Cognitive Task Analysis:
Current use and practice in the UK Armed Forces and elsewhere

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Reference HFIDTC/WP2.3.1/1

Version 1

Date .... 23rd January 2005

The work described in this document has been undertaken by the Human Factors Integration Defence Technology Centre, part funded by the Human Sciences Domain of the U.K. Ministry of Defence Scientific Research Programme.

Contents

Abstract

This report is concerned with Cognitive Task Analysis (CTA). It covers the origins, growth, and diversity of CTA as an activity, current practice in the UK Armed Forces and civilian operations, reviews an extensive range of archive material and draws a number of conclusions as to the best practice. It reveals that there is no consistent use of CTA in the Armed Forces. Recommendations are made as to how CTA techniques could be implemented so as to benefit UK MoD with regard to both training and procurement.

1 Introduction

1.1 Origins of Cognitive Task Analysis

Cognitive Task Analysis (CTA) can be defined as any method of Task Analysis (TA) that investigates the task requirements associated with the use and handling of knowledge. These task requirements and activities may or may not be observable, thus differentiating CTA from many traditional forms of TA, but they are all associated with the maintenance of the work aim and the achievement of mission goals.

The development of CTA practice will be discussed later in this report with regard to its usage both in the military and elsewhere. Firstly, it is necessary to consider the purpose of CTA and the way in which the term came into use. Whilst the need for CTA will become apparent it will be seen that there is a general lack of a clear understanding in the workplace as to the specific meaning or forms of CTA.

While such commentators as Schraagen (2000) have traced the development process for CTA back to the 1950s, and even before, it can be argued that the expression “Cognitive Task Analysis” started to come into general use in the 1980s. In this decade, many areas, both of psychology and systems work, began to use the prefix “Cognitive”. Thus, as well as Cognitive Psychology, there was Cognitive Social Psychology, Cognitive Developmental Psychology, Cognitive Systems Engineering, Cognitive Ergonomics, and some of the therapeutic techniques also acquired the “Cognitive” prefix. In the area of work, this can be seen as an acceptance of the worker as having a cognitive input into the performance of his/her task, and of the effects of inappropriate cognitive inputs or processes on that performance.

From the “Taylorism” of the early 1900s, and through the “Hawthorne Studies” of the late 1920s and 1930s (Roethlisberger and Dixon, 1939), organizations have sought to improve the efficiency of their operations.

> *“…use of complex and tightly coupled technological systems in the workplace is rapidly increasing, as companies seek to make performance and efficiency gains and edge out the competition”*
>
> (Rasmussen, 1999).

Traditionally, the same methods of Task Analysis (TA) have been used for all types of jobs and activities. In the 1950s, the focus of the psychological study of work began to move away from manual to mental activities, as for the first time the number of white-collar workers exceeded blue-collar workers (Schraagen, 2000). It was necessary for psychologists to develop new techniques to match this shift; whilst traditional Task Analysis (TA) outputs were sufficient when a step-by-step description of observable behaviour was sought, they were generally inadequate when studying the cognitive processes involved in mental tasks.

Different approaches to the problem of studying cognition at work were taken over the next 30 years, with varying degrees of success. These approaches included computational modelling, hierarchical task analysis, expert-novice performance and system design (Schraagen, Chipman and Shalin, 2000). It should be noted that only a decade ago, Merkelbach and Schraagen (1994) identified 20 approaches to CTA; just 6 years later, Schraagen could refer to over 100 (Schraagen, 2000). However, many of the approaches deemed to be CTA had been previously termed as task analysis or knowledge elicitation methods and had changed little since their conception.

In military tactical work, the tasks performed can be predominately non-procedural being strongly influenced by environmental artefacts. Also, technology is initiating change in the nature of many areas of work from the physical to the cognitive. Thus, many modern systems function at the limits of their operators, in terms of the demands placed upon their cognitive resources. Moreover, the consequences of operator error when using such systems can be disastrous. System designers require an understanding of the role of mental processes and cognition in the performance of work activities, in order to allocate tasks, develop interventions and training procedures, and evaluate operator competence and performance.

Cascio (1995) noted a change in the consideration of work from task-based to a more process-based approach. As more and more jobs are involved in management, supervision, and trouble shooting with systems, so cognitive approaches to the understanding of work become more appropriate to identify the tactics and strategies needed for effective performance. Additionally, the consideration of teamwork both within and between teams has become more important as technology has allowed improved and faster communication worldwide.

Furthermore, many researchers are involved in the study of competency as an important contributor to performance, whether related to the individual or the team (Cannon-Bowers, Tannenbaum, Salas, and Volpe, 1995). The study and understanding of competencies shares a common ground with the traditional analysis of Knowledge, Skills, and Abilities (KSA). However the understanding of competence involves a consideration of a greater range of skills than traditional KSAs afford. Thus, whilst the knowledge component is similar, there is a need to also focus on other relevant areas, such as Attitudes, as contributors to performance.

Many separate research efforts have led to the development of a number of TA techniques, that aim to assist Human Factors (HF) practitioners in the analysis and description of the cognitive processes required during the performance of work. These numerous and diverse techniques are referred to collectively as TA methods, or by the TA or CTA acronym. However, it will be seen later in this report that the terms used vary in their specificity.

1.2 Scope of Report

This report provides an introduction to the group of research techniques that have been associated with both TA and CTA; it gives an overview of many of the methods and approaches that are in use in both military and civilian TA and CTA research; it also summarises the supporting software that is currently in use and highlights the requirement for a new generation of software support tools.

This report does not go into great detail about the history of CTA development, nor does it examine any single method in great detail. For one more detailed account of the origins of CTA, readers are referred to Schraagen et al., (2000). Further reading on particular methods, approaches and software tools will be referenced in the relevant sections of this report.

1.3 Outlines of Report Sections

Section 1 – The Introduction. Section 1 introduces CTA, outlines the scope of the report, and gives a high level outline of its different sections.

Section 2 - CTA Definition and Description. Section 2 addresses the nature of CTA, its areas of application, critiques that might be placed on its application, and the approach taken by the report on the consideration of CTA.

Section 3 – CTA methods and Approaches. Section 3 argues classifications for CTA methods and establishes a taxonomy on methods based on a library search. Limitations in classification and the argued taxonomy are presented. The section also discusses various approaches to CTA and introduces the Cognitive Work Analysis Framework that arguably includes the application of several specific CTA methods. The section also discussed the problem of the uses of terminology and acronyms.

Section 4 – CTA Usage: Military and Elsewhere. Section 4 addresses the foundation question of this report, namely what usage of CTA is made by the UK Military? Current practice relevant to the UK armed forces is addressed considering all three military services. Civilian practice with CTA is then considered. The section ends with a review of military related CTA published papers.

Section 5 – Software Support for CTA. This section considers many of the tools that are used in support of CTA.

Section 6 – Conclusions. Section 6 is the conclusion of the report and considers the discussions contained in all the previous sections.

Section 7 – References. Section 7 contains the references cited in the main text of the report.

Section 8 – Appendices. Section 8 contains 2 tables covering: 1) the classification scheme applied to CTA abstracts; 2) A listing citing some military CTA Studies.

Section 9 – Acronyms. Section 9 contains a short list of acronyms used.

2 CTA: Definition or Description

2.1 Defining Cognitive Task Analysis (CTA)

As mentioned in Section 1.1, traditional TA techniques are used to analyse observable manual work activities that can be governed by sequence, or procedures, or both.

“Task analysis involves the study of what an operator (or team of operators) is required to do to achieve a system goal. The primary purpose of task analysis is to compare the demands of the system on the operator with the capabilities of the operator, and if necessary, to alter those demands, thereby reducing error and achieving successful performance.”

[Kirwan and Ainsworth, 1992, p15]

The CTA intention must be to go further in its coverage than traditional forms of TA, in that it should aim to describe the knowledge, knowledge usage, thought processes and goal structures within the individual or team that lie behind the task performance observed (Schraagen, et al, 2000). Furthermore, any consideration on the skilled use of knowledge and information must also address the environmental affects and organisational factors on task performance. In addition, CTA should consider the influences on task performance arising from the situation and context of work, awareness skills, and task-associated information requirements and cues. Thus, CTA may be used to address the performance of non-procedural innovative tasks that are driven by environmental artifacts including hard-to-anticipate hazards.

“CTA propels us further, providing a means to examine the cognition that underlies the behaviours identified using traditional task analysis techniques. The focus of CTA is on difficult decisions, judgments, and perceptual skills, elements that cannot be seen as overt behaviors, but play an important role in many tasks. Cognitive Task Analysis is the description of the cognitive skills needed to perform a task proficiently.”

[Militello and Klein, 1997, p2)

Indeed, CTA should attempt to consider cognitive behaviours that cannot be determined by traditional forms and methods of TA. CTA will normally include a description of the actions carried out by the operator (both observable behaviours and internal activities, e.g. decision making), combined with details of the knowledge states they require to perform the role successfully (Jonassen, Tessmer and Hannum, 1999).

CTA outputs are typically used to inform the design of procedures and processes, the design of new technology and systems, levels of automation within a system, the development of training procedures and interventions, and the evaluation of individual and team performance within complex systems.

It can be seen from the above that the term CTA can mean a range of methods and activities, and that will vary from one commentator to another (as indeed does conventional TA).

2.2 The Application of CTA

"Because CTA techniques have been developed independently in research throughout the world, there is considerable variety in approach, emphasis, and resource requirements."

[Militello and Klein, 1997, p2]

Flanagan (1954) first probed the decisions and actions taken by pilots in near accidents using the Critical Incident Technique (CIT). However, as is noted in Section 1, the term 'Cognitive Task Analysis' did not appear until the early 1980's when it began to be used in research texts to describe approaches to the understanding of the cognitive activities required of man-machine systems (Woods and Hollnagel, 1987; Hollnagel, 2003).

Multiple strategies for the study of cognition at work have been adopted (see Section 1.1), leading to the development of a great many research methods, approaches and software applications that offer some potential for all or part of a CTA [1]. The CTA Resource website (an online community of CTA practitioners) has a published list of over 100 methods which have been used in CTA research, ranging from passive observation of individuals at work to structured interview techniques and the production of computer models and simulations.

These methods also differ in terms of the data they use, the nature of their outputs and the kinds of activities that they are suited to studying, which has meant that CTA has purportedly been carried out in support of a number of research activities:

"CTA has been successful across a variety of domains, including system design, training design, interface design, accident investigation, and consumer research."

[Militello and Klein, 1997, p2]

In addition, this range of techniques has meant that CTA has been used to study a number of very different work environments, including (but by no means limited to) aviation, the emergency services, nuclear power plant operation, air traffic control, command and control, military operations, naval maintenance and even white-water rafting (Chin, Sanderson and Watson 1999; Klein, 2000; O'Hare and O'Brien; 2000; Shaafstal and Schraagen 2000). It is also treated (somewhat in parallel) as an essential component in Software Engineering, Human Computer Interaction, and Knowledge Engineering (see, for example, Preece 1994). Note that many supposed CTA techniques (more accurately described as Knowledge Elicitation techniques) are also used for traditional task analysis.

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[1] www.ctaresource.com

A form of CTA that is often ignored in the consideration of CTA techniques is the range of Knowledge, Skills, and Attitudes (KSA) analyses in regular use [for example, sometimes Abilities rather than Attitudes are considered]. KSA is used to assist the selection and training of personnel and is specified by JSP502. However, outside the prescribed use in JSP502 it is also applied in both the military and civilian domains in many countries. The reason that KSA can be considered to be CTA is explicit by its title.

2.3 Issues with TA and CTA Research and Practice

A number of concerns exist regarding the use of both TA and CTA in terms of the appropriateness of the research being undertaken, the associated costs, the application of the results and the perception of the domain amongst host organisations:

Is it Appropriate? For practitioners who are new to TA or CTA the abundance of techniques can be bewildering – it is not obvious what types of activities are suitable for examination with TA or CTA, which methods should be chosen or the types of outputs that they generate. Furthermore, there is little guidance available to practitioners regarding the selection and use of TA or CTA methods (Schraagen et al, 2000). Several of the TA techniques covered by Kirwan and Ainsworth are still valid (and still in use), and it may be that the problem lies with an incorrect use of the word “Cognitive”.

Is it Beneficial? This diversity of methods has led to confusion as to what TA or CTA actually refers to, what it should involve and how the results are to be applied (Potter et al, 2000). This lack of established approaches to CTA means that potential customers (not directly confined to the military) may not understand the benefits of CTA, what CTA can (and cannot) do and what constitutes ‘good’ CTA research. This criticism can also be levelled in part against TA.

Is it Economical? Both TA and CTA techniques can be time consuming and labour intensive, in terms of the collection, evaluation and analysis of data (Hoffman, 2003), as can traditional techniques. They have also been criticised for being overly reliant on specialists, such as professional researchers, designers and subject matter experts, whose availability is often limited (Seamster, Redding and Kaempf, 2000).

Taken together, these factors mean that regardless of the approaches taken to TA, research can have a large financial cost and a slow turnaround. A subsequent lack of understanding of how to apply analysis results (Potter et al, 2000) may mean that the potential benefits of TA and CTA research are not being realized and/or that TA and CTA are portrayed badly in cost-benefit analyses, and/or that the subject analysis is rejected out of hand. Remembering that CTA encompasses the use of some more recently developed techniques for the analysis of tasks, but also shares many techniques with TA. CTA’s general worth is arguable more difficult to prove than that of traditional TA as the concepts are newer.

2.4 Approach Taken in this Report

Despite the wide variety of methods, approaches, support tools and domains of research which can be found in the CTA literature, it is possible to gain an overview of CTA research and to have an understanding of some of the more significant CTA methods and approaches.

This can be achieved because some CTA methods and approaches are far more widely used in published research and practice than others, and because these methods can be classified according to the types of work they are deemed suitable for, or have been used on, and the ways in which they are used. This should not be interpreted as making any judgement on their practical use. Furthermore, some CTA techniques, such as KSA, are not commonly referred to as belonging to CTA.

This report summarizes a majority of types of available CTA methods in the form of a classification system. The most heavily used CTA methods (as in the most frequently cited) have then been examined in more detail, along with approaches to CTA (which combine multiple methods). The application of CTA methods within military contexts is then reviewed, along with existing support software for CTA.

3 CTA Methods and Approaches

3.1 Classification of CTA Methods

Figure 3-1 represents a Cognitive Task Analysis classification structure. The aim here is to define a scheme that can be applied to CTA methods in order to classify them according to the type of data they use and the research aims they support. The classification scheme is adapted from four sources (Cooke, 1994; Roth, Patterson and Mumaw, 2002; Roth, 2002; CTA Resource Website). Some of the sources (e.g. Cooke, 1994) go into greater detail as to how to group and define CTA methods than has been used here.

This classification is also somewhat subjective; some of the methods could arguably fit into different or multiple sub-categories. Moreover, the classification is strongly USA based. However, it does give an overview of the different method types available and, when populated with CTA methods, will show the purpose for which a method has been designed.

1. *Goal-Means Decomposition*

2. *Empirical Analysis of* P*ractitioner Performance*
    - Observation (Expert; Expert vs. Novice)
        - Elicitation (Field Observations, Simulated Exercises, Performance under Controlled Conditions)
        - Analysis
    - Documentation
        - Elicitation (Manuals, Procedures, Memos, Letters, Textbooks)
        - Analysis
    - Interviews (Expert; Expert vs. Novice)
        - Elicitation
        - Analysis
    - Questionnaires
    - Group Activities
        - Elicitation
        - Analysis
    - Psychometrics
    - Miscellaneous Analysis Techniques

3. *Cognitive Modelling*

Figure 3-1: CTA Method Classification

An alternative (and simpler) classification would be on predominant use. This high level classification has equivalence to the classification of Figure 3-1:

1. Goals-means analysis.
2. Knowledge Elicitation (KE).
3. Cognitive and mental process modelling.

The selection of a CTA method depends on the aims and objectives of the study, the nature of the task(s) to be studied, their context, and the time and financial constraints on the research (Hoffman, 2003). The practitioner should also consider the particular context and application of the analysis.

To consider the simplified CTA classification structure of Figure 3-1: Goal-Means, Empirical Analysis and Cognitive Modelling.

The *goal-means* strategy focuses on the overall goals that need to be reached to successfully complete the task, followed by an analysis of the work domain in terms of the means by which these goals may be achieved, the task cues required, the task conditions, and the environment in which they are performed (Roth et al., 2002; Roth and Mumaw, 2002). The resulting hierarchy of activities is an idealised version of the task, which does not necessarily reflect the way that users perform the task. Here CTA has some similarities to Hierarchical Task Analysis (HTA), HTA initially devised to assist the determination of training, apart from the flexibility of the consideration of goals, means, and task outcomes that CTA can afford. A Goal-means decomposition provides a description of the main cognitive processing demands placed upon the role in question and the information required to complete the task. CTA is most effective when there is a good understanding of the goals, sub-goals and means by which they may be achieved within the domain in question (Roth et al., 2002).

Empirical elicitation and analysis techniques aim to establish how tasks are actually performed and assist in capturing the knowledge and strategies that are required in order to perform the task well (Roth et al., 2002). Many techniques are available, including observation in the working environment or simulations, structured and unstructured interviews, comparison of expert vs. novice performance, Concept Mapping, Repertory Grids, Verbal Protocol Analysis (Roth et al., 2002; Hoffman, 2003). These techniques are an effective approach to CTA when little is known about the task or the domain in question (Roth et al., 2002).

The third strategy for CTA involves the development of *cognitive models* (often computer-based) that can be used to simulate the cognitive activities required during the task under analysis (Roth et al., 2002). Such models have been successfully applied both in the exploration of existing working environments and in the prediction of the effects of proposed changes to work environment tasks (Hoffman, 2003). Task Analytic Simulation is a widely adopted approach (i.e. Micro-SAINT and its extension with appendages such as with IPME, CREWCUT), or Stella (e.g. Jaber, 1999). There are strong advantages in using dynamic modelling techniques to analyse tasks as the static representation of the dynamics of work, as offered by most TA and CTA techniques, has obvious limitations.

3.2 A Taxonomy of CTA Methods

Ninety eight separate methods were identified from the list published on the CTA Resource website; this list was used as the basis for the final taxonomy of methods. In Appendix 1, Table 1 - the classification structure from Section 3.1 has been populated with these 98 methods. A search of the Ergonomics Information Analysis Centre (EIAC) database (which holds over 170,000 Ergonomics and Human Factors abstracts) was carried out, yielding 595 publicly available CTA related abstracts. These abstracts were then searched for references to each of the 98 CTA methods. The results of these searches are listed in table 1, in the columns 'Number of References', 'First Mention', 'Latest Mention' and 'Percentage of CTA abstracts'. There are 3 additional columns – "Military References", "CTA Approach" and Software Tools". It is acknowledged that the use of CTA is not necessarily solely under the ownership of Ergonomics/Human Factors (HF). However, the coverage of the EIAC was considered to be sufficient for the purposes of this paper.

Military References

The 595 CTA abstracts were searched for military (or military-related) references. Where a CTA method is mentioned in a military-related CTA paper, the paper number is listed (the military-related CTA papers are summarised in Appendix 2, Table 2). Military-related applications of CTA are discussed in Section 4.

CTA Approach

If a method can be used in combination with other methods as part of an established approach to CTA then this is shown. Specific CTA Approaches will be covered in more detail later in this section.

Software Tools

The CTA abstracts were also searched for mentions of software support tools. Where a tool was mentioned that supports a particular method, the name of the tool is shown. Software support for CTA will be discussed in Section 5.

The analysis carried out for this report has concentrated on publicly available, HF related, journals. There may well be references to CTA methods in journals concerned with other domains (e.g. Cognitive Psychology, Computer Science, Cognitive Engineering, Training, or Artificial Intelligence), or in restricted military publications. However, note that EIAC abstracts do refer to some of the journals in these latter domains. Since, however, a separate set of searches on the Internet (incorporating CTA or Cognitive Task Analysis in the search terms) failed to find many of the methods mentioned in this paper, the approach is considered to be useful for the purposes of this paper. The EIAC database was used, rather than military sources as these papers are unrestricted – the analysis of restricted military research would severely limit the distribution of this report. Additionally, as will be shown in Section 4, military-related research is only a small part of all CTA work (though in the case of KSA this is burgeoning), and therefore concentrating only on military research would have been another constraint on this review.

A reference to a method was found if the method name or similar term was mentioned either in the Title, Abstract or Classification Term(s) sections of the abstract. Method references may not have been found, despite having been used in the research, if they were not mentioned in any of these sections, or if the authors did not use a recognisable or specific method name. This comment is also applicable to the separate Internet searches mentioned above.

3.2.1 Selection of Methods for the Final CTA Taxonomy

For the final CTA Taxonomy to be of a practical size, it was decided to select a shortlist of methods to be further examined, based on their prevalence in the CTA literature. An assumption made is that the more commonly reported methods are of more value to researchers and practitioners than those methods that have received only a small number of mentions. Figure 3.2 shows the number of CTA Methods (as shown on the x-axis) against the number of references in the 595 CTA Abstracts (as shown on the y-axis). From this, it can be seen that 45 of the CTA Methods are not mentioned in any of the 595 CTA Abstracts, whilst 1 CTA Method is mentioned 101 times in the abstracts. It is realised that the definition of what is CTA varied widely within the considered abstracts.

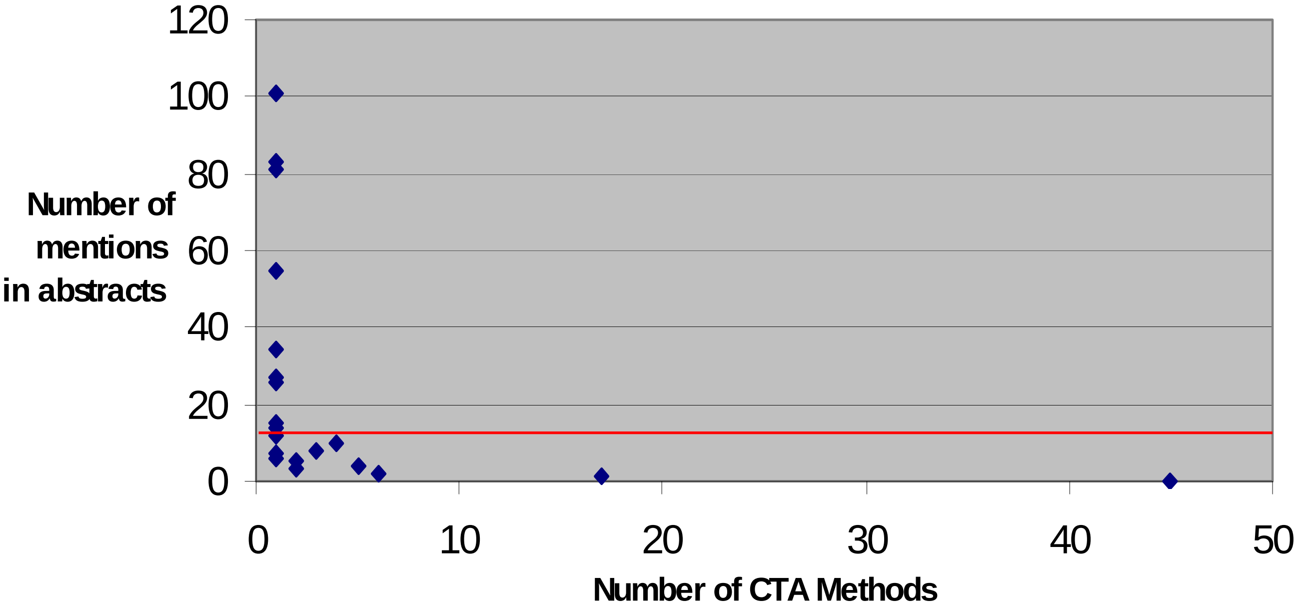

Figure 3-2: Prevalence of CTA Methods in available literature

The Taxonomy needs to be representative of the CTA methods that are in use, without becoming too unwieldy. In order to do this, a cut-off point of a minimum of 10 mentions (or 1.68% of total abstracts) per method in the CTA Abstracts was chosen for practical reasons (indicated by the red line on Figure 3.2). That left 14 methods (14.58% of the total) in the taxonomy, that between them represent over 80% of the method references in the abstracts (488 mentions).

The final taxonomy of CTA methods is shown in Table 3-1, below. Where a method has a related CTA Approach or is mentioned in a military-related CTA paper, this has been shown in the appropriate column. CTA Approaches, and Military–related CTA researches are discussed in Section 3.3 and Chapter 4 respectively.

It can be seen that – as with the term CTA itself – several of these methods have a circular definition, or have been labelled as a CTA method for reasons not related to either the research or the analysis, or both. Many methods classed as CTA are in fact extensions of traditional task analysis methods. In many cases these latter extensions are thinly argued to encompass aspects of cognitive. As an example, Hierarchical Task Analysis (HTA) is considered by several researchers to be a CTA method. As mentioned in a previous report (HFI-DTC 2.2.1/1) one of the originators of HTA has (privately) considered CTA to be part of HTA. To a certain extent this opinion must be valid as all human work implies some degree of cognition. Many views are not compatible, and are indicative of the lack of an accepted definition of the remit or purpose of CTA.

METHOD NAME	RELATED CTA APPROACH	REF. NO. IN THE MILITARY REFERENCES
1. *Goal-Means Decomposition*		
Hierarchical Task Analysis		14, 64, 74
2. *Empirical Analysis of practitioner Performance*		
o Observation		
▪ Elicitation		
Nonverbal Reports		
Process Tracing/Protocol Analysis		18, 38, 39, 58
Walk-Through		72
▪ Analysis		
Task Analysis		2, 9, 10, 16, 17, 27, 35, 42, 49, 64, 76
o Documentation		
▪ Elicitation		
▪ Analysis		
Diagram Drawing	SCTA, ACTA	12
Failure Modes and Effects Analysis	SCTA	72, 74
o Interviews		
▪ Elicitation		
Critical Decision	SCTA	13, 26, 58
Critical Incident		11, 13, 51, 71
▪ Analysis		
o Questionnaires		
o Group Activities		
▪ Elicitation		
▪ Analysis		
o Psychometrics		
o Miscellaneous Analysis Techniques		
Job Analysis	CWA	30, 34, 41, 49, 62, 63, 64, 68, 70, 73, 76, 77
Social Organization and Cooperation Analysis	CWA, SCTA	72
Strategies Analysis	CWA	4, 15, 24, 53, 62
Work Domain Analysis	CWA	41, 56, 65, 68
3. *Cognitive Modelling*		
GOMS		3, 12

Table 3.1: CTA Method Classification

3.2.2 Method Descriptions

Following, are brief descriptions of (or comments on) the CTA methods included in the taxonomy. Whilst some of the methods in the taxonomy are not used to directly analyse cognitive activity (e.g. Task Analysis) they have all nevertheless been reported as used as part of CTA research. Moreover, many methods known to be commonly used by researchers into cognition are not covered by the taxonomy i.e. Repertory Grid.

Hierarchical Task Analysis (HTA)

HTA involves breaking down the task under analysis into a hierarchy of goals, operations and plans:

- Goals – The unobservable objective associated with the task in question.
- Operations – The observable behaviours or activities that the operator has to perform in order to accomplish the goal of the task in question.
- Plans – The unobservable decisions and preparation made on behalf of the operator.

See also the report HFI-DTC WP 2.2.1/1, and also the two views that HTA encompasses CTA, and that CTA encompasses HTA. HTA was initially devised to assist the definition of training on fully specified or developed systems. However, it has been used to effect over a wide range of domains, most notable with relation to sequential and procedural task architectures. For example, for TA in support of Safety Cases and Human Reliability Analysis for the Nuclear Industry both civilian and military.

Nonverbal Reports

These can be held to comprise any recorded data, the value of which is directly related to the design of the collection method.

Process tracing/Protocol Analysis

This can be seen as an analysis of the procedures used to accomplish a complex task, and as having strong connections to the domains of Business Process Re-engineering, and Systems Engineering. Verbal Protocol Analysis is a well-used technique used to elicit task knowledge through the analysis of subject’s speech when asked to verbalise on their work performance.

Walk-Through

Walkthrough analysis is a very simple procedure used by designers whereby experienced system operators perform a walkthrough or demonstration of a task or set of tasks using the system under analysis. A walkthrough involves an operator walking through a scenario, performing (or pretending to perform) the actions that would occur, explaining the function of each control and display used. The walkthrough is also verbalised and the analyst(s) can stop the scenario and ask questions at any point. As “Cognitive Walkthrough” it is also to be found in several reviews of Software Engineering methods.

Task Analysis

Task analysis is a generic term used to refer to any method or technique used for the analysis of tasks.

Diagram Drawing

It is not surprising that “Diagram Drawing” emerges as a method, if the comment about keywords in the preceding paragraph is considered. Many of the tools and methods available for Business Process Re-engineering, training development, and Systems Engineering (Vista and Extend, for example; or SSM and UML) are reliant on constructing some form of drawing or chart as part of the methodology. Drawings are a method of depiction or description, and require some prior knowledge before they can be constructed – and this in turn will usually have required some prior analysis. A form of diagram drawing originating in the training domain is Concept Mapping.

Failure Modes and Effects Analysis (FMEA)

This is effectively an advanced form of risk analysis approach. It considers:

Steps in a process
Failure modes (WHAT could go wrong)
Failure causes (WHY would it happen)
Failure effects (What would be the consequences)

A tool for FMEA is available for Healthcare professionals from the Institute of Healthcare Improvement in Boston, MA; and a related measure derives a Risk Priority Number. Several other FMEA tools have also been developed.

Critical Decision

The Critical Decision Method involves the use of observation, semi-structured interviews and cognitive probes in order to elicit information regarding the cognitive aspects of expert decision-making. CDM outputs provide knowledge engineering for expert system development, the identification of training requirements, the development of training materials and the evaluation of task performance and the impact of expert systems (Klein, Calderwood and MacGregor 1989). The technique is a development of the Critical Incident Technique (Flanagan 1954) and was developed in order to study naturalistic decision-making strategies of experienced personnel. CDM has been applied in a number of domains involving complex and dynamic systems, including fire fighting, military, paramedic activity (Klein, Calderwood and MacGregor 1989) and white water rafting (O’Hare et al 2000).

Critical Incident

Critical Incident Technique (CIT) (Flanagan, 1954) is an interview technique that is used to collect specific data regarding non-routine incidents or events and associated operator decisions and actions made. The technique was first used to analyse aircraft incidents that almost led to accidents and has since been used extensively and also developed in the form of the Critical Decision Method (CDM) (Klein, 2003). CIT involves using interview techniques to facilitate operator recall of critical events or incidents, including what actions and decisions were made by themselves and colleagues and why they made them. CIT can be used to highlight vulnerable system features or poorly designed system features and processes. Examples of the CIT probes used by Flanagan (1954) include; “Describe what led up to the situation?”, “Exactly what did the person do or not do that was especially effective or ineffective?”, “What was the outcome or result of this action?”, “Why was this action effective or what more effective action might have been expected?”. It can be seen that this bears directly on cognitive processes.

Job Analysis

Job Analysis is a process to establish and document the '*job relatedness*' of employment procedures such as training, selection, compensation, and performance appraisal. Some researchers consider Job Analysis is improved by CTA or is an extension to CTA (Gordon and Gill, 1997; Reynolds and Brannick, 2000; Reynolds and Neville, 2002).

Social Organization and Cooperation Analysis

Vicente considers this to be a part of Cognitive Work Analysis. See also Section 3.3.3.

Strategies Analysis

Again, Vicente considers this to be a part of Cognitive Work Analysis*. See also section 3.3.3.*

Work Domain Analysis

The work domain analysis technique is used to better understand the task or work environment that is involved in a CTA effort. A work domain analysis involves describing the work environment in terms of system goals and objectives, artefacts, tangible characteristics of the work domain and also individual and group roles within the work domain (Chin, Sanderson and Watson 2000). Note, however, that Goals-Means Task Analysis (GMTA) (Hollnagel, 1993) and HTA (Stanton, 2004) can also address many of the issues and their implications related to these areas.

GOMS

GOMS (Goals, Operators, Methods and Selection Rules) was developed as a Human-Computer Interface tool, but some believe that it is best considered as a Software Engineering approach. It is based on an information processing theory, and interprets all cognitive activities in terms of searching a problem space. The GOMS technique is used to provide a description of human performance in terms of the user's goals, operators, methods and selection rules. GOMS first attempts to define the user's goals, decompose these goals into sub-goals and then demonstrate how the goals are achieved with the other components through user interaction. GOMS can be used to provide a description of how a user performs a task, to predict performance times and to predict human learning. The GOMS techniques are based upon the assumption that the user's interaction with a computer is similar to solving problems. Problems are broken down into sub-problems, and these sub-problems are broken down further. The four basic components of human interaction are used within the GOMS technique are Goals, Operators, Methods and Selection Rules *(*Card, Moran and Newell, 1983).

3.2.3 Taxonomy Limitations

This short-listed taxonomy seeks to reduce the extensive array of CTA methods down to those that seem to be most traditionally used in HF research. It also illustrates what type of research each method is best suited to (Goal-Means, Empirical Analysis, Cognitive Modelling) and the way in which the method is to be used. This provides a structured overview of CTA methods for those new to the field.

However, this taxonomy does not address all of the problems associated with CTA research. Whilst the methods listed in Table 3 are those that appear most widely used in CTA research (as determined on a quantitative basis), each one still has limited applicability in terms of the type of task, the application domain or technology that it may be applied to (Barnard and May, 2000; Schraagen et al, 2000). The result of this is that practitioners must either become adept in the use of several different techniques, or severely limit their scope in terms of work environments that they are able to study. All HF methods, when used in isolation, are of limited value – usually good practice suggests that several methods must be combined to produce an accurate picture of the cognitive demands of a role:

> *"…they should be viewed as complementary rather than as alternative methods. In practice, a mix of analytical and empirical techniques are required for a thorough cognitive task analysis..."*
>
> [Roth, Patterson and Mumaw, 2002 p16]

It should be noted that, in general, HF methods can be divided into those methods used in a predictive manner, those applied during the actual performance of work, and those applied retrospectively. The prevalence of the multi-method approach is illustrated by the fact that 25.6% of the Military papers analysed in this report mention two or more CTA methods in their abstract. There are however methodological and theoretical concerns that continue to exist with multi-method research:

- Practitioners may not know how to combine output from different methods in order to generate meaningful results, possibly with the result that the research is flawed, without the practitioner realising this.

- Combining methods with multiple theoretical bases may result in contradictory results and an inability to draw coherent conclusions, as well as limiting the research value of the work.

Having said this, it should be noted that practitioners are usually concerned with the delivery of some findings (product) that will benefit their client organisation – not with abstract research.

Due to the large number of CTA methods relative to the amount of CTA research that had been conducted, it is difficult to validate the methods in terms of the applications to which they are suited and the conclusions, which can safely be drawn from their results. When methods and tools are combined on an ad-hoc basis it becomes increasingly difficult to validate that the output of such a combination has any value – even when the product can be seen to be of value. Note the truth of this statement to the use of most HF related methods and techniques.

3.3 CTA Approaches

A solution to the problems associated with the combining of CTA methods is the provision of a framework or toolkit of CTA techniques that the HF practitioner can use in the examination of the cognitive components of the task under analysis. The concept of a toolkit or framework is an established one and has in the past been used in other psychological fields such as the prediction of human error (Kirwan 1998a, 1998b) and the dynamic modelling and measurement of mental workload (MacLeod and Helyer, 1993; MacLeod, Farkin and Helyer, 1994).

Several approaches to Cognitive Task Analysis have been developed, which combine knowledge elicitation and analysis techniques to produce a coherent, multi-method research technique. Five CTA Approaches have been identified and their prevalence in the 595 CTA abstracts is summarised in Table 3.2, below.

Approach	No. of Refs	First mention	Latest mention	% CTA refs	Military References	Software Tools
Cognitive Work Analysis (CWA)	32	1990	2003	5.38	30, 34, 41, 49, 53, 60, 63, 65, 68, 70, 73, 77	CAATS WDAW
Cognitive Function Model (CFM)	5	1989	2001	0.84	6, 20, 26	
Applied Cognitive Task Analysis (ACTA)	3	1997	2000	0.50		
Goal Directed Task Analysis (GDTA)	2	2002	2002	0.34	64, 66	

Approach	No. of Refs	First mention	Latest mention	% CTA refs	Military References	Software Tools
Skill-Based CTA Framework (SCTA)	1	2000	2000	0.17		

Table 3.2: Prevalence of CTA Approaches in the EIAC CTA abstracts.

It should be noted that the table above also indicates that those papers identified from the EIAC database do not – in turn - identify some of the approaches currently in use by practitioners, such as Repertory Grid Technique, GMTA, KSA analysis, or Concept Mapping.

The adoption of an established multi-method approach to the analysis of cognitive tasks would address many of the concerns regarding CTA research that have been highlighted in this report (c.f. Sections 2.3 and 3.2.6):

1. *The absence of a universally accepted CTA technique and the limited applicability of individual methods.*

   It would not be possible for any single CTA technique to achieve universal acceptance, as all CTA techniques are designed for fairly specific analyses and have limitations. However, multi-method approaches to CTA are versatile enough to be applied across a variety of situations and environments and some of the CTA components of Cognitive Work Analysis in particular, are already widely used in civilian and military CTA research (see SOARs April and June 2002).

2. *The lengthy training requirements associated with CTA techniques.*

   The choice of one established approach to CTA would also mean that practitioners would not need to study a multitude of methods in order to be able to undertake analyses of a number of different roles, thus reducing their training time and increasing the scope of work that they are able to undertake. However, a requisite understanding of the method would still have to be complete. The possibility that a single technique may well provide the solution to a single problem should not be overlooked.

3. *A shortage of adequately qualified/experienced personnel.*

   The adoption of one multi-method CTA approach may also mean that non-specialised personnel could be trained in some of the data collection and analysis methods, rather than in 100s of different methods. This would help to reduce the demand on the limited number of qualified practitioners. Note that the same comment could be made to justify the adoption of existing well-established methods of analysis such as HTA or Repertory Grids.

4. *Poor interpretation of CTA outputs.*

The use of an established approach should mean that the type of output produced by the analysis is expected and practitioners can be trained to interpret them. This reduces the risk of misinterpretation that is associated with the selection of different techniques for each CTA or any HF method. This should also allow customers to develop some understanding of what the research will involve and what kinds of output they should receive. Note that many practitioners argue that HTA is a Task Analysis technique where the use of a single method can be successful. Nevertheless prior to the accomplishment of HTA there has to be some form of knowledge elicitation performed to discover tasks and their properties.

5. The theoretical problems of combining CTA or any HF method

Selecting an established CTA Approach grounds the study in a coherent theoretical framework, which should remove the risk of practitioners trying to combine results from incompatible methods or draw unfounded conclusions from their studies. The frequent use of the same approach across a number of situations also allows for a thorough evaluation of its effectiveness and applicability, giving it further credibility.

3.3.1 Approach Descriptions

These are brief descriptions of the 5 CTA approaches as identified in Table 3.2.

Applied Cognitive Task Analysis (ACTA)

ACTA is a proprietary method generated by Klein Associates. No tools are available to the general public, but a training CD is available from Klein Associates for US$45. Applied Cognitive Task Analysis (ACTA) uses specific interview techniques in order to determine the cognitive skills and demands associated with a particular task or scenario. The output of ACTA is typically used to aid system design. ACTA was developed as part of a Navy Personnel Research and Development Center funded project as a solution to the inaccessibility and difficulty associated with using existing cognitive task analysis type methods (Militello and Hutton 2000). The overall goal of the project was to develop and evaluate techniques that would allow system designers to extract the critical cognitive elements of a particular task. The ACTA procedure consists of the following components:

Task diagram interview. The task diagram interview is used to provide an overview of the task under analysis. The task diagram interview also allows the analyst to identify any cognitive aspects of the task that require further analysis.

Knowledge audit. The knowledge audit allows the analyst to determine the expertise required for each part of the task. During the knowledge audit interview, the analyst probes Subject Matter Experts (SMEs) for specific examples of expertise that were employed during task performance.

Simulation Interview. The simulation interview allows the analyst to probe specific cognitive aspects of the task under analysis. The analyst probes SMEs using specific probes that are designed to elicit information regarding the decisions made and the associated actions and information requirements.

Cognitive Demands Table. Once the task diagram, knowledge audit and simulation interviews are complete, the cognitive demands table is used to group and sort the data.

The ACTA probes are presented below:

Basic Probes	**Examples**
Past and Future	Is there a time when you walked into the middle of a situation and knew exactly how things got there and where they were headed?
Big Picture	Can you give me an example of what is important about the big picture for this task? What are the major elements you have to know and keep track of?
Noticing	Have you had experiences where part of a situation just 'popped' out at you; where you noticed things going on that others didn't catch? What is an example?
Job Smarts	When you do this task, are there ways of working smart or accomplishing more with less – that you have found especially *useful?*
Opportunities/Improvising	Can you think of an example when you have improvised in this task or noticed an opportunity to do something better?
Self-Monitoring	Can you think of a time when you realised that you would need to change the way you were performing in order to get the job done?
Optional Probes	**Examples**
Anomalies	Can you describe an instance when you spotted a deviation from the norm, or knew something was amiss?
Equipment difficulties	Have there been times when the equipment pointed in one direction but your own judgement told you to do something else? Or when you had to rely on experience to avoid being led astray by the equipment?

Simulation interview probes
As the (job you are investigating) in this scenario, what actions, if any, would you take at this point in time?
What do you think is going on here? What is your assessment of the situation at this point in time?
What pieces of information led you to this situation assessment and these actions?
What errors would an inexperienced person be likely to make in this situation?

Table 3.3 ACTA probes (Source: Militello and Hutton 2000)

A more detailed description of the ACTA approach is provided in the CTA review carried out as part of Work Packages 1.3.2 and 1.3.3.

Cognitive Function Model (CFM)

This is a computer-based approach developed by the Klein Corporation and Aptima Inc as a way to guide an analyst in choosing which tasks or functions to pursue using CTA. It is claimed to be linked closely with Systems Engineering (see, for example: Chrenka, Hutton, Klinger and Anastasi, 2001) but, since it can only be applied by the Klein Corporation, no independent assessment is possible.

Cognitive Work Analysis (CWA)

Cognitive Work Analysis (CWA) can be argued to include forms of CTA within its framework. Developed by Rasmussen, Pejtersen and Goodstein (1994) of the Risø National Laboratory in Denmark, CWA is a work-centered, rather than user-centered conceptual framework for the analysis of cognition at work. It is a framework that is used to model and analyse decision-making in complex environments. A CWA involves five main stages. These are work domain analysis, activity analysis, strategies analysis, socio-organisational analysis and worker competencies analysis.

The work domain analysis involves describing the work environment under analysis in terms of system goals and objectives, artefacts, tangible characteristics of the work domain and also individual and group roles within the work domain (Chin, Sanderson and Watson 2000). The activity analysis component involves identifying the tasks that need to be performed in the work domain under analysis. Strategies analysis involves identifying the mental strategies that the system personnel may use during task performance in the domain under analysis. Social organisation analysis involves identifying exactly how the work is distributed amongst the actors and artefacts in the domain under analysis. Finally, worker competencies analysis involves the identification of the competencies that the agents involved are required to possess in order to perform the task(s) in the work domain. The worker competencies are simply classified using Rasmussen's Skill, Rule, and Knowledge (SRK) framework.

The CWA is an exhaustive procedure that uses a number of different methods, including an abstraction-hierarchy, decision ladders, flowcharts and the SRK classification. A more detailed description of this Approach is provided in the CTA review carried out as part of Work Packages 1.3.2 and 1.3.3.

Goal Directed Task Analysis (GDTA)

GDTA is also considered to be part of Human-Centered Design, Cognitive Engineering, and Systems Engineering. It should be noted that the US think-tank Mitre Corporation consider GDTA as being particularly appropriate for Concept Definition (or the C in CADMID) and for establishing the information needed to maintain Situation Awareness. It is also considered of value during requirements definition. (Mitre, 2004).

Skill-Based CTA Framework (SCTA)

SCTA is a framework for conducting CTA based on the assumption that simpler cognitive skills form the basis for more advanced skills, and which attempts to identify the hierarchy of skills needed to operate in a domain. This hierarchy, starting at the most complex skill type, includes: Strategies, Decision-Making Skills, Representational Skills, Procedural Skills, and Automated Skills. A different CTA technique is used for each skill type (Redding, 1992).

3.3.1.1 Conclusion to Section 3.3.1

According to this literature review, Cognitive Work Analysis is by far the most widely used of these approaches, having been referenced in 32 (5.4%) of the CTA abstracts, compared with 5 references (0.8%) for the next most widely mentioned Approach – Cognitive Function Modelling. Cognitive Work Analysis is also the most widely adopted CTA Approach in Military research, with 12 references in the military-related CTA abstracts (15.4%), compared to 3 mentions (3.8%) for Cognitive Function Modelling. Many treat the meanings of task and work as synonomous. However, CWA is a work-centered rather than individual user-centered conceptual framework that may explain the small percentage of references mentioning the approach. CWA is concerned with the analysis of the many forms of cognition affecting work and that implies focus on a high level consideration of the work domain rather than on a pure consideration of the specific individual or team's tasks within that domain. Therefore CWA may be argued to include CTA rather than be a form of CTA.

3.3.2 Product Development Lifecycle

HF work is required throughout the lifecycle of a system or product, to ensure that the technology accounts for the requirements and the limitations of the operator(s):

> *"To ensure a system is as effective and reliable as possible (i.e. that it is operable and maintainable), the human element must be considered in parallel with the equipment at all stages in the 'system life cycle'. This consideration of the human element (i.e. explicitly via the task analysis process), should be undertaken as an integral part of the system life cycle, making use of the different task analyses techniques at appropriate stages of design or operation."*
>
> [Kirwan and Ainsworth, 1992, p15]

Although Kirwan and Ainsworth are discussing Task Analysis as it was some 14 years ago, their comments are equally applicable to knowledge elicitation for CTA. It is important that any CTA Approach used is versatile enough to be applied across the development lifecycle, to support the HF work at each stage. Table 3.3 below shows the applicability of each of the 5 CTA Approaches identified earlier to the stages of the system development life cycle. It can be seen that the Cognitive Work Analysis (CWA) framework is versatile enough to be appropriate in a number of different situations, parts arguably having high applicability to all of the stages of system development**.**

Development Phase	**CTA Approach**				
	ACTA	*CFM*	*CWA*	*GDTA*	*SCTA*
Concept Definition	***		***	*	*
Requirements Analysis	***		***	***	*
Function Analysis	*	***	***	***	
Function Allocation	*	***	***	***	*
Task Design	***	***	***	***	***
Interface and Team Development	***	*	***	***	*
Performance, Workload and Training Estimation	*	***	***	***	*
Requirements Review	*		***	*	
Personnel Selection	***		***		***
Training Development	***	***	***	***	***
Performance Assurance	*		***	*	*
Problem Investigation	*		***	*	

Table 3.4: The fit between CTA Approaches and system development phases. (Taken from Bonaceto and Burns, 2003).
3 stars indicate high applicability, 1 star indicates medium applicability and no stars low/no applicability.

3.3.3 Cognitive Work Analysis

As identified above, CWA appears to be the most widely reported, and potentially the most applicable, of the CTA or CTA associated approaches examined in this report’s main literature research. Therefore, CWA will be given a more detailed review than that of the description in Section 3.3.2.

Conceptualised by Rasmussen, Pejtersen and Goodstein (1994) of the Risø National Laboratory in Denmark, CWA is a work-centered, rather than user-centered conceptual framework for the analysis of cognition at work (Vicente, 1999; Fidel and Pejtersen, 2004 and 2005). This means that it is the work domain itself that is of main interest, rather than the actions of individual actors working within it (Fidel and Pejtersen, 2004). CWA is primarily concerned with the goals that guide the work being undertaken and examines the constraints and conditions that restrict and shape the way in which these goals may be achieved, rather than choosing to concentrate solely on the actions and activities of actors in the work environment (Sanderson et al., 1999). From this analysis of the current system in place, in terms of work goals and the constraints relating to them, it is then possible to develop recommendations for improvements to the work environment, which can be used as design requirements during development (Fidel and Pejtersen, 2004).

In order to perform CWA, a multi-method approach is required (Fidel and Pejtersen, 2004). This is because there are several CWA dimensions, which constrain the way work activities may be carried out, and each of these has a corresponding level of analysis within CWA (Sanderson et al., 1999). Figure 3-3 shows one set of dimensions that would need to have corresponding methods and analysis applied as part of CWA performance:

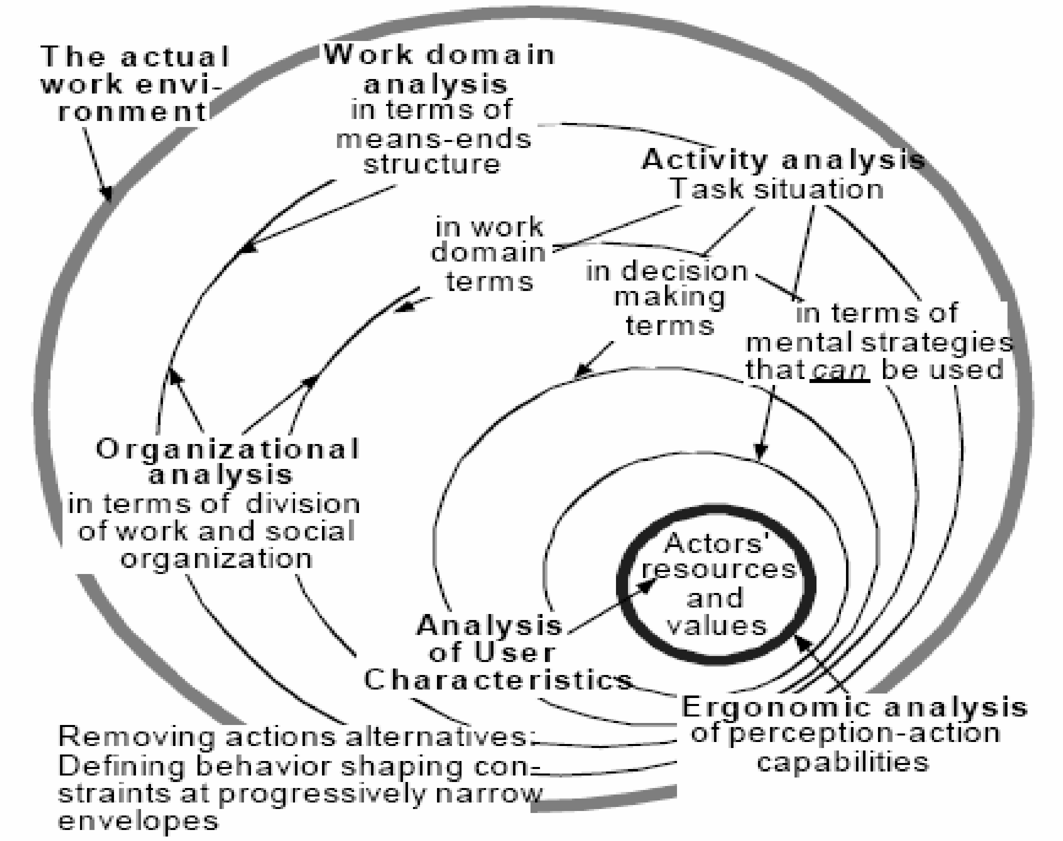

Figure 3-3: The Dimensions of CWA
(Taken from Fidel and Pejtersen, 2004, p7)

Vicente (1999) describes five phases of CWA, which analyse the dimensions shown in Figure 3-1. These phases are summarised below:

Work Domain Analysis

Work Domain Analysis is the study of the structure and functioning of the work domain itself, in terms of organisation goals, the means of their achievement, the constraints operating upon the organisation, the types of activities it undertakes and the tools it uses in this work (Sanderson et al., 1999; Fidel and Pejtersen, 2004; Woods and Hollnagel, 1987).

Control Task Analysis

This phase of analysis examines the tasks that need to be carried out in order to achieve the goals of the organisation and identifies the constraints that act upon them (Fidel and Pejtersen, 2004).

Strategies Analysis

Strategies Analysis examines the possible strategies that could be adopted for each task and decision (Fidel and Pejtersen, 2004)

Social Organization and Cooperation Analysis

This is the analysis of the social and organizational factors that affect work roles, such as the prevalent management style, culture and communication structures within the organisation (Sanderson et al., 1999; Fidel and Pejtersen, 2004)

Worker Competencies Analysis

This phase of analysis concentrates on identifying the cognitive abilities of the workers performing the tasks in question (Sanderson et al., 1999)

The various outputs from the different phases of analysis may be combined to produce a comprehensive yet clear picture of the work being carried out:

> *"Being a holistic approach it examines simultaneously several dimensions: the environmental, organizational, social, activities, and individual… It provides concepts and templates to facilitate an analysis of complex phenomena, without reducing their complexity."*
>
> [Fidel and Pejtersen, 2004, p 2]

A complete CWA, taking all relevant influences and constraints into account should enable the CWA practitioner to produce recommendations for changes that will improve performance of the work in question. These proposals can affect all of the dimensions previously discussed, thereby enabling the redesign of not just specific roles, but of entire work environments, leading to more effective system changes and improvements.

3.3.2 Could CWA become a major approach to CTA?

It can be seen from Table 3.4 that CWA could well be suited to the full range of system development activities. Note the argued differences between the remits of CWA and CTA given in Section 3.3.1.1.

Within proposed CWA frameworks, there are currently no formal agreements on what techniques and methods should be used as part of the analysis. This is a current major weakness in the approach, but could equally be seen as strength, since it means that the practitioner is free to choose the most appropriate tool for the environment or domain in question.

It is realised that this latter statement may appear contrary to the critique of TA and CTA given in Section 2.3. However, in order to address the problems with CTA research raised in Sections 2.3 and 3.2.6 of this report, it is suggested that there is a need to come to an agreement as to what methods should and should not be included within the approach. This would not mean that researchers would be limited to just one method for each phase of analysis, but that a restricted group of the most appropriate methods for each phase of CWA should be agreed. This needs to happen if the advantages of adopting a single CWA approach highlighted in Section 3.3 are to be realised and may happen if CWA is to become a major CTA approach to be adopted within military or civilian research. Note, however, that practitioners may well choose to employ a different set of methods to make up their own analysis tool-set, and this most probably will be determined on an empirical basis.

A further problem is that there are CTA and other techniques that have not been identified by this (Section 3.3) particular research approach; this is due in part to the somewhat vague terminology in use within the CTA community, and in part to the restrictions implicit in the use of the EIAC database. The method known as Goals Means Task Analysis (or GMTA) was mentioned in the HFI-DTC report on HTA, and is also worthy of consideration as is an established CTA approach (see Hollnagel, 1993; Hollnagel and Woods, 1987). Any analysis method or approach must have at least one goal (and perhaps a structure of goals), and thus both GMTA and the hard/soft goal modelling approach of Donzelli (Donzelli and Moulding, 1999, Donzelli and Marazza, 2000) should also be considered.

Regardless of the CTA methods to be considered, it should be accepted that the inclusion of such methods in CWA should increase CTA efficacy through the increased understanding of work promised by CWA.

3.4 The Terminology Problem Revisited

It has already been shown that several of the CTA approaches use methods drawn from the same pool of resources, and that an approach can be regarded as independent of CTA by one and integral to CTA by another. The problems of any literature search in this area have also been brought out. As one example, the omission from the search of GMTA (Goals Means Task Analysis).

GMTA was developed at the Risö Laboratory and research conducted for the European Space Agency about two years prior to the development of the prototype Cognitive Activity Analysis Toolset (CAATS – ESA Final Report 3535S). Subsequently CAATS was integrated into a larger GMTA based toolset termed CADETS. GMTA has been used for many applications (for example see SOARs, Hollnagel, 1993, CORAS project - http://coras.sourceforge.net). Forms of GMTA have also been used in practice on several projects including the UK Airborne Standoff Radar (ASTOR), Apache Ground System (GSS), and Nimrod MRA4 Tactical Command and Control (TCSS).

Moreover, the search also failed to identify the KSA (Knowledge Skills Attitudes) approach – or indeed any of the KSA variants – yet KSA is mandated in the official guide to Training Needs Analysis (TNA as in JSP502) and KSA as Knowledge, Skills and Aptitudes (i.e. also as KSA) is considered within a USA Data Item Description (DID) (Instructional Performance Requirements Document, DI-ALSS-81518A).

To discuss CTA or TA in any general terms may be to overlook the arguments as to whether CTA is part of HTA (or the reverse). Sufficient to say that TA is of course the generic – of which the others are part. Much of the research cited stresses that the methods used must be selected for the work in hand, and it has been shown here that few methods are universally applicable, but that some have a much broader theoretical base than others.

It may well be that addressing a specific domain would have produced a different set of methods – possibly resulting in a different categorisation. One example may serve here, that of Application Domain Modelling (or ADM). As propounded by Hone and Moulding (1998, 2000) this approach features two Training Needs Analysis (TNA) stages, separated by a HTA, and followed by a CTA (and there are other stages at the beginning and end). Note, however that ADM was proposed solely for the development of training simulations (it was referred to as the Training Process Development Framework); and references to this approach will normally be found only by using “Simulation” or “Validation and Verification” as keywords; this same comment must also apply to Donzelli and Moulding (1999).

The CTA method suggested within ADM was a variation of the KSA approach and it will be seen later that even something as apparently simple as this does not have an accepted basis for use. It will be seen that the Royal Navy have a simplified view of “skills”, and also that the KSA analysis required in JSP502 is not always considered to have a firm basis.

3.5 Section 3 Conclusions

In this section many of the issues associated with CTA research have been addressed:

- Through the analysis of published CTA research, it has been shown that the majority of these studies have been based on only a few of the great many methods available.

- Through the classification system and taxonomy of short-listed methods, it has been shown that it is possible to gain a rapid appreciation of some of the types of CTA techniques available, their prevalence in published literature and the kinds of tasks that they are suited to.

- An argument has been presented that CTA research often needs to involve the use of multiple methods in order to create a thorough and accurate understanding of the work environment and that this is not without its own problems. The adoption of one of several multi-method approaches to CTA may address many of the practical and theoretical problems associated with CTA and the use of multiple methods.

- It has been suggested that, of the multi-method approaches to CTA identified in this report, CWA is worthy of adoption as a standard encompassing approach to CTA, due to its adaptability.

- It has also been shown that some techniques have not been brought out by the approach of this paper, and it may well be necessary to start from the domain requirement and move to the analysis approach, in order to determine the most suitable form of analysis.

4 CTA usage – Military and Elsewhere

4.1 Section 4 Structure

This section will start by considering the findings from a set of interviews with personnel involved with training for the Services. It will be seen that there is no consistent view of the training analysis process either between or within the different services, although there is a marked degree of commonality. Then, those papers identified by the process described in the previous Section will be discussed, with a view to establishing the relevance of the methods identified.

4.2 Current Practice Relevant to the UK Armed Forces

This section will start with the Royal Navy – their training processes being perhaps the longest established – and will then compare the practice within other services.

4.2.1 Royal Navy Task Analysis Practice.

The current Royal Navy (RN) approach to Task Analysis within the Training Process is centred on HTA. RN HTA is conducted as part of TNA to capture the training requirements and identify the most cost-effective method of meeting those requirements in support of a new or changed capability. The use of TNAs was mandated in the RN Training Strategy Paper in 1992. The RN has established a TNA Group under the Naval Recruitment and Training Authority (NRTA) who are responsible for the quality assurance of all TNAs and they are the default provider for the conduct of the TNA.

The RN HTA Process is a logical progression that generates the Task Descriptions, which are then used to drive the TNA process to determine the media and method solution to meet the training requirement. It will be seen that some of the terms used can be found in the CTA literature, but the meaning here will be that applicable to RN use.

4.2.1.1 The elements of RN HTA

Job Analysis. Job Analysis is the process of examining a job to identify its component tasks and the circumstances in which the tasks are performed. It is recognised as the first step in gathering information required to design efficient and effective training. However, it is also performed to assist in identifying the target audience for recruitment, to provide objective and comparative data on responsibilities and working conditions (job evaluation) and during job restructuring to rationalise the distribution of tasks.

Inputs to the Job Analysis are: Job Duties and Tasks. The activities of the individual need to be identified as a first step. For existing equipment, this can be done by observing and recording the actions performed by the operator, during the processes that are addressed. The individual processes are then recorded as the tasks and the steps the operator goes through to complete the task become the sub-tasks (if themselves composed of a number of individual actions) or task elements (if they are stand alone). All decompositions should, therefore, logically end in a task element.

RN Training Guide 2 requires that the job context in which the current job analysis is based must be identified. It enables the impact of the introduction of new methods or new equipment on the task decomposition to be assessed and can highlight the consequences of inadequate performance of the jobholder.

Conditions. The physical and environmental conditions, under which the job is expected to be performed, are important to ensure that the same level of performance is achieved during training. Performance of tasks may vary significantly and the impact of the following influences needs to be assessed and recorded:

a. The physical environment.
b. The personnel involved either individually or collectively.
c. The supervision level allocated.
d. The availability of reference material and job aids.
e. The availability and condition of tools, instruments, equipment and materials.

Standards. The standards to which the tasks are expected to be performed are often published in regulations defining procedure, acceptable tolerances or expected results. Other standards, such as sequential requirements or temporal aspects, may not be specified and must be determined through either observation exercises or estimation.

Target Audience. Through consideration of the Target Audience the percentage of the total job candidates actually performing each task can be quantified so that training resources can be targeted and not wasted.

Task Frequency. The frequency of performance of a task is important to establishing the training priority for it. Often the tasks that are performed frequently require less concentration on training than those likely to be performed less frequently but which have more potential for error.

Level of Supervision. The presence or absence of supervision directly influences the level of training required for the task and the mechanisms required to ensure that the level of supervision available during training is both sufficient and consistent enough to provide a reliable training standard.

Difficult Tasks. Identifying the more difficult tasks enables the training designer to bias the training emphasis towards those tasks that are `hard to learn' or `hard to do' and which, consequently are more likely to result in performance shortfalls.

Distastes. People avoid elements of a job that are unpleasant and this extends into the training theatre. Distastes therefore lead to a reduced level of training enthusiasm, a reduced level of operational practice, compromised performance and the introduction of errors. Increased training is less likely to improve the performance in these areas and efforts are better directed to addressing the root cause of the distaste.

Responsibility. The person responsible for supervision and acceptance of the performance of the task must be identified.

Job Analysis Sources. RN guidance identifies the best sources of job analysis information as those doing or supervising the job, followed by the reports of any other specialists who have studied the job. While this seems logical, it ignores the basic question of how to cope with new equipment being built to address a new requirement or to re-address an existing requirement. There appears to be a minimal mechanism for the Knowledge, Skills and Attitudes (KSA) of the target audience to be incorporated by the equipment Contractors at the design stage.

For existing equipment the RN guidance catalogues a rich list of potential sources including:

- Jobholders (current and former);
- Job supervisors (current and former);
- External specialists;
- Reference materials;
- Expert panels.

All of these sources rely on experience in using equipment that, in the case of new build, may not be available. The only guidance available for conducting job analysis of new equipments appears to be through experience using similar equipment, through simulation, and through the use of assumptions; the former is only applicable after the design is established, and is therefore unable to benefit from the HTA input, while the last has a high potential for inaccuracy.

Analysis Output. The output of the Job Analysis is the Job Scalar which is a diagrammatic representation of the activities that an operator does in the performance of their job.

Job Scalar. The Job Scalar process is a paper based analysis without reference to special tools and is based on a methodology that produces a hierarchical decomposition.

The Job Scalar only provides a `picture' of the job and does not identify any training required. The next stage of the RN HTA process is referred to as Task Analysis (though it should be noted that both the Scalar, and the Task Analysis output is very similar to one form of HTA output as advocated by Stanton (2004).

Task Analysis. Task Analysis is defined as the systematic analysis of a task, by examining its sub-tasks and elements, to identify the necessary behaviour required to perform it. In moving from job analysis to task analysis, the emphasis changes from what the jobholder does, to identifying the particular knowledge, skills and attitudes that have to be learned in order to perform the task (see the preceding paragraph).

The object of RN Task Analysis is to generate Enabling Objectives and the selection of the appropriate training methods and media.

Knowledge. Knowledge involves recalling information. Task Analysis identifies the supporting knowledge required for task performance, taking care not to overload training with knowledge that does not contribute to task performance.

Skills. Skills are sub-divided into Physical Skills and Mental Skills. Physical Skills are defined as `learned capabilities of performing actions in an organised and fluid manner' and can be divided into sub-categories as in the table following:

Categories	**Examples**
1. Guided Response. Guided Response is concerned with the early stages of learning a complex skill. It includes imitation and is supervised by an instructor. There is an element of trial and error.	Learning to ride a bicycle
2. Mechanism. Mechanism is concerned with performance acts where the learned responses have become habitual and movements can be performed with some confidence and proficiency. Learning outcomes at this level are concerned with performance skills of various types but movements are less complex than at higher levels	Riding a bicycle in optimum conditions
3. Adaptation. Adaptation is concerned with skills that are so well developed that the individual can modify movement patterns to special requirements or to meet a problem situation.	Riding a bicycle in all fit conditions of weather and road surface
4. Origination. Origination refers to the creating of new movement patterns to fit a particular situation or specific problem. Learning outcomes at this level emphasise creativity based upon highly developed skills.	Riding a bicycle off road, cross country or BMX-ing

Table 4.I - Hierarchy of Physical Skills

Mental Skills can be defined as `learned capabilities of reacting with the environment by using symbols' and are also divisible into sub-categories, ordered according to the complexity of their operation. The hierarchy of mental skills is illustrated at Figure 4.1.

DISCRIMINATIONS	
Lead to	
CONCEPTS	
Lead to	Increasing Complexity
RULE USING	
Lead to	
PROBLEM SOLVING	

Figure 4-1 - Hierarchy of Mental Skills

__Attitudes.__ An Attitude (in this context) is defined as `An acquired mental state which influences the choice of personal actions'. Learning outcomes associated with attitudes are said to belong to the `affective' domain and can also be classified as illustrated in Table 4.2.

Categories	Examples
Receiving. Receiving refers to an individual's willingness to attend to a particular stimulus and represents the lowest level of learning outcomes in the affective domain.	Concentrate on activity. Listen attentively.
Responding. Responding refers to active participation on the part of the individual. Learning outcomes in this area may emphasise consent, willingness or satisfaction in responding.	Follow correct procedures. Obey rules.
Valuing. Valuing is concerned with the worth or value an individual attaches to a particular object, phenomenon or behaviour. Learning outcomes in this area are concerned with behaviour that is consistent and stable enough to make the value clearly identifiable.	Appreciate need for a systematic approach. Defend rules.
Organising. Organising is concerned with bringing together different values, resolving conflicts between them and beginning the building of an internally consistent value system. Learning outcomes may be concerned with the conceptualisation of a value or with the organisation of a value system.	Balance conflicting choices. Develop a positive outlook.
Characterising. At this level of the affective domain, the individual has a value system that has controlled behaviour for a sufficiently long time to develop a characteristic `life style'. Learning outcomes at this level cover a broad range of activities, but the major emphasis is on the fact that the behaviour is typical or characteristic of the individual	Display Integrity. Maintain self- discipline.

Table 4.2 - Hierarchy of Attitudes

Task Analysis Procedure. The TA procedure proposed within the RN is outlined in Table 4-3 and accompanying Task Analysis Sheet in Figure 4-2.

Step	Procedure
1	Copy the job, duty, task, sub-task and element details from the scalar to the task analysis worksheet, an example of which is at Figure 1-3.
2	For the first element, identify the physical skills required and list them in the appropriate column.
3	For the first element, identify the mental skills required and list them in the appropriate column.
4	For the first element, identify the associated attitudes and list them in the appropriate column.
5	Identify and list the knowledge required to support the identified skills and attitudes.
6	Cross reference information that has been recorded previously on other task analysis sheets.
7	When appropriate, enter any training requirements or ideas into the Training Notes column.
8	Repeat Steps 2 - 7 inclusive for the next element until all tasks have been analysed.

Table 4-3 - RN Recommended Task Analysis Procedure

Job:		**Duty:**		**Task No:**	**Task:**	
Unit No	**Sub-Task/Task Element**	**Required for execution**				
		Knowledge	**Mental Skills**	**Physical Skills**	**Attitudes**	**Training Notes**

Figure 4.2 - Task Analysis Sheet

4.2.1.2 Areas for Improvement

The RN process for TNA encompassing job and task analysis has now been in place for 10 years and has evolved over that period. It is now a well-honed and well-rehearsed tool with which the majority of training designers and practitioners are familiar.

However, probably as a result of early experience (where a number of retrospective TNAs were conducted to define the training requirement for several systems that were already in service) guidance on the general conduct of TNAs and the attendant HTAs are focussed, in the main, on structured interview and analysis of the job being performed by the individual performing it. This begs the question of how to perform HTA of new equipment using new technologies before there is a user population to interrogate. There is an apparent disconnect between the designers of new equipment and the designers of Training, in that by the time the training authorities are introduced to an equipment, the Human Machine Interface (HMI) is a done deal. Little guidance on the conduct of HTA for new equipment or the availability of data to inform the process is contained within the guidance documentation.

4.2.1.3 Guidance for New Equipment

Within the defence procurement arena, guidance for new systems designers is contained in Defence Standard (DEFSTAN) 00-25 - Human Factors for Designers of Systems. This standard is invariably called up in the Contract for any new defence equipment, however there appears little within either the DEFSTAN or other guidance material to explain how compliance with the DEFSTAN can be measured or determined by the Acceptance authorities.

DEFSTAN 00-25 Part 19 covers advice on technical guidance and data in the human engineering domain under the following headings:

a. Systems Issues.
b. General Ergonomics.
c. Workspace Design.
d. Lighting.
e. Human Computer Interface/Interaction.
f. Controls/Control Types.
g. Labelling.
h. Information Displays.
i. Maintenance and Access Ergonomics.
j. Accommodation and Habitability.

DEFSTAN 00-25 Part 15 covers, inter alia, the process of task definition. It suggests a 3-stage process of:

Task Synthesis.
Task Description.
Task Analysis.

In summary, it can be seen that many Royal Navy processes are well established. It should be noted that the RN are the only service supporting DEF STAN 00-25; and, while they have contributed to the JSP502 document on Training Needs Analysis, they make no apparent great use of the KSA analysis which is a mandatory part of JSP502.

Interservice differences will be commented upon later.

4.2.2 Army Task Analysis Practice

In general terms, the Army have a similar set of procedures to the RN. The TNA processes detailed under JSP502 are normally performed under contract by either the equipment supplier, or by independent contractor. This is regarded as something to be done in the early stages of the CADMID cycle, as something that may inform the training process, but which is not essential to it.

The fundamental difference between the Army and RN approaches is that the Army have a network of Training Advisors in post at Arm/Service/Corps level, and these are expected to analyse all low-level training needs. The Training Advisory Group (TAG) at Upavon run regular courses on TNA for the Training Advisors (who are only in post for the normal 2-year period), and these generally focus on HTA, DIF Analysis (Difficulty, Importance, Frequency) and the production of Job Scalars. The Task Statements that are the end product of an HTA, are transferred by hand to become a list of Training Objectives (and are effectively synonymous with Enabling Objectives).

TAG has stated that they regard the principal limitation of HTA as being that HTA does not address any of the cognitive issues. They would not, however, be inclined to adopt (or even recommend) any complex CTA methodology, but would like to see a simple form of cognitive analysis based on the KSA framework, as this would be more in keeping with the Training Advisor structure. A view was also put that some development should be put into the DIF analysis technique, as this is considered to be somewhat simplistic in its present form. In this context, see also the RAF comments below that indicate an informal approach to DIF analysis. It was emphasised that the Director General of Training and Education now “owns” JSP502 and thus supports the KSA approach; and that the Director of Individual Training is now also responsible for Collective Training.

4.2.3 Royal Air Force Practice

RAF personnel have stated two separate views on the use of TA and TNAs. The first can be described as an “Engineer’s” view, while the second represents more of a Human Resources view.

4.2.3.1 Engineering View

The Engineering view considers primarily the training of those trades that go to support the RAF’s aircraft fleet. The reference document is taken to be DEFSTAN 00-60, and in particular Task 301 within that DEFSTAN which refers to:

"… identify the human performance requirements for operation, maintenance and support, and to document those requirements in task inventory"

The task inventory is used in Task 401 to produce a TNA.

Apart from DEFSTAN 00-60, reference is frequently made to US DoD Mil-Std 1388-2B, and to the relevant Civil Aviation standards – particularly those emanating from the US Federal Aviation Authority. It was stressed that the RAF similarity to a civil aviation operation had produced a set of procedures that were regarded as independent of the skilled tradesmen, and which must be complied with. Out of a list of over 20 points that a TNA under Task 401 must consider, only two relate to people, and one refers to an HFI task performance analysis. With relation to the "people-related" items, one does mention *"personnel capabilities (target audience)"*. Unlike the RN and Army, the RAF prefer the term "Use Study" to "Target Audience Description".

Two other forms of analysis come within the "Engineering" view: a Failure Modes, Effects and Criticality Analysis (FMECA) and a Reliability-Centred Maintenance (RCM) analysis (see above, Section 3.2.5).

4.2.3.2 Human Resources View

The Human Resources View is considerably wider in scope, and takes in all personnel, rather than just those directly concerned with carrying out aircraft maintenance. The two views are linked in that while the Training Development Wing is responsible for course content, this content has to be approved by the Defence Aviation Safety Centre (DASC).

Here, training is seen as a 3-phase process, with some element of HF awareness in each phase

Phase 1: generic training, or 'square bashing'.

Phase 2: trades specific training.

Phase 3: post specific training that is undertaken when trainees change post to perform a variation of the technical trade tasks they have previous experience of e.g. a different type of aircraft engine.

Training is in terms of 'how things should be done' e.g. maintenance procedures. The 'Personnel Management Agency' manages and organise personnel attendance for all phases. The training development wing is responsible for course content.

4.2.3.3 TNA and TA

An in house TNA is undertaken or a verification of commercial training is performed with regard to Customer2 needs and Integrated Product team (IPT) requirements. The first part of the TNA is a Scoping Study

TA methods used are:

- Tools used to perform TA and TNA are pen and paper.
- The way in which people think about tasks for training development and task/training analysis considers both text and graphics.

The TNA group at Halton did work with and provide input to a development project - part of Future Offensive Air Systems (FOAS) - that incorporated HF expertise. However, this was the exception to the rule and the arrangement was ad hoc.

- Links to HF expertise in general is ad hoc.
- HF reference information has to be uncovered by individuals e.g. Def Stan 00-25, STGP 10 and 11.
- There is a clear requirement for a 'Definitive HF Reference'. This would have MoD approved HF definitions. Such a document would be published as 'worker version', 'supervisor version, 'specialist trainers version', 'trainers version' and a 'HF expert version'.
- There is no formal input between engineering disciplines and HF, TNA and TA activities. There are no HFI courses, no HFI ownership or training, and no HF training. Even a standard HF vocabulary is lacking.
- There is a new initiative to assess and train Attitudes during Phase 1 Training. This is to be extended to Phase 2 training and to officer training.

4.2.4 Interservice comparisons.

Each service makes the point that training policy is to some extent dictated by personnel factors and service ethos. Each service claims to have different problems with staff retention – the RAF argue that their NCOs generally serve for up to 20 years longer than Army NCOs, and that training is more concerned with differences in procedures (e.g. relating to a different engine type). The Army have a higher turnover of personnel in the sense of the two-year posting cycle, and the shorter engagements, and this requires continual training – including that for the Training Advisors. RN personnel retention is not as good as the other two services, but their people tend to stay working with, or on, one type of equipment for several years.

Each service would probably be receptive to any ideas that will improve their existing procedures, but would not welcome any major changes to TA or TNA (or indeed be able to accommodate any major change).

4.2.5 Potential military requirement for CTA

The armed forces as they exist today are already heavily reliant on sophisticated technological systems in the performance of operations, in terms of intelligence, command and control and weapons systems and platforms. Several of the "Future" systems are not yet firm in concept and may well benefit from a CTA approach to their deployment and use (FRES, FOAS, and possibly FIST, come to mind).

In addition, the realisation of Network Enabled Capability (NEC) will require further development of communications infrastructure, as is illustrated in the description below:

"[NEC is] the ability to gather knowledge; to share it in a common and comprehensible form with our partners; to assess and refine it to turn into knowledge; to pass it to the people who need it in an edited, focussed form; and to do it in a timescale necessary to enable relevant decisions to be made in the most economic and efficient manner."

[Deputy Chief of Defence Staff (Equipment Capability), 2001
http://www.mod.uk/issues/nec/]

Establishing NEC across a large theatre of operations will create a highly complex, tightly coupled socio-technical system; with information being gathered from multiple sources, combined, analysed and then acted upon within *"…a matter of minutes or even 'in real time'…"* (Secretary of State for Defence, 2002), the consequences of errors or omissions at any point could prove disastrous.

Some of the possible effects of such large scale networking of the armed forces can be seen in (albeit small scale) examples from civilian organisations where high proportions of workers use computers connected to office networks and corporate intranets. Such technologies can increase the flow of information across organisations and communication between departments that may be geographically far apart. However, as well as enabling increased cooperation and coordination, such initiatives also reveal a lack of complete understanding of the way in which people embrace such technology (JWID being a good example) and an appreciation of a need for improved or additional skills in the workforce. These skills may include requirements for a greater trained work awareness of the social and organisational structures that have been changed or replaced. There are many important issues related to this area. Some of these issues are being addressed by the HFI DTC through current research on Education Requirements Analysis. CTA (and particularly CWA) could enable a better understanding of the socio-technical processes involved.

Given the costs of implementation and the negative consequences of system failure, it is important that the design and implementation of such technologies are carefully managed. A former Infantry Company Commander (name withheld) commented recently on the NEC initiative *"We will do what we always do – keep the bits that work and dump the rest"*

The development of reliable and easy to use computer based programmes, designed to remove the onerous activities from task and work analyses whilst at the same time promoting high quality analysis product, must help to provide overall benefits to military systems in terms of decreased life-cycle costs and improved performance.

4.3 Civilian Practice

A number of organizations will be considered under this header. These may be commercial concerns carrying out military or governmental work, or national organizations.

4.3.1 The National Fire Service (NFS).

The Fire Service has an Integrated Personal Development System (IPDS), which structures the fire service training for Fire Officers (FO). The approach to training is role based and training reflects what happens in the real world, in order to familiarise FO with incidents they are likely to come across during the course of their working life. A Functional Task Analysis was rolled out to the IPDS and this analysis formed the basis of an 8-part career development system which maps the whole career path for fire fighters

Training is assessed through line management but this does not filter through to the training that individuals undertake at the Fire Service Training College. Also, On the Job Training (OJT) is used to identify those personnel likely to be suitable as FO's. Regrettably, however, effective feedback to actual training is missing. The Chief and Assistant Chief Fire Officers Association (CACFOA) is the body able to initiate changes in procedure. Such changes happen on a more informal basis within brigades at a local level. National level task descriptions exist; these are referred to by line managers to assess OJ training needs and are used to compare what happens with what should happen.

At the Fire Service Training College, a level of expertise is assumed, however this is not always the case so people with different skills have to be accommodated on the courses. Training programmes are assessed and the review process supports modifications. Procurement is an ad hoc process and does not link to training at all. Unusually, trainers may be asked to try out pieces of equipment but this is rare. There are working groups (WG) for different types of incident (e.g. Road Traffic Accident WG), which meet to consider the broad approach to different types of emergency, but there appears to be no formalised Task Analysis being carried out regularly. Incident procedures are trained by repetition, and new procedures are introduced infrequently; in this respect, a parallel can be drawn with low-level infantry training.

4.3.2 Warsash Maritime Center

Warsash Maritime Centre provides training in Crew Resource Management, Crisis Management and Human Behaviour, which includes decision making under stress and situation awareness for the Merchant Navy, and other shipping organisations. Training is for international seafarers (otherwise “Foreign Going”) at Officer level and incorporates:

- HF Issues;
- Competence Assessment;
- Recruitment and Retention;
- Simulator based training scenarios;
- Team training;
- Situation assessment;
- Decision-making.

The International Maritime Organisation dictates a standard set of training competencies for 130 countries. As some of these countries are unable to provide adequate training the competencies tend to accommodate the lowest possible denominator.

As Warsash is more of a training provider there is no structured approach to TNA. The courses have involved from the domain knowledge of the trainers in relation to awareness of HF and human behaviour. Generally a shipping organisation will acknowledge a problem area due to an incident or commercial issues and will then approach providers to identify a course in relation to this.

A training scenario in the full mission engine room simulator would reflect the real rank structure on board ship. An example of a training objective will be to put an un-used laid up ship to sea. Generally the trainers do not need to add additional stressors as these drop out of the session due to lack of communication, errors and taken for granted assumptions. This scenario generally demonstrates a major lack of planning as the trainees are used to simply taking over from another crews. The scenario is very immersive and the trainees tend to fill in any fidelity gaps

Once a course has been completed the trainee receives a certificate. The majority of shipping organisations view the certificates as an ‘inoculation against error’. However, after the trainee has returned to work, the culture of the industry (and the shipping line) can be highly influenced by commercial issues, and the more human and safety related aspects are often lost! There is no process to ensure a training path for individual is tracked. Another difficulty is cross-cultural issues and relationships, whereby some nationalities will not receive input from other staff. Other nationalities blindly follow instruction regardless of whether they know a situation assessment to be incorrect and so on.

The ‘STEP’ approach is used to help determine appropriate situations and then a repertoire of ‘stories’ are tested in relation to an incident. (NB, there was no clear understanding of the basis for this STEP analysis, but it appears to be based on a Business Process Re-engineering model, which considers the Social Technological, Economic and Political dimensions.) The object of this is to:

- Look to identify sharing of a mental model
- Use of individual mental model

- Identify decision making in terms of:
  - Working through a routine
  - Running with a hypothesis

From a training perspective the goal is to improve a repertoire of experiences to draw upon. A second goal is the development of meta-cognitive skills, or training for people to think about how they are thinking.

4.3.3 Survey on task and work analysis methods

It was intended to conduct a survey of other task and work analysis methods and a questionnaire had been developed for this purpose. The response rate was not good – even when an organisation had already agreed to take part – and there were not enough replies for a meaningful quantitative analysis. In qualitative terms, all respondents but one indicated that they used a wide variety of methods, including all of the components of CWA, but never on the same project. It should be noted that the development of a CWA methodology must offer more than the sum of the parts and that will only be achieved by devising some method of meaningfully combining the results of the various parts and establishing some form of validation of the result.

One exception in the survey used only a limited range of tools and methods, but had a focus on training (and on the use of their own proprietary tool). With this one exception (Quintec, using “TRAP”) no software based analytical tools were used.

One company (Human Engineering Ltd) went beyond the scope of the questionnaire on request, and looked at the possible use of CWA against their existing methods. This should be seen as a review of applicability of the Cognitive Work Analysis (CWA) methodology to ergonomics projects of varying scale, scope and objective.

Three projects were selected for review, based on their similarity to the sort of technology implementation for which CWA is frequently proposed.

Project A	Development of Revised Communications Protocols for a Railway Line Controller.
Project B	Workload and Human Error Assessment of a Control Room
Project C	Early HF Assessment of a New In-cab Signalling System

Question	**Project A**	**Project B**	**Project C**
Would it have been possible to apply CWA to the project?	Y	Y	Y
Would CWA have increased data collection costs?	Y	Y	Y
Would CWA have increased modelling costs?	Y	Y	Y
Would CWA have added value to the results of the project?	Y	N	Y
Could CWA have altered the results if the scope had been different?	Y	Y	Y
Would CWA have supported the goals of the project cost effectively?	N	N	Y

Table 4.4: Potential Value of CWA

It was found that CWA has potential to be technically beneficial to all three projects. However, CWA would have increased the cost of the ergonomics project in all cases. The costs would probably have outweighed the benefits in the case of Projects A and B, which had smaller scopes. In the case of Project C, whose scope was similar to a typical Human Factors Integration (HFI) project, the conclusion was reached that CWA would probably have been worth using because the increased costs and probable increased benefits were estimated to be comparable.

The tools originally used on these projects were HTA, Tabular Task Analysis (TTA) – which can be accomplished by the HTA extensions proposed by Stanton (2004), ATLAS (a proprietary tool developed by Human Engineering Ltd, and SHERPA (Systematic Human Error Recovery Prediction Approach) also developed by Human Engineering Ltd (Embrey, 1986). Both these extensions are incorporated in the DTC produced HTA Tool.

The conclusions drawn were that the CWA approach may be a useful one. Its value lies in identifying candidate tasks or *strategies* that define the activities upon which such analyses are performed. CWA can now be seen to be a viable candidate for the description of an activity such as controlling train speed (previously considered to be procedural in nature).

CWA should not be seen as an alternative to detailed, quantitative or qualitative ergonomics analysis such as human error analysis or workload analysis. It was considered unlikely that it would have been possible to obtain comprehensive CWA *work domain* and *control task* information within the scope of the projects and, particularly within the timescales and budgets available.

This limited but positive indication for the applicability of CWA should, however be viewed in the light of potential additional costs, and a limited opportunity to make use of CWA in projects where much of the *work domain* is fixed, or is out of the scope of HF analysis.

4.4 Review of Military CTA Papers

The 595 CTA Abstracts were searched for military references to establish whether the research was conducted within, or had specific application to the military. 78 papers (13.11%) mentioned the military either in the Title, the Abstract itself or the Applications section. Table 2 in the Appendix provides references for these papers and, where available, a summary of the study and the outputs from the research are summarised. Where a specific CTA method is mentioned in one of the military-related abstracts, the abstract number from Table 2 is listed in Appendix 1, Table A-1.

The Military-related abstracts were then considered in terms of:

- Domain – what branch of the military conducted or made use of the work;
- Subject – what type of activity has been studied in the paper;
- Output – the primary use to which the results of the studies were put.

Table 4.5 shows that the domain of Military Aviation has the highest prevalence of published material on CTA, followed by the Navy.

Domain	Number of References
Military Aviation	28
Navy	21
Armed Forces	18
Army	3
Naval ASC	2
Research Organisations	2
Aviation	1
Air Defence	1
Military	1
Unspecified	1

Table 4.5: Military-related CTA abstracts sorted by domain.

Table 4.6 indicates what the main activity being analysed in each paper is. This Table shows that, when specified, Equipment Operation is the main type of activity that is being analysed in the military CTA papers.

Type of Activity	**Number of References**
Unspecified	21
Equipment Operation (e.g. aircraft, weapons systems)	15
Decision Making	14
Monitoring	8
Performance Evaluation and Training	6
Personnel Requirements / Selection	4
Command and Control	3
Planning (e.g. mission planning)	3
Analysis (e.g. fault diagnostics, weather forecasting)	3
Communications / Coordination	1

Table 4.6: Military CTA Abstracts sorted by activity.

Table 4.7 shows that the primary output of CTA is to inform the specification of systems or design of user interfaces.

Output	**Number of References**
System Specification / interface design	29
Overview of methods	14
User model	9
Unspecified / general purpose	9
Procedure / Training / Standards	8
Workload	5

Output	Number of References
Teamwork	3

Table 4.7: Military CTA Abstracts sorted by type of output.

From this analysis, it would appear that much of the current application of CTA to military research is directed towards what might be termed ‘traditional’ HF considerations of system / interface design. The main benefit to be gained from applying a CTA approach to these studies would appear to be related to the type of work being considered, which often takes the form of highly complex decision-making.

4.4.1 CTA methods used in military-related publications

Forty Four of the seventy eight military-related abstracts examined in this report mention a specific CTA method (56.4%); Table 4.8 on the following page summarises the methods referenced in these abstracts. 24 different CTA Methods were identified in the abstracts, 90.9% of abstracts (that specified a method) mentioned one or more of the 14 methods listed in the classification system produced as part of this report.

As mentioned in Section 3.2, the prevalence of the multi-method approach is illustrated by the fact that 25.6% of the Military papers analysed in this report mention two or more CTA methods in their abstract; 14.1% mention two or more of the short-listed CTA methods.

CTA Method	Military Abstracts*																																											
	1	2	3	4	9	10	11	12	13	14	15	16	17	18	20	24	26	27	30	34	35	38	39	41	42	45	49	51	53	54	56	58	62	63	64	65	68	70	71	72	73	74	76	77
Hierarchical Task Analysis										🟦																									🟦							🟦		
Operator Function Model															🟪		🟪																											
Control Task Analysis																											🟪																	
Process Tracing/Protocol Analysis														🟦								🟦	🟦									🟦												
Walk-Through																																								🟦				
Task Analysis		🟦			🟦	🟦						🟦	🟦					🟦			🟦				🟦		🟦								🟦								🟦	
Time Line Analysis	🟪				🟪																																							
Diagram Drawing								🟦																																				
Failure Modes and Effects Analysis																																								🟦		🟦		
Critical Decision									🟦								🟦															🟦												
Critical Incident							🟦		🟦																			🟦											🟦					
Functional Flow Analysis																		🟪																										
Reclassification/ Goal Decomposition																																										🟪		
Hazard and Operability Analysis																																										🟪		
Psychometrics							🟪																			🟪																		
Concept Listing									🟪																							🟪												
Design Storyboarding												🟪																																
Functional Abstraction Hierarchy Approach																														🟪	🟪					🟪		🟪						
Job Analysis																			🟦	🟦				🟦			🟦						🟦	🟦	🟦		🟦	🟦			🟦		🟦	🟦
Social Organization and Cooperation Analysis																																								🟦				
Strategies Analysis				🟦							🟦					🟦													🟦				🟦											
Work Domain Analysis																								🟦							🟦					🟦	🟦							
COGNET - Cognitive Network of Tasks			🟪					🟪																																				
GOMS			🟦					🟦																																				

Summary of Military Abstracts		
Method unspecified	34	(43.6%)
Method specified	44	(56.4%)
1 Method referenced	24	(30.8%)
2 or more Methods referenced	20	(25.6%)
Total Military Abstracts	**78**	-

Summary of Method References		
🟦 References to CTA methods in classification system	53	73.6%
🟪 References to other CTA methods	19	26.4%
Total references	**72**	-
Number of methods referenced	24	-

*Military Abstracts which did not specify a method are not listed

Table 4.8: Summary of CTA methods referenced in the military-related abstracts analysed in this report.
(Abstract numbers are highlighted in red where more than one method has been referenced)

4.4.2 CTA and CADMID

Within the British armed forces, the acquisition of new systems or equipment follows the CADMID (Concept, Assessment, Demonstration, Manufacture, In-service and Disposal) life cycle. Using information on the MoD Acquisition Management System website, it was possible to map the 12 system development phases (from Table 5 in Section 3.3) to aspects of the 6 CADMID stages. This was done in order to indicate the applicability of the 5 CTA Approaches to the CADMID life cycle. The fit between CTA Approaches and CADMID Stages is shown in Table 15, below. It should be noted that only CWA has a high applicability to the first 5 CADMID stages.

CADMID Stage	Development Phase	CTA Approach
Concept	Concept Definition; Requirements Analysis; Function Analysis; Function Allocation; Task Design; Interface and Team Development; Performance, Workload and Training Estimation.	ACTA, CWA GDTA
Assessment	Requirements Review	CWA
Demonstration	Requirements Review; Performance Assurance.	ACTA CWA GDTA
Manufacture	Training Development; Performance Assurance.	ACTA CWA GDTA SCTA
In-service	Requirements Review; Personnel Selection; Training Development; Performance Assurance; Problem Investigation.	ACTA CWA
Disposal		

Table 4.9: Mapping of the 12 development phases to the 6 CADMID stages Table to suggest which CTA Approaches are suited to use in the acquisition of military equipment (Adapted from Bonaceto and Burns, 2003; http://www.ams.mod.uk). CTA Approaches were only listed if they had at least a medium applicability to the CADMID stage.

4.5 Section 4 Conclusions

In this section, it has been shown that the UK Armed Forces are all different in the way that they approach the analysis that precedes training, and that each service has a slightly different view of the process to the other services.

Even where a process is mandated, observance of such process may be cursory in nature. This may, however, be due to either the lack of suitable tools, or to a lack of understanding of the terminology.

The review of those identified papers which refer to military CTA use (mainly US in origin), should be considered as predominantly concerned with the Aviation domain, and with a lesser interest in matters naval. It can also be seen that the aviation bias may be due to the prolific research output of a small number of teams involved in the military aviation world.

5 Software Support for CTA

5.1 A Review of Current CTA Software Tools

As previously mentioned in section 2.3, many CTA methods and approaches can require substantial outlay in terms of time, effort and money to complete properly (Hoffman, 2003; Lee, 2004). As a result, several academic groups and commercial organisations have attempted to automate parts of the CTA process, in order to reduce workload on the practitioner.

The most common approach to this has been the creation of software packages that remove some of the more resource intensive aspects of CTA by supporting the gathering, representation, or analysis of data. Computer models such as MIDAS attempt to simulate the cognitive processes required during task performance. At present there are numerous software packages that claim to be CTA orientated. Of course, whilst the provision of a software package that effectively automates part of the CTA process is useful, the extent to which this removes the burden of cost and time invested is questionable. Typically, software packages are costly to purchase, and a lengthy training process is often required before analysts become proficient enough to actually use them. Furthermore, the extent to which a software package can remove the time-consuming process of data collection for CTA is questionable, and so observation and interviews may still be required, which are in themselves time consuming. A universal CTA software package has yet to emerge, and it remains to be seen whether one will.

The 595 Abstracts were searched for any references to software support tools that had been used during CTA research. References were made to 19 different software tools and are summarised in Table 5.1 on the following page. The tools have been classified according to the type of activity or CTA method, which they have been designed to support.

CTA Tool	**Application / CTA Method**	**No. of Refs**	**First Mention**	**Latest mention**	**Military Refs**
ACQUIST	Knowledge Acquisition (unspecified)	2	1990	1991	
Apex	Cognitive Modelling	1	2002	2002	
Brahms	Multi-agent Simulation	1	1998	1998	
CAATS – Cognitive Activity Analysis Toolset	Cognitive Work Analysis	1	1994	1994	
CAP – Computer Aided Protocol	Protocol Analysis	1	1986	1986	
CASE	Modelling Cognitive Operator Procedures	1	1992	1992	
CAT - Cognitive Analysis Tool	Goal Analysis	1	1998	1998	
CES – Cognitive Environment Simulation	Cognitive Modelling	1	1992	1992	
DNA – Decompose, Network and Assess	Knowledge Acquisition (unspecified)	1	2000	2000	
KADS	Knowledge Acquisition (unspecified)	2	1990	1991	
KEATS	Knowledge Acquisition (unspecified)	2	1990	1991	
KRITON	Knowledge Acquisition (unspecified)	2	1990	1991	
Micro Saint	Discrete Event Simulation	2	1997	1998	19, 22
Pathfinder	Network Scaling	1	1996	1996	
PRONET	Exploratory Sequential Data Analysis	1	1996	1996	
PUMA - Performance and Usability Modelling in ATM	Task Analysis (in Air Traffic Control)	1	1998	1998	
ROGET	Knowledge Acquisition (unspecified)	2	1990	1991	
SANE	Modelling Cognitive Operator Procedures	1	1992	1992	
WDAW – Work Domain Analysis Workbench	Cognitive Work Analysis	2	1998	1999	

Table 5.1: Software Tools used in CTA Research

Nine additional CTA software tools were identified from the CTA Resource website, however there were no references to these in the EIAC abstracts. In order to establish how widely these tools are used in other research areas, the Ergonomics Online database was searched for mentions of them in any type of research. The results of this search are summarised in Table 5.2, below.

	Proposed CTA Function	**EAIC Results**	**Application(s)**
Analytica	Influence Diagrams	0	-
DEMOS	Influence Diagrams	3	Task Analysis; Simulation
KNOT – Knowledge Network Organizing Tool	**Tool**	0	-
INDSCAL	Comparing two or more representations	0	-
IPME	Discrete Event Simulation	4	Human Performance Modelling
MacShapa	ESDA	6	Unspecified Data Analysis; Cognitive Engineering
OFMSpert	Operator Function Model	8	Intelligent Tutoring/ Supervisory Control Support; Team Decision Making
OMAR – Operator Model Architecture	-	4	Human Performance Modelling
SemNet	Graph Construction	1	Graph Construction

Table 5.2: CTA Tools not referenced in the Abstracts examined

Some of the more commonly referenced tools will now be commented upon.

5.1.1 MicroSaint

Supplier: Micro Analysis and Design (http://www.maad.com/):

MicroSaint has now been replaced by Micro Saint Sharp (MSS). Both products are discrete-event simulation tools, with a range of plug-in modules. MSS can be seen as analogous to Matlab in the world of physics research, in that it can be customised to provide a simulation for almost any circumstance. The publishers (who are also a consultancy house) claim that any process that can be represented by a flow-chart can be modelled in MSS. Some modules will aid the analyst by indicating the type of data required (but will not actually assist in obtaining it). The tool is being extensively used in several major USA military projects and is the base for IPME in the UK.

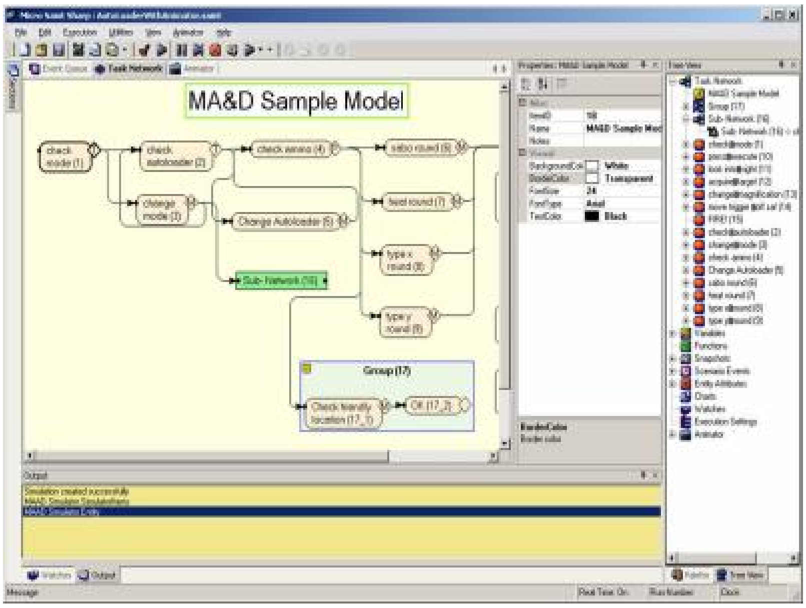

Figure 5.1: Image taken from Micro Analysis and Design Inc (http://www.maad.com/index.pl/product_tour)

For a more detailed description of the original Micro Saint, see Lee (2004); Micro Analysis and Design offer an extensive walkthrough of MSS from their website, using the URL above.

5.1.2 Work Domain Analysis Workbench

WDAW is a tool intended to contribute toward CWA. Presented as “Work in Progress” (Skilton, Cameron and Sanderson, 1998) it was still regarded by Mitre as having that status at the beginning of August 2004.

5.1.3 Cognitive Activity Analysis Tool Set

The Cognitive Activity Analysis Tool Set (CAATS) has its origin in research work done for the European Space Research and Technology Centre. It is closely linked with the Goals-Means Task Analysis (GMTA) approach. The components of CAATS are:

- System tasks overview and predicted workload assessment, based on task analysis and task analytic simulation.
- Observed behaviour analysis of the man-machine system based on video analysis.

- Resource conflict analysis.
- Comparison of predicted and observed results.
- Subjective workload analysis (TLX Tool).

CAATS was reported on by MacLeod, Farkin and Helyer (1993). It was succeeded by the Cognitive Activity, Development, and Evaluation Tool Set (CADETS). The EIAC reference review (above) notes one reference in 1994. Note these two projects were performed as a part of ESA research to investigate concepts only and as well as using the initial version of Microsoft Access they also used Microsaint for Windows.

5.1.4 Other Tools

There are other tools in existence for some form of Cognitive Analysis, and some have been identified above. These include:

The Cognimeter. This is a proprietary tool developed/used by Klein associates

The IH Tool. This is a Failure Modes and Effects Analysis (FMEA) tool, available at the US Institute for Healthcare Improvement.

Cognosys is a 15-year old university research tool, used for Knowledge Engineering. As the approach known as Cognitive Mapping may be undergoing a comeback, it is possible that Cognosys might be resurrected. Semnet is another such tool.

MacSHAPA is a tool for performing video analysis and subsequent data analysis. Whilst dating back to the early 1990s, it was updated in 2003 to run on Apple System X.

OFMspert is an expert system approach to control modelling from the 1980s.

Omar (D-OMAR, OmarL) is another AI approach for human-performance modelling, using simulation and agent theory. BBN Technologies developed it for the US Airforce.

Analytica is a commercial product from Lumina Decision Systems (US) and can be considered as an improvement on the use of spreadsheets for creating multi-dimensional tables. Lumina consider it as a tool for building business models, and for policy analysis.

INDSCAL is a Dutch university approach to Individual Differences Scaling Analysis. While this might appear to have an HF application, the INDSCAL Manual emphasises that all object data must be transformed in to one standard type prior to analysis.

IPME or Integrated Performance Modelling Environment. This is another modelling and simulation approach based on the MicroSaint package. It is focussed on networked simulations, and on the use of

HLA (the High Level Architecture mandated by the US DoD) in particular.

GMTA or Goals-Means Task Analysis originated from the work of Hollnagel and Lind in the late 1980s and early 1990s. The approach can be used in parallel to HTA, for procedural tasks, or independently for non-procedural tasks. The method places a high value on the quality of task products, and task supporting conditions, as a means of satisfying task goals. A software tool was developed for the European Space Agency and although theoretically in the Public Domain as an ESA project, no examples of the program are readily available for inspection. Since GMTA has a relatively simple structure, and an established notation, and since software environments have become both more user friendly, and more powerful, in the last decade, the prototyping of a new GMTA tool may repay the time investment by offering an analysis approach that is intermediate between KSA and CWA.

5.1.5 Limited Availability of Support Tools

It can be seen that there is a plethora of approaches claiming some link to CTA, and an almost complete absence of accepted software tools. The following excerpt was taken from a conversation on the CTA Resource Website Discussion forum and illustrates the current lack of appropriate software support tools for CTA:

“I was wondering if you have come across any software that you use for conducting/analyzing cognitive task analyses.. or for extracting/analyzing verbalizations in teams.”

“I wish we had better tools for this. For documenting the Cognitive Task Analyses we have tried different outlining and charting programs as our method is very hierarchical. None of the program we've tried are great. (Flowchart was okay, Visio was terrible!) We are currently just using the charting functions in MS Office. Not great, but sufficient for what we are doing.”

“I found the same problem - there are a few companies out there who supply task analysis software...”

[Taken from CTA Resource Discussion forum, 2002]

(http://www.ctaresource.com/discussion/)

5.2 Specifications for a New CTA Software Tool

The big question here is: “What should be the theoretical basis for any CTA Software tool?” Subsidiary questions relate to the benefit to be obtained by any or all of the Armed Forces; whether any benefit would so obtain in the short, medium or long term, whether any proposed tool would actually be used if delivered, and if so, by whom.

Three approaches appear to be viable:

Short Term KSA Development. The KSA approach is already in use – to varying extents – in all three UK Services, and is mandated in JSP502. There is no doubt that a software tool based on the Knowledge and Skills decompositions advocated by Hone and Moulding (2000), together with the Attitudes decomposition used by the Royal Navy and RAF could be prototyped very quickly and would integrate well with the HTA tool/specification being developed as part of HFI-DTC WP 2.2. Such a tool could probably be brought into the cycle of test-revise spec-test again-revise again-etc within a few months – leading to a usable tool within six months. This would offer a direct benefit to the Training branches of all services, and would also offer a standard KSA method to anyone who has to observe JSP502.

Medium Term GMTA development. For a more comprehensive analysis tool, the GMTA approach has the advantage of a well-developed set of principles, and an established notation. It may still be possible to locate one of the original S/W tools (to use as an example) but, given that a fund of know-how still exists, it is envisaged that a working prototype could be developed from scratch in 9-12 months. The use of some of the existing software engineering methods could produce a non-working pre-prototype in a shorter time (in order to obtain Service impressions and opinions). Such a tool would have applicability to (at least) the first three phases of the CADMID cycle.

Long Term CWA Development. It is suggested that CWA is the most comprehensive approach to CTA and work analysis in general. The development of a CWA tool would require:

- An outline specification for each of the 5 main components of CWA included in a CWA architecture;
- A plan for the integration of these components, and then of all of them with the current HTA tool;
- Further research to see if any tools currently exist for any of the CWA components, such as could be incorporated into a unified CWA tool;
- The development of a non-working pre-prototype that could be offered for comment to the wider MOD audience (i.e. not restricted to Service training).

Since a developed CWA toolset could be most usefully applied at the beginning of the CADMID cycle (although it seems to be applicable to most of the cycle), this approach would only deliver the maximum benefit if used from the start of a major project. This could be seen as restricting its use to FOAS and possibly FRES. It is considered unlikely that the development of a CWA tool would reach the prototype / test stage before the end of the current DTC contract. Developing a non-working pre-prototype would enable the concept of a CWA tool to be presented to DPA and the Directors of Equipment Capability, so that they could assess its potential value, prior to undertaking full development.

It can be seen that the development of a CTA tool (or even the specification for such a tool) represents substantial risk - both technical and commercial. The short-term approach indicated above (KSA and GMTA) is considered to have the lowest risk in progression towards CWA, and to offer the maximum payback in terms of immediate utility.

6 Conclusions

6.1 CTA Methods

It can be seen from the foregoing that there is no consensus of opinion as to what constitutes a CTA method. This is exemplified by the argument over whether HTA is part of CTA, or the reverse, and whether Task Analysis is to be considered as distinct from HTA or CTA.

6.2 CTA Approaches

The comments in the preceding paragraph could be repeated here to some extent. Several of the approaches stem from the Artificial Intelligence community; they cannot, however, be considered as “Cognitive” processes merely because they reproduce the output of a human brain unless there is also some understanding of the internal processes of that brain.

Three approaches were identified in 5.2 (above) as being suitable for Defence related work.

> CWA is potentially the best all-round methodology but still requires considerable development. It has been shown that it may not be cost effective on all projects.
>
> GMTA appears to be a good intermediate approach, suited to both training and procurement.
>
> KSA is the easiest to implement, has already got support within the Armed Forces, is probably the best suited to interoperate with the HTA tool (from WP2.2.1), and offers a direct benefit to training. However, the Attitude domain needs to be developed to make it applicable to the needs of all 3 services and the civil service.

6.3 Military CTA Research

The Military-related research identified in the EIAC database is predominantly aviation and Ergonomics related, and it would be unwise to generalise too much from such work. It was also noted that a small number of research teams contributed the bulk of the work – this may have been responsible for the bias toward the aviation domain.

6.4 CTA Support tools

The lack of good CTA tools appears to be directly related to the lack of agreement on the best CTA methodology. Some of the alleged CTA tools only support a very small part of CTA, and many are tools from other domains that may have been pressed into service for CTA for reasons of availability rather than suitability.

In the previous section, this report identified short, medium and long-term solutions to the lack of CTA tools that would be of direct benefit to the UK Armed Forces.

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8 Appendices

8-1 Table A-1: Classification Scheme Applied to CTA Abstracts

	No. of Refs	**First Mention**	**Latest mention**	**% of CTA Abstracts**	**Military References**	**CTA Approach**	**Software Tools**
1.*Goal-Means Decomposition*	-	-	-	-	-	-	*CAT*
o Hierarchical Task Analysis	14	1993	2003	2.35	14, 64, 74		
o Operator Function Model (can be used as an observational tool as well)	5	1997	2001	0.84	20, 26	Cognitive Function Model	*OFMSpert*
o Control Task Analysis	1	2000	2000	0.17	49		
o Worker Competency Analysis	4	1988	1999	0.67		Cognitive Work Analysis	
2. *Empirical Analysis of practitioner Performance*	-	-	-	-	-	-	-
o Observation (Expert; Expert vs. Novice)	43	-	-	-	-	Goal Directed Task Analysis	-
▪ Elicitation (Field Observations, Simulated Exercises, Performance under Controlled Conditions)	-	-	-	-	-	-	*KRITON, KADS, ACQUIST, KEATS,*

							ROGET
• Activity Sampling	0	-	-	0		Cognitive Work Analysis	
• Active Participation	0	-	-	0			
• Event Co-Occurrence/Transition Probabilities	2	1995	1996	0.34			
• Focused Observation	0	-	-	0			
• Interruption Analysis	0	-	-	0			
• Nonverbal Reports	27	1988	2003	4.54			
• Process Tracing/Protocol Analysis (can be used to analyse team activity)	81	1984	2002	13.61	18, 38, 39, 58		*CAP*
• Self-Critiquing/Eidetic Reduction	0	-	-	0			
• Shadowing Another	0	-	-	0			
• Structured Observation	0	-	-	0			
• Thinking Aloud	8	1986	1995	1.34		*Skill-Based CTA Framework*	
• Walk-Through	10	1990	2003	1.68	72		
▪ Analysis	-	-	-	-	-	-	-
• Exploratory Sequential Data Analysis (ESDA)	1	1996	1996	0.17			*MacShapa* *PRONET*
• Link Analysis	0	-	-	0			

• Operational Sequence Diagrams	2	1993	1995	0.34			
• Task Analysis	83	1985	2004	13.95	2, 9, 10, 16, 17, 27, 35, 42, 49, 64, 76		*PUMA (Air Traffic Control)*
• Time Line Analysis	6	1986	1998	1.01	1, 9		
o Document Analysis	-	-	-	-	-	Goal Directed Task Analysis	-
▪ Elicitation (Manuals, Procedures, Memos, Letters, Textbooks)	-	-	-	-	-	-	-
▪ Analysis	-	-	-	-	-	-	-
• Barrier and Work Safety Analysis	8	1987	2003	1.34			
• Diagram Drawing	10	1988	2003	1.68	12	*Skill-Based CTA Framework*	
• Event Trees	1	1988	1988	0.17			
• Failure Modes and Effects Analysis	10	1989	2003	1.68	72, 74	*Skill-Based CTA Framework*	
• Fault Trees	1	1988	1988	0.17			
• Management Oversight Risk Tree Technique	0	-	-	0			
o Interviews (Expert; Expert vs	46	-	-	-		*Applied*	

Novice)						*Cognitive Task Analysis;* Goal Directed Task Analysis; *Skill-Based CTA Framework*	
▪ Elicitation	-	-	-	-	-	-	-
• Cloze Experimental/Minimal Scenario Technique	0	-	-	0			
• Critical Decision	10	1991	2004	1.68	13, 26, 58	*Skill-Based CTA Framework*	
• Critical Incident	34	1989	2004	5.71	11, 13, 51, 71		
• Critical Retrospective	1	1990	1990	0.17			
• Crystal Ball/Stumbling Block	0	-	-	0			
• Functional Flow Analysis	3	1998	1999	0.50	27		
• Identifying Aspects of the Representation	0	-	-	0			
• Information Flow Analysis	4	1996	1999	0.67			
• Interaction Analysis	1	2002	2002	0.17			
• Reclassification/ Goal	4	1994	2003	0.67	74		

Decomposition							
• Retrospective/Aided Recall	2	1990	1990	0.34			
• Step Listing	0	-	-	0			
• Talk-Through	0	-	-	0			
• 20 Questions	0	-	-	0			
• Unstructured Interview	0	-	-	0			
• Workflow Model	0	-	-	0			
▪ Analysis	-	-	-	-			
• Comparing Two or More Representations	0	-	-	0			*INDSCAL*
• Conceptual Graph Analysis	4	1991	1995	0.67			*DNA*
• Content Analysis	3	1986	1999	0.50			
• Correlation/Covariance	1	1989	1989	0.17			
• Discourse/Conversation/ Interaction Analysis	1	2002	2002	0.17			
• Grounded Theory	0	-	-	0			
• Influence Diagrams	0	-	-	0			*Analytica, DEMOS*
o Questionnaires	6	-	-	-			
o Group Activities	-	-	-	-			
▪ Elicitation	-	-	-	-	-		-
• Focus Groups/Joint Application Development	0	-	-	0			

• Group Discussion	0	-	-	0			
• Group Interview	0	-	-	0			
• Hazard and Operability Analysis	1	2003	2003	0.17	74		
• Precursors, Actions, Results and Interpretations (PARI)	0	-	-	0		*Skill-Based CTA Framework*	
• Role Play	0	-	-	0			
• Table-Top Analysis	0	-	-	0			
▪ Analysis	-	-	-	-	-		-
o Psychometrics	6 (method not specified)	1991	2003	-	11, 45	*Skill-Based CTA Framework*	
• Concept Listing	4	1986	2002	0.67	13, 58		
• Controlled Association	0	-	-	0			
• Controlled Simulated Observations	0	-	-	0			
• Distinguishing Goals	0	-	-	0			
• Dividing the Domain	0	-	-	0			
• Drawing Closed Curves	0	-	-	0			
• Eliciting Estimations of Probability and Utility	0	-	-	0			
• Free Association	0	-	-	0			
• Graph Construction	1	1995	1995	0.17			*SemNet*
• Hierarchical Sort	0	-	-	0			

• Laddering	1	1995	1995	0.17			
• Likert Scale Items	0	-	-	0			
• Magnitude Estimation	0	-	-	0			
• Multidimensional Card Sorting	0	-	-	0			
• Multidimensional Scaling	1	2003	2003	0.17			
• P Sort	0	-	-	0			
• Paired Comparison	0	-	-	0			
• Q Sort	1	1996	1996	0.17			
• Repeated Sort	0	-	-	0			
• Repertory Grid	1	1995	1995	0.17			
• Statistical Modelling/ Policy Capturing	1	1987	1987	0.17			
• Structural Analysis Techniques	0	-	-	0			*KNOT*
• Triad Comparison	0	-	-	0			
o Miscellaneous Analysis Techniques	-	-	-	-			*Brahms, CAATS, CASE, CES, OMAR, SAME,*
• Design Storyboarding	2	1997	1999	0.34	16		
• Functional Abstraction Hierarchy Approach	8	2000	2003	1.34	54, 56, 65, 70		

• Function Allocation Issues and Tradeoffs	2	1988	2001	0.34			
• Job Analysis	55	1989	2003	9.24	30, 34, 41, 49, 62, 63, 64, 68, 70, 73, 76, 77		
• Network Scaling	1	1996	1996	0.17			*Pathfinder*
• Social Organization and Cooperation Analysis	15	1987	2003	2.52	72	Cognitive Work Analysis	
• Strategies Analysis	101	1984	2004	16.97	4, 15, 24, 53, 62	Cognitive Work Analysis	
• Work Domain Analysis	12	1998	2002	2.02	41, 56, 65, 68	Cognitive Work Analysis	
3. *Cognitive Modelling*	62 (method not specified)	-	-	-	4, 17, 21, 23, 28, 58, 76		APEX
o ACT-R	2	2001	2003	0.34			DNA
o COGNET - Cognitive Network of Tasks	7	1989	1998	1.18	3, 12		
o GOMS	26	1985	2002	4.37	3, 12		
o Man-machine Integration Design and Analysis System (MIDAS)	1	1994	1994	0.17			
o Clustering Routines(?)	0	-	-	0			

o Discrete Event Simulation	0	-	-	0			*IPME* *MicroSaint*
o EPIC (Executive Process Interactive Control)	2	1997	1997	0.34			
o Operator Model Architecture (OMAR)	0	-	-	0			
o SOAR	5	1992	1996	0.84			
o Task Knowledge Structures (TKS)	4	2000	2004	0.67			

8.2 Table A-2: Military CTA Studies

Abstract Number	**Domain**	**Activity / Operator**	**Method**	**Output**	**Year**	**Reference**
1	Military Aviation (US Army)	Helicopter Operation (flight control, mission functions)	Analysis of workload during mission segments to determine feasibility of single crewmember operation of multipurpose helicopter.	Computer models of workload for 1 and 2 crewmember situations, as well as prediction of reduction in workload with individual or multiple automation options.	1986	ALDRICH, T.B.; SZABO, S.M. "A Methodology for Predicting Crew Workload in New Weapon Systems" *A Cradle for Human Factors. Proceedings of the Human Factors Society 30th Annual Meeting, Dayton, Ohio, September 29-October 3, 1986,* Volume 1, 633-637. The Human Factors Society, Santa Monica, California.
2	Naval Air Systems Command	Computer Based Training (CBT)	A review of standards governing CBT development and procurement.	High-level recommendations for evolving standards that will govern the next generation of CBT systems	1988	SEAMSTER, T.L.; SNYDER, C.E.; TERRANOVA, M.; WALKER, W.J.; JONES, D.T. "Human Factors in the Naval Air Systems Command: Computer Based Training" *Riding the Wave of Innovation. Proceedings of the Human Factors Society 32nd Annual Meeting, Anaheim, California, October 24-28, 1988,* Volume 2, 1095-1099. The Human Factors Society, Santa Monica, California.
3	Military Aviation;	Anti-submarine warfare – Airborne	COGNET modelling methodology.	An adaptive intelligent interface for TACCOs.	1989	ZUBRITZKY, M.C.; ZACHARY, W.W.; RYDER, J.M. "Constructing and Applying

	Navy	Tactical Coordinators (TACCOs)				Cognitive Models to Mission Management Problems in Air Anti-Submarine Warfare” *Perspectives. Proceedings of the Human Factors Society 33rd Annual Meeting, Denver, Colorado, October 16-20, 1989,* Volume 1, 129-133. The Human Factors Society, Santa Monica, California.
4	Military Aviation	Aircraft operation (flight control, mission functions)	Modelling of pilot activities.	A Computerized Cognitive Model.	1989	VALOT, C.; AMALBERTI, R.; BATAILLE, M.; DEBLON, F.; PAIGNAY, J.M. “Metaknowledge for Time and Reliability. Luxury or Necessity?” *Proceedings of the Second European Meeting on Cognitive Science Approaches to Process Control, Siena, Italy, October 24-27, 1989.* 81-92. Organised by the Commission of the European Communities - JRC, Ispra and the University of Siena, Italy. 81-92.
5	Naval Air Systems Command (NAVAIR)	Training systems	Cognitive task analysis of airborne weapons operators.	Explanation of the role that cognitive task analysis can play in the development of advanced training systems; examples of CTA methodology are presented.	1989	TERRANOVA, M.; SNYDER, C.E.; SEAMSTER, T.L.; TREITLER, I.E. “Cognitive Task Analysis: Techniques Applied to Airborne Weapons Training” *Perspectives. Proceedings of the Human Factors Society 33rd Annual Meeting, Denver, Colorado, October 16-20, 1989,*

						Volume 2, 1989. The Human Factors Society, Santa Monica, California.
6	Military Aviation	Combat aircraft operation (flight control, mission functions)	Knowledge acquisition and study of cognitive architecture.	Computer Model of operator's cognitive functioning – AID; Context Analyser to assist the pilot.	1989	VALOT, C.; DEBLON, F.; AMALBERTI, R. "AIDE: Towards Human Based Models for Rapid Process Control" in J. Ranta (Ed) *Analysis, Design and Evaluation of Man-Machine Systems 1988*. 393-398. Pergamon Press, Oxford.
7	Navy	Tactical Displays	Development and use of an evaluation method.	Definition and evaluation of options for a standardised coding scheme for naval tactical displays.	1990	CAMPION, J.; BROCKETT, M.A.; MARTIN, D.; RATE, M. "A Cognitive Approach to the Definition and Evaluation of a Standard for Naval Tactical Display Symbology" in D. Diaper, D. Gilmore, G. Cockton and B. Shackel (Eds) *Human-Computer Interaction - INTERACT '90.* 505-512. North-Holland, Amsterdam.
8	Navy	(Ship) Command and Control	Static and dynamic analyses of workload, effectiveness and efficiency during mission critical tasks.	Recommendations for control centre design improvement.	1990	PELLY, R.C.; CRAMPIN, T. "Human Factors Today and Tomorrow in Ship Control Centres" *Human Factors in Warships and Naval Systems, a Symposium Hosted by the British Naval Equipment Association and Sponsored Jointly by the Assistant Chief of the Defence Staff, Operational Requirements (Sea Systems),*

						and the Director General, Naval Manpower and Training, UK. 99-114.
9	Military Aviation (US Army)	Helicopter Operation (flight control, mission functions)	Development of Task Analysis/Workload (TAWL) methodology.	Predictive models of workload; Evaluation of system manning and training requirements.	1990	HAMILTON, D.B.; BIERBAUM, C.R. "Task Analysis/Workload (TAWL): A Methodology for Predicting Operator Workload" *Countdown to the 21st Century. Proceedings of the Human Factors Society 34th Annual Meeting, Orlando, Florida, October 8-12, 1990,* Volume 2, 123928. The Human Factors Society, Santa Monica, California.
10	Military	Electronic Warfare training	Integrated (Cognitive and Behavioural) task analysis of experts vs. novices.	Information on expert and novice mental models, effective problem solving heuristics and algorithms; training aids, recommendations and support of the development of a military training system.	1990	REDDING, R.E.; LIERMAN, B. "Development of a Part-Task, CBI Trainer Based upon a Cognitive Task Analysis" *Countdown to the 21st Century. Proceedings of the Human Factors Society 34th Annual Meeting, Orlando, Florida, October 8-12, 1990,* Volume 2, 1337-1341. The Human Factors Society, Santa Monica, California.
11	Military Aviation	Selection of Air Traffic Control Cadets	Review	Suggested influence of new technologies on the ability requirement of future Air Traffic Control Specialists (ATCSs).	1991	HATTIG, H.J. "Selection of Air Traffic Control Cadets" in R. Gal and A.D. Mangelsdorff (Eds) *Handbook of Military Psychology.* 115-129. John Wiley, Chichester.

12	Navy	Anti-Submarine Warfare	COGNET modelling methodology.	Requirement for decision aids for managing goals and goal conflicts.	1992	WEILAND, M.Z.; COOKE, B.; PETERSON, B. "Designing and Implementing Decision Aids for a Complex Environment Using Goal Hierarchies" *Innovations for Interactions. Proceedings of the Human Factors Society 36th Annual Meeting, Atlanta, Georgia, October 12-16, 1992,* Volume 1, 394-398. The Human Factors Society, Santa Monica, California.
13	Military Aviation	Airborne Warning and Control System – AWACS (Weapons Director Station)	Cognitive Systems Engineering: Cognitive Task Analysis, development and evaluation of the revised interface.	Re-design of the Weapons Director Station.	1993	KLINGER, D.W.; GOMES, M.E. "A Cognitive Systems Engineering Application for Interface Design" *Designing for Diversity. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, Seattle, Washington, October 11-15, 1993,* Volume 1, 16-20. The Human Factors and Ergonomics Society, Santa Monica, California.
14	Navy	Command and Control	Adaptation of Hierarchical Task Analysis (HTA) to study teams.	Suggests training procedures.	1996	ANNETT, J. "Recent Developments in Hierarchical Task Analysis" in S.A. Robertson (Ed) *Contemporary Ergonomics 1996*. 263-268. Taylor and Francis, London
15	Armed Forces	Medicine - Patient Evacuation	Analysis of operator understanding of	Predicted effect on operator of proposed automated scheduling	1996	COOK, R.; WOODS, D.; WALTERS, M.; CHRISTOFFERSEN, K. "The

			problem space and resulting strategy.	system.		Cognitive Systems Engineering of Automated Medical Evacuation Scheduling and Its Implications” *Proceedings of the Third Annual Symposium on Human Interaction with Complex Systems - HICS '96, Dayton, Ohio, USA, August 25-28, 1996*, 202-207. IEEE Computer Society Press, Los Alamitos, California.
16	Navy	AEGIS Cruiser Officers	Use of Cognitive Task Analysis methods to identify decision requirements.	Storyboards for a human-computer interface that supports the user's needs.	1997	KLEIN, G.; KAEMPF, G.L.; WOLF, S.; THORSDEN, M.; MILLER, T. “Applying Decision Requirements to User-Centered Design” *International Journal of Human-Computer Studies*, Volume 46(1), 1-15.
17	Navy	Commanders of Nuclear Powered Attack Submarines	Cognitive process analysis of situation assessment behaviour.	An evaluated computational cognitive model of situation assessment behaviour.	1997	EHRET, B.D., GRAY, W.D., KIRSCHENBAUM, S.S. “Submariner Situation Assessment: A Cognitive Process Analysis and Modeling Approach” *Ancient Wisdom - Future Technology. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, Albuquerque, New Mexico, September 22-26, 1997,* Volume 1, 163-167. The Human Factors and Ergonomics Society, Santa Monica, California.

18	Navy	Damage Control Officers on Naval Frigates	Cognitive Task Analysis of Damage Control activity.	Functional requirements for a Damage Control Decision Support System.	1997	SCHRAAGEN, J.M. “Discovering Requirements for a Naval Damage Control Decision Support System” in C.E. Zsambok and G. Klein (Eds.) *Naturalistic Decision Making*. 227-232. Lawrence Erlbaum, Mahwah, New Jersey.
19	Military Aviation	Combat aircraft operation (flight control, mission functions)	Analysis of operator workload and Situational Awareness during simulated combat missions.	An evaluated computer model of mental workload and Situational Awareness.	1997	SEE, J.E.; VIDULICH, M.A. “Assessment of Computer Modeling of Operator Mental Workload during Target Acquisition” *Ancient Wisdom - Future Technology. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, Albuquerque, New Mexico*, *September 22-26, 1997,* Volume 2, 1303-1307. The Human Factors and Ergonomics Society, Santa Monica, California.
20	Unspecified	Weapons Platform operation	Cognitive Function Modelling (a combination of Cognitive Task Analysis techniques with the Operator Function Modelling methodology) of operator role.	A set of requirements for system support of human decision-making.	1997	ANASTASI, D.; HUTTON, R.; THORDSEN, M.; KLEIN, G.; SERFATY, D. “Cognitive Function Modeling for Capturing Complexity in System Design” *Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics, Computational Cybernetics and Simulation, Orlando, Florida*, *USA, October 12-15, 1997,*

						Volume 1, 221-226. Institute of Electrical and Electronics Engineers, Piscataway, New Jersey
21	Military Aviation	Combat aircraft operation (flight control, mission functions)	Cognitive Task Analysis of combat aircraft operation.	Human-performance model of a fighter pilot.	1997	BAUTSCH, H.S.; NARAYANAN, S.; MCNEESE, M.D. “Development and Evaluation of a Cognitive Model of Human-Performance in Fighter Aircraft” *Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics, Computational Cybernetics and Simulation, Orlando, Florida, USA, October 12-15, 1997,* Volume 3, 2109-2113. Institute of Electrical and Electronics Engineers, Piscataway, New Jersey.
22	Military Aviation	Combat aircraft operation (flight control, mission functions)	Analysis of operator workload and Situational Awareness during simulated combat missions.	An evaluated computer model of mental workload and Situational Awareness.	1998	SEE, J.E.; VIDULICH, M.A. “Computer Modeling of Operator Mental Workload and Situational Awareness in Simulated Air-to-Ground Combat: An Assessment of Predictive Validity” *International Journal of Aviation Psychology*, Volume 8(4), 351-375.
23	Armed Forces	Unspecified	Review.	Examples of Cognitive Model use and their implications for user interface design.	1998	JOHN, B.E. “Cognitive Modeling for Human-Computer Interaction” in W. Davis, K. Booth and A. Fournier (Eds.) *Proceedings of Graphics*

						Interface '98, Vancouver, British Columbia, British Columbia, 18-20 June 1998, 161-167. Canadian Information Processing Society (CIPS), Toronto, Ontario, Canada.
24	Military Aviation	Air Campaign Planning	Cognitive Task Analysis of plan evaluation and judgement of plan robustness.	The production of a campaign planning software tool – the Bed-Down Critic.	1998	MILLER, T.E. “A Cognitive Approach to Developing Tools to Support Air Campaign Planners” *Proceedings of the Fourth Conference on Naturalistic Decision Making, Warrenton, Virginia, May 29-31, 1998.* 10pp.
25	Military Aviation	Uninhabited Combat Aerial Vehicle (UCAV) operation (flight control, mission functions)	Consideration of the use of Cognitive Work Analysis in designing interfaces.	No details available.	1998	FLACH, J.; EGGLESTON, R.; KUPERMAN, G.; DOMINGUEZ, M.C. “Uninhabited Combat Aerial Vehicles: Who's Driving?” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998,* Volume 1, 113-117. The Human Factors and Ergonomics Society, Santa Monica, California.
26	Navy	Manning requirements of new Aircraft Carrier and Cruiser designs.	Use of Cognitive Function Modelling (combination of Operator Function Model and Cognition Task	Description of the critical decisions, judgements, and challenges associated with cognitively complex roles.	1998	THORDSEN, M.; HUTTON, R.; ANASTASI, D. “The Cognitive Function Model” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society*

			Analysis) in the identification of tasks and assessment of their cognitive complexity.			*42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998,* Volume 1, 385-389. The Human Factors and Ergonomics Society, Santa Monica, California.
27	Military Aviation	Radar Operation	Team Cognitive Task Analysis techniques used to model the operations independent of the current roles and team structure.	Radar operation model which provides input into the design of a modernized radar system.	1998	ANASTASI, D.; MILLER, D.; LIND, A.M.T. “Team CTA Applied to Radar Operations System Modernization” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 1, 210-214. The Human Factors and Ergonomics Society, Santa Monica, California.
28	Navy	Command Centre design	Cognitive Modelling techniques used to capture and represent users goals and actions.	An evaluation of different User Interface (UI) options prior to prototype development.	1998	COURY, B.G.; STRAUSS, R.A. “Cognitive Models in User Interface Design” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 1, 325-329. The Human Factors and Ergonomics Society, Santa Monica, California.
29	Navy	Landing Signal Officer role	Team Cognitive Task Analysis of	A set of requirements for new systems/interfaces	1998	KLINGER, D.; THORDSEN, M. “Team CTA Applications and

		aboard Aircraft Carriers	decision making requirements.	to assist the team in performing their role.		Methodologies” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 1, 206-209. The Human Factors and Ergonomics Society, Santa Monica, California.
30	Military Aviation	Fighter aircraft training and Simulator development	Cognitive Work Analysis of operator role.	A set of requirements for the training system.	1998	LINTERN, G.; NAIKAR, N. “Cognitive Work Analysis for Training System Design” in P. Calder and B. Thomas (Eds.) *Proceedings of the 1998 Australasian Computer Human Interaction Conference, OzCHI '98, Adelaide, South Australia, November 30-December 4, 1998*, 252-259*.* IEEE Computer Society, Los Alamitos, California.
31	Navy	Landing Signal Officer role aboard Aircraft Carriers	Team Cognitive Task Analysis of decision making requirements.	A set of requirements for new systems/interfaces.	1998	MORPHEW, M.E.; THORDSEN, M.L.; KLEIN, G. “The Development of Cognitive Analysis Methods to Aid Interface Design” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 1, 305-309. The

						Human Factors and Ergonomics Society, Santa Monica, California.
32	Military Aviation	Combat aircraft operation (flight control, mission functions)	Review of a Plan-Goal-Graph representation of cognitive task content.	A critique of the utility of the Plan-Goal-Graph representation.	1998	SHALIN, V.L.; JACQUES, P.F. “Task Representation for Decision Support, Performance Enhancement and Training” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 1, 380-384. The Human Factors and Ergonomics Society, Santa Monica, California.
33	Armed Forces	Unspecified	Cognitive Task Analysis and modelling of decision making.	No details available.	1998	ZACHARY, W.W.; RYDER, J.M.; HICINBOTHOM, J.H. “Cognitive Task Analysis and Modeling of Decision Making in Complex Environments” in J.A. Cannon-Bowers and E. Salas (Eds.) *Making Decisions under Stress: Implications for Individual and Team Training*, 315-344. American Psychological Association, Washington, D.C.
34	Defence Science and Technology Organisation (DSTO)	Unspecified	Review: introduction to the principles of Cognitive Work Analysis (CWA).	Introduction to a DSTO paper, detailing their use of CWA.	1998	SANDERSON, P. “Cognitive Work Analysis and the Analysis, Design, and Evaluation of Human-Computer Interactive Systems” in P. Calder and B.

						Thomas (Eds.) *Proceedings of the 1998 Australasian Computer Human Interaction Conference, OzCHI '98, Adelaide, South Australia, November 30-December 4, 1998,* 220-227. IEEE Computer Society, Los Alamitos, California.
35	Military Aviation	Coastal Patrol Aircraft operation (flight control, mission functions)	PTA (task analysis method based on Perceptual Control Theory).	Information requirements for interface and/or systems design.	1998	FARRELL, P.S.E.; CHERY, S. “PTA: Perceptual Control Theory Based Task Analysis” *Human-System Interaction: The Sky's No Limit. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Chicago, Illinois, October 5-9, 1998*, Volume 2, 1314-1318. The Human Factors and Ergonomics Society, Santa Monica, California.
36	Defence Evaluation Research Agency (DERA)	Police Training and Tactical Firearms Unit	Investigation of how mental models contribute to team performance.	Prototype computer-based tools which can be used to provide feedback and identify training interventions.	1999	PASCUAL, R.G. “Tools for Capturing and Training Shared Understanding in Teams” *People in Control*, 57-63. Institution of Electrical Engineers, London.
37	Armed Forces	Crew station design process.	A review of Cognitive Engineering use in military system design.	Details of the differences between Cognitive Engineering practices in academic research and in military system design.	1998	EGGLESTON, R.G. “Cognitive Engineering: The Latest Fad or a True Step Forward as an Approach to Complex Multi-Person System Analysis and Design?” *Collaborative Crew Performance in Complex*

						Operational Systems. Report No.RTO-MP-4, 15/1-15/12. North Atlantic Treaty Organization, Research and Technology Organization, Neuilly-sur-Seine, France.
38	Military Aviation	Combat aircraft operation (flight control, mission functions)	Observation of human-human cooperation in a simulator, followed by a protocol analysis.	A modified coding scheme for cooperative activities; also highlighted the main features of cooperation in fighter aircraft.	1999	LOISELET, A.; HOC, J.M. “Assessment of a Method to Study Cognitive Cooperation in Fighter Aircraft Piloting” in J.M. Hoc, P. Millot, E. Hollnagel and P.C. Cacciabue (Eds.) *CSAPC '99. Proceedings of the 7th European Conference on Cognitive Science Approaches to Process Control, Villeneuve d'Ascq, France, 21-24 September 1999*, 61-66. Presses Universitaires de Valenciennes, Valenciennes, France.
39	Military Aviation	Aircraft Maintenance and Maintenance Manuals	Cognitive task analysis of aircraft maintenance role.	A set of user requirements for 3D electronic Technical Order graphics.	1999	BAUTSCH, H.S.; CALHOUN, C. “Implementing 3D Graphics in Aircraft Maintenance Manuals: A Cognitive Task Analysis Approach” in R.S. Jensen, B. Cox, J.D. Callister and R. Lavis (Eds.) *Proceedings of the Tenth International Symposium on Aviation Psychology, May 3-6, 1999*, Volume 2, 724-729.
40	Military Aviation	Uninhabited Aerial Vehicle	Cognitive Task Analysis of UAV	Development of a UAV simulator, representing	1999	GUGERTY, L.; DEBOOM, D.; WALKER, R.; BURNS, J.

		(UAV) operation (flight control, mission functions)	operators.	the key cognitive demands of the task.		"Developing a Simulated Uninhabited Aerial Vehicle (UAV) Task Based on Cognitive Task Analysis: Task Analysis Results and Preliminary Simulator Performance Data" *Houston... We Have a Solution! Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting, Houston, Texas, September 27-October 1, 1999,* Volume 1, 86-90. The Human Factors and Ergonomics Society, Santa Monica, California.
41	Military Aviation	Airborne Early Warning and Control (AEWandC) aircraft	Cognitive Work Analysis (CWA) review.	Illustration of CWA techniques in the tender evaluation for Australia's AEWandC system.	1999	SANDERSON, P.; NAIKAR, N.; LINTERN, G.; GOSS, S. "Use of Cognitive Work Analysis across the System Life Cycle: From Requirements to Decommissioning" *Houston... We Have a Solution! Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting, Houston, Texas, September 27-October 1, 1999*, Volume 1, 318-322. The Human Factors and Ergonomics Society, Santa Monica, California.
42	Armed Forces	Unspecified	A summary of current research and advanced	No details in abstract.	2000	ANNETT, J.; STANTON, N.A. (Eds) *Task Analysis* Taylor and Francis, London.

			practice in Task Analysis.			
43	Military Aviation	Combat aircraft operation (flight control, mission functions)	Cognitive Engineering and Cognitive Task Analysis of three prototype displays for aircraft navigation and tactical hazard awareness.	Improvements to each display in terms of resolving ambiguities and facilitation of allocation of attention.	2000	OLMOS, O.; WICKENS, C.D.; CHUDY, A. "Tactical Displays for Combat Awareness: An Examination of Dimensionality and Frame of Reference Concepts and the Application of Cognitive Engineering" *International Journal of Aviation Psychology*, Volume 10(3), 247-271.
44	Navy	Submarine Approach Officer - location of an enemy submarine in deep water.	Detailed Cognitive Task Analysis of the role.	The production of a scaled world.	2000	EHRET, B.D.; GRAY, W.D.; KIRSCHENBAUM, S.S. "Contending with Complexity: Developing and Using a Scaled World in Applied Cognitive Research" *Human Factors*, Volume 42(1), 8-23.
45	Navy	Ship Command Team - decision making	Hierarchical Task Analysis of domain.	Development of objective measurement of team performance.	2000	ANNETT, J.; CUNNINGHAM, D. "Analyzing Command Team Skills" in J.M. Schraagen, S.F. Chipman and V.L. Shalin (Eds.) *Cognitive Task Analysis*. 401-415. Lawrence Erlbaum Associates, Mahwah, New Jersey.
46	Navy	Weapons Engineering - troubleshooting	Cognitive Task Analysis of the work domain.	Recommendations for the training of troubleshooting.	2000	SCHAAFSTAL, A.; SCHRAAGEN, J.M. "Training of Troubleshooting: A Structured, Task Analytical Approach" in J.M. Schraagen, S.F. Chipman and V.L. Shalin (Eds.) *Cognitive*

						Task Analysis. 57-70. Lawrence Erlbaum Associates, Mahwah, New Jersey.
47	Navy	Command Centre design	No details available.	No details available.	2000	ESSENS, P.J.M.D.; POST, W.M.; RASKER, P.C. “Modeling a Command Center” in J.M. Schraagen, S.F. Chipman and V.L. Shalin (Eds.) *Cognitive Task Analysis*. 385-399. Lawrence Erlbaum Associates, Mahwah, New Jersey.
48	Armed Forces	No details available	No details available.	No details available.	2000	POTTER, S.S.; ROTH, E.M.; WOODS, D.D.; ELM, W.C. “Bootstrapping Multiple Converging Cognitive Task Analysis Techniques for System Design” in J.M. Schraagen, S.F. Chipman and V.L. Shalin (Eds.) *Cognitive Task Analysis*. 317-340. Lawrence Erlbaum Associates, Mahwah, New Jersey.
49	Air Defence	Unspecified	A Cognitive Work Analysis of operator tasks.	A Human-System model of the task.	2000	SANDERSON, P.M.; NAIKAR, N. “Temporal Coordination Control Task Analysis for Analysing Human-System Integration” *Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, San*

						Diego, California, USA, July 29-August 4, 2000, Volume 1, 206-209. Human Factors and Ergonomics Society, Santa Monica, California.
50	Armed Forces	Unspecified	No details available.	No details available.	2001	MILLER, T.E. "A Cognitive Approach to Developing Tools to Support Planning" in E. Salas and G. Klein (Eds.) *Linking Expertise and Naturalistic Decision Making*. 95-111. Lawrence Erlbaum Associates, Mahwah, New Jersey.
51	Armed Forces	Unspecified	No details available.	No details available.	2001	WORM, A. "Tactical Mission Analysis by Means of Naturalistic Decision Making and Cognitive Systems Engineering" in E. Salas and G. Klein (Eds.) *Linking Expertise and Naturalistic Decision Making*. 407-431. Lawrence Erlbaum Associates, Mahwah, New Jersey.
52	Armed Forces	Unspecified	No details available.	No details available.	2001	FLACH, J.M.; KUPERMAN, G.G. "Victory by Design: War, Information, and Cognitive Systems Engineering" in M. McNeese, E. Salas and M. Endsley (Eds.) *New Trends in Cooperative Activities: Understanding System Dynamics in Complex Environments*. 259-283. Human

						Factors and Ergonomics Society, Santa Monica, California.
53	Military Aviation	Airborne Early Warning and Control (AEWandC) aircraft	Cognitive Work Analysis (CWA) of work processes.	Input into the design process of the AEWandC throughout the development lifecycle.	2001	NAIKAR, N.; PEARCE, B. "Analysing Activity for New, Complex Systems with Cognitive Work Analysis" in M. Stevenson and J. Talbot (Eds.) *Better Integration: Bringing Research and Practice Together. Proceedings of the 37th Annual Conference of the Ergonomics Society of Australia, Sydney, NSW, 27-30 November 2001*, 217-222. Ergonomics Society of Australia, Downer, ACT, Australia.
54	Navy	Design of a new surface combatant.	A functional abstraction hierarchy model, and a series of cross-linked matrices were produced to integrate inputs from Cognitive and functional analyses.	Input into design decisions regarding levels of automation, manning requirements and displays.	2001	BISANTZ, A.M.; ROTH, E.; BRICKMAN, B.; GOSBEE, L.L.; HETTINGER, L.; MCKINNEY, J. "Integrating Cognitive Analyses into a Large Scale System Design Process" *Human Factors/Ergonomics: It Works. Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting, Minneapolis/St Paul, Minnesota, October 8-12, 2001*, Volume 1, 434-438. The Human Factors and Ergonomics Society, Santa Monica, California.
55	Military	Tactical team	An analysis of the	Training guidelines and	2001	NEVILLE, K.; FOWLKES, J.;

	Aviation (Navy Air Wing Strike Team)	training	knowledge and skills experts use to coordinate large and distributed tactical teams.	approaches that support the acquisition of the required knowledge and skills.		MILHAM, L.; BERGONDY, M.; GLUCROFT, B. “Team Coordination Expertise in Complex Distributed Teams: A Preliminary Cognitive Task Analysis of the Navy Carrier Air Wing Strike Team” *Focusing Attention on Aviation Safety. Proceedings of the 11th International Symposium on Aviation Psychology, Columbus, Ohio, USA, March 5-8, 2001*, 6pp.
56	Army	Tactical Operations	A Work Domain Analysis using the abstraction hierarchy analytical tool.	No details available.	2001	MARTINEZ, S.G.; TALCOTT, C.; BENNETT, K.B.; STANSIFER, C.; SHATTUCK, L. “Cognitive Systems Engineering Analyses for Army Tactical Operations” *Human Factors/Ergonomics: It Works. Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting, Minneapolis/St Paul, Minnesota, October 8-12, 2001*, Volume 1, 523-526. The Human Factors and Ergonomics Society, Santa Monica, California.
57	Military Aviation	Unspecified	A review of Cognitive Systems Engineering (CSE) in the design of complex systems.	Details of the various CSE theories, methods and examples of their application.	2002	MCNEESE, M.D., VIDULICH, M.A. (Eds) *Cognitive Systems Engineering in Military Aviation Environments: Avoiding Cogminutia Fragmentosa!* Human Systems Information

						Analysis Center, Wright-Patterson Air Force Base, Ohio.
58	Navy	Weather Forecasters	Cognitive Task Analysis support of system prototyping, as well as a comparison of methods.	A knowledge model which integrates training and performance support.	2002	HOFFMAN, R.R.; COFFEY, J.W.; CARNOT, M.J.; NOVAK, J.D. “An Empirical Comparison of Methods for Eliciting and Modeling Expert Knowledge” *Bridging Fundamentals and New Opportunities. Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, Maryland, September 30-October 4, 2002.* 482-486. Human Factors and Ergonomics Society, Santa Monica, California.
59	Armed Forces	Military Planners	Presentation of DAISY – the Design Aid for Intelligent Support SYstems.	Illustration of the DAISY tool through the development of FOX, a decision support tool for military planners.	2002	Campion, C.B.; HAYES, C.C. “DAISY: A Decision Support Design Methodology for Complex, Experience-Centered Domains” *IEEE Transactions on Systems, Man, and Cybernetics. Part A: Systems and Humans.* Volume 32(1), 50-71.
60	Military Aviation	Special Assignment Airlift Mission Planning	A Cognitive Work Analysis of the task was combined with an ecological interface design framework.	Design of a virtual workspace.	2002	LINTERN, G.; MILLER, D.; BAKER, K. “Work Centered Design of a USAF Mission Planning System” *Bridging Fundamentals and New Opportunities. Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, Maryland,*

						September 30-October 4, 2002. 531-535. Human Factors and Ergonomics Society, Santa Monica, California.
61	Armed Forces	Military Commanders (decision making).	The paper proposes the use of intermediate design artefacts to bridge the gap between Cognitive Task Analysis and system design.	The development of a decision support system.	2002	POTTER, S.S.; ELM, W.C.; ROTH, E.M.; GUALTIERI, J.W.; EASTER, J.R. "Using Intermediate Design Artifacts to Bridge the Gap between Cognitive Analysis and Cognitive Engineering" in M.D. McNeese and M.A. Vidulich (Eds.) *Cognitive Systems Engineering in Military Aviation Environments: Avoiding Cogminutia Fragmentosa!* 137-166. Human Systems Information Analysis Center, Wright-Patterson Air Force Base, Ohio.
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63	Military Aviation	Air Defence	A review of Cognitive Work	Examples of CWA use across a number of Air	2002	NAIKAR, N.; LINTERN, G.; SANDERSON, P. "Cognitive

			Analysis application at the Defence Science and Technology Organisation, including specific examples.	Defence projects.		Work Analysis for Air Defense Applications in Australia" in M.D. McNeese and M.A. Vidulich (Eds.) *Cognitive Systems Engineering in Military Aviation Environments: Avoiding Cogminutia Fragmentosa!* 169-199. Human Systems Information Analysis Center, Wright-Patterson Air Force Base, Ohio.
64	Military Aviation	Unspecified	A review of Perceptual Control Theory (PCT).	Description of the PCT perspective, methods and outputs.	2002	HENDY, K.C.; BEEVIS, D.; LICHACZ, F.; EDWARDS, J.L. "Analyzing the Cognitive System from a Perceptual Control Theory Point of View" in M.D. McNeese and M.A. Vidulich (Eds.) *Cognitive Systems Engineering in Military Aviation Environments: Avoiding Cogminutia Fragmentosa!* 201-250. Human Systems Information Analysis Center, Wright-Patterson Air Force Base, Ohio.
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9. Acronyms

ACTA	Applied Cognitive Task Analysis
ADM	Application Domain Modelling
ASTOR	Airborne Standoff Radar
CAATS	Cognitive Activity Analysis Toolset
CAATS	Cognitive Activity Analysis Tool Set
CACFOA	The Chief and Assistant Chief Fire Officers Association
CADMID	Concept, Assessment, Demonstration, Manufacture, In-service and Disposal
CDM	Critical Decision Method
CFM	Cognitive Function Model
CIT	Critical Incident Technique
CIT	Critical Incident Technique
CTA	Cognitive Task Analysis
CWA	Cognitive Work Analysis
DID	Data Item Description
DIF	Difficulty, Importance, Frequency
DASC	Defence Aviation Safety Centre
EIAC	Ergonomics Information Analysis Centre
FMEA	Failure Modes and Effects Analysis
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FO	Fire Officers
GDTA	Goal Directed Task Analysis
GMTA	Goals Means Task Analysis
GSS	(Apache) Ground Support System
HF	Human Factors
HFI	Human Factors Integration
HMI	Human Machine Interface
HTA	Hierarchical Task Analysis
IPDS	Integrated Personal Development System
IPME	Integrated Performance Measurement System
IPT	Integrated Product Team
KE	Knowledge Elicitation
KSA	Knowledge, Skills and Abilities
MSS	Micro Saint Sharp
NEC	Network Enabled Capability
NRTA	Navel Recruitment and Training Authority
OJT	On the Job Training
RCM	Reliability-Centred Maintenance
RN	Royal Navy
SCTA	Skills-Based CTA Framework
SME	Subject Matter Experts
SRK	Skill, Rule, Knowledge
STEP	Social Technological, Economic and Political dimensions
TA	Task Analysis
TAG	The Training Advisory Group
TCSS	Nimrod MRA4 Tactical Command and Control
TNA	Training Needs Analysis
TTA	Tabular Task Analysis
WG	Working Group