Ministry of Defence
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Human Factors for Designers of Equipment
-
Military Land Vehicle Design

AMENDMENT RECORD

Amd No	Date	Text Affected	Signature and Date

REVISION NOTE

This standard is raised to Issue1.

HISTORICAL RECORD

This standard supersedes the following:

Draft Defence Standard (Def Stan) 00-68 Issue 1 dated November 1998.

CONTENT

SECTION 1 GENERAL REQUIREMENTS

PREFACE

Standards for Defence

Human Factors for Designers of Equipment in Military Land Vehicle Design

a. This standard provides requirements for Guidelines for Human Factors in Military Land Vehicle Design.

b. This standard has been produced on behalf of the Defence Materiel Standardization Committee (DMSC) by the Defence Evaluation & Research Agency (DERA).

c. This standard has been agreed by the authorities concerned with its use and is intended to be used whenever relevant in all future designs, contracts, orders etc. and whenever practicable by amendment to those already in existence. If any difficulty arises which prevents application of the Defence Standard, the Directorate of Standardization (DStan) shall be informed so that a remedy may be sought.

d. Any enquiries regarding this standard in relation to an invitation to tender or a contract in which it is incorporated are to be addressed to the responsible technical or supervising authority named in the invitation to tender or contract.

e. Compliance with this Defence Standard shall not in itself relieve any person from any legal obligations imposed upon them.

f. This standard has been devised solely for the use of the Ministry of Defence (MOD) and its contractors in the execution of contracts for the MOD. To the extent permitted by law, the MOD hereby excludes all liability whatsoever and howsoever arising (including, but without limitation, liability resulting from negligence) for any loss or damage however caused when the standard is used for any other purpose.

TEXT

Standards for Defence

Human Factors for Designers of Equipment in Military Land Vehicle Design

SECTION 1 GENERAL REQUIREMENTS

0 INTRODUCTION

This Defence Standard has been prepared by the Centre for Human Sciences (CHS) and Land Systems (LS) Sectors, Defence Evaluation and Research Agency (DERA) as part of the Applied Research Package (ARP) 03b, Research Objective 2, Assignment 3, Crew Systems. This report presents guidelines for Human Factors (HF) in military land vehicle design and constitutes customer milestone M92302.

These guidelines are based on draft Defence Standard 00-68 [Ref. 1], the earlier drafts of which were produced in collaboration with Industry, and resulted in the format and style of the present document. The history of this collaboration is given in the above draft.

The document has been assembled to meet the customer's milestone and it is expected that a later version will need to be produced, either if more and updated information is required or to cover advances in research and technology. It is hoped that an updated version of these guidelines will be produced as a Defence Standard at a later date.

The guidelines have been written around the needs of "A" or Armoured vehicle design, as this was originally set as the priority. However, much of the information can be read across to the other military vehicle classes.

1 SCOPE

1.1 This standard specifies requirements for these guidelines are to provide information to vehicle and associated equipment designers. It is intended to help them understand more fully the human factors issues which should be considered during all phases of military land vehicle/platform design and procurement.

1.2 It is also intended to help human factors experts who may not be aware of some of the military and design issues associated with these types of systems.

2 WARNING

The Ministry of Defence (MOD), like its contractors, is subject to both United Kingdom and European laws regarding Health and Safety at Work, without exemption. All Defence Standards either directly or indirectly invoke the use of processes and procedures that could be injurious to health if adequate precautions are not taken. Defence Standards or their use in no way absolves users from complying with statutory and legal requirements relating to Health and Safety at Work.

3 RELATED DOCUMENTS

3.1 The publications shown below are referred to in the text of this standard. Publications are grouped and listed in alphanumeric order.

1. STREETS, D. F., *Partial Draft for Defence Standard 00-68. Military Land Vehicle Human Factors Design Criteria. November 1998 Version (U)*. DERA/CHS5/5.07/6/8/3. November 1998. UNCLASSIFIED.
2. Ministry of Defence. *Human Factors for Designers of Equipment*. DEF STAN 00-25.

Part 1	Introduction	Issue 2 (30 Sep 1987), Amendment 1 (19 Apr 1988)
Part 2	Body Size	Issue 2 (14 Feb 1997), Amendment 1 (7 Aug 1997)
Part 3	Body Strength and Stamina	Issue 2 (24 Jan 1997), Amendment 1 (17 Nov 1997)
Part 4	Workplace Design	Issue 1 (30 Aug 1991)
Part 5	Stresses and Hazards	Issue 1 (29 May 1992)
Part 6	Vision and Lighting	Issue 2 (1 Jan 1997)
Part 7	Visual Displays	Issue 2 (20 Dec 1996)
Part 8	Auditory Information	Issue 1 (28 Apr 1989)
Part 9	Voice Communication	Issue 1 (30 Apr 1991)
Part 10	Controls	Issue 1 (31 Dec 1992)
Part 11	Design for Maintainability	Issue 1 (31 Aug 1988)
Part 12	Systems	Issue 1 (15 Jul 1989)
Part 13	Human Computer Interaction	Issue 1 (29 May 1996)

SECTION 1 GENERAL REQUIREMENTS

3. Chief of Defence Procurement Instruction for Project Management, *Managing Human Factors Integration.* CDPI/TECH/330 Issue 1.0, January 1998.

4. Defence Procurement Management Guide. *Managing Human Factors Integration.* DPMG/TECH/330 ISSUE 1.0. June 1998.

5. BEEVIS, D. ed. *Analysis Techniques for Man-Machine Systems Design.* Technical Report AC/243 (Panel 8) TR/7, Vols 1 & 2. Brussels: NATO Defence Research Group. 31 July 1992.

6. BEEVIS, D., ESSENS, P. and SCHUFFEL, H. eds. *Improving Function Allocation for Integrated Systems Design.* CSERIAC SOAR 96-01. Ohio: Wright-Patterson Air Force Base. June 1996.

7. STREETS, D.F. and EDWARDS, R.J. Function Allocation for the Design of a Reconnaissance Vehicle. In: BEEVIS, D. et al, eds. *Improving Function Allocation for Integrated Systems Design.* CSERIAC SOAR 96-01. Ohio: Wright-Patterson Air Force Base. June 1996

8. ROGERS, A.S., ROBERTSON, K.A. and STONE B.M. *A Land Forces Guide to the Management of Irregular Work/Rest Schedules*. DERA Centre for Human Sciences. (In Draft).

9. Ministry of Defence. *Environmental Handbook for Defence Materiel*. Parts 1 to 4. DEF STAN 00-35.

Part 1	Control and Management	Issue 3 (7 May 1999)
Part 2	Environmental Engineering Rationales	Under Compilation
Part 3	Environmental Test Methods	Issue 3 (7 May 1999)
Part 4	Natural Environments	Issue 3 (7 May 1999)

10. NEVOLAR V.R. *A Guide for Commanders – Drinking for Optimal Performance during Military operations in the HEAT*, DERA/CHS/PP5/CR980062/1.0, Version 1.1, April 1998

11. National Institute for Occupational Safety and Health. *Work Practices Guide for Manual Lifting*. Technical Report DHHS (NIOSH) Publication No. 81-122. Cincinnati OH: NIOSH. 1981.

12. Health and Safety Executive. *Manual Handling. Manual Handling Operations Regulations*. L23. 1992 (2nd Edition, 1998).

13. WATERS, T. R., PUTZ-ANDERSON, V., GARG, A. and FINE, L. J., *Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks*. Ergonomics. 36(7), (pp 749 776).

14. ASTRAND, P.-O. and RODAHL, K. *Textbook of Work Physiology: Physiological Bases of Exercise*. New York: McGraw-Hill. 1986.

15. WICKENS, C.D. *Engineering Psychology and Human Performance.* New York: Harper Collins. 1992

16. HART S.G. and WICKENS, C.D. Workload assessment and prediction. In: H.R. BOOHER, ed. *MANPRINT: An emerging technology. Advanced concepts for integrating people, machines and organisations.* (pp. 257-300). New York: Van Nostrand Reinhold. 1990.

17. PARKES, A.M. and COLEMAN, N. Route guidance systems: A comparison of methods of presenting directional information to the driver. In: E.J. LOVESEY, ed. *Contemporary Ergonomics.* (pp. 480-485). London: Taylor and Francis. 1990.

18. PARKS, D.L. and BOUCEK, G.P., Jr. Workload prediction, diagnosis, and continuing challenges. In: G.R. McMILLAN, D. BEEVIS, E. SALAS, M.H. STRUB, R. SUTTON, and L. VAN BREDA, eds. *Applications of human performance models to systems design.* (pp. 47-64). New York: Plenum Press. 1989

19. HART, S.G. and STAVELAND, L.E. Development of NASA TLS (Task Load Index): Results of empirical and theoretical research. In: P.A. HANCOCK and N. MESHKATI, eds. *Human and Mental Workload.* Amsterdam: North Holland. 1988.

20. REID, G.B. and NYGREN, T.E. The subjective workload assessment technique: A scaling procedure for measuring mental workload. In: P.A. HANCOCK and N. MESHKATI, eds. *Human Mental Workload.* Amsterdam: North Holland. 1988.

21. COTTER, S.A. *Driving AFVs at Night with II and TI Systems.* DERA/CHS/PP5/CR97086/1.0. July 1997. UK RESTRICTED.

22. COTTER, S.A. *Comparison of Reverse Driving Systems in an Armoured Fighting Vehicle (R).* DERA/CHS/PP5/CR97087/1.0. July 1997. UK RESTRICTED.

23. BOFF, K.R. and LINCOLN, J.E., eds. *Engineering Data Compendium – Human Perception and Performance, Volumes 1 to 3.* Ohio: Wright-Patterson Air Force Base. 1988.

24. SMITH, A.P. and JONES, D.M., eds. *Handbook of Human Performance, Volumes 1 to 3.* London: Academic Press. 1992.

25. British Standards Institute. *Guide to Measurement and Evaluation of Human Exposure to Whole-Body Mechanical Vibration and Repeated Shock*. BS 6841. 1987.

26. International Standards Organisation. *Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration*. ISO 2631-1. 1997

27. International Standards Organisation. *Ergonomics Assessment of Speech Communication. Speech Interference and Communication distances for Persons with Normal Hearing Capacity in Direct Communication (SIL Method)*. BS ISO 9921-1. 1996.

28. British Standards Institute. *Hearing Protectors. Safety Requirements and Testing*. BS EN 352. (3 parts). 1993 to 1997.

29. British Standards Institute. *Acoustics. Hearing Protectors*. BS EN 24869 (Part 1 and 2). 1993.

30. Ministry of Defence. *MoD Health and Safety Handbook*. JSP 375, Volume 2, Chapter 11 *Occupational Noise*.

31. Ministry of Defence. *Countersurveillance Requirements*. DEF STAN 08-6. RESTRICTED.

Part 2	Acoustics Aspects	Issue 1 (14 May 1990)
Part 3	Visual and Near Infra-red Aspects	Issue 1 (10 Jul 1987)
Part 4	Thermal and Intermediate Infra-red Aspects	Issue 1 (10 Jul 1987)
Part 5	Radar Aspects	Issue 1 (10 Jul 1987)

32. Ministry of Defence. *Acceptable Limits for Exposure to Impulsive Noise From Military Weapons, Explosives and Pyrotechnics*. DEF STAN 00-27. Issue 1. 16 Jul 1985.

33. European Standard. *Safety of Laser Products*. EN 60825-1. 1994.

34. British Standards Institute. *Medical Information on Human Reaction to Skin contact with Hot Surfaces*. PD 6504. 1983.

35. TURK, J., *The Methodology of Vehicle Habitability Trials*. APRE Working Paper 14/88. December 1988.

36. Health and Safety Executive. *Occupational Exposure Limits 1999*. EH40/99. 24 Jun 1999.

37. US Department of Defense. *Human Engineering Design Guidelines*. MIL-HDBK-759C. July 1995 (Amended 28 Feb 1997).

38. NICHOLSON, A.N. and STONE, B.M. *Influence of Back Angle on the Quality of Sleep in Seats*. In: C. O'BRIEN, ed. *Ergonomics*. 30(7), (pp 1033 - 1041). 1987.

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(Also referred to as: North Atlantic Treaty Organisation. *Nomenclature in Air Crew Status, NATO Safety Signs and Controls*. STANAG 3647, Edition 3).

40. US Department of Defense. *Design Criteria Standards – Human Engineering*. MIL-STD-1472E. 31 October 1996.

41. British Standards Institute. *Ergonomic Requirements for Office Work With Visual Display Terminals (VDTs)*. BS EN ISO 9241. (Part 11 – *Guidance on Usability*). 1998.

42. Ministry of Defence. *Reliability and Maintainability*. DEF STAN 00-40 (Parts 1 to 8). 1988 to 1994.

43. Ministry of Defence. *Reliability and Maintainability. MoD Guide to Practices and Procedures*. DEF STAN 00-41. Issue 3. 25 Jun 1993.

44. Ministry of Defence. *Reliability and Maintainability Assurance Guides*. DEF STAN 00-42 (Parts 1 to 2). Issue 1. 1997.

45. Ministry of Defence. *Reliability and Maintainability Assurance Activity*. DEF STAN 00-43 (Parts 1 to 2). Issue 1. 1993 and 1995.

46. Ministry of Defence. *Reliability and Maintainability Data Collection and Classification*. DEF STAN 00-44 (Parts 1 to 4). 1994 to 1997.

47. Ministry of Defence. *Reliability and Maintainability. MoD Guide to Terminology Definitions*. DEF STAN 00-49. Issue 1. 26 Jan 1996.

48. Ministry of Defence. *The General Requirements for Product Acceptance and Maintenance Test Specifications and Test Schedules*. DEF STAN 00-42. Issue 3. 27 Sep 1991.

49. Ministry of Defence. *Integrated Logistics Support*. DEF STAN 00-60 (Parts 0, 1, 2, 3, 10, 11, 20, 21, 22, 23, 24, and 25). Issue 2. 31 Mar 1998.

3.2 Reference in this standard to any related document means in any invitation to tender or contract the edition and all amendments current at the date of such tender or contract unless a specific edition is indicated.

3.3 In consideration of **3.2** above, users shall be fully aware of the issue and amendment status of all related documents, particularly when forming part of an invitation to tender or contract. Responsibility for the correct application of standards rests with users.

3.4 DStan can advise regarding where related documents are obtained from. Requests for such information can be made to the DStan Helpdesk. How to contact the helpdesk is shown on the outside rear cover of Def Stans.

4 DEFINITIONS

For the purpose of this standard ISO/IEC Guide 2 "Standardisation and Related Activities - General Vocabulary" and the definitions shown below apply.

4.1 Standards Review

Defined at the examination of a Defence Standard to establish if its content is suitable as written for continued use. The Standards Review process establishes whether a Defence Standard can be confirmed as written or should be cancelled, declared obsolescent, revised or amended.

4.2 Standards Obsolescence

Defined as the identifier for Defence Standards when the content shall only be used for reference in maintaining existing equipment. Defence Standards declared obsolescent shall not be updated and therefore are not to be used for the purchase of new equipment.

SECTION 1 GENERAL REQUIREMENTS

4.3 Enhanced Standards

Defined as a Defence Standard produced by extensively enhancing an existing standard to make it suitable for MOD procurement purposes.

4.4 Original Defence Standards

Defined as a Defence Standard created from original material, in the absence of any existing standards appropriate to the subject matter.

4.5 Mandatory Clauses in Defence Standards

Defined as clauses which use the word "shall". Optional or non-mandatory clauses use the word "should".

4.6 Technical Definitions

Bideltoid Breadth

Defined as Shoulder Breadth – The minimum lateral clearance required in a workspace. (Remember to allow clothing increments)(NB - Not the same as bi-acromial breadth).

Closed Down

Defined as A vehicle state in which all hatches and apertures are closed for protection, thus all crewmen operate head in.

Crew Compartment

General areas within which crews or a crewman are accommodated within a vehicle. May be defined more specifically - eg Driver's Compartment.

Crewman

Generic use of the word, describing male and female "crew" members. Also, unless otherwise defined, embraces all vehicle occupants, such as Infantry Section soldiers and specialist passengers being transported.

Crewstation

A crew position within a vehicle at which an interface is provided to gain access to platform functionality. Usually associated with turreted crewspaces and specifically designed to allow the crewman to fight the vehicle (either when stationary or mobile). In the case of an integrated vetronics system, this is likely to include multi-function input/output devices to access a number of vehicle sub-systems. In the MBT example there could be up to four crewstations: Commander's; Gunner's, Operator's and Driver's - each are likely to be of differing complexity and level of functionality.

"C" Vehicle

Military vehicles used for construction work, such as earth moving.

Debussing

The act of leaving a vehicle to perform a role on foot – usually applies to infantrymen leaving their AIFV, APC or another vehicle type.

Fightability

The accommodation of the user and his interaction with the platform and its systems to perform the requisite military function, role or task in the operational environment.

Head-in

A working position in which a crewman is completely inside the vehicle. Any overhead hatches may be either open or closed.

Head-out

A working position in which a crewman has his head or head and shoulders outside the vehicle, giving him direct contact with the outside world.

O Group

Orders Group.

Out of Combat

When vehicles and men are withdrawn to a hide or rest area, though sentries will still be posted and radio watches maintained.

Usability

In this document it refers to the ease of use and the utility of a Crewstation in terms of available system functions.

Vetronics

Vehicle Electronics

Workplace/ Workstation

Individual crewman's location within Crew Compartment. May be defined more specifically - eg Commander's Workstation or Crewstation.

SECTION 1 GENERAL REQUIREMENTS

5 ABBREVIATIONS

Designation	Title
AIFV	Armoured Infantry Fighting Vehicle
AFV	Armoured Fighting Vehicle – Often referred to as “A” Vehicle
AL	Action Limit
ANR	Active Noise Reduction
APC	Armoured Personnel Carrier
APRE	Army Personnel Research Establishment
APU	Auxiliary Power Unit – Means of power supply when main engine not running
ARP	Applied Research Package
BIT	Built in Test
BMS	Battle Management System
BSI	British Standards Institute
C4I	Command, Control, Communications, Computers and Information
CBA	Combat Body Armour
CDPI	Chief of Defence Procurement Instructions
CES	Complete Equipment Schedule - A listing of all the equipment carried on a vehicle that is not designated as personal equipment.
CO	Carbon Monoxide
COLPRO	Collective Protection
CR2	Challenger 2
CSV	Combat Support Vehicle
DERA	Defence Evaluation and Research Agency
DPA	Defence Procurement Agency
DRI	Detection, Recognition, Identification
EC	European Community
EH40	Document providing Health and Safety Executive Occupational Exposure Limits
FIFV	Future Fighting Infantry Vehicle
FOV	Field of View
GFE	Government Furnished Equipment - Items of equipment that have to be installed in the vehicle. e.g. standard radio equipment.
GPS	Global Positioning System
GUI	Graphical User Interface - As part of an MMI it comprises the layout, style and schemes for the access to system functions via a computer generated graphics display. For example, MS Windows™ has a GUI primarily providing access to functionality via a mouse pointer.
GW	Guided Weapon
HCI	Human Computer Interface - As for Man-Machine Interface, except that it is usually associated with the interface to computer equipment only.
HF	Human Factors
HFI	Human Factors Integration

Hg	Mercury
HMD	Helmet Mounted Display
HSE	Health and Safety Executive
HUD	Head Up Display
IEE	The Institution of Electrical Engineers
II	Image Intensifier
ILS	Integrated Logistics Support
INS	Inertial Navigation System
IPE	Individual Protection Ensemble - Personal NBC protection
ISO	International Standards Organisation
KBS	Knowledge Based Systems
LI	Lifting Index
LRU	Line Replaceable Unit
LS	Land Systems
MANPRINT	MANpower and PeRsonnel INTegration
MBT	Main Battle Tank
MMI	Man-Machine Interface - The interface of a system that provides an operator (crewman) access, via control devices (e.g. keyboard), to system functions and information from the system via output devices. (e.g. VDU).
MoD	Ministry of Defence
MPW	Maximum Permissible Weight
NASA	National Aeronautical and Space Administration
NASA TLX	NASA Task Load Index
NATO	North Atlantic Treaty Organisation
NBC	Nuclear, Biological, Chemical - The generic term used to cover this form of warfare threat
NH3	Ammonia
NIOSH	National Institute of Occupational Safety and Health (US organisation)
NO2	Nitrogen Oxides
NVG	Night Vision Goggles
OOTW	Operations Other Than War
OP	Observation Post
P3I	Pre-Planned Product Improvement
REME	Royal Electrical and Mechanical Engineers
replen	Replenishment
RWL	Recommended Weight Limit
SDR	Strategic Defence Review
SLA	Service Level Agreement
SME	Subject Matter Expert
SOPs	Standard Operating Procedures
SPL	Sound Pressure Level
SR	System Requirements
SRD	System Requirements Document
SRP	Seat Reference Point
STA	Surveillance and Target Acquisition

SECTION 1 GENERAL REQUIREMENTS

STANAG	Standardisation Agreement
SWAT	Subjective Workload Assessment Technique
TAD	Target Audience Description
TI	Thermal Imager
TLX	Task Load Index
TRS	Technical Requirement Specification
TWA	Time Weighted Average
UGV	Unmanned Ground Vehicle
UR	User Requirements
URD	User Requirements Document
US	United States
VDU	Visual Display Unit
VDT	Visual Display Terminal
VDV	Vibration Dose Value
WBGT	Wet-Bulb Globe Temperature

6 HUMAN FACTORS AND TOTAL SYSTEM DESIGN

6.1 Introduction

6.1.1 Human factors issues must be considered during all stages of the design process. The human must be treated as part of the total system, and considering him and his roles from the start of the design. This means from when the initial thoughts, ideas and concepts are being examined, rather than as an add-on later when a significant amount of the design has been finalised. (When using Heading 2, Subclause style for subclause heading, manually embolden the text)

6.1.2 The human provides an important input to the functionality of a platform, especially in terms of command, control, decision making, information fusion, etc. Therefore if the human input is efficiently utilised, the platform effectiveness and fightability is significantly enhanced. If on the other hand the design does not take account of human abilities and limitations and does not fully integrate the crew into the system the full technical performance of the platform can not be exploited.

6.1.3 Therefore effective integration of man's capabilities with the harnessing of the vehicle platform technologies and systems forms an essential part of realising the full fightability potential of the platform.

6.1.4 All the time that man is operating or accommodated within the vehicle system, he is the key link to its efficient and therefore effective operation. Even with robotic vehicles or unmanned ground vehicles (UGVs), which will probably play a greater role in the future, the man-machine interface is simply transferred to a location away from the vehicle, and the man is still vitally important.

6.1.5 It is essential to note that human factors issues are not always quantifiable, unlike engineering parameters. Therefore it is often necessary to use the services of human factors experts who use their experience to interpret the situation and provide their best predictions, when it is not possible to measure human performance or relevant criteria. Some examples of this are covered is Section 3, where the effects of combined stresses are discussed, as well as mental workload.

6.1.6 Man is also very adaptable, and will adjust to cope with difficult physical and mental situations. The result can be that he is still performing all his tasks, but not in the most efficient manner. The appropriate human factors specialist can help designers and engineers to achieve efficient performance from the man in the system. In the past, man has made up for his deficiencies in system design to the eventual detriment of his own efficiency, safety, health or well-being.

6.1.7 The need to consider the human interaction and performance outside of just meeting HF design parameters places an important emphasis on the use of trials, using virtual and real mock-ups, from the early stages of the design process.

SECTION 2 DEFENCE STANDARD SPECIFICATION

6.2 Man in the System

6.2.1 The Management of Human Factors Integration

6.2.1.1 The human factors input to procurement programmes is now formally managed through the Chief of Defence Procurement Instructions (CDPI) on Managing Human Factors Integration [Ref. 3] and the Defence Procurement Management Guide on Managing Human Factors Integration [Ref. 4].

6.2.1.2 This is a developing process, which reflects the changes in the Ministry of Defence (MoD) procurement strategy. Human Factors Integration (HFI) has replaced the MANPRINT (MANpower PeRsonnel and INTegration) as the process for managing human factors integration in defence procurement. It is still structured in broadly the same way, with the six domains of Manpower, Personnel, Training, Human Factors Engineering, System Safety and Health Hazard Assessment.

6.2.1.3 The HFI programme for a vehicle or piece of equipment is managed by the Defence Procurement Agency (DPA), who receive responses at various stages in procurement process from Industry, Defence Evaluation and Research Agency (DERA), the Service Users and Central Staffs. Further information is contained in the above referenced documents.

6.2.2 Task Analysis

6.2.2.1 Task analysis is one of the main techniques used by human factors specialists to study and describe the human operator in a system. Some of the commonly used techniques are Time Lines, Flow Process Charts, Operational Sequence Diagrams, Information/action or Action/information tabulation, Critical task analysis and Decision tables. Human factors task analysis and other analytical techniques used have often been derived and developed from those used by engineers.

6.2.2.2 Task analysis techniques can be applied at all stages through the design process. They help to predict crew performance and workload distribution and can help to assess proposed changes to these. The techniques can also aid design decisions on displays and controls for crewmen and maintainers as well as maintenance planning for the life cycle of the vehicle or equipment. Further information on these and other analysis techniques is contained in a North Atlantic Treaty Organisation (NATO) Research Study Group Report [Ref. 5].

6.2.2.3 Additionally, the techniques can help to determine where automation may assist in reducing the crewman’s workload.

6.2.3 Allocation of Function

6.2.3.1 Function allocation is another of the important processes that can be used in making design decisions at the man machine interface. It can help to decide if a system function should be carried out by the human operator, the equipment, or a by combination of the two.

6.2.3.2 Allocation of function techniques can therefore provide valuable tools when considering, for example, which tasks should be automated and whether the number of crewmembers proposed for a particular design could be reduced, or perhaps increased. Function allocation can therefore play an important role in making decisions that result in the design on a total system that is safe and effective to operate.

6.2.3.3 The application of improved technology, in particular the use of generic crewstations linked to an integrated vetronics system, provides improved flexibility in dynamic task allocation and hence the potential for improved system effectiveness.

6.2.3.4 Further information on this technique is contained in the above NATO Report and in the proceedings report from a workshop on allocation of function [Ref. 6]. A paper on applying function allocation to the design of a vehicle and some of the practical problems when considering human to human allocation as opposed to human to machine allocation is contained in the proceedings [Ref. 7].

6.3 Human Factors Through the Design Process

6.3.1 **General**

6.3.1.1. It has already been discussed how human factors must be considered through all stages in the design process. This process is defined in the Acquisition management System (AMS) as passing through concept, assessment, demonstration, manufacture, in service and disposal (CADMID).

6.3.1.2 With the advent of Smart Procurement, there is a greater emphasis on the requirement to recognise that the key human factors activities are identified, and undertaken as appropriate throughout the procurement process.

6.3.2 **Concept/Assessment Phases**

6.3.2.1 At these initial stages, the designer must be aware in general terms of where and how the human will interface with the emerging systems and the functions it has to achieve. An overview of human capabilities and limitations is required and depending on the project, specialist human factors input will be provided when required.

6.3.2.2 It will also be necessary to contribute to the emerging User Requirement Documents (URDs) and System Requirement Documents (SRDs) that are being generated, derived and defined, particularly in the areas of Fightability, Human Factors Integration, Surveillance and Target Acquisition (STA), Command, Control, Communications, Computers and Information (C4I), Human Computer Integration (HCI) and Man Machine Interface (MMI).

6.3.3 **Simulations**

6.3.3.1 Simulation techniques have developed rapidly in the last decade or so, especially in the field of computer man modelling. They can give invaluable feedback to the designer, and provide the human factors specialist with a tool to examine specific design interface problems in detail, rather than just having to offer up the data book solutions or general experience, which may not be completely appropriate to the design under consideration.

6.3.3.2 Simulations can take the form of the modelling of humans within the confines of a 3-d geometry (virtual prototype), allowing reach, posture, field of view, etc. to be investigated for a range of representative crewman sizes. They can also take the form of man-in-the-loop virtual reality simulations in which the cognitive input of the crewman can be assessed.

6.3.3.3 Laboratory simulations of complete crewstations are particularly valuable when studying specific aspects of a crewstation design, especially those involving new technologies. The capabilities of synthetic environments, when used to drive laboratory simulations of complete crewstations, means that very high fidelity can be achieved with the operation of all sensors and effectors modelled and interacting with the simulated external environment. Mobile simulators, built on a wheeled or tracked chassis, have been used with great success to study new technologies under conditions closer to operational situations.

6.3.3.4 Simulation techniques are also a valuable means of demonstrating successes and problems in designs to Customers and Users, as well as obtaining their military opinions at an appropriate stage in the design process.

6.3.4 **Mock-ups**

6.3.4.1 The mock-up still has a part to play, though the earlier stage functions are now carried out by simulation. There is an important role for the mock-up just before the design is finalised, as it can be used to highlight problems that may not be evident in simulation, and make final confirmatory checks before metal is cut.

6.3.5 **Prototypes**

6.3.5.1 Prototypes offer the last opportunity to check that the human factors design recommendations have been implemented, and also that the design is fightable. This is achieved using military crews representing the User.

6.3.5.2 Prototypes can be in the form of hardware designs but also in the form of software prototypes of the MMI. Both can be used to elicit system requirements and verify emerging designs with the user.

6.3.6 **First-off Production**

6.3.6.1 It is important for the human factors specialists, as well as for the engineers, to assess at random, first-off production vehicles, ensuring that the build standard is the same as for the vehicle that was accepted. Changes can occur after acceptance, which can result in operational efficiency and safety issues that are not always immediately obvious.

6.3.7 **Technology Insertions**

6.3.7.1 Technology Insertions, previously known as Mid Life Improvement programmes, offer the opportunity to up-grade a vehicle and extend its total life. This can sometimes cause major human factors problems, especially when extra equipment is being fitted. Space claim and ergonomic problems, particularly regarding posture, were encountered when Thermal Imager systems were retrofitted to Chieftain and Challenger 1.

6.3.7.2 As the expected in service life of platforms increases it is important to design in ‘stretch potential’ to allow improved or additional functionality to be incorporated at a later date. The provision of stretch potential is as important for the crew interface as any other aspect of the platform.

7 HUMAN PERFORMANCE LIMITATIONS

7.1 Introduction

7.1.1 When designing equipment, it is important to be aware of the limitations as well as the breadth of abilities that exist in human performance. It is also important to remember that humans do not all react in the same way, and that their ranges of performance are not the same. The performance of individuals will also vary with stress, tiredness and extreme environmental conditions.

7.1.2 Another key factor not always appreciated is that, whilst a single stress on a human in a working situation may be coped with perfectly well, the impact of a combination of stresses at the same time may result in a severe reduction in his operational efficiency. It can result in a complete breakdown in his performance.

7.2 Degradation in Human Performance

7.2.1 General human performance will be affected by various factors including fatigue, sleep loss, work overload. It is important where possible to optimise human performance by planning suitable work/rest patterns. Advice on this topic for land systems commanders is given in a DERA guide [Ref. 8]. The document (currently in draft) is intended to help recognise the physical signs of sleep loss and its detrimental effects on mental tasks. It also provides advice on sleep management and coping strategies that can be employed to optimise soldier performance.

7.2.2 The combinations of stresses occurring in the military land vehicle environment can be quite severe. The climatic environment often imposes an initial stress on the operator, in the form of extremes of cold, hot and/or humid conditions. The ranges of climatic conditions in which vehicles may be required to operate are covered in DEF STAN 00-35/2 [Ref. 9].

7.2.3 The addition of an artificial Nuclear Biological and Chemical (NBC) environment, and the need at times to wear full NBC Individual Protection Ensemble (IPE) clothing and possibly Combat Body Armour (CBA) as well, can further add to the stress on crewmen whilst working/operating in or on vehicles.

7.2.4 The above protective clothing and equipment not only adds to thermal stress, but also places extra restrictions on body movements, especially when worn in conjunction with cold weather clothing. Visual field of view can also be restricted by protective clothing and equipment, particularly if a respirator has to be worn. Care must also be taken to ensure that respirator design does not inhibit visual performance.

7.2.5 Hot conditions require an increase in fluid intake in order to help minimise heat stress and the onset of dehydration, which directly impairs physical and possibly mental performance. Dehydration also reduces the body's ability to regulate its temperature in hot conditions, which may further degrade performance. DERA has produced a commanders' guide to drinking requirements [Ref. 10].

7.2.6 Superimposed on the above are the effects of vehicle movement, which can result in high noise and vibration levels and extreme movements in roll, pitch and yaw, particularly when travelling cross-country away from roads and well maintained tracks.

7.2.7 Also, extremes of high or low body temperature resulting from any of the factors mentioned can cause mental and physical performance decrements.

7.2.8 Yet another factor to consider is the stress of battle, with the resulting anxiety and fear that may occur. This is of course difficult to quantify.

7.2.9 It can be appreciated that combinations of interactions between the various stressors that have been highlighted can result in crewmen performing significantly below their normal ability levels, thus reducing the efficiency of the total vehicle system.

7.2.10 Guidance for designers on the individual elements that affect degradation in human performance are covered in Section 4 of this document, as well as in the rest of this Section.

7.3 Body Strength and Stamina

7.3.1 General

7.3.1.1 Even though technologies such as lifting aids and powered traverse mechanisms can aid the crewman, the human limitations imposed by body strength and stamina are still an important element to consider in the overall design. The working environment in an AFV will not always involve sedentary postures. It is also important to allow for all elements which may affect activities requiring strength and stamina, such as wet, oily and dirty surfaces. These sorts of contamination develop during training and operational use and can have an affect on balance, posture and safety.

7.3.2 Manual Handling

7.3.2.1 When designing a military system or device, the human factors implications of any manual handling activities, including the removal of items for maintenance, must be considered. Where any modification to existing equipment is planned, it should also be tested for handling and maintenance procedures under field conditions. Further information on maintainability is contained in Section 8.

7.3.2.2 A clear space in which to perform the physical handling manoeuvres should always be available and there should always be a clear area on which to place the load at the end of the manoeuvre. This will naturally be easier to achieve under static conditions, for example in maintenance areas. In vehicles this objective is difficult to achieve, however sufficiently large areas for handling equipment (eg for the removal and repositioning of equipment items), should be provided.

7.3.2.3 In the event that physical design precludes the handling spaces described above, the designer shall ensure that these manoeuvres can be achieved and indicate how they will be achieved. **[Mandatory]**

7.3.2.4 Crew are required to climb on and off vehicles and move around, especially during replenishment. The configuration of the vehicle and location of external and internal stowage should be such that it is not awkward for the crew to carry out such tasks. That is to say they should not be required to adopt unnatural postures or make repetitive lifting movements of heavy equipment over long periods.

7.3.2.5 Camouflage netting can prove a hazard if it reduces vehicle access and the workspace around stowage bins and equipment locations. Such situations should be avoided where possible, even under operational conditions. The camouflage net problem illustrates to the designer the importance of considering the total system as seen from the human factors viewpoint.

7.3.2.6 During replenishments, it shall be possible to carry and pass the items safely onto and into the vehicle, without risk of injury to the crews involved. **[Mandatory]**

7.3.2.7 Internal and external stowage areas shall be readily accessible to the crew and the access to them shall comply with the anthropometric requirements given in Section 5. Stowage positions and spaces shall be commensurate with the items to be stowed, their weights and the handling postures that have to be adopted by the crew. **[Mandatory]**

7.3.2.8 When designing vehicle stowage, lighter objects should be stored at higher and lower levels, with heavier items between knee and shoulder height, to make manual handling easier and less hazardous.

7.3.2.9 Stowage of objects required frequently should be more accessible than those used less regularly.

7.3.2.10 The floorspace, as well as any handholds and steps used by crewman when handling items and moving about, should have grip/anti-slip surfaces and be designed so that they can be kept as clear and clean as possible. This is because wet, oily and dirty surfaces develop during training and operational use, reducing frictional contact between the surfaces and hand and footwear.

7.3.2.11 Access and routes to stowage locations shall have grip/anti-slip surfaces. **[Mandatory]**

7.3.2.12 It is important for handling, particularly in confined spaces, that loads to be moved frequently should be regular in shape and balanced in weight. The limit for a single person lift is 15 kg. Stowage should be readily accessible and require minimal bending, stooping, or body twisting. For loads to be handled outside the vehicle, the single person unassisted lift limit is 20 kg, or 30 kg for a two man lift. Where loads either exceed these limits, require lifting above shoulder height, or demand frequent handling and repetitive movement or similar upper body flexion, then some form of mechanical lifting aid should be provided. For further information on stowage, see Section 6. NIOSH [Ref. 11] recommends that if the frequency of a lift is more than once every 5 minutes, it should be regarded as a separate frequency or series. By implication, frequent handling can therefore be defined as a series of lifts taking place within 5 minutes of each other.

7.3.2.13 Hand grips or handles should be fitted to heavy items such as vehicle batteries, and should accommodate the full range of the user population's hands enabling them to manoeuvre and lift the items safely and efficiently. They should be positioned according to the number of people required to carry each particular load and the location of its centre of gravity.

7.3.2.14 Handles are desirable for loads between 10 and 20 kg, and are normally essential for those over 20 kg. When access is restricted and retractable handles are not feasible, special design arrangements will need to be approved. The caveat in para. 7.3.2.12 regarding the 20kg limit for single, unassisted lift should be noted. Handles should be positioned so that they do not interfere with the operation or maintenance of the equipment to which they are attached. When a single handle is provided as a lifting and carrying aid, it should be positioned over the item's centre of gravity. If two or more handles are required, these need to be positioned equidistant from the centre of gravity. However, this philosophy may have to be modified due to the shape of the load, access through doors/hatchways and the method of carriage.

7.3.2.15 In confined spaces, loads for single person, unassisted lifts shall not exceed 15 kg. Also, there shall be minimum bending, stooping and body twisting associated with the activity. **[Mandatory]**

7.3.2.16 Outside the vehicle, single person unassisted lifts shall not exceed 20 kg and two person unassisted lifts shall not exceed 30 kg. **[Mandatory]**

7.3.2.17 If the single and two person lifts, covered in paras 7.3.2.12 and 7.3.2.14 above, are above shoulder height or are required to be performed frequently, some form of mechanical lifting aid shall be provided. **[Mandatory]**

7.3.2.18 The amount of force or resistance designed into a control should be appropriate to the control operation as recommended in DEF STAN 00-25 Part 10 **[Ref. 2]** and strength/stamina data in Part 3 [Ref. 2]. The maximum force required to operate a control should not exceed the greatest force that can be exerted by the weakest person from the user population, operating in the environment in which the control is to be used, though this is not always specified as a 5th percentile strength or force figure.

7.3.2.19 Differences in strength between males and females should be noted. These vary considerably, depending upon the part of the body, type of lift performed, and the size of the individual. Male to female ratios can be found in the Health and Safety Executive (HSE) Manual Handling Guidance on Regulations [Ref. 12]. Another guide to differences in male and female lifting strength is in the National Institute for Occupational Safety and Health (NIOSH) Work practices guide for manual lifting [Ref. 11]. The Action Limit (AL) and Maximum Permissible Weight (MPW) are suggested.

7.3.2.20 The Action Limit relates to the lifting capacity of the 25^{th} percentile female and 1^{st} percentile male, whilst the Maximum Permissible Weight relates to the lifting capacity of the 99^{th} percentile male and 75^{th} percentile female. The equation used to calculate these limits also expresses the ratio of a chosen load to the AL. These two limits refer to symmetrical lifting in the sagittal plane or side elevation of the body.

7.3.2.21 A later 1991 NIOSH document [Ref. 13] uses a Recommended Weight Limit (RWL), instead of AL and MPW. The RWL gives the capability of at least 90% of females in the working population, expressing a given load as a Lifting Index (LI), which its ratio to the RWL. The RWL takes account of asymmetric or twisted postures. This later measure is not as helpful as the AL and MPW when defining manual handling limits.

7.3.2.22 In terms of forces exerted, the design of handles and their actuation varies with their function. Because of the necessary weight of some doors and hatches the force of gravity should be utilised, where it is safely possible for ease of opening. Mechanical assistance should be provided for closing where the force exceeds 220N. For armoured doors, fixed handles are usually required as pull/push aids, particularly on specified adverse slopes, in addition to rotating handles for opening/closing. For safety, it will be necessary to employ some form of damping on heavy doors.

7.3.2.23 There may be a requirement to provide power assistance for opening a door from inside, for example, when a vehicle is on a slope and an Infantry Section needs to de-bus.

7.3.2.24 The direction and method of actuating handles should follow population stereotypes, to ensure rapid operation in an emergency. Pictorial labelling should be employed to show the direction of handle movement.

7.3.2.25 When a handle is used to unlock a hatch or door, the unlocking force required shall not exceed 90N. Overhead hatches, doors and ramps shall require no more than 220N of force for opening and closing. They shall be operable by a suitably equipped and clothed 5th percentile user from inside or out. **[Mandatory]**

7.3.2.26 The above requirements may be relaxed when dealing with light but bulky objects. However when deciding on the location of handles, the implications for lifting, carrying and posture should be considered.

7.3.2.27 For the replenishment of vehicle fuel, supplies and ammunition, as well as for their other physical activities, crews will be aware of correct lifting procedures and limits for the various manual handling tasks. They will be instructed in general and specific handling for all lifting tasks during initial training and vehicle familiarisation respectively. Further details can be found in the HSE Manual Handling Guidance and Regulations [Ref. 11] and DEF STAN 00-25 Part 3 [Ref. 2].

7.3.2.28 Vehicle designers shall be aware of and allow for the range of human limitations associated with manual lifting and handling that have been discussed and referenced in the preceding paragraphs. **[Mandatory]**

SECTION 2 DEFENCE STANDARD SPECIFICATION

7.3.3 **Physical Workload**

7.3.3.1 Heart Rate

a. Consideration must be given to the work situation in which the man's cardio-vascular system is operating. In a general population, exercise becomes less sustainable as either the workload increases and/or the duration of the activity extends. As a general rule for healthy young adults, as an individual's heart rate approaches 60 to 65% of theoretical maximum, the ability of the person to maintain that level of exercise will decrease. Further related information on stamina, work-rate and energy expenditure is contained in DEF STAN 00-25 Part 3 [Ref. 2];

b. Equipment shall be designed to ensure that the operator does not have to exert high cardio-vascular effort in the execution of his crew tasks. This means that he shall not be required operate generate a heart rate above 60 to 65% of his own theoretical maximum. **[Mandatory]**

7.3.3.2 Localised Fatigue

a. In association with the above, there may be a situation when, although cardio-vascular workload is sustainable, localised fatigue may occur in discrete parts of the body (associated with muscle fatigue and blood circulation). This can be severely limiting to the task being carried out. Further information on localised fatigue and its implications is contained in the Astrand and Rodahl et al Textbook of Work Physiology [Ref. 14];

b. The overall design of the vehicle shall include consideration for the operation, stowage and retrieval of all stowed equipment under all foreseeable operational conditions. The procedures identified shall be able to be accomplished by the smallest and weakest crewmembers without inducing undue fatigue.

[Mandatory]

7.3.3.3 Autoloaders

a. Although an autoloader in a weapon system can reduce the workload during target engagement, there may still be significant manual loading tasks associated with an autoloader, depending on vehicle type. This means that there will still be some tasks associated with loading to be carried out by the remaining crewmembers;

b. Some of the tasks associated with artillery ammunition handling are very arduous and need automated loading and lifting aids wherever possible;

c. The designer shall ensure that any tasks associated with feeding an autoloader are kept to a minimum and comply with the manual handling and posture guidelines referred to above; **[Mandatory]**

d. The designer shall consider the above guidelines when providing of any reversionary modes for use in the event of autoloader failures, either when rectifying the failure or when continuing operations with manual override.

[Mandatory]

7.4 Mental Demands

7.4.1 **General**

7.4.1.1 The need to include human factors issues as part of total system design is again underlined when considering mental demands. Engineering psychology, which is a component element of human factors, helps us to explain the importance of mental aspects of human performance when considering design.

7.4.2 **Mental Workload**

7.4.2.1 Mental aspects of human performance can be described in terms of three general stages, which can then be dissected in more detail, to consider in particular their effect on the design of tasks, displays and controls. The first of these is perception, which covers how the brain deals with the sensory messages relayed from the eyes, ears and other senses. The second stage is decision, covering how the operator decides what to do with this information. The third stage is action, covering how the actions decided upon by the operator are carried out. This approach is taken from Wickens' book on engineering psychology and human performance [Ref. 15].

7.4.2.2 As with many work situations, a crewman in a crewstation seldom has the luxury of only attending to one task at a time. Whilst dividing his attention between tasks, different mental operations have to be carried out. Each of these operations uses part of the man's limited processing resources, and he has to time-share between tasks. The process of time-sharing becomes more difficult when activities cannot be performed serially, because they overlap. For example two tasks that have to be performed in the same timeframe and therefore overlap. This leads to the concept of concurrent processing.

7.4.2.3 Wickens [Ref. 15] goes on to explain that concurrent processing introduces three other factors that influence multi-task performance. These are: confusion of task elements, co-operation between task elements and competition for task resources. A critical factor in concurrent task time-sharing is related to task difficulty.

7.4.2.4 It is obviously important to examine the demand that a task places on an operator's limited resources. Wickens considers mental workload from three viewpoints: workload prediction, for which various techniques exist, [Ref. 16], [Ref. 17], [Ref. 18]; the assessment of workload due to equipment design; and the assessment of workload experienced by the man. The equipment design interface can often be modified to reduce the crewman's workload. Assessing the workload experienced by the crewman can result in selection of the most suitable operators for the task or the provision of further training for those crewman operating the crewstation or system.

7.4.2.5 High levels of mental workload, continuing over a period of time, can cause stress. This stress can alter the information processing activities, thus affecting performance. Hence there is the potential for another type of stress to be added to those covered in Section 3.2, underlining the importance of minimising multi-stress situations.

7.4.2.6 It can be seen that mental workload is an important element to consider when designing workstations. Many features that assist efficient mental performance can be designed into a workstation from the start. However, it will normally be necessary to assess

the design using a simulator and then at least a final mock-up/prototype, with representative crewmen operating the system. This enables the design to be finalised from the mental workload, as well as from all the other the human factors viewpoints. Subjective measures can be valuable when studying the workload at this and earlier stages in the design process. The National Aeronautics and Space Administration Task Load Index (NASA TLX) technique and the Subjective Workload Assessment Technique (SWAT) scale, [Ref. 19], [Ref. 20], are examples of the types of measures that can be used.

7.5 Vision

7.5.1 General

7.5.1.1 An Armoured Fighting Vehicle (AFV) is normally, by definition, designed with a ballistic and NBC protective shell containing as few intrusions as possible, to prevent the compromise of its integrity. The types of features that can weaken the protection are hatches and vision apertures. Against this, it is essential that vehicles be provided with efficient, fit for purpose vision systems that enable their occupants to perform their tasks effectively.

7.5.1.2 The visual requirements of crewmen vary, depending on the role of the vehicle and the tasks of individual crewmembers, however some general requirements exist.

7.5.1.3 For driving, a crewman needs to see as much as possible of the area immediately around his vehicle, as well as being able to identify surfaces, holes, trenches, gullies etc., to enable him to manoeuvre and proceed safely. He also needs to see well ahead and to either side at the front of the vehicle, for normal forward driving on roads and tracks.

7.5.1.4 The vehicle commander may have to provide assistance to the driver, as well as performing his other roles. The vehicle design and layout would allow him to see more from a higher position in the vehicle. This task may sometimes be delegated to another crewmember, if he has the same visual arcs as the commander. In some vehicle designs, the commander and/or another crewman may have a driving facility.

7.5.1.5 The commander’s other visual requirements include the need for good all-round vision over 360° with vision devices that enable him to carry out his surveillance and command and control activities, as well as orienting himself with his surroundings, the terrain and other vehicles. For example, a troop commander can be controlling the movements and positioning of other vehicles operating around him.

7.5.1.6 The vehicle gunner or weapon system operator will need a visual system appropriate to the specified role and performance of his weapon system. He will often have a second role of assisting the commander with surveillance and other tasks. In this case he will need access to the same visual information as the commander. In most vehicle designs, the commander will need to operate the weapon system as well, and will therefore need access to the full, or sometimes part of, the weapon sighting system functionality.

7.5.1.7 It is important that vehicle crews have visual cues which orient them with the outside world. This is because sights, hulls and turrets (if fitted) can all be pointing in different directions which can result in confusion, especially when rapid responses are called for. Other vehicle occupants may require visual information, depending on their role. For example, an infantry section, travelling in the rear compartment of an Armoured Personnel Carrier (APC), will be assisted by having a visual appreciation of the immediate outside world before de-bussing.

7.5.1.8 As vehicle design and technology advances, the need for vision devices tailored to the crewman's tasks will always exist. The proportion of electro-optical devices offered compared with traditional optical systems may increase, but vehicle crewmen will always need the best possible visual access to the outside of the vehicle, regardless of which type of system provides it. As already explained, this is necessary for accurate vehicle manoeuvring, navigation, situational awareness and vehicle command and control, as well as for surveillance. It is important to emphasise that the vision devices installed must enhance rather than degrade the crewman's performance, whatever his tasks. (See also Section 7 under 7.7).

7.5.2 **Image Quality**

7.5.2.1 The importance of image quality should be evident from the preceding descriptions of how crewmen rely on the visual information provided to them from the outside world. The key issues regarding visual quality are outlined below.

7.5.2.2 All vision devices provided must be of the highest possible quality. Coatings to maximise light transmission should be incorporated in any optical devices, but naturally other factors in the design, such as laser protection, also affect transmission. The resolution of any electro-optic devices should attempt to approach or improve upon 1 min of arc and the display update rate should be at least 25 Hz. All vision devices should incorporate appropriate protection for both the user and the device from, for example, nuclear, directed energy and ballistic weapons, depending on vehicle type and role. If these protection measures include lens coatings, care must be taken to minimise any degradation in the optical quality of the devices.

7.5.3 **External Considerations**

7.5.3.1 External considerations affecting the visual information presented to crewmen must also be considered.

7.5.3.2 The fitting of any extra armour or other external equipment shall not obscure the field of view from any vision device. **[Mandatory]**

7.5.3.3 There shall be means of avoiding obscuration due to weather conditions such as rain, mud, ice etc. by providing wash and wipe, de-misting and de-icing for the external surfaces all vision devices/sights. **[Mandatory]**

7.5.3.4 Orientation with the outside world shall be retained when using any type of external vision device. (See also para 3.5.1.7). This will require a visual cue in the eyepiece or display of the vision system, unless it has been agreed that the level of orientation required is provided by another means. **[Mandatory]**

7.5.4 Compatibility

7.5.4.1 Crewmen must be able to position their eyes and therefore heads in the optimum position relative to sight eyepieces or displays. If this is not possible, they will have a degraded view, which usually reduces or slows down the performance of the total system with which the sighting system is being used. This positioning of the eyes can be affected by equipment worn by crewmen.

7.5.4.2 All vision devices shall be compatible with all items of the crewman's personal equipment and clothing, i.e. respirator, defence pattern spectacles, helmet, with a minimum loss in field of view. It shall be possible for the crewman to see and/or use any controls or subsidiary displays he requires with the minimum disruption, when using the vision devices. **[Mandatory]**

7.5.5 Binocular, Biocular and Monocular Sights

7.5.5.1 The choice between binocular, biocular and monocular sights depends on the visual needs of the crewman, based on his role and the tasks he has to perform.

7.5.5.2 Binocular sights, which present separate images to each eye should be considered whenever possible. If these are not practical, biocular devices, which present the same image to both eyes, are recommended and are nearly always preferable to monocular sights, where the image is only presented to one eye.

7.5.5.3 Sights allowing both eyes to be used should include a control for adjusting the inter-ocular separation. Monocular sights should be adjustable to allow the user to select which eye he wishes to use without resulting in any twisting, leaning to one side, or turning of his head, neck or torso (33% of the population are left eye dominant). The unused eye should be occluded from the vehicle's interior lighting by the darkened surround of the sight face piece to enable it to remain open.

7.5.6 Vision Devices for Driving

7.5.6.1 It is important that the crewman driving the vehicle sees the outside world in its correct proportions. If the image is either bigger or smaller, there is a danger of misinterpretation of images or misjudgement of distances and mistakes or accidents may occur.

7.5.6.2 The vision device supplied to the driver, whether optical or electro-optical, shall present a true unity view of the outside world to the driver's eye, i.e. no magnification or minimisation. It should have as wide a field of view as is practicable. The ideal is 360°, but this will not normally be possible. **[Mandatory]**

7.5.6.3 All drivers' vision devices should preferably be binocular with separate views to each eye or biocular with the same image to each eye, but never monocular where only one eye receives an image. The sight should include a control for adjusting the inter-ocular separation.

7.5.6.4 The ability to see forward and rearward is essential. The forward looking vision device shall be directly in front of the driver and at eye height, when he is sitting in an axially straight posture, that is without his body or head leaning to either side. Mirrors may be used to provide rearward vision. **[Mandatory]**

7.5.6.5 Indirect vision systems using thermal imaging technology and the image presented to the driver on a flat panel display have been trialled [Ref. 21]**.** Provisional of a Thermal Imager (TI) system to the driver was considered to deliver a viable solution to some problems associated with operating AFVs, although the operational cost effectiveness of such an installation has yet to be assessed.

7.5.6.6 TV systems have been tried for reverse driving of AFVs [Ref. 22], though the operational cost effectiveness of such systems has yet to be assessed.

7.5.6.7 The vision device for the driver shall also enable him to identify the terrain detail immediately around and well ahead of his vehicle in the forward arc, in order to manoeuvre and drive safely. (See also para 3.5.1.3). It shall not degrade his visual performance. **[Mandatory]**

7.5.6.8 The importance of allowing for the effects of fatigue when using vision devices for driving must never be overlooked. These effects are discussed in para 3.5.7.8 and Section 7.

7.5.7 **Vision Devices for Other Crewmen**

7.5.7.1 As already mentioned, crewmen who are not driving can have roles requiring different vision devices. Care must be taken to ensure that these devices meet their needs and that performance is enhanced rather than degraded by their use.

7.5.7.2 Vision devices shall not degrade the visual performance of their users. **[Mandatory]**

7.5.7.3 If unity vision is called for in a particular vision device, the role of that particular crewman shall be studied when deciding whether to use an electro-optical solution. (See paras 3.5.2.1 and 2). **[Mandatory]**

7.5.7.4 The widest possible field of view should be provided and give an uninterrupted view over 360° at unity or near unity magnification, whenever the crewman's tasks (such as vehicle commanding) require this. If more than one vision device is used to provide a wider field of view, these should have contiguous or overlapping windows or displays to ensure that there are no gaps in the view presented to the crewman, depending on the vision system used.

7.5.7.5 The commander shall be provided with 360° unity vision. (See para 3.5.1.5). If it is necessary to use electro-optics for part of this capability, the image quality and fields of view shall be at least as good as that from a conventional optical system. **[Mandatory]**

7.5.7.6 The degree of magnification provided will dependent on roles the crewman has. For example sights may have switchable or zoom magnifications to aid the different surveillance tasks of detection, recognition, and identification.

7.5.7.7 Care must be taken to ensure that any information that needs to be displayed in the external vision devices (for example aiming marks) does not add to the difficulty of using the device by introducing obscuration, etc.

7.5.7.8 Care must also be taken to allow for the fatiguing effects from long term use of visual systems, especially those provided by indirect/electro-optical vision systems. An example of this is the continuous length of time without a break for which a driver has to use his sights. Further information on fatigue and eyestrain when using display screens is contained in Section 7 under 7.6.3.

7.5.7.9 All vision systems and their locations shall be designed to minimise fatiguing effects on their users. Practical operational regimes shall be possible for their use. **[Mandatory]**

7.5.8 Vision during Night Operations

7.5.8.1 Along with other military vehicles, AFVs are required to operate at night, therefore passive night sights are necessary when they are operating tactically. All night sights should be incorporated into a combined day/night sight rather than being stand-alone devices. These should have similar fields of view and not require the crewman to change his body or head position to use the two features of the sight.

7.5.8.2 For non-tactical situations, conventional vehicle lighting will be provided and for some situations, extra lighting will need to be provided, such as for earth moving by “C” vehicles.

7.5.8.3 The need for crewmen to retain their dark adaptation and how this can be achieved is covered in Section 6 under 6.3 on Illumination.

7.5.8.4 As with other crewmen needing a night vision capability, the provision of a combined day and night drivers sight is highly desirable. This may be a switchable system but both day and night sights must be of similar fields of view and be presented in the same position relative to the driver’s eyes. If head or helmet mounted night vision goggles are proposed, the driver’s control panel must have the appropriate lighting for the displays to be read easily, for example by providing a dimming capacity.

7.5.8.5 Night vision devices shall be compatible with crewmen’s personal equipment (see para 3.5.4.2) and shall not require unacceptable changes in posture when being used.
[Mandatory]

7.5.8.6 Some work has been carried out to compare driving at night using TI and Image Intensifier (II) systems [Ref. 21]. The trial did not demonstrate significant performance differences between the two technologies and further work was recommended on Thermal Imaging as a technology to provide a full 24 hour capability.

7.5.8.7 Work has also been carried out on the value of Night Vision Goggles (NVG) and TI linked to a Head up Display when driving trucks at night in convoy. This unpublished work carried out by DERA Centre for Human Sciences and Land Systems Sector with support from Industry, points to positive advantages of the systems in terms of safety and operational efficiency.

7.5.9 **Head in/Head out**

7.5.9.1 The option for both head in and head out operation is still specified in vehicle design for some crew positions and tasks. Head in is where the crewman is dependent on the optical or electro-optical vision devices to carry out his visual tasks. Head out is where he has an un-aided or ‘natural’ eye view of the world, with his head outside the vehicle. Care must be taken to ensure that the head out field of view is maximised and obscuration from external architecture and equipment is minimised.

7.5.9.2 The value of a head out position is that the crewman’s normal peripheral vision is complimented by his other senses of hearing, smell, orientation, body position and its movement in space. In other words, his total body system is able to function together in a natural manner. This can be valuable for some surveillance tasks. Also, the head out position is usually required for safety when driving AFVs on public roads.

7.5.9.3 The obvious disadvantages of the head out positions are lack of environmental, NBC and armour protection and difficulties in interfacing with some in controls and displays and with integrating with other crewmembers. The value of the positions therefore has to be considered in terms of the vehicle’s function, as well as vehicle safety. Advances in technology are continually influencing the decisions on this topic. Further information is contained in Section 6 under 6.4.

7.5.9.4 When a head-out option is required, the position shall be easy to adopt, provide a satisfactory supported posture, and ensure that crewman can operate and read essential controls and displays from both head-out and head-in positions. **[Mandatory]**

7.5.9.5 Soft skinned or “B” vehicles such as trucks and Landrovers, are examples of an intermediate level of vision, where a windscreen normally exists between the person’s eyes and the outside world, reducing signals from the other senses.

7.5.10 **Additional Information**

7.5.10.1 The use of displays for other activities and crew tasks is dealt with in Section 7.

7.5.10.2 Further information on human performance can be found in volumes edited by Boff and Lincoln [Ref. 23] and Smith and Jones [Ref. 24].

8 PROTECTION IN WORK SITUATIONS AND ENVIRONMENTS

8.1 Introduction and General Information

8.1.1 Whilst working in and around his vehicle, the crewman must be protected from occupational and environmental hazards. Some of these are Health and Safety issues, whilst others result directly from the military working environment and it is sometimes difficult to separate the two. Therefore they are both covered in this Section of the document, to reduce text overlap and cross-referencing. The repeal of Section 10 of the Health and Safety at Work Act; 1974 has resulted in added impetus for dealing satisfactorily in crewstation and vehicle design with many of the topics covered below, by supporting and drawing attention to some of the human factors issues.

8.1.2 Through good design, the human influence on systems safety can be very positive, whilst bad design can result in unnecessary accidents. The possibility of human error can be minimised through good design of complete systems and component items. Further information on systems design is contained in Section 2.

8.1.3 Military equipment should be capable of sustained operations within the climatic extremes specified in the requirement. Environmental demands can be identified as being either external or internal to the vehicle. The external environment can in broad terms be classified as being from either an atmospheric or mechanical source.

8.1.4 Equipment design can control most environmental factors to some extent. There are three broad categories:

a. Those factors that can be controlled by appropriate design, eg space allocation, illumination, ventilation, temperature, etc.;

b. Those that cannot be controlled by design, eg amount of solar radiation, dust, mud, rain, etc., although careful design can indirectly help to minimise their effects;

c. Those that are a by-product of the design itself such as noxious substances, vibration, noise, etc.

8.1.5 The environmental extremes to which a vehicle and its occupants will be subjected should be considered throughout the design process, because the maximum effectiveness and performance of the system should be the designer's highest priority. For this to be effective, designers will need to allow for additional crew requirements such as protective clothing, as well as effective reach, workspace and access which are covered in Section 6. Without these adaptations, there may be reduced human performance, and conditions that contribute towards increased maintenance time and errors, oversights, erroneous decisions, safety, stress and health hazards.

8.1.6 The designer must control the effects of the above factors on the internal workplace environment, in order to promote the life support, health, safety, physical and mental well-being of the operators. This can be achieved by either reducing their internal effects, or protecting crewmen from these sources to within acceptable limits, so that the physical and mental demands of the overall task can be met, and effectiveness maintained.

8.1.7 When the designer cannot guarantee the health and safety of the crewman from external and platform generated effects, protection must be provided. This should either be designed into the vehicle, or the design must be compatible with protection worn by the individual crewman. From a human factors viewpoint, it is usually better for overall protection to be designed into the vehicle, in order to protect all the crew. This is because protecting individuals often degrades performance by interfering with the human senses, tethering the crewman to the vehicle and adding to anthropometric dimensions with extra clothing bulk. If, in the course of duties, the crewman requires to leave the vehicle and enter a hostile environment, protection will need to be worn, or stowed internally beside the crewman, in dedicated places close to the operating position.

8.1.8 If the system being designed emits noise, heat, cold, radiation, vibration, toxic fumes or any other potential hazard, the design team must ensure that the levels are safe or that adequate protection is provided (see DEF STAN 00-25, Part 5) [Ref. 2]. For example, in the climatic conditions under which the equipment is required to operate, a habitable environment for the crew must be provided. However, the designer must always be aware that the crew can be exposed to the above multi-stress environment.

8.2 Vibration and Shock

8.2.1 **General**

8.2.1.1 The vibration experienced by the human body is complex, in that it does not respond in the same way as, say, vehicle components. For example, vibration spectra inside and outside the body are different and organs move at different resonant frequencies within their restraining cavities.

8.2.1.2 Because of the vibration associated with moving platforms, it is important that, when appropriate, control laws within the design of the systems allow for operation by crewmen in moving vehicles (e.g. the control of a gun firing on the move).

8.2.1.3 Vibration is defined as any sustained mechanical oscillatory disturbance; whereas shock, jolt, or recoil is a transient mechanical disturbance. Land vehicles will expose their occupants to vibration and, depending upon certain factors, can impair or limit performance, present a health risk (severe vibration loads can result in physical reactions of the musculo-skeletal system, blood circulation, and the internal organs), cause motion sickness (when vibration values are between 0.05 and 0.7 Hz, with a peak effect at 0.17 Hz), or discomfort and annoyance. Factors can be extrinsic (frequency, intensity, direction and duration of exposure) or intrinsic (body posture, seating, restraint, type of task, experience, expectation, arousal, motivation). It should also be noted that other factors such as noise, temperature, etc. could affect the operator's response to vibration.

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8.2.1.4 Designers must also be aware of the limits of human tolerance to vibration when finalising vehicle performance and the implications of factors such as suspension design on this tolerance.

8.2.1.5 Vibration and shock are usually transmitted to the body through some physical interface, e.g. a floor, seat or control, and is dependent upon the posture, orientation and muscle tone of the operator, as well as on an individual's size or mass. Every attempt should be made to reduce vibration at its source. If this is not possible, attempts to reduce vibration transmission to the crew by providing vibration-absorbing materials, or by seat design, should be made. If design is poor, the interface between a seat and its occupant can amplify vibration to an unacceptable level.

8.2.1.6 Another type of shock that could be experienced by an AFV crew is the "percussive" type high acceleration associated with mine blast and other devices. Some protection can be afforded from this by well designed body restraints in the form of seat harnesses, to help prevent crewmen being thrown about inside the crew compartment in the event mine detonation by the vehicle. Strategically placed padding and correctly fitted helmets also help. Further research is being carried out to suggest improvements in harness design and associated forms of protection.

8.2.1.7 It should also be noted that gunfire produces a mechanical stimulus that may be classified as repeated shocks, accelerations or as vibration with a high crest factor. (See mandatory para 4.3.4.5 under noise).

8.2.1.8 In the performance of certain tasks, it should be noted that the vibration of displays or hand controls, as well as the operator himself, is detrimental to task performance. Relative vibration between the operator and displays is also detrimental.

8.2.1.9 The overriding consideration is that the efficient performance of crew tasks must not be compromised by vehicle vibration.

8.2.1.10 For any crewman in his seat, in any posture, with the vehicle moving at any speed across any type of terrain, the Vibration Dose Value (VDV), as specified in BS 6841 (1987) [Ref. 25] and ISO 2631-1 (1997) [Ref. 26], shall not exceed 15 $m.s^{-1.75}$ during any 24 hour period. **[Mandatory]**

8.2.2 Ride and Comfort

8.2.2.1 The level of vibration that may be deemed to be "comfortable" will depend on many factors. It is not possible to define an absolute level of vibration beyond which the ride will become uncomfortable for all individuals, or for a given individual under all conditions. Generally however, the higher the vibration, the greater the discomfort. BS 6841 (1987) [Ref. 25] states that a frequency weighted r.m.s. vibration magnitude in excess of 1.6 $m.s^{-2}$ is likely to correlate to a subjective rating of "uncomfortable" to "very uncomfortable". Notwithstanding para 4.2.1.10, the level of vibration might be deemed as comfortable.

8.2.2.2 For the finalised vehicle design, the manufacturer should provide a level of ride comfort which is subjectively comfortable, as specified in BS 6841 (1987) [Ref. 25].

8.3 Noise

8.3.1 Health and Performance

8.3.1.1 Noise affects human health, performance and operational effectiveness in various ways:

a. Exposure to noise leads to a loss of hearing acuity. This may at first be temporary; but severe, prolonged or frequently repeated exposures give permanent and incurable loss. The loss is typically greatest at 3, 4 or 6 kHz. There are very marked differences in susceptibility between individuals;

b. Noise impairs the ability to hear and understand speech and other auditory information;

c. Noise causes fatigue, sleep disturbance and general annoyance to off-watch crewmen;

d. Noise affects performance, especially at intellectually demanding tasks;

e. Very intense noise can damage the respiratory tract, especially the lungs. Such noise may occur, for instance, during firing anti-tank or support weapons from an enclosed space such as a vehicle. In most cases, such noise will exceed limits set for conservation of hearing, even where hearing is protected.

8.3.2 Personnel not using hearing protection

8.3.2.1 For personnel not using hearing protection, noise shall not exceed any of the following values at any crewstation:

a. A-weighted sound pressure level (SPL) of 80 dB(A) (desirable), and 85 dB(A) (essential) for any operating condition specified in the requirement; **[Mandatory]**

b. The Speech Interference Level (defined in BS ISO 9921-1: 1996) [Ref. 27] shall be consistent with intended usage. **[Mandatory]**

8.3.3 Personnel using hearing protection

8.3.3.1 For personnel using hearing protection, the following applies:

a. The use of hearing protection, and the type to be used, shall be agreed with the User. If the specification does not refer to the use of hearing protection, its use shall not be assumed without reference to the project sponsor; written agreement of the project sponsor is required. Any form of headgear, including spectacles, helmets, protective hoods and respirators may degrade hearing protection; the project sponsor shall specify whether this is to be taken into account; **[Mandatory]**

b. Ergonomic factors of hearing protectors, such as comfort, robustness and compatibility with other equipment, are as important as acoustical aspects. For conventional hearing protection, the requirements in BS EN 352 [Ref. 28] shall be met; for military communications headsets, those requirements in BS EN 352 which are relevant to military headsets shall be met; **[Mandatory]**

c. The A-weighted SPLs at the ear shall be calculated at each crew position and for each vehicle condition. The calculation shall be made from measurements of the noise in octave or narrower bands, and from measurements of hearing protector attenuation in octave or narrower bands. The hearing protector attenuation shall be taken as the assumed protection, i.e. the mean attenuation less one standard deviation. The levels shall not exceed 80 dB(A) (desirable), or 85 dB(A) (essential);

d. Where the hearing protection incorporates a communications facility, levels of speech shall be reduced as far as possible, consistent with speech clarity. Vehicle noise transmitted through the communications system shall be minimised; **[Mandatory]**

e. Where the hearing protection incorporates a communications facility; the minimum requirements for speech intelligibility are given in Annex C of DEF STAN 00-25 Part 9 [Ref. 2], and shall be met; **[Mandatory]**

f. The minimum requirements for other auditory information are given in DEF STAN 00-25 Part 8 [Ref. 2], and shall be met. **[Mandatory]**

NOTE 1: Acoustical performance of hearing protection is normally measured according to BS EN 24869, Part 1 [Ref. 29]. A-weighted SPL at the ear can then be calculated using the octave-band method in BS EN 24869-2:1995 [Ref. 29]. This method is not suitable for use with Active Noise Reduction and other systems where some electronic noise may be present during normal operation, or where attenuation may vary with sound pressure. In such cases, other methods are available but at time of writing are not yet standardised, and specialist advice should be sought.

NOTE 2: Where noise is sufficiently intense to require use of hearing protection, and no communications facility is built into the protection, speech and other auditory information is unlikely to be understood.

8.3.4 **General Vehicle Considerations**

8.3.4.1 Noise can be a serious problem for crewmen in and around military vehicles. Health and Safety regulations legislate for peacetime conditions (JSP 375 provides a useful Health and Safety reference handbook) [Ref. 30]. However care must be taken to protect operational crewmen, both for their own well-being, but also so that any degradation in hearing does not affect military effectiveness in areas such as surveillance, overall performance, speech and hearing ambient sounds, as well as alarms and alerts.

8.3.4.2 The best design solution is to reduce the causes of noise to acceptable levels at source, but in the military environment this is not always possible and alternative ways of addressing the problem have to be found.

8.3.4.3 Noise generated externally may allow the source to be detected aurally by a soldier, e.g. Auxiliary Power Unit (APU) running in a vehicle. Further information on tactical considerations for the limits of noise generated externally in relation to detection and countersurveillance are given in DEF STAN 08-6 Part 2 [Ref. 31].

8.3.4.4 During assessment trials, measurements shall be taken at or near crew head positions. Conditions shall include, as appropriate, movement at various speeds, movement on hard road surface and across country, vehicle stationary with main or auxiliary engine running, and hatches open and closed. Results shall be given as an r.m.s. average in any one position for any one condition, but shall not be averaged across conditions or positions. For wheeled vehicles, measurements of noise levels may take account of the need to run on one or more flat tyres, though at reduced speeds. Standard noise trials shall be undertaken with tracks tensioned, tyres at correct pressures and all equipment and stowage fitted. **[Mandatory]**

8.3.4.5 Limits for impulse noise and blast (the terms are roughly synonymous) from explosive sources such as gunfire (including the user's own gun) are described in DEF STAN 00-27 [Ref. 32], and requirements shall be met. **[Mandatory]**

8.4 Optical Safety

8.4.1 In order to protect crewmen’s eyes and the parts of their bodies that come into contact with optical and electro-optical equipment, safety aspects relating to the equipment’s design, installation and use must be addressed. Non-safety design aspects of sighting systems and vision are dealt with in Section 7 under 7.6 and Section 3 under 3.5 respectively.

8.4.2 Major areas of human factors concern are laser pulse or nuclear flash injuring the eye and ballistic impact damaging the sight and hence possibly injuring the crewman.

8.4.3 Also, because of the harsh vehicle movements that occur operationally, cushioning is also required around sight eyepieces and periscopes to enable them to be used without injury and discomfort occurring to the crewmen, especially around the head and eyes.

8.4.4 All sights, periscopes and sensors shall be protected against laser damage in accordance with the requirements and guidelines detailed in [Ref. 33]. **[Mandatory]**

8.4.5 All sights, periscopes and sensors shall be protected against nuclear weapon effects, as detailed under nuclear survivability criteria. **[Mandatory]**

8.4.6 All sights, periscopes and sensors shall be protected against ballistic attack. **[Mandatory]**

8.4.7 All sights, periscopes and sensors shall provide the crewman with protection from the eyepiece(s), by incorporating satisfactory facepieces, browpads and eyecups into their design. **[Mandatory]**

8.5 Mechanical Safety

8.5.1 An AFV can provide a particularly hazardous working environment, but adherence to safety in design and operating procedures will make for safe operation. The designer must ensure that the vehicle and its associated sub-systems does not have projections and protrusions which may cause injury and snag the crewman's clothing.

8.5.2 All moving parts should be guarded, shielded or enclosed.

8.5.3 If moving parts cannot be guarded, warning signs or labels shall be attached conspicuously, adjacent to the hazard. **[Mandatory]**

8.5.4 Warning signs or labels shall be attached conspicuously, adjacent to or on any equipment which presents a hazard to personnel. **[Mandatory]**

8.5.5 Warning placards or labels should be placed adjacent to any equipment that presents a hazard to personnel (e.g. high voltage, heat). All edges and corners should be rounded and protrusions from equipment surfaces minimised.

8.5.6 An AFV has heavy armoured hatches and doors, which have to be functional with the vehicle in various attitudes on sloping ground, especially when it is operating off-road. This can considerably increase the effort needed to open them, which could be a critical factor in an emergency situation.

8.5.7 Hatches and doors shall be easy and safe to open and close, from inside and out, under the range of vehicle attitudes listed in the design specification, as well as being fit for purpose, especially in terms of protection levels. **[Mandatory]**

8.5.8 The design and installation of latches, knobs and similar devices, including hatch handles and hand rails, shall be such that they do not allow hands and fingers or clothing to be trapped. **[Mandatory]**

8.6 Physical Safety

8.6.1 An AFV can provide a hostile environment for the crewman to operate in. However, attention to his physical safety considerably reduces the risks.

8.6.2 One basic rule is that AFVs are normally mounted and dismounted from the front, so that the driver is aware when people enter or leave the vehicle, and does not move off or manoeuvre during this process. This is also normally the safest route for climbing on board as it generally presents the least difficult route onto the vehicle. It may be necessary to specify additional routes onto specific types of vehicles.

8.6.3 Unless otherwise specified for a particular vehicle type, it shall be possible to mount and dismount the vehicle from the front in full view of the driver, using approved steps or footholds. These shall be integrated so as not to compromise any other design features, such as radar signature etc. **[Mandatory]**

8.6.4 Hatches and doors shall permit rapid and easy entry and exit to and from crewstations. **[Mandatory]**

8.6.5 It shall be possible to either escape or extract an injured crewman from any crewstation by a minimum of two different routes, with the vehicle in any of the attitudes listed in the design specification. **[Mandatory]**

8.6.6 Crewstation design shall ensure the exclusion or guarding/padding of projections, protrusions, burrs, sharp edges and corners which could result in injury to crewmen or the snagging of their clothing or equipment. **[Mandatory]**

8.6.7 The design shall exclude slipping and tripping hazards, and additionally, non-slip surfaces shall be provided where appropriate. **[Mandatory]**

8.6.8 Head obstructions and low overhead clearances shall be clearly identified. **[Mandatory]**

8.6.9 The operation and static location of cranks, levers, controls and securing pins in hand rails shall not pinch, cut or snag the crewman or his clothing. Turrets shall be provided with safety switches to ensure overriding safety control of their movement. **[Mandatory]**

8.6.10 Care must be taken in the design to guard against the need for activities that could result in physical/musculo-skeletal injury due to lifting heavy equipment, whether operationally or during maintenance. Under operational conditions, this often presents difficult situations. The designer must be aware of this human limitation and, where practicable, design small, easily movable modules. Further information on Body Strength and Stamina is contained in Section 3 under 3.3.

8.6.11 All removable components shall be no heavier than a two person lift, unless designed to be with the aid of lifting equipment moved. **[Mandatory]**

8.6.12 Where items to be lifted are heavier than a one person lift, warning signs shall be provided, giving: weight, number of lifters needed and/or requirement for lifting equipment. **[Mandatory]**

8.6.13 Where the design incorporates stored energy devices, such as spring loaded equipment, torsion bars, levers, bungee restraints etc., safety features such as locking devices, removable tabs, or other forms of protection as well as warning signs shall be provided.

[Mandatory]

8.7 Electrical/Electronic Safety

8.7.1 Electrical and Electronic interfaces between crewmen and equipment must be designed with safety in mind and in accordance with IEE regulations. This is particularly important as an AFV presents a potentially dangerous electrical environment, the situation applying to both the operational and maintenance situations.

8.7.2 All equipment shall be designed so as to protect crewmen from all electrical hazards.

[Mandatory]

8.7.3 All metal parts of electrical equipment liable to contact with crewmen shall be at ground potential and shall be provided with grounded or non-conducting covers.

[Mandatory]

8.7.4 Equipment access doors or covers shall incorporate interlocks to remove all hazardous voltage potentials when open and be labelled to identify voltage hazards to maintainers.

[Mandatory]

8.7.5 Warning signs shall be provided where voltage potentials are hazardous to crewmen, and in addition, recessed connectors or other protective measures shall be incorporated where excessive voltages are present. **[Mandatory]**

8.7.6 The design of plugs and sockets shall prevent polarities and voltage ratings from being incorrectly connected. **[Mandatory]**

8.7.7 All exposed electrical conductors shall be insulated. **[Mandatory]**

8.7.8 All power tools used near high voltages shall have insulated handles. **[Mandatory]**

8.7.9 Portable equipment shall be designed using 3-core power leads, with one wire at ground voltage potential. Alternatively, a double insulation design or its equivalent without a ground wire can be used, but only if approved. **[Mandatory]**

8.7.10 Equipment shall be designed so that moisture cannot collect near electrically operated controls. **[Mandatory]**

8.7.11 The design of equipment shall ensure that crewmen are protected from static charge build-up. **[Mandatory]**

8.7.12 It shall not be possible for any connector installation/removal tool to make contact with adjacent connectors. **[Mandatory]**

8.7.13 Vehicle batteries shall have guarded terminals to prevent inadvertent short-circuiting.

[Mandatory]

8.8 Fire Protection

8.8.1 All reasonable precautions shall be taken to minimise fire hazards. **[Mandatory]**

8.8.2 Any potential fire hazard shall be contained in a non-combustible enclosure and equipment shall be designed not to emit flammable gases, undesirable or dangerous smoke, or fumes into crew compartments. **[Mandatory]**

8.8.3 The vehicle shall incorporate a fire detection system appropriate to its type, to warn the crewmen of a fire in, for example, the engine, crew compartment, or elsewhere. **[Mandatory]**

8.8.4 Extinguishant shall be piped into the engine compartment. Internal and external handles shall be provided to trigger the release of extinguishant. **[Mandatory]**

8.8.5 Non-toxic hand-held fire extinguishers shall be provided for internal and external use and they shall be within easy reach of crewmen, both internally and externally. **[Mandatory]**

8.9 Range Safety

8.9.1 Range Safety requirements will not normally affect the design of vehicles from the Human Factors viewpoint, except possibly for the satisfactory location and accessibility of range safety flags etc.

8.9.2 Provision will need to be made for Gunnery Instructors to mount the vehicle from the side and/or rear, but this should not be possible when the vehicle is operational, and should be part of the range facilities.

8.10 Road Safety

8.10.1 The design of Armoured Fighting Vehicles can present problems in terms of road safety, as operational procedures sometimes contravene the regulations.

8.10.2 The most common example with current vehicle designs is that under operational conditions, the AFV driver will frequently be closed-down which limits his vision. This is unacceptable in peacetime on the public highway. Therefore on roads he is normally required to drive opened-up with assistance from another crew member, usually the commander, who will also be head-out with the best view around the vehicle.

8.10.3 The design of future vehicles may not allow this type of solution to be adopted for peacetime road use, but the designer must carefully consider this aspect of design as future vehicles will required to undertake more flexible roles in any Operations Other than War (OOTW).

8.10.4 Current and reasonably foreseen Road Traffic Regulations as they legally apply to vehicles and their crewmembers shall not be compromised during peacetime use. **[Mandatory]**

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8.11 Safety and Lack of Sleep

8.11.1 It is important to remember the link between safety and tiredness and further information on this is contained in Section 3.

8.11.2 Despite all the best plans, Standard Operating Procedures (SOPs) and man-management, under operational conditions there will be crewmen operating systems whilst suffering from a lack of sleep. Good design can not only help address the safety aspects in the ways already highlighted in the preceding paragraphs, but also by giving the crewman positive feedback that confirms and checks his actions when interacting with systems in the vehicle.

8.12 Thermal Environment

8.12.1 **Background**

8.12.1.1 To maintain comfort, well-being, and health, the temperature inside the human body and on the skin surfaces must be maintained within narrow ranges. Internal temperature is termed "deep body temperature" and is usually measured in the rectum or ear. For manned vehicle assessments, skin temperatures are usually measured at the extremities of the body, on the fingers and toes. Both deep body temperature and skin temperature are used to monitor thermal equilibrium. If these temperature ranges are not maintained, the crewman's performance levels will decrease.

8.12.1.2 The body and/or skin temperatures discussed in the following paragraphs should not be used to determine length of occupancy times for humans in vehicles. The designer must provide a system that maintains the body's thermal equilibrium.

8.12.1.3 Ideally, the air temperature in the crew compartment should be maintained at around 21°C, but allowance must be made for the clothing that a crewman may have to wear, depending on his operational tasks in and outside the vehicle, as well as its type and role on the battlefield. Current British, European and International Standards do not yet adequately deal with heat stress for clothed workers/crewmen. A list of clothing and equipment to be worn in different environments and operational situations will be provided in the vehicle specifications.

8.12.1.4 The maintenance of thermal equilibrium in the crew compartment can be aided by providing good thermal insulation between the compartment and its surroundings. This also helps minimise condensation, and reduces the number of contact surfaces. (See hot and cold burns below, see Hot Burns and Cold Burns).

8.12.1.5 The following paragraphs highlight some of the effects and implications of the clothing worn in different environments. In general, fewer clothing layers and thinner clothing is worn in hot /humid environments, but its presence in these conditions can impede in the evaporation of sweat from the body. In cold conditions, clothing insulation helps slow (but cannot stop) the rate of heat loss from the body, whilst its bulk restricts body movement, increases space requirements and results in losses in manual dexterity. The degree of trade-off possible between clothing worn and crew compartment temperature has to be considered for different operational situations, together with the overall design of the vehicle system to match those situations.

8.12.1.6 The designer shall provide a thermal environment at each crew workplace which maintains each crewman's body in thermal equilibrium under the range of climatic conditions specified in the vehicle specification. **[Mandatory]**

8.12.2 Thermal Hot

8.12.2.1 Hot Burns

a. Momentary contact between the skin and surfaces hotter than 43°C can cause hot burns. With this in mind, it may be necessary to insulate some surfaces such as hand controls and areas adjacent to the face and arms or other uncovered skin. Further information is contained in BSI document PD 6504. [Ref. 34].

8.12.2.2 Deep Body Temperature

a. This must be maintained within about 1°C of the normal of 37°C. For unimpaired mental and physical performance, the upper limit is usually set as 37.5°C. This value is used in the manned habitability assessments of Armoured Fighting Vehicles for service with the British Army;

b. Any air-conditioning system shall be able to maintain the deep body temperature of all healthy vehicle occupants at a maximum of 37.5°C whilst at their normal seated positions, under the range of climatic conditions specified in the vehicle specification. **[Mandatory]**

8.12.2.3 Hot Climates

a. The maximum allowable value for deep body temperature has the following physiological basis: in normal healthy adults, the deep body temperature is controlled within narrow limits by physiological mechanisms which balance heat lost from the body with heat gained. When a human is placed in a hot environment, the blood vessels in the skin dilate and the sweat glands are stimulated to produce sweat. The increased flow of blood through the skin increases the skin temperature and this assists the evaporation of sweat from the surface of the skin, removing the latent heat of evaporation. This process cools the skin and the blood flowing through it, thus assisting the body to limit the rise in deep body temperature. Regulated and directed airflow around the body can assist this process. It is necessary to replace the above evaporative and water loss and to achieve this under hot conditions, at least 15 litres/man /day of drinking water must be provided. More specific quantities for a range of climatic conditions are not readily available, and advice should be sort from experts agencies, (for example the Centre for Human Sciences);

b. The delicate balance of heat loss and heat gain can easily be disturbed by circumstances which result in the body gaining heat (e.g. by physical activity or exposure to high ambient temperature), or which reduce the evaporation of sweat (e.g. the wearing of insulating clothing, or clothing which impedes the transfer of moisture vapour). Thus the body has increasing difficulty in losing heat and deep body temperature begins to rise uncontrollably. A rise of even 0.5°C above the normal level of about 37°C causes the individual to become uncomfortable and irritable, and the efficiency with which mental and physical tasks can be performed is reduced. If the body temperature continues to rise, the amount of water lost as sweat compromises the effective function of the heart and circulation. This can lead to fainting, heat exhaustion, irrational decisions and eventually heat stroke. It is therefore imperative to understand that even small, unchecked rises of body temperature may be the prelude to a life-threatening series of events that can be reversed only by immediate medical intervention.

8.12.3 **Thermal cold**

8.12.3.1 Cold Burns

a. Momentary contact between the skin and cold surfaces can cause cold burns. As with protecting from hot burns, it may be necessary to insulate some surfaces such as control handles and areas adjacent to the face.

8.12.3.2 Skin Temperature

a. Sustained skin temperatures must also be kept within a narrow band of the 'normal' of about 33°C. An upper limit is about 36°C above which acute discomfort is experienced. Over most of the body, a lower limit is about 25°C. For hands and feet, the lower limits are 15°C and 12°C respectively.

8.12.3.3 Cold Climates

a. If the core temperature falls below 35.5°C, an individual is likely to become confused and slow to react. This can have serious safety and operational implications;

b. When a human is placed in a cold environment, the blood vessels in the skin constrict (maximally in the extremities) and shivering occurs as skin temperature is reduced. If the environment is cold and the clothing inadequate, the human loses heat and below a deep body temperature of 36.0°C, the individual becomes uncomfortable, and the efficiency of mental and physical task performance is reduced. If heat loss continues, the individual becomes confused. The vasoconstriction of the extremities causes pain and a loss of function that leads to a reduction in manual dexterity, with resulting difficulties and slowness in performing the majority of tasks. Insulation of footplates and footwells helps to slow the rate of heat loss from the feet to the cold metal surfaces on which they rest but cannot prevent the heat loss;

c. Heating shall be provided within crewstations utilised for sedentary work or occupied during extended periods of time in order to maintain normal deep body and extremity skin temperatures at high enough levels to minimise discomfort and loss of effectiveness. It is necessary to provide an environment that maintains the air temperature around each crewman's feet at 10°C within one hour of a cold start of the vehicle.

8.12.4 **Humidity**

8.12.4.1 The values of dry and wet bulb temperatures that are acceptable depend on many factors, including airflow over the body, clothing worn, and the level of work being done. However, approximately 45% relative humidity should be provided at 21°C. This should decrease with rising temperatures, but should remain above 15% to prevent irritation and drying of body tissues, e.g. eyes, skin, and respiratory tract.

8.12.4.2 It is possible under some circumstances to use the Wet-Bulb Globe Temperature (WBGT) Index as a guide to crew workstation acceptability. However, this index was not developed for personnel exposed to heat stress in confined spaces, or when wearing clothing. Its applicability for use as an index for evaluation of AFVs needs to be considered on a case-by-case basis by a Human Factors Expert.

8.12.5 **Crew Compartment Conditions**

8.12.5.1 Experience has shown that to maintain the above physiological limits in modern vehicles, an air conditioning and heating system are needed in most climatic conditions. The vehicle should be habitable at the climate specified for the areas of operation, and preferably for world-wide climates. (See DEF STAN 00-35/2 [Ref. 9]).

8.12.5.2 Thermal insulation should be fitted to the interior of the vehicle and the insulating materials used should all have low combustibility, smoke generation, and no emission of toxic fumes in a fire situation. The heating/ventilating system should be designed to minimise degradation of visibility due to frosting or misting of vision devices including any windshield that might be fitted.

8.12.6 **Manned Habitability Trials**

8.12.6.1 During the vehicle development plan, manned habitability trials should be carried out to verify the above criteria. A methodology for carrying out these trials is contained in APRE Working Paper 14/88 [Ref. 35].

8.13 Airflow, Filtration, Fumes and Toxicity

8.13.1 **Fresh Air Supply and Filtration**

8.13.1.1 For closed down operation, adequate fresh, filtered, dust-free air, uncontaminated by gun fumes or engine exhaust gases shall be supplied through the NBC filters to the crew compartments of the vehicle. The filtered air shall be available at the crew positions via the temperature control system ducting. **[Mandatory]**

8.13.1.2 The system must deliver ducted air that impinges on the maximum surface area of the body. In addition, it must be possible to preferentially direct cool air to the head and warm air to the feet. **[Mandatory]**

8.13.1.3 The ducted air shall be in sufficient quantity to provide oxygen replacement and carbon dioxide removal for the number of personnel within the crew compartment, whatever their level of physical activity. **[Mandatory]**

8.13.1.4 The airflow shall also be sufficient to clear gun fumes. To achieve this, it may be necessary to provide air leakage routes to prevent the build up of fumes. **[Mandatory]**

8.13.1.5 The dust concentrations to which military land vehicles are exposed vary widely from imperceptible levels to dense clouds that may reduce visibility to almost zero. Dust causes temporary eye and throat irritation and at times degrades performance and interferes with operations. Dust skirts are of great value in reducing the dust raised around a vehicle.

8.13.1.6 Individual exposure to total inhalable dust should be kept below 10 mg m^{-3} Time Weighted Average (TWA) or 4 mg m-3 8 hour TWA for respirable dust. These concentrations should be taken as substantial and are hazardous to health. Where no short term limit is specified, it is recommended that a figure of three times the long term limit be used as a guideline for controlling short term excursions in exposure. For definitions of total inhalable and respirable dusts see HSE Occupational Exposure Limits Note as laid down in EH40 of the current year [Ref. 36]. **It must be noted that the values given in EH40 are subject to review every year.**

8.13.1.7 If the enclosure volume is 4.25 m^3 or less per person, a minimum of 0.85 m^3 of ventilated air per minute shall be introduced into the enclosure; approximately two-thirds should be from the outside atmosphere.

8.13.1.8 Sufficient outside fresh air shall purge through the crew compartment to maintain crewmen in thermal equilibrium under the range of climatic conditions specified in the vehicle specification.

8.13.2 **Toxicity**

8.13.2.1 Toxic contaminants generated from various sources can have debilitating effects on the efficiency of occupants and operators of vehicles, and in the worst case, cause death. For AFVs, the ventilation system must scavenge and eliminate all toxic fumes from the crewstations at least to within HSE Occupational Exposure Limits as laid down in EH40 of the current year [Ref. 36]. Extraction of fumes should be at or near the source. **It must be noted that the values given in EH40 are subject to review every year.**

8.13.2.2 It should be noted that the S10 in-service respirator does not protect the wearer against Carbon Monoxide (CO). Adequate respiratory protection against toxic levels of CO can only be provided by breathing apparatus incorporating a compressed air supply.

8.13.2.3 CO, Nitrogen Dioxide (NO2) and Ammonia (NH3) are produced when weapons are fired. CO can cause loss of mental alertness, disorientation and collapse. Ammonia is highly irritating to the eyes and is also a pulmonary irritant and asphyxiant. Recommended NO2 levels should not be exceeded as it can produce grave damage to the lower respiratory tract. The HSE EH40 (For EH40/99 [Ref. 36]) exposure standards are as follows:

Carbon Monoxide	200 ppm for 15 minutes 30 ppm over an 8 hour TWA
Ammonia	35 ppm for 15 minutes 25 ppm over an 8 hour TWA
Nitrogen Dioxide	6 ppm for 15 minutes 3 ppm over an 8 hour TWA

8.14 NBC

8.14.1 NBC Collective Protection for Vehicles

8.14.1.1 AFVs should have full Collective Protection (COLPRO) unless otherwise stated in the vehicle specification. The ventilation system should be integrated with the NBC system and must be capable of maintaining an overpressure of 7.5 mm Hg. If air conditioning is fitted, it should be integrated with the NBC system. Careful design will be needed to meet the requirements of delivery of hot air at foot level and cool air at face level, covered under 4.13.1.2.

8.14.2 Clothing for IPE

8.14.2.1 NBC clothing places an extra heat load on the wearer, as it restricts or prevents the evaporation of sweat, as well as adding thermal insulation to the body. Hence the problems of heat loss and gain explained in the background commencing at 4.12.1, are amplified when NBC clothing has to be worn.

8.14.2.2 Measures used as a defence against chemical and biological contaminants can impair the efficiency and performance of a human operator. Physical defence is provided by the IPE which is bulky and restricts movement. As the ambient air temperature and humidity increase, the capacity for sustained physical activity is reduced. The respirator restricts peripheral vision, as well as distorting and attenuating perception. Sound may need to be amplified or filtered, and visual information should be designed for foveal vision in the photopic range. Touch and finger dexterity are severely impaired when wearing NBC gloves and therefore switches and controls should be large and well spaced.

8.14.2.3 The clothing assembly worn with the IPE suit, gloves, overboots respirator and AFV or Infantry helmet, will be dependent upon the climate, the NBC threat and the operational situation at the time.

8.14.2.4 In AFVs, the workspace constraints and operational procedures normally require the wearing of NBC IPE less the respirator and gloves, the latter being stowed in dedicated locations adjacent to each crewman or carried, ready for immediate use.

8.15 Radiation

8.15.1 The effect of ionising radiation on human tissue is dependant upon how much is absorbed, the dose rate, and its type (i.e. whether alpha particles, neutrons, etc.). Effects include skin damage, gastro-intestinal symptoms, nausea, vomiting, diarrhoea, and increased likelihood of inducing cancer or genetic defects. Details are contained in DEF STAN 00-25, Part 5 [Ref. 2].

8.15.2 Non-ionising electromagnetic radiation results in heating of exposed tissues, this can vary from sunburn to whole body heating. There is clear evidence of harmful effects above a specific absorption rate of 4 WKg^{-1} and thus limits are very low. The European Community (EC) limit is $0.4WKg^{-1}$.

8.15.3 Lasers can also produce a similar harmful heating effect, especially affecting the eyes. Specific advice needs to be taken from the manufacturer of the individual laser type depending upon its intended purpose.

8.15.4 External sensors to show external ionising and non-ionising radiation, chemical and nuclear levels should be readable from inside the crew compartment.

8.16 Body Protection

8.16.1 Restraints and Harnesses

8.16.1.1 The provision of restraints and harnesses in AFVs often presents a design challenge, because of the harsh vibration/shock/impact environment in which vehicles operate, together with the range of clothing and equipment worn by crewmen and their need to move in and out of their restrained locations rapidly. The environment will normally dictate the use of a full seat harness, together with a robust "crashworthy" seat incorporating a head restraint.

8.16.1.2 Restraint harnesses and associated seating shall be provided which are appropriate to each crewman's workplace or location and the tasks he has to perform. **[Mandatory]**

8.16.1.3 All restraint harnesses shall be fully adjustable to accommodate the full anthropometric range of users dressed in the maximum and minimum bulks of clothing. **[Mandatory]**

8.16.1.4 All restraint harnesses shall be retractable and capable of being stowed when not in use. **[Mandatory]**

8.16.1.5 Restraint harnesses shall be designed with a quick release and fastening mechanism which can be operated and adjusted wearing NBC and cold weather gloves. **[Mandatory]**

8.16.2 Helmets

8.16.2.1 Because of the harsh vibration/shock/impact environment already mentioned above, it is essential that the design allows space for wearing a helmet to protect the crewman's head, whilst allowing space for access to sight eyepieces and any other locations into which he needs to put his head. Further information on body space is contained in Section 6.

8.16.2.2 The crewman shall be able to carry out all his duties and tasks whilst wearing his helmet, and shall have a clearance of 50 mm above his helmeted head, as detailed in Section 5, para. 5.2.10. **[Mandatory]**

8.16.3 Protective Clothing

8.16.3.1 The physiological aspects of heat cold and NBC have already been discussed in this section. Therefore the importance of integrating protective clothing into the overall design is evident. Any special requirements for the clothing must be allowed for, such as extra space for cold weather clothing, access to sights etc. when wearing a respirator and operation of controls, pushbuttons and keyboards when wearing cold weather or NBC gloves. Further information on clothing is contained in Section 6.

8.16.3.2 The crewman shall be able to carry out all his duties and tasks whilst wearing the protective clothing called up for use with a specific vehicle. **[Mandatory]**

8.16.4 **Body Armour**

8.16.4.1 The situations where body armour will be worn inside AFVs varies, but when this is called for, allowances must be made for it in the same way as more conventional protective clothing.

8.16.4.2 When required to wear body armour inside an AFV, the crewman shall be able to carry out all his duties and tasks whilst wearing it. **[Mandatory]**

9 BODY DIMENSIONS AND RANGES OF MOVEMENT

9.1 Introduction

9.1.1 It is essential to provide sufficient space for the different sized crewmen who will use the vehicle and equipment (i.e. the intended user population), as well as allowing for their changes in posture or movement whilst carrying out tasks or simply riding in the vehicle (i.e. the provision of spatial envelopes). This normally necessitates providing adjustment in seats and some crewstation components.

9.1.2 As with most other human related criteria, man is adaptable and can therefore often squeeze into a space which is not satisfactory for the task, though this incompatibility may not be immediately obvious. However, the crewman’s efficiency in carrying out his duties will be severely impaired, particularly with the passage of time and when compounded by other stressors such as fatigue, ride motion, environmental extremes and mental demands.

9.1.3 DEF STAN 00-25 Part 2 [Ref. 2] covers body size and includes detailed explanations of percentile ranges and human body dimension variations. It is worth noting at this stage that, for example, there is no such thing as a 95th percentile person in all dimensions, though there are correlations between groups of body dimensions. This means that a crewstation must be designed to accommodate different combinations of percentile ranges, such as short torsos with long legs and large stomach depths.

9.2 Body Size

9.2.1 To configure the individual operator's workspace, the designer will have to arrange the crewman’s system interfaces according to the human factors principles of display and control layout and the ease with which it can be maintained (see Sections 6 and 7). The use of computer generated 3 Dimensional man models can be useful for initial allocation of body space requirements in a workspace design. In providing satisfactory space for the operator to carry out his tasks, the designer will need to take account of the basic human data considerations related to body size and user group’s characteristics, including gender. The designer should be aware of the way in which the body measurements were made, as this may differ internationally.

9.2.2 The final version of a workspace layout within an overall crewstation design must be checked by carrying out human factors assessments usually using a full scale mock-up and a representative range of crewmen. DEF STAN 00-25, Part 4, clause 4.3.3 [Ref. 2], covers this requirement. Alternatively, a Technology Insert at the mid-life of a vehicle may involve mock-ups/space models for assessment with in-service vehicles.

9.2.3 These types of assessment are essential because the “fine detail” feedback from humans simulating the operation of the crewstation in confirming the final body dimension space claims cannot be achieved by any other means. It can also allow final adjustments to be made to the workspace, thus transforming an unacceptable space into one that is workable.

Any available Government Funded Equipment (GFE) items and other available finalised equipment should be installed in the mock-up to add realism and claim space. Further manned assessments will be needed as the design matures.

9.2.4 Measuring human body dimensions is more difficult than many engineering measurements on inert objects. The systematic measurement of body dimensions is called anthropometry. These basic dimensions are normally given for a 5th to 95th percentile range, as explained in DEF STAN 00-25 Part 2 [Ref. 2], which also identifies the sources of the data provided. To obtain acceptable accuracy and repeatability of the measurements, they have to be made on the nude body.

9.2.5 Clothing increments are also provided to allow for the specific clothing assemblies to be worn in different situations, such as hot, cold and NBC environments, as well as to allow for specialist clothing and equipment. This naturally includes headgear, such as helmets. In terms of fit, dimensions at the upper end (95^{th}) of the percentile range, wearing maximum clothing are used to initially determine if there is sufficient space in the crewstation. It should be noted that clothing can be restrictive, allowing for example, less reach than with the nude dimension. Further information on clothing is contained under 5.7.

9.2.6 More specific information for a particular vehicle system that is being designed and procured will be given in the technical content of the Specification for that system, and will also refer to DEF STAN 00-25 Part 2 [Ref. 2]. This specification will include the most up to date anthropometric data available that is appropriate to the male and female users of the vehicle and equipment being procured. The specification documentation will include a Target Audience Description (TAD), which gives relevant physiological, psychological and career profile information on the potential users of the vehicle and equipment to be designed. This document includes key anthropometric data.

9.2.7 There are 16 key dimensions that are particularly important in the allocation of space for the human operator when designing a vehicle. These are: stature; sitting height; eye height (sitting); chest depth; elbow-rest height (above seat); thigh clearance height; stool height; knee height; buttock to knee length; inter-elbow span; shoulder (bideltoid) breadth; hip breadth (sitting); vertical functional reach; elbow functional reach; forward functional reach; and inter-pupilliary distance.

9.2.8 Figures 5-1 to 5-7, which are taken from DEF STAN 00-25 Part 2 [Ref. 2]. The Defence Standard numbering of the dimensions has been retained to simplify cross-referencing between the standards, hence the gaps in the numbering sequence. The chest depth dimension (Dimension 9a) does not appear in DEF STAN 00-25, but has been included to provide extra data which is necessary for accommodating female crewmembers. An explanation of these dimensions is given in the following paragraphs, where additional information to that provided in the figures is considered necessary.

9.2.9 Another important measure is body weight which, along with stature, give an initial references when considering human body and size variations. However, as a practical starting point, the 16 key dimensions must be used when integrating crewspace into the design. Other dimensions covered in DEF STAN 00-25 Part 2 [Ref. 2] will be needed for specific detailed aspects of a design.

9.2.10 For stature and sitting height (Dimensions 1 and 7), 50mm must be added to allow for clearance above the helmeted head. This allows for the postural changes between relaxed and upright postures, as well as the prevention of head contact with the roof. Sitting height gives to the minimum seat to roofline measurement without clearance or helmet. The effect of seat geometry and the effects of clothing/restraint systems must be taken into account.

9.2.11 Stool or popliteal height (Dimension 12) is measured with the person's thighs horizontal, shanks vertical, and the soles of the feet flat on the footpan. Fatigue will develop if thighs are not supported to take the weight of the lower leg. This can often be overcome with adjustable footrests. As with thigh clearance, this dimension is affected by vertical seat adjustment.

9.2.12 Knee height (sitting) (Dimension 13) when the lower leg is vertical equates to the minimum vertical clearance between the floor (or footrest/pedal) and the underside of a control panel, table or other obstruction.

9.2.13 When considering the buttock to knee length (Dimension 15) dimension, it should be noted that the seat surface height, fore and aft adjustment and pedal operation will all vary according to the required percentile range to be accommodated, as they will when adjustment for seated head-out operation is required.

9.2.14 The depth of a seat must accommodate those with both short and long thigh lengths. If the design is not satisfactory in this respect, the short thigh sized person can be required to sit forward, away from the backrest, and the long thigh sized person have insufficient support for the lower thighs.

9.2.15 Knee height (Dimension 13) and buttock to knee length (Dimension 15) combined or buttock to heel length indicate overall leg length, giving the relationship between foot pedals and seat in terms of dimensions.

9.2.16 Shoulder or bi-deltoid breadth (Dimension 18) equates to the minimum lateral clearance required in the crewstation. This lateral dimension should be increased by up to 70 mm to provide sufficient working space. When arm rests or guards are required, they will normally dictate a greater lateral dimension than the shoulder breadth, as will some designs of high-backed seats or restraint systems. Hatches should equate to the 99th percentile bi-deltoid breadth, enabling crewmen to pass through without undue twisting. It is necessary to specify 99th percentile in this case for safety/emergency evacuation.

9.2.17 Hip breadth (sitting) (Dimension 19) equates to the width of the posterior. Note that the minimum lateral clearance for the thighs will be up to 70mm greater than this dimension. It must also be noted that the lateral space for a seated crewman is determined by shoulder (bi-deltoid) breadth, which is greater than hip breadth.

9.2.18 Other human factors aspects will also need to be taken into account (for example, body strength and stamina, vision and entry and exit, see Sections 3 and 6 respectively). In addition the effects of clothing which add to the clearance requirements and can also restrict movement must be considered, including allowances for NBC IPE, Body Armour, and Webbing, where appropriate.

9.2.19 The following Mandatory requirements relate to body size:

a. The 16 key dimensions outlined above shall be used as an absolute minimum when providing the space needed to accommodate the vehicle occupants; **[Mandatory]**

b. The 16 key dimensions outlined above shall be for the representative user population specified in the TAD and allow for the full range of clothing and equipment to be worn; **[Mandatory]**

c. For both sitting and standing working postures, a clearance of 50 mm shall be provided above the crewman's helmeted head; **[Mandatory]**

d. The absolute minimum lateral sitting space shall be taken as the shoulder or bi-deltoid breadth, and not hip breadth. An extra 70 mm shall be provided for lateral clearance and movement on both dimensions. **[Mandatory]**

9.3 Reach

9.3.1 Dimensions of the larger (95th percentile) operators are used for determining fit, clearances as well as and near (i.e. minimum) limits of horizontal reach (elbow functional reach), especially when the seated operator has either a seat backrest or some other obstruction interfering with the rearward movement of the elbows. For this dimension, the large operator's seat will be adjusted to the fully rearward position and he will be wearing maximum clothing bulk.

9.3.2 Horizontal reach dimensions (forward functional reach) of the small (5th percentile) operator wearing minimum clothing should be used to determine the far (i.e. maximum) limits of reach and location of controls etc., particularly when the crewman is seated and harnessed in the fully forward adjustment position with any inertia reel belt locked in the restraining position.

9.3.3 Adjustments to dimensions for gripping objects are dealt with in DEF STAN 00-25 Part 2 [Ref. 2]. Ideally, controls should be placed between elbow and shoulder height.

9.3.4 The distance to pedals for the 5th percentile operator must also be allowed for and knee height plus buttock to knee length gives dimensions, see para 5.2.15.

9.3.5 Vertical functional reach gives to the maximum height for controls above the seat surface. With the seat height adjusted to the fully raised position, the dimensions of the lower (5th percentile) end of the range wearing minimum clothing will determine the far limit of reach when harnessed to the seat. It should be noted that vertical reach in maximum clothing bulk can often present the worst case, because of reach restrictions explained in above paras.

9.3.6 It should be noted that leg and arm reach is related to an individual's strength and the type of joint movement called for, particularly for off-set controls. Therefore care must be taken to ensure that all controls can actually be operated and not just reached.

9.3.7 The positioning of equipment shall be based on the reach limits of representative 5th and 95th percentile crewmen, wearing the specified minimum and maximum clothing bulk respectively. When establishing reach limits, the seat harness must correctly restrain the wearer and the seat shall be adjusted fully forwards and up for the 5th percentile and fully backwards and down for the 95th percentile. **[Mandatory]**

9.4 Posture

9.4.1 It is important that the crewstation and crew compartment also allow good postural positions and stances to be attainable in the workplace both when seated and when it is necessary to stand whilst performing tasks. This is essential to reduce the onset of fatigue and minimise its effects, and must be taken into account in the detailed design covered in Section 7. Good posture necessitates positioning the body and limbs so that there is minimum muscular contraction. When seated, the back should be supported, especially in the lumbar region. In general, a posture which uses the middle third of a joint's range is required. Further information on posture is contained in DEF STAN 00-25 Parts 2 and 3 [Ref. 2].

9.4.2 The design of the crewstation and crew compartments shall ensure that all crewmen can achieve good postures at all times, whether they require to be seated or standing. **[Mandatory]**

9.4.3 It is equally important to allow space for changes in these postures, through the re-positioning of the body, for example by raising the buttocks off the seat to change position for postural relief (headroom needed) or stretching and changing leg positions (leg well or foot space needed). Postural changes are mainly to reduce fatigue, but also to enable all tasks to be performed satisfactorily. When allowing for postural changes, it must be remembered that the crewman's body position has to be related to his eye position.

9.4.4 Space shall be allowed for changes in posture to reduce fatigue and to allow all tasks to be performed satisfactorily. **[Mandatory]**

9.4.5 For the vision parameter, sitting eye height will determine the height of optical equipment above the seat surface, and also provide the reference level for calculating sightlines when optimising the location of visual displays, see also 5.7.7 and Figure 5-7. It also provides the reference for positioning displays, because of the importance of a posturally acceptable head position. This, for a seated person, is with sightlines between 15° and 45° below the horizontal. DEF STAN 00-25 Part 3 [Ref. 2] gives further information. Vertical seat adjustment must be sufficient to accommodate the variations in user population.

9.4.6 For fixed optical eyepieces, the eye position in the vertical plane is used as a common reference point, with variations in sitting eye height of the user population accommodated by the vertical seat height adjustment, see also 5.7.7 and Figure 5-7. The crewman needs to sit in a symmetrical laterally straight viewing posture to avoid postural stress. (i.e. no sideways flexing of the spine). This is achieved by positioning the sight oculars equidistant laterally above the seat squab longitudinal centreline. Monocular sights need to be positioned so that the laterally straight viewing posture can be maintained.

9.4.7 For fixed optical eyepieces, the vertical eye position shall provide a reference point, with vertical seat adjustment being provided to accommodate the specified user population range. **[Mandatory]**

9.4.8 The installation of optical systems shall be such that crewmen can sit and use them whilst retaining a symmetrically laterally straight posture. **[Mandatory]**

9.4.9 Sitting eye height to optical unity vision blocks is normally determined by an erect seated posture, and provided for the required percentile range by seat height adjustment.

9.4.10 When installing vision blocks located to the sides and rear of the normal sitting posture, designers shall provide extra space and/or seat movement to minimise postural discomfort when using the blocks. **[Mandatory]**

9.4.11 Viewing posture to the head-in optical sight may require the crewman to adopt a slumped rather than an erect posture. The postural change may involve rotating forward and down, rather than executing a pure vertical downward slump. This will vary according to the geometry of the crewstation, the location of the sight ocular(s), the seat adjustment position, and the anthropometric dimensions of the seated operator. As a guide, a vertical height decrement of between 20 to 40 mm may account for postural slump, but this height decrease must not result in any reduction in the seat to roofline dimension, as slump simply represents another working posture. In practice, this effectively lowers the sitting eye height relative to the sitting height, thus providing more space between the sight eyepiece ocular(s) and the interior roofline. This is in addition to the 50mm clearance needed above the helmeted head.

9.4.12 The slumped posture adopted when operating head into an optical sight shall not result in any reduction in the 50 mm head clearance above the helmet. **[Mandatory]**

9.5 Seating

9.5.1 The importance of functional, comfortable and rugged seating is very important in AFVs and has often been overlooked in the past. The fact that vehicles are lived in for periods of days or even weeks, and that they are operated in varying and harsh environments means that their seating systems , which often have to serve more than one function, need to be particularly well designed.

9.5.2 General recommendations for the design of a workseat include a slight hollow, with the front edge rounded and inclined at approximately 4° to 6° from the horizontal to prevent the Crewman’s buttocks from sliding forward. The supporting seatback should slope at an included angle between 105° and 110°, and be limited to a recommended included angle of approximately 125°. For a functional working posture, a limit of 40° beyond the seat reference vertical is recommended.

9.5.3 Reclined angles beyond 40° for a workseat are not recommended on human factors grounds. Relaxation beyond this angle will be dictated by stated operational requirements and other design constraints, but can impose functional degradation on the Crewman. Seatback angles beyond the seat reference vertical require upper back support, and for angles beyond 30 °, a head support is required. Headrest design must be compatible with the Crewman's helmet profile. Reclined seat back angles beyond 20° from the seat reference vertical are considered to provide a relaxing (i.e. non-alert) posture. (See also Section 7).

9.5.4 Head restraints should be incorporated into seat designs when possible. If attached to the crewstation separately, there is a danger of the head not being restrained in the correct position relative to the rest of the body as the seat is adjusted.

9.5.5 The seating surface should prevent sliding. It should be made from a hard wearing, fire retardant, NBC decontaminable and low toxicity material, and be permeable in order not to trap perspiration.

9.5.6 For both safety and well being, seats must face the forward direction of travel whilst the vehicle is on the move. Seating must be adjustable to provide the correct postural support for the full anthropometric range of users and normally in AFVs, allow the commander and driver safe functional head-out and closed down positions, thus enabling the vehicle to be commanded and driven safely in accordance with peacetime traffic regulations. This requires the commander to assist the driver in achieving between them the ability to see all round the outside of the vehicle, so that they can control its safe movement relative to other road users and potential obstructions.

9.5.7 Seats shall face the normal forward direction of travel during vehicle movement for drivers and other permanent vehicle crewmembers. This orientation is also desirable for infantry sections or those travelling in the rear of a vehicle. **[Mandatory]**

9.5.8 Seat adjustment in all directions shall be easily achieved from the sitting position, and be continuous or discrete in small increments with positive lock positions. The ranges of adjustment shall comply with the required anthropometric range of the target population and functionality characteristics of the crewstation. The leg-space provided shall be dependent on the tasks carried out in the crewstation. **[Mandatory]**

9.5.9 When called for in the design/specification, driver's and commander's seats shall adjust to provide safe and functional head-out and closed-down operating positions. **[Mandatory]**

9.5.10 Commanders and any other crewmen who operates head-out shall have his legs fully supported by a footrest attached to the seat. This rest shall be adjustable, if not set for the shortest knee height. The Driver's feet shall be supported to remain in functional contact with his pedals. The seats shall be adjustable rapidly from the head-out to the head-in position in an emergency. **[Mandatory]**

9.5.11 When seated head-out operation is required, the range of seat adjustment shall accommodate the minimum sitting eye height of the specified user percentile range to allow specified sight lines to be achieved above the vehicle's exterior armour profile. **[Mandatory]**

9.5.12 If necessary, seats must enable off-watch crewmen to sleep in their crewstations. However, the workplace design may necessitate a change of seat if only one “sleep seat” can be provided (See also Section 6 under 6.6). The seating should minimise fatigue and avoid inducing cramp. General recommendations on workseat design are provided in DEF STAN 00-25 Part 4 [Ref. 2]. Seat height should be higher than heel height to prevent blood pooling and space for the legs should provide comfortable hip and knee angles, which will depend on the overall crewstation design. Limits are also provided in Part 4 of DEF STAN 00-25 [Ref. 2].

9.5.13 Seating shall be provided which enables crewmen to sleep comfortably either at their crewstation by adjustment, or by moving to a dedicated sleep seat. They shall be able to attain a relaxed hammock-like posture, but with the seat height above heel height. **[Mandatory]**

9.5.14 Seats shall be provided with a fully adjustable and, where possible, retractable harness with a quick release mechanism. Harnesses shall not inhibit the achievement of greater cross-country speeds or impair the crew's operational efficiency while on the move, due to inefficiency or delay in the method of locking in the restraining position. **[Mandatory]**

9.5.15 The seat is invariably used to assist entry and exit and must be sufficiently robust to withstand being jumped on from the height of the hatch opening during entry, and used as a step when leaving the vehicle.

9.5.16 Whenever the vehicle is being used or maintained, seats shall withstand being jumped on from hatch height and being used as a step when leaving the vehicle. **[Mandatory]**

9.5.17 Bench seat lengths should be determined by bideltoid breadth which is larger than hip breadth. A user population mean plus two standard deviations breadth should be sufficient to accommodate each person in the population range when sitting side by side. (This formula has only been validated for a maximum of four persons). Bench seats are not usually adjustable. Normally webbing belts are undone when seated, so that webbing equipment is not the limiting dimension.

9.5.18 Support for the lumber region of the back is very important for all types of vehicle seat and is required roughly at waist height, about 230 to 255 mm above stool height. Good ergonomic design recommends that lumbar support is made adjustable, to suit the user population.

9.5.19 All seats including bench types shall provide positive support to the lumbar region of the back and be designed to accommodate the specified user population of the vehicle. **[Mandatory]**

9.5.20 On health and safety grounds, crew seats for mobile operation shall be securely attached to the rigid structure of the vehicle, and not, for example, be bolted to an opening rear door or ramp. **[Mandatory]**

SECTION 2 DEFENCE STANDARD SPECIFICATION

9.6 Clothing Effects

9.6.1 Effects of Clothing on Body Size Allowances

9.6.1.1 As already mentioned under 5.2, allowance must be made in the overall workplace design for variations in clothing thickness from thin, hot weather clothing to thick, bulky cold weather assemblies, as well as NBC items, which can increase the effective size of the body in some dimensions by up to 50%.

9.6.2 Compatibility of Clothing Bulk with other Equipment

9.6.2.1 The operation of equipment may be affected by the bulk of clothing items. Gloves may affect dextrous tasks involving the operation of keypads, panels, controls and alphanumeric keyboards, whilst boots may influence the separation and sizing of required pedals.

9.6.2.2 Clearances around and access to equipment including hand and foot controls shall accommodate specified bulky clothing items worn such as gloves and boots. **[Mandatory]**

9.6.2.3 The design shall ensure adequate feedback to the operator to enable him to perform his tasks efficiently when wearing the specified hand and footwear. **[Mandatory]**

9.7 Space Envelopes

9.7.1 Anthropometric data are used to determine the dimensions of the workspace envelope needed by personnel to perform their tasks, and should be expressed two forms. As a starting point, static dimensions are taken with the subject in a number of rigid standardised positions, as already described under 5.2, but the next stage is functional anthropometry which is more pragmatic and takes account of the specific workspace envelopes needed by operators to perform their particular tasks. These dimensions are constructed from working positions and therefore take account of essential body movements and flexibility. They will therefore vary according to the crew compartment and crewstation being designed and its intended occupants.

9.7.2 Practical workspace envelopes evolve as the design develops. Having applied the key static dimensions in the initial outline design, 3D computer modelling and/or studies are carried out. Then, using representative clothed and equipped operators, assessments are performed on full-scale mock-ups and later on prototypes. The computer modelling phase is intended to allow design alternatives to be considered and minimises the need for changes to full scale mock ups. The prototype assessments should normally only have the nevertheless important roles of confirming the workspace envelopes allocated in the earlier design phases and ensuring that unscheduled changes have not subsequently been made.

9.7.3 The workspace envelope should accommodate the task requirements of dynamically active crewmen, wearing the appropriate combat clothing as well as space to access the crewstation and other crewmembers. The appropriate range of the key dimensions will be detailed in the technical content of the Target Audience Description (TAD) for the user group of the system. However, it will often be necessary to consider the space claim for the crew in relation to other key design features such as armour thickness and vehicle silhouette. When this occurs, crewstations must still be designed to allow the crewman to efficiently operate his crewstation within the crew compartment, otherwise the effectiveness of the total system will be compromised. If any conflict in these requirements cannot be resolved, they will be documented and the Customer will be the final arbitrator for decisions on any trade-offs that may be offered.

9.7.4 In AFVs, the crew must be able to operate the vehicle efficiently and safely at all times. This will often necessitate both closed down and head-out operations. For example, the driver should be able to read his essential instruments and operate his controls at all times. The workspace layout should accommodate the specified range of the user population, allowing satisfactory workspace envelopes for movement, entry/exit and emergency evacuation.

9.7.5 Workspace calculations should account for the impingement of periscopes, controls, displays, insulation, anti-spall liner and anti-vibration mat thicknesses, if present. They should also ensure there is room for maximum seat adjustments and the additional minimum head clearance of 50 mm around the helmeted head, already mentioned in 5.2.10.

9.7.6 The clothed anthropometric data excluding stature, hip breadth, shoulder breadth and knee height are measured from the vertical and horizontal reference planes which intersect at the seat reference point (SRP). See Figure 16.1, which is taken from DEF STAN 00-25 Part 4 [Ref. 2]. The SRP shall be used as a standard starting point for the dimensioned envelopes of seated Crewman, and is defined as the midpoint of the intersection of the plane of the seat surface, with the plane of the backrest surface of the seat, and tangents of the mid-line contours of the seated man. Measurements are made with the seat at the extremes of its adjustment. The SRP is difficult to define in complex seats, with features such as adjustable seat back rake angles and lumbar supports.

9.7.7 In order to use the eyepieces of sighting systems which are fixed in the vertical plane within the crew compartment, the eye must be positioned at the eyepiece location. Therefore as a further reference point, the eye position is used in conjunction with the SRP to define spatial envelopes. (See Figure 16.1).

9.7.8 Following any earlier outline modelling activities or design studies, assessments shall be carried out on full scale mock-ups of crew compartments and crewstations, using crewmen representing the specified user population of the vehicle being designed. **[Mandatory]**

9.7.9 Prototype assessment checks shall be carried out at appropriate stages to ensure that agreed human factor design features and space envelopes are not subjected to unscheduled modification due to other design activities. **[Mandatory]**

9.7.10 Practical spatial envelopes shall be provided to allow members of the specified use population to occupy, operate and move around in each crewstation efficiently under all operational conditions, wearing all specified clothing assemblies. **[Mandatory]**

SECTION 2 DEFENCE STANDARD SPECIFICATION

10 GENERAL CREW COMPARTMENT DESIGN AND OUT OF ACTION FACILITIES

10.1 Introduction

10.1.1 Crew compartment arrangements will vary with the type and design of vehicle. For example, all the crew may be located together, or perhaps the driver may be in a separate compartment. In an infantry vehicle, there may be three crew locations: driver; turret crew and infantry section. (For simplicity, the generic definition of "crew" includes infantry section soldiers unless otherwise described).

10.1.2 It is important that vehicle occupants can interact with each other as fully as possible. Being able to see each other's facial expressions and to talk directly, possibly even pointing to items under discussion, is the ideal, but this may be precluded by the design or operational situation at the time. However, crew compartment design should approach this ideal as fully as possible. For example, during quieter periods, it is valuable if a crew can talk directly without intercom, even if seeing each other is impossible.

10.1.3 With most Armoured Fighting Vehicles and their support vehicles, there is a requirement for crews to live in the field with their vehicles for days or weeks at a time. This necessitates a design approach which takes account of the crews' special needs in terms of factors such as cooking, waste disposal, sleeping /resting, personal hygiene and the stowage of personal equipment. These important factors are highlighted in this Section.

10.2 Integration and Compatibility

10.2.1 Within the overall crew compartment, the design, location and layout of controls, displays, workspaces, maintenance accesses, stowage provisions and passenger accommodation must be compatible with the various assemblies of clothing and personal equipment to be worn by personnel operating, riding in, or maintaining the military systems or equipment. For example, eyepieces and headrests or browpads should be compatible with helmets, protective masks, and other clothing and personal equipment.

10.2.2 Where the ingress of bright daylight or sunlight is an issue, care must be taken to design the crew compartment or displays so that they are not "whited out" by the brightness of ambient light.

10.2.3 Sufficient space must be available when wearing bulky clothing for not only sedentary tasks, but also for operating and reaching equipment and moving around the crew compartment. (See Section 5 for information on Body Dimensions and Ranges of Movement).

10.2.4 Special care must be taken to avoid designs which could entrap items of clothing, footwear or headgear during specific crew tasks or when moving about the crew compartment. Surface finishes should be durable, functional, hardwearing, non-slip and of low reflectance.

10.2.5 The design shall avoid the entrapment of clothing, footwear or headgear under both normal operational use and emergency use. **[Mandatory]**

10.3 Illumination

10.3.1 The types of illumination provided in crew compartments are critical to the efficient functioning of each crewman. It must be adjustable to each individual's requirements, depending on the variety of tasks being carried out. General information on illumination for military tasks is contained in DEF STAN 00-25 Part 6 [Ref. 2] and MIL-HDBK-759C [Ref. 37].

10.3.2 Interior Lighting

10.3.2.1 The type and level of interior lighting needed depends on the priorities of the crewmen's visual tasks. Two principle conflicting tasks are the need to concentrate on viewing displays and screens and operating keyboards/panels inside the vehicle, which are the interfaces to the relevant and often advanced technologies of the System, or to remain fully dark adapted for external surveillance. Under operational conditions, there must be an automatic cut-off for interior lighting when hatches are opened, so that inadvertent light emissions do not compromise the concealment of the vehicle. There will also be a need to consider compatibility with head mounted night vision devices such as passive night vision goggle systems when these systems are deployed.

10.3.2.2 Crew compartment design shall be compatible with the use of night vision devices. **[Mandatory]**

10.3.2.3 Full dark adaptation takes as long as 30 minutes, though the reverse process, light adaptation, usually takes less than a minute. The fully dark adapted eye is minimally affected by long-wavelength red light (>620 nm), at a luminance or lighting level not greater than 0.03 Cd m^2. The disadvantages of red light, such as problems with seeing some colours, are explained in DEF STAN 00-25 Part 6. [Ref. 2].

10.3.2.4 Where it is deemed operationally acceptable or necessary for specific crew tasks, crew compartment lighting shall be switchable to red, for naked eye operation. **[Mandatory]**

10.3.2.5 Lighting levels and colours shall be compatible with crew tasks including the use of colour coded displays, as well as electronic and paper maps used in the different areas of operations. The crew shall be able to select and adjust the variables of the lighting system. **[Mandatory]**

10.3.2.6 Crew compartment lighting controls shall have a dimming range suitable for day and night operation. **[Mandatory]**

10.3.2.7 Crew compartment lighting shall be supplemented with local lighting specifically designed for map reading tasks using paper maps. **[Mandatory]**

10.3.2.8 Inside crew compartments, when viewing screens, displays etc., the use of low white light is recommended, as specified in DEF STAN 00-25 Part 6. [Ref. 2] This will minimise visual discomfort whilst allowing crewmen to remain reasonably dark-adapted. Those crewmen whose skills require higher levels of white light illumination shall be well screened or physically separated from those needing to remain dark adapted, as should crewmen who need to retain full dark adaptation, by limiting their exposure to red light only (see para 6.3.2.3). **[Mandatory]**

10.3.2.9 It is recommended that any display device installed shall be fitted with controls to adjust the overall luminance of the display and any associated keypads, from off to maximum, in order to accommodate the full range of ambient illumination in the crew workplace/compartment.

10.3.3 **Interior Colours**

10.3.3.1 The enclosed, dark working environment which crewmen occupy for long periods should be enhanced by the use of light colours to surface finishes. This must not impose any tactical disadvantages, such as the detectability of light, un-camouflaged surfaces or edges of open hatches etc. where exposed on the outside of the vehicle.

10.3.3.2 Interior crewstation surfaces shall be coated with white, non-toxic, non-flammable, cleanable, wear resistant paint or surface finishes, without imposing any tactical disadvantages. **[Mandatory]**

10.4 Head-in and Head-out Operation

10.4.1 In some vehicles, crewstation roles require specific crewmen to move between a head-in and head-out position to perform some of their tasks. The head-out position ranges from just having the head outside the vehicle profile to the complete upper body, depending on the crew task involved. Head-in/Head-out operation is further discussed in Section 3 under Vision.

10.4.2 As technology advances, the need for some head-out operations is disappearing. For example, many tasks which require a crewman to look outside the vehicle using binoculars and the naked eye, rather than using optical sights and episcopes, may be performed satisfactorily or better whilst seated inside using optronics and a screen.

10.4.3 This does not imply that no head-out operations will be needed in future vehicles. Driving head-out will almost certainly remain a necessity for safety on roads and when out of action or combat, as well as for close manoeuvring. Also some surveillance/reconnaissance tasks will still require a head-out position, to ensure full contact with the outside world. It must be remembered that senses such as smell, directional hearing and movement detection are vital components in the overall information gathering process.

10.4.4 Where there is a need specified for crewmen to move between head in and head out positions at their crewstation, the design shall enable them to carry out all their relevant tasks efficiently in both positions with access and adjustment to the controls and displays necessary to allow their efficient operation, as well as to execute the changeover easily (see also Section 3 under 3.5). **[Mandatory]**

10.5 Entry, Exit and Routes to Workplaces

10.5.1 All vehicles, including Armoured Fighting Vehicles (AFVs), require suitable hand and footholds for mounting and dismounting the vehicle. These are primarily to assist in entering and leaving the vehicle in an operationally efficient and safe manner, but also in some circumstances to assist in gaining access to equipment on the outside. (See also Section 9 under 9.2).

10.5.2 Hatches and doors in AFVs must not impair the operation of the system or delay actions in case of emergency. This could include a vehicle roll-over. Crewmen must always be able to enter and leave the vehicle quickly and easily, by the normal and an emergency route, as well as being able to secure hatches or doors in normal situations. (See also Section 4 under 4.6).

10.5.3 The step heights and arm reaches to handholds on access routes to crew compartments, should be satisfactory for the 5th percentile crewman. Handholds and toeholds shall accommodate the 95th percentile gloved hand and booted foot. Where a “step down” through a top access hatchway or similar manoeuvre is required, appropriate footrests or steps and handholds shall be provided. **[Mandatory]**

10.5.4 All hatches and doors shall be capable of being opened, closed and locked manually by the user population from both inside and outside on all slopes upon which the vehicle is required to operate. They shall be designed for correct and logical manual operation. It shall be possible to enter rapidly through the hatches and then onwards to each crew crewstation and likewise exit the crewstation via the hatches. Any crew interchanges deemed operationally necessary shall be possible when closed down including, where specified, with the driver's crewstation. This is particularly important in layouts similar to those of conventional Main Battle Tanks, where a gun or bustle may overhang and prevent easy exit through the driver’s own hatch. **[Mandatory]**

10.5.5 Evacuation in Emergency

10.5.5.1 Emergency evacuation routes should be clearly indicated, easy to use, and also be dimensioned to allow for unhindered and rapid escape by the full range of the user population, including clearance allowance for maximum clothing bulk worn and personal equipment carried (See also 6.5.1 to 6.5.3). Handholds and toeholds shall be positioned to assist this rapid movement. The stowing of heavy and bulky items of equipment in these passageways/routes shall be avoided. Light, rapidly removable stowage is permissible, but not recommended. **[Mandatory]**

10.5.5.2 If light stowage is to be placed in these routes, the manufacturer shall provide evidence that it can be removed and re-located without delaying emergency evacuation. **[Mandatory]**

10.5.5.3 It shall be possible to evacuate an injured or unconscious crewman safely from any crewstation without the aid of a stretcher. Alternative routes for escape and rescue from all crewstations shall be provided. **[Mandatory]**

10.5.5.4 Emergency lighting is an important facility in an AFV. Its functions are:

a. To minimise disorientation, especially in the event of vehicle roll-over;

b. To illuminate exit routes and exit hatches;

c. To switch on automatically in an emergency;

d. To operate under water.

10.5.5.5 Emergency Lighting with the above functionality shall be provided to assist during emergency evacuation. **[Mandatory]**

10.5.6 Hatches and Handles

10.5.6.1 For vehicles where both head-in and head-out operation is necessary, the size, shape and position of hatches should be designed to allow for this required combination of working postures (see also 6.4).

10.5.6.2 Hatches shall be designed to enable them to be opened and closed quickly in an emergency from both inside and out. Hatches for emergency evacuation shall be circular and therefore independent of vehicle orientation, and their diameter shall accommodate the full bi-deltoid range of the user population. (i.e. 100% of users in the bi-deltoid dimension, wearing the maximum clothing and personal equipment bulk, including cold weather and NBC Individual Protection. **[Mandatory]**

10.5.6.3 Hatches shall lock positively in the open position, for safety, but shall be easy to unlatch and move when closing. **[Mandatory]**

10.5.6.4 Information on handles has already been covered in under 6.5.

10.6 Sleep/Rest Arrangements

10.6.1 As technology allows vehicles to be used operationally for up to 24 hours a day, and over many consecutive days, linked with the continued pressure to reduce crew numbers, vehicle design must incorporate sleep and rest facilities for off-duty crewmen. These facilities will vary with the type of vehicle and the operational/tactical needs. Further information on workseat design is contained in Section 5, and Section 4 covers implications of lack of sleep.

10.6.2 It is normally better for a crewman to leave the crewstation for sleep and rest. When a vehicle is withdrawn out of combat, for example to a hide, crewmen may be able to rest outside the vehicle. However when the vehicle is in combat or in NBC contaminated environments, rest must be taken inside.

10.6.3 Rest inside a vehicle is best carried out away from the crewstation, but due to vehicle design constraints, particularly that of space, this is normally precluded. Because of the way in which the vehicle has to be operated or fought, it may be necessary to designate a “sleep seat”, to be used in turn by members of the crew, with minimal disruption to the vehicle’s state of readiness.

10.6.4 The ideal solution is to provide crewstations in which key surveillance/watch duties can be carried out from any crewstation, and each crewstation seat can be adjusted for sleeping. This normally raises practical design problems, particularly in terms of the length of the space and the swept volume required by a crewstation seat that reclines for sleeping, and the next best solution is a sleep seat.

10.6.5 Information on conventional seating postures at the crewstation is contained in Section 6 of this document and DEF STAN 00-25 Part 4 [Ref. 2]. For sleeping, a fully reclined posture should be adopted, but the limited space available in an AFV will normally make this difficult. Research carried out for passenger aircraft by Nicholson and Stone [Ref. 38] has shown that adequate sleep can be obtained in a reclined seat with a backrest angle of at least 40° and an extended rest for the legs, so that the body is supported in a hammock-like posture.

10.6.6 Crewstation design must be based on analysis of the operational scenario. This will indirectly dictate duties, sleep/wake cycles and the number of crew requiring to sleep at any time. This information will then be reflected in the Technical Requirement Specification for a particular vehicle type. Further information on this topic is contained in a guide to irregular work/rest schedules [Ref. 8], already referred to in Section 3 under 3.2.

10.6.7 Provision shall be made for crews to sleep and rest inside a vehicle. The number of crewmen needing to do this simultaneously will be stated in the Technical Requirement Specification for the vehicle. **[Mandatory]**

10.7 Stowage of Equipment and Personal Items Under Armour

10.7.1 As already stated, most crews live in their vehicles, and will therefore have to carry and stow appropriate items to both sustain themselves and operate the vehicle for several days without replenishment. The accessibility of stowage locations and the items they contain must be priority-based, depending on how quickly and frequently access is needed to an item.

10.7.2 As an example, first aid kits and fire extinguishers will be high on the priority list, whilst food and cooking facilities must not be too difficult to access, as feeding frequently has to be carried out at short notice and on an opportunity basis. It must always be remembered that in the field, hot food and drink are essential and a great morale booster.

10.7.3 The design of a fighting compartment should ensure that the replenishment of all internal stores, both operational and personal, can be carried out quickly and efficiently. During preliminary design stage, plans must cover stretch potential under Pre-Planned Product Improvement (P3I), even in the areas of stowage. The starting point for this is the known Complete Equipment Schedule (CES) for the vehicle and information on future equipment and technology trends.

10.7.4 Some personal and shared items such as sleeping bags, combat body armour and rations may be considered as common stowage and be stored in one location, providing the location does not compromise any crewman's duties and activities. This might be better than utilising several smaller areas, depending on the overall design. Cooking and water boiling equipment should be in easily accessible positions, being stored and used together in the same location to minimise the work required for cooking and cleaning.

10.7.5 Sufficient space should be provided adjacent to the crewstation for the storage and use of operational paperwork, manuals, worksheets and other materials required by operational or maintenance personnel. For specialist vehicles, which are often derivatives of a base vehicle, there must be sufficient storage and space for specialist equipment and tools and seating for specialist crew.

10.7.6 Stowage exercises and previous experience will clarify which personal and specialist equipment needs to be stowed in closed compartments or containers and how all items should be secured. In general, the need to minimise radar signature and reduce the occurrence of NBC contamination means that it is desirable to stow the majority of items under cover. The full list of personal clothing and equipment items to be stowed will be provided by the User for each type and role of vehicle.

10.7.7 Crewmen requiring to leave the vehicle in a combat and/or contaminated external environment will need their individual protection items stowed internally beside them, in a dedicated location as close as possible to their operating/sitting position. There must be space to don these items before leaving the vehicle.

10.7.8 Sufficient stowage space for three days rations shall be accommodated, with at least 24 hours worth being under armour and accessible to the crew. Internal stowage shall include the crewman's essential personal kit (to include personal weapons, respirator, NBC clothing and CBA). Some designated CES items can be securely stowed externally. **[Mandatory]**

10.7.9 Facilities to store 15 litres of potable (drinking) water per man per day for three days shall be provided on the vehicle, with outlets inside the crew compartment for at least a 24 hours supply. **[Mandatory]**

10.7.10 Stowed items, whether under armour or not, shall not be positioned where they could interfere with operational crew tasks, including surveillance and external sightlines to driving mirrors and hull length/width indicators. Restraining devices will be needed to secure stowed items during vehicle movement. Items that are flammable or likely to be damaged by the leakage of lubricants, fuels and water, or heat and cold, shall either be stowed elsewhere or be protected from engines, generators, the environment, etc. **[Mandatory]**

10.7.11 All external stowage bins or containers and their securing catches shall be accessible by the full percentile range of the user population. **[Mandatory]**

10.8 Sustenance and Waste Management

10.8.1 Feeding, waste storage/disposal and general "housekeeping" duties need to be fitted in around the operational activities of each vehicle, since they cannot be guaranteed to coincide with out of combat periods. This can only be achieved with a vehicle design that ensures that important secondary activities can be carried out rapidly and efficiently when opportunities present themselves, and without compromising NBC Collective Protection.

10.8.2 Eating, Drinking and Water Supply

10.8.2.1 Food should be packaged in quantities optimally suited for ease of handling and rate of consumption dictated by the number of crewmen per vehicle. The surface finish of items that come into intimate contact with any food or drink should either be manufactured from or coated with inert materials suitable for long term exposure to any foodstuff.

10.8.2.2 Internal drinking water must remain unfrozen and non-toxic under minimum temperature conditions encountered when the vehicle is in operating in any of the specified climatic conditions. The water allowance should be as stated in para 6.7.9. It might be worth considering the use of non-spill mugs, to prevent waste and spillage in the event of short notice moves.

10.8.3 Cooking/Hot Drink Preparation

10.8.3.1 For Armoured Fighting Vehicles, a reliable and efficient means of heating food and water inside the crew compartment shall be provided, including Collective Protection conditions, to ensure that hot food and drink can be prepared and consumed at short notice. The capacity of the equipment shall be at least 1.1 litres for every four men. **[Mandatory]**

10.8.3.2 It shall be possible to provide all crewmembers with a hot meal every 8 hours and a hot drink every 4 hours, from the rations provided, using on-board facilities. **[Mandatory]**

10.8.3.3 It shall be possible to fill and empty the cooking facilities easily. **[Mandatory]**

10.8.4 Waste Disposal

10.8.4.1 In AFVs, the disposal of waste products must be compatible with a Battlefield Mission of up to 72 hours. Stowage space allotted to ammunition, rations, etc. may be used for this purpose when empty, but allowance should be made for partial replenishment without the opportunity to dispose of waste. Ration and other packaging should be placed in heavy duty plastic bags of thick gauge with airtight seals for later disposal. The bags should preferably be an opaque colour and labelled "food waste".

10.8.5 Human Biological Waste Disposal

10.8.5.1 The hygienic collection and disposal of human biological waste on-board a vehicle is essential in an NBC contaminated environment, but must be allowed for in the design, due to the duration and tactical requirements of Battlefield Missions.

10.8.5.2 A commode is the most suitable device for collecting faecal waste, or at the very least, a commode seat to which a bag can be attached. The commode will need to be similar in size to those used by campers and caravanners. Whenever practicable, the commode and/or seat should be in a location not normally occupied by a crewman, but this is not always possible. A commode seat can convert to a normal seat with the provision of a sealed lid on top of which the work seat folds down.

10.8.5.3 In order to minimise storage and hygiene difficulties, urine should be collected separately from faecal waste. A system that allows urine to be discharged outside the vehicle at appropriate times can be installed. This enables urination to take place separately from the commode location when required, especially as this function takes place much more frequently.

10.8.5.4 A hygienic method for the collection and disposal of biological waste shall be provided and be capable of supporting the crew over the Battlefield Mission period, including 24 hours closed down. The system shall be usable by all crew members in an “NBC clean” vehicle interior which is accessible to all when closed down. Some form of retractable privacy curtain or screen shall be provided. The design of crew seats shall not be compromised by the requirements of the waste disposal system. The capacity of the system shall accommodate 400 gm by weight and 300ml by volume per person per day, with a suitable safety margin.
[Mandatory]

10.8.5.5 Bags for faecal waste shall be of similar design to food waste bags but labelled "faecal waste". The waste shall be neutralised by adding the powder called up in the CES after each person’s use before immediately sealing that bag to prevent cross- infection. The sealed faecal waste bags shall be temporarily stored in the commode (which could be located beneath a seat squab), until such time as operational conditions allow for permanent disposal by burying in the ground. **[Mandatory]**

10.8.5.6 Urine shall be collected separately in a Beresford funnel with bladder attachment, or a device with similar dimensions and capacity. The Beresford funnel system should be stowed adjacent to the commode to prevent urination into the latter, thus reducing the volume of waste to be collected and stored, as well as the risk of overflowing. It should however be possible to use the Beresford funnel system at other crewstations if required. Disposal of the collected urine shall be carried out by connecting the end of the collecting bag (bladder) to an internal disposal pipe for discharging by gravity directly outside the vehicle. The pipe shall be fitted with a non-return valve. **[Mandatory]**

10.9 Personal Hygiene

10.9.1 Arrangements for personal hygiene within vehicles are normally limited. Most of these activities take place outside the vehicle, but provision should be made through training procedures and equipment design to prevent cross contamination amongst the crew.

10.9.2 Regular shaving is necessary to maintain a respirator seal around the face, which often means shaving inside the vehicle, because of operation and tactical constraints.

11 WORKSTATION AND CREWSTATION DESIGN

11.1 Introduction

11.1.1 This Section covers the layout of a crewman's workstation, crewstation or workplace, within the crew compartment. It is analogous to considering the office worker at his desk in an office complex, or perhaps the operator of a large container tower crane on the quayside at a port. All have direct visual tasks; communication and command links with others remote from their workplace; interactions with information on displays at their workplace and some form of controls to operate.

11.1.2 The crewman at his workplace is interfacing directly with the equipment around him and indirectly with other elements of the larger system of which he forms a part. The system may be as large as a Battlegroup or as small as the rest of his vehicle, depending on his task at the time. Detailed information on workplace design is contained in DEF STAN 00-24. Part 4 [Ref. 2].

11.1.3 Most of the information contained in this section relates to crewmen who are operating a vehicle, rather than infantry section and specialist soldiers being transported. Information relevant to the latter groups will be specified accordingly.

11.1.4 The primary functions at each crewstation should be as generic as possible, having similar layouts to facilitate changeover of crew duties. During periods of prolonged operations of up to and over 24 hours without relief, if it is not possible to watch-keep from other crewstations, it must be possible to move to the dominant (usually the commander's) crewstation. Watch-keeping periods must be defined and specified to ensure that crews can remain efficient throughout the duration of their duties, by providing adequate off-watch rest periods. When a Battle Management System (BMS) is fitted, its integration and the level of automation are to be taken into account to ensure that the crew can operate with maximum efficiency. This also applies to automated target detection, recognition and identification and any navigation system. Section 6, under 6.6 gives details of sleep/rest arrangements.

11.2 Application of New Technology to AFVs

11.2.1 In the past, AFV design has not always incorporated new technology as rapidly as air and sea systems. The major reasons for this were possibly associated with the cost in relation to the total land system. The situation has now changed significantly.

11.2.2 The inclusion of technologies which are either advancements or new to AFV design can, if carefully incorporated, have the potential to reduce the workload of the crew. However, this is only possible if they are carefully integrated into the complete system, and enhance rather than complicate the crewman's operation of the crewstation by making it simpler and easier to use.

11.2.3 When implementing new technology, a human factors expert shall be involved at the earliest design stage, to ensure an integrated approach, and to focus attention on features which shall be designed with the human operator in mind. If this is not done, the overall workload may, in fact, increase. **[Mandatory]**

11.3 Communications and Information Transfer

11.3.1 Methods of Receiving and Supplying Information

11.3.1.1 Technology now offers more options for receiving and supplying information in an AFV. The major methods available are by audible radio, or digital data and video links. Radio communication (using the human auditory, voice and manual sensory systems) has been the traditional method, but digitisation in the form of text and graphical information and video imagery now offer more options and combinations for communicating. Detailed information on visual displays, auditory information, voice communications and controls are given in DEF STAN 00-25 Parts 7, 8, 9 and 10 [Ref. 2].

11.3.1.2 In designing a system, the importance of feedback to the sender and maximum useful value of the information must always be considered. Voice communication has the great advantage here, in that it is a two-way communication, and extra information is provided by the intonation of the sender's voice, in terms of factors such as understanding the message, morale level, sense of urgency, etc.

11.3.1.3 The workload of crewmen in a hide position can possibly be reduced by exploring the use of an induction loop, so that crewmen resting or on sentry duty outside the vehicle can still be on the radio net.

11.3.1.4 Because of the advantages that voice communication offers, care must be taken to strike a balance and not overload the crewman via this method of communicating.

11.3.1.5 It is probable that some information, such as vehicle position and logistics information such as fuel, ammunition and food requirements may be sent automatically via the computer system. If this is done, it is essential that the crew are able to interrogate the system to make themselves aware of this information. They should be able to control automatic off-vehicle data transfers so that the operational role/concealment of the vehicle is not compromised.

11.3.1.6 The key consideration shall always be to provide the crewman with the most efficient and appropriate methods of information transfer for his particular level of responsibilities and tasks. The methods chosen shall also be compatible with the other systems he has to operate at the crewstation, to ensure that none of his sensory systems become overloaded.

[Mandatory]

11.3.2 **Computer Based Information and Supporting Systems – General Considerations**

11.3.2.1 Digital Maps

a. Using a digital map can reduce the commander's and other crewmen's workloads if the total system is designed to minimise unnecessary manual data input. The planning task can be made easier and there is also the opportunity for orders to be given and received visually and presented pictorially/graphically, reducing the need for verbal orders, thus reducing the chance of ambiguity. Increased interaction times with the display system needs to be avoided so that time on the surveillance task is not reduced. A real time indication of vehicle position and platform sensor orientations reduces the requirement for the commander to continually monitor his position and improve his situational and tactical awareness. The commander is not required to memorise or write down all the data, as further information can be stored electronically on the map. Electronic storage enables more information to be placed on the map, with less "clutter" than on a conventional paper map, since specific information can be either displayed or hidden;

b. The digital map can, given available data, also show automatically intervisibility between own vehicle position and a specific point to aid dead ground route planning. It is also possible to provide intervisibility from a known enemy position. Routes can be planned and later altered if required. A simplified directional guide may be provided for the driver, linked to a Navigation System, such as a Global Positioning System (GPS) or Inertial Navigation System (INS);

c. Scale change reminders are necessary to provide an indication of context. When a map or other graphic display has been expanded from its normal presentation, an indication of the scale expansion shall be provided. Care must be taken to ensure that these screen displays do not result in visual fatigue problems.

11.3.2.2 Inertial Navigation and Global Positioning Systems (INS and GPS)

a. These systems provide an accurate present position and heading of the vehicle, the turret and any sensors on the platform. When used in conjunction with the electronic map, they can be used to measure distance between waypoints and to major land features. These systems can reduce crew mental workload and aid situational awareness.

11.3.2.3 Digital Message Sets

a. Pre-formatted reports can be compiled and completed. These must be designed to be easy and rapid to complete so that it will be possible for all levels of the command chain to make use of the capability. Where appropriate, report information can be compiled by interacting directly on the digital map to create overlays containing information relating to the tactical situation in graphical format.

11.3.2.4 Knowledge-Based Systems (KBS)

a. A knowledge-based system can aid the crew in a number of ways but must only be available on request, not automatically. It can indicate an appropriate weapon to use, or provide a weapon choice to the crewman, or prioritise messages for the crew. For re-planning, it could give the best course of action to take, identify the relevant information to display, and depending on the operational conditions, make a more rapid response available. The primary aim of a KBS is to reduce the maximum workload of the crewmembers by, for example, emphasising essential and timely data at the expense of other data that would otherwise cause unnecessary clutter.

11.3.3 **Human Computer Interactions**

11.3.3.1 The incorporation of computer systems into AFV design is expanding as technology advances, and is illustrated under 7.3.2.1 above. The normal requirement of having interfaces for operators that are straightforward to use is even more important for crewman operators, because of the environment and range of other tasks they are required to carry out in AFVs. This is especially relevant when the vehicle is engaged in action, and the crew have to act quickly, decisively and accurately under conditions of severe stress. Detailed information on human computer interaction is contained in DEF STAN 00-25 Part 13 [Ref. 2].

11.3.3.2 Data entry functions should be designed to minimise the operator's input actions and memory load, ensure data entry transactions are consistent, and ensure that data entry is compatible with data display.

11.3.3.3 The content of displays within a system should be presented in a consistent, standardised manner. Coding should be used to draw the operator’s attention to critical information, unusual values, changed items, high priority items, special areas, errors, criticality of command entry, and targets.

11.3.3.4 Changing alphanumeric values which the operator must be able to read reliably should not be updated by more than once a second. If rate of change needs to be identified, then it should be updated between two and five times a second.

11.3.3.5 Audio displays (signals) used in conjunction with visual displays should be supplementary to them, and used to alert the operator to the appropriate visual display. Signals can be one-off or intermittent. Intermittent signals should be automatically terminated when no longer applicable, and by operator control.

11.3.3.6 Control/display relationships should be simple, straightforward, explicit and compatible with the lowest anticipated user skill levels.

11.3.3.7 Control functions to delete information should be designed so that they require confirmatory actions by the operator.

11.3.3.8 Menu selection control should be used where operators are unlikely to be able to commit all of the commands to memory. Menu selection interactive control should be used for tasks that involve little or no entry of arbitrary data.

11.3.3.9 Where operators are required to make entries into the system, an easy means of correcting errors should be possible, without the requirement of re-entering correct data or commands.

11.3.3.10 Feedback which presents status information, confirmation and verification shall be provided throughout any operational use of the computer system. **[Mandatory]**

11.3.3.11 The interfaces between the computer system and operator shall be designed to minimise conditions that can degrade human performance or contribute to human error. **[Mandatory]**

11.3.4 **Internal Communications**

11.3.4.1 Internal communications between members of a crew are essential, both psychologically and for the efficient operation of the vehicle.

11.3.4.2 Ideally, crew members should be able to see each other’s faces and communicate through normal direct, unaided speech. This is not always possible because of different physical locations in the vehicle and/or vehicle generated noise. However, even if crewmen cannot see each other, it is very valuable to be able to talk to each other during quiet periods.

11.3.4.3 The use of the intercom part of the radio system is an acceptable substitute for direct voice contact, and enables internal communications to continue despite vehicle generated noise.

11.3.4.4 An efficient intercom system shall be provided to enable crewmembers of an individual vehicle to communicate with each other clearly at all times and under all operational conditions. **[Mandatory]**

11.4 Control/Display Layout Integration

11.4.1 The layout of controls and displays is an important part of the overall crewstation design. It can help to reduce crew workload and fatigue considerably if the devices are laid out logically in the best locations, following sound human factors principles.

11.4.2 The functional grouping, importance and frequency of use, as well as the sequence of operation must all be considered when positioning controls and displays, and when siting controls and displays which functionally relate to each other. Sound human factors procedures and standards should be applied to all layouts. It is recommended that controls are colour coded according to function, to help integrate controls and displays.

11.4.3 The design and layout of controls and displays should ensure that they are operable, readable and understandable to the desired level of functionality over the whole range of possible lighting conditions. Information, labels, signs and documentation should be clear, easy to read and unambiguous. Detailed information on controls and displays is contained in DEF STAN 00-25 (Parts 7 and 10) [Ref. 2].

11.4.4 The controls and displays in the driver's crewstation need special consideration, as he normally has to have a head-out as well as head-in driving position, to meet road safety regulations. This means providing a design which enables him to reach hand and foot driving controls and see essential displays from both positions.

11.4.5 Controls which are operated in association with specific displays shall be positioned to ensure easy operation as a combined activity. **[Mandatory]**

11.4.6 Controls for use with sighting devices shall be designed to be operated without the need to move the head or eyes from the device. **[Mandatory]**

11.4.7 The locations of reversionary mode equipment shall be given similar but lower priority consideration to primary systems. **[Mandatory]**

11.4.8 Controls, displays and vision devices shall be located in front of each crewman in natural positions, with the highest priority devices being allocated prime positions. Controls shall ideally be positioned between elbow and shoulder height. Instrument panels and display screens shall be located at or below sitting eye height. All controls and displays shall be operable when wearing normal clothing or cold weather clothing, full Nuclear, Biological and Chemical Individual Protective Ensemble (NBC IPE) clothing and Combat Body Armour (CBA), if specified. **[Mandatory]**

11.4.9 Driving controls and driving displays shall be within normal reach and vision of the driver in both head-in and head-out driving modes. **[Mandatory]**

11.5 Controls

11.5.1 **General**

11.5.1.1 The control devices necessary for AFVs vary considerably, depending on what is being controlled and range from substantial elements requiring a reasonable amount of physical effort, down to small computer related control devices. Other more specialised forms of control such as Direct Voice Entry may be appropriate in special circumstances, but not for general use in the AFV environment.

11.5.1.2 Because of the harsh AFV environment, control devices have to be larger and better protected than in many civilian applications, due to the levels and ranges of vibration, climate and dirt. For example, the types of gloves required for colder climatic conditions necessitate control devices that can be used when wearing them. Special attention therefore has to be paid to the size of devices such as keyboards and switches to be used in the cold, under vibration.

11.5.1.3 The adoption of stereotype layouts of main controls should be encouraged for crewstations, both from the safety viewpoint and to simplify and speed up crew readiness for action when they change positions. Reversion to stereotype in an emergency is an accepted fact, and a standardised layout should be adopted whenever possible. The classic example is when one drives a car with the direction indicator control switch on the right, rather than the left.

11.5.1.4 Foot controls should be considered when the force required is greater than the hand or arm strength of the 5th percentile operator (or near enough to this limit to cause serious fatigue), when the operator's hands are otherwise occupied with a simultaneous control task, or when the population stereotype is adhered to (e.g. accelerator). The control should not be positioned where it can be actuated accidentally.

11.5.1.5 Detailed information on control devices is given in DEF STAN 00-25 Part 10 [Ref. 2]. Because of the harsh AFV environment mentioned above, the larger sizes for control devices should be selected from the data.

11.5.1.6 Control devices shall be correctly sized for efficient operation in the full range of environmental conditions specified for the vehicle. **[Mandatory]**

11.5.2 Keyboard Layout

11.5.2.1 Any keyboard should be kept as simple as possible with a minimum number of keys, especially as space will be at a premium. Depending on the crewman’s task, the use of a QWERTY keyboard may be appropriate. It will probably be desirable and necessary for the keyboard to fold away or be stowed when not in use. This will protect it from impact damage, especially when crew enter and leave the crewstation and help to keep it cleaner.

11.5.3 Cranks and Handwheels

11.5.3.1 When it is necessary to install cranks and handwheels, it is important to allow sufficient space for their operation. Often their operation requires physical effort combined with speed, therefore a clear swept volume for crewmen in their worst case clothing is required.

11.5.4 Switches

11.5.4.1 A wide range of switches will be found detailed in the Defence Standard on controls, together with advice on their application and dimensions. For vehicle use, the same requirement of making them sufficiently large because of the environmental conditions applies, as highlighted in para 7.5.1.2.

11.5.5 Pushbuttons

11.5.5.1 Pushbuttons can be regarded as discrete keys. They often require feedback of operation, preferably by self-illumination which prevents misinterpretation. They can provide good emergency stop control.

SECTION 2 DEFENCE STANDARD SPECIFICATION

11.5.6 **Pointing Devices**

11.5.6.1 Pointing devices such as joysticks and trackerballs, and more recently eye pointing devices, are used in conjunction with computer systems. However, they do not always lend themselves to use in AFVs for providing a computer interface, due to the types of vehicle motion.

11.5.6.2 The whole hand joystick or grip is a suitable control device in vehicles for tracking tasks, provided the forearm is supported. Some types of thumb controller and rollerball have also been successfully used as pointing devices in mobile crewstation research demonstrators, supporting a range of tasks, including the selection of points on a geographical information system or digital map and cursor control (for free-hand drawing).

11.6 Displays

11.6.1 **General**

11.6.1.1 The range of display device types available is quite large. Displays are generally thought of as being visual, but audio displays are also covered under 7.6.5. As with controls, the AFV environment will dictate which displays are most suitable. In particular they need to be robust, sealed against dirt, and operable through the specified climatic range. The integration between controls and displays is dealt with under 7.4.

11.6.1.2 There may be a requirement to have access to some displayed information, for example from the digital map, when off the vehicle, away from the crewstation. This would probably be achieved by using an independent laptop computer.

11.6.1.3 Information on the best human factors practice in the design and choice of displays and their content is contained in DEF STAN 00-25 Part 7 [Ref. 2].

11.6.1.4 The use of Helmet Mounted Displays (HMD) in future AFVs is a possibility in situations where all round vision cannot be achieved by other means. Head Up Displays (HUD) may find applications, particularly in driver's crewstations.

11.6.2 **Labelling**

11.6.2.1 Labels and signs are an important means of displaying information in vehicle crewstations, as well as in crew compartments in general. They are used for displays such as information on the operation of equipment, where this not self evident or not sufficiently well covered by training and manuals; directional information (e.g. escape routes) and safety warnings.

11.6.2.2 General information is contained in DEF STAN 00-25 Part 7 [Ref. 2], which refers to BS 5378 Part 1 [Ref. 39], for information on safety signs and colours. MIL-STD-1472E [Ref. 40] contains detailed information on labelling.

11.6.2.3 All labels and signs displayed at each crew crewstation shall be visible, legible and understandable, and be produced to the best human factors principles provided in the above reference documents. **[Mandatory]**

11.6.3 **Multi-Function Displays**

11.6.3.1 A set of factors influences the relationship between the crewman's eye position and his multi-function display. These include viewing position and distance relative to the screen, size and quality of displayed information, screen size, as well as lighting and contrast levels.

11.6.3.2 The screen size is restricted by the general space limitations within the crewstation, in particular the vertical (height) dimension of a turreted crew compartment. Space also constrains the viewing distance achievable between the eye and screen and the resulting angle subtended at the eye by small objects on the screen in terms of readability. The problem is exacerbated by vibration. Screen sizes around 330 mm (13 in) would be suitable, but in practice it is sometimes necessary to install smaller devices, particularly as retrofits to current vehicles. Detailed information on these and other relevant factors is contained in DEF STAN 00-25 Parts 7 and 13 [Ref. 2], and ISO 9241 [Ref. 41].

11.6.3.3 As well as viewing distances from multi-function displays, the time for which they can be used without causing fatigue and eyestrain is important. Focusing occasionally on a distant object can be beneficial. Breaks should be as often as possible and ideally should be away from the multi-function display. Operationally, both of these are difficult to schedule, but continuous viewing should be avoided. If possible work routines performing non-display tasks should be arranged to at least give 5 or 10 minute breaks every 50 to 60 minutes. Short, more frequent breaks are better than longer, less frequent breaks. This is most likely to cause problems during surveillance and target acquisition tasks.

11.6.3.4 Visual Displays will normally need to provide multifunctional capabilities at each crewstation. This is because of the range and interchangeability of crew tasks to be catered for and the space limitations. Also it would be anticipated that the display would present imagery from a variety of sensor sources as well as digital map, graphical and textual information.

11.6.3.5 Although the number of display technologies is increasing, the devices are not necessarily interchangeable. The range of display devices currently available, together with their display characteristics and suitability for different applications is covered DEF STAN 00-25 Part 7 [Ref. 2].

11.6.3.6 The multi-function display installed at each crewstation shall enable the crewman to achieve a comfortable viewing distance for the efficient use of his screen for both surveillance and all other computer generated tasks, without eye or body fatigue (See para 11.6.3.2).
[Mandatory]

11.6.3.7 The layout of each crewstation shall enable the crewman to relax his eyes occasionally by being able to see and focus on a distant object. **[Mandatory]**

11.6.3.8 Ideally, the multi-function displays installed at each crewstation should enable crewmen to interchange crew tasks and duties with each other as specified in the vehicle specification.

11.6.4 **Glare**

11.6.4.1 Dealing with glare is an important factor in efficiently performing visual tasks and can be particularly troublesome in AFVs, especially when there is a need to operate both head-in and head-out but still use multi-function displays and other types of vision devices.

11.6.4.2 Glare can be due to the excessive brightness outside the vehicle relative to inside, or due to a display's luminance relative to the internal surroundings. Information on the different types of glare, its calculation and suggestions for reducing the effects are contained in DEF STAN 00-25 Parts 7 and 6 [Ref. 2].

11.6.4.3 Displays shall be designed, located and shielded so that glare does not prevent the crewman at each crewstation from using them efficiently to carry out their visual tasks. This includes displays needed during head-out tasks. **[Mandatory]**

11.6.5 **Audio Displays**

11.6.5.1 These are audio attentional directors or "attention-getters", aimed at attracting the operator's attention to his display. They can be valuable, as in less noisy environments, an auditory stimulus attracts attention quicker than a visual stimulus. An example from another application is the passenger aircraft "chime", attracting attention to the illumination of the seat belt sign. AFVs present a noisy environment and therefore any use of audio displays/warnings needs to take this into account.

11.6.5.2 Audio attentional directors are mentioned in DEF STAN 00-25 (Part 7, clause 10.3) [Ref. 2], where they are described by the little used term "attensons". Warnings are covered under 11.8.2.

11.6.5.3 Where it is necessary to attract a crewman's attention to key information on visual displays, audio attentional directors shall be integrated with the display system. **[Mandatory]**

11.7 Sighting Systems

11.7.1 **General**

11.7.1.1 Crews of AFVs are in a different position to some other weapon systems operators in that they need to move their vehicles and be aware of their very immediate terrain surroundings, whilst carrying out duties. Because of this, crewmen need to maintain direct or indirect visual contact with the world outside the vehicle for situational awareness, but the level of this contact depends on crew task.

11.7.1.2 Awareness may be for self-orientation, vehicle control (driving), command of own and other vehicles, or for surveillance and target detection. There is usually still a requirement for a head-out driving position to meet peacetime road traffic regulations, though some designs will probably overcome this problem. Other crewmen also need to operate head-out to perform some tasks effectively.

11.7.1.3 Most vehicles will require a mixed sighting system, to enable crewmen to utilise the advantages of a particular system, depending on his task and the threat. The need to incorporate the chosen systems must be considered at the concept stage, because of the effect on crewstation layout and design, especially in relation to the crewman's head, eyes, reach and upper body movement. Section Three gives information on vision performance.

11.7.1.4 Each crewstation layout shall be designed to incorporate the range of sighting systems needed by the crewman to perform his specified tasks efficiently. **[Mandatory]**

11.7.2 **Optical Systems**

11.7.2.1 Traditional optical systems provide the crewman with a natural view outside the vehicle during daylight. They can incorporate more than one level of magnification, and require the crewman to sit with his head engaged with a protective browpad to correctly position his eye(s). Sighting systems can be binocular, biocular or monocular. Where both eyes are used, inter-ocular adjustment has to be provided over the anthropometric range of users.

11.7.3 **Unity Vision**

11.7.3.1 Unity vision of the outside world provides a major contribution to situational awareness and orientation. Ideally it is provided by a complete ring of vision blocks or episcopes around the crewstation, giving the crewman 360° or all round vision. This is the ideal design, especially for a vehicle commander, as it is the next best position to being head-out for all round unity vision.

11.7.3.2 The vision block ring is like a set of windows, with frames in between them. The crewman does not have to position his head against the block, and can move his head from side to side to view features masked by the frames.

11.7.3.3 Design compromise sometimes results in partial vision block rings. If this occurs, the frontal arc should always be covered. Sometimes the ring is split in a two-man configuration, each crewman being able to see 180°.

11.7.3.4 Drivers are normally provided with vision blocks for their head-in unity vision. It is important to ensure that their of view enables them to see both front corners of their vehicle.

11.7.3.5 A means of achieving satisfactory all round unity vision for the vehicle crew shall be provided. **[Mandatory]**

11.7.3.6 Drivers shall be provided with unity vision which enables them to see the front left and right extremes of their vehicle without head movement. **[Mandatory]**

11.7.4 **Indirect Vision**

11.7.4.1 Indirect vision enables crewmen to be located deep inside armour protection, as well as overcoming the potential threat of laser damage to the eye through an optical sight. This is because of the mechanical and direct optical disconnect between the sight head or sensor and screen displaying the sight image. Further information on indirect vision is contained in Section 3 under 3.5.

11.7.4.2 Television cameras and displays provide one form of indirect vision. Another is the type that generates a thermal picture, through a thermal imaging system. The latter was originally developed for night vision, but can be used in all levels of illumination.

11.7.4.3 One advantage of indirect vision is that one can integrate signal information from various sources into the display. Also, provided there is no disorientation of the operator, there is flexibility in positioning the sensors outside the vehicle, for example they can be on a mast to aid surveillance tasks or close to vehicle sides to provide close-in vision.

11.7.4.4 The major disadvantage of current indirect vision systems is that display resolution cannot approach that of the retina, thus the information displayed on a screen is degraded compared to that seen by the human eye. Therefore optical systems will provide the best performance for the foreseeable future, but the computer enhancement of indirect systems can often fulfil specific sighting system roles.

11.7.4.5 An indirect vision system shall only be acceptable as part of the design if it enables the visual tasks for which it is specified to be performed satisfactorily. **[Mandatory]**

11.7.5 **Surveillance Tasks**

11.7.5.1 The surveillance task of target detection requires concentration by crewmen and tends to be an exclusive activity. It is therefore a candidate for automation in the interests of reducing crew workload.

11.7.5.2 Computer enhancement of sensor information from indirect systems has resulted in the development of automatic target detection systems which can be incorporated into future vehicle designs. Recognition and identification require higher levels of enhancement and image processing in order to automate them. With current technology, such systems can only assist in Detection, Recognition and Identification (DRI) capabilities and there will still be incidents of false or missed targets.

11.7.5.3 New platforms will increasing make use of sensors operating in different wavebands, for example visual, thermal, radar and acoustic. It must be possible for the crew to correlate information from one sensor type with that from others covering the same general arc of view.

11.7.6 **Sight Compatibility**

11.7.6.1 The problems of compatibility between the crewman and other equipment have been highlighted in Section 3 under 3.5.4. Sight compatibility is especially important. The eye or eyes and therefore the head must be able to be positioned in the correct location relative to each type of sight.

11.7.6.2 Each type of sighting system shall be compatible for the full anthropometric range of users specified for the vehicle, and must accommodate variations in interpupillary distance, defence pattern spectacles (when worn), head size, helmet size and respirator size, without any loss of field of view. It must achieve good compatibility both with and without the respirator and NBC hood on the head. **[Mandatory]**

11.8 Signals

11.8.1 **General, Auditory and Visual**

11.8.1.1 It is important to have a consistent design approach to the use and interpretation of signals, particularly because warnings and alarms must be clearly identifiable from other signals. The major primary type of signal is normally auditory, though depending on its function, it may have a visual back-up. Detailed information and definitions on auditory signals, including warnings, is given in DEF STAN 00-25 (Part 8) [Ref. 2]. (See also 7.6.5).

11.8.1.2 Because of the background noise levels that exist in moving AFVs, and the fact that crewmen will be wearing headsets, it is important that audio signals allow for these factors, but without damaging their hearing. This may encourage the use of supplementary visual signals, to ensure that crewmen are alerted to each type of signal.

11.8.1.3 The choice, designation and allocation of all signal types, including warnings, shall be considered for the crewstation and its equipment as a whole, and rationalised with other crewstations, to ensure that a coherent systems approach is adopted. **[Mandatory]**

11.8.2 **Warnings**

11.8.2.1 Warnings shall be attention-getting, to indicate unambiguously their meaning and urgency, and neither overload nor induce a startle reaction from the crewman. **[Mandatory]**

11.8.2.2 Visual warnings shall be located within the primary visual field and visible under all expected background lighting conditions. **[Mandatory]**

11.8.2.3 Voice warnings should be used only to supplement non-verbal warnings.

11.9 Reversionary Modes

11.9.1 Reversionary modes are the fall-backs that enable the total vehicle system to remain operable in the event of component or sub-system failure. The approach favoured for complex parts of the total system, such as those that are computer based, is known as graceful degradation, where one reverts gradually down through a range of fall-backs.

11.9.2 A classic example of a simple reversionary mode is the optical telescope, mounted co-axially with a main gun barrel, to enable the gun to be fired in the event of a sighting system failure.

11.9.3 Another example is the use of a paper map plus radio communication, to provide a reversionary mode in the event of failure of the digital map and navigation systems supplying tactical information to the map. This raises a further issue, that of the retention of skills. As a crewman becomes reliant on his digital map he may, depending on other his tasks, cease to actually read a map and loose this skill. A mechanism will need to be put into place to ensure that map reading skills are not lost, and further research work is on-going in this area.

11.9.4 The human factors issue when considering reversionary modes is to ensure that they are correctly designed to the best human factors principles, as spelt out elsewhere in this document. Because the reversionary mode will normally, by definition, provide a less efficient contribution to the total system than the primary mode, it is vital that its man-machine interfaces are as well designed as possible, offering the crew as much functionality and support as possible.

11.9.5 Reversionary modes within a total vehicle system shall be designed to the best human factors principles, to ensure minimum degradation in the operation and performance of the total system. **[Mandatory]**

11.9.6 Training schedules shall ensure that the skills required to operate reversionary modes are practised regularly. **[Mandatory]**

12 DESIGN FOR MAINTENANCE

12.1 Introduction

12.1.1 It is imperative that vehicle designers allow, from the concept stage onwards, for the need to carry out maintenance tasks efficiently and rapidly when considering how they will design vehicles. The importance of this is illustrated and spelt out in the other key Defence Standards that relate to Reliability and Maintenance, covered in DEF STAN 00-25 Part 11 [Ref. 2], DEF STANs 00-40 to 00-52 (not inclusive) [Refs. 42, 43, 44, 45, 46, 47, 48] and Integrated Logistic Support (ILS) series contained in DEF STAN 00-60 [Ref. 49].

12.1.2 Within these Defence Standards, more activities are embraced by the term maintenance than would perhaps be covered elsewhere. DEF STAN 00-25 Part 11 [Ref. 2] defines maintenance as: "All activities necessary to keep material in, or restore it to a specified condition".

12.1.3 The definition given in the other Defence Standards (00-40 to 00-52 and 00-60) [Refs. 42 to 49] supports the above definition. They define maintainability as: "The ability of an item under stated condition of use, to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels under stated conditions and using prescribed procedures and resources".

12.1.4 To conform to the definitions given in the other Defence Standard documents, the term maintenance in this document will include repair and the other associated activities as defined above.

12.1.5 In order to assist in adopting an ease of maintenance philosophy and integrating it into the design process from the beginning, a task analysis should be carried out covering the required maintenance tasks to support the design. This will help the designer to think through in steps how and where the maintainer will need to gain access to the vehicle system, and what tasks he will need to perform.

12.1.6 Some maintenance tasks will need to be carried out inside the vehicle, whilst others may require access from the outside. The latter may either involve climbing on the outside or working from ground level. By their very nature, some tasks will require the vehicle to be in a base location, whilst others can be performed in the field but out of combat.

12.1.7 When deciding the intervals between scheduled maintenance tasks, the designer must consider, in general terms, the types of operational scenarios in which the vehicle is likely to be deployed.

12.1.8 Many maintenance tasks will be performed by vehicle crews, whilst some more specialised and lengthy activities will be carried out by Royal Electrical and Mechanical Engineers (REME) technicians. The trade-off between crewmen and technicians in terms of the skills and resources needed to carry out a specific maintenance task is an important consideration in the overall design, relative to the maintenance activities required. This,together with ease of maintenance, must be considered throughout the design process, starting at the concept stage.

12.1.9 Human variabilities in body dimensions and strength are important when considering maintenance tasks and these ranges must be allowed for when deciding how tasks will be carried out. Information on this is contained in Sections 5 and 3 of this document and the related Defence Standards.

12.1.10 The designer shall integrate all required maintenance procedures into the design in a practical manner, so that the relevant tasks can be performed easily and rapidly, using the most appropriate resources. This shall be achieved with due consideration for the operational implications of how and when the tasks need to be carried out. **[Mandatory]**

12.1.11 The designer shall take account of the variations in human body dimensions and strength when planning procedures for carrying out maintenance tasks. **[Mandatory]**

12.1.12 It is also necessary for equipment design and activities to conform to the statutory Health and Safety regulations when maintenance is carried out. Examples include electrical cut-out switches, emergency stops, lockable controls, and warning signs. Health and Safety at work is covered in Section 4 of this document.

12.1.13 The designer shall ensure that Health and Safety at Work regulations are complied with when designing the maintenance tasks. **[Mandatory]**

12.2 Accessibility for Maintenance

12.2.1 General

12.2.1.1 One of the major problems that can be encountered during maintenance procedures is that of accessibility to the area where maintenance is to be carried out.

12.2.1.2 It has already been suggested that problems can usually be overcome or minimised by considering maintenance as an integral part of the design process. This involves building up the necessary maintenance schedules as the design develops and working through the steps to be carried out to achieve each maintenance task. Retaining access to the items requiring maintenance is probably one of the difficult problems in a complex and evolving design. However, it has been shown in some of the more operator friendly designs produced in the past that it is possible, if an ease of maintenance philosophy is adopted from the beginning of the design process.

12.2.2 Space for Access

12.2.2.1 The space and clearances needed to gain access to an item or components requiring maintenance is critical to the easy and rapid performance of the task. This will depend on how much of the operator’s body needs access space. For example, it may just be a question of a hand reaching in to unscrew a drain plug or union, the whole upper body being used to apply a two-handed purchase on an item to be removed, or the whole person getting in beside the equipment to be maintained.

12.2.2.2 Extra clearances need to be provided for gloved hands, boots (where appropriate) and protective clothing.

12.2.2.3 Clearances must be provided for appropriate tools, such as spanners, extractors etc to be used in the maintenance process. If a panel or similar cover has to be removed to provide access for maintenance, extra clearances may be needed.

12.2.2.4 Section 5 gives some data relevant to space and clearances, as a starting point, and further information is contained in DEF STAN 00-25 Parts 2 and 11 [Ref. 2].

12.2.2.5 The designer shall provide sufficient space and clearances to allow access for maintenance tasks to be performed easily and quickly. This is to include clearances for protective clothing and the operation of maintenance tools. **[Mandatory]**

12.2.3 **Visual Access**

12.2.3.1 As well as allowing space for access, the operator will normally need to see what he is doing, which means having line of sight to the maintenance task, as well as being able to reach it. This may mean moving his head into a different position, which could sometimes be a problem in the constraints of a crewstation or other surrounding equipment. It is sometimes necessary to carry out some tasks by feel, though this is not ideal, and should only occur in exceptional circumstances. These circumstances should be agreed by the User.

12.2.3.2 It will often be necessary to provide subsidiary lighting in order that maintenance tasks can be carried out. This will normally be achieved with inspection lamps, plugged into the vehicle’s electrical system or into an independent supply. In special cases, this lighting requirement could be built into the vehicle system, but this has the disadvantage that it may be found to be inoperative just when it is needed, or be part of a vehicle system failure.

12.2.3.3 The designer shall ensure that the maintainer can see what he is doing when carrying out his tasks. **[Mandatory]**

12.2.4 **Physical Access**

12.2.4.1 As well as having the space to carry out maintenance, the operator needs to be able to undo and remove components. The designer must therefore be aware of the body strength that operators can exert under different situations during maintenance tasks, particularly when dismantling items and lifting components. Relevant information is contained in Section 3, as well as in DEF STAN 00-25 Parts 3, 10 and 11 [Ref. 2].

12.2.4.2 Components which have to be removed or moved, in order to allow maintenance to be carried out, may need to be fitted with handles or similar aids to assist with their physical movement. The above references give relevant information.

12.2.4.3 The designer shall ensure that the tasks to be carried out during maintenance are within the physical capabilities of the maintainer, and that lifting and manoeuvring aids are provided where necessary. **[Mandatory]**

12.3 Maintenance Alerting Devices

12.3.1 As equipment complexity increases, the crew may need more alerting devices to tell them when equipment requires attention. These must not be add-on devices, but must form an integral part of the total vehicle system.

12.3.2 Section 7 on crewstation layout discusses signals, warnings, displays etc. and further information on auditory warnings is contained in DEF STAN 00-25 Part 8 [Ref. 2]. Maintenance alerting should be classed as signal, but will probably be presented visually, only upgrading to auditory if emergency alerting is required to prevent an equipment failure.

12.3.3 Any maintenance alerting devices fitted shall form part of the vehicle's integrated display and signal presentation system. **[Mandatory]**

12.4 Checklists

12.4.1 Checklists can provide useful aids when addressing maintenance considerations at various stages in the design process. DEF STAN 00-25 Part 11 [Ref. 2] gives general examples of a design requirement checklist and one for a maintenance review within a total system, though these would need developing considerably to be of better value in a vehicle design.

12.4.2 Specialised checklists can also be constructed to cover specific items, helping the designer to remember particular maintenance considerations as he progresses with the design. These checklists can cover topics such as :-

a. **Vehicle Platform** (e.g. - can driver/responsible crewman access all lubricant fillers/level checks without help ; is access to stowed tools/lubricants/any spares satisfactory);

b. **Unit/Assembly Construction and Design** (e.g. - does removal of one unit necessitate removal of others; are any adjustment screws captive to prevent loss; are adjustment devices protected or distant from dangerous power sources; are fuses replaceable without tools);

c. **Unit/Assembly Protection** (e.g. - are covers easily removable; are cover fasteners captive; are cables/wires/hydraulic pipes protected from covers);

d. **Connectors and Cables** (e.g. - do plugs and sockets have different shapes or numbers of pins to prevent mis-connection; do cables have enough slack for easy disconnection; are keyways marked for easy plug and socket assembly);

e. **Space for Access** (e.g. – is there sufficient space between panel mounted connectors to allow hand access for removal when required).

12.5 Test Equipment Connections /Interfaces

12.5.1 **General**

12.5.1.1 The technologies now being applied to military land vehicle design dictates the need for testing on board. This can either be plug-in equipment, brought onto the vehicle for test purposes or built in test equipment.

12.5.2 **Built-in Test**

12.5.2.1 Built-in equipment must be fully integrated with the part of the system that it is monitoring, for example the engine system or fire control system. Built-in Test (BIT) can be used to detect and diagnose faults in different ways.

a. **Interruptive BIT –** The BIT performs a rapid performance test to confirm serviceability of the system;

b. **Continuous BIT –** The BIT continuously tests the performance of the system as a background task;

c. **Fault Detection –** The BIT detects faults which are functional failures. (a function is a unique process or task within the equipment – there can be many co-located within a single hardware module);

d. **Automatic Fault Diagnosis –** BIT diagnoses detected faults to within a single Line Replaceable Unit (LRU);

e. **BIT Data Recording –** All faults detected during Continuous BIT operation recorded, together with selected system parameters. Aim is to store all relevant information at time fault occurs, together with any Automatic Diagnostic information.

12.5.2.2 It can be seen from the above that test equipment can be sophisticated and there is the potential for gathering and presenting a lot of information. It is important that only essential information is presented to the vehicle crew, whilst the rest is stored separately for analysis by REME technicians. This latter information may be downloaded and transmitted from the vehicle when requested or collected later at base, depending on its importance.

12.5.2.3 Only essential test information shall be presented to the vehicle crew, with all other test data being stored separately, and possibly telemetered, for interrogation by the REME.
[Mandatory]

12.6 Tools for Maintenance

12.6.1 Maintenance tasks often require special tools. Some of these will be carried by the REME technicians, whilst others may form part of the vehicle CES. This will certainly be the case if they are needed for crew maintenance tasks. Designers should avoid the need for special tools as much as possible.

SECTION 2 DEFENCE STANDARD SPECIFICATION

12.7 Protective Clothing

12.7.1 As already mentioned under 8.2.2, extra clearances need to be provided for maintainers wearing protective clothing such as coveralls or combat suits, gloves, boots and possibly protective headgear designed for cold weather and/or NBC conditions. Under NBC conditions it may also be necessary to wear a respirator, depending on the alert state.

12.7.2 Protective clothing not only takes up more space but also makes maintenance tasks more difficult to perform, due to its bulk and additionally in, the case of NBC clothing, the extra heat load it imparts to the wearer in hot weather.

12.7.3 Special gloves may be worn by maintainers in cold weather, to prevent cold burn from metal surfaces whist retaining a reasonable level of dexterity for the maintenance tasks.

12.7.4 When planning maintenance schedules, the designer must consider the fact that maintenance tasks are more difficult and take longer to perform when wearing protective clothing. **[Mandatory]**

13 OUT OF CREW COMPARTMENT/OUTSIDE VEHICLE TASKS

13.1 Introduction

13.1.1 In contemplating overall vehicle design from the human factors viewpoint, consideration must be given to the fact that the crews of most AFVs have to perform tasks which involve leaving the crew compartment. At first sight, this may appear to be irrelevant when designing crew compartments and crewstations, but in fact it must be considered as part of the systems approach to the whole design. This because some of the crewman’s out of crew compartment tasks interact or are influenced by design factors or activities inside the vehicle. These tasks must also be allowed for as part of the crew workload when considering task allocation, crew numbers etc.

13.1.2 It must also be remembered that the word crewman is being used as a generic term in this document. It covers all vehicle occupants including infantry soldiers and specialist passengers being transported, as well as crews who stay with a vehicle (and both male and female personnel).

13.1.3 Out of crew compartment activities can be sub-divided into three groupings: on-vehicle; off-vehicle and remote or away from vehicle. Head-out operation is not considered as an out of crew compartment activity and is dealt with where appropriate in Section 3, 5 and 6.

13.2 On-Vehicle Activities

13.2.1 **Routes to Crew Compartments**

13.2.1.1 One basic requirement when designing the outside of a vehicle is to ensure that there is safe route for crewmen to reach the entrance to their crew compartment. General requirements such as step heights, hatch dimensions, etc., are covered in Section 6 under 6.5.

13.2.1.2 Depending on the vehicle type, entry may be directly through a door at ground height, as into the back of a conventional Armoured Personnel Carrier, or across the top of the vehicle and into a hatch, as in a tank type vehicle. Some vehicles will have a combination of both entry routes. For safety and operational integrity, the driver and/or commander must always be aware that someone is attempting to enter the vehicle. For tank type vehicles, this usually means that the route is from the front, where the driver or commander can easily see the person. Also, the initial step up is normally lower at the front.

13.2.1.3 Safe routes shall be provided on the outside of vehicles for each crewman to reach his workplace in the crew compartment. The driver or commander shall be aware of his movement. **[Mandatory]**

13.2.2 **Vehicle maintenance/adjustment tasks**

13.2.2.1 Routine maintenance and adjustments are carried out by the vehicle crew and most require them to be outside the crew compartment. For example drivers will regularly need to open engine decks to make visual checks of fluid levels, drive belts and other engine and power transmission components, to supplement information provided by their crewstation displays. Levels may need to be topped up from containers carried in the external stowage.

13.2.2.2 Some maintenance tasks can involve lifting and manipulating heavy and/or awkward items whilst in difficult postures, if the tasks are not designed correctly. Also, every effort should be made to design maintenance interfaces so that they are preferably within the recommended lifting and manipulation capabilities of one man, or are correctly designed for two men. Human performance limitations for manual handling are contained in Section 3 under 3.3.2**.**

13.2.2.3 Access to hatches and covers provided for crew maintenance and items to be maintained shall have correctly designed handles, opening devices and handling surfaces. They shall be positioned to allow safe and posturally acceptable operation, preferably by one man, but if not by two men. **[Mandatory]**

13.2.2.4 Other tasks include checking and cleaning the outside surfaces of optical systems, sensors, and vision blocks, together with any cleaning or wiping devices with which they are fitted. Externally mounted weapons may also require periodic attention which necessitates leaving the crew compartment. This means ensuring that access to these items on the outside if the vehicle is possible and safe.

13.2.2.5 Safe access shall be provided to the outside surfaces of optical systems, sensors, vision blocks and cleaning/wiping devices, as well as to externally mounted weapons.
[Mandatory]

13.2.2.6 Some maintenance and adjustment tasks, such as checking tracks, tyres and security of equipment, are performed at ground level (i.e. off-vehicle), but are grouped here for convenience. Maintenance topics are covered in detail under Section 8.

13.2.3 **Access to equipment associated with in-vehicle tasks/operations**

13.2.3.1 In addition to the types of maintenance tasks mentioned in para 13.2.2.2, there are tasks associated with deploying equipment fitted to the outside of some vehicles, which need to be erected or assembled once it arrives at a location, before it can be operated from inside the vehicle. This will normally apply to specialist vehicles.

13.2.3.2 Examples are the deployment of meteorological masts, some radar receivers and specialist air sampling intakes. In order to deploy such equipment, it may be necessary to extend steps down to ground level and ladders to reach the roofline. If the vehicle is a box body type, it may be necessary to design a strengthened the roof to take the weight of the number of crewmen needed to deploy the equipment.

13.2.3.3 Safe access shall be provided on the outside of relevant vehicles to allow the erection and assembly of any equipment that needs to be deployed on arrival in a location.

[Mandatory]

13.2.4 **Access to external stowage**

13.2.4.1 Access to externally stowed items must be planned logically and with safe access to them. Stowage for items that are for use on the vehicle should be provided as close as possible to where they will be used, for example engine related items close to the engine compartment. Stowed items for off-vehicle use should normally be accessible to crewmen when standing on the ground. Any personal equipment stowed externally should be adjacent the hatch or door used by the relevant crewman and rapidly retrievable without dismounting. Attention should be paid to the weatherproofing and drainage of bins and other stowage arrangements.

13.2.4.2 Safe, logical access shall be provided to all items stowed on the outside of the vehicle, with due consideration to where the items will be used and who is to retrieve them.

[Mandatory]

13.2.5 **Resting out of crew compartment**

13.2.5.1 When out of combat and provided it is operationally acceptable, crewmen take the opportunity to rest on the outside of some vehicle types, to take a break from the confines of their crew compartment.

13.2.5.2 For short breaks, it is preferable and safer to rest on the vehicle, as vehicle moves can be achieved more quickly and crews are not subject to possibly being struck by rapidly deploying vehicles. Although this activity does not directly affect the design of the vehicle, designers might bear in mind that it happens, perhaps for example, when considering factors such as the positioning of brackets and fixtures that limit lying spaces.

13.2.6 **Camouflaging Vehicles**

13.2.6.1 Vehicle camouflaging using fairly conventional netting/sheet materials to help prevent optical, thermal and radar detection, complements developments in stealth type systems. The deployment of nets naturally involves leaving the crew compartment and is a mixture of on and off-vehicle activities, but is dealt with here as at least half the activity is on-vehicle.

13.2.6.2 Efficient and rapid access to and re-stowing of camouflage nets is important, as they normally have to be erected and removed quickly by the crew. The need to drape and spread the nets and prevent snagging again emphasises the requirement for the crew to move safely over the outside of the vehicle. Once erected, nets must not deny access to the crew compartment from underneath. Depending on the system and vehicle, location points for supporting poles and tie down points may be called for.

13.2.6.3 Crews shall be able to move safely and rapidly over the outside of their vehicles when erecting and re-stowing camouflage nets. Erected nets must not deny access to the crew compartment. **[Mandatory]**

13.2.7 **Replenishment of Vehicles**

13.2.7.1 The replenishment (replen) of vehicles with ammunition, diesel, oil, lubricants, food, water, mail, etc. in the field is carried out as rapidly as possible and often in the dark. It requires the participation of all crewmembers, working efficiently as a team, with the assistance of the supporting echelon that deliver the replen. The crew are deployed both on and inside the vehicle to receive and stow the replen items as quickly as possible.

13.2.7.2 Replenishment activities emphasise the need for stowage arrangements to be as easy to use as possible. This also applies to access to the crew compartment, whether by hatch or door. It also emphasises the importance of safe, non-slip routes on the outside of relevant vehicles, as during their replenishment, crewmen have to move about, rapidly taking on board heavy objects under difficult conditions. This also applies to the access to internal stowage locations.

13.2.7.3 The routes on and in vehicles which are negotiated during replens shall be safe to traverse and climb. Hatches and stowage locations shall be easy to negotiate and use when handling the various replen items. **[Mandatory]**

13.2.8 **Radio watch out of combat**

13.2.8.1 Radio watch when out of combat is often performed outside the vehicle. Designers should consider this, both in the positioning and configuration of the radio interface and the length of harness leads. There is also the possibility of remote radio operation to allow a crewman on radio watch more freedom, including dismounting from the vehicle and perhaps performing more than one task concurrently.

13.2.8.2 There is often the need for a fully operational crewman who is on radio watch to move onto the outside of the vehicle. The above remoting would be equally useful to him, obviating the need to disconnect and get someone else to listen out for him.

13.2.9 **NBC decontamination prior to re-entry**

13.2.9.1 In an NBC environment, if a crewmen has been exposed to NBC agents whilst outside the protection of the vehicle’s Collective Protection system, he will need to decontaminate himself in the specified manner before re-entering the vehicle. Use will be made of the nearest flat, non-slip surface to the point of entry during this activity.

13.3 Off-Vehicle Activities

13.3.1 Construction of vehicle hides

13.3.1.1 When vehicles are out of combat, a hide is usually constructed by the vehicle crew or crews, where possible with the aid of natural cover such as wood lines and hollows or other naturally occurring features of ground. This is supplemented by camouflage nets and branches etc. The hides and their construction is normally shared by a troop of vehicles and its crews, unless vehicles are deployed separately.

13.3.1.2 As with resting outside the crew compartment, hide construction does not directly affect vehicle design. It does, however, illustrate to the designer the need for easy access to the tools and equipment used in this and other off-vehicle crew tasks, and the fact that they must be rapidly re-stowed when the order to move is received. This is because the move order can be at short notice.

13.3.2 Vehicle security and hides

13.3.2.1 Whilst in hides, vehicles have to be guarded from surprise attack. The radio watch element has already been discussed under 9.2.8 on radio watch out of combat. The option of remote radio operation in a hide will be clear to the vehicle designer. The other form of hide security is the deployment of sentries. These are rostered from the crews and they patrol the hide area on foot.

13.3.2.2 The remote radio function would give the option for sentries to be on radio watch as well, in acceptable circumstances.

13.3.3 Resting in hide positions

13.3.3.1 Rest in hide positions is taken either on vehicles or beside them. The difference between hide resting and resting out of the crew compartment covered under13.2.5 is that hide rest and sleep is likely to be more formal, with the use of sleeping bags and shelters.

13.3.3.2 Resting when in hide positions is very important in the unpredictable timescales prevailing under operational conditions. The quality of rest and sleep attainable in a hide is likely to be superior to that in-vehicle, due to the more tranquil environment and the better rest/sleep postures. The possibility of doubling some sentry duties with radio watch would enable more crewmen to take the opportunity to rest.

13.3.3.3 Designers need to be aware that when in a hide and off the vehicle, easy access is required to stowed personal clothing and equipment, as well as cooking facilities, food and water. It must be possible to re-stow all items rapidly if a move is ordered.

13.3.3.4 It shall be possible to rapidly and easily re-stow all items of equipment and clothing so that a vehicle can respond rapidly to an order to move. **[Mandatory]**

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13.4 Remote From Vehicle Activities

13.4.1 **Foot Reconnaissance**

13.4.1.1 Crewmen often need to leave their vehicles and go on foot to assess the situation around them. This could be because their vehicle might be seen, make too much noise or have difficulty in reaching the chosen vantage point for reconnaissance.

13.4.1.2 Crewmen on foot will need their personal weapon, extra clothing, maps, binoculars etc. This again illustrates to designers the need for certain stowed items to be readily available to crewmen as they leave their vehicle.

13.4.2 **Orders Groups**

13.4.2.1 Orders or O Groups are briefing meetings, called usually by the Commander of a vehicle and/or manpower grouping, to brief his sub-units on the situation and plan of action. This requires attendance of senior representatives from individual or groups of vehicles such as a tank troop, and it is usually held centrally in the area of deployment.

13.4.2.2 With advances in technology and secure communications, less O Groups will possibly be necessary, but they will still probably take place as an essential part of human leadership due to the face to face communication and the positive effect on morale. Crewmen going to O Groups need access to the same items as those on foot reconnaissance.

13.4.3 **Infantry tasks**

13.4.3.1 When an Infantry Section leaves its Armoured Personnel Carrier, it takes on its infantry role. This means carrying much more equipment, as they are essentially fighting on foot, though normally supported by their vehicles.

13.4.3.2 This again reflects the need to design the vehicle in question so that items of equipment and clothing needed by the section are readily available as they leave. This is particularly important, as the Section frequently has to deploy immediately and tactically outside the vehicle.

13.4.3.3 Crewmen leaving their vehicle shall have rapid and easy access to items of clothing, personal and other equipment that they need to take with them. This applies especially for foot reconnaissance and infantry tasks. **[Mandatory]**

13.4.4 **Remote Guided Weapon operation**

13.4.4.1 Some Guided Weapons (GW) Systems have a facility whereby they can be operated by a soldier at a remote location, positioned some distance from the host vehicle.

13.4.4.2 The vehicle and equipment designers must consider this facility, both in terms of where and how the GW System is installed in the vehicle, as well as the removal and portability of the remote controller and display unit.

13.4.5 **Remote sensor operation**

13.4.5.1 Remote sensors, such as portable Thermal Imagery Systems and portable Chemical Agent Detectors, have a similar set of requirements to other equipment being used remotely from the vehicle. They must therefore have good operator/HCI interfaces and be designed to be demountable from the vehicle. Human performance limitations for manual handling are contained in Section 3 under 3.3.

13.4.5.2 Size and weight are important for demounting, disconnecting and removal through hatches and/or doors. They must be designed with carrying handles and be specified as a one or two person lift. If the equipment has rechargeable gas bottles or batteries, charging points should be provided inside the vehicle.

13.4.5.3 The design of vehicles with a remote system facilities shall allow for easy removal and portability of the remote workstation or equipment, as well as any integration necessary with the main on-vehicle system. **[Mandatory]**

13.4.6 **Observation Posts**

13.4.6.1 Observations Posts (OPs) are set up away from vehicles, to observe tactically from a better vantage point, or where vehicles would give the position away.

13.4.6.2 The equipment used in these OPs could include remote GW and sensors, but will certainly include a communications link back to the vehicle groups and, where appropriate, to Headquarters. The vehicle design requirements to support remote equipment apply to OPs as well.

13.4.6.3 The exception to this arrangement is for the Artillery, where an OP can be tens of kilometres away from the guns, rather than relatively close. Manning of artillery OPs is normally a separate role, and is not provided by gun detachments or artillery gun vehicles.

SECTION 2 DEFENCE STANDARD SPECIFICATION

14 CONCLUSIONS

14.1 The fightability of future platforms will demand that the vehicle design exploits the advantages that emerging technologies can offer, whilst matching these to the capabilities and limitations of the vehicle crew. To ensure that the delivered vehicle meets its performance requirements, it is therefore fundamental that human factors issues as well as technology issues are considered at all stages of the system design process. This activity is essential if the crews of future platforms are to effectively utilise the information available and control the complex systems that will form part of a future AFV.

14.2 This document has identified the key human factors criteria to be taken into account in the specification, design and procurement of future military land platforms and the integration of technologies into legacy platforms. It is anticipated that the guidelines will act as a mechanism to inform system designers, specifiers and procurers and to enable valid system design decisions and tradeoffs to be made.

15 RECOMMENDATIONS

15.1.1 It is recommended that the human factors guidelines contained in this document be employed as widely as possible in the specification, design and procurement of future military land platforms and also for the technology insertion and upgrade programmes of legacy platforms.

15.1.2 Specifically, it is recommended that the employment of the document is achieved through the following mechanisms:

a. Utilisation of the human factors guidelines in the development of URD and SRD documents, in particular through the inclusion of the mandatory statements identified in this document;

b. Distribution of this document to key stakeholders in the specification, design and procurement process, both within the MoD and in industry. To facilitate this, the initial distribution of the document has identified stakeholders for the current major land platform procurements. In the future, it its recommended that the document should be made available to further parties as required;

c. Encouragement for designers in industry to embrace the human factors guidelines in the emerging platform designs. This may be achieved via the relevant MoD Project Offices approving the guidelines and specifying their use in the platform design programme.

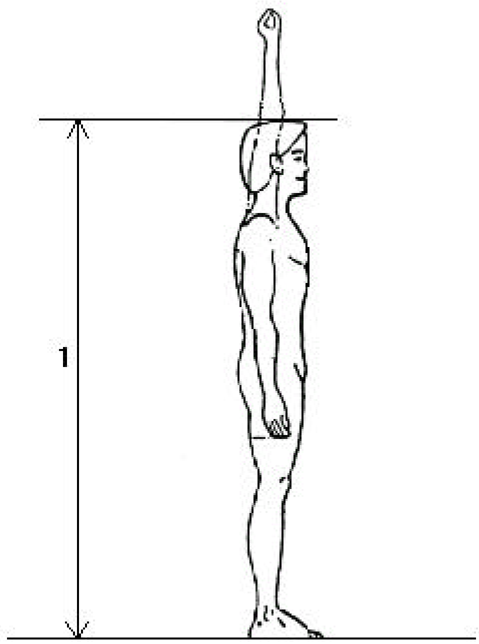
15.1.3 It is recommended that the original intention to publish these guidelines as a Defence Standard should be pursued. This must involve securing an appropriate funding route for the DEF STAN preparation activities and also for “servicing” the document (ie a Service Level Agreement (SLA)) once published under DEF STAN auspices.

16 ACKNOWLEDGEMENTS

16.1.1 The authors wish to acknowledge the assistance given by representatives of UK defence manufacturers in the review of earlier drafts of this document. We are also grateful to the Subject Matter Experts (SME) within DERA Centre for Human Sciences and Land Systems Sectors for their contribution to the various Sections of this document.

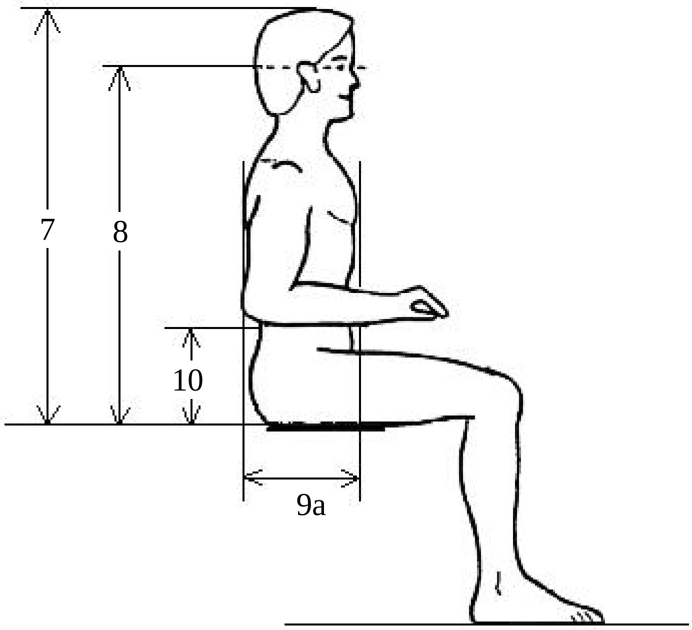
SECTION 3 FIGURES

17 FIGURES



	After DEF STAN 00-25 (Part 2)/2, Fig. 3
	Dimensional Descriptions and Applications
1	**Stature** Minimum floor to roof clearance. See also paras 9.2.1 to 9.2.7. Stature is also a useful dimension for making rapid comparisons between populations.

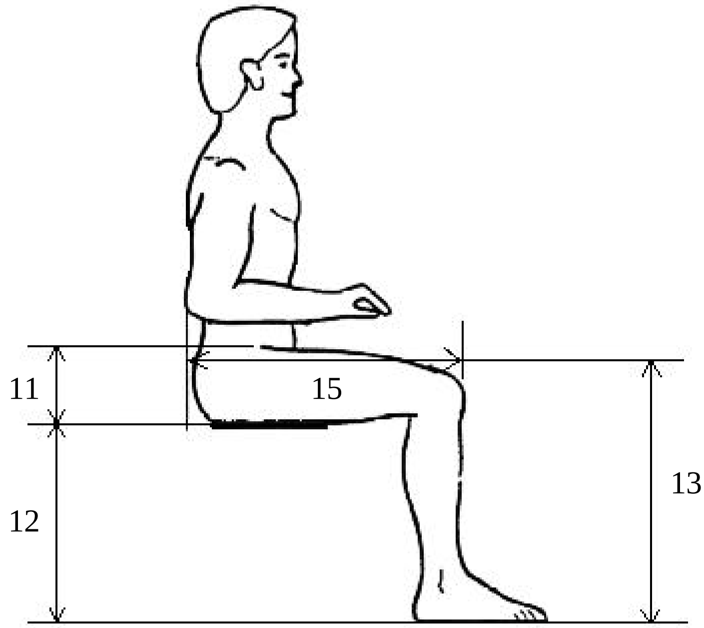
Figure16-1: Body Dimension (Standing)



	After DEF STAN 00-25 (Part 2)/2, Fig. 4
	Dimensional Descriptions and Applications
7	**Sitting Height** Minimum seat to roof clearance. Maximum height of the visual obstruction caused by sitting person. See also paras 9.2.1 to 9.2.7.
8	**Eye Height** Height of optical equipment above the seat surface, reference level for calculating lines of sighting order to optimise the location of visual displays. Variability in this dimension may determine the range of seat adjustment required.
9a	**Chest Depth** Minimum forward clearance between seat back and obstructions at chest level, e.g. lower part of sight bodies, control panels, hatch openings when seat raised. See also paras 9.2.1 to 9.2.7.
10	**Elbow-Rest Height** Height above the seat surface of arm-rest, desk-tops, keyboards and other important controls. Variability in this dimension may determine range of vertical adjustment required of the seat.

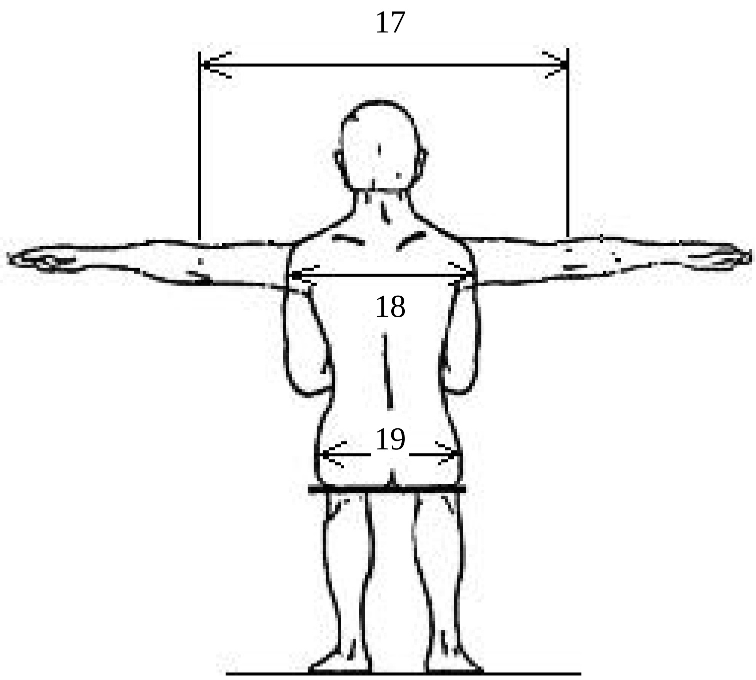
Figure16-1: Body Dimensions (Sitting)

SECTION 3 FIGURES



	After DEF STAN 00-25 (Part 2)/2, Fig. 5
	Dimensional Descriptions and Applications
11	**Thigh Clearance** Minimum vertical clearance between seat surface and underside of control panel, table or other obstruction.
12	**Stool Height** (Represented with subject's thighs horizontal, his shanks vertical, and the soles of his feet flat on the floor.)
13	**Knee Height** Minimum vertical clearance between floor (or footrest) and underside of control panel, table or other obstruction.
15	**Buttock to Knee Length** Minimum forward clearance between seat back and obstructions at level of the seat surface.

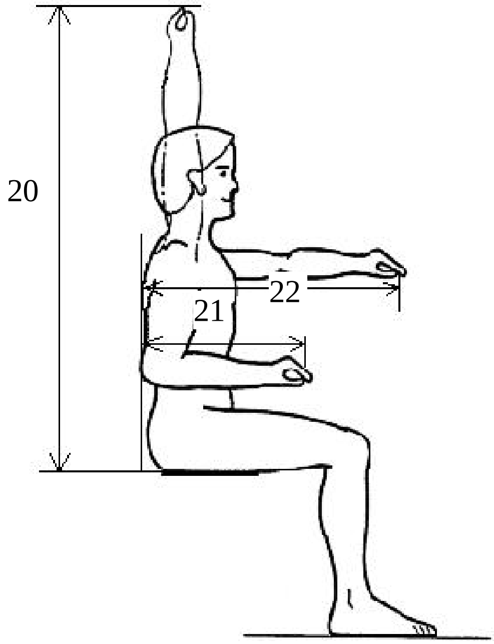
Figure16-1: Body Dimensions (Sitting)



	After DEF STAN 00-25 (Part 2)/2, Fig. 6
	Dimensional Descriptions and Applications
17	**Inter-Elbow Span** Lateral Clearance for good elbow room during manual activities.
18	**Shoulder Breadth** (Bi-Deltoid Breadth) Minimum lateral clearance required in workspace. Note- This dimension is not the same as bi-acromial breadth (see DEF STAN 00-25 Part 2 [Ref. 2])
19	**Hip Breadth** Width of seat. Note- Minimum lateral clearance for thighs will be up to 70 mm greater than this dimension.

Figure16-1: Breadth and Span Dimensions

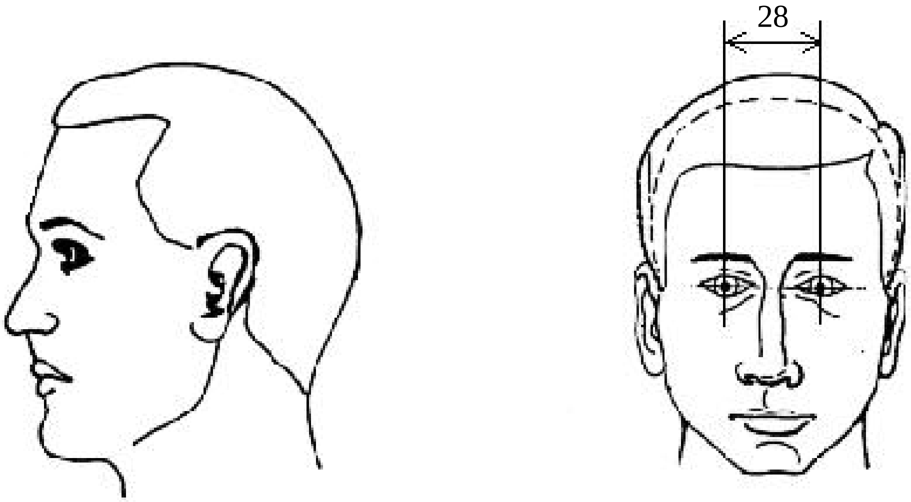
SECTION 3 FIGURES



	After DEF STAN 00-25 (Part 2)/2, Fig. 7
	Dimensional Descriptions and Applications
20	**Vertical Functional Reach** Maximum height of controls above the seat surface.
21	**Elbow Functional Reach** Maximum forward location of the controls for operation with the upper arm vertical and the forearm horizontal.
22	**Forward Functional Reach** (This represents the distance from the back of the shoulders to the thumb-tip of a pinch grip). Maximum forward location of controls for easy operation.

Note: These reach measurements are made to the tip of the thumb as it makes a pinch grip with the forefinger. Corrections must be made for other types of grip. The subject of reach is discussed in DEF STAN 00-25 Part 2, Section 4, clause 5 [Ref. 2].

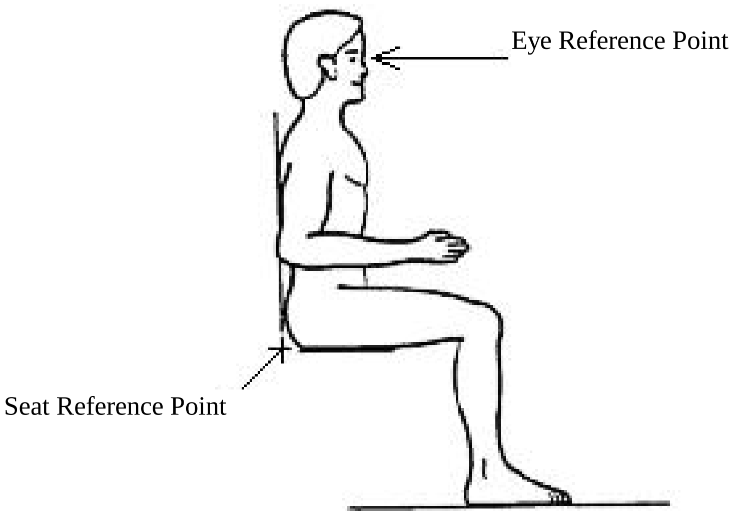
Figure16-1: Functional Reaches (Sitting)



	After DEF STAN 00-25 (Part 2)/2, Fig. 10
	Dimensional Descriptions and Applications
28	**Interpupillary Distance** The horizontal distance between the centres of the pupils when the subject looks straight ahead. Used, for example, in the design of binocular devices.

Figure16-1: Head Dimension

SECTION 3 FIGURES



After DEF STAN 00-25 (Part 2)/2, Fig. 11

Figure16-1: Seat and Eye Reference Point

Collation page

Inside Rear Cover

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