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HUMAN FACTORS
FOR DESIGNERS OF EQUIPMENT

PART 12: SYSTEMS

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Revision Note

Historical Record

This Defence Standard has its origins in the 2-volume handbook "Human Factors for Designers of Naval Equipment" published in 1971.

Arrangement of Defence Standard 00-25

The proposed arrangement of the complete series of Defence Standards comprising Def Stan 00-25 is shown below:

Part 1 - Introduction
Part 2 - Body Size
Part 3 - Body Strength and Stamina
Part 4 - Workplace Design
Part 5 - The Physical Environment: Stresses and Hazards
Part 6 - Vision and Lighting
Part 7 - Visual Displays
Part 8 - Auditory Information
Part 9 - Voice Communication
Part 10 - Controls
Part 11 - Design for Maintainability
Part 12 - Systems

Two or more Parts may apply to any one equpment and it is therefore essential that all Parts be read and used where appropriate.

HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT

PART 12: SYSTEMS

PREFACE

i This Part of Defence Standard 00-25 provides designers of military equipment with a description of, and guidance on how to apply, human factors methods and techniques during the various design stages of the system.

ii This Part of this Defence Standard is published under the authority of the Human Factors subcommittee of the Defence Engineering Equipment Standardization Committee (DEESC).

iii This Standard should be viewed as a permissive guideline, rather than as a mandatory piece of technological law. Where safety and health is concerned, particular attention is drawn to this Standard as a source of advice on safe working limits, stresses and hazards etc. Use of this Standard in no way absolves either the supplier or the user from statutory obligations relating to health and safety at any stage of manufacture or use.

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vi This Standard has been agreed by the authorities concerned with its use and shall be incorporated 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 shall be informed so that a remedy may be sought.

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

viii This Defence Standard is being issued as an INTERIM Standard. It shall be applied to obtain information and experience of its application. This will then permit the submission of observations and comments from users using D Stan Form No 22 enclosed.

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Section One. General

0 Introduction

Human factors is an interdisciplinary science concerned with influencing the design of manned systems, equipments, and operational environments so as to promote safe, efficient and reliable total system performance.

This Part of the Defence Standard establishes a framework for the application of human factors throughout the various design stages of a system and relates these throughout the procurement life-cycle phases from concept formulation to in-service use.

1 Scope

This Part of the Defence Standard provides designers of military equipment with a description of and guidance on how to apply human factors data, methods and techniques during the various stages of system design. In a document of this size the treatment of the subject cannot be comprehensive. Because of the nature of human factors this Part of the Defence Standard is both descriptive and prescriptive in content.

Section two of this Part of the Defence Standard, which serves as an introduction to the remainder of the document, describes the role of human factors in the system design process, the characteristics of that process and its stages. Section three prescribes the human factors methodology for the design of manned systems. Sections four and five describe and provide guidance on how to apply various design aiding and design evaluation techniques. Finally, in section six, information on conducting experiments and on statistics is presented.

2 Related Documents

2.1 The documents and publications referred to in this Part of the Defence Standard are listed in annex B.

2.2 Reference in this Part of the Standard to any related documents means, in any invitation to tender or contract, that edition and all its amendments current at the date of the tender or contract unless a specific edition is indicated.

3 Definitions

For the purpose of this Part of the Defence Standard the definitions shown at annex A apply.

Section Two. The System Design Process

4 The Role of Human Factors in the System Design Process

4.1 Design team role. The role of the design team in the system design process is to conduct analyses of the system requirements, functions and tasks to determine their behavioural implications; to design aspects of the manned system according to human factors principles (ie the other Parts of this Defence Standard); to evaluate both analytically and experimentally the design of the manned system so as to ensure safe, efficient and reliable total system performance.

4.2 Human factors activities. The human factors activities that can be conducted during system design are many and varied. For the purpose of this Part of the Defence Standard a number of major activities have been identified. They are:

System Requirements Analysis	(see clause **8**).
Function Analysis	(see clause **9**).
Allocation of Functions	(see clause **10**).
Task Synthesis	(see clause **11**).
Task Description	(see clause **12**).
Task Analysis	(see clause **13**).
Design of Equipment and User Manuals	(see clause **14**).
Design of Workspace and the Workplace	(see clause **15**).
Design of Training Programme	(see clause **16**).
Design Evaluation	(see clause **17**).
Post-Design Evaluation	(see clause **18**).

These activities, which are described in detail in section three, span the entire system design process. The activities are highly iterative processes, but otherwise they occur in a logical sequence (see figure 1).

4.3 Design relevance. The importance of the human factors contributions to the system design process cannot be stressed too strongly. The design team should ensure that human factors issues are considered throughout the design process. Issues such as, for example, selection and training of personnel, and their health and safety, are, ultimately, just as important as the design of system hardware.

4.4 Design priorities. Ideally, all human factors contributions that could be made during the system design process, should be made. It is expected, however, that because of limited time and resources all contributions can never or very seldom be undertaken. It is difficult to assign priorities to particular activities but the following points should be noted:

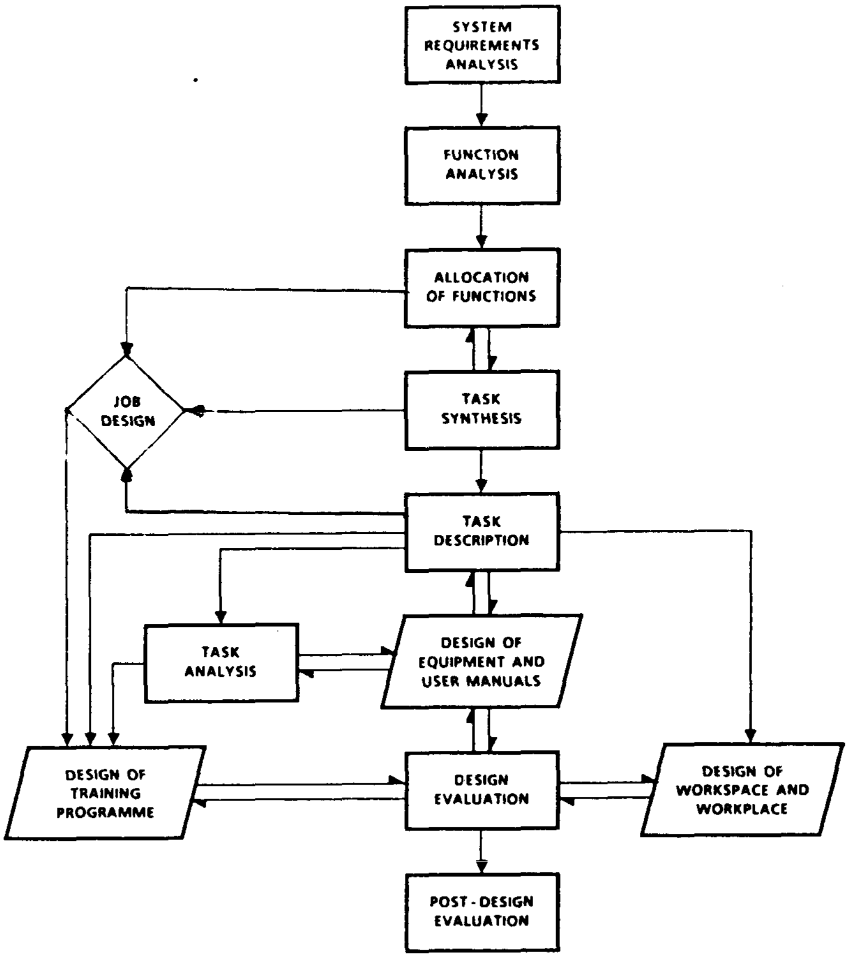


Fig 1
Sequence Of Human Factors Activities
Conducted During System Design

4.4 (Contd)

(a) Human factors issues must be considered at the earliest design stages since the decisions made at this time have a significant effect upon how the system is subsequently developed (see also **5.3).** In addition, most of these decisions are at best expensive, and at worst impossible to reverse later if they are wrong.

(b) As a corollary to (a), user requirements must be established clearly before all else. A system, no matter how well engineered, cannot be considered well designed if it fails to meet these requirements.

5 Characteristics of System Design

5.1 Alternative solutions. System design at the feasibility stage will require technical approval of alternative solutions including the results of any experimental work.

5.2 Innovation. System design is an inventive process depending on expert judgement as much as on analysis and formal procedures; it also depends on skill and ingenuity. New systems are, however, rarely entirely novel. Typically, they are advanced versions of an earlier system. As a consequence many functions are carried over from the old to the new system. This has important implications for the design team, eg that personnel may be transferred from the old to the new system (see also **9.1).** Novel systems, however, can be required and their importance should not be overlooked.

5.3 Decomposition. The system design process as a whole is one of working from broad, general functions, eg engage target, to progressively more specific, detailed tasks, eg fire missile, and subtasks, eg press button. Choices made at an earlier, more general (system, subsystem) level have profound consequences for later, lower (task, subtask, component) levels. If, for example, it has been decided to use a thermal imager the design team will have to face all the problems associated with such equipment including the use of a Cathode-Ray Tube (CRT) display for presenting the imagery which has special features of its own to be considered, eg display brightness, resolution, ambient lighting, etc.

5.4 Interaction. System design is a highly interactive process. The design team consists of different groups each concerned with its own field, eg human factors, electronics, mechanics, optics, who discuss, arrive at design solutions and compromise over competing interests but all working towards the common goal of satisfying the system requirements. Also, different parts (subsystems) of the system are developed in parallel or at different rates, and the results of one activity are fed across into another.

5.5 Iteration. System design is an iterative process. Firstly, like all effective design, it proceeds by hypothesis and experimentation as design solutions are proposed, tested, rejected or revised and, finally, accepted. The analytic efforts of the design team are also iterative for another reason. That is, the same questions and activities arise at different stages in the process but require analysis in greater detail as the design proceeds from one stage to the next.

6 Stages of System Design

6.1 Number of stages. In practice system design is not a simple linear process, significant overlaps occur both in time and content. This is typical of ordinary equipment design as well as for systems. However, because of the scope and complexity of the system to be constructed, the system design process is usually of long duration. Seven major stages may be distinguished, any of which, depending on the complexity of the project, may last months or years. The stages from a human factors point of view (based on Meister 1982) occur in succession and are shown in figure 2 with the related procurement phases. Descriptions of the stages are as follows:

6.2 System planning. In this stage, in response to the customer's or user's system requirements, the concept of the new system is outlined and its major functions described. If, as is most likely the case, the system is not entirely novel (see **5.2)** the effort in system planning is focussed on the changes in the new compared with the old system, eg replacing electro-mechanical displays with one or more CRT displays.

6.3 Preliminary design. In this stage alternative concepts of the new system are examined in feasibility studies (mathematical modelling, mock-ups, simulations or, simply, pen and paper exercises). If none appear workable then the design team has to re-examine the system requirements at the system planning stage.

6.4 Detailed design. In this stage the proposed system design is expanded in more detail. Drawings are made, the design is evaluated by means of mock-ups and simulation, and the equipment components specified. Periodic design reviews are carried out and, at the conclusion of this stage, the design is considered 'frozen'.

6.5 Prototype system. In this stage a prototype of the new system is built.

6.6 Test and evaluation. In this stage the prototype system is tested and evaluated and user opinion sought. Modifications, if necessary, are fed back to the detailed design stage.

6.7 Production. In this stage the system is manufactured.

6.8 Operation. In this stage the system is in use by the customer. The design team still has a role to play since, despite their best efforts, from a human factors point of view, systems are often developed with faults. Changes to the system at this stage can, depending on the system and the changes required, be extremely costly.

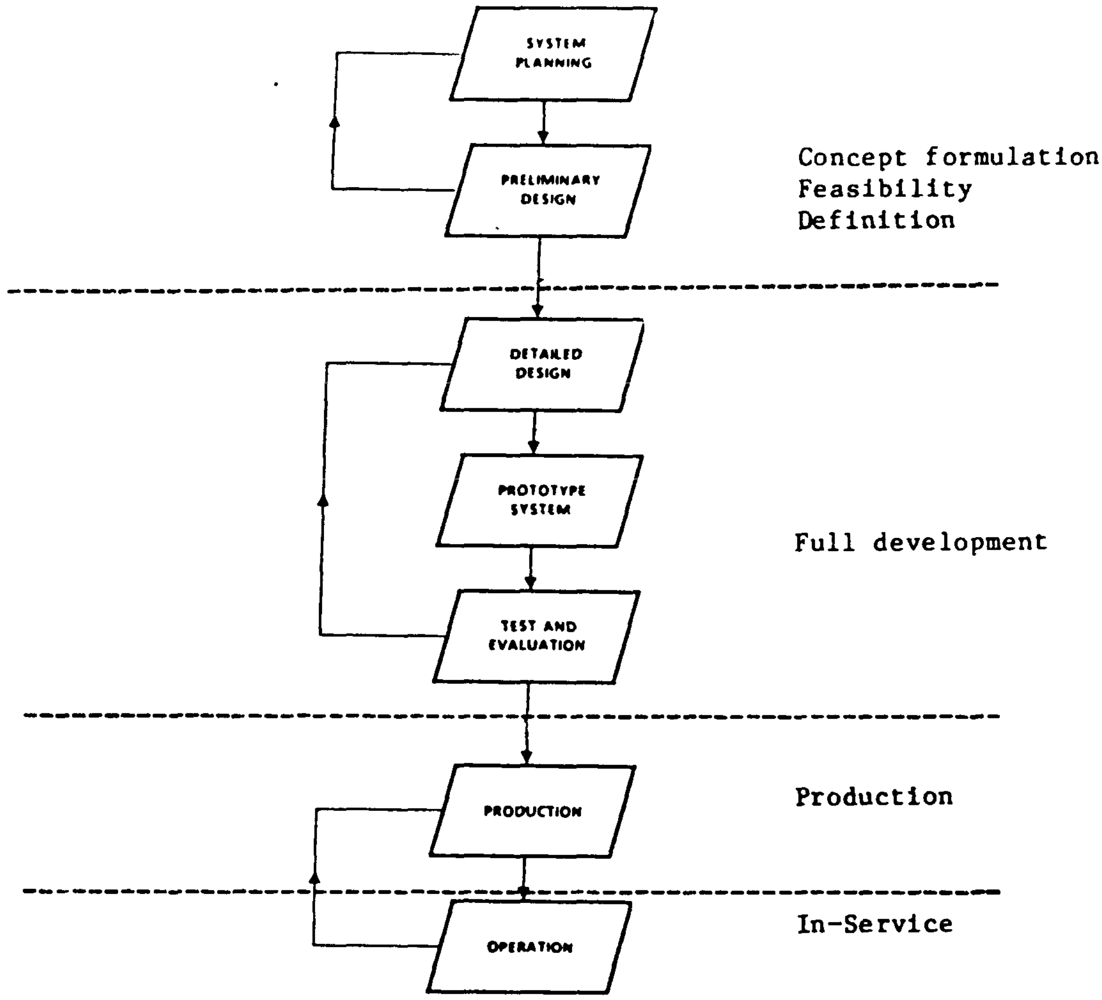


Fig 2

System Design Stages and Procurement Cycle Phases

Section Three. Human Factors Activities and Methodology

7 Introduction

The human factors activities identified at **4.2** and described in this section at clauses **8, 9, 10, 11, 12, 13, 14, 15, 16, 17** and **18)** are related to specific stages of system design (see figure 3). Although the relationship between the two is to a certain extent ideal and in practice is much less precise and orderly, the designer should note that human factors activities commence before the start of system design, and continue throughout.

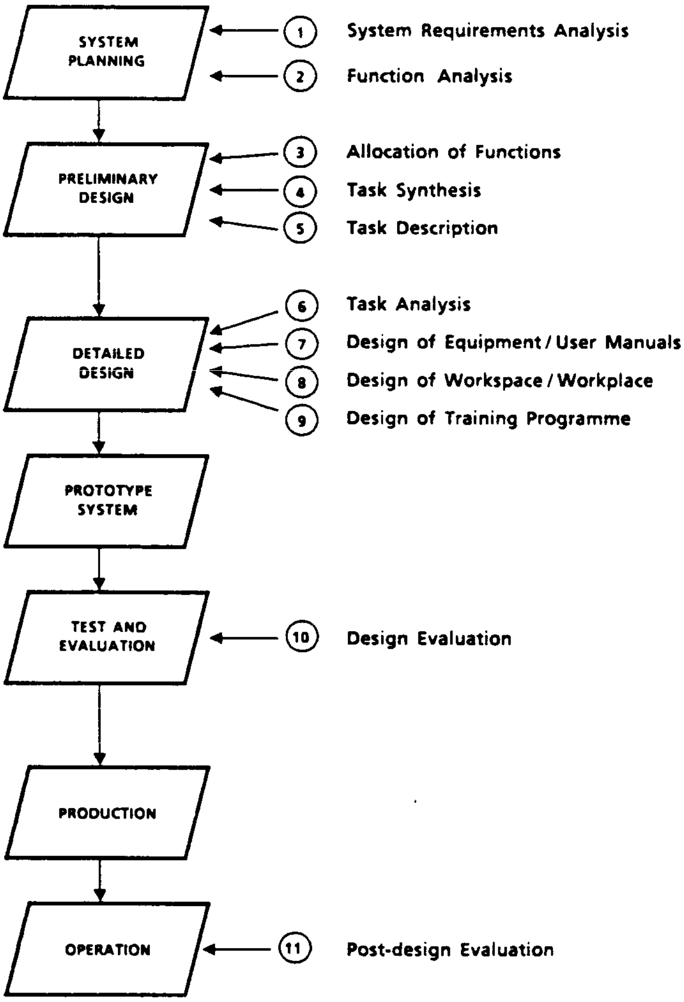


Fig 3
Relationship Between Human Factors Activities And System Design Stages

8 System Requirements Analysis

8.1 Purpose. A system requirements analysis should be carried out so as to determine the behavioral implications of the system requirements. If, for example, an aircraft is required to be flown at low-level and at night, the pilot will require certain visual aids, eg night vision goggles. If, to take a more simplistic example, the system is to be operated at sea, operators may suffer from seasickness. Or, if the system is to be operated in Arctic conditions, personnel may require special cold weather clothing, and controls may have to be larger and more widely spaced to be operated with gloved hands. The major system requirements are physical - eg speed, range, endurance, power consumption, and reliability, but there are always explicit behavioral requirements, eg must be viewable in red ambient lighting. The system requirement, in the form of a contract specification or comparable document, eg staff target, technical requirement, is what initiates and stimulates the design process, and must be based upon sound human factors practice.

8.2 Method. Several methods of examining system requirements exist. Controlled Requirements Expression (CRE) (1985) is one of several dataflow analysis methods which examine the requirements expression phase of system development. Although it may not be possible at this very early stage of system planning to do more than draw the other team member's and user representative's attention to potential areas of concern, any guidance is valuable.

9 Function Analysis

9.1 Purpose. A function analysis should be conducted so as to identify system functions, particularly those requiring human implementation and involvement, and to examine their behavioral implications. If, as is predominantly the case, the system being developed is not novel (see **5.2)** the effort of the design team will be mainly to analyze the functional implications rather than identification. The design team should note that even supposedly fully automated functions require some human involvement or have some behavioral implications, eg installation and maintenance (see Part 11 of this Defence Standard). It is important to conduct a function analysis of the old as well as the new functions since often these have not been, or at best have been inadequately, analyzed.

9.2 Method. Using their judgement and experience the design team should examine relevant system documentation, including the results of the system requirements analysis, to deduce the system functions, and, more importantly, discern their behavioral implications. To assist in carrying out a function analysis the design team should construct function flow diagrams (see clause **20).** For further information consult MOD/DTI Human Factors Guidelines for Computer Based Systems.

10 Allocation of Functions

10.1 Purpose. An allocation of functions should be carried out to ensure that the system functions are implemented in the most efficient manner to meet the system requirements.

10.1.1 Automation. It is important to consider the implication of automation where appropriate. Ill-conceived introduction of automation, without a detailed analysis of task requirements, can create a variety of problems, eg underload or overload (each of which should be avoided where possible), shortage of personnel to deal with emergencies or an undue trust that the automated part of the system will function perfectly.

10.2 Method

10.2.1 Consider alternatives. Consider, without preconceptions, all possible ways of implementing the function. There are usually several ways in which a function can be performed and the choice can be ordered on a continuum from completely manual (operator or operators alone) to completely automatic (equipment alone). This activity should be one of the most creative steps in the design process. The design team should, therefore, instead of concentrating on relatively few design configurations (usually those that they have found successful in the past) conceptualize all possible alternatives. The design team should also consider the possible effects of the system on the operators. Not only are health and safety involved (see **14.1.2.6)** but also there are organizational problems associated with task sharing, methods of supervision, methods of assistance, allocation of functions between teams, which are predetermined by design decisions. Such considerations are also relevant to task synthesis (see clause **11)** which, to some extent, overlaps with allocation of functions.

10.2.2 Describe alternatives. Describe, preferably in narrative form, the various ways in which each (unallocated) function can be implemented. An example of such a description is shown in table A.

Table A

Analysis Of Alternative Man-Machine Combinations
(From Meister (1971))

Alternative 1 (Operator primarily)	**Alternative 2 (Man-machine mix)**	**Alternative 3 (Machine primarily)**
Sonarman detects target signal on scope, examines brightness, shape, recurrence, movement, etc, and reports ‘probable submarine’ or ‘non-submarine target'.	Sonarman detects target signal on scope. Associated computer also detects signal, records it, and searches library of standard signals. Computer displays to sonarman original signal and comparison signal on sonar gear, together with the probability of its being a submarine. Sonarman decides on basis of his own analysis and computer Information whether target signal is submarine or non-submarine and reports accordingly.	When a signal having a strength above a specified threshold is received by the sonar array, a computer associated with the detection apparatus automatically records the signal, analyzes its strength, brightness, recurrence, etc, according to pre-programmed algorithms, compares it with a library of standard sonar signals, and displays an Indicator reading ‘probable submarine’.
Operator Functions	Operator Functions	Operator Functions
1. Detection of signal 2. Analysis of signal 3. Decision making 4. Reporting of decision	1. Detection of signal 2. Analysis of signal 3. Decision making 4. Reporting of decision	1. Take action on receipt of ‘probable submarine’ signal
Machine Functions	Machine Functions	Machine Functions
1. Display of signal	1. Detection of signal 2. Recording of signal 3. Searching of comparison signals 4. Analysis of signal 5. Display of information	1. Detection of signal 2. Analysis of signal 3. Decision making 4. Display of conclusion
Advantages/Disadvantages	Advantages/Disadvantages	Advantages/Disadvantages
1. No machine back-up for operator inadequacies	1. Operator/machine back each other up	1. No operator back-up for machine inadequacies

10.2.3 Establish criteria. Establish and weight the criteria by which each alternative can be compared. In general, the criteria to be applied in evaluating alternatives are time, cost, reliability, maintainability, manning, etc. Cost may be a crucial factor for one system development, time for another, or several criteria may each have some influence on the decision (see Meister (1971)). Establishing and weighting of criteria is primarily the job of the system engineer because it is his responsibility to dictate the system criteria. The design team should ensure that behavioral requirements, including job design considerations, are part of those criteria and that the weighting they are given is appropriate. Nonetheless, determining the weight of each criterion is an entirely subjective judgement because it is a matter of value. By following a formal procedure the design team is forced to make their decision biases visible.

10.2.4 Compare alternatives. Each design alternative is compared with every other on the basis of each criterion so as to derive an overall 'score' for the alternatives.

10.2.5 Select alternative. Finally, the design alternative that has the best score is selected for the system.

10.2.6 Further information on function allocation can be found in Price (1985). The use of "Fitts' List" (a comparison of capabilities and limitations of man versus machine) is not recommended.

11 Task Synthesis

11.1 Purpose. The purpose of task synthesis is to provide an initial statement of the operator(s) tasks that would be required to be performed to carry out a particular function. It is a prerequisite for describing and subsequently analyzing the tasks (see clauses **12** and **13).**

11.2 Method

11.2.1 General. The method of conducting a task synthesis entails the design team, using their judgement and expertise, proposing a combination or sequence of tasks appropriate to the function. If the system is not new, that is, it is an advanced version of an earlier system, the tasks may to a certain extent suggest themselves. If, however, the system is entirely novel then deciding on the tasks may be somewhat speculative. The process of task synthesis is not, of course, conducted in isolation. It is a highly iterative process and there is a two-way interaction between task synthesis and allocation of functions (see figure 1). It can also be seen that in describing 'alternative man-machine combinations', a task synthesis is implicitly undertaken. It may be necessary, therefore, to re-allocate because of the manning level available and the level of skills available or required. In fact, since the 'synthesized' tasks form only one part of the user’s overall job (see **3.6),** task synthesis has implications for job design (see figure 1). Conversely, an operator’s existing job, eg consisting of system operation, staff supervision, and cleaning, etc, may influence the task synthesis process.

11.2.1 (Contd)

For a function such as 'engage target', for the relatively straightforward operation of a ground-to-air missile system, the task synthesis might yield the following operator tasks:

(a) Target search.

(b) Target tracking.

(c) Target identification.

(d) Fire missile or return to standby, etc.

Problems of task sharing, methods of supervision, team roles and responsibilities should also be considered (see **10.2.1).**

11.2.2 Computer-based systems. For systems that involve considerable human-computer interaction task synthesis can be very problematical. For example, for a function such as 'picture compilation' for a submarine command system the following tasks might be generated:

(a) Report new track number (of contact) to command.

(b) Monitor track compilation.

(c) Set up graphic displays.

(d) Check data-processing systems.

(e) Note time of possible manoeuvre.

(f) Check track compilation.

(g) Check classification.

(h) Report track characteristics to command, etc.

No easily specified methodology exists as yet for deriving such tasks. There are many obstacles to formulating such a methodology, eg the continuously evolving nature of the information gathering and processing, and the conflicting requirements of various users. The most effective approach to the design process would seem to be a matter of trial and error using demonstrator systems to exemplify possible task designs.

12 Task Description

12.1 Purpose. A task description is conducted for several reasons. Firstly, it is necessary to describe the task before one analyzes it. Secondly, the listing of tasks enables them to be grouped and organized on the basis of criteria such as purpose or function, operator concerned or common equipment. Thirdly, a task description can suggest required control and display hardware, and lastly, it serves as a prerequisite for determining manning levels and required personnel skills (see clause **13).**

12.2 Method

12.2.1 General. There are several methods of conducting a task description which are beyond the scope of this document to describe. The method illustrated below is based, loosely, on Singleton (1974). For further information consult Drury (1983).

12.2.2 Construct table. Construct a table, as shown in table B, with the tasks listed in the first column and the other columns headed 'stimulus', 'action' and 'response'.

12.2.3 Describe tasks. Describe each task according to the column headings shown in table B. The description needs only to be brief.

Table B

Sample Task Description

TASK NO.	TASK	STIMULUS (TRIGGER)	ACTION		RESPONSE (OF SYSTEM)
			PERCEPTUAL	PHYSICAL	
7.2.1	Target search	Alarm	Scan field of view (FOV)	Operate sensor bearing control	Sensor slewed
7.2.2	Target tracking (manual)	Target seen	Observe target	Align reticule over target	Sensor slewed
7.2.3	Target tracking ('auto')	Reticule over target	Observe target	Operate 'auto' tracking control	'Auto' tracking of target
7.2.4	Fire missile	Target within range (verbal order to fire)	Observe target	Operate 'fire' control	Missile launched

13 Task Analysis

13.1 Purpose. A task analysis is conducted so as to assist in the design of the system with regard to equipment, job aids, operating manuals, working environment and operator training. When properly performed it is immensely valuable for analyzing all the behavioral aspects of system design. A task analysis does not, however, define the system. Its purpose is to identify human factors implications of the system design and merely points the skilled analyst towards design solutions. Task Analysis deals with the individual tasks which comprise a job. Essentially it consists of making deductions and drawing conclusions about a task based on the Task Description.

NOTE: For information on job analysis methodology consult McCormick (1979) and MOD/DTI Human Factors Guidance for Computer Based Systems.

13.2 Method

13.2.1 General. Generally, but not always, in a task analysis the equipment is, to a certain extent, already designed. Therefore, if from a human factors standpoint the equipment is poorly designed, the task analysis will still be based upon that equipment. Task analysis may reveal that equipment is poorly designed for the operator, and may show why it is poorly designed but the analysis per se will be a statement of the task requirements of the equipment as it stands, or of the specification. There are many methods of conducting a task analysis beyond the scope of this document to describe (for further information consult Drury (1983)).

13.2.2 Select tasks. The tasks to be analyzed are first selected. Because task analysis is complex and time-consuming not all tasks can, or need to be, analyzed (in fact there is nothing in the task analysis method that specifies the tasks to which it is applied). The decision on which tasks to analyze should have already been made during the task description (see **12.2**). Usually, the tasks selected should be those that are critical (whose failure might cause serious system problems), and to those tasks of special importance, eg those most frequently or perhaps infrequently performed.

13.2.3 Collect data. The primary data for task analysis should be the task description. Other sources of data (which are especially pertinent when conducting a post-design evaluation of a system (see **18.1** and **18.3**)) are:

(a) System documentation which includes procedures, specifications, test reports (and any previous task analyses) of a predecessor or related system;

(b) Interviews with personnel and experts or predecessor or related system;

(c) Observation of predecessor or related system operations.

The latter three sources of data will be especially pertinent when conducting a post-design evaluation of a system (see **18.1** and **18.3**).

13.2.4 Conduct analysis. Conducting a task analysis entails either listing in detail the human factors problems for each task or tabulating answers to specific questions, eg 'manipulative requirements', 'characteristic errors or malfunctions'. (See Drury (1983)). An example of the former approach is shown in table C. As an aid to performing the task analysis the designer can utilize the following design aiding techniques:

(a) Decision/Action (D/A) Diagram (see clause **21).**

(b) Operational Sequence (OS) Diagram (see clause **22).**

(c) Workload Prediction (see clause **23).**

Table C

Sample Task Analysis

TASK DESCRIPTION (SEE TABLE B)	TASK ANALYSIS	
	PROBLEM IDENTIFICATION	REMARKS/RECOMMENDATIONS
Target search	Type of sensor bearing control Variable sensor field of view Target detection Target identification (target type and characteristics	Rotary knob preferred (avoids dual role of joystick used for tracking); Carry out optimization study; Indication of approx. range/bearing required (what if target not seen - search time limit?); Operator training
Target tracking (manual)	Type of Joystick	Thumb-operated force controller acceptable (minimal operator transfer of training problem); Joystick control law requires optimization.
Target tracking (automatic)	No manual/automatic status Indicator Manual/automatic mode switch presently a button Target lock may be lost occasionally	Light or alphanumeric symbol? Could use DVI (check ambient noise level); Operators must be trained accordingly (ie for manual reversion).
Fire missile	Button rather small. Can it be operated wearing gloves? Safety cover?	Enlarge size of button. Safety cover is mandatory.

14 Design of Equipment and User Manuals

14.1 Equipment (hardware) design

14.1.1 Purpose. The purpose of equipment (hardware) design is to ensure the safe, efficient and reliable operation of the equipment by system personnel and that the personnel will not be harmed during such operation.

14.1.2 Method

14.1.2.1 Anthropometry. The design of the equipment - workstation, console, control board etc - shall begin by addressing the agreed anthropometric percentile range of the user population (see Part 2 of this Defence Standard). The designer's attention is drawn to the existence of computerized design methods (see clause **26)** and the use of mock-ups (see **30.1)** (see also Part 4 of this Defence Standard).

14.1.2.2 Control and display selection. Based upon the operational requirements previously specified, the controls and displays should be selected for positioning on the equipment surfaces or panels (see Parts 7, 8 and 10 of this Defence Standard).

14.1.2.3 Control and display layout. The equipment controls and displays shall be arranged on the surfaces or panels according to the ergonomic principles of workstation layout (see also Parts 4, 7 and 10 of this Defence Standard). Although the four principles (a), (b), (c) and (d) as follows (not mutually exclusive) may seem to the designer to be trivial, even pedantic, it is well established that their proper application improves the ease of operating equipment. An ergonomic layout of controls and displays is especially beneficial in demanding situations when a weary or stressed operator may revert to 'stereotyped' behaviour and any adaptation that he may have made to awkward features of the design may be lost. As an aid to control/display layout it is recommended that the designer uses the diagrammatic technique known as link analysis (see clause **25).**

(a) Functional grouping: the most common panel layout practice is to provide clearly distinguishable functional groupings of panel components, eg engine instrumentation, weapons controls, communications. These groups of related components should be made distinguishable from each other by using labelling, lines of demarcation, spacing, and variously shaded panel areas.

(b) Sequence of operation: when an operator observes events and selects control options in a fixed sequence of operations, control panels lend themselves to sequential arrangements of control/display components. Sequences from left-to-right and top-to-bottom are helpful in ensuring that all operational actions are made in the proper order. Application of this principle minimizes operator movements required in performing time-critical or safety-related operations. Related to arranging components sequentially are mimic displays (see Part 7 of this Defence Standard, **12.2).**

(c) Importance: this principle emphasizes placing the most important controls and displays within the primary field of view around an operator's line-of-sight (see Part 7 of this Defence Standard, **6.1)** and reach envelope (see Part 2 of this Defence Standard, **4.2).**

(d) Frequency of use: the controls and displays are provided a level of availability which matches their frequency of use, and sometimes importance.

14.1.2.4 If the system being designed has to be carried (ie it is a man-portable system) the designer shall give consideration to human strength and lifting capabilities (see Part 3 and Part 11 of this Defence Standard).

14.1.2.5 The design team should take into account, when designing the system, how it will be maintained and make adequate provision for ease of access, connecting/disconnecting components, labelling, and user manuals (see Part 11 of this Defence Standard).

14.1.2.6 Health and safety. If the system being designed emits noise, heat, cold, radiation, vibration or any other potential hazard, eg toxic fumes, the design team shall ensure that the levels are safe or that adequate protection is provided (see Part 5 of this Defence Standard). The climatic conditions in which the equipment is required for operation should also provide a habitable environment for the crew. Health and safety implications are linked to considerations of the functional problems associated with task sharing, supervision, allocation of function and the design to implement this effectively.

14.2 Equipment (software) design

14.2.1 For further information consult Williges and Williges (1984), Smith and Mosier (1984), Foley, Wallace and Chan (1984) and Part 7 of this Defence Standard. The major topics that have to be considered are as follows:

(a) Data organization: information coding (shape, colour, brightness, flashing, etc), information density, labelling, data formats (tabular, numeric, alphanumeric, textual and graphical data) and screen layout;

(b) Dialogue mode: choice of mode (ie command language, menu selection, form-filling, computer inquiry, query language, natural language), dialogue design (structure, nomenclature, selection codes, abbreviations, defaults, etc);

(c) Feedback and control: system messages (status, errors), hard-copy output, user control, error correction and recovery, help facilities.

14.3 Design of User Manuals

14.3.1 Purpose. The purpose of the human factors design of user manuals is twofold. Firstly, it is to ensure that the text describes adequately how to operate or maintain the system or subsystem in question. Secondly, it is to ensure that the information contained in the text conforms to established principles of typography, eg legibility.

14.3.2 Method

14.3.2.1 Content. User manuals should contain the following:

(a) A description of the system on which the task is to be performed.

(b) A listing of trained personnel required to perform the task.

(c) All required setting up and securing operations.

(d) A step-by-step sequence of instructions, timed if possible.

(e) Required safety precautions.

14.3.2.1 (Contd)

(f) All critical operations emphasized.

(g) Information about how to respond to contingency, eg emergency events.

(h) Any additional reference manual or technical data (however, it is desirable, where feasible, to write most manuals out in full).

14.3.2.2 Information presentation. The presentation of the information (text, figures, tables etc) in the user manual should conform to good typographic practice. For example, to ensure adequate legibility, the print should be at least as large as standard typewriter print; the layout of the text should be planned so that page-turning is minimized - ie an associated text is on the same page as the illustration it discusses, and the topic is not split at a critical point forcing the operator to turn back and forth between pages; also differentiate between headings and main text by use of capitals, underlining and colour, etc. The information should also be matched, as far as possible, to the user's level of education, skill, etc. Hartley (1978) has done extensive work on the design of such text. For further information consult Joint Service Publication (JSP) 182 and Part 7 of this Defence Standard.

14.3.2.3 Pocket-sized manuals. User manuals are frequently large and bulky, sometimes even to the extent of being unusable. The designer should consider producing pocket-sized manuals, or reference cards, so that operators can carry or have them readily to hand. Pre-flight checklist cards for pilots are an example of such 'job-aids'.

15 Design of Workspace and the Workplace

To a certain extent the workspace design associated with military equipment overlaps with the design of the equipment itself, as for example with control consoles, cockpits, etc. However, design of equipment workspace is still relevant and should not be overlooked. Details of workspace and workplace design are given in Parts 4, 5 and 6 of this Standard.

16 Design of Training Programme

16.1 Purpose. The purpose of training programme design is to ensure that the training programme is constructed systematically and will produce trained personnel, without which no system can function, to the required standards. Regrettably, it is an aspect of system design that is frequently neglected during the system design process.

16.2 Method

16.2.1 General. This Part of the Defence Standard advocates the systems approach to training which, typically, emphasizes the specification of instructional objectives based upon needs assessment procedures, precisely controlled learning experiences to achieve these objectives, criteria for performance, and evaluation information. In fact, the systems approach to training resembles very much the overall system design process of which it forms one part. That is, the development of the training programme proceeds sequentially through distinct stages of analysis, design and evaluation.

16.2.1 (Contd)

The systems approach to the design of a training programme entails a number of major steps (see figure 4). These steps are as follows:

Assess instructional need (see **16.2.2**).

Derive objectives (see **16.2.3**).

Select training media (see **16.2.4**).

Conduct training (see **16.2.5**).

Evaluate training (see **16.2.6**).

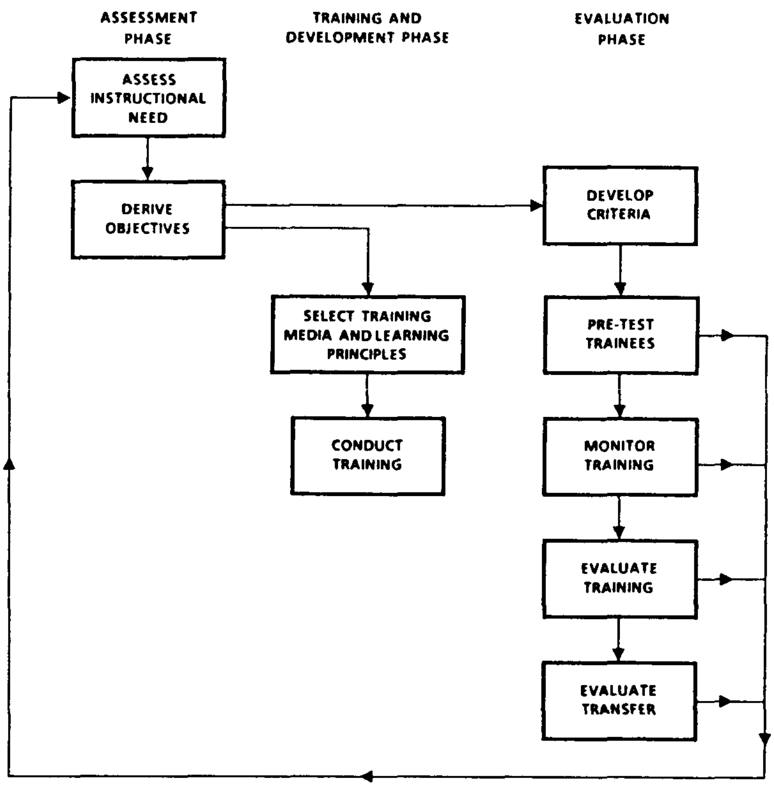


Fig 4
The Systems Approach To Training
(From Goldstein (1974))

16.2.2 Assess instructional need. Needs assessment is concerned with determining what tasks should be performed, and what knowledge, skills and abilities are necessary to perform the tasks.

16.2.2.1 Tasks. Information about tasks is obtained, logically, from a task description, task analysis, and job design (see figure 1). Once the tasks are specified it is then necessary to collect judgments, usually from 'subject matter experts', as to which tasks are most relevant for the design of the training programme. For example, it would not ordinarily be useful to design a training programme for tasks that are not important and are easily learned on the job.

16.2.2.2 Personnel. To obtain information on personnel knowledge, skills and abilities, the use of interview procedures (see **33.2)** with job supervisors, personnel specialists or, when appropriate, existing experienced operators, is usually recommended. Often the best procedure is to supply several panels of five to eight knowledgeable persons with a list of the tasks and ask the following type of questions:

(a) What does a person need to know in order to (name of task)?

(b) What do you expect a person to learn in training that would make him effective at (name of task)?

(c) Describe the characteristics of good and poor operators on (name of task).

(d) Think of someone you know who is better than anyone else at (name of task).

(e) What is the reason that they do it better?

The final step in this procedure is similar to that in judging task relevance. Some of the dimensions which might be used for knowledge, skills and abilities are: difficulty to learn, importance, and opportunity to acquire.

16.2.3 Derive objectives. The purpose of assessing instructional need (see **16.2.2)** is to derive the objectives of the training programme, which are prerequisites to developing the criteria for training evaluation and the choice of training media (see figure 4). For example, logically, the training programme should consist of the materials necessary to develop the knowledge, skills and abilities to perform successfully at the job. Similarly, the success of the training programme should be determined from criteria (measures) that tell the training evaluator how well the training programme does in teaching the trainees the same knowledge, skills and abilities. Training will be most effective and efficient when the objectives are specified and the whole training programme is then developed to meet those objectives.

16.2.4 Select training media

16.2.4.1 General. Selection of training media tends to resolve itself into a choice between three broad approaches:

Telling the trainee what to do using verbal methods, eg lectures, discussions, notes; (see (a))

16.2.4.1 (Contd)

Showing the trainee what to do by demonstration or guidance, eg films, videotapes; (see (b))

Having the trainee practice what to do, eg simulators, part-task trainers. (see (c))

Also of value are:

Computer-based training, (see (d)) and

Embedded training. (see e))

(a) Verbal methods: These contribute a natural approach to training objectives. A basic decision at the outset of any training programme is the extent to which verbal instruction is to be employed and what amount of such instruction should precede on-the-job practice. The effectiveness of verbal instructions depends on the form they take - which should be as simple and direct as possible - and on the nature of the task for which the instructions are designed. Verbal methods seem most appropriate for communicating the rules that apply to successful performance, or the theories and concepts that make for an understanding of the task.

(b) Demonstration: In its most general form training by demonstration can be an effective way to teach entire segments of behaviour. Material presented by film/videotape is as well remembered as material presented live, and very often the same material could not be presented in a classroom. In addition, special facilities like the animated diagram or the slow-motion sequence could not be achieved by any other method. Disadvantages include: the inflexibility of its timing (ie the viewer typically has no control over the rate at which information is presented); lack of adaptability to variation in the composition of the audience; need for instructor preparation; and, of course, expense.

(c) Practice: Having the learner practice is, or should be, the basic activity in most forms of training. The effectiveness of practice depends on the conditions in which it takes place, including the amount and kind of knowledge of results that is offered.

(d) Computer-based training: As the term implies, computer-based training refers to the use of computer technology to present and manage the instructional material; it can be thought of as 'automated teaching'. Computer-based training has many inherent advantages; for example, consistent high quality instruction, (training strategies of the best instructors can be incorporated and replicated); mobility of training (equipment can be easily transferred to remote sites without having to send trainees to an instructor or vice versa); privacy (trainees can succeed or fail in private so that embarrassment of failure is reduced); individualized training (performance standards or objectives can be set for each lesson for the individual trainee). The major disadvantage of computer-based training is the time and expense of computerizing the instruction.

16.2.4.1 (Contd)

(e) Embedded training: Embedded training refers to the inclusion of instruction as an integral part of an equipment or system. A simple example is the incorporation of a small light emitting diode/liquid crystal display in many products and machines for presenting brief prompting messages to help people use them. Although not essential, a computer capability for a system appears to be one of the determinants of situations in which embedded training has operational potential. Associated with the computer should be some computer-driven array of presentations to enable scenarios, and other forms of training material which offer instruction and practice under controlled conditions, to be presented.

There are many issues to be considered concerning the use of embedded training. For example, it must be designed in such a way that the system can switch instantly from training mode to operational mode without affecting system performance adversely. For further information see Ditzian et al (1986).

16.2.5 Conduct training

16.2.5.1 General. As in any teaching situation, the number and content of the lessons should be considered carefully. For optimal learning, lessons should neither be too long and complex nor too simple. As for determining the right amount of information, for example, it is clear that training will be inefficient if insufficient information is provided. Distributing practice sessions too sparsely, or covering too little ground in any one session, are obviously wasteful training procedures. However, many tasks and concepts will overload the trainee, so that other procedures, like the use of part-practice, are often to be recommended. Again, information may be inserted at the right or the wrong point in a sequence of skilled activity, with resulting consequences for efficiency in training. A guiding word at each of the successive stages of an activity is likely to prove far more effective than a set of elaborate instructions provided beforehand, which will have to be held in memory throughout the operation.

16.2.5.2 Adaptive training. Adaptive training is a method of training in which the level of difficulty at any stage is made to depend on the trainee's level of achievement at that point. Instead of separating a complex skill into parts so as to present the trainee with a subtask that is not too difficult to master, adaptive training achieves the same objective by initially simplifying the whole task, then increasing the difficulty level in successive steps until the full operational level is reached. Adaptive forms of training are potentially superior to fixed difficulty methods, since the trainee is always presented with the right degree of challenge at each level of progress. Automated adaptive training is a closed-loop variation in which the trainee's performance is monitored by a computer and the difficulty level of the task is changed by the computer according to the trainee's performance.

16.2.5.3 Team training. Teams are a pervasive and an increasingly important means of system operation, and the training of teams should therefore be considered by the design team. The training of a team begins, logically, with the individual mastering of the basic skills of operational tasks; the most visible and concrete activities of teams are the operational tasks that achieve the team's output. However, the training emphasis must not only be on operational tasks but also on team functioning and team skills. The essence of 'teamness' lies in the way team members relate and interact while carrying out these operational tasks. Essential to team functioning is some shared understanding of the team plan, that is, the strategy for accomplishing the team's goal, eg the tracking and destruction of submarines by an anti-submarine warfare team. Sharing of the plan as a common frame of reference enables individual members to coordinate their behaviour to the actions of their team-mates and the conditions under which the team is performing. Team identity and pride are also factors in team performance, although usually neglected in the research literature. Team identity is associated with attributes like 'cohesiveness' and loyalty. Team members should be encouraged to set up and share performance standards and exercise an internal social discipline for the good of the team. The emergence of pride and team identity, although not directly trainable attributes, may be useful as a measure of a stage in team development.

16.2.6 Evaluate training

16.2.6.1 General. Two aspects of training evaluation can be distinguished: the evaluation of the training programme as a whole (ie to produce trained personnel) and the evaluation of the training device or materials itself (ie to produce a required amount of training). The training programme and training device can both be evaluated either by measuring trainee performance (satisfactory performance equals effective training) or by assessing their attributes (satisfactory characteristics equal effective trainers). Performance measurement is the preferred methodology since the purpose of training (the programme or device) is to develop trained personnel. It is a more direct evaluative measure.

16.2.6.2 Training device evaluation. A training device is best evaluated by means of the 'transfer of training' paradigm. Transfer of training refers to the process whereby a skill learned in one setting has an effect (either positive or negative) on performance in a different setting or on a different task undertaken subsequently. A positive effect or 'transfer' is said to occur when something previously learned benefits performance or learning in a new situation, eg driving a different motor car. Negative transfer is said to occur when something previously learned hinders performance or learning in a new situation, eg learning to drive one's motor car on the opposite side of the road to normal.

16.2.6.3 Training programme evaluation. The ideal method of evaluating the training programme consists of a training school pre-test/post-test evaluation of trainees followed by measurement, at a later date, of their actual performance in the operational setting; in other words, a transfer of training assessment. The traditional pre/post test determines that some training has been accomplished and on-the-job measurement indicates that the trainee can perform his job. The operational measurement is most critical since without it the preceding evaluations are of little value. To perform the training evaluation and on-the-job measurement the evaluator requires criteria, measures, and methods of measurement just as he does for any other measurement. To develop these he should refer back to the original definition of training objectives and task analyses (see **16.2.2, 16.2.3** and figure 4) which should contain the performance criteria on which the school tests were based and which should suggest on-the-job measures. Performance measurement in the operational environment is, undoubtedly, difficult and costly. It is to be expected that the transfer of training evaluation as specified above might be impossible to implement properly. Indeed, the classic transfer of training evaluation employing a control group (ie a second group of subjects who are tested on-the-job but did not receive the relevant training) is also of doubtful practicability. There will be circumstances, dictated perhaps by administrative or safety considerations, in which a control group cannot be employed. For example, it might be unacceptable to 'penalize' the control group by requiring that it receive presumably inferior training. Less formal methods of receiving feedback from the operational environment have been suggested (Meister (1985)):

(a) The trainee may be asked to answer, and return to the training school, a critique - in questionnaire form - of the training he received in the light of his new job responsibilities. The technique leans heavily on the willingness of personnel to volunteer information and their skill in being able to analyze their own performance in training-related terms.

(b) Skilled evaluators and 'subject matter experts' can visit the operational system and observe/rate the trainee’s performance and then interview him and/or his supervisor (see clauses **32** and **33).**

(c) Ratings by the trainee’s supervisor can be sent back to the training school for evaluation but their adequacy depends on the supervisor’s evaluative skills.

17 Design Evaluation

17.1 Purpose. Design evaluation is carried out before production so as to verify that the proposed system design conforms to human factors standards and that it functions as intended. Analytic approaches, no matter how systematic or thorough, can overlook design details and fail to anticipate fundamental operator preferences.

17.2 Method. Depending on the nature of the system being developed a number of evaluative techniques can be used:

Checklists	(see clause **29).**
Mock-ups and Models	(see clause **30).**
Simulation and Simulators	(see clause **31).**
Observation	(see clause **32).**
Interviews and Questionnaires	(see clause **33).**
Objective Measurement	(see clause **34).**

Equipment drawings should be evaluated using checklists (which, of course, are compiled from standards). Mock-ups and models should be used to check that the design is practical, and that items have not been overlooked. Mock-ups are extremely useful because theoretical analyses are not infallible. Complex aspects of a system design should be evaluated by means of simulations.

18 Post-Design Evaluation

18.1 System effectiveness

18.1.1 Purpose. System effectiveness is evaluated so as to check that, from the human factors point of view, the system operates as intended. Analytic approaches, and even an evaluation of the system design (see clause **17,** no matter how systematic or thorough, can fail to anticipate operational realities.

18.1.2 Method. System effectiveness can be evaluated during war games (North Atlantic Treaty Organization (NATO) exercises, fleet exercises, simulated combat etc) and during hostilities.

Evaluation of the system effectiveness is carried out using the following techniques:

Observation	(see clause **32).**
Interviews and Questionnaires	(see clause **33).**
Objective Measurement	(see clause **34).**

18.2 Training effectiveness

18.2.1 Purpose. The purpose of training effectiveness is to determine that operators' performance meets the training objectives in a time and cost efficient manner. That is, that using the particular training programme or device training has been achieved more quickly and at less cost than alternative training resources.

18.2.2 Method. For further information consult Rolfe and Caro (1982) and Orlansky (1986).

18.3 Problem investigation

18.3.1 Purpose. Problem investigation is undertaken to identify the causes of problems that have become apparent during the operational use of the system, and to recommend solutions to those problems.

18.3.2 Method. Problem investigation, in the main, is a repeat of the systems analysis that led originally to the system under investigation. This is because the areas of investigation (function and task analyses) are much the same as those emphasized during development. Other techniques can be employed:

Observation	(see clause **32).**
Interviews and Questionnaires	(see clause **33).**
Objective Measurement	(see clause **34).**
Reverse Engineering	An analysis of the life-history of the system to determine the reasons for failure to meet the stated requirements. It is the design process which is examined as well as the system which has resulted.

Section Four. Design Aiding Techniques

19 Introduction

In Section four of this Part of the Defence Standard various design aiding techniques are presented. The list of techniques is not comprehensive; to those currently included could be added, for example, time-line analysis, and time and motion methods. Each of the following techniques has been developed for a slightly different purpose. Careful consideration should be given to the purpose of the investigation before a specific technique is used.

Function Flow Diagram (FFD)	(see clause **20).**
Decision/Action (D/A) Diagram	(see clause **21).**
Operational Sequence (OS) Diagram	(see clause **22).**
Workload Prediction	(see clause **23).**
Error Analysis	(see clause **24).**
Link Analysis	(see clause **25).**
Computerized Design Aids	(see clause **26).**
Mathematical Modelling Techniques	(see clause **27).**

20 Function Flow Diagram (FFD)

20.1 Purpose. The purpose of an FFD is to assist in the determination of required operator functions and their sequential interrelationships. An FFD can also serve as an aid to Allocation of Functions (see clause **10).** The FFD is best suited to gross analysis at a very early stage in system analysis because the amount of information it contains is limited to function sequence and relationship. An FFD can aid discussion within the design team and also serves as a record of the design.

20.2 Method. An FFD (see figure 5) is constructed by arranging in sequential all of the various functions that are believed to pertain to a particular system (or subsystem depending on level of detail). Each function is a verb-noun combination; occasionally nouns are assumed and adjectives added. In general, during the construction of higher level flows no distinction should be made between operator, equipment or software implementation of system functions. The lack of distinction is for the purpose of conducting unbiased allocation of functions.

20.2 (Contd)

Each function is depicted within a rectangular block and numbered for reference more or less according to its sequence on the page. The numbering system represents a progressive level of hierarchy: top-level functions 1.0, 2.0, etc; first-level functions 1.1, 1.2, 1.3, etc; second-level functions 1.1.1, 1.1.2, etc, and so on. These numbers, which remain with the function as long as it is unique, are important to enable the flow to either higher level functions or between functions for retracing. Functions are drawn from left to right and usually from top to bottom, indicating the normal sequence of occurrence of system functions. Arrows should enter the block from the left and exit to the right (ie they should not be used on either the top or bottom of the blocks). Wherever arrows join or diverge they should be connected by an 'and', 'or', or 'and/or' junction as shown in figure 5. The significance of the 'and' junction is that all of the following or preceding functions must be performed. The 'or' junction indicates a choice between two or more of the following or preceding functions to be performed. The 'and/or' junction combines the two and is useful if page-space is limited.

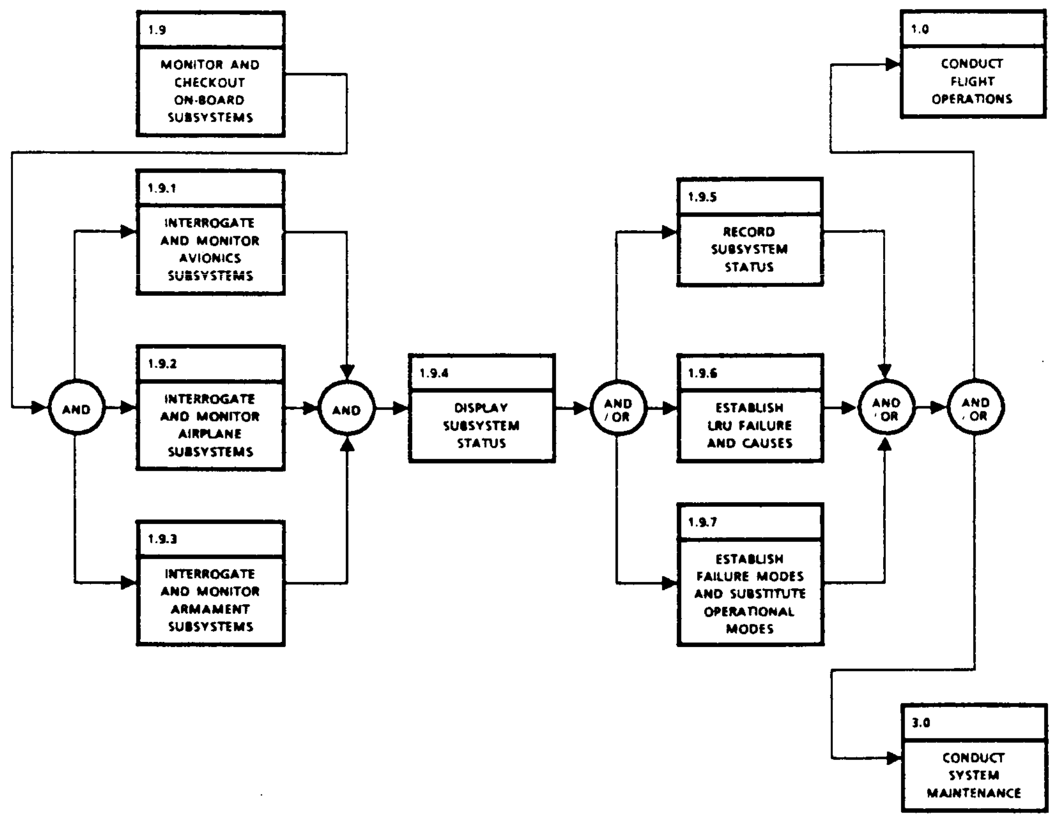


Fig 5
Sample Function Flow Diagram
(Modified From Geer (1981))

20.2 (Contd)

The concept of functional level detail is based on the total size or scope of the particular system to be analyzed. Naturally, the smaller the system being worked, the more detailed will be the corresponding level of functional analysis. Larger systems will require more levels to get to the same layer of detail. Top and first level functions tend to be identical for similar systems, eg perform: preflight, taxi, takeoff, etc. For large systems, such as a complete aircraft, they are gross system operations. The second level functions would tend to describe system operational (or maintenance) functions within the various mission phases. The third level may define specific functions with measurable performance. Allocation of functions between operators, equipment and/or software may occur at this level. Fourth level functions may be the level at which operator task analysis may occur.

21 Decision/Action (D/A) Diagram

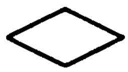
21.1 Purpose. A D/A diagram portrays the sequential flow of information between a series of operator tasks or sub-tasks. It is used to clarify the information needed by the operator, to identify potential sources of operation error, and to assist in determining control and display requirements. Typically, it is used as an aid to task analysis (see clause **13)** but can also be used at other stages of system development.

21.2 Method

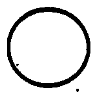
21.2.1 Symbology. There is not a standard symbology for D/A diagrams. The following symbols, derived from several accepted symbol conventions (see Singleton (1974); p.36), are recommended for denoting events:

(a) Operator action.

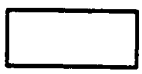
(b) Operator decision.



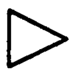
(c) Information or data.



(d) System action/status.



(e) Enter/exit.



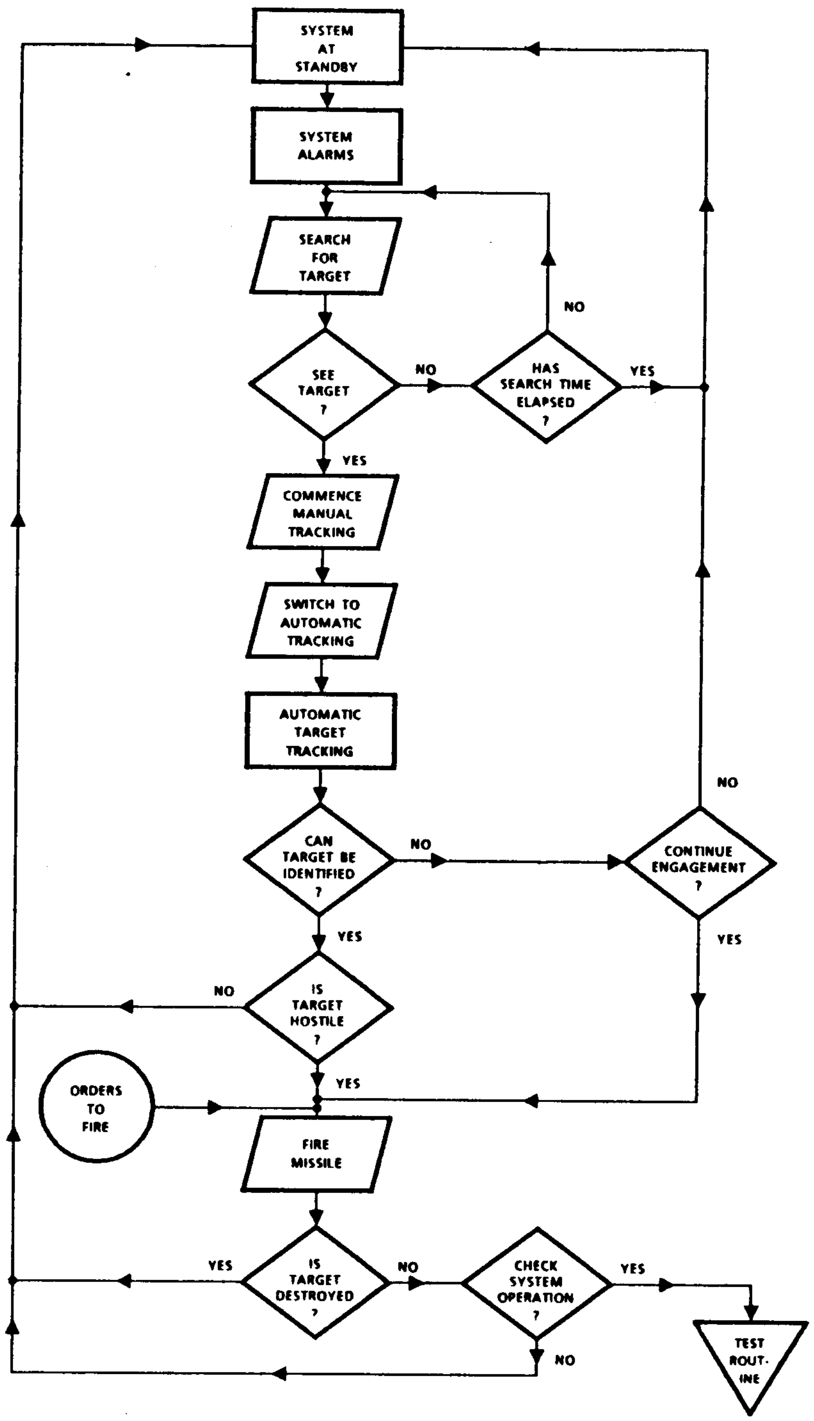


Fig 6
Sample Decision/Action Diagram

21.2.2 Decision analysis. Based on the information contained in the task description (see clause **12** and table B) the tasks that comprise a particular function are analyzed in greater detail (to subtask level, as necessary) to determine the decisions made by the operator.

21.2.3 D/A diagram construction. Each event (subtask, decision, etc) is drawn on paper using the special symbology and linked in its sequence of occurrence. The flow of information is usually drawn vertically, top to bottom (see figure 6) in a similar fashion to flow charts used by computer programmers. Each event is described by a relatively short verb-noun combination with occasional adjectives or other modifiers contained within the symbol. Sometimes numbers are added to the symbols to aid in retracing the flow between decision/action events. It should be noted that flow paths should be complete. That is, every path should either recirculate or end in a valid exit (ie indicate route to another diagram). Finally, operator decisions are depicted as binary choice events and the words 'yes' and 'no' are added to the diagram as appropriate.

22 Operational Sequence (OS) Diagram

22.1 Purpose. An OS diagram portrays the sequence of operator/crew behaviours and system events during system operation. It is used to examine in detail operator actions and decisions, and interactions between the operator, other operators, equipment and the system. In effect, an OS diagram is a simulation of system operation - on paper. As with the D/A diagram the OS diagram is used primarily as an aid to task analysis (see clause **13).** It differs from a D/A diagram (see clause **21)** in that the operator’s sensory mode of communication (ie sight, touch, hearing) is included and becomes much more complex.

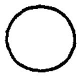
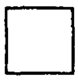
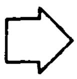
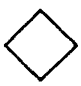
22.2 Method

22.2.1 Symbology. To construct an OS diagram a more or less standardized symbology is employed, as shown in table D). It should be noted that this symbology differs from that employed in a D/A diagram (see **21.2.1).**

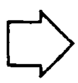
22.2.2 OS diagram construction. As shown in figure 7 the operators and their system are entered into the column headings; it generally proves convenient to place the operators and the equipment they control in adjacent columns. Any number of operators may be depicted on the OS diagram (although beyond a certain point the complexity of the diagram reduces its effectiveness) and it helps to group together all the operators and equipment of a specific subsystem or functional division of the system, eg weapons control. However, if the operators and equipment have not been specified, the designer will have to specify them tentatively. The OS diagram is initiated by the first event designated by the set of operations and, in a similar manner to the D/A diagram, the flow of information is always from the top to the bottom of the sheet. The time and events are written in columns 1 and 2. All of the equipment or operators receiving the input are listed and the transmission mode is noted by using the appropriate letter code (see table D). The subsequent actions taken by the operators/equipment (ie operations, transmissions, etc) as they react to the input are shown and, finally, external outputs are plotted in column 6.

Table D

Operational Sequence Diagram Symbology
(From Geer (1981))

	Operate -	an action function, to accomplish or continue a process. (Sometimes used for received information)
	Inspect -	to monitor or verify quantity or quality. An inspection occurs when an object is examined. (Sometimes used for action)
	Transmit *-	to pass information without changing its form.
	Receipt *-	to receive information in the transmitted form. (Sometimes used for stored information)
	Decision -	to evaluate and select a course of action or inaction based on receipt of information
	Storage -	to retain. (Sometimes used for transmitted information)

* - Mode of transmission and receipt is indicated by a code letter within the

 and  symbols

V	-	Visual
E	-	Electrical/Electronic
S	-	Sound (verbal)
IC	-	Internal Communication
EX	-	External Communication
T	-	Touch
M	-	Mechanically
W	-	Walking
H	-	Hand Deliver

22.2.2 (Contd)

The construction of an OS diagram requires a great deal of information and the integration of that information is generally a tedious and time-consuming process. Experience has shown that the construction of OS diagrams requires trained individuals with analytical skills.

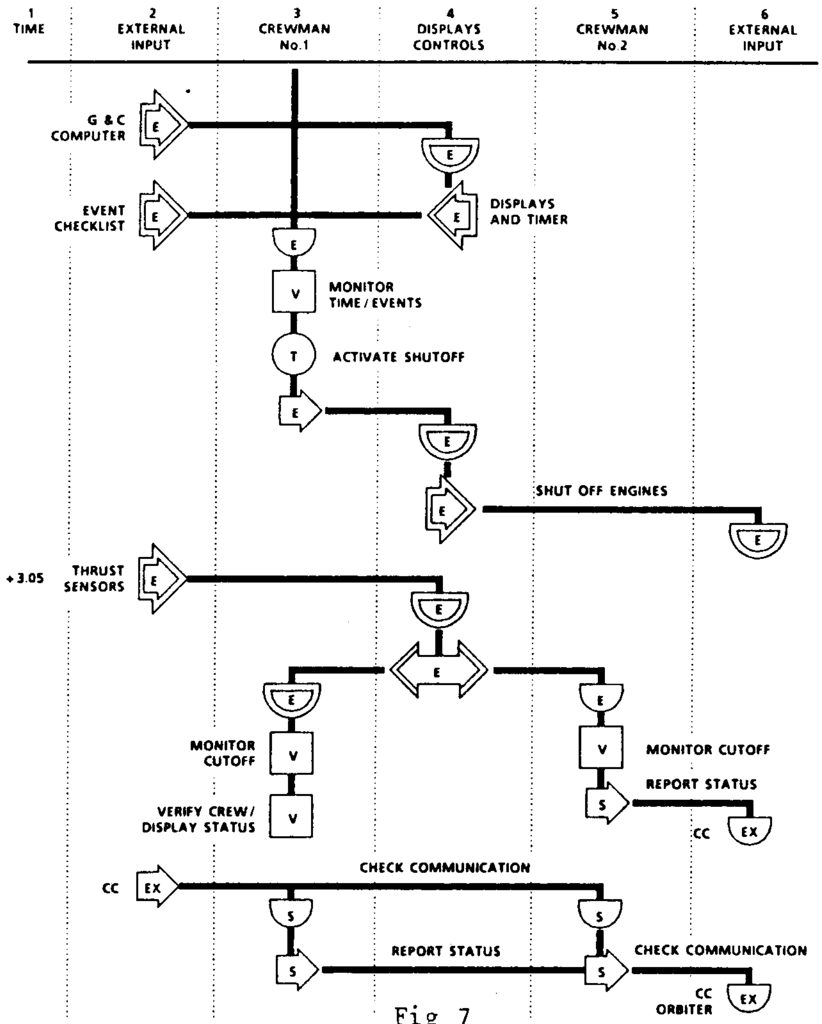


Fig 7
Sample Operational Sequence Diagram
(From Geer (1981))

23 Workload Prediction

23.1 Purpose. The purpose of workload prediction, given that it is a design aim to optimize workload, is to identify those aspects of the system being developed that might impose either an excessive or insufficient physical and mental load on the operator. These must be changed. Insufficient workload, or underload, is just as important as excessive workload since it is well established that boredom can result in a deterioration of performance (see Smith (1981)). Another purpose of workload prediction is to compare the relative merits of design alternatives. Workload prediction can be used as one of the criteria in task synthesis (see clause **11).**

23.2 Method

The topic of workload, both its prediction and measurement (see **35.1)**, is fraught with difficulty, and reference should be made to a human factors specialist for further details. There is no agreed definition of workload and it can be conceptualized in different ways, eg as effort, demand or as performance.

24 Error Analysis

24.1 The nature of human error

24.1.1 Human error is, functionally speaking, the failure to attain an objective goal given a situation in which available information could lead to its attainment. For the purpose of this Part of the Defence Standard it is presumed that errors are seldom random and, in fact, can be traced to specific causes and contributing factors. Once isolated, these factors can be ameliorated or eliminated.

24.1.2 Classification of errors. There are many kinds of errors and the recognition of this has resulted in a wide variety of error classification schemes.

24.1.3 Error rates. It is difficult to estimate human error rates because many are not directly observable. Errors of perception or memory may not have immediate consequences and so go unnoticed; some errors may be of very low frequency, particularly with well-trained personnel. A typical error rate cited is one error per 1000 opportunities ($p = 0.001$) for simple actions like pushing a button or reading a number. Error rates are fundamental to human reliability engineering (see **24.2.3)** but it is advised that they should be used with caution. The designer should note that behaviour error rates are probably very high, perhaps approaching $p = 0.1$ or more per action, but that self correction reduces this by one or two orders of magnitude. In tasks where self correction is impossible or unlikely, the probability of a behavioral error may be in the range $1 > p > 0.1$ and may approach 1.0 when stress is high and errors have already occurred.

24.1.4 Causes of error. It is customary to distinguish between Situation-Caused Errors (SCE) and Human-Caused Errors (HCE). Sometimes causes are referred to as 'exogenous' and 'endogenous', or in human reliability terminology as 'performance shaping factors'. For example, if a communication system is noisy, with a poor signal to noise ratio, even an optimal listener will make errors; these would be SCE’s. If, on the other hand, errors are due to the operator’s lack of skill, these would be HCE’s. Even the latter could be considered SCE’s, since the system designers should have better trained the operator or should not have selected him for the job in the first place.

24.1.4 (Contd)

The design of the system can produce operator error. For information on theories of human error,. consult Singleton (1973). A related point to minimizing the effect of an error is that, given that a system failure has occurred, the most urgent requirement may be to know what facilities or equipment are still functioning correctly and can be used with confidence; the user of a system may not have time to diagnose and correct errors. The design team should, where appropriate, consider this problem.

24.2 Error Prevention

24.2.1 Purpose. The purpose of error prevention is to minimize the opportunities for the occurrence of human error which might otherwise affect system operation adversely. Because people will make errors even in the best designed system, with the best of training and motivation, the purpose of error prevention is also to minimize the effect of an error on system operation.

24.2.2 Method

24.2.2.1 General. The method of error prevention is rather imprecise but entails, essentially, anticipating and avoiding 'error-likely situations'. The rationale behind the technique is that if one examines the system in terms of all the errors its personnel might make, one can design or redesign the system to reduce the likelihood of those errors.

24.2.2.2 The primary method of error prevention is the proper implementation of this Part, and all other Parts of this Defence Standard. That is, to conduct human factors analyses of the system, eg task analysis, and to design equipment according to well-established ergonomic principles (see **14.1).** Reflecting this broad approach, a 'total error reduction strategy’ has been proposed (Singleton (1972)) consisting of a list of specific areas of concern:

Allocation of function.

Interface and workspace design.

Selection and training.

Overqualified personnel.

Rigid procedures.

Contingency planning.

Human and hardware based monitoring.

Working hours and other conditions.

24.2.2.3 Design rules. By analyzing the classes of errors that people make with systems, it is possible to develop principles of system design that minimize the occurrence and effect of error. Four such principles, directed primarily at computer-based systems but also of general use, are as follows:

24.2.2.3 (Contd)

(a) Feedback: The state of the system should be clearly available to the user, ideally in a form that is unambiguous and that makes the set of options readily available so as to avoid mode errors (ie doing something believing the system is in one state when in fact it is in another).

(b) Response sequences: Different classes of actions should have quite dissimilar command sequences (or menu patterns).

(c) Actions should be reversible: To avoid unintentional performance, actions should, as far as possible, be reversible. Those actions that are irreversible and of relatively high consequence should be difficult to execute, eg as in the required release of 'safeties' before a pilot can eject from his aircraft.

(d) Consistency of the system: The system should be consistent in its structure and design of command so as to minimize memory problems in retrieving the operations.

24.2.3 Human reliability engineering. Human reliability engineering is a branch of human factors concerned with predicting and evaluating the performance of system personnel in quantitative terms using, for example, such indices as error probability.

24.2.3.1 Particular mention is made of Technique for Human Error Rate Prediction (THERP). The method depends heavily on task analysis (see clause **13)** to determine error-likely situations. Potential system or subsystem failures are defined, after which all the human operations involved in the failure and their relationships to system tasks are described by drawing them in the form of an event probability tree. Error rates for both correct and incorrect performance of each branch of the event tree are predicted by drawing upon a variety of data sources for inputs. Where an error rate is considered to be too high the system is analyzed to determine the causes, and changes are recommended. For further information consult Meister (1984a, 1985).

24.3 Error Reduction

24.3.1 Purpose. The purpose of error reduction is to improve human performance (and health and safety) and thereby improve overall system performance. Error reduction, as distinct from its prevention (see **24.2)** is the method or methods of reducing the occurrence of human error once a system is operational. It is a remedial technique.

24.3.2 Method. The type of information to be collected and recorded will depend partly on the system operations in question but the list below indicates some of the information which would be needed to identify and analyze the errors.

(a) Operator(s): The specific individual is unimportant unless he has some special characteristics that made the error more probable.

(b) Equipment: What equipment was being operated or maintained, and its location.

24.3.2 (Contd)

(c) Task: Description of the individual task in which error was made.

(d) Time: When was the error made? (eg in what part of the system mission, on what shift).

(e) Error: Description of the error and classification. Was the error correctable?

(f) System response: What were the consequences of the error? How critical was the error?

(g) Operator response: Was the operator aware that he had made an error? Was the error corrected?

(h) Error cause: What was the apparent cause of the error?

(i) Recommendations for reducing or eliminating the error: As a general guideline, situation-caused errors call for system redesign, human-caused errors for retraining.

24.3.2.1 The most common procedure for recording errors manually is to use an operating procedure as a sort of template. As the operator performs his tasks, the investigator checks off each action on the procedure. An action deviating from that specified in the procedure would be noted accordingly. With computer-based systems it is a relatively simple matter to record all operator inputs to the system and even, possibly, to indicate automatically where errors have been made. For further information consult Swain (1973) and Meister (1985).

25 Link Analysis

25.1 Purpose. The purpose of link analysis is, by portraying the frequency and nature of the interactions among system components, to provide a graphic aid for the layout of controls and displays on an equipment panel or console (see **14.1.2.3).** It also acts as an aid to arrange equipment in a facility or control room, that is, workspace layout (see clause **15).** Additional information on link analysis can be found in Part 4 of this Defence Standard.

25.2 Application. The aim is to redraw the workplace or control panel diagrams so as to reduce the number and length of the links and link crossings, which suggest 'activity' and 'confusion' and thereby produce a more efficient design arrangement. The data required for the analysis is:

(a) Information on flow requirements,

(b) Flow medium,

(c) Equipment/operator’s requirements,

(d) Functional allocation,

(e) Any special constraints.

26 Computerized Design Aids

26.1 Purpose. The purpose of computerized design aids is primarily to save time (but not necessarily data collection which may still have to be laboriously done by hand). Computerized design aids are more versatile and flexible than their manual counterparts enabling different design solutions to be examined easily, and aid conceptualization of the man-machine interface. Some computerized design aids, eg CAFES, incorporate function allocation and workload assessment programmes, in addition to the anthropometry/panel layout routines (see Meister (1985); p.105).

26.1.1 It should also be noted that computer technology offers another design aid, distinct from the design 'packages' as defined above, in the form of graphics facilities. That is, computer graphics in their drawing and manipulative modes can assist design work,in much the same way as an electronic calculator is a tool for mathematical calculations.

26.1.2 Human factors tasks are frequently too many to be completed manually in accordance with the system design programme. This results in either minimal consideration or heavy reliance on professional experience and judgement. Computerized design aids offer a means of making the human factors contribution to system design more effective (see also **4.4).**

26.2 Application. It is beyond the scope of this Part of the Defence Standard to include more than a cursory discussion of computerized design aids. Most of the available systems, with the exception of United Kingdom SAMMIE, (see Part 4 of this Defence Standard) have been developed by, or are under contract to, United States government establishments and are not commercially available. The major techniques are restricted to aircraft and automotive design. A comparison of the functional capabilities of the best known techniques is shown in table E.

26.2.1 It should be noted that most computerized design aids seem only able to evaluate pre-derived designs whilst some others, eg CAFES, can assist in producing design alternatives. For further information on computerized design techniques the reader is referred to Rothwell (1985) and Barfield and Salvendy (1984).

27 Mathematical Modelling Techniques

27.1 Purpose. The purpose of mathematical modelling techniques is to enable manipulation and studying of system parameters that would otherwise require the collection of operational data at great expense and time and more importantly at the possible risk of human life. It also allows one to study a system that may not as yet exist. Unlike computerized design aids (see clause **26)** mathematical modelling is used for evaluating and predicting operator performance and makes extensive use of psychological theory. Models of human performance can serve, ultimately, as an aid to the designer’s thinking about the problem being addressed. For example, they can form a basis for the extrapolation of information given, to draw new insights and new testable or observable inferences about system or component behaviour. Mathematical modelling of human performance also serves to improve the fidelity of overall system models where the system includes other non-human components. If human performance is a major factor in system effectiveness, then the better the human model, the better the system model. For further information consult Pew and Baron (1983).

Table E

Comparison Of Some Anthropometric Computerized Design Techniques (From Dooley (1982))

	BOEMAN	CYBERMAN	COMBIMAN	SAMMIE	BUFORD
Operator/System Communication	Vector graphics; dynamic display; batch input.	Vector graphics; static display; interactive system; partial batch input; prompt system.	Vector graphics; dynamic display; interactive system; partial batch input; prompt system.	Vector graphics; static display; interactive system; hidden line removal.	Vector graphics; static display; interactive system.
Data Files	50th-percentile 3-D human model, from Hertzberg, Dreyfus, and Dempster; A7-E cockpit model.	Any percentile 3-D human model from SAE 2-D Manikin and HEW 1960 census.	Any percentile 3-D human model using 1970 Army and 1967 USAF males survey; ATE cockpit model.	Any percentile 3-D human model using male and female Dreyfus survey.	50th-percentile 3-D human model from 1966 Dreyfus.
Model Construction	Batch input of environment, human models, and task sequences.	Environment constructed from separate systems; human model interactively constructed and manipulated.	Batch input of basic environment; interactive construction and manipulation of human and environment models.	Interactive construction and manipulation of human and environment models.	Interactive construction and manipulation of human and environment models.
Graphics Presentation	Operator-specified viewpoints of models.	36 standard operator eye locations; operator-defined distance.	Operator-specified viewpoints of models; entity labeling.	Operator-specified viewpoints of models.	Operator-specified viewpoints of models; entity labeling, dimensioning.
Human Model Reach and Clearance Analysis Capabilities	Body motions realistically constrained within accurate joint movements, lap and shoulder harness restraints; interference and collision detection and avoidance during task sequence runs; reach baskets defined.	Joint movements operator defined, spearation of body segment not allowed, clearances visually determined; swept areas, envelopes, or motion paths can be generated for graphic display.	Body motions realistically constrained within accurate joint movements, lap and shoulder harness restraints, flight suit and helmet; reach success/failure indication; clearance visually determined.	Body motions realistically constrained within accurate joint movements; reach success/failure indication (failure distance given); reach areas and volumes graphically depicted; clearance visually determined.	Joint movements operator defined; clearances visually determined; hard hat graphically depicted on model.
Human Model Visual Analysis Capabilities	Eyepoint graphically depicted on model; visual interferences identified.	Eyepoint graphically depicted on model.	Human model's line-of-sight azimuth and elevation angles on hardcopy; Aitoff projections available.	Human model's viewpoint available, with angular and/or length increments; generalized mirror views available.	None.
Sample Compatible Systems	Information unobtainable.	CDC 73 computers; Tektronix 4014 graphics terminal.	IBM 370, Model 155 computer; 2250 graphics display.	Prime 300/400 series, GEC 4070 series, or VAX minicomputers; Tektronix 4010 or 4014 storage or Imlac PD84 refresh graphics terminal or anything that can support GINO-F graphics package.	CV turnkey CAD/CAM system.
Link and Joint Parameters	23-joint figure with variable link lengths; 3-D outline of model.	15-link stick figure with or without complete wireframe outline—either representation can be graphically displayed.	35 internal link-skeletal system derived from 12 readily measurable anthropometric surface dimensions; fleshed out ellipsoids cover this link system and these ellipses are connected with tangent lines to define the contour of the model.	Total of 21 rigid links with 17 pin joints in total; 3-D flesh contours surround this model; variations in both percentile and flesh contours (thinness, muscularity, fatness) are allowable.	Each of the 15 links is a discrete entity; the enfleshment lines normally define a 50th-percentile man, but are scalable to any dimension.

27.2 Types of human performance models

27.2.1 General. It has been remarked that there are as many different types of models and modelling methodologies as there are inventive minds. Similarly, models of human performance have been categorized in numerous ways. The following types of human performance model are distinguished:

Task network models (see **27.2.2).**

Cognitive models (see **27.2.3).**

Control theory models (see **27.2.4).**

Search and detection models (see **27.2.5).**

27.2.2 Task network models. Task network models are those in which the subtasks comprising an operator's overall task are represented by a type of flow chart - a network - describing their logical interconnections and the sequences and loops in which they are performed. In addition, completion times, or a statistical distribution of completion times, together with probability of successful completion or reliability are specified. When all of the network elements and their interconnections have been described, initial conditions are selected and a stochastic (Monte Carlo) simulation is run to estimate the parameters relating to overall system performance.

27.2.2.1 The first and best known task network models of human performance were those of Siegel and Wolf (1969, 1979). The success of their approach stimulated the later development of a special purpose simulation language called Systems Analysis of Integrated Networks of Tasks (SAINT). For a brief review of SAINT consult Seifert (1979).

27.2.2.2 The advantages of network models are their intrinsic generality and their ability to be formulated at any desired level of detail. The disadvantages are that to apply the approach, it is necessary to analyze tasks into discrete elements having well-defined inputs and outputs; highly interacting elements can lead to a prohibitive level of complexity, but assuming the independence of task elements can lead to inaccurate results. Moreover, as in any other application the models are only as good as the data on which they are based.

27.2.3 Cognitive models. Cognitive models are of two types; information-processing models concerned with attention, perception and memory, eg Broadbent (1958), and problem solving models concerned with mental processes such as decision making and problem solving, eg Rouse (1983). The latter type of models have tended to concentrate on the fault diagnosis and system dynamics assessment behaviour of process control operators. The models have not been used very much in aid of system design and have been used primarily, if not exclusively, for research purposes.

27.2.4 Control theory models. Control theory models are concerned primarily with predicting total man-machine system performance as a means of analyzing and designing systems. The models include information processing algorithms but unlike cognitive models (see **27.2.3)** these are stated in terms relevant to the system context, so that the model can be used to compute system performance. That is, the human operator is viewed as an information processing and control/decision element of the system in a closed-loop fashion. Furthermore, trained operators are expected to exhibit many of the characteristics of a 'good' or even optimal inanimate system performing the same functions in the 'loop'. For more information see Rouse (1977).

27.2.4.1 Certain strengths and weaknesses characterize the control theory approach. These models are more quantitative than other types of model. Because of the explicit nature of their assumptions, inputs and outputs, they have been more thoroughly and carefully validated. Because human limitations are specified at the processing level rather than directly at the performance level, the models are typically general enough to predict performance in other control situations. The models, however, neither attempt to deal with discrete operator inputs, with monitoring or decision making, nor with procedural aspects of tasks which must be performed by the operator, eg communications, checklists. All of this makes it difficult to use this type of model to describe total job performance.

27.2.5 Search and detection models. These models are concerned with human performance - primarily visual but also auditory - at various search and detection tasks; eg monitoring displays, inspection, target surveillance. For further information and references consult Sinclair and Drury (1979).

27.3 Application

27.3.1 Model development

27.3.1.1 Selection of model type. The first question with which the model developer or user must concern himself involves the type of model required. Models may be controlled (driven) on the basis of tasks or events, or on the basis of time increments; performance may be represented functionally or it may be represented on the basis of psychological constructs.

27.3.1.2 Selection of variables. The true test of a model is its ability to assist in solving problems and not necessarily to describe the world in all its details. Since there are usually more variables than is feasible to use, the variables to be included in the model must be selected.

27.3.1.3 Data requirements. The ultimate success of a model depends on the availability and validity of its input data. A model may be acceptable in terms of its constructs (ie hypothetical entities such as 'short-term memory') but may be unusable because the input required for implementing these constructs are not available or fail to reach some necessary level of accuracy.

27.3.1.4 Model outputs. The model output and its interpretation present another consideration. Obviously, the user should be provided with the information he needs at the level of detail he wants and in a form he can use.

27.3.1.5 Validation. Model validation is one of the least understood and least accomplished aspects of model development. It has been remarked that the only possible evidence of validity for a simulation model is that it has made satisfactory predictions in the past.

27.3.2 Modelling disadvantages. Despite its obvious advantages, mathematical modelling can lead the designer astray in a number of ways. These pitfalls, listed in table F, vary from the obvious to the subtle and hidden, and should be carefully borne in mind.

Table F

Pitfalls of Mathematical Modelling
(From Sinclair and Drury (1979))

1. Models can be a poor fit to the human operator
2. Models can encourage inappropriate extrapolation
3. Models can adversely affect job design
4. Models can encourage oversimplified experiments
5. Customers may object to 'theoretical models'
6. Models may have their own internal problems
7. Modelling can be more fun than working

Section Five. Design Evaluation Techniques

28 Introduction

In Section Five of this Part of the Defence Standard various design evaluation techniques are presented. The techniques are not inclusive of all those possible, and to some extent are an arbitrary selection of evaluative methods, eg checklists, objective measurement, evaluative media (ie mock-ups, models, simulators) and evaluative applications (ie workload assessment).

With regard to subjective evaluation techniques, or methods, it is useful to consider the full range of techniques available and to provide some sort of classification of them (see table G). The techniques in table G marked with an asterisk are those included in this Part of the Defence Standard.

Table G

Taxonomy of Subjective Evaluation Techniques as a Function of the Source and Type of Assessment

<table>
<tr><th rowspan="2">SOURCE OF ASSESSMENT</th><th colspan="2">TYPE OF ASSESSMENT</th></tr>
<tr><th>STRUCTURED</th><th>UNSTRUCTURED</th></tr>
<tr><td>Individual Participant</td><td>Checklists.*
Questionnaires.*
Rating Scales.*
Formalized Psychological Procedures.
Peer Ratings.</td><td>Narratives.
Verbal Protocols.
Reviews.</td></tr>
<tr><td>Individual or Group of Participant(s)</td><td></td><td>Diaries.
Log Books.</td></tr>
<tr><td>Pair or Groups of Participant(s)/Others</td><td colspan="2">Interviews. *
Debriefings.
Discussions.</td></tr>
<tr><td>Individual or Group of Others</td><td colspan="2">Observations.*
Commentaries.
Informed Opinions.</td></tr>
<tr><td colspan="3">*See text</td></tr>
</table>

29 Checklists

Design evaluation by means of a checklist is an unsatisfactory technique because of its serious conceptual and technical deficiencies (see Meister (1984b; 1985)). Checklists should not be taken as a substitute for human factors expertise.

30 Mock-ups and Models

30.1 Mock-ups

30.1.1 Purpose. A mock-up serves a variety of purposes. By enhancing the conceptulization of the man-machine interface it can aid the evaluation of the system design (ie by allowing the designer to evaluate the arrangement of controls and displays, and their ease of operation and accessibility); it can assist room layouts; it can assist in design review; it can serve as a training aid. In fact, mock-ups can be used throughout the life-cycle of the system (see table H). It should also be mentioned that mock-ups serve a useful purpose of eliciting users' comments; that is, to obtain comments from existing system users on problems or advantages which they may foresee or on any factors which appear to have been either minimized or exaggerated.

Table H

Mock-up Applications in the System Procurement Cycle
(From Meister (1985): As Modified from Buchaca (1979))

SYSTEM PROCUREMENT PHASE	MOCK-UP APPLICATION
Feasibility	To develop and portray concepts of equipment configurations and room layouts. To document concepts with photographs of the mock-ups. To identify potential problem areas and additional study requirements.
Definition	To aid in the preliminary design of equipment operating and maintenance control panels. To aid in the identification of design requirements for ease of maintenance of equipment, for example, accessibility features, access covers, mounting hardware, test point locations, etc. To develop preliminary specifications for equipment operability and maintainability. To aid in design reviews. To document developed design for test and experimentation.
Full Development	To aid in detailed design of equipment panels, packaglng and mounting characteristics, room arrangement, cable and duct routing, and accessibility features. Design review and presentation vehicle. To aid in developing preliminary installation, operating, and maintenance procedures.
Production and In-Service	To refine installation procedures and to familiarize installation personnel with procedures. As a tool for configuration control (see Defence Standard 05-57). To familiarize operational and maintenance personnel with the system. As a training aid.

30.1.1 (Contd)

Mock-ups are so useful that all major system procurement efforts, and many minor ones, should construct them. The simplest mock-ups must be developed as early as possible to have the greatest value.

30.1.2 Method. The construction of a mock-up needs little explanation. It can be fabricated of materials such as wood, plywood, cardboard, plastic with adhesive tape, glue or screws; it can have fixed or removable equipment panel faces and either be a plain representation with bare surfaces, have paper drawings and photographs attached or be fitted with actual controls and displays to be in the equipment.

30.2 Models. A model, which can be defined as reduced-scale representation, is less useful than a mock-up because it can deal with fewer man-machine interface features. It does, however, have some uses and Buchaca (1979) lists preliminary room layout and equipment location studies, and aiding design reviews and presentations. Needless to say, models are simple, inexpensive, lightweight and portable. Models may also be used for the purpose of simulation, for example, in terrain model-boards for certain types of simulator, or as the 'picture-source' for image processing in a computer simulation.

31 Simulation and Simulators

31.1 Purpose. The purpose of simulation is to enable operator performance to be investigated, or operators trained, without having to use the real system (if it exists). As with mathematical modelling (see clause **27)** simulation allows system parameters to be manipulated and studied quicker and at far less of a cost than if using the operational system. In some circumstances simulation may be the only possible or practical means of investigating design problems.

31.2 Types of simulator. Two types of simulator can broadly be distinguished:

(a) Research simulator.

(b) Training simulator.

(a) In its purely physical manifestation the research simulator can be thought of as equivalent to the functional mock-up, that is, a mock-up (see **30.1)** with controls, displays and electronics that function in a similar manner to the real system. Although a research simulator could be used to train an operator, its distinguishing characteristic is that it is used to investigate aspects of operator performance, eg tracking, as part of an evaluation of the system design. The prime example of a research simulator is probably an aircraft cockpit simulator with which the design of new controls and displays, eg multifunction display, head-up display, are evaluated. Research simulators may also be non-physical representations, that is, existing in the form of computer software.

31.2 (Contd)

(b) The training simulator, as its name implies, is one that is employed specifically for the purpose of training. There are many different types of training simulators such as, for example, weapon trainers (small arms and gunnery), operational control room and command and control simulators, and flight simulators. Typically the training simulator is an exact replica of the real system, but part-task trainers are also available which simulate one element of the task/system. As with research simulators, the training simulator can be synthetic. In fact, given the trend towards computer simulation there may eventually be no need for a three-dimensional representation of the task.

31.3 Simulator fidelity. Simulator fidelity is the degree to which the characteristics of the simulator match, both objectively and subjectively, those of the real system. Thus, objective fidelity is the degree to which, from an engineering viewpoint, measurements show it to resemble physically, dynamically, and operationally its real-life counterpart. Subjective fidelity is the degree to which, from the trainee’s viewpoint, the simulator is perceived to look, feel, function and to be used as its real-life counterpart. Fidelity is not a concept that may be discussed in isolation but rather as a function of the total training context, ie the stage of learning of the trainees, individual differences (trainees' abilities) and the type of task to be trained.

31.4 Simulator design. The design of a simulator should follow the same basic procedure as outlined for developing the overall system (see **6.1** and **16.2.1).** Such a procedure has been propounded (AGARD (1980)) and, modified for the purpose of this Part of the Defence Standard, consisting of the following steps:

(a) Analyze the training task, detail training requirements, objectives and evaluation criteria.

(b) Identify the levels of skill, knowledge and experience possessed by the instructional staffs who will operate the simulator.

(c) Define methods and facilities to perform the training, specifically:

i define the physical and functional cues experienced by the operator, eg pilot, while performing the task being trained, eg flying the aircraft;

ii define the functional cues needed to train;

iii define the hardware and software needed to provide the training cues.

(d) Develop simulator hardware and software.

(e) Validate the simulator. This is a complex multi-step process involving the following:

i perform objective tests against the hardware and software specifications (ie (b) above);

ii perform training effectiveness tests;

31.4 (Contd)

iii rework steps (a) through (e) until satisfactory transfer of training is achieved or alternative methods and/or facilities are resorted to.

Additional information on the design of simulators can be found in Cream, Eggemeier and Klein (1978).

32 Observation

32.1 Purpose. The purpose of observation is to obtain data, either quantitative or qualitative (ie respectively measuring or describing performance), on operator/team performance. Direct observation is useful in situations in which operators are free to vary their responses in many ways with few or no constraints imposed by an investigator. Observation is one of the most common methods of evaluating personnel and system performance and it is used in one form or another in almost every test and evaluation.

32.2 Method. The major steps for conducting observation are, based on Chapanis (1959), as follows:

(a) Decide what activity to observe, ie consider what categories of tasks or activities to observe, and to what level of detail. To a large extent, the answer to this question is determined by the purpose of the analysis and what the investigator hopes to find out. It is implicit that the investigator is fully familiarized with the operator’s tasks.

The categories should cover all of the activities that the operator engages in or else meaningful percentages cannot be calculated. The categories should be observable behaviour (ie should not include such things as 'thinking') and to be practicable, number no more than 25 different activities. The important thing is to have a clear-cut definition of each activity so that the operator’s behaviour can be classified with no ambiguity. In short, to avoid ending up with an excessive amount of data it is well worth the observer spending some time thinking about what it is he wants to observe and why, before he starts the observations. For information on behavioral taxonomies consult Fleishman and Quaintance (1984).

(b) Decide how each activity is to be observed. That is, the investigator has to decide whether he wishes to observe a live performance (ie observe activity directly as it occurs) or a film/videotape recording; the choice will depend on (a). It should be noted that if the latter is chosen the caveat to decide exactly what to observe still applies.

(c) Decide on a sampling strategy. That is, the investigator has to decide upon a sampling interval and a sampling duration. The sampling interval is the time between successive observations, which should be no shorter than about two seconds without the assistance of film/videotape recordings. The sampling duration is the total duration over which observations will be made.

32.2 (Contd)

With regard to the number of observations, Chapanis (op. cit) recommends that 1000 observations should be the minimum number collected so as to ensure valid and reliable data. There is an interaction between the sampling rate (reciprocal of sampling interval) and the sampling duration. That is, if the sampling interval is five seconds then the sampling rate is 12 per minute and the sampling duration should be 83 minutes. The sampling procedure will, obviously, depend on the particular system and the nature of the tasks being observed.

(d) Select a representative sample of personnel. People differ in the way they carry out the same task, and if the observation data are to be useful the investigator should, where appropriate, study several operators. Moreover, he should assure himself that the operators he has selected for study are representative, or typical, of the operators who normally carry out these tasks.

(e) Select a representative sample of tasks and jobs. Although it is readily recognized that there are large individual differences between operators in the way they do things, the problem of job sampling is often overlooked. Unless the observations made will be used only for making general statements about one particular system, eg a particular aircraft, the investigator should be sure to take measurements on a representative sample of equipment, jobs, or installations.

(f) Prepare data sheet and record observations. An example of a data, or log sheet is shown in figure 8. The data can then be analyzed to estimate the percentage of the operator’s total time spent in various activities, the average length of time spent in each activity and, if recorded, the sequence in which the operator performs various parts of his job.

32.3 Critical Incident Techniques. The Critical Incident Techniques (CIT) consist of a set of procedures for collecting direct observations of human behaviour and making systematic analysis of the causes of good and poor performance. The CIT, as described by Flanagan (1954), consists of five main steps, they are:

(a) Establish general aims of the activity. This should be a brief statement which expresses in simple terms those objectives to which most people would agree.

(b) Develop plans and specifications for data collections. Precise instructions to the observers must be given. These instructions need to be as specific as possible with respect to the standard used in evaluating and classifying the behaviour observed. The studied group also need to be specified.

(c) Collect the data. The incident may be reported in an interview or written up by the observer. In either case it is essential that reporting is objective and includes all relevant details.

32.3 (Contd)

Activity: First Navigator - DC-6B			
Operator: J. Hodgkins		Recorder: G. Wendell	
Time: 0130	Date: 9/7/57	Sampling interval: 5 Sec.	
Flight: Reconnaissance squadron A/C No. 456-F			
Remarks: Departed Juneau, Alaska, 0055. Weather cloudy. Enroute to Los Angeles.			

Activity	Tally	Sum	% of Grand Total
Log work	卌 卌 卌 卌 卌 卌 卌 卌	40	16.7 %
Interphone	卌 卌 卌 卌 卌 卌 卌 //	37	15.4 %
Chart work	卌 卌 卌 卌 卌 卌 卌 /	36	15.0 %
Inactive	卌 卌 卌 卌 卌 ///	28	11.7 %
Transition	卌 卌 卌 卌 卌 /	26	10.8 %
Sextant work	卌 卌 卌 ///	18	7.5 %
Eating	卌 卌 ///	13	5.4 %
E-6B computer	卌 ////	9	3.8 %
Map reading	卌 ////	9	3.8 %
Astrocompass	卌	5	2.1 %
Auxiliary radar	////	4	1.7 %
Radio	///	3	1.2 %
Altimeter	//	2	0.8 %
Drift reading	/	1	0.4 %
Other activity	卌 ////	9	3.8 %
Grand total		240	100.1 %

Fig 8
Sample observation Data Sheet
(From Chapanis (1959))

(d) Analyze the data. The purpose of the data analysis is to summarize and describe the data in an efficient manner for effective use in various practical purposes.

(e) Interpret and report. The requirements of each activity as obtained above need interpretation for proper use. Each of the four preceding steps should be examined to see what biases, if any, have been introduced by the procedures adopted and reported clearly.

The CIT is essentially a procedure for gathering important facts concerning behaviour in defined situations. It should be emphasized that the CIT does not consist of a single, rigid set of rules governing such data collection. Rather it should be thought of as a flexible set of principles which should be modified and adapted to meet the specific situation at hand.

32.4 Observer variance. When several observers are used in gathering subjective data it is essential that the (inevitable) variance and unreliability in the data reporting between observers is minimized. There are various techniques for overcoming this problem, for example, preliminary training; practice and rehearsal to identify and remove anomalies between individuals; the independent assessment of the same material by different observers. If these steps fail to produce satisfactory agreement then, ultimately, limitations on the data have to be accepted. The designer should note that in certain cases it is better to discard the data altogether if, because of observer differences, it proves impossible to achieve reasonable reliability.

33 Interviews and Questionnaires

33.1 General. Interviews and questionnaires are both similar and related measurement techniques for gathering information from a person or persons. Because their contents change from one situation to another, both the interview and questionnaire are general methods rather than fixed procedures. The generally formless and verbal nature of the interview makes it particularly awkward to describe. It is, nevertheless, possible to specify guidelines for conducting interviews and for developing and administering questionnaires (see **33.2** and **33.3).** Since self-reporting techniques are the only way of tapping mental processes, the techniques are indispensable. Rating scales, which are used for both interviews and questionnaires and are the most frequently employed subjective measurement tool, are treated separately (see **33.4).**

33.2 Interviews

33.2.1 Degree of structure. Interviews can be structured (ie standardized or formalized) to varying degrees. In a structured interview the interviewer asks a predetermined list of questions in a set order. In fact, a highly structured interview, as might be used for a survey, is little different from a questionnaire except that it is oral. The advantages of a structured interview are that all the topics of interest are covered and digression is minimized. In addition, the interviewer requires only moderate skill and proficiency. The disadvantage is that important information may be missed because the subject is not given an adequate opportunity to speak. In a semi-structured interview the interviewer follows a predetermined list of questions but allows himself the opportunity to quiz the subject more closely if his responses are inadequate, and also pursue other problem areas which may arise during the interview. More skill by the interviewer is therefore required. The subject is also allowed to expand on topics of personal interest. According to Meister (1985), the semi-structured investigation interview is almost always preferable to a questionnaire when the test group is small (ie 10-20) and when time and test conditions permit. In the unstructured or 'non-directive' interview the freedom permitted to the interviewer is both the major advantage and the disadvantage of interviews of this type. As a measurement device such an interview procedure is inadequate, because its flexibility results in lack of comparability of one interview with another. According to Kidder (1981) this type of interview achieves its purpose to the extent that the interviewer’s responses are spontaneous rather than forced, are highly specific and concrete rather than diffuse and general, and self-revealing and personal rather than superficial.

33.2.2 Implementation. Interviews should be conducted in a fairly quiet place free from any interruptions or distractions. When the performance being evaluated is that of a team, the interview should be conducted with the team as a group. The most convenient way of conducting an interview is to tape record it, but if it is a short one, or the interviewer is highly skilled, it may suffice to take notes. The duration of the interview will depend on how much the subject(s) can tell the interviewer. Twenty minutes is estimated as a good average length; whereas beyond 30 minutes the subject tends to become tired. Interviews play an important role in problem and accident investigation (see **18.3).**

33.3 Questionnaires

33.3.1 Questionnaire development

33.3.1.1 Purpose of questionnaire. The first step in developing a questionnaire is to determine what kinds of information are desired, eg general views and opinions, anecdotal and critical incident information, or quantitative data. It is implicit that the investigator responsible for developing the questionnaire is familiar with the system or the operations to be queried. If not, it may be necessary to interview operational personnel so as to assist in determining the content of the questionnaire.

33.3.1.2 Types of questions. Questionnaire items are of two basic types: 'open-ended' questions (subjects compose their own answers) and 'closed' questions (subjects choose an answer from a given set). The former type of question, an example of which might be 'Describe any problems you have experienced in operating this control console', allows the subject to express himself and may provide unexpected, new information. However, open-ended questions are frequently an inefficient means of obtaining information, the results are more difficult to analyze and, in general, are best avoided, see Meister (1985). Closed questions are typically multiple-choice and rating scales (see **33.4).** Multiple-choice questions, as the name implies, asks the subject to choose his answer from several options, usually by ticking or circling the appropriate item. If it is known or suspected that subjects do not have the background or experience necessary to answer a question, a 'don't know' response alternative should be included. Multiple-choice questions are also known as 'forced-choice' since the subject is expected to choose one, or sometimes more than one, of the response alternatives. If, however, a multiple-choice question includes a 'don't know' option, the compulsion to respond is almost totally removed.

33.3.1.3 Wording of questions. The wording of questions in the questionnaire is very important to ensure valid and reliable responses. The questions and response alternatives should be worded clearly and unambiguously. It should not be necessary for the person answering the questionnaire to infer anything essential. All of the questionnaire items should be expressed as neutrally as possible and should be grammatically and factually correct. It has to be stressed that if there are two issues, two questions should be asked. That is, each question should always address a single issue and questions should never be combined.

33.3.2 Questionnaire administration. Questionnaire pretesting, or 'piloting', is essential if faults are to be discovered and remedied. It is here that the last chance occurs in discovering the fallacies and unnoticed assumptions in one’s thinking. Pretest subjects who appear to be representative of eventual respondents should be tested one at a time. During pretesting the subjects should be encouraged to make marginal notes on the questionnaire regarding sentence structure, unclear questions, or statements, etc. Open-ended questions may, and often should, be included in early pretest versions of a questionnaire in order to identify requirements for additional questions. After pretesting, each question should be reviewed and its inclusion in the questionnaire justified. If a high proportion of respondents give a 'don't know' response, it should alert the developer that he has problems with his questionnaire. In addition, questions that do not add significant information or that largely duplicate other questions can profitably be eliminated. The time required to administer the final questionnaire can be determined by pretesting. For further information on questionnaires consult Meister (1985) and Sinclair (1975).

33.4 Psychometric scaling

33.4.1 Purpose. The purpose of scaling is to allow numbers to substitute for the objects or events in question. Having done so, it is possible to derive additional relationships by performing mathematical operations on those numbers.

Rating scales, in particular, are employed for a variety of purposes, as described by Meister (1985).

(a) To evaluate how well someone is performing a job (appraisal) or to determine someone’s suitability to perform that job (selection).

(b) To measure some quality of performance, eg coordination of team members, or an attitude/trait of the operator.

(c) To quantify the adequacy of some feature of a system, eg its displays or job procedures.

(d) To evaluate the effect of some condition, eg visibility, on performance, eg target detection.

33.4.2 Application

33.4.2.1 General. There are several different scaling methods, such as scaling by paired comparisons, ranking, sorting, and scaling by rating. The use of rating scales is by far the most frequently employed subjective measurement tool. This Part of the Defence Standard considers only a small aspect of this complex topic. Many varieties of rating scale have been developed but essentially they take one of two forms, namely, the analogue rating scale and the category rating scale, see Oborne (1976). The use of the former is not recommended. Almost anything can be rated. All one needs is paper and pencil and the subject himself is the means of measurement (see also clause **35).**

33.4.2.2 Category rating scale. This type of rating scale consists of a straight line with, usually, five, seven or nine equal divisions along which a series of adjectives (with or without a number) which describe the stimulus attribute are positioned. An example of a category rating scale for measuring thermal sensation is shown in figure 9. This type of scale, known popularly as the Likert-type scale, is the one most practitioners are familiar with. It should be noted that the ordinal character of the rating scale implies that the intervals represent equal orders of magnitude of some stimulus quantity (ie the difference between 'cool' and 'slightly cool' is the same as the difference between 'warm' and 'hot'). This is not necessarily true unless it has been experimentally and statistically verified. Valid and reliable scales require careful development.

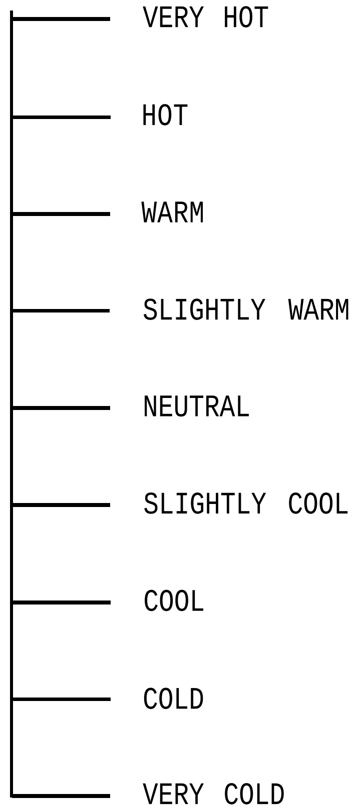


Fig 9
Thermal Sensation Rating Scale
(After ASHRAE (1985))

34 Objective Measurement

34.1 Purpose. The purpose of objective measurement is to obtain quantitative data on operator/crew performance but without the extreme subjectivity of observation and judgement (see clauses **29, 32** and **33)** as this leads to questions of validity and reliability. Objective measurements are somewhat limited because they measure only relatively simple (although fundamental) dimensions and they often provide much less information than subjective measures. What makes a measurement objective is the absence of the investigator's interpretation required in recording the datum. With computer-based systems data can be recorded automatically thus ensuring objectivity.

34.2 Types of objective measures

34.2.1 General. In a system of any reasonable size the number of performance outputs that could be measured is immense (see table L). However, when considered in terms of their similarity they reduce to a few generic measures (ie time, frequency, accuracy and quantity).

34.2.2 Time. Reaction time is the time between the occurrence of an event requiring action on the part of the operator or team, and the start of that action, eg pressing a button in response to a warning light. If the operator’s reaction time is very short, there may be difficulty accomplishing the task. If reaction time is delayed, system performance may be affected. Unless there is a system or job requirement requiring the operator to make a quick reaction, time will mean very little. Therefore before selecting this measure the investigator should check that the information is necessary. Time taken (ie the duration of the initiating stimulus to the time the task is accomplished) is an extremely common measurement, eg Into-Action deployment time. Normally, it does not have to be very precise unless there is a system requirement which necessitates it.

34.2.3 Frequency. Frequency is simply the tabulation of either personnel actions or events/outputs occurring as a result of personnel actions as a function of time. For example, the adequacy of a control panel recording layout can be evaluated by recording the frequency that certain controls are operated. A special case of frequency is what may be termed logistics measures - amount achieved or consumed (see table J). Examples of logistics measures can be seen in military aircraft situations where the frequency measurement is the number of sorties flown or bomb tonnage dropped. Such measures are not only concerned directly with personnel performance but also with events related to and reflecting personnel performance.

Table J

Classification Of Generic Objective Performance Measures (From Meister (1985))

Time

1. Reaction time, i.e. time to

    a. perceive event;
    b. initiate movement;
    c. initiate correction;
    d. initiate activity following completion of prior activity;
    e. detect trend of multiple related events.

2. Time to complete an activity already in process, i.e. time to

    a. identify stimulus (discrimination time);
    b. complete message, decision control adjustment;
    c. reach criterion value.

3. Overall (duration) time

    a. time spent in activity
    b. per cent time on target.

4. Time sharing among events

Accuracy

1. Correctness of observation. i.e. accuracy in

    a. identifylng stimuli internal to System:
    b. identiying stimuli external to system;
    c. estimating distance, direction speed, time;
    d. detection of stimulus change over time;
    e. detection of trend based on multiple related events;
    f. recognition: signal in noise;
    g. recognition: out-of-tolerance condition.

2. Response-output correctness, i.e. accuracy in

    a. control positioning or tool usage;
    b. reading displays;
    c. symbol usage, declslon making and computing;
    d. response selection among alternatives;
    e. serial response;
    f. tracking;
    g. communicating.

3. Error characteristics.

    a. amplitude measures;
    b. frequency measures;
    c. content analysls;
    d. change over time.

Frequency of Occurrence

1. Number of responses per unit, activity, or interval.

    a. control and manipulation responses;
    b. communications
    c. personnel interactions;
    d. diagnostic checks.

2. Number of performance consequences per activity, unit, or interval.

    a. number of errors;
    b. number of out-of-tolerance conditions.

3. Number of observing or data gathering responses.

    a. observations;
    b. verbal or written reports;
    c. requests for information.

Amount Achieved or Accomplished

1. Response magnitude or quantity achieved.

    a. degree of success;
    b. percentage of activities accomplished;
    c. measures of achieved reliability (numerical reliability estimates);
    d. measures of achieved maintainablllty;
    e. equipment failure rate (mean time between failure);
    f. cumulative response output;
    g. proficiency test scores (written).

2. Magnitude achieved.

    a. terminal or steady-state value eg temperature high point;
    b. changing value or rate eg degrees change per hour.

Consumption or Quantity Used

1. Resources consumed per activity.

    a. fuel/energy conservation;
    b. units consumed In activity accomplishment.

2. Resources consumsed by time.

    a. rate of consumption.

Physiological and BehavIoural State

1. Operator/crew condition

    a. physiological;
    b. behavioural.

34.2.4 Error. Error, as distinct from inaccuracy, is probably the most common and perhaps the most useful measure of personnel performance. In the operational environment error data are important primarily for diagnosis of a problem. An excess of errors may indicate a design, procedural, training or workload problem. In the design environment the error is primarily useful as indicating a potential problem which may need remedying (see 24.3). Errors are not, of course, all equivalent. Some errors have potentially significant or catastrophic effects on the accomplishment of a task or function, others do not. For example, an error in performing a continuous task such as tracking may be much more significant for performance than one in a discrete task like operating a switch, where the error is more visible and can more readily be reversed. Error data are usually meaningful only as a whole except in the case of specific catastrophic errors, only in terms of how the system is affected by error) or in relationship to the number of opportunities to make the errors.

34.3 Application. Objective measurement is especially suited to the measurement of task and job performance as opposed to non-task behaviours, attitudes and traits. The task/job performances must be overt since cognitive and most perceptual activities are not accessible for observation or instrumentation. In many cases the only objective, observable measures in performance are time and errors. The measurement of reaction time and duration is straightforward and requires no explanation. Frequency is easy to secure, provided one can arrange personnel actions on some sort of chronological basis. Before counting frequencies, some relevant taxonomy of categories of behaviour needs to be developed, see Fleishman and Quaintance (1984).

35 Workload Assessment

35.1 Purpose. The purpose of measuring workload is, primarily, to determine the operator is neither being overloaded nor underloaded, both states which might affect his performance adversely. The purpose of measuring workload is also, as far as possible, to validate workload predictions. Workload can be viewed in several ways. Firstly, one can view workload as some feature of the system that 'loads' the operator and either forces him to work harder or remain too inactive; secondly, as the operator’s feelings of difficulty and discomfort ('stress') and having either to work harder or cope with boredom; thirdly, as the effect of the latter two that affect the operator’s performance and possibly system performance as well.

35.2 Method

35.2.1 General. The different methods of workload measurement are categorized as physiological, objective and subjective. For further information consult Wierwille and Williges (1979) and Moray (1984), or contact a human factors specialist.

Section Six. Experimentation

36 Experiments

For information consult Kirk (1968) and Keppel and Saufley (1980). The designer should note that if he is in any doubt as to how to design and conduct an experiment he must consult a human factors or experimental psychology practitioner.

37 Statistics

37.1 Purpose. The purpose of statistics is twofold. Firstly, it is to present information in a convenient usable and understandable form (descriptive statistics); secondly, it is to generalize this information and draw inferences about the numerical properties of 'populations' (inferential or inductive statistics). Basic to all experimentation (see clause **36)** is a working knowledge of statistics.

37.2 Method. Statistical methods are as follows:

(a) Descriptive statistics. The methods employed are frequency distributions, graphing techniques, percentiles, measures of central tendency (mean, median, mode, etc), measures of dispersion (range, standard deviation, etc) and correlation techniques.

(b) Inferential statistics. These are of two basic types: parametric and non-parametric. Parametric tests of significance involve assumptions about the nature of the distributions of the variables in the populations from which the samples are drawn (the t-test and analysis of variance, for example, assume normally distributed data). Non-parametric statistics, in contrast, make few assumptions about the population distribution, and hence are known alternatively as 'distribution-free' tests. Many non-parametric tests, eg Mann-Whitney U-test, are based on a simple ranking of the data.

With regard to choosing a statistical test, when large populations are employed the parametric tests are almost always appropriate because of the 'central-limit theorem'. For small samples a non-parametric test may well be as powerful as its parametric counterpart and indeed if there is doubt concerning the population’s distribution, more appropriate. Whatever test is chosen it should be specified in advance of the collection of the data. For further information, consult Ferguson (1981) and Siegel (1956).

Definitions

Definitions of terms appropriate to (Def Stan 00-25 Part 12) Human Factors for Designers of Equipment: Systems are shown below.

A.1 For the purpose of this Part of the Defence Standard the following definitions apply:

A.1.1 Design team. A multi-disciplinary group of individuals concerned with, and responsible for, all aspects of the design of the system including human factors.

A.1.2 Designer. A member of the design team.

A.1.3 Duty. A set of operationally related tasks within a given job. These may involve operating, maintaining, supervising and training, etc. Duties might be divided into 'primary' and 'secondary' duties.

A.1.4 Front-end analysis. Collective term for those analyses conducted at the earliest stages of system design and concerned with a system’s personnel, training and logistics requirements.

A.1.5 Job. A grouping of duties and responsibilities constituting the principal work assignment of one person. In the broadest sense, one’s job is the totality of one’s role in an organization or system, including one’s career path.

A.1.6 Man-machine interface. The controls and displays which an operator uses to control, monitor, or otherwise interact with, the system.

A.1.7 Methodology. An integrated and coherent set of methods (notations and techniques) and rules applicable to the overall design goal, eg human factors methodology.

A.1.8 System. A purposeful organization of equipment (hardware and software), personnel and procedures all of which interact and thus influence each other to produce some specified result or goal.

A.1.9 Systems analysis. A generic term for the various human factor techniques applied before or during the system planning stage, eg systems requirements analysis, function analysis, etc.

A.1.10 Systems engineer. A member of the design team responsible for interpreting and translating system requirements into system performance, design, and production specifications, and ensuring that all aspects of the system are integrated properly.

A.1.11 Task. A set of related functions performed by one or more individuals and directed towards accomplishing a specific functional objective and, ultimately, to the output goal of a system.

A.1.12 System requirements analysis. An analysis of what is required of the system. System objectives are those characteristics which the system (both personnel and equipment) must exhibit so as to satisfy the purposes of the system.

A.1.13 Function analysis. An analysis of system functions. Functions describe relatively broad activities which may be implemented by personnel alone (deploy equipment), by equipment alone (self-test/equipment circuitry), or, as in most cases, by some combination of both (pre-flight checks). Functions can be instantaneous (fire missile) or prolonged (monitor radar), simple (start engines) or complex (assess tactical situation). At a certain level of detail, functions become indistinguishable from tasks; there are no clear-cut rules for making the distinction.

A.1.14 Allocation of functions. The process of deciding how system functions shall be implemented - by human, by equipment (automation) or by both - and assigning them accordingly. It is the most basic of system design decisions since it establishes the framework within which the design of the system (equipment, workspace, training, etc) is developed.

A.1.15 Task synthesis. The process of creating or putting together - hence 'synthesis' - the tasks (see **A.1.11)** of which a system function consists.

A.1.16 Task description. A listing of tasks, usually in tabular form, arising from the results of a system description/analysis. It should not be confused with task analysis (see **A.1.17).**

A.1.17 Task analysis. A process for analyzing the behavioral implications of operator tasks and identifying any resulting constraints and requirements on the system configuration. It should not be confused with Task Description.

A.1.18 Equipment (hardware) design. The application of human factors 'engineering' principles (ie the other Parts of this Defence Standard) to the design of system equipment.

A.1.19 Equipment (software) design. The application of human factors to the design of the information displayed by, and the style of interaction with, computer-based systems. In other words, it refers to the design of the 'human-computer interface' as it relates to computer software (but excluding programme coding).

A.1.20 Link analysis. Link analysis is a diagrammatic technique for representing the physical interactions between operator(s) and equipment, operator-to-operator, and between equipments.

A.1.21 Mock-ups. A mock-up is a three-dimensional, full-scale replica of the physical characteristics of a system or subsystem (of model). A mock-up can be developed only after equipment drawings are produced, although these drawings may be only preliminary ones.

A.1.22 Psychometric scaling. Psychometric scaling is the process of assigning numbers to objects, events or properties in such a way that the numbers represent relationships among scaled entities.

Related Documents

The documents referred to in this Part of the Standard, together with additional publications providing greater coverage on special aspects of the subject are listed below.

B.1 The following documents and publications are referred to in this Part of the Standard.

Def Stan 00-25	Part 1 -	Introduction
	Part 2 -	Body Size
	Part 3 -	Body Strength and Stamina
	Part 4 -	Design of Workspace
	Part 5 -	The Physical Environment: Stresses and Hazards
	Part 7 -	Visual Displays
	Part 8 -	Auditory Information
	Part 10 -	Controls
	Part 11 -	Designs for Maintainability
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MOD/DTI	Human Factors Guidelines for the Design of Computer Based Systems	
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B.1.1 Reference in this Part of the 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.

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The following Defence Standard file reference relates to the work on this Standard - D/D Stan/328/l/12(Stan 6d).

Contract Requirements

When Defence Standards are incorporated into contract users are responsible for their correct application and for complying with contract requirements.

Revision of Defence Standard

Defence Standards are revised when necessary by the issue either of amendments or of revised editions. It is important that users of Defence Standards should ascertain that they are in possession of the latest amendments or editions. Information on all Defence Standards is contained in Def Stan 00-00 (Part 3) Section 4, Index of Standards for Defence Procurement - Defence Standards Index published annually and supplemented periodically by Standards in Defence News. Any person who, when making use of a Defence Standard encounters an inaccuracy or ambiguity is requested to notify the Directorate of Standardization without delay in order that the matter may be investigated and appropriate action taken.

DIRECTORATE OF STANDARDIZATION
MINISTRY OF DEFENCE
Room
KENTIGERN HOUSE 65 BROWN STREET GLASGOW G2 8EX

Telephone: 041 248 7890 Ext

Your reference

Our reference
D/D Stan 328/01/12
Date
May 1989

INTERIM DEFENCE STANDARD IMPROVEMENT PROPOSAL

Defence Standard No: 00-25 (Part 12)/1

Title: Human Factors for Designers of Equipment
Part 12 Systems

The above Defence Standard has been published as an INTERIM Standard and is provisional because it has not been agreed by all authorities concerned with its use. It shall be applied to obtain information and experience on its application which will then permit the submission of observations and comments from users.

The purpose of this form therefore is to solicit any beneficial and constructive comment that will assist the author and/or committee to review the INTERIM Standard prior to it being converted to a normal Standard.

Comments are to be entered below and any additional pertinent data which may also be of use in improving the Standard should be attached to this form and returned to the Directorate of Standardization at the above address. No acknowledgement will normally be sent.

NAME C D KILLBOURN SIGNATURE C D Killbourn BRANCH: STAN 6d

1. Has any part of the Standard created problems or required interpretation during use:

❑ **YES** ❑ **NO** **if 'yes' state,**

a. **clause number/s and wording:**

b. **recommendation for correcting the deficiencies:**

2. Comments on any requirement considered too rigid:

Continued over

D Stan Form No 22

3. Is the Defence Standard restrictive:

☐ YES ☐ NO (if 'yes' in what way)

4. General comment:

5. We agree that this INTERIM Standard (subject to amendments to take account of our comments) when published in final form will cover our requirements. Should you find our comments at variance with the majority, we shall be glad of the opportunity to enlarge upon them before final publication.

Signature . . . . Reptesenting . . . .

Submitted by (print or type name and address):	Telephone number:
	Date:
	Our Ref: