEN-END WRENCH, WITH FREEDOM TO TURN WRENCH THROUGH 60°.
	120	155	USING ALLEN-TYPE WRENCH WITH FREEDOM TO TURN WRENCH THROUGH 60°.
	90	90	USING TEST PROBE.

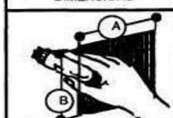
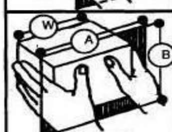
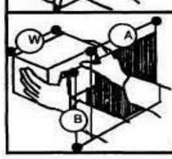
OPENING DIMENSIONS	DIMENSIONS (IN MM) A	B	TASK
	110	120	GRASPING SMALL OBJECTS (UP TO 50mm WIDE) WITH ONE HAND.
	W+45	125*	GRASPING LARGE OBJECTS (50mm OR MORE WIDE) WITH ONE HAND.
	W+75	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH HANDS EXTENDED THROUGH OPENINGS UP TO FINGERS.
	W+150	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO WRISTS.
	W+150	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO ELBOWS.

FIGURE 58. Access Opening Dimensions

1.7.2.5 Arm and Hand Access. Arm and hand access designs shall provide openings that are sized and located to permit the required adjustment or handling; openings shall provide an adequate view of the item being manipulated.

1.7.2.5.1 *Reach Access Dimensions and Shape*. The dimensions of access openings shall be not less than those shown on Figure 59. Allowances shall be made for the clearance of the maintainer's hand, applicable handwear and clothing.

1.7.2.6 Access to Test Points. Test points shall be located on surfaces or behind accesses which may be easily reached or readily operated when the equipment is fully assembled and installed. (5.9.16.4)

1.7.2.6.1 *Minimum Clearance*. Test points shall be located so that a minimum clearance of 19 millimeters (0.75 inch) is provided when only finger control is required, and 75 millimeters (3.0 inches) is provided when a gloved hand must be used. (5.9.16.6)

1.7.2.7 Connector Spacing. Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting. (5.9.15.7)

1.7.2.7.1 *Space between Adjacent Connectors*. Space between adjacent connectors, or between a connector and any adjacent obstructions, shall be compatible with the size and shape of the plugs, and the type of clothing worn by the maintainer (e.g., cold weather handwear, CBRNE gloves). (5.9.15.7.1)

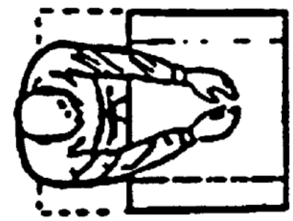
1.7.2.7.2 *Bare Finger Operation*. For bare finger operation, space between adjacent connectors shall be not less than 25 millimeters (1.0 inch), except where connectors are to be sequentially removed and replaced and 25 millimeters (1.0 inch) clearance is provided in a swept area of not less than 270 degrees around each connector at the start of its removal/replacement sequence. (5.9.15.7.2)

1.7.2.7.3 *Gloved Finger Operation*. Space between adjacent connectors shall be not less than 32 millimeters (1.25 inches) if the connector is to be operated with gloved fingers, 64 millimeters (2.5 inches) if the connector must be gripped firmly, and 75 millimeters (3.0 inches) if the connector is operated with mittened hands. (5.9.15.7.3)

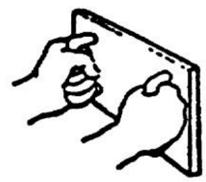
1.7.2.7.4 *Measuring Spacing*. Spacing shall be measured from the outermost portion of the connector, i.e., from the backshell, strain relief clamp, dust cover, or EMI/RFI shield. (5.9.15.7.4)

Minimal two-hand access opening without visual access

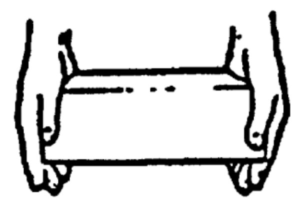
Reaching with both hands to depth of 150 to 490 mm (6.0 to 20 in)		
Light clothing:	Width:	200 mm (8.0 in) or the depth of reach [1/]
	Height:	125 mm (5.0 in)
Arctic clothing:	Width:	150 mm (6.0) plus ¾ the depth of reach
	Height:	180 mm (7.0 in)
Reaching full arm's lengh (to shoulders) with both arms:		
	Width:	500 mm (20 in)
	Height:	125 mm (5.0 in)



Inserting box grasped by handles on the front:		
13 mm (0.5 in) clearance around box, assuming adequate clearance around handles		

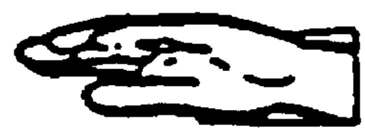


Inserting box with hands on the sides:		
Light clothing:	Width:	Box plus 115 mm (4.5 in)
	Height:	125 (5.0 in) mm or 13 mm (0.5 in) around box [1/] [2/]
Arctic clothing:	Width:	Box plus 180 mm (7.0 in)
	Height:	215 mm (8.5 in) or 15 mm (0.6 in) around box [1/] [2/]



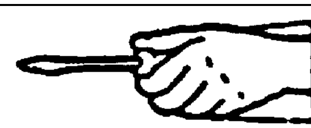
Minimal one-hand access opening without visual access

	Height	Width
Empth hand, to wrist:		
Bare hand, rolled	95 mm (3.75 in) sq or dia	
Bare hand, flat	55 mm (2.0 in)	100 mm (4.0 in) or 100 mm (4.0 in) dia
Glove or mitten	100 mm (4.0 in)	150 mm (6.0 in) or 150 mm (6.0 in) dia
Artcic mitten	125 mm (5.0 in)	165 mm (6.5 in) or 165 mm (6.5 in) dia



Clenched hand, to wrist:		
Bare hand	95 mm (3.75 in)	125 mm (5.0 in) or 125 mm (5.0 in) dia
Glove or mitten	115 mm (4.5 in)	150 mm (6.0 in) or 150 mm (6.0 in) dia
Arctic mitten	180 mm (5.0 in)	215 (8.5 in) mm or 215 mm (8.5 in) dia

Hand plus 1 in (25 mm) dia object, to wrist:	
Bare hand	95 mm (3.75 in) sq or dia
Gloved hand	150 mm (6.0 in) sq or dia
Arctic hand	180 mm (7.0 in) sq or dia



Hand plus object over 1 in (25 mm) in dia, to wrist:	
Bare hand	45 mm (1.75 in) clearance around object
Glove or mitten	64 mm (2.5 in) clearance around object
Arctic mitten	90 mm (3.5 in) clearance around object

FIGURE 59. Arm and Hand Access Dimensions

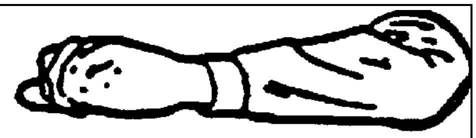
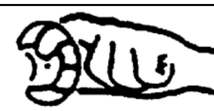
Arm to elbow:			
Light clothing	100 mm (4.0 in)	115 mm (4.5 in)	
Arctic clothing	180 mm (7.0 in) sq or dia		
With object	Clearances as above		
Arm to shoulder:			
Light clothing	125mm (5.0 in) sq or dia		
Arctic clothing	215 mm (8.5 in) sq or dia		
With object	Clearances as above		
Minimal finger access to first joint			
Push button access:			
Bare hand	32 mm (1.25 in) dia		
Gloved hand	38 mm (1.5 in) dia		
			
Bare hand	object plus 50 mm (2.0 in)		
Gloved hand	object plus 65 mm (2.5 in)		
NOTES:			
[1/] Whichever is larger.			
[2/] If hands curl around bottom, allow an extra 38 mm (1.5 in) for light clothing and 75 mm (3.0) for arctic clothing.			

FIGURE 59. Arm and Hand Access Dimensions - Continued

1.7.2.8 Connector Spacing. Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting. (5.9.15.7)

1.7.2.8.1 *Space between Adjacent Connectors*. Space between adjacent connectors, or between a connector and any adjacent obstructions, shall be compatible with the size and shape of the plugs, and the type of clothing worn by the maintainer (e.g., cold weather handwear, CBRNE gloves). (5.9.15.7.1)

1.7.2.8.2 *Bare Finger Operation*. For bare finger operation, space between adjacent connectors shall be not less than 25 millimeters (1.0 inch), except where connectors are to be sequentially removed and replaced and 25 millimeters (1.0 inch) clearance is provided in a swept area of not less than 270 degrees around each connector at the start of its removal/replacement sequence. (5.9.15.7.2)

1.7.2.8.3 *Gloved Finger Operation*. Space between adjacent connectors shall be not less than 32 millimeters (1.25 inches) if the connector is to be operated with gloved fingers, 64 millimeters (2.5 inches) if the connector must be gripped firmly, and 75 millimeters (3.0 inches) if the connector is operated with mittened hands. (5.9.15.7.3)

1.7.2.8.4 *Measuring Spacing*. Spacing shall be measured from the outermost portion of the connector, i.e., from the backshell, strain relief clamp, dust cover, or EMI/RFI shield. (5.9.15.7.4)

1.8 Vehicle Seating

1.8.1 **General.** The system shall be designed such that seating allows the user population to perform their mission functions without degradation of their performance capability in alertness, cognition, strength, or dexterity and without significant or lasting pain or injury. (5.10.3.2.4)

1.8.1.1 Operator Seating Dimensions and Clearances. Vehicle operator seating dimensions and clearances shall be in accordance with Figure 41, Figure 42, and Table XXX, as applicable. (5.6.2.1)

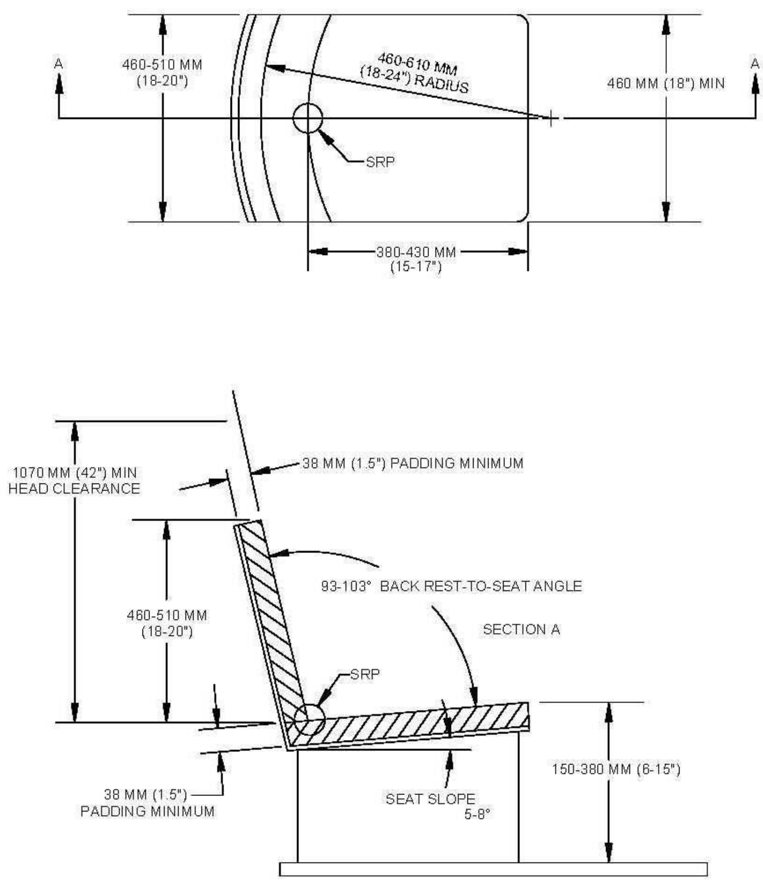


FIGURE 41. Dimensions for Vehicle Operator's Seat

TABLE XXX. Recommended Clearances around Vehicle Operator's Station to Accommodate a Soldier Dressed in Arctic Clothing

A. Elbow (dynamic)	91 cm (36 in)
B. Elbow (static)	71 cm (28 in)
C. Shoulder	58 cm (23 in)
D. Knee width (minimum)	46 cm (18 in)
E. Knee width (optimum)	61 cm (24 in)
F. Boot (provide adequate clearance to operate brake pedal without inadvertent accelerator operation)	15 cm (6.0 in)
G. Pedals (minimum)	5.0 cm (2.0 in)
H. Boot (provide adequate clearance to operate accelerator without interference by brake pedal)	15 cm (6.0 in)
1. Head (seat reference point (SRP) to roof line)	107 cm (42 in)
2. Abdominal (seat back to steering wheel)	41 cm (16 in)
3. Front of knee (seat back to manual controls on dash)	74 cm (29 in)
4. Seat depth (SRP to front edge of seat pan)	41 cm (16 in)
5. Thigh (underside of steering wheel to seat pan)	24 cm (9.5 in)
6. Seat pan height	38 cm (15 in)
7. Boot (front of seat pan to heel point of accelerator)	36 cm (14 in)
8. Minimum mitten clearance around steering wheel	8.0 cm (3.0 in)
9. Knee-leg-thigh (brake/clutch pedals to lower edge of steering wheel)	66 cm (26 in)
NOTE: 1. See Figure 42.	

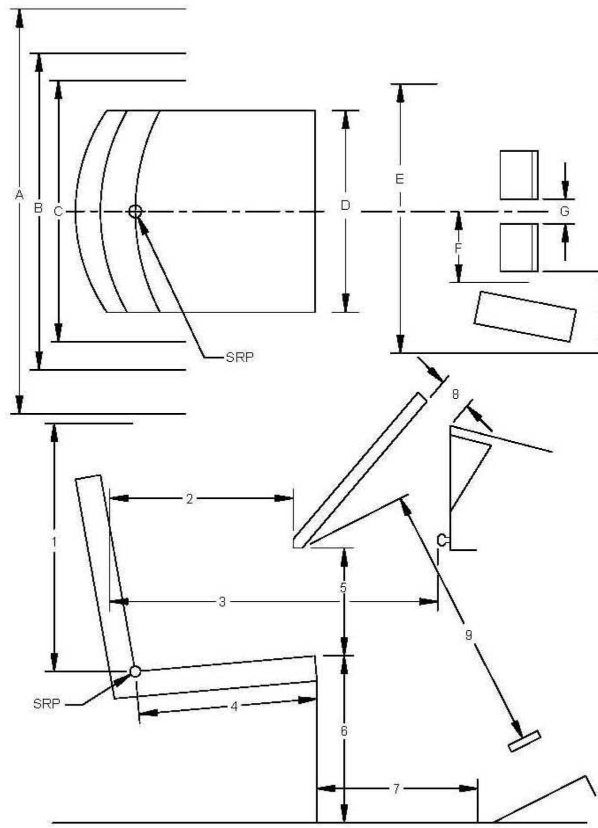


FIGURE 42. Measurements for Clearances around Equipment

1.8.1.2 Adjustable Dimensions. Seats, restraint systems, safety harnesses, belts, controls or any equipment that must be adjusted for the comfort or performance of the individual user shall be adjustable for the range of personnel using them. (5.8.4.1.5)

1.8.1.2.1 *Vertical Adjustment*. Vertical adjustment of a seat to a higher position shall also increase leg room and footrest angle; seats shall adjust at least 15 centimeters (6.0 inches) in the fore-aft direction. (5.6.2.2)

1.8.1.2.2 *Back-Rest*. The seat back-rest angle shall not be more than 110 degrees from horizontal. If only the lumbar area is supported, the back-rest angle of tilt shall be 95 to 100 degrees for erect operators. (5.6.2.4)

1.8.1.2.2.1 The backrest shall engage the lumbar and thoracic regions of the back, and support the torso in such a position that the user's eyes can be brought to the "Eye Line" with no more than 8 centimeters (3.0 inches) of forward body movement. The backrest width shall be 30 to 36 centimeters (12 to 14 inches). (5.10.3.2.8)

1.8.1.3 Seat Pan and Vertical Adjustment. Seat pan and vertical adjustment shall have an adjustable height of 38 to 54 centimeters (15 to 21 inches) in increments of no more than 3.0 centimeters (1.0 inch) each (5.10.3.2.7)

1.8.1.3.1 If the seat height exceeds 53 centimeters (21 inches), a footrest shall be provided.

1.8.1.3.2 The seat pan shall have a 0- to 7.0-degree adjustable tilt rearward, be between 38 and 46 centimeters (15 and 18 inches) wide and not more than 40 centimeters (16 inches) deep.

1.8.1.3.3 Where exclusive use by male personnel is specified (see 6.2), the adjustable height of 40 to 54 centimeters (16 to 21 inches) shall be used.

1.8.1.4 Stool Seating. Stools may be used for temporary seating, especially where the user frequently moves from a sitting to standing posture. Stool heights shall range from 711 to 813 millimeters (28 to 32 inches) from the floor to the top of the seat. (5.10.3.4.8)

1.8.1.5 Seat Padding. Seat padding shall be designed to support adequate blood flow to and from the legs by precluding “pinching off” (by weight or pressure) of nerves. (5.6.2.5)

1.8.1.5.1 Seat padding shall be designed to provide protection from bruising.

1.8.1.5.2 Seat padding shall be resilient enough to keep the operator’s body from contacting the seat bottom during the loading environments predicted for the vehicle.

1.8.1.5.3 Seat cushions shall meet crashworthy compliance.

1.8.1.5.4 Padding shall maintain effectiveness when subjected to environmental conditions (i.e., temperature, humidity, sand/dust, etc.).

1.8.1.6 Safety Restraints. When specified by contract, safety restraints shall be installed in accordance with operational requirements. (5.6.2.6)

1.8.1.7 Head Restraints. For occupant vehicles, the headrest shall be attached to the seat bucket so that it moves with the seat bucket during stroking of the energy absorption mechanism so as to support and protect the head. (5.6.2.7)

1.8.1.7.1 The headrest shall be contoured to provide energy absorption qualities to minimize whiplash injuries for the desired range of the expected, clothed, occupant population.

1.8.1.7.2 The headrest cushioning material shall also be resilient, durable, comfortable, and will not lump during use.

1.8.1.7.3 The headrest shall not interfere with the ingress or egress of an occupant wearing body armor.

1.8.1.8 Footrests. Whenever the users must work for extended periods in seats higher than 46 centimeters (18 inches) footrests shall be provided. Footrests, where provided, shall contain nonskid surfaces. Footrest inclination shall be 25 to 30 degrees. (5.10.3.2.12)

1.8.1.9 Cushioning and Upholstery. Where applicable, both the backrest and seat shall be cushioned to protect occupants from bottoming-out in seated operations. Upholstery shall be durable, nonslip, and porous. (5.10.3.2.9)

1.9 Weapon Systems

1.9.1 **Projectile Handling**. The system's weapons systems shall be operable by the full range of operators as specified in the contract.

1.9.1.1 Projectile Storage. The ready rack shall be designed so that several different types of ammunition can be stowed and removed without shifting other rounds and to minimize interference with the work area. Means shall be provided to prevent stowed projectiles from dropping or impacting each other when the vehicle is moving or when the gun is fired. The design shall provide for easy stowage and removal of ammunition by hoist or manual means. (5.13.3.1.1)

1.9.1.2 Handling. Particular attention shall be devoted to stowing ammunition when manual handling is required so that the gun may be loaded safely, rapidly, and effectively. Projectiles shall be stowed with their noses pointing away from the breech so that both loader and projectile are oriented correctly when positioning the rounds in the ramming trough. (5.13.3.1.2)

1.9.1.3 Projectile Transfer. Unobstructed workspace shall be provided for transferring the projectiles from outside the vehicle to the ready rack and from the ready rack to the breech. Provisions shall be made for disposing of empty shell cases in vehicles using fixed and semi-fixed ammunition. (5.13.3.1.3)

1.9.1.4 Ammunition Stowage Racks. Ammunition stowage racks, whether loaded or empty, shall not impede escape from the crew compartment, obstruct access to controls, obscure displays, or interfere with the footing of crewmembers; and they shall be located so personnel can remove and replace ammunition from the stowage rack without striking any protrusions. (5.13.3.1.5)

1.9.1.4.1 *Ready Racks*. Where ready racks are located to the rear of the gun breech, sufficient distance shall be provided between the rack and the breech to accommodate the longest round anticipated for use plus the thickness of the

95th percentile gloved hand, and an additional 50 millimeters (2.0 inches) channel.

1.9.1.4.2 *Floor and Hull*. Floor and hull stowage tube-type ammunition racks shall be spring loaded so that stowed rounds will travel 50 millimeters (2.0 inches) out of the rack when the latching mechanism is released. Where spring loading is not feasible, the end of the tube shall be recessed to facilitate gripping by hand.

1.9.1.4.3 *Latching Mechanisms*. Ammunition rack latching mechanisms shall be of a quick release design which requires no more than 53 Newtons (12 pounds of force) of force to operate, and be free of sharp edges or protrusions which can snag clothing or injure personnel during entrance, exit, and movement within the vehicle. The latching mechanism shall not allow distortion, bursting, or rupturing of the round or cartridge case and shall prevent damage to the internal components of the missile or rounds.

1.9.2 **Armament**

1.9.2.1 Primary Armament. The system shall be designed such that the primary armament complies with the following requirements: (5.13.3.2.1)

1.9.2.1.1 Provision shall be made to minimize vibrations of the gunner's sight from the shock of loading main armament.

1.9.2.1.2 A breech weighing over 22.5 kilograms (50 pounds) shall not be considered manually removable.

1.9.2.1.3 For manual breech operation, the operating force shall not exceed 130 Newtons (29 pounds of force) of force for one-handed operation and 220 Newtons (50 pounds of force) of force for two-handed operations.

1.9.2.1.4 The main armament recoil mechanism shall be capable of being exercised by crew personnel without damage to the system or danger of injury to personnel.

1.9.2.1.5 Casing ejection shall not endanger personnel or equipment. Space shall be provided to store expended casings within the fighting compartment or a means shall be incorporated into the design to allow disposal of these casings by another method.

1.9.2.2 Secondary Armament. The system shall be designed such that the secondary armament complies with the following requirements: (5.13.3.2.2)

1.9.2.2.1 The secondary weapon shall be capable of being mounted on the vehicle by crewmembers from a natural working position with the weapon fully assembled. The secondary weapon shall be capable of being removed or replaced without the use of tools. The number of turns required for installing or removing threaded fastening devices shall be minimized.

1.9.2.2.2 *Assembly and Disassembly*. The secondary armament shall be designed such that the barrels are not capable of incorrect assembly and are capable of being changed from the inside of the fighting compartment without affecting the boresight.

1.9.2.2.3 *Loading.* The weapon shall be capable of being loaded by a 5th percentile female and 95th percentile male hand in both the vehicle and the ground mount.

1.9.2.2.4 Expended brass and links shall be caught by a spent brass container or be ejected outside the fighting compartment. The trajectory and path of the ejected casings shall be such that ejection will not injure a crewmember, interfere with crew operations, or affect other equipment. The weapon design shall permit the central 90 percent of suitably clothed and equipped users to remove jammed cases simply and quickly without disassembly of the weapon and without endangering the hand.

2 System Safety

Description: The design features and operating characteristics of a system that serve to minimize the potential for human or machine errors or failure that cause injurious accidents.

2.1 Warnings, Hazards and Safety.

2.1.1 General. The design shall reflect the safety related human engineering criteria specified herein. The order of precedence (in descending order) for satisfying system safety requirements shall be as follows: (5.7.1**)**

- Design for minimum risk
- Incorporate safety devices
- Provide warning devices
- Provide procedures and training

2.2 Egress and Ingress

2.2.1 **Hatches**. The system shall have hatches that open with a single motion of the hand or foot. (5.11.2.4)

2.2.1.1 Force Requirements. The system design shall require no more than 90 Newtons (20 pounds) of force when a handle is used for unlocking a hatch.

2.2.1.2 Overhead Hatches. The system design shall require no more than 220 Newtons (50 pounds) of force for opening and closing hatches placed in the overhead position while operators are equipped with gear. (5.11.2.4.2)

2.2.1.3 Dimensions. The system's hatches shall accommodate suitably equipped and clothed user personnel in terms of limiting dimensions for location and operability, and clearance dimensions for size and passage factors. (5.11.2.4.3)

2.2.2 **Whole-Body Access**. The system's hatches shall be designed to permit for ingress and egress of the full population of user with gear.

2.2.2.1 Access Opening Requirements. The system's hatches shall be designed so that dimensions for rectangular access openings for body passage are not less than those dimensions shown in Figure 84. In the event that personnel are required to wear Protective Personnel Equipment (PPE), hatch dimensions must be modified to incorporate the additional PPE dimensions.

2.2.2.2 Minimum Circular Hatch Dimensions. They system's hatches shall be designed so that the diameter of any circular hatch is not less than 76 centimeters (30 inches). In the event that personnel are required to wear Protective Personnel Equipment (PPE), hatch dimensions must be modified to incorporate the additional PPE dimensions. (5.11.2.5.2)

2.2.2.3 Minimum Oval Hatch Dimensions. The system's hatches shall be designed so that the diameter of oval hatches is not less than 43 and 71 centimeters (17 and 28 inches). In the event that personnel are required to wear Protective Personnel Equipment (PPE), hatch dimensions must be modified to incorporate the additional PPE dimensions. (5.11.2.5.3)

2.2.2.4 Foot Rests or Steps for Top Access**.** The system shall provide appropriate foot rests or steps when a "step down" through a top access exceeds 69 centimeters (27 inches). (5.11.2.5.5)

2.2.2.5 Doorway Width. The system's doorway openings shall be not less than 1.4 meters (54 inches) wide and 2.0 meters (77 inches) high if it is necessary for two or more people to use a doorway simultaneously. (5.11.2.3.4)

2.2.2.6 Personnel Protective Equipment (PPE). The system shall allow adequate clearance for personnel wearing bulky protective clothing and carrying equipment as specified by contract PPE provisions and equipment lists. (5.11.2.2.3)

2.2.2.7 Minimum Passage Widths. To allow people to move without restriction, the minimum widths given in Figure 83 shall be observed.

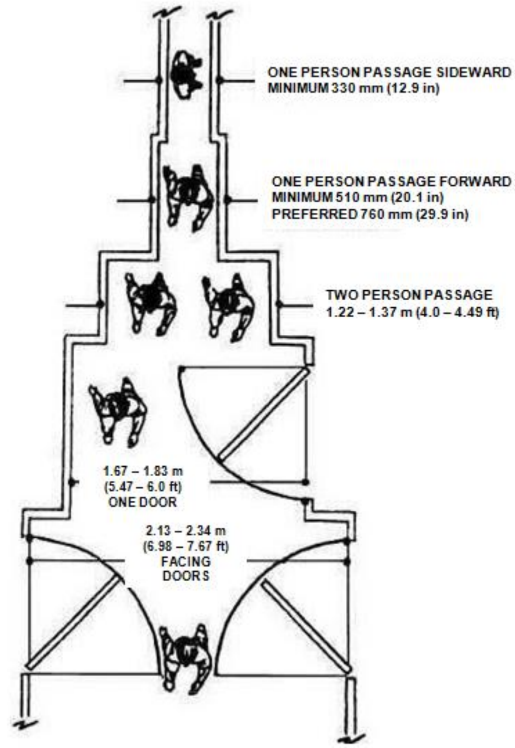
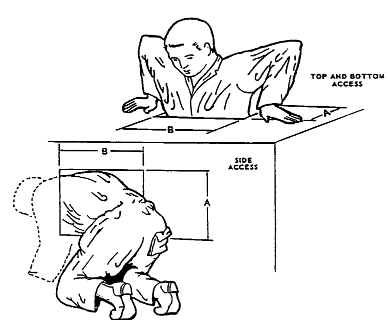


FIGURE 83. Walkway and Passageway Dimensions.



Dimensions	A. Depth		B. Width	
Clothing	**Light**	**Bulky**	**Light**	**Bulky**
Top and bottom access	330 mm (13 in)	410 mm (16 in)	580 mm (23 in)	690 mm (27 in)
Side access	660 mm (26 in)	740 mm (29 in)	760 mm (30 in)	860 mm (34 in)
NOTE: 1. Dimensions shown based on male data.				

FIGURE 84. Whole-Body Access Opening

2.3 Emergency Egress

2.3.1 **Emergency Exits/Hatches**. The system shall be designed to allow emergency egress of all occupants, including any who must carry essential equipment or wear bulky protective clothing, without danger of injuring personnel or damaging the equipment they carry. (5.11.2.1.4)

2.3.1.1 Total Crew Egress. The system's design shall allow for emergency egress that does not exceed 20 seconds for total crew egress.

2.3.1.2 Exit Door/Hatch Opening. The system's emergency doors/hatches shall be opened in 3.0 seconds or less.

2.3.1.3 Emergency Doors/Exits. Emergency doors and exits shall permit one person egress in 5.0 seconds or less. (5.7.6.2)

2.3.1.4 Operating Force. The system shall be designed so that emergency exit hatches/doors are unobstructed and simple to operate and require 44 to 133 Newtons (10 to 30 pounds of force) of operating force to open.

2.4 Vehicle Visibility

2.4.1 **Operator Visual Field**. The system shall accommodate the operator with forward visibility through a lateral visual field of at least 180 degrees and preferably 220 degrees. (5.6.5.1)

2.4.2 **Ground View.** (5.6.5.2)

2.4.2.1 Forward Visibility. The design shall enable the operator, in the normal operating position, to view the ground starting at a minimum of 3.0 meters (10 feet) in front of the vehicle and continuing to all distances beyond. Mirrors or driver's vision enhancers (DVE) may be used to meet this requirement, if tactical requirements permit. (5.6.5.2.1)

2.4.2.2 Upward Visibility. Upward visibility shall extend to not less than 15 degrees above the horizontal. (5.6.5.2.2)

2.4.2.3 Field Restriction. The visual field restriction shall not exceed 20 degrees of subtends with one eye. (5.6.5.2.3)

2.4.3 **Rear View (Vehicle).** The system shall be designed to permit the operator to view the rear of the vehicle (directly or by use of mirrors or DVE) in order to observe the load and to facilitate trailer attachment and backing maneuvers. (5.6.5.3.1)

2.4.4 **Exterior Lighting Systems.** (5.6.5.7)

2.4.4.1 Headlights. They system shall include headlights which permit for the choice of either upper (bright) or lower (dim) distribution of light. Headlights shall provide illumination to at least 150 meters (492 feet) of roadway in front of the vehicle or equipment under clear atmospheric conditions when the upper headlight beam is in use. Headlights shall provide measures to ensure that regular (bright or dim) headlights cannot be turned on when the blackout system is on. (5.6.5.7.1)

2.4.4.2 Parking and Side Lights. The system shall include parking and side lights to indicate the location of the vehicle or equipment. (5.6.5.7.2)

2.4.4.3 Tail Lights. The system shall include tail lights to indicate the rear of the vehicle or equipment. (5.6.5.7.3)

2.4.4.4 Brake Lights. The system shall include brake lights to indicate the vehicle is stopping. (5.6.5.7.4)

2.4.4.5 Turn Signals. The system shall include turn signals to indicate the vehicle is turning. (5.6.5.7.5)

2.5 General Equipment-Related Hazards

2.5.1 **Protection from Hazards during Equipment Access.** The system's equipment items shall be located and mounted so that access to them can be achieved without danger to personnel from electrical, thermal, mechanical, chemical, radiological, or other hazards. (5.7.7.4)

2.5.1.1 Access to High-Voltage Potential. Doors, covers, or lids that provide access to voltages in excess of 500 volts or allow exposure to microwave and radio frequency radiation in excess of 300 kiloHertz shall have non-bypassable interlocks.

2.5.1.2 Ground Potential. The system's equipment shall be designed so that all external parts, other than antenna and transmission line terminals, will be at ground potential. (5.7.9.1.13)

2.5.1.2.1 All external metal parts which users ordinarily touch shall be at ground potential. There shall be a provision for discharging high-voltage circuits and capacitors to 30 volts within 2.0 seconds before maintenance personnel work on them.

2.5.1.2.2 Locations for radio antennas shall be selected to minimize the possibility of radio frequency hazards to personnel. Antennas and waveguides shall be at ground potential except for the radio frequency energy meant to be radiated.

2.5.2 **Edge Rounding.** The system shall be designed so that all exposed edges and corners are rounded to a radius not less than 0.75 millimeters (0.03 inches). Sharp edges and corners that can present a personnel safety hazard or cause equipment damage during usage shall be suitably protected or rounded to a radius not less than 13 millimeters (0.51 inches). (5.7.7.6)

2.5.3 **Guards.** The system design shall incorporate guards around all exposed rotating equipment, as well as other dangerous situations (e.g., hot or cold points, exposed electrical wiring, crushing points). (5.10.2.4)

2.5.4 **Recessed Handles.** The system shall be designed so that handles located in crewstations are recessed whenever practicable, to eliminate projections on the surface. If handles cannot be recessed, they shall be configured, located, and oriented to preclude injuring personnel or entangling clothing or equipment. (5.10.2.5)

2.5.5 **Protrusions on Equipment Surfaces.** The system shall be designed to minimize protrusions from equipment surfaces. Flat-head screws shall be used where possible; otherwise, pan-head screws shall be used. If small projecting parts (such as toggle switches or small knobs) must be mounted on a front panel, recessed mountings shall be considered. (5.7.9.2.3)

2.5.6 **Nonslip Coating.** The system shall provide nonslip coating on surfaces where conditions warrant special precaution or are elevated.

2.6 Cables and Connectors

2.6.1 **Error-Proof Design.** The system's design shall incorporate error-proofing in equipment mounting, installing, interchanging, connecting, and operating. (5.9.1.11)

2.6.1.1 Physical features. The system's equipment shall include physical features (e.g., supports, guides, size or shape differences, fastener locations, alignment pins) that prevent improper mounting. (5.9.1.11.1)

2.6.1.2 Connectors. The system's connectors serving the same or similar functions shall be designed to preclude mismating or misalignment. (5.9.1.11.5)

2.6.1.3 Keying. The system's connector design shall be such that it will be impossible to insert a wrong plug into a receptacle or to insert a plug into the correct receptacle the wrong way. (5.9.15.2)

2.6.2 **Cable Routing**. The system's cable routing shall not obstruct visual or physical access to equipment for operation or maintenance. (5.9.14.4)

2.6.2.1 Avoid Misuse. The system's interconnecting cables shall be routed to minimize the possibility of their use as handholds or steps. (5.9.14.4.1)

2.6.2.2 Stow Cables Out of the Way. All interconnecting cables shall be routed neatly (clamped at approximately 300-millimeter (12-inch) intervals) to eliminate droop and unnecessary loops so that personnel are not apt to use them as handholds or steps. If neat routing is not feasible, cables shall be covered by protective guards.

2.6.3 **Cable Identification.** The system's cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate. All receptacle wires and cables shall be uniquely identified with distinct color or number codes. Color-coded wires shall be color coded over the entire length of the wire. Number codes shall be repeated every 508 millimeters (20 inches) over the entire length of the wire. (5.9.14.7)

2.7 Warning Labels

2.7.1 **Caution and Warning Labels for Safety and Hazards.** The system shall be designed so it does not present hazards to personnel or equipment. If hazards are unavoidable, warning signs or labels shall be displayed prominently. (5.4.8.5)

2.7.1.1 Warning Labels and Placards. The system shall be designed so that warning labels or placards (signs) are attached or adjacent to any equipment that presents a hazard to personnel (e.g., high voltage, heat, toxic vapors, explosion, radiation, or other bodily hazards). Facility placards and warning labels on equipment not covered under this section shall be in accordance with ANSI Z535.2. (5.7.2.1)

2.7.1.2 Warning Content. Warning labels and placards shall explicitly describe all of the following: the hazard, how to avoid the hazard, and the consequences of not avoiding the hazard. (5.7.2.1.2)

2.7.1.3 Signal Word. Warning placards or labels shall display the appropriate signal word (DANGER, WARNING, CAUTION, or NOTICE) formatted in accordance with ANSI Z535.2 or ANSI Z535.4, respectively. (5.7.2.5)

2.7.1.3.1 DANGER shall be used when failure to avoid the hazard will almost certainly result in serious injury or death. Danger is reserved for the most serious hazards only. (5.7.2.5.1)

2.7.1.3.2 WARNING shall be used when failure to avoid the hazard may result in serious injury or death. (5.7.2.5.2)

2.7.1.3.3 CAUTION shall be used when failure to avoid the hazard may result in minor or moderate injury. 5.7.2.5.3

2.7.1.3.4 NOTICE may be used when failure to obey precautions may result in system damage or to indicate important information not directly associated with a hazard or hazardous situation. (5.7.2.5.4)

2.7.1.4 Lift Requirement Markings. When equipment must be transported by more than one person, the lifting requirement (2-man, 3-man, machinery, etc.) shall be distinctly marked. (5.7.2.6.3)

2.7.1.5 "NO-STEP" Markings. "NO STEP" markings shall be provided when necessary to prevent injury to personnel or damage to equipment.. (5.7.2.6.4)

3 Health Hazards

Description: Consideration in the design features and operating characteristics of a system that create significant risks of bodily injury or death; prominent sources of health hazards include acoustics energy, chemical substances, biological substances, temperature extremes, radiation energy, oxygen deficiency, shock (not electrical), trauma and vibration. (Reference)

3.1 Operations and Maintenance in Environmental Extremes

3.1.1 **Environmental Range.** The system shall be designed to accommodate the full range of environmental extremes to which the system will be subjected and meet all specified performance over that range. Environmental conditions and extremes and their impact upon human performance and design shall be specified in the design documentation. Where performance standards vary over the range of environmental conditions and extremes, the system shall meet performance standards for each environmental condition. (5.5.1.)

3.1.1.1 Mitigations. When deviations from the stated tolerable conditions are necessary, consequences shall be mitigated in design to prevent adverse effects. Mitigating actions taken to prevent adverse effects of environmental conditions shall be approved by the cognizant Government technical authority. (5.5.1.4)

3.1.1.2 General. Where the system will be used in or otherwise be exposed to precipitation, direct sunlight (solar loading), dusty conditions, or other climatic effects during normal operations and maintenance activities, the designer shall identify all adverse effects upon personnel and equipment; and to the extent possible, mitigate all identified adverse climate effects identified. (5.5.2.2.3)

3.1.1.3 Cold Weather Gear. The system shall accommodate for the use of cold-weather gear and other protective equipment for operations and maintenance conducted in temperatures below –12 °C (10.4 °F). (5.5.2.2.5)

3.2 Crew Compartment Heating, Cooling and Ventilation

3.2.1 **Heating.** The system shall provide crew compartments with a heating system capable of maintaining temperatures above 20 °C (68 °F) during occupancy when personnel are not wearing arctic clothing and exposure exceeds 3 hours. The heater shall achieve these requirements within one hour after the heater is turned on. (5.6.6.1.1)

3.2.2 **Arctic Conditions.** When arctic clothing is worn, cab heaters shall be capable of maintaining a reference temperature of not less than 5.0 °C (41 °F) at the minimum ambient design temperature with the vehicle moving at two-thirds maximum speed and the defrosters operating at maximum capacity. The reference temperature is measured 61 centimeters (24 inches) above the seat reference point of each operator/passenger position. (5.6.6.1.3)

3.2.3 **Hot Climate Operation.** The system shall be designed so that air flow rates for hot climate operation (temperatures above 32 °C (90 °F) are maintained between 4.2 and 5.7 m^3 (150 and 200 ft^3)/min/person unless air conditioning or individual (microclimate) cooling is provided. (5.6.6.2.2)

3.2.3.1 Air Temperature. The system shall be designed so that air temperatures around any part of the operator/passenger's body do not vary more than ±5.0 °C (±9.0 °F). (5.6.6.1.4)

3.2.4 **Ventilation.** The system shall provide outside fresh air to the crew compartments at minimum rate of 0.57 m^3 (20 ft^3)/min/person. (5.6.6.2.1)

3.2.4.1 Ventilation system. The system shall include a ventilation system capable of removing dust particles above five microns in diameter. (5.7.11.2)

3.2.5 **Air Velocity.** The system shall be designed so that air velocity at each person's head location is adjustable either continuously or with not less than three settings (OFF, LOW, and HIGH) from near zero to at least 120 meters (400 feet)/minute. (5.6.6.2.3)

3.3 Touch Temperatures

3.3.1 **Thermal Contact Hazard Exposure Limits.** The system shall be designed so that during normal operations, equipment does not expose personnel to surface temperatures greater than those shown in Table XXXI or less than 0 °C (32 °F). In the event that temperatures are exceeded, the system shall provide appropriate guards to avoid personnel contact with the unit. (Note: Surface temperatures induced by climatic environment are exempt from this requirement.) (5.7.6.9.1)

TABLE XXXI. Temperature Exposure Limits.

	Temperature limits		
Exposure	**Metal**	**Glass**	**Plastic or wood**
Momentary contact	60 °C (140 °F)	68 °C (154 °F)	85 °C (185 °F)
Prolonged contact or handling	49 °C (120 °F)	59 °C (138 °F)	69 °C (156 °F)

3.3.2 **Burn Hazards.** The system shall be designed so that surfaces requiring personnel touch that exceed the requirements of Table XXXI are shielded, insulated, relocated, or contain warning decals, signs, or labels. Figure 46 shows the burn criteria for human skin.

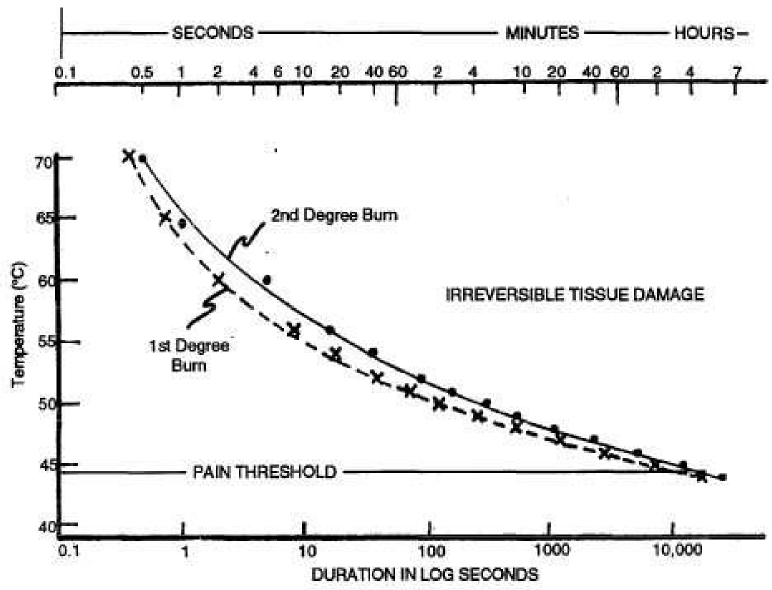


FIGURE 46. Burn Criteria for Human Skin.

3.4 Radiation, Electrical and Toxic Hazards

3.4.1 **Radiation.** The system shall protect the crew from exposure to Radio Frequencies to the limits as stated in Table XXXII and shown graphically in Figure 47. (5.7.7.2)

3.4.1.1 Radiation Limits. The system shall be designed to limit personnel exposure to Microwave, Radio Frequency, X, and Laser Radiation in accordance with MIL-HDBK-454. (5.7.9.5.4)

3.4.1.2 Nuclear Radiation. The system shall be designed so that personnel exposure to nuclear radiation does not exceed limits specified in accordance with 20 CFR 10. (5.7.9.5.6)

Table XXXII. Maximum Permissible Exposure (MPE) to Radio Frequency Electromagnetic Fields. [1/]

Frequency Range (MHz)	RMS Electric Field Strength (E) [2/] (V/m)	RMS Magnetic Field Strength (H) [2/] (A/m)	RMS Power Density (S) E–Field, H–Field (W/m^2)	Averaging Time [3/] $\|E\|^2$, $\|H\|^2$, or S (minutes)	
0.1 – 1.34	614	$16.3/f_M$	$(1000, 100000/f_M^2)$ [4/]	6	6
1.34 – 3.0	$823.8/f_M$	$16.3/f_M$	$(1800/f_M^2, 100000/f_M^2)$	$f_M^2/0.3$	6
3.0 – 30	$823.8/f_M$	$16.3/f_M$	$(1800/f_M^2, 100000/f_M^2)$	30	6
30 – 100	27.5	$158.3/f_M^{1.668}$	$(2, 9400000/f_M^{3.336})$	30	$0.0636 f_M^{1.337}$
100 – 300	27.5	0.0729	2	30	30
300 – 5000	–	–	$f/150$	30	
5000 – 15000	–	–	$f/150$	$150/f_G$	
15000 – 30000	–	–	100	$150/f_G$	
30000 – 100000	–	–	100	$25.24/f_G^{0.476}$	
100000 – 300000	–	–	100	$5048/[(9f_G-700)f_G^{0.476}]$	

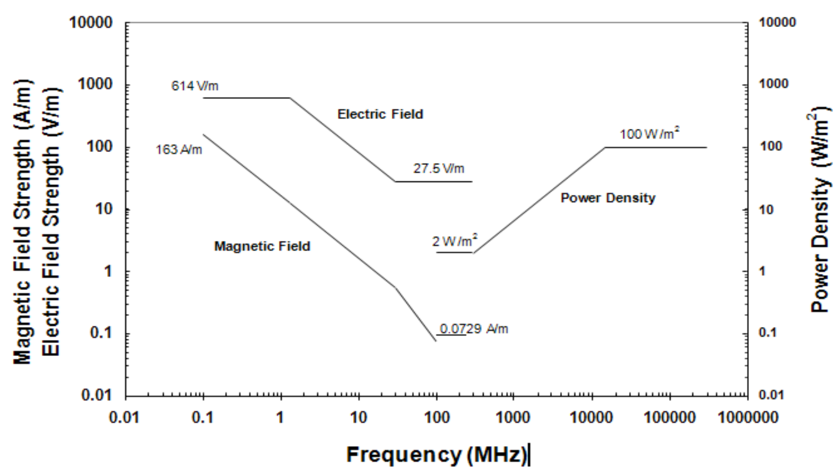
NOTES:

1/ f_M is the frequency in MHz; f_G is the frequency in GHz.

2/ For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the MPEs in the table. For non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the squares of the field strengths or averaging the power densities over an area equivalent to the vertical cross section of the human body (projected area), or a smaller area depending on the frequency (for further details please see IEEE C95.1), are compared with the MPEs in the table.

3/ The left column is the averaging time for $|E|^2$, the right column is the averaging time for $|H|^2$. For frequencies greater than 400 MHz, the averaging time is for power density S.

4/ These plane-wave equivalent power density values are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.



NOTES:

1. Illustrated to show whole-body resonance effects around 100 MHz.
2. Modified from IEEE C95.1.

FIGURE 47. Radio Frequency Electromagnetic Field Exposure Limits.

3.4.2 **Electrical Hazards.** The system shall be designed to treat electrical systems of 30 volts or more to be potential shock hazards and dangerous to personnel. Table XXXIII summarizes typical effects of various levels of electrical current. (5.7.9.1.1)

TABLE XXXIII. Shock Current Intensities and Their Probable Effects.

Current (milliamperes)		**Effects**
AC (60 Hz)	**DC**	
0 – 1.0	0 – 4.0	Perception
1.0 – 4.0	4.0 – 15	Surprise
4.0 – 21	15 – 80	Reflex action
21 – 40	80 – 160	Muscular inhibition
41 – 100	160 – 300	Respiratory block
Over 100	Over 300	Usually fatal

3.4.2.1 Electrical Currents. The system shall include provisions to protect personnel from exposure to electrical currents in accordance with Table XXXIV. (5.7.9.1.5)

TABLE XXXIV. Electrical Currents Exposure Limits for All Systems.

Frequency (Hz)	**Maximum current (ma) (AC + DC components combined)**
DC	40
15 – 2000	8.5
3000	13.5
4000	15
5000	16.5
6000	17.9
7000	19.4
8000	20.9
9000	22.5
>10000	24.3

3.4.3 **Toxic Hazards.** The system shall be designed so that personnel are not exposed to the concentrations of toxic substances in excess of the limits specified in either the DoD Occupational Safety and Health (OSH) standards or specialized standards applicable to military unique equipment, systems, or operations (including 29 CFR 1910, OSHA Standards, and also in the Federal Register). Critical contaminants include: Carbon Monoxide, Ammonia, Nitrogen Oxides, Sulphur Dioxide and Aldehydes (Methane). (5.7.9.4.1)

3.4.3.1 Carbon Monoxide (CO). The system shall not expose personnel to concentrations of CO that will result in COHb levels in their blood greater than 5.0 percent for all system design objectives and 10 percent for all other system performance limits (Table XXXV). (5.7.9.4.2)

TABLE XXXV. Constants for Predicting COHb Blood Content

Work effort scale	Work effort description	A value	B value
1	Sedentary	425	806
2		241	1421
3	Light work	175	1958
4		134	2553
5	Heavy work	109	3144

NOTE:

1. When using the equations to estimate the percent COHb blood levels for combat vehicle occupants, the following work stress levels shall be applied as appropriate: activities involving weapons fire: level 4; all other mission activities: level 3. An initial value of COHb = 1.0 percent shall be assumed for all estimates.

3.5 Noise

3.5.1 **Acoustical Energy and Noise.** The system shall provide personnel with an acoustical environment that will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade system effectiveness. (5.5.4.1)

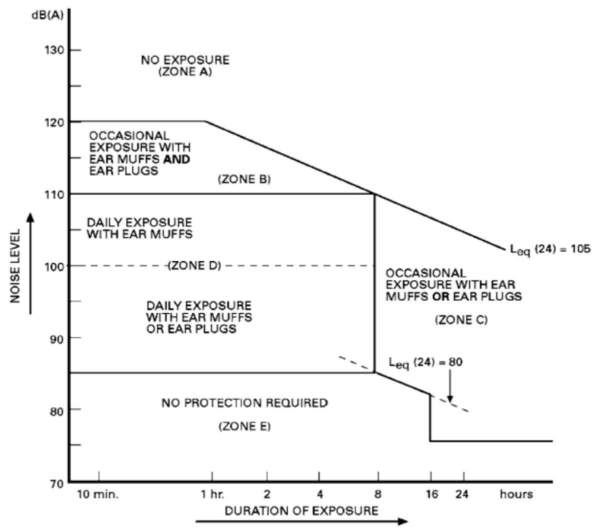
3.5.2 **Equipment and System Design.** The system shall be designed in accordance with MIL-STD-1474 Noise Limits. If any conflict is identified in interpretation or applicability between this document and MIL-STD-1474, it shall be resolved by the Government. The fact that a component which contributes to the overall noise may be Government furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein. (5.5.4.3)

3.5.3 **Hazardous Noise.** The system shall be designed so that equipment does not generate noise in excess of maximum allowable levels in accordance with MIL-STD-1474.

3.5.3.1 Personnel Hearing Protection. *Where* sustained noise levels cannot be maintained below 75 dBA (continuous), below 85 dBA (8.0-hour exposure), and below 140 dB peak SPL (impulse or impact), the system shall accommodate the wearing of personal hearing protection devices (ear plugs or ear muffs) within the context of mission activities.

3.5.3.2 General Hearing. The system's hearing protection devices shall be designed to permit for communications activities, listening (auditory surveillance) tasks, visual tasks, physical comfort in the operational environment, and any other considerations impacting the likelihood that the user would wear the personal hearing protection devices.

3.5.3.3 Hearing Protection Devices. The system shall incorporate personnel hearing protection devices in accordance with Figure 37 for maximum permissible daily and occasional noise exposure limits. (5.5.4.4.1)



NOTES:

1. Figure and description adapted from IMO Assembly Resolution A.468 (XII).
2. Zone A, Maximum exposure with protection: No personnel, even those wearing hearing protectors, shall be exposed to levels exceeding 120 dBA or to an Leq(24) (24-hour equivalent continuous sound level) exceeding 105 dBA.
3. Zone B, Occasional exposure: Only occasional exposure shall be allowed and both ear muffs and ear plugs shall be used unless the exposure duration is restricted to not more than 10 minutes when only ear muffs or plugs are required.
4. Zone C, Occasional exposure: Only occasional exposures shall be allowed and ear muffs or plugs shall be required.
5. Zone D, Daily exposure: If personnel routinely work with daily exposure in spaces with noise levels within Zone D, hearing protectors shall be worn.
6. Zone E, Maximum exposure without protection: For exposures of less than 8 hours, personnel without hearing protection shall not be exposed to noise levels exceeding 84 dBA. When personnel remain for more than 8 hours in spaces with a high noise level, an Leq(24) of 80 dBA shall not to be exceeded. Consequently, for at least a third of each 24 hours, the personnel shall be subject to an environment with a noise level not exceeding 75 dBA.

FIGURE 37. Permissible Noise Exposure Limits

3.5.3.4 The system's sound levels shall be no greater than 80 dBA when personnel noise exposure is continuous for a period of 24-hours or more. Any area where noise levels exceed 84 dBA shall be classified as a "High Noise Area."

3.5.3.5 The system shall incorporate hearing protectors that provide the noise attenuation at the ear as shown in Table XXV. Where the hearing protection levels in Table XXV can be met, noise cancelling headsets may also be used. (5.5.4.4.4)

TABLE XXV. Recommended Noise Attenuation from Hearing Protectors.

Hearing protection	Minimum attenuation
Ear plugs	20 dBA
Ear muffs	30 dBA
Ear plugs and ear muffs	35 dBA

3.6 Vibration and Shock

3.6.1 **Vehicular Whole-Body Vibration**. The following provisions apply to whole-body vibration, in accordance with ISO 2041 and ISO 5805, where the vibratory motions are limited to those transmitted to the human body as a whole through supporting surfaces. This includes the feet for the standing occupant, the buttocks, back, and feet for the seated occupant, and the supporting surface of the occupant lying on his or her back. The applicable frequency range is defined below: (5.5.5.1)

3.6.1.1 Motion Sickness (0.1 to 0.5 Hertz)

3.6.1.2 Health, Performance, Comfort and Perception (0.5 to 80 Hertz)

3.6.2 **Operational Environments.** The anticipated operational dynamic environment and exposure duration is required to determine the analysis method and threshold for whole-body vibration or shock. Table XXVII defines environment categories expected to occur during operation of military vehicles. For each category, the exposure duration determines the exposure threshold. These environments are associated with vibration occurring primarily in the frequency range of 0.5 Hertz and above. (5.5.5.1.2)

3.6.2.1 Mitigation of Whole-Body Vibration by Design. Vehicles shall be designed to control the transmission of whole-body vibration to levels that will permit safe and effective operation and maintenance.

3.6.2.2 ISO 2631 and Evaluation of Whole-Body Vibration and Shock. Evaluation of military vehicle vibration and its possible effects on health, performance, comfort, perception, and motion sickness shall be in accordance with ISO 2631 and associated amendments. The basic evaluation method shall be applied for all environment categories listed in Table XXVII.

3.6.2.3 Measurement of Whole-Body Vibration and Shock. Categories A and B, triaxial accelerations shall be measured at the interface between the human and the predominant vibration source. For standing occupants this is the floor or deck. For seated occupants, measurements shall be taken at the interface between the buttocks and seat support, usually a seat cushion (seat pan). Triaxial accelerations shall also be measured at the interfaces between the occupant and the seat back and foot support, particularly for assessing comfort and perception in accordance with ISO 2631. For Categories A and B, the acceleration time histories need to be sufficiently long so that a minimum of 5 to 10 complete cycles for the minimum frequency are obtained. For Category C, triaxial accelerations shall be measured on the occupant at the lower lumbar (L4) or as close as possible to the interface of the human and predominant impact source (e.g., seat cushion). If instrumentation locations other than at the lower lumbar are used, mathematical transfer functions shall be applied to appropriately translate between the impact force at the source and the human back. For statistical significance a minimum of 300 impact encounters is required. For additional detail on instrumentation, see ISO 2631-1 and ISO 5348.

TABLE XXVII. Operational Environment Types.

Category	Description of environment
A	The environment is classified as strictly vibration and can be characterized as oscillatory in nature (periodic).
B	The environment is classified as predominately vibration and can be characterized as oscillatory in nature (periodic) but also contains occasional shocks or transient vibration (aperiodic).
C	The environment may contain some underlying vibration, but is dominated by repeated or multiple shocks or transient vibration.

3.6.3 **Health.** In an effort to minimize or prevent adverse health effects or injury, the vehicle design shall be in accordance with the following requirements for the operational environment categories specified below: (5.5.5.1.3)

3.6.3.1 Category A: Vibration. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic evaluation method and the frequency weightings and multiplying factors for health. For exposures lasting 8.0 hours or less, the seat pan frequency weighted triaxial RMS accelerations in any orthogonal direction for any occupied space shall not fall within the zone labeled “Health Risks are LIKELY” as shown on Figure 40. Preferably the weighted accelerations shall fall within the “Minimal Risk to Health” zone. For exposures lasting greater than 8.0 hours, the seat pan frequency weighted triaxial RMS accelerations shall not exceed 0.315 m/s2 (see Figure 40). If the weighted accelerations fall within the “Caution Zone”, a warning to occupants shall be provided indicating the potential health risk.

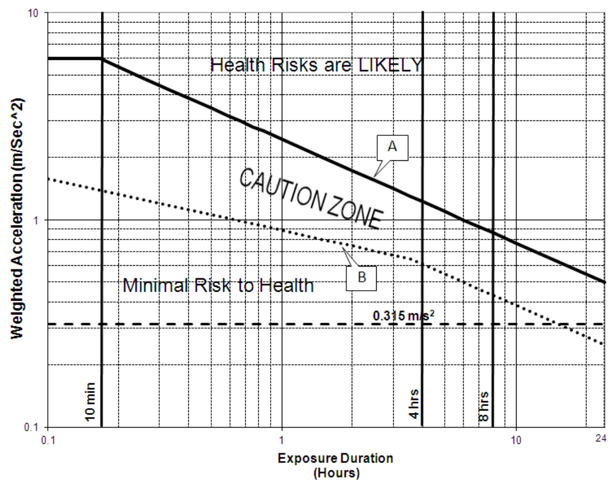
3.6.3.2 Category B: Vibration with Occasional Shock or Transient Vibration. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic evaluation method and the frequency weightings and multiplying factors for health. If the crest factor for the dominant vibration source is less than or equal to 9.0, or the criteria referenced in 3.6.2.2 do not suggest that additional evaluation methods should be considered, the limits shall follow the guidelines provided for Category A. If the crest factor exceeds 9.0, or the criteria described in 3.6.2.2 suggest that additional evaluation methods be considered, the fourth power vibration dose method described in ISO 2631-1, or the multiple shocks method described in ISO 2631-5, or both shall be applied in addition to the basic method. The daily vibration exposure or equivalent continuous 8.0-hour exposure in any orthogonal direction shall not exceed an exposure limit value of 1.15 m/s2. The seat pan vibration dose value in any orthogonal direction shall not exceed an exposure limit value of 21 m/s1.75. The limits using the multiple shocks method shall follow the guidelines provided in Category C.

3.6.3.3 Category C:Rrepeated/Multiple Shocks or Transient Vibration. The primary evaluation methodology and limits for this environment shall be in accordance with ISO 2631-5. For operational environments where impacts are less than or equal to 4.0 G, and for a general population (military or civilian), the resulting Equivalent Daily Static Compressive Stress (Sed) or Spinal Stress Dose shall not exceed 0.5 Megapascals (MPa) for a low probability of adverse health effects at a lifetime exposure. If the resulting Sed exceeds 0.8 MPa, there is a high probability of adverse health effects. For operational environments where impacts routinely exceed 4.0 G, and given a military only population, the Sed value shall be normalized over an 8.0-hour period and shall not exceed an Sed(8) value of 4.7 MPa, with a 3.9 MPa limit preferred, for a low probability of adverse health effects at a lifetime exposure.

3.6.4 **Performance.** Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method and the frequency weightings and multiplying factors for health. To minimize the degradation in task performance during vibration exposure, the vehicle design shall meet the requirements of 3.6.4.1 and 3.6.4.2. (5.5.5.1.4)

3.6.4.1 Acceleration Limits. The seat pan frequency weighted triaxial RMS accelerations in any orthogonal direction shall be limited to the zone labeled “Minimum Risk to Health” on Figure 40.

3.6.4.2 Frequency Limits. Whole-body vibration shall be minimized in the frequency range below 20 Hertz where major body resonances occur. To preclude impairment of visual tasks, vibration between 20 and 70 Hertz shall be minimized. The transmission of higher frequency vibration through a seating system shall be minimized, especially where transmission of vehicle vibration to the occupant’s head can occur.



Exposure duration (hrs)	Weighted Acceleration (m/sec^2)	
	Curve A	**Curve B**
0.1667 (10 min)	6.00	1.39
1.0	2.449	0.89
3.5	1.309	0.65
4	1.225	0.63
6	1.0	0.5
8	0.866	0.433
15	0.632	0.316
24	0.5	0.25

NOTE:

1. Curve A represents the upper zone associated with Equation B.1 in ISO 2631-1, Annex B, Amendment 1. Curve B represents the lower zone associated with Equation B.2 in ISO 2631-1, Annex B, Amendment 1 up to 3.5 hours exposure duration, and represents the lower zone associated with Equation B.1 in ISO 2631-1, Annex B, Amendment 1 beyond 3.5 hours exposure duration.

FIGURE 40. Health Guidance Zones for Limited Exposures.

3.6.5 **Comfort.** Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method and the frequency weightings and multiplying factors for comfort. When considering the overall comfort of the occupant during exposure to vibration, the vehicle design shall meet the requirements of 3.6.5.1 and 3.6.5.2. (5.5.5.1.5)

3.6.5.1 Acceleration Limits. For environment Categories A and B, the vector sum of the seat pan frequency weighted RMS accelerations in the three orthogonal directions shall not exceed 0.315 m/s^2. Comfort levels have not been defined for Category C. Additional guidelines are given in ISO 2631-1 for including accelerations measured at other locations (seat back, foot support) in the assessment, particularly when significant levels of vibration are present.

3.6.5.2 Frequency limits. See 5.6.3.2.

3.6.6 **Sensation.** Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method and the frequency weightings and multiplying factors for sensation. In order to minimize the perception that the occupant is being exposed to vibration, the vehicle design shall meet the following requirements: (5.5.5.1.6)

3.6.6.1 Acceleration Limits. To minimize the human sensation of vibration, the vector sum of the frequency weighted RMS accelerations combined for all three orthogonal axes shall be below 0.015 m/s^2.

3.6.6.2 Frequency Limits. See 5.6.3.2.

3.6.7 **Motion sickness.** In order to minimize the potential for motion sickness, the vehicle design shall meet the following requirements: (5.5.5.1.7)

3.6.7.1 Acceleration Limits. To maintain a motion sickness rate of less than 10 percent sick, the motion sickness dose value (MSDV) shall be less than 0.3 m/s1.5 determined by the method in accordance with ISO 2631-1, Annex D. This method only applies to limited duration exposures and does not account for adaptation that occurs for longer duration exposures.

3.6.7.2 Frequency Limits. The method applies primarily when vibration conditions exist in the 0.1 to 0.5 Hertz frequency range for accelerations and angular velocities. These frequencies shall be avoided if possible.

3.6.8 **Vehicle Seating Systems.** Vehicle seating systems shall be designed to minimize the transmission of vehicle vibration and shock to the occupant. System resonances below 20 Hertz shall be avoided, but may be necessary to properly mitigate shocks in Category C environments. Seating systems shall also minimize vibration in the operational frequency range of the vehicle. Where visual performance is critical, higher frequencies at the seatback and headrest shall be avoided. (5.5.5.1.8)

3.6.9 **Protective Equipment and Work Practice.** Where protective equipment is used to reduce personnel exposures, only full finger gloves, certified by a third party as meeting anti-vibration criteria in accordance with ANSI S2.73/ISO 10819, may be used.