The use of Commercial Off-the-Shelf Information Technology in Operational Defence Equipment

Ph.D. Thesis

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ABSTRACT

This thesis examines the impact on future military systems, from an operational and procurement point of view, of the use and the consequences of the use of commercial off-the-shelf (COTS) information technology (IT) in all forms of operational defence equipment by the UK armed forces. The main objectives of the research were to identify uses for IT by UK MoD, to examine the impact of this technology on operational military equipment, to establish where COTS IT is applicable, to examine procurement implications for the suppliers and MoD, to consider the consequences of using COTS IT and to see whether lessons can be learned from the United States Navy utilisation of COTS IT.

Employing COTS IT appears an attractive financial proposition, provided the required performance can be achieved. A literature survey gathered relevant data and highlighted benefits, problems and issues. An examination was also made of the various uses of COTS IT by MoD. A COTS IT Circular Model was developed to examine the issues, decisions and organisations involved if COTS IT is to be used to meet any military requirement. This tool is a potentially useful training aid.

To understand the views of MoD and the UK defence industry, some 550 completed questionnaires were analysed, supported by personal interviews. These provide statistically significant results, which were compared with information about the US Navy experiences with COTS IT.

The implications for MoD are that for COTS IT-based projects, MoD will need to set up acquisition and through-life support guidelines, manage the dissimilar life cycles and development time scales of COTS IT and military equipment, take a different approach to funding and maintenance, avoid insisting of the application of existing military requirements, manage security issues and bandwidth requirements, and research how to use COTS IT in safety critical systems.

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This thesis is dedicated to the memory of my father, Professor Roberto Weiss, who was for many years head of UCL's Italian Department. He never dreamed that one day I might do research at his university.

AUTHOR OVERVIEW

Alex Weiss is definitely a mature student, (aged 62) who spent a lifetime in the electronics industry before taking early retirement and starting to study at UCL. His interest in electronics was first sparked at GEC Electronics, while his real exposure to IT dates from the early 1980s.

ABBREVIATIONS

ADF Australian Defence Force
ARTD Applied Research Technology Demonstrator
ASCII American Standard Code for Information Interchange
ASIC Application specific integrated circuit
ASW Anti-submarine warfare
ATCCIS Air traffic control CIS
ATM Automatic teller machine
AWACS Airborne warning and control system
B Soft-skinned (vehicle)
BITE Built-in test equipment
C^2 Command and control
C^2W Command and control warfare
C^3 Command, control & communications
C^3I Command, control, communications & intelligence
CAA Civil Aviation Authority
CALS Computed aided logistic support
CD ROM Compact disk, read-only memory
CECOM Communications-Electronics Command
CHS Common hardware/software
CIS Command information system
COE Common operating environment
CORBA Common object request broker architecture
COTS Commercial off-the-shelf
CTIS Combat terrain information system
D Director
DARPA Defence Advanced Research Projects Agency
DCDS Deputy Chief of Defence Staff
Def spec Defence specification
DEG Defence Engineering Group
DERA Defence Evaluation & Research Agency
DESO Defence Export Services Organisation
DG Director General
DICC 99 Defence Information Capability Conference
DISA Defense Information Systems Agency
DLO Defence Logistics Organisation
DMS Defense Message System
DoD Department of Defense (US)
DPA Defence Procurement Agency
DSAC Defence Scientific Advisory Council
DSEI Defence Systems and Equipment International
DSTO Defence Science & Technology Organisation
DVD Digital video disk
ECC Equipment Capability Customer
EMC Electro-magnetic compatibility
EMP Electro-magnetic pulse
ETSI European Telecommunication Standards Institute
EW Electronic Warfare
GDP Gross Domestic Product
GHUMS Generic health usage monitoring system
GIS Graphical information system
GOTS Government off-the-shelf
GPS Global positioning system
HIC High intensity conflict
ICS Information & Communications Services
ICT Information & communications technology
IEEE Institute of electrical & electronic engineers
IEWCS Intelligence & EW common sensor program
ILS Integrated logistics support
IMA Integrated modular avionics
IPT Integrated project team
ISCS Integrated ship control system
IT Information technology
IV&V Independent verification and validation
JOC Joint operations centre
LIC Low intensity conflict
Mil spec Military specification
MLS Multi-level security
MMI Man-machine interface
MoD Ministry of Defence
MOTS Military off-the-shelf
MSTRAP Multi-Sensor Torpedo Recognition & Alertment Processor
MTBF Mean time between failures
MTTR Mean time to repair
NBC Nuclear, biological & chemical
NDI Non-developmental item
OR Operational Requirements (now ECC)
OTS Off-the-shelf
PPP Public Private Partnership
R&D Research and development
RAM Random access memory
Recce Reconnaissance
RF Radio frequency
RFI Radio-frequency interference
RISC Reduced instruction-set computing
RPGS Rugged portable ground station
RPV Remotely piloted vehicle
S&T Swiftsure and Trafalgar
SATCOM Satellite communications
SMCS Submarine command system
SSBN Strategic submarine, ballistic nuclear
STANAG Standard NATO agreement
TCP/IP Transmission control protocol/Internet protocol

FOREWORD

> *'When we go back as far as the 15th century ... foundry work in the casting of bells is a prime example of skills developed for peaceful purposes, being able quickly to prepare for war, and many an ancient bell-foundry has found itself involved in the casting of war-time cannon rather than tuning up the bells of peace.'*

This quote from **English Church Bells** by William Mowll, Vicar of Boughton Under Blean w. Dunkirk and Hernhill shows that the application of commercial off-the-shelf technology for military purposes is not a new phenomenon!

In a prepared statement at the end of the 20th century, Paul G. Kaminski, US Under-Secretary of Defense for Acquisition and Technology said [i]:

> *'The lives of our soldiers, sailors, marines and airmen may depend upon shortened acquisition cycle times.... In a global market everyone, including our potential adversaries, will gain increasing access to the same commercial technology base. The military advantage goes to the nation, who has the best cycle time to capture technologies that are commercially available, incorporate them in weapon systems and get them fielded first.'*

The emphasis may have changed over the last six hundred years, but it is clear that the principle of benefiting from the availability of commercial technology has not.

1 INTRODUCTION

This section provides an overview of the information technology environment and the background to UK MoD use of COTS IT. A summary is provided of technology changes that have taken place over the five-year period of this research. The objectives of the research and an overview of the thesis contents are also provided.

This thesis examines the use, and the consequences of the use, of commercial off-the-shelf (COTS) information technology (IT) in all forms of operational defence equipment by the United Kingdom armed forces. It also looks to see whether any lessons can be learned from the United States Navy's utilisation of COTS IT. As well as seeking a wide range of documentary evidence, the key feature of the research was to understand the views of the various relevant branches of UK MoD, as well as UK industry.

The thesis considers the impact on future military systems, both from an operational and a procurement point of view, of the increasing availability, off-the-shelf, of commercial information technology. It covers the period from 1995 until 2010. To obtain an objective rather than a subjective view, a key area of the research has involved the mailing of some 1200 questionnaires to relevant people in both military and industrial organisations, of which approximately 550 were returned. This was supported by 46 personal interviews and has provided statistically significant results that were collated and analysed. The information forms a cornerstone of the research and every effort has been made to remove bias from the results.

1.1 IT background

Information technology is becoming more and more pervasive as the twenty-first century opens. It impacts all aspects of society, including the armed forces. The investment in commercial information technology is now reputed to be the second largest of any engineering discipline. This investment continues to produce remarkable increases in processing power and memory at steadily reducing unit cost. It is also generating increasingly complex software programs that demand and use the rapid escalation in both processing speed and memory capacity.

The pervasiveness of IT in all aspects of mankind's endeavours is reflected in UK MoD's current efforts to come to terms with the widest possible use of this technology in the new century. Its use to improve efficiency and performance is a crucial issue. The way other joint civil/military innovations of the 20^{th} century were employed in peace and war has been examined to ascertain if there is a read across to the way that IT should be procured and used.

1.2 Background to the military use of COTS IT

The timing of the severe cut backs in the real purchasing power of the defence budgets of the UK and other industrialised nations in the last decade of the twentieth century came at a time when the capabilities of information technology were seen to be increasingly important. Thus the use of COTS IT appears to present an attractive proposition financially, provided that the required performance, in all senses of the word, can be achieved. At the start of work on this thesis in 1995, little had been written about the military use of COTS IT and most of that which had concentrated on 'business applications'. Five years later, there is a plethora of published information relating to the use of COTS IT in military equipment. However, there has still been little written about the consequences of such use by UK MoD, or by any other armed forces for that matter.

The defence ministries of the industrialised nations are all pursuing a policy of increasingly using COTS IT wherever possible in order to save money. For example, US Defense Secretary William Perry [ii] paved the way in 1994 for acquisition reform within the US Department of Defense, and with it, the infusion of commercial technology into government systems. A similar policy applies to UK MoD.

Although saving money was clearly the initial motivation for turning to COTS IT, an alternative view today is that the prime driver is to obtain the best possible performance. If one postulates a situation where money is no object, it is unlikely in the extreme that even the US DoD, let alone the UK MoD, could establish a range of military IT research, development and production facilities to allow it to make military equipment with the same performance as its civil counter parts, even if it could afford it. The obstacles, which lie in the way, include:

- Persuading government that such duplication of effort by a scarce, GDP and export enhancing national resource is justified.
- Persuading specialist staff to work on such a military project, both in hardware and software research and development, and in production.
- Paying staff rates competitive with those in the civil sector.
- Obtaining the latest manufacturing plant in a timely manner from suppliers.
- Dealing with the relatively low volumes involved – only 1% of the commercial market size.
- Maintaining the investment to match the rapid changes in the civil sector.

Thus, it seems that the drive towards COTS IT in operational defence equipment is, in truth, no longer primarily based on the desire to save money, although this may be a convenient and necessary factor. It is in fact based on the impossibility of any other course of action and the overriding requirement of armed forces to obtain the best possible performance from the IT used in military systems and equipment.

A further driver is the shortage of software engineers that would be necessary to write custom programs for increasingly complex military systems. There is already a severe shortage of this resource in the commercial field and with complex programs running to tens of millions of lines of code, the limits of this finite resource would be exceeded.

Accepting, then, that UK MoD has no choice but to use COTS IT in future equipment, this represents a sea change in the culture and approach to the procurement of IT-based equipment by MoD.

1.3 Changes since 1995

A number of factors have affected the research undertaken over the past five years. First and foremost is the rate of change occurring within the IT industry itself at a time when IT is assuming an increasing importance in all walks of life. Second is the demand on the UK and other industrial nations to reduce their defence budgets at a time when there is a clear understanding of the impact of increasing weapon system costs in real terms.

In 1995, DERA (Defence and Evaluation Research Agency) had recently been formed from DRA (Defence Research Agency) now the subject of a PPP initiative, and in April 1999, MoD PE (the Procurement Executive of MoD) became the DPA (Defence Procurement Agency). However, the recent change of MoD OR (Operational Requirements) to MoD ECC (Equipment Capability Customer) came too late to be incorporated in many of the diagrams of this document. Therefore, the term MoD OR is still found, but only in Sections 8 and 9 – 'Data gathered by questionnaire', and 'Data analysis'.

It is interesting to consider the rate of change of information technology over the five-year period of this research. In July 1995, when work began, Windows 95 had just been launched and the commercial era of the Internet was but a year old. Amazon.com sold its first book over the Internet and AOL was launched as an Internet Service Provider. Netscape did not launch its browser until 1996 when Internet Explorer did not even exist. 1998 saw the launch of the Apple iMac as well as Windows 98. The year 2000 saw Windows 2000 become widely available. On the hardware side, in 1995, a state of the art personal computer had a P133 Pentium chip with 32Mb of RAM and a 2Gb hard disk. Less than five years later it has 1000 MHz Pentium 3, 256Mb of RAM and a 50Gb hard disk. Furthermore, despite the performance increase, the price of such hardware has reduced by some twenty percent in real terms.[iii]

1.4 Objectives of the research

This research, which has been carried out over the past five years starting in July 1995, has had eight main objectives and these are detailed in Section 3.1. They include identification of uses for IT by the military community in the UK, examination of the impact of this technology on future operational military equipment, establishing where COTS IT is applicable, examining the procurement implications both for the suppliers and for the relevant parts of MoD, and looking at the consequences for UK MoD of using COTS IT in its operational equipment.

The research has also examined whether there are any lessons to be learned from the US Navy and in April 2000 was able to access the latest NATO views on the subject.

1.5 Thesis content

This thesis starts by defining and also discussing some important definitions and then spells out in detail the research objectives that were set and the areas that have specifically been excluded. There is an explanation of the research methodology applied and the approach to data gathering. Next there is an examination of a wide range of articles, books, papers and other information obtained from a library and Internet search, as well as from a range of symposia, conferences and exhibitions. The thesis then considers a number of the innovations, other than IT, that were used by the armed forces during the twentieth century. Those that have both military and civil applications are considered to see if there are any parallels that might be applied to IT. The financial situation of the UK armed forces and their future budget plans are examined and the financial constraints facing the armed forces and the impact of these pressures considered. A review is made of the uses of IT by the UK armed forces, including their current purchases of COTS IT. Consideration is given to the potential uses of COTS IT in a range of different military equipment. Some of the current purchases of COTS IT by UK MoD are outlined, as are some of those by US DoD.

As the research progressed, it became clear that it would be useful to develop a tool that would examine the issues, decisions and organisations that have to make the decisions if COTS IT is to be used to meet any military requirement. This resulted in the development of a COTS IT circle, which considers in detail the life to death use of COTS IT in operational military equipment. It could be used as a training aid for those in MoD involved in the specification and purchase of equipment.

The data obtained from 547 MoD and industry questionnaires are presented and its analysis used to highlight the resulting issues. To this is added the information gathered from 46 personal interviews. The outcome is compared with the experiences of the US Navy to see whether any lessons can be learned from their experience in this field. The reason for selecting the US Navy was that it has led the field in using COTS IT for military purposes, it has ready access to the huge US IT industrial base and it is in the forefront when it comes to publishing information about its experiences with COTS IT.

The implications for MoD of using COTS IT in operational military equipment are summarised and this is followed by the conclusions of the research. The key issues for MoD to address are the need for:

1. A set of guidelines on acquisition and through-life support of equipment incorporating COTS IT.
2. Early consideration of differences between the development time scales and life cycles of military equipment and COTS IT, including the need for more linear programme through-life spend profiles.
3. The Equipment Capability Customer to recognise the potential to use COTS IT at the earliest stage of any programme and not to obviate its use in the requirement document.
4. A different maintenance policy for COTS IT.
5. Recognition of the COTS IT security issue and its impact on through life costs.
6. Consideration of the bandwidth requirements of much COTS software in trade-off activities.
7. Application of some of the US Navy lessons to MoD COTS IT practices.

8. A COTS IT circle, or similar model, to help to teach staff about the various COTS IT issues.

Whether the use of COTS IT will have an adverse impact on total life cycle costs remains the unanswered question.

Some recommendations for future work and four appendices follow the conclusion of this thesis; copies of the two questionnaires sent out, a list of organisations visited during the research and a comprehensive bibliography.

2 DEFINITIONS AND GLOSSARY OF TERMS

This section provides lengthy and a descriptive definition of the key terms used in this thesis and also provides a glossary of certain less important terms. It also discusses the various different definitions of the expression COTS IT.

2.1 Information Technology

Chambers 21st Century English Dictionary (1996) defines ***Information Technology*** as 'The use, study or production of a range of technologies (especially computer systems, digital electronics and telecommunications) to store, process and transmit information.'

In this thesis, IT is taken to have two distinct parts. The first is the communication of information and the second is the processing and storage of information.

In ***Explaining the Black Box*** [iv], Nathan Rosenberg provides the following useful definitions:

> *'In the most general terms, telecommunications systems "use electricity and electromagnetism to transmit ... information." Telecommunications systems are composed of a well-defined sender, some transmission device, and some population of receivers. Currently, the economically relevant devices for transmitting information are the telephone, ... the radio, and, in recent years, the computer ... One important qualification should be made. Telecommunications does not presently include ... the manipulation of electronic information, namely data processing. Nevertheless, in some ways, these two fields have broad-based complementarities and similar theoretical principles, and the activities within each field have in fact become more and more similar over the last twenty years. Thus, the distinction between telecommunications and data processing has become harder to draw... The transmission of information obviously falls under the aegis of telecommunications, while the possibility of electronic manipulation of information is more akin to data processing. As a result, the technological barriers between telecommunications and data processing have been considerably weakened over time.'*

Major thought was given as to whether communications bearers should be included in this thesis as part of IT. While the bearers themselves may be considered as the equivalent of a twisted pair of wires, there is much interaction between IT and communications, particularly in communications control. Therefore, for the purposes of this research, communications were excluded, except where the communications equipment includes built in IT; increasingly common in satellite and other complex communications systems [v].

Commercial IT is thus considered to comprise:

- Computers and their peripherals - printers, plotters, monitors, keyboards, mice, roller balls, joy sticks, graphics tablets and touch input devices, cameras and scanners.
- Standard processing and memory devices, such as µ processor chips, RAM and ROM in both solid state and mechanically rotating drive forms, graphics cards and ASICs (Applications specific integrated circuits).
- Software operating systems such as Windows®, Unix® and Linux®.
- Standard software applications and algorithms.

- Communications interfaces, modems, wireless interconnection such as Bluetooth [vi] and protocols, including the Internet.
- Development and diagnostic tools.

2.1.1 US Marine Corps definition [vii]

Information technology (IT) is defined as any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the executive agency. The term 'information technology' includes computers, ancillary equipment, software, firmware, and similar procedures, services (including support services) and related resources.

2.2 COTS IT

2.2.1 US Defense Information Systems Agency (DISA) definition [viii]

DISA define COTS as referring to an item of software or hardware that has been produced and is available for general purchase. Such items must have been sold and delivered to Government or commercial customers, must have passed the customer's acceptance testing, and must be operating under the customer's control and within the local environment. Further, such items must have meaningful reliability, maintainability, and logistics historical data.

2.2.2 DERA Malvern definition [ix]

COTS software is a general-purpose application, utility or system developed and supplied by a commercial organisation, for which a means of providing through-life support may be available.

2.2.3 DERA Portsdown definitions [x]

Commercial COTS products are characterised by having been developed to support a commercial (i.e. non-military) market and being currently available for purchase. It is generally assumed that a viable commercial product will have a strong market share and will be well supported. These additional caveats distinguish products that deliver the expected advantages of COTS.

Military Off The Shelf (MOTS) and Government Off The Shelf (GOTS)

MOTS describes equipment previously developed for military customers. Such items may have been developed as a private venture by industry. GOTS products are government-funded developments that are commercially available.

2.2.4 US term Non developmental Item (NDI)

1. Any item available in the commercial marketplace.
2. Any item previously developed for use by the U.S. Government or an allied government.
3. Any item of supply needing only minor modification to meet U.S. Government requirements.

2.2.5 COTS Criteria

COTS IT components are now widely being incorporated into military equipment because of their availability, low initial cost and normally high levels of functionality. However, because they are produced for the civil marketplace, they reflect the pressures on suppliers of time to market, cost competitiveness and maximisation of market share. They exhibit short market life and are influenced by customer tolerance of shortfalls in quality.[xi] These factors differ markedly from the demands of traditional defence procurement.

2.2.6 So what is COTS IT?

Although there is a degree of conflict in the definitions given in Paragraph 2.2, there is a near consensus that COTS IT refers to hardware or software (firmware is not mentioned but assumed to be included) that has been produced for commercial markets and that is currently available. It includes computers and their peripherals, standard processing and memory devices, ASICs, operating systems, standard software packages and algorithms, communications interfaces and protocols, and development and diagnostic tools. These may be sold as individual items, built into specific products or assembled into systems.

However, its end user may have a significant impact on its suitability for use in military equipment, regardless as to whether it is hardware or software, as the list below suggests. This list has been specially developed and is in roughly ascending order of reliability and safety criticality.

- Domestic.
- Commercial.
- Industrial.
- Automotive.
- Maritime.
- Medical.
- Nuclear.
- Aerospace.

The impact of the market for which COTS IT has been designed is further studied in Section 6.

All military sources refer to the ability of COTS IT to be supported, though this is clearly wishful thinking in the longer term. Items developed for military use or other government tend to be excluded, being covered by the terms GOTS and MOTS.

2.3 Legacy

This is a term applied both to existing military equipment, particularly custom military IT systems. The term is also used to define parts of requirements that still demand military or defence specifications.

2.4 Ministry of Defence

The word Ministry of Defence is used in this thesis to include the UK Ministry of Defence, Defence Procurement Agency – DPA (formerly the MoD Procurement Executive), Equipment Capability Customer – ECC (formerly Operational Requirements – OR), Defence Evaluation and Research Agency – DERA (formerly DRA) and the Armed Forces, regardless of whether individuals are uniformed or civil servants. Despite the changes of names, the most recent ones are used throughout.

2.4.1 *Military*

The use of the word 'military' in Sections 8 and 9 distinguishes uniformed members of the armed forces from civil servants working along side them.

2.4.2 *Purple*

The term 'purple' is used to define those military and civilian personnel working in tri-service roles in the Ministry of Defence.

2.5 Miscellaneous other terms

2.5.1 *C^4I*

The term command, control, communications and computers (C^4I) has not been used in this thesis, as it is inconceivable to imagine any C^3I that does not employ computers. The use of the fourth 'C' is therefore considered redundant.

2.5.2 *Embedded IT*

The phrase embedded IT is used to define any IT that is built into equipment as an integral part of that equipment, normally without any direct human/computer interface, and which cannot operate as a stand-alone entity.

2.5.3 *Firewall*

A type of access control gateway, placed between a private or restricted access network and a public network, to filter selectively incoming and/or outgoing traffic. Firewalls enhance network and application security.

2.5.4 *Information*

Information is any communication or representation of knowledge in any medium or form.

2.5.5 *Interface*

An interface is a connecting link or interrelationship between two systems or two devices, or between a user and an application, device, or system. In the OSI reference model, it is the boundary between adjacent layers.

2.5.6 *Internet*

The collection of networks and gateways that use the TCP/IP protocol suite and function as a single, co-operative virtual network with near-universal connectivity. There are three levels of network services - unreliable connection-less packet delivery, reliable full duplex stream delivery, and application-level services like electronic mail that build on the first two.

2.5.7 *Interoperability*

Interoperability is the ability of two or more systems or components to exchange and use information or services, so that they will operate effectively together.

2.5.8 *Life Cycle*

The life cycle of a piece of equipment is the period of time between conception of the equipment and its removal from active use. Generally, it refers to the usable life of a piece of equipment.

2.5.9 *Open box, closed box and black box*

These terms are used to describe COTS software. Closed box or black box applies where there is no access to the source code, while open box applies to software where the source code is available to the purchaser.

2.5.10 *Open Standard*

A precise definition of open standards is not simple, but in general, they are characterised by a clear public domain definition of the standard and widespread adoption in the commercial world. In some cases there is a formal, vendor independent body that oversees the development of standards. In other cases the widespread use of a commercial proprietary product has led to a de facto standard, which is under control of a single vendor.

2.5.11 *Open System*

An open system is one based on open standards. It implements sufficient open specifications for interfaces, services, and supporting formats to:

- Enable utilisation of properly engineered components across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems.
- Interact with users in a style that facilitates portability.

An open system:

- Has well defined, widely used, non-proprietary interfaces/protocols.
- Uses standards, which are developed/adopted by industrially, recognized standards bodies.
- Defines all aspects of system interfaces to facilitate new or additional systems capabilities for a wide range of applications.
- Includes explicit provision for expansion or upgrading through the incorporation of additional or higher performance elements with minimal impact on the system.

2.5.12 *Operating System*

A group of computer programs that manages a computer system, including such functions as memory, processing tasks, inter process communications, and interfaces with physical devices.

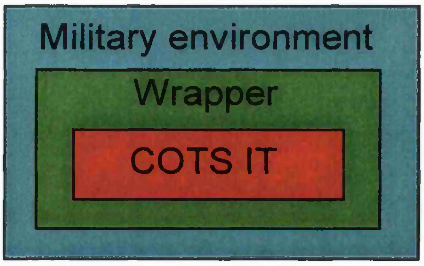
2.5.13 *Tempest*

An MoD standard defining acceptable levels of RF emissions from electronic equipment.

2.5.14 *Wrapping*

The term 'wrapped' COTS IT refers to the protection of COTS IT hardware by suitable packaging or mounting of standard, unmodified items. It also refers to the protection of COTS software by wrapping the program to enable it to interact with other software. The questions that needs to be answered for any particular COTS IT that is to be incorporated in military equipment are:

- What should be wrapped?
- Why should it be wrapped?
- Who will produce the wrapper?



The purpose of the wrapper is to trap poor or dangerous performance and to enhance existing performance. A wrapper may comprise additional hardware, software or an additional acquisition test.

There are a number of suppliers who specialise in the construction of hardware wrappers and a typical example is shown in Figure 1. This particular unit houses standard COTS processor, memory and ancillary cards, together with a custom power supply, in an environment that they can survive when installed in an aircraft.

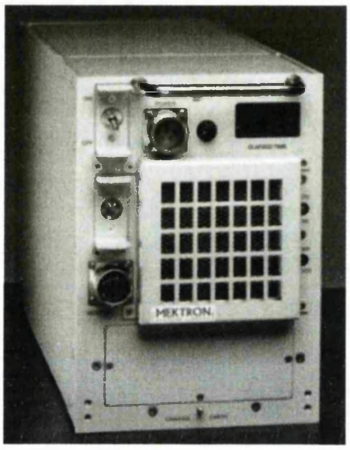


Figure 1. A Mektron airborne case that protects a COTS computer from the environment and provides a suitable source of electrical power.

3 RESEARCH OBJECTIVES, METHODOLOGY AND AREAS EXCLUDED

This section outlines the objectives set for the research work and describes the various methods used during the research to gather, analyse and draw conclusions from a wide range of information sources. It provides a timetable showing when the various aspects of the work were carried out. It also lists a number of areas that have purposefully been excluded from consideration during the research.

3.1 Research objectives

In order to examine the use of commercial off-the-shelf information technology in operational defence equipment, the title of this thesis, a number of key questions were set, the answers to which had to be established. It is finding the answers to these questions that define the main objectives of this research. These questions are [xii]:

1. To what extent does UK MoD envisage needing to rely on purchasing IT hardware and software, for what purposes and what efficiency improvements are likely?
2. What is the attitude of MoD to the use of COTS IT and what are the plans for its purchase and use?
3. What problems are likely to affect such purchases?
4. Could MoD make more use of COTS IT and if so, how should this be done?
5. What is the attitude of UK and foreign IT companies and defence contractors towards meeting both the general and the special IT needs of MoD?
6. How are defence contractors dealing with the procurement of COTS IT?
7. What is the likely impact, and in particular the risks, MoD faces in procuring COTS IT hardware and software?[1]
8. How does the US Navy experience match that of UK MoD?

The answers were established by a number of different means, but without leaving the United Kingdom except for a single visit to NATO in Brussels. The outcome is shown in Section 12.

Question 8 was included because the US armed forces are indisputably the largest and best equipped in the world. As such, they may be contrasted with those of the UK that have only one tenth of the US annual defence budget. Because the US also leads the world in both its civil and military uses of IT and the size of its commercial IT industry, its work in this field is an important consideration. Moreover, the US Freedom of Information Act allows access to material that in other NATO countries would be classified or otherwise not available. For this reason and the wide range of material published by the US Navy, it has been decided to compare their experience with the results of this UK based research.

[1] One item is excluded from the list in the M.Phil Transfer Thesis: 'Where are IT companies concentrating their investments in R&D?' (See Section 13) A new item 8 has been added.

3.2 Research methodology

The research work has involved nine separate groups of actions. There was:

1. A library and Internet search, and attendance at conferences, symposia and exhibitions.
2. The gathering of statistics about UK MoD budgets and information about MoD IT usage.
3. The construction of COTS IT usage diagrams.
4. The creation of a model of the COTS IT issues, decisions and decision makers.
5. Data gathering from MoD, DERA and industry using questionnaires and interviews.
6. The analysis of the data.
7. The gathering of information about the experiences of the US Navy with COTS IT.
8. Consideration of the implications for MOD in using COTS IT.
9. Drawing conclusions from all the sources.

In addition, recommendations for further work were considered throughout the research.

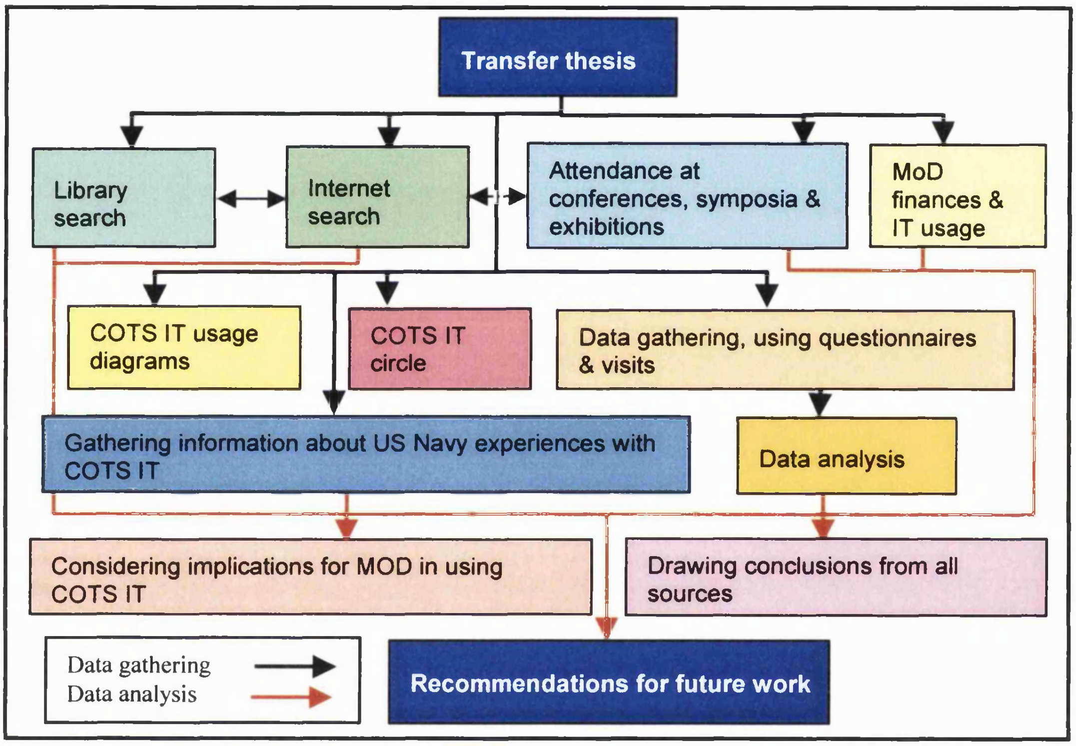


Figure 2. The work packages and their interaction during the research.

3.2.1 Library search

The British Library, UK MoD library in Scotland Yard and the UCL Science Library were searched using their own built-in computer search engines. Selected up-to-date books were read dealing with commercial IT and military applications of IT. Searches and reading have shown that while a plethora of books deal with IT, comparatively little has been written about the application of IT to military usage, apart from articles in journals.

Appropriate magazines articles in the UCL and MoD libraries both in paper and CD ROM format were accessed and read. It was only in the second half of work on this thesis that many articles about military use of COTS IT appeared. A cut off date of 1st January 1990 has been used since, with few exceptions, earlier books and articles are too outdated except from a historical viewpoint. Details are given in the bibliography.

3.2.2 Internet search

Data have been obtained from the Internet to keep abreast of the latest developments in the IT field. The Internet was searched using the Metacrawler and Altavista search engines with 'COTS IT', 'Defence', 'Defense', 'US' and 'Navy' as key words. The American spelling of Defense was an essential for this application. What immediately became clear was the dearth of information that had been published by the end of 1997 on the use of COTS IT in military equipment. Later searching, however, revealed some really useful post 1997 sources.

The amount of information on COTS IT has snowballed in the last two and a half years, so that only selected and relevant information is included. Much of this, including Internet web sites, is listed in the bibliography. More details are shown in Section 4.

3.2.3 Attendance at conferences, symposia and exhibitions

Selected conferences, symposia and exhibitions were attended. These have included Farnborough 96, Euromilcomp 97, Farnborough 98, DICC 99, DSEI 99 and the Ruthless Pursuit of COTS 2000. Most of these were general events with some IT involvement, but two were orientated towards the topic of this thesis. Many useful contacts were made and a few practical demonstrations of COTS IT in operational military equipment were observed. Most useful were the relevant papers presented at DICC 99 and the Ruthless Pursuit of COTS 2000. Summaries of these papers are given in Section 4.

3.2.4 MoD finances and IT usage

Military innovations were examined to try and establish where IT fits in the pattern of other advances. The boundaries between military and civil usage were also considered. It has been important to scrutinise MoD's budgets over the period from 1993 to 2000 and to consider their impact. Some of the related industrial issues are also discussed. The use of IT by MoD and the potential to employ COTS IT are reviewed. The position of the UK MoD in terms of COTS IT usage is examined and compared with published DoD information.

COTS IT usage diagrams

Schematic diagrams were produced, showing where COTS IT may be incorporated into C^3I and weapon systems. From these, an understanding of the potential opportunities for COTS IT was developed which, together with an appreciation of MoD and industry's attitudes to the purchase of COTS IT, has enabled an assessment of the impact to be defined. The results are shown in Section 5.

3.2.5 COTS IT circle

A model, the COTS IT Circle, has been developed to show the issues, decision makers and the decisions that have to be made from the first thought about a new piece of military equipment containing COTS IT to its upgrading or exit from service. A commentary on each item in the model gives it clothes. The model has been shown to a number of people in MoD and presented at the Ruthless Pursuit of COTS 2000 symposium in Brussels in April 2000.

3.2.6 Data gathering, using questionnaires and interviews

A great deal of information has been gathered, both by using written questionnaires and from face to face meetings with personnel in four different groups. These groups were selected as those most likely to affect the use of COTS IT in military equipment. The four groups are:

1. Defence Procurement Agency (formerly MoD Procurement Executive) staff.
2. MoD Equipment Capability Customer (formerly Operational Requirements) staff.
3. Defence Evaluation and Research Agency staff.
4. People working in the UK Defence Industry. This includes industrial companies in the military field using IT in their systems and products and supplying MoD as prime or sub-contractors, as well as commercial companies in the information technology field.

A copy of the questionnaire used for military personnel is reproduced in Appendix 1. There is a copy of the similar questionnaire used for industry in Appendix 2. In order to increase the positive response rate, everyone was offered a copy of the information contained in this thesis.

3.2.7 Data analysis

The information from the questionnaires has been processed using the computer program SPSS for Windows 7.5. This program allows both statistical and graphical analysis to be carried out on multiple variables with cross-tabbing and automatic calculation of standard deviations, variances and mean values. The data have also been examined for skew based on seniority, age group, organisation and experience of using computers.

An analysis has been carried out and an assessment made of the information obtained from all the questionnaires and interviews to obtain a best view of the consequences for UK MoD of the use of COTS IT in military equipment. The assessment of all this information has been based on establishing the acceptability, applicability and potential problems viewed by those in both military and commercial organisations. Details of this information are presented in Sections 8 and 9. Common themes drawn from these and the other main sources form the basis of the conclusions of the research.

3.2.8 Gathering information about US Navy experiences with COTS IT

To examine what might be the consequences for MoD in using COTS IT in military equipment and to see whether any lessons can be learned from elsewhere, information about the experience of the US Navy's in this area has been gathered. The reason for the choice of the US Navy is that it has been in the forefront in applying COTS IT to military equipment. Perhaps more important is that it has published a great deal of unclassified information that is accessible on the Internet. Furthermore, the majority of its COTS IT comes from companies like Microsoft and Intel; part of the huge IT industrial base in the United States.

3.2.9 *Considering the implications for MOD in using COTS IT*

The responses from the literature search, attendance at conferences and exhibitions, the creation of the COTS IT circle, and the analysis of the data gathered from MoD, DERA and industry questionnaires and interviews were summarised into a set of implications for MoD to consider.

3.2.10 *Drawing conclusions from all the sources*

In drawing conclusions, the answers to the eight questions in Paragraph 3.1 were established and some recommended actions have also been outlined.

3.2.11 *Recommendations for future work*

Throughout the five years that this research has taken, consideration has been given to a few possible areas of useful future work and these are outlined in Section 13.

3.3 Programme of research carried out

The programme of research has been undertaken over a five-year period on a part-time basis. The first year was spent preparing a transfer thesis, which proposed the work to be carried out during the subsequent four years. The table below shows the timings of the main areas of work.

Q3 95	Q4 95	Q1 96	Q2 96	Q3 96	Q4 96	Q1 97	Q2 97	Q3 97	Q4 97	Q1 98
Start transfer thesis										
Locate and read relevant books/articles										
		Initial DERA discussions								
			Complete transfer thesis							
			Final thesis level 1 headings							
			Initial MoD and industry contact							
					Further initial MoD and DERA interviews					
							Final thesis level 2 headings			
							Initial industry interviews			
								Mail DPA questionnaires		
									DPA interviews	
Q2 98	**Q3 98**	**Q4 98**	**Q1 99**	**Q2 99**	**Q3 99**	**Q4 99**	**Q1 00**	**Q2 00**	**Q3 00**	**Q4 00**
Mail ECC questionnaires & further initial industry visits										
Final thesis level 3 headings										
	Initial data analysis									
	Euromilcomp 98									
		ECC interviews & mail DERA questionnaires								
			DERA interviews							
			50% first thesis draft							
				Mail industry questionnaires						
					DICC 99 & DSEi 99					
					Industry interviews					
						Data analysis				
								Ruthless Pursuit of COTS		
								Complete draft of thesis		
									Complete thesis	

Figure 3. The timetable of the work carried out for this thesis.

3.4 Exclusions

3.4.1 'Business applications'

While the UK armed forces make much use of information technology, those applications that use standard COTS IT for 'business applications' have been excluded from this research unless they form an integral part of equipment or a system used in an operational environment, or are themselves likely to be employed in an operational environment. Excluded applications include accounting, secretarial work and personnel records, but the operation of a laptop computer on board ship or on the battlefield for word processing is included.

3.4.2 Overseas nations

Because of the cost and difficulties of dealing with the defence organisations of overseas nations, the work in this field of all overseas defence organisations including NATO, with three exceptions, has been excluded. The first exception is the US Navy, which has published a great deal of information on the subject that is readily available and freely accessible from the UK.

The second exception is the information gathered from the papers and personal discussions at the NATO Ruthless Pursuit of COTS Symposium held in Brussels in April 2000.

The last exception is data gathered, mainly about the US DoD, via the Internet.

3.4.3 Nuclear and crypto

In the light of significant security issues, and the need for this thesis to be an unclassified document, it was agreed that no research would be carried out either into the use of IT for nuclear weapons and their control or into the technology of military decryption of coded messages originating from potentially hostile nations.

3.4.4 Artificial intelligence

Although much research is being carried out into artificial intelligence, its current state of development is such that it has yet to impact on COTS IT. This is likely to change in before long.

3.4.5 Safety critical applications

There are special problems in the use of COTS IT in safety critical applications. Although the problem is mentioned, details of possible solutions are beyond the scope of this research.

3.4.6 General IT problems including information warfare

It is apparent that information technology specially developed for military applications is just as prone to reliability and safety problems as its commercial counterparts. In his book Computer Related Risks [xiii], Peter G Neumann states that:

> *'Some of the applications that stretch computer and communication technology to the limits involve military systems, including both defensive and offensive weapons. We might like to believe that more money and effort therefore would be devoted to solving problems of safety and lethality, system reliability, system security, and system assurance in defence-related systems than that expended in the private sector. However, the number of defense problems...suggests that there are still many lessons to be learned.'*

He classifies as military IT related accidents, among others, the shooting down of the Iranian Airbus by the USS Vincennes (inflexible software and archaic hardware), the destruction of two Black Hawk helicopters by US F15s in northern Iraq and the bombing of HMS Ark Royal by an RAF pilot (target offset error). More recently, the USS Yorktown off the coast of South Carolina was unable to operate its engines for hours because of a problem with its IT-based control system (unchecked divide by zero) [xiv].

In assessing the future use of COTS IT and its possible deficiencies from MoD's point of view, the shortcomings which would have occurred, should the IT have been specially produced for military purposes, will not be considered. Likewise, Information Warfare is not taken into account, except where it is felt that COTS IT makes such warfare easier for an enemy.

3.4.7 Y2K bug

Early in the research programme, it was recognised that the so-called Y2K bug was a problem for MoD as it was for other organisations worldwide. However, as the problem would have been resolved (and has been resolved) before this thesis was finished, it was decided to exclude it from the work being undertaken. In the event, major suppliers such as Dell Computer Corporation [xv] on the hardware side and Microsoft [xvi] on the software side have provided free down loadable fixes on the Internet for systems dating back to the early 1990s. Added to this is the fact that the problem was seen as one that required perspiration rather than inspiration.

3.4.8 GOTS and MOTS

Military equipment and systems developed and produced for overseas armed forces, particularly those of the United States and other NATO countries, should meet the similar requirements of the UK's armed forces. When these items are purchased off-the-shelf by UK MoD, they could be considered as COTS, but in reality are better classified as government off-the-shelf (GOTS) or military off-the-shelf (MOTS), and are excluded from further consideration.

4 INFORMATION GATHERED FROM LIBRARIES, THE INTERNET, SYMPOSIA, CONFERENCES AND EXHIBITIONS

This section gives details of the information that has been gathered from the searches of libraries and the Internet, as well as that gathered through attendance at the various exhibitions, conferences and symposia. It summarises useful published information and objectively reviews the key points from each source.

4.1 Introduction

A wide range of data sources have been examined, including the British Library, the UCL Science Library, the MoD library in Whitehall and the Internet. In addition, several defence/aerospace exhibitions were attended, as well as a number of relevant symposia and conferences. Those sources that are pertinent to the topic of this research, most of which were not available when the transfer thesis was written, are summarised, regardless of whether the source is a book, a published paper, an article in a journal or a presentation at a conference or symposium. In addition, some sources are detailed that have provided useful background information. Excluded here, but included in Section 10, is information about the experiences of the US Navy with COTS IT.

The aim was to distil from existing literature the essence of COTS IT, to indicate where there is a strong consensus of views and to highlight any significant conflict of opinions without taking a judgemental view that might introduce bias. In the event, there was much more consensus than conflict and this is reflected in the conclusions of this Section in Paragraph 4.25.

Many sources were examined in detail and over eighty were excluded from this section either because they are not directly relevant or because they do not provide particularly useful data. For the vast majority of sources actually used, the information they contain is reviewed in terms both of the content and the writer's background, highlighting the benefits, problems and other issues involved in the use of COTS IT in military equipment. For minor sources (Paragraphs 4.2 – 4.7), details are given of the reasons for their use and where they are referenced in the text.

4.2 The Making of the Micro – A History of the Computer [xvii]

This book deals with the history of computers from the earliest times until 1981. It thus provided useful background reading and, in particular, details of the first military uses of electronic computers – the birth of IT. It has been used to provide a historical perspective for this thesis and is referred to in Paragraph 5.1.

4.3 From components to integrated systems: Technological diversity and interactions between military and civil sectors [xviii]

This book proposes a classification of systems in a vertical hierarchy from materials at the bottom to the most complex systems at the top. This has helped to define the place of COTS IT in military equipment. An extract from this book can be found in Paragraph 5.2.

4.4 The Relations between Defence and Civil Technologies [xix]

In this book, the editors usefully examine the differences between civil, multiple and military uses. They mention that the multiple-use category is the most important due to its effect on military spending and civil-funded technologies for the defence industrial base. An extract from this book can be found in Section 5.3.

4.5 Virtual Reality Systems [xx]

An extract from this book, which has provided a good basic grounding in virtual reality, can be found in Paragraph 5.6. This technology is of growing importance for military training and simulation systems.

4.6 Realising our Potential A Strategy for Science, Engineering and Technology [xxi]

This document comments on the decisive edge technology can give in conflict situations and the vital need for substantial investment in defence research and development, quoting figures. It also states that MoD buys commercial technology when it offers best value for money, producing opportunities for microelectronics and IT companies to offer their technology in bidding for defence projects. This has been important when considering how the UK defence budget is spent. An extract from this book can be found in Paragraph 5.3.

4.7 The diffusion of information and communication technology in the world economy in the 1990s [xxii]

Chapter 2 of this book defines radical innovations. This is useful in the context of IT as a radical innovation and its comparison with other radical inventions in terms of their impact on military equipment. An extract from this book can be found in Paragraph 5.1.

4.8 Journal of Defence Science [xxiii]

The April 2000 edition of this journal carried a number of unclassified articles on the military application of COTS equipment. To quote Professor Damien McDonnell, Director, Defence Diversification Agency:

> *'At the height of the Arms Race, half of the world's physicists and mathematicians were employed in defence R&D and much of today's electronics and information technology derived from their work.... Today, the position is quite different. The MoD's funding of research has halved in real terms over the past decade, whilst civil research, in mobile communications and Internet technologies for example, has grown strongly. The UK's main industrial sectors are telecommunications, banking and financial services, oil and gas, pharmaceuticals, insurance, media and photography, and information technology ... together account for 75% of the market capitalization of the FTSE (Financial Times Stock Exchange) 100 (Shares Index). All of them depend heavily on technology and research. It is hardly surprising therefore that defence now relies increasingly on civil research.*
>
> *This issue of the journal explores ... the challenge of using COTS technology in defence systems. This challenge comes not just from the mismatch of time-scales and culture between defence and civil industry but also from the very difficult requirements of military equipment and the uncertainty over how it will be used... '*

4.8.1 Defence systems procurement in a COTS world [xxiv]

Exploiting COTS components in defence systems seems likely to be ever more important. The approach has many advantages but it also raises important issues. This paper outlines some of these issues, discusses the impact of COTS on defence systems and their procurement, and summarises the activity of a related Defence Scientific Advisory Council (DSAC) working party.

Using COTS items in defence equipment can save on procurement costs and time-scales, and improve reliability and interoperability. But there are drawbacks: design control by MoD passes to dependence on commercial sources, so raising issues of availability, certification and security. This paper considers some of the key issues that face MoD when procuring and using systems with significant COTS content. Many apply whether the COTS items are hardware or software; however, the emphasis here is on software.

A short discussion of COTS in relation to traditional development leads to recognition of the greater suitability of the Smart Procurement approach and to the scope for more radical approaches, especially to software. The concluding section of the paper is a summary of the studies of a DSAC working party, which has yet formally to report. A thread that emerges from the paper is the need for COTS-based acquisition to be underpinned by technically informed support at all stages. However, the advantages that COTS IT offers MoD are also available to potential enemies and this must be considered.

There are several defence-specific requirements that are unlikely to be met by COTS items because the global market does not demand them. These requirements, if retained, will limit the exploitation of COTS. A long-term risk is that meeting these requirements will become ever more expensive as they represent an increasingly niche market.

A key consequence of extensive exploitation of COTS is loss of control by MoD, especially where the COTS item is single-source. This affects upgrades but also introduces issues such as certification when the COTS item is a black box. COTS items also bring concerns for security, both because of their black-box nature and because any weaknesses are likely to be common knowledge to potential enemies.

COTS software is especially likely to change rapidly and to do so asynchronously with MoD's programmes. Where appropriate, an upgrade strategy that caters for this is needed. Open-source software, which by its nature is not black box and is much more controllable, potentially offers many of the benefits of COTS without the attendant disadvantages.

The move from traditional approaches to Smart Procurement provides many opportunities for exploiting COTS, because of its focus on flexibility and shortened time scales. A DSAC working party addressing COTS issues (amongst others) has highlighted some additional important points and is making detailed recommendations for corresponding action by MoD.

Review of information

This authoritative source, written by a member of DERA, considers the advantages and disadvantages of COTS software in particular. It sees benefit in cost, time scales, interoperability and reliability and thinks that MoD's Smart Procurement initiative can help to get the best from the use of COTS. On the negative side, it sees the loss of product control, in its various forms, by MoD as serious and highlights the need to plan ways of overcoming these problems. It is, however slightly disappointing in that, while it outlines the work being undertaken by DSAC for MoD, it gives little detail.

Benefits

Savings can be made on procurement costs and time-scales with improved reliability and interoperability

Problems

Design control is lost. Availability, certification and security are difficulties. Advantages of COTS IT are available to potential enemies. COTS items are likely to change rapidly and asynchronously with MoD's programmes.

Other issues

Smart Procurement is seen as more suitable to COTS IT-based acquisition.

4.8.2 Military COTS-based systems – instant solution or long-term headache? [xxv]

COTS products are increasingly being used in military systems, an approach that offers many advantages including lower initial acquisition costs, faster delivery to the front line and the ability to exploit the latest technology advances. COTS products do, however, bring their own problems, including rapid obsolescence, lack of product control, and boxed functionality optimised for the non-military market. Both MoD and industry will have to adapt their management approaches and practices to realise the full potential of commercial technology. This article outlines the characteristics of COTS-based systems and discusses some of the resulting management issues.

COTS components are becoming an increasingly important part of acquiring military systems, particularly in the areas of information technology and communications. They should offer the potential to harness the rapid technological developments in the commercial world and to capitalise on the lower costs delivered by mass-market developments. Over recent years, these potential advantages have led to a view within the MoD that using COTS would solve many long-standing problems in military systems, and would allow more capable systems to be delivered quicker and at lower cost. In essence, COTS would enable systems to be procured 'faster, cheaper, better', the central mantra of the UK's Smart Procurement Initiative.

This initial widespread optimism is now being replaced by a realisation that, while using COTS delivers many advantages, it also brings challenges of its own. These include rapid product obsolescence, lack of control over product support and difficulty in predicting future developments. Many of these factors become most critical after entry into service and obsolescence has started to have a significant effect on support and development.

If these problems with COTS-based systems are to be solved and the attendant risks contained, changes are required to the management of their acquisition and support. Much work has been directed at the technical and design issues relating to the use of COTS products. This article, however, explores aspects of the through-life *management* of COTS-based systems, including initial acquisition, requirements management, managing upgrades, spares support and costing. It focuses on IT systems but includes many lessons of wider application.

Developing and supporting military COTS-based systems brings many challenges. A typical system will incorporate a large number of COTS components in a new configuration unique to the application. This leads to a greater complexity than is often appreciated, and may require as much design effort as a bespoke system. The commercial components will not have been aimed at military environmental requirements of applications, nor will compatibility with other components used in the development have been considered. Moreover, COTS components age rapidly as technology advances and manufacturers strive for commercial advantage, while military systems are intended to have long lives. If defence systems are to benefit from the immediate COTS advantages of low initial costs and avoidance of the need for bespoke component development, and if evolving improvements are to be exploited, then system design practices will have to change to cope with trade-offs between functionality offered and required, obsolescence, upgrading, uncertainties in through-life cost predictions, spares management and configuration control. The challenges of making best use of COTS components are more than technical: some run counter to current management practices in military acquisition and call for a new approach to represent and balance the needs of stakeholders in government and industry.

Review of information

This is one of a number of papers written by the same author[2] on the subject of COTS IT in military equipment[3]. It is particularly useful in summarising MoD's current views, hopes and aspirations while at the same time highlighting many of the difficulties that result from the use of COTS IT. It explains both the advantages and potential problems of using COTS. It mentions benefits of lower initial acquisition costs, faster delivery and the ability to exploit the latest advances in technology. Against these must be balanced rapid obsolescence, lack of product control, and functionality optimised for commercial use, which require active through life management if they are to be overcome. It considers the most important need is to change acquisition management and the benefits in this area from the UK Smart Procurement Initiative.

Benefits

COTS IT is delivered faster, cheaper and better.

[2] The author works for a British company that contracted him to work part-time for DERA.

Problems

Obsolescence is a problem for long-lived military systems, as is lack of control of product support and difficulty predicting future developments. COTS components do not match military environmental requirements and are not compatibility with other components.

Other issues

Use of COTS components in new and unique configurations. Greater complexity than appreciated may require as much design effort as bespoke systems. System design practices must change to cope with trade-offs between functionality, obsolescence, upgrading, uncertainties in through-life cost predictions, spares management and configuration control. Some challenges of making best use of COTS components run counter to current management working practices in military acquisition and call for a new approach to balance needs of government and industry.

4.8.3 Strategies for dealing with through-life obsolescence [xxvi]

Electronic components now become obsolete ever more quickly as technology advances. Military systems are affected because of their increasing dependence on COTS components. Thus the advantages of lower costs and shorter development times using COTS components call for strategies for dealing with their shortcomings. Centralized component monitoring could provide a solution to managing obsolescence, while techniques are within sight for predicting unreliability. A systems engineering approach to obsolescence management could determine the most effective solutions for equipment modifications, upgrades or inserting new technology during the equipment life-cycle, and enable exploitation of the beneficial COTS performance advantages.

The military requirement for semiconductor products is now greater than it has ever been but the market is increasingly driven by civil applications; the military share is less than 0.5% today. Major semiconductor manufacturers now see military needs as low priority and many have withdrawn from this sector of the market. Thus military-qualified parts are becoming fewer, and greater reliance is being placed on COTS technology. The average rate of turnover in such technology is increasing to an expected rate of once every two years by 2005, so products are becoming obsolete more quickly. As a result, components now being designed into new military systems will probably be obsolete when the equipment enters service and unavailable thereafter.

COTS components have other drawbacks but marked advantages. Their environmental robustness may be inadequate and they escape normal military screening processes. Their rapid obsolescence raises the need to be able to introduce upgraded technology into systems. On the other hand, COTS components provide technology updates quickly and at a fraction of the cost of components derived traditionally from MoD-funded research. Where they can be introduced, COTS components are an economic way of keeping up to date. The advantages are dominant, and military systems that are expected to see many years' service must cater for the disadvantages.

[3] The others are: Impact of the increased use of COTS & open standards on MoD procurement policy & procedures. – Through Life Management of COTS-Based Systems.

While semiconductor obsolescence influences the long-term support of electronic components, other areas of technology such as software, are similarly affected and raise cost and operational through life support issues. Many of these technologies are inextricably linked within equipment, thus calling for a systems engineering approach to obsolescence management in place of conventional components-based discrete technology solutions.

Research in DERA is showing that there is a growing interdependency in future systems between solutions to obsolescence, concerns over reliability, and exploiting COTS technology. Overcoming the obsolescence problem must recognise this if the goal of effective low-cost through-life support is to be met. This paper describes possible medium and long-term strategies for coping with obsolescence.

Review of information

This paper, written by a DERA specialist on the subject, concentrates almost entirely on a single but important topic – obsolescence. Its views on the advantages and disadvantages appear to have been included as a frame for the main topic, rather than as a comprehensive view of COTS IT. It concentrates on the ever-increasing rate of COTS component obsolescence and the need to plan for this in basic system design so that new technology insertion can readily be implemented. It mentions as possible solutions the need for centralised component monitoring and the benefits of using a systems engineering approach. It highlights the fact that military-qualified components are rapidly disappearing and that the military market is now unattractive to COTS suppliers.

Benefits

Lower costs and shorter development times are certain. Rapid technology updates can be made at a fraction of the cost of components derived traditionally.

Problems

Electronic components become obsolete increasingly quickly as technology advances, raising need to introduce upgraded technology into systems. Military-qualified parts are becoming fewer with greater reliance on COTS technology. Difficulties arise from inadequate environmental robustness and lack of military screening processes.

Other issues

A systems engineering approach is needed to obsolescence management. Centralized component monitoring could provide solution to managing obsolescence.

4.8.4 The EMC implications of using COTS in military systems [xxvii]

The electromagnetic environment in which military COTS electronics will be expected to survive is likely to be more severe than its civil counterpart. Thus using COTS equipment could lead to more vulnerable systems than if only military-specified equipment were used. The problem is getting worse because, as technology advances, devices are likely to become more vulnerable. The paper explains how the difficulty may be contained. It identifies the key differences between the civil and military electromagnetic environments, describes the basic requirements and standards, and summarises design guidance. Protection and hardening methods are then examined. It concludes that, while the necessary knowledge, techniques and procedures are available, caution is needed in integrating COTS items into defence equipment, not least because savings from using COTS items can be largely lost in the costs of testing and protecting them.

Review of information

This is a 'Restricted' paper [4] by an avionics specialist working for DERA. It concentrates on the potential problems in ensuring EMC for military systems containing COTS items. It provides much useful advice on overcoming incompatibility, but points to the potential cost of ensuring compatibility. The widespread application of its advice by COTS IT hardware producers may, to an extent, be limited by its classification.

Benefits

Identifies key differences between civil and military electromagnetic environments, describes basic requirements and standards, and summarises design guidance. Examines protection and hardening methods.

Problems

Electromagnetic environment in which military COTS electronics are expected to survive is more severe than its civil counterpart giving increased vulnerability.

Other issues

Savings using COTS items can be largely lost in costs of testing and protection.

4.8.5 The application of COTS technology in future modular avionic systems[xxviii]

Current avionic systems make extensive use of military specifications and standards but are based on dedicated implementations for individual avionic functions that are expensive to develop, procure and support. Future systems will be based on integrated modular avionic concepts in which all functions are implemented on a common processing platform constructed from standard hardware and software modules. To optimise the application to future modular systems, an architecture based on standardised interfaces will allow modules to use COTS components and standards to achieve affordability and exploit rapid advances in commercial technology. At the same time, approaches are being developed to deal with short commercial time-scales and loss of control over specifications and standards.

The main problems and benefits in terms of system architecture, software, networks and processing must be addressed when designing advanced avionic systems using COTS technologies. An architecture using standardised commercially available interfaces leads to lower costs and leverage from the commercial market-place. However, the avionic community demands solutions tailored to provide scalable, flexible, implementations adaptable to future needs.

[4] The author has confirmed that this summary of his paper is unclassified.

The specific technical requirements of integrated modular avionics (IMA) software make it difficult to decide if the benefits of COTS outweigh the drawbacks. Unfortunately, there are no actual examples where through-life cost savings have been demonstrated by using COTS software. Only some inconclusive cost-modelling results exist. The correct approach is to design architectures that cater for COTS software components and to postpone the decision on whether actually to use COTS or custom-developed products until required by a particular aircraft project.

For networks, new COTS technologies often offer significantly better performance at potentially lower costs. However, although COTS can save money on basic design, the savings are less when the upgrade to 'COTS plus' is implemented, even in a largish military avionic market. Thus the savings predicted by using COTS networks are much more limited in practice. Moreover, the pace of technical change, coupled with unpredictable market forces, can easily undermine the definition of the military platform's architecture before the in-service date is reached.

The development of military-specific processing technology is prohibitively expensive, and there is no alternative to using COTS solutions. Generally, the potential for directly exploiting commercial processing technologies is excellent, with a wide variety of high performance devices being readily available. However, in some areas, IMA system design is at risk owing to obsolescence and environmental considerations, although these effects can be reduced. When the implementation of application functions is examined in more detail, some features of COTS processing devices are not ideal, and so there are still performance issues. However, with careful design, and accepting that some tailoring of applications will be necessary, it should be possible to cater for these shortcomings.

Review of information

This paper, co-authored by a group from DERA, deals with the specialist area of avionics but their views may also have application to other types of platform. It highlights the tough environmental specifications faced by avionics equipment and the key issues that are faced in designing such systems using COTS IT, in particular, the architectural approach. It recognises that there is no alternative but to use COTS and suggests that some tailoring of applications will be needed. Some of the cost modelling issues, which arise from using COTS, are identified.

Benefits

Affordability and exploitation of rapid advances in commercial technology are features. Significantly better performance is realisable at potentially lower costs.

Problems

Obsolescence and environmental factors are obvious snags. Unpredictable market forces can easily undermine definition of military platform architecture before the in-service date is reached. Short commercial time-scales and loss of control over specifications and standards are problems.

Other issues

No examples of systems using COTS software with demonstrated through-life cost savings.

4.9 DERA Guide to Software Purchasing [xxix]

This guide dated 1998, supplied in draft form, comprises 43 sides of A4 paper and deals, amongst other things, with the evaluation, acquisition and management of COTS software. Its stated purpose is to provide advice on:

1. Assessing and choosing the best approaches to software purchasing.
2. Evaluation, acquisition and management of COTS software.
3. Evaluation, acquisition and management of bespoke software.
4. Understanding software contractual issues.

While item 3 is not relevant to this thesis, the other three items, particularly item 2, are fundamental to the use by MoD of COTS software. The guide starts by stating that it is not a substitute for experience and that software practice training courses are provided by DERA.

It highlights the three options available for sourcing software – 'Do it yourself', purchase COTS, and purchase bespoke. It points out that this is unlikely to be a straight choice but will involve a degree of competition. For MoD, the first option is not generally a possibility.

It then outlines the general software procurement life cycle and emphasises the need to be aware of good purchasing principles. Under 'choosing the right option', it suggests among other things:

1. Always buy COTS software in preference to building it yourself or contracting out.
2. Consider integration of COTS software in preference to custom development
3. Use object libraries (e.g. Microsoft Foundation Classes) rather than write your own.
4. Look at DERA, MoD and industry for sources of similar software.

It highlights the advantages of COTS as:

1. Reduced development cost.
2. Multiple use could lead to discounts.
3. Reduced testing costs.
4. Economies of scale.
5. Earlier delivery.
6. Reduced risk of failure.
7. Reduced long-term maintenance costs.
8. Reusable components for other systems.
9. Reduced risk.

It stresses the need to spend time finding out what is available but says overall time and money will be saved. It also mentions that the use of COTS software is almost always a compromise and that COTS often requires customisation. The disadvantages of COTS software are:

1. Suppliers exaggerate the capabilities of their products making assessment difficult.
2. Requirements may only partially be met.
3. Missing functions are often promised in the next release.
4. Releases are often late (allow twice the elapsed time after the promised date).
5. Dependence on COTS products means more dependence (e.g. on operating systems).
6. Future compatibility with dependencies may not be guaranteed.
7. Some functions may not be available (and may or may not be easy to add).
8. Documentation standards are often poor (same is often true for bespoke systems).

9. Whole life costs need careful consideration.
10. Product support levels may not meet expectations.

Under the section headed 'Managing COTS product selection and purchases' it mentions that the purchaser has no control over the design, product management or development of COTS software. Contractual issues and integrating COTS software are seen as important factors. Assurance that software has adequate quality and reliability for its future use can be gained from:

1. Buying from a reputable and reliable supplier.
2. Using suppliers on which DERA has vendor information.
3. Testing and accepting the software on receipt.
4. Ensuring the availability of adequate support and post-development service.

The most common problems with COTS software are:

1. Failing to define requirements for the product.
2. Defining too many requirements and stating too many 'mandatory' requirements.
3. Having unbalanced evaluation weightings against individual requirements.
4. Having prejudices about one solution before evaluation.
5. Failing to allocate sufficient resources and experience to the procurement process.

There are also caveats against becoming over-dependant on COTS products, and that when COTS products are embedded in systems, the architecture of the main system may well be affected. There is a better chance of replacing COTS products or having some competition if international de facto standards are used to define interfaces. An exit route should be planned so that other COTS products can be bought if one supplier fails or a better product emerges.

Preferred COTS products can be used across an individual project as well as in many projects, but information must be updated as the market changes and re-evaluations run at sensible intervals. Care is needed in specifying requirements and deciding whether to use a COTS product, as well as in dealing with contract issues such as licensing, shrink-wrapped purchase, intellectual property rights, maintenance, indirect supply and standards. In addition to price and benefits, there is an exhortation to consider whole life cost implications when deciding what to purchase.

4.9.1 Review of information

This guide, although still in draft form, is valuable as it represents an outcome of a significant effort by DERA to look as the issues involved in procuring IT including COTS IT. Clearly it provides an extremely useful cross-reference to other information gathered, albeit only for software, and could form the basis of a possible guide on the subject by DPA. Its comprehensive views include nine advantages and ten disadvantages of using such software. It also suggests four routes to obtaining quality COTS software and highlights the five most common problems that occur when taking this route. It also gives caveats on over-dependence on COTS products and the need for a careful contractual approach.

Benefits

Reduced development and testing costs as well as earlier delivery help. There are reduced chances of failure, long-term maintenance costs and risk, and reusable components for other systems.

Problems

Suppliers exaggerate product capabilities making assessment difficult. Requirements may only partially be met. Releases are often late. Missing functions are often promised in the next release. Some functions are not available. There is an ongoing dependence on COTS products. Future compatibility may not be guaranteed. Poor documentation standards are normal. Product support levels may not meet expectations. Whole life costs need careful consideration.

Other issues

The most common problems with COTS software are failing to define requirements for product, defining too many requirements, having unbalanced evaluation weightings against individual requirements, having prejudices about one solution before evaluation, and failing to allocate sufficient experienced resources to the procurement process. Caveats are made against becoming over-dependant on COTS products.

4.10 Guidance on Off-the-Shelf System Acquisition [xxx]

This twelve-page document provides guidance for IPTs on issues arising out of the use of COTS technology in MoD procurement and support. The guidance focuses on IT systems, since using COTS IT poses the greatest management challenges. COTS-based solutions generally offer reduced initial purchase costs, reduced acquisition times and the capacity to remain close to the state-of-the-art. For these reasons using COTS products has become a common feature of many defence procurements in the on-going drive to improve value for money and reduce whole life costs. However, this approach has its drawbacks, which are stressed so that they can be managed throughout the acquisition process. The essential issues underlying the use of COTS products are:

- Obsolescence.
- Lack of product control.
- Requirements trade-offs.
- Open standards.
- A changing relationship with contractors.
- System flexibility.
- Interfaces.

The document provides brief recommendations for through life management, inter-project liaison, managing the contractor, managing COTS software, safety, security, reliability and environmental issues. Of these, the sections on costs and support are particularly relevant.

4.10.1 Costs

MoD-specific requirements that lead to changes in COTS products will be key cost and risk drivers. Whole-life cost estimating for COTS-based systems is complex and unreliable. Major

COTS-based systems require as much design effort as a bespoke development and provision is needed for the redesign process that characterises COTS-based systems throughout their life. To maintain the capability of COTS-based systems, there will be a significant and probably unstable cost throughout the life of the system. Short-term savings in funding of COTS-based systems may lead to loss of skills or missed opportunities for upgrades, thus increasing overall whole life costs.

4.10.2 Support

The extent and nature of COTS IT hardware and software products in the system must be reflected in the whole life support strategy, addressing the issue of short lifetime for much COTS IT. With COTS-based systems, there will be a need for front line maintainers to access software design if some bug fixes and reconfigurations are to be successful in operational situations. The long-term support process must keep pace and reduce costs in line with current commercial practice and technology developments.

Plans (and funding) must be in place to provide relevant COTS market knowledge, to inform on upgrade decisions, provide realistic user aspirations for maintaining state-of-the art capabilities and give warnings of future obsolescence.

4.10.3 Review of information

This comprehensive DPA guide is important because it has been written for the members of integrated project teams. However, it by no means deals with all the issues associated with the use of COTS IT and, to an extent, is indicative of the gulf between DPA and the Equipment Capability customer. It starts with the benefits of using COTS IT and highlights the key issues. It then examines through life management, inter-project liaison, managing the contractor, managing COTS software, safety, security, reliability and environmental issues. On the subject of costs, it highlights the significant and probably unstable life cycle costs of COTS IT. Considering support, it emphasises the need to keep pace with current commercial practice both in process and cost reduction terms.

Benefits

Reduced initial acquisition costs and acquisition times. Ability to remain close to state-of-the-art.

Problems

Cost estimating for COTS-based systems is complex and unreliable. Short-term savings in COTS-based systems can increase overall whole life costs. Obsolescence, lack of product control, interfacing difficulties, requirements trade-offs and open standards are all difficulties.

Other issues

There is a need for requirements trade-offs and a changing relationship with contractors. To maintain COTS-based systems capability involves significant through life cost. Plans and funding must be in place to provide relevant COTS market knowledge.

4.11 Engineering in the Information Age [xxxi]

This paper includes a section dealing with the basic technology used in COTS IT and the way in which the use of the technology is growing. Moore's Law [5] says the performance of silicon microchips doubles every 18 months for no extra cost and appears to have another 10 years to go.

- Reduction of feature size in semiconductor processes continue to progress at about 30% every three years – 0.18μ in 1999, 0.15μ in 2001, and 0.1μ forecast by 2006.
- High-end processor chips run at 750 MHz with four million transistors per chip. By 2003, the most powerful microprocessors will run at 1500 MHz with 18 million transistors per chip. The next generation of processor architectures will have at least 10 billion instructions per second per chip in the initial products.
- Semiconductor memory is providing 60% more bits/chip/year. The cost of semiconductor memory is now around 50 cents per megabit and the number of megabits per dollar is likely to double every 18 months for the next few years. The latest Technology Forward Look Paper from the ITEC Foresight Panel [xxxii] expects the first commercial applications of 1-Gigabit semiconductor memory chips in 2002 and 1 Terabit between 2007 and 2010. In 10 years, developments will hit the physical limitations of lithography. However, the $2 billion cost of the fabrication facilities may slow progress earlier.

Computing is moving into the consumer price domain, and becoming embedded in a huge range of products. Forbes Magazine[xxxiii] estimated 99% of all microprocessors manufactured go into embedded systems not into personal computers. In 1997, the industry shipped about 300 million 16/32-bit microprocessor chips, two-thirds for embedded systems There have also been dramatic advances in on-line magnetic disc storage with hard disc capacities growing at around 60% per year. A current CD-ROM stores 650 Mbytes and DVD technology increases this seven fold. However, a survey article in Forbes Magazine [xxxiv] predicts that bits stored magnetically will become unstable at densities of around 40 – 80 Gbits per square inch. Applying Moore's Law, there is another 5 - 10 years of disc storage progress, with new technology in the pipeline.

The Internet was developed in the late 1960s as a US DoD experiment to link American universities. Two developments transformed the Internet into a worldwide information medium – the invention of the WWW in 1989 and the introduction in 1993 of the first multimedia Web browser. The Internet has grown to a user base of between 60-100 million within four years; the growth rate showing no signs of diminishing. The anticipated number of Internet users will reach 300 – 1000 million by the end of 2000. The Internet is already becoming a viable alternative to the telephone network for fax and even for voice.

Radical innovations and huge investments have brought about great change and disruption in the technical and business structures of global telecommunications. In particular mobile communications have developed very rapidly over the past 10 years. Over the next five years, the

[5] See Figure 6 on Page 92.

five largest projects plan to spend $25 billion putting up over 500 satellites, offering global wireless communications services [6].

A key driver and enabler is the rate at which the necessary common standards emerge, diffuse, stabilise and become pervasive. There has been conflict between top-down, de jure, global and bureaucratic standards used by telecommunications and CCITT; and bottom up, de facto ad-hoc standards typical of the Internet and the personal computer. There have been some very important successes on both sides. The world's communications infrastructure now runs basically on just two protocols; the Internet depends on TCP/IP from the public, global, de facto but ad-hoc camp.

In computing, UNIX® and NT are the two de facto industry standard platforms. In neither case has any de jure public standards body made any pivotal contribution. Now, HTML and its derivatives from the open, public WWW community are emerging. There has been intense competition to establish the de facto industry standard browser and a universal standard for transporting program code around the Internet.

The paper stresses the extent of IT dependence in the national infrastructure, mentioning that computers and networking are now mission-critical to most kinds of business activity. In telecommunications, the combined global telephone network and Internet is the largest and most complex system ever built. The transport infrastructure crucially depends on IT. National retail/ distribution networks have thousands of point of sale computers and complex supporting IT systems linking suppliers, distributors, banks and credit card companies. Financial services depend entirely on huge IT system, from secure ATM machines to electronic stock exchanges. Government itself is one of the biggest users of IT for tax, social services, health and the like. Large national and international companies also boast major corporate IT networks. To all of this can be added the tens of millions of personal computers now found in most businesses and many households.

As this IT, and the national dependence on it, is virtually all COTS, it bodes well for the future availability and support for military use of COTS IT.

4.11.1 Review of information

This paper, by the then President of the Institution of Electrical Engineers, and published in their two-monthly journal, provides an important background to the rapid development of COTS IT. It indicates the progress that has been made and will continue to be made in all areas of IT. It shows where the pressures are emerging from and its importance to governments. The fact that it makes virtually no mention of defence, highlights the relative unimportance of this sector in the overall development of information technology. Despite this, it suggests that the pervasiveness, availability and support are likely benefits for military applications.

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[6] The Iridium satellite telephone project has already become an early and major casualty.

4.12 Guideline for COTS Insertion [xxxv]

This document provides guidelines for the use of COTS IT in Naval Combat Systems, addressing all aspects of its life cycle. Some or all of the guidelines are aimed towards military end-users, system integrators, and sub-system suppliers.

The document considers all phases of a combat system life cycle: requirements definition, development, manufacture, and life cycle support, all conducted within a competitive procurement environment. COTS poses different issues at each phase, although there are common threads that run through all of them. There are some significant implications of COTS that result in a top-level life cycle model quite different from that of the traditional model associated with bespoke development. The key guidelines that emerge from this new model are:

1. Establish requirements based on what COTS can do, not how it can be modified to meet 'special' needs.
2. Set up IPTs of all participants, empowered to authorise change within well-defined boundaries.
3. Negotiate requirements at an early stage with potential system suppliers through this IPT process.
4. Select architectures and standards favoured by the commercial marketplace, even if not optimal for combat systems, to maximise the probability of compatible long-term upgrades.
5. When using COTS IT where there are no standards, use architectures to minimise impact of product change.
6. Make batch procurements of a particular configuration, and limit logistics support to that batch.
7. Develop updated designs in parallel with procurement of a fielded batch by embracing the concept of 'continuous engineering'. Insert decision points in the life cycle indicating whether to qualify and implement the new design, or to retain the existing design, for the next batch.
8. Insert points in the life cycle where retrofit decisions can be made or different configurations retained.
9. Provide funding authorisation that reflects a more linear spend profile than the traditional one of high initial design and build costs followed by lower logistics support costs.

It is felt that if all parties, including the end customer, buy into the ownership issues of COTS by following these guidelines, command systems (naval or otherwise) will result that are potentially more supportable, continuously closer to the state-of-the-art, and lower cost than traditional bespoke systems.

4.12.1 Review of information

The NATO Industrial Advisory Group has always been an influential source of guidelines for the member nations. Although this guideline is aimed at a single service, the nature of naval combat systems is such that many of them are equally applicable to the other two services. It is process rather than issue orientated. It establishes nine useful guiding principles for those involved with procuring equipment that incorporates COTS. These deal, in particular, with early work by integrated project teams to establish COTS compatible requirements. These are based on commercial architectures and standards, and procurement, support and upgrades on the basis of batches. It also highlights the need for a more linear through-life spend profile.

Benefits

Commercially favoured architectures/standards allow compatible upgrades.

Problems

Configuration control is non-existent.

Other issues

Avoid modifying COTS. Timing of upgrades is hard. A more linear spend profile is needed.

4.13 Military Hardware Procurement: COTS: Pipe Dream or Salvation? [xxxvi]

The integration of commercial technology into military systems makes sense in the current climate of fiscal restraint. It allows military forces to take advantage of existing technology to reduce development time and cost, and rapidly deploy new systems. However, military systems that contain COTS components are not COTS systems, nor should they be treated as such. Failure to recognise this fact will lead either to lost capabilities or expensive and complex life cycle management. There is a limit on cost reduction. This limit is reached when military commanders are at risk of losing essential combat capabilities because of the lack of support for their equipment. A Canadian Forces policy on the acquisition of military systems, using commercially available components, should be written to ensure the long-term support of these systems.

4.13.1 Review of information

The fact that this paper is directed at the Canadian armed forces does not make its message any less relevant to UK MoD. It recognises that there is a need in the Canadian armed forces for a policy on the use of COTS components in military systems and that such systems need to be treated differently if capabilities and through life costs are to be controlled. However, it might have done better to focus on the need for guidelines on the use of COTS, rather than the requirement for a policy.

Benefits

Reduced development time and cost.

Problems

Lost capabilities or expensive, complex life cycle management/long-term support are common.

Other issues

Guidelines are needed on the acquisition of military systems using COTS components.

4.14 Practicable Open System Technology Applied Research Technology Demonstrator [xxxvii]

The Practicable Open Systems Technology (POST) Applied Research Technology Demonstrator (ARTD) programme is investigating and providing practical demonstration of an open systems technology approach for use in the infrastructure of future maritime combat systems. The first phase of the programme developed a baseline demonstrator to investigate the design and implementation issues of using a commercial middleware approach (Common Object Request Broker Architecture - CORBA) to link three real time ARTDs. The second phase, due to complete in December 1998 addresses the performance issues of the baseline demonstrator. This paper presents results and lessons learned from the first phase of the work.

Lessons learned from this programme [7], include:

1. Continuous discussion between the engineers on either sides of the interface is essential, should commence early and be maintained throughout the programme.
2. Quoted supplier delivery times are often unattainable and the product dependency chain needs understanding.
3. COTS product availability is dictated by market trends, which MoD can rarely influence. Designing applications to be portable helps avoid potential problems of being reliant on a declining product.
4. Do not treat COTS computers as black boxes. Understanding the operating system can result in a better or cheaper solution to a problem.
5. COTS product standards compliance can be difficult to define and prove. COTS products normally contain undocumented features.
6. When considering upgrades, obtain an understanding of COTS product interdependencies from the vendors.
7. COTS software products must be supplied with sufficient documentation about functionality and interfaces to allow efficient system integration.

In addition the features of COTS product should be characterised in terms of their relevance to the application, and design information obtained from vendors, to develop an understanding necessary for integration purposes. A database of suitable COTS products should be developed and maintained to minimise the dependency on specific products or vendors. Forecasting COTS product availability and development is required to try to future-proof the adoption of COTS products. Flexibility should be added to the application system development programme to allow for likely COTS product development slippage and product specification changes.

Management action is required to ensure co-ordination and liaison where technical interfaces exist between COTS products. These interfaces should be described in terms of functionality, behaviour and performance parameters. Exception handling by COTS software must be carefully

[7] A full list is provided in POST Engineering Lessons Learned DERA/SS/WI/TR980146/1.0

controlled as part of its integration into an application system. The parties responsible for the respective products should jointly agree the interfaces between any two COTS products that interact. Interdependencies between COTS products must be ascertained and potential product developments, which could impact on such interdependency, should be closely monitored.

4.14.1 Review of information

This paper is the result of work on a naval combat system technology demonstrator at DERA. On the one hand, it offers lessons learned from an actual prototype implementation, on the other, the lessons are limited to a single specialist project. It does provide a useful list of seven detailed recommendation that have resulted from the experience gained in using COTS IT in the development of a future combat system.

Benefits

Understanding operating systems results in better/cheaper solutions.

Problems

Supplier delivery times are often unattainable. The market dictates COTS product availability, which MoD can rarely influence. COTS products normally contain undocumented features. Standards compliance is difficult to define and prove.

Other issues

Characterise COTS products in terms of relevance to application. Develop and maintain a database of suitable COTS products. Forecast COTS availability. Add programme flexibility to allow for COTS slippage and specification changes. Continuous discussion between the engineers on either side of interfaces is essential. COTS software needs documentation to allow efficient system integration. Applications portability avoids problems of reliance on declining products. Understand product dependency chains.

4.15 The challenge of adopting COTS [xxxviii]

The author, following a discussion on COTS IT, provided a copy of this presentation, written in 1997 when he was employed at MoD PE (now DPA) where the term COTS is used to mean COTS IT. It covers:

- The trade off between requirements and COTS products and that they rarely match.
- COTS products are probably not COTS if they are customised.
- What is really meant by open systems?
- How to implement the use of COTS and is it possible keep up with the latest technology?
- How to accommodate change.
- How to support COTS.

4.15.1 Review of information

The author of this presentation was working in DPA on command support systems for the Royal Navy. He is a COTS IT enthusiast, has worked in the US on COTS IT, and has practical experience of its use on a Royal Navy warship. His presentation represents the outcome of serious thought on some of the more important COTS IT factors. It highlights some of the key issues in employing COTS IT and also methods of dealing with the concerns that this approach raises.

Problems

COTS products rarely match requirement. Keeping up with latest technology and accommodating change are difficult as is supporting COTS.

Other issues

COTS products are probably not COTS if they are customised.

4.16 Facing the risk in COTS [xxxix]

Military information systems have got much bigger and smarter, but they still have difficulty intercommunicating. Wider use of COTS software products promises to help these systems work together and also make them easier and cheaper to build. Unfortunately, COTS vendors sometimes emphasise getting leading-edge products to market quickly at the expense of reliability. An errant commercial application recently caused a server computer at the Australian DSTO C^3 Research Centre to become paralysed and all work in progress was lost. Such incidents occur all too frequently. In using COTS technology to build critical military systems, how can the associated hazards be reduced?

The Australian Defence Forces information systems have evolved over many years. Recent work indicates that existing systems have only limited ability to share data and to co-operate in other ways. A study of sixteen key defence databases revealed many problems, including differing sets of attributes and formats for the same entities. Use of COTS technology and 'software component' architectures promises to help here. Component-based military systems could evolve over time through substitution of improved technology and addition of new functions. Use of common components and standard interfaces would also help them to work better together.

A prototype portable information system has been constructed using a laptop computer. It includes a weather map, graphical situation display, geographic information system, remote database access and e-mail and took one person just three weeks to construct. It could easily be adapted for new missions. Compared with custom solutions, COTS-based systems can have distinct advantages in terms of functionality, user familiarity, speed of implementation and cost. However, COTS products are rarely of military grade and their use in critical systems requires particular care. The internal details of such products are usually hidden, making reliability assessment more difficult and increasing the likelihood of accidental or deliberate malfunctions, such as viruses. In the worst case, secret functions or trapdoors hidden in a COTS module could be used to compromise associated systems.

Military-grade versions of COTS products could be produced through collaboration with suppliers and industry partners. This would introduce delays, but would mean many 'teething' problems would be resolved in commercial use before military versions were deployed. By removing access to non-essential information, services and functions, many trapdoors and potential triggers for hidden functions could be disabled, and modules could then be monitored for any unexpected behaviour. Through effective isolation of individual COTS modules, 'denial of service' attacks could also be contained. Finally, if critical systems perform frequent integrity checks and are constructed with backup hardware, software and communications, they could continue to operate despite malfunctions.

There are many challenges to be faced in building future military information systems. Requirements are increasing while budgets are stable or shrinking, previously self-contained systems now need to work together and to survive both failures and deliberate attacks, and the speed of technological change means that systems can be obsolete before they are free of errors. Use of COTS technology will play a crucial part in addressing these challenges, but introduces new problems with security and reliability. Given unity of purpose by COTS suppliers, industry partners and coalition forces, these problems can be solved.

4.16.1 Review of information

This Australian paper, by an author working in their DSTO, in some ways seems to draw conclusions from a rather simplistic approach to the use of COTS IT, providing direct examples of some of the benefits and problems. It also highlights the speed with which new systems can be implemented and their potential for regular updates and easier interfacing. It suggests the benefits of military-grade COTS but advises that caution is necessary both in terms of security and reliability.

Benefits

Easier, faster and cheaper to build with increased functionality and user familiarity.

Problems

Reliability, security, rapid obsolescence and lack of military grades cause problems. Internal product details are hidden. There is an increased chance of accidental or deliberate malfunctions.

Other issues

Use in critical systems requires particular care.

4.17 Impact of the increased use of COTS and open standards on MoD procurement policy and procedures – Annex B [xl]

This annex, provided by the author who was working under contract to DERA Portsdown, differentiates between the various types of off-the-shelf (OTS) procurement, compares and contrasts their characteristics and provides definitions that are included in Section 2. It also considers the impact of open standards and open systems.

4.17.1 COTS and types of OTS Products

A number of different categories of OTS procurement share some common features but present different advantages and disadvantages. The general use of a single term COTS to encompass all OTS categories obscures these diverse factors but is endemic and unlikely to change in the short term. It mentions that where there is a need to identify truly commercial COTS (i.e. non-military

OTS) the terms ‘commercial’ or ‘commercial COTS’ is used. Commercial COTS products have been developed to support a commercial market and are currently available for purchase. Viable commercial products should have a strong market share and be well supported. These caveats distinguish products that deliver the expected advantages of COTS. Military off-the-shelf (MOTS) describes equipment previously developed for other military customers that may have been developed as a private venture by industry. Government off-the-shelf (GOTS) products are government-funded developments that are commercially available.

4.17.2 Related Issues

The re-use of software components is closely related to OTS procurement, but is generally used to refer to the use of previously developed software or algorithms within a new development.

Non Developmental Items (NDI) are those where MoD is not prepared to fund the development. In these cases MoD expects a fully developed solution to meet all or part of a requirement. This approach has been used to procure items to meet standard military requirements. The relevance of COTS principles to NDIs depends on the equipment selected.

Legacy items are elements developed for a previous application and re-used within a new procurement. Their use may be mandated by MoD, or imposed by stringent cost ceilings or the need for commonality. Legacy items have existing MoD support and fixed functionality but will typically use older technology and may be harder to incorporate into a new design or architecture.

In some situations, it may be expedient to buy OTS to meet an urgent operational need and will have the same advantages and disadvantages of COTS procurement.

4.17.3 Practical COTS Procurement

The boundaries between the COTS and non-COTS elements of procurement are rarely clear. However COTS elements can be embedded within, or linked by, bespoke software and may be modified during the procurement process to overcome particular difficulties.

In the current climate (a dominant civil IT marketplace and constant pressure to reduce costs), all future operational procurement will, in practice:

Include COTS - It is inconceivable that the MoD will procure major systems that have no COTS elements. Systems currently being procured are heavily dependent on COTS items such as processors, operating systems, infrastructure software and storage devices.

Require some bespoke hardware and software – With a few minor exceptions, pure COTS procurement is unrealistic because commercial systems are unlikely exactly to satisfy operational requirements. By virtue of the operational requirement, interfaces, environment or support policy, there will be a need to make some modifications or use some bespoke hardware or software. More typically, the COTS IT hardware and software will be supporting bespoke applications and interfaces to military sensors and communications systems. In addition, every complex system requires some bespoke code to integrate the elements within it, even if these are COTS items.

There will be funding pressure to bring technology-driven requirements into service with minimal or no modification. The various aspects that have to be balanced are:

- Modified systems will differ from equivalent commercial systems, increasing support costs.
- Development/upgrades of the commercial system will in time divorce them from their modified versions.

4.17.4 Open Standards and Open Systems

A distinction is drawn between open standards (well understood standards simplifying the interfacing of system components) and Open Systems (systems based on open standards). A precise definition of open standards is not simple, but in general, they are characterised by:

- A clear public domain definition of the standard.
- Contractor independence.
- Widespread adoption in the commercial world.

In some cases there is a formal, vendor independent body that oversees the development of standards. In other cases the widespread use of a commercial proprietary product has led to a de facto standard, which is under control of a single vendor.

The term 'Open Systems' is widely used without precise definition. A number of documents have attempted to define or characterise Open Systems, including the US DoD Joint Technical Architecture [xli], which offers the following definition:

A system that implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems, and to interact with users in a style that facilitates portability. An open system is characterized by the following:

- *Well-defined, widely used, non-proprietary interfaces/protocols.*
- *Use of standards developed/adopted by industrially recognized standards bodies.*
- *Definition of all aspects of system interfaces to facilitate new or additional systems capabilities for a wide range of applications.*
- *Explicit provision for expansion or upgrading through the incorporation of additional or higher performance elements with minimal impact on the system.*

4.17.5 Review of information

This DERA interim study report [8], the second document written by this author, provides a useful background to COTS and its various definitions. It deals with the issues related to its procurement and use. It also considers the relationship between COTS IT and bespoke IT. It concludes by examining the terms Open Standards and Open Systems, again giving some helpful definitions.

Issues

Major systems will include COTS IT and need some modification or bespoke hardware/software. Modifying COTS IT increases support costs and in time divorces it from standard COTS.

[8] The others are: Through Life Management of COTS-Based Systems. – Military COTS-based systems – instant solution or long-term headache?

4.18 Putting COTS in Command [xlii]

This article examines the exploitation of COTS technology in a new generation of naval combat-management systems and highlights some of the promise and the potential drawbacks. The new generation of C^2 systems is being based on COTS software and industry-standard open-systems hardware, taking advantage of the high volumes, low prices and reduced development timescales of the commercial marketplace at a time of declining military budgets. It points out the cost benefits in terms of development, acquisition and life cycle. It mentions that Lockheed Martin realised savings in four key areas:

1. Hardware availability at contract allows faster software development on target hardware.
2. The availability of mature development toolsets.
3. The use of COTS operating systems and application software.
4. The elimination of input/output handling software.

It says that COTS IT hardware also yields significant savings – as much as 5:1 in initial acquisition, spares and use of the commercial repair infrastructure. In addition, there is the ability to upgrade through technology infusion. Another benefit is the ease of re-using software and moving it to new hardware platforms.

It suggests that the use of COTS is not a panacea and that problem areas include performance short falls, true standardisation, ruggedness, life cycle support and configuration control. For a naval C^2 system, upgrading processors or network bandwidth cannot simply overcome the problems of real-time performance (e.g. against an incoming missile). Some particular issues are:

- Supplier lock in reduces control over obsolescence, upgrade and support.
- COTS IT-based systems become unsupportable more quickly than bespoke ones.
- The use of COTS IT requires long-term financial planning to cope with through life enhancements.
- Configuration management is a challenge.

While this paper deals only with naval C^2 systems, it provides a positive view for the use of COTS IT on board warships, but places caveats on some major issues in the use of COTS IT.

4.18.1 Review of information

This article published in Navy International concentrates on the new generation of naval combat systems. It is especially useful in listing four practical areas of software development where a US contractor actually realised cost savings – hardware savings of as mush as 80% in initial acquisition. It also, however, lists four key problem areas. It provides an overall positive overview of the use of COTS IT in naval systems installed on warships. These factors may well have application to the equipment of other services.

Benefits

Low prices and reduced development time scales are available through the use of COTS IT.

Problems

Performance short falls, standardisation, ruggedness, life cycle support, configuration control and obsolescence are all difficult to resolve.

Other issues

COTS IT requires long-term financial planning to deal with through life upgrades.

4.19 Through life management of COTS-based systems [xliii]

This thirty-one-page paper provides guidance for Integrated Project Teams (IPTs) and others on the through-life management of COTS products in military systems. It concentrates on management, rather than technology, issues. In particular, it addresses operational COTS-based systems acquisition under Smart Procurement, the management of system upgrades and the management of spares support. It mentions that discussions have been held with a wide range of authorities involved in COTS-based system acquisition, including DPA, DLO, DERA, industry and academia. Reports and studies from UK, Australia and US have been reviewed and discussed.

4.19.1 COTS-Based System Characteristics

It is important to distinguish between complete COTS solutions and new systems using COTS components, (COTS-based systems). Contrary to widespread opinion, major COTS-based systems are inherently complex and require as much system design effort as a bespoke development.

COTS components suffer from short supported lifetimes, bringing a need for continuous development if the system is not to be overwhelmed by obsolescence. Design effort will not cease when the initial design is completed. As the underlying COTS components are replaced, the system solution will need revisiting to address the characteristics and functionality of the new components.

Some changes will be minor, not impacting on overall systems design, but will require effort and testing to ensure that the overall system performance is not adversely affected. Other changes will be more substantial and could have a major impact on system architecture design. In the typical 25-year system life, as well as component obsolescence, most commercial technology will change beyond recognition. This means that COTS-based systems never leave the design stage, with each implementation or design being rapidly superseded by another. Management of system development will require funding and a good knowledge of technology advances.

4.19.2 COTS Component Characteristics

- Obsolescence.
- Lack of product control.
- Lack of design detail.
- Mismatch with military standards.

4.19.3 COTS-Based Systems and Smart Procurement

The key to successful incremental acquisition is the development of a suitable technical infrastructure combined with flexible management practices. These will cost more than developing a system that merely meets the current, known requirements. COTS-based systems need major requirement negotiation and through life trade-offs. The new acquisition procedures provide scant guidance on the maintenance and development of capability for in service systems. The design effort to maintain a COTS-based system requires skills and experience that have been developed in the DPA, and which are, for historical reasons, less widespread in DLO.

Accurate whole life cost predictions for COTS-based systems are impossible. This runs counter to the aim of putting close bounds on whole life costs. Flexibility in spend profiles will be required if COTS-based systems are to deliver optimum cost effectiveness.

4.19.4 Management and Planning of System Upgrades

The responsibility for funding and specifying any significant upgrade of a mature COTS-based system will be shared, and governed by a wide range of tightly interrelated factors. Successful and cost-effective management of upgrades will only be possible if there is a close and trusted working relationship between MoD and industry. This will require cultural changes in both parties. Conventional contractor logistic support arrangements, with firm prices for maintenance of a system for a fixed period, will often be inappropriate for COTS-based systems. They have the potential to increase through life costs and decrease operational effectiveness, by spending on obligations during the contract period, rather than on future needs for upgrades. Alternative support models must be sought.

4.19.5 Spares Management and Configuration Control

The principles of configuration management are just as important for a COTS-based system as for any other procurement, but the use of COTS products brings the potential for an explosion in system and sub-system configurations. This diversity carries a cost overhead for configuration data maintenance, which must be contained. The use of COTS products brings specific problems for spares management, revolving around the short supply life of any particular product version and the need to gain assurance that replacement products will be effective and compatible. Whole-life buys of spares for COTS products will rarely offer a viable solution. They are likely to render a system inflexible and incapable of further development.

4.19.6 Review of information

This lengthy page paper written under contract by DERA for DPA is the last by this author to be reviewed here [9]. Like the paper 'Guidance on Off-the-Shelf System Acquisition' (see paragraph 4.10), it also provides IPTs with guidance on through-life management of COTS IT in military systems. It is comprehensive and has drawn information from a wide range of national and international sources. It starts by examining COTS-based system and component characteristics. It then considers three area; COTS-based systems and smart procurement, management and system

[9] The other two are: Putting COTS in Command & Military COTS-based systems – instant solution or long-term headache?

upgrade planning, and finally spares management and configuration control. These are all key topics and the parts dealing with smart procurement and management are particularly interesting.

Problems

Accurate whole life cost predictions for COTS-based systems are impossible. Obsolescence, lack of product control, lack of design detail and mismatch with military standards are all snags.

Other issues

COTS-based systems require as much system design effort as bespoke developments. COTS-based systems never leave the design stage; each implementation being rapidly superseded. A close and trusted working relationship is needed between MoD and industry.

4.20 MoD Technology Programme Directory (pilot edition) [xliv]

In this MoD document, Technology Package 4, Electronics, contains the following relevant programmes that also have reference to COTS IT:

4.20.1 Enhancing Commercial Electronics Technology for Military Systems

It is the commercial market that is driving silicon integrated circuit manufacturers to produce higher performance devices, and it is essential that MoD has early access to these technologies.

4.20.2 Low Power Electronics

In certain areas, the performance demanded of military electronics is increasing at a rate that the commercial market cannot satisfy.

4.20.3 Survivable and Reliable Microelectronics

Silicon microelectronics are ubiquitous in military systems, but encounter scenarios and environments that go beyond those normally specified for civil applications. This package considers the threat to military systems, at the component level, from nuclear and electromagnetic sources. A knowledge base is being maintained of the hardness and vulnerabilities of modern commercial components in military nuclear environments.

4.20.4 Avionics and Sensors – Advanced Networks and Photonics

Ongoing research aims to enhance performance, increase sustainability and reduce platform maintenance costs by adapting emerging network protocols from civil data communications.

4.20.5 Optical Signal and Image Processing

The current expansion of interest in optical techniques has largely arisen from the needs of the telecommunications industry. It has resulted in the availability of many sophisticated components, such as laser diodes, optical fibre, compact disks, laser printers and flat panel displays. Work aims to exploit these developments for military benefit.

4.20.6 Review of information

MoD's Assistant Chief Scientific Adviser (Research) introduces this comprehensive MoD Technology Programme Directory. Although only covering four technology packages, it provides an excellent information source into areas of research actually being undertaken that impact on

COTS IT in operational military equipment. The document shows six relevant fields; silicon integrated circuit manufacture, survivability, reliability, low power consumption, adaptation of emerging network protocols and exploitation of existing sophisticated optical components.

Benefits

Increased communications sustainability and reduced maintenance costs.

Problems

COTS IT hardware does not meet military specifications. COTS technology is not advancing fast enough to meet a few military requirements, particularly EMP and other electro-magnetic weapons.

Other issues

There is a database of commercial component hardness and vulnerabilities in nuclear environments.

4.21 Euromilcomp 97

Euromilcomp 97 was timely in providing a great deal of military IT background and some useful COTS IT information. Brochures were obtained from 19 different companies exhibiting there, which were involved to some degree in supplying COTS IT for military use. People were met from seven of these companies. Five of the meetings proved fruitful. The 19 companies were:

Akhter	EDS	Integris	Siemens Plessey
Autometric	ERDAS	Lockheed Martin	Softelec
Computant Systems	ESRI	Litton Data Systems	Sophos Data Security
Dassault Electronique	IBM	Mektron	Verity
Dragon Systems	INRI	NCC	

INRI, Southampton)	
Integris, Hemel Hempstead)	Meetings were subsequently arranged with staff
Mektron Systems Ltd, Bedford)	from these four companies
Siemens Plessey Systems, Christchurch)	

Dassault Electronique showed a Sun workstation and mentioned that ruggedising the workstation doubles its price. A rugged laptop with a Dassault processor board and Intel chipset cost between five and eight times the cost of a commercial board but has an 8,000-hour MTBF.

The keynote speaker, Professor L Freedman [10] made the following interesting points about COTS IT:

1. The length of procurement time scales requires delaying design freeze as long as possible.
2. The possibility of designing virtual military products and only building them in quantity when needed, providing sufficient warning time can be obtained.
3. The commercial lead in development tends to level the playing field between own forces and potential enemies.

[10] Department of War Studies, Kings College, London.

4.21.1 Logistics CIS requirements for operations [xlv]

While largely not germane, this presentation mentioned that for large systems, evolution increases complexity and complexity increases risk. Logistics CIS systems are now using COTS IT to provide the functionality.

4.21.2 Business methodologies and defence management [xlvi]

The only relevant comment was that IT represents 3% of US GDP but 33% of US GDP growth.

4.21.3 Open and legacy Systems [xlvii]

Work on the Royal Navy's CINCFLEET FOCSLE Project commenced in 1995 and a system is in service at Northwood at Interim Operational Capability. This system entails interface and exchange of operational information with several disparate legacy systems. The approach to interoperability with these systems with regard to upgrade ability and the 'open' approach of the new elements of FOCSLE is detailed along with a discussion of specific aspects such as:

- Operational Information Exchange mechanisms: The current methods of data transfer format followed by a brief discussion of the DCADM. The wrappers used as delivery envelopes are also discussed.
- Security domains and mechanisms: Data separation and how the boundary with other non-multi level secure systems is handled.
- Transfer protocols: Discussion of the use of legacy mechanisms such as signal messages over the various legacy bearers and their pros and cons. Also the use of X.400 and the military equivalent STANAG 4406.

Review of information

This informative presentation was given by a member of the industrial electronics company involved in the development and implementation of the RN FOCSLE. It provided a constructive insight into the problems of intercommunications between FOCSLE, an example of a COTS-based open system, and bespoke legacy systems. The presentation examined in some detail information exchange, security and transfer protocols.

Benefits

Upgrade ability and open approach.

Problems

Use of wrappers is not straightforward. Security and interfaces to legacy systems are snags.

Other issues

Transfer protocols.

4.21.4 Maintainable and survivable technical information [xlviii]

Often overlooked, in system integration projects for the defence industry, is the criticality of accurate and complete technical information that is both maintainable and survivable. Electronic technical information is the nucleus of logistics IT solutions and has tremendous impacts on the overall life cycle costs of weapon system that may be operational for over 40 years. As technology rapidly advances and is offered in new low cost COTS products, focus must be placed on providing maintainable and survivable technical information, such that the benefits of these new technologies can be realised by the defence industry. Factors driving maintainability and survivability include the elimination of data redundancy, format-free data representation, a high granularity in relational data linkages and a single instance of data capable of supporting multiple applications. While technology has been a limiting factor in the attainment of survivable technical information, the primary limitation has been monetary – the labour intensive nature of capturing technical information has been cost prohibitive. Recent advances in this area are demonstrating promising results for attaining maintainable and survivable technical information integrated into a COTS or bespoke system.

Review of information

A member of a major US defence and aerospace contractor gave this very specialised paper. It concentrates solely on the need to maintain technical information throughout the long life of military equipment; an area often neglected. It highlights the promising signs of potential benefits that can be gained in the era of the potential to use of COTS IT in military logistics systems.

Benefits

Reduced cost and labour requirements.

Other issues

Accurate and complete technical information is needed that is maintainable and survivable.

4.21.5 Strategies for controlling technology diversion and dual use [xlix]

There are a number of forces pushing towards convergence between military and civil technologies. These include:

- Economic – restrictions in an ever-tightening fiscal regime.
- Political – purely military R&D, which does not provide wider benefits to society or the economy, can be hard to justify.
- Organisational – in-house government R&D is down-sized or out sourced to commercial organisations that have significant civil interest.
- Technological – civil R&D is 'ahead' of military technology.

Many potential benefits accrue from convergence, flowing, for example, from the above considerations. This paper focuses on the potential costs, arising from risks associated with technology diversion and dual use. Examples such as GPS, the Internet and satellite surveillance illustrate the nature of these risks, and the decisions, which face policy makers and practitioners. Options for dealing with these increasingly complex problems in the face of economic, political, organisational and technological pressures are discussed.

Review of information

This paper from the Parliamentary Office for Science and Technology is important both because of its influential source and the information it contains. It points to the factors pushing military and civil technologies towards convergence. It confirms the reduction in military R&D and the drivers towards outsourcing anything with significant commercial potential. Examples are given of the potential cost, in terms of risk, of dual-use COTS.

Benefits

There is convergence between military and civil technologies that reduces costs.

Problems

COTS is ahead of military solutions.

Other issues

There are risks associated with technology diversion and dual use.

4.21.6 Procurement of CIS for use in low intensity conflicts [1]

UK and other national forces are increasingly deployed into scenarios involving low-intensity conflict or operations other than war, often in a peace support or humanitarian role. These types of deployment are of a different nature to the high-intensity conflict scenarios of the Cold War era and provide a distinct set of drivers for the procurement of communications and information systems (CIS). Important characteristics of this CIS environment include the following:

1. The need to interoperate with other national contingents, some NATO or other established allies, others from nations with which previous links have not necessarily been established.
2. The need to be able to deploy forces rapidly in a very flexible manner in terms of force size and mix, depending on the specific operation.
3. Defence budgets overall have been squeezed down following the end of the Cold War; only the minimum number of equipment types will be affordable.
4. Requirements for equipment hardening and design for use in NBC environments may be relaxed for this type of operation.
5. Many low-density conflicts have the capability of escalating (perhaps very rapidly) into higher intensity conflicts, so equipment deployed in support of a low-intensity scenario should have immediate utility in a higher-intensity scenario. These drivers tend to lead to requirements for CIS that diverge as little as possible from COTS products while still offering capabilities in higher intensity conflicts.

The paper explores the impacts of the factors outlined above on the acquisition strategies and methods needed for CIS to support low intensity. They see low intensity conflict (LIC) requirements as a subset of high intensity conflict (HIC). The problems are:

- The possibility of a rapid escalation from LIC to HIC.
- The cost of two types of IT-based system.
- Training issues.

A possible solution is an incremental solution with basics for LIC but specialist and hardened for HIC. The danger is, for example, the use of laptops for C^2 during LIC, which are then not compatible with customised systems, albeit containing COTS IT.

Review of information

This paper, co-authored by two people from a UK industrial company, examines the issues of military operations in scenarios other than war, considering the CIS needs of deployed forces. They consider five main characteristics of such operations that favour the use of COTS IT. The value of this paper is that it reflects the types of military operation that look more likely in the future and the potential effect of these operations on the use of COTS IT.

Benefits

There is potential to relax environmental constraints.

Problems

Budget constraints and escalation capability cause difficulties.

Other issues

Interoperability, flexibility and scalability must be considered.

4.21.7 Multimedia on every desktop? Trends and Opportunities [ii]

Universal (object-relational) databases will dominate the database market to allow integration of multi media with traditional applications. They are also an unavoidable component of future infrastructures. Examples include:

- DB2 Universal databases
- Informix universal server
- Oracle universal server

The requirement for media asset management will be just as important as the requirement for database management systems was in the 1970s. This is also necessary to prevent chaos in organisations using thousands of images, video-sequences and the like. A new generation of development tools will come to the market able to use current data sources as well as objects residing in the universal databases, for example Formida's universal development environment

Finally, as more and more information, simple and complex, becomes accessible through public networks, security will become a very important aspect of new information systems. Protection with chip cards, cryptography and digital signatures can help overcome these challenges.

Review of information

This is another specialised paper that only considers the use of COTS databases to allow the integration of multimedia images on displays. The author works for a Dutch software company and is aware of the challenges in this field. Several COTS databases were discussed, their importance as the volume of data increases, and ways of improving security. The import of this dissertation lies in the ever-increasing relevance of multimedia to military equipment.

Benefits

Integration of multimedia.

Problems

Security.

Other issues

The importance of media asset management.

4.22 DICC 99 [lii]

This Defence Information Capability Conference provided some useful views.[liii] Both the Deputy Chief of Defence Staff (Systems) [DCDS (Systems)] and Director Operational Requirements Information and Communications Services [DOR (ICS)] quoted almost identical information; DCDS (Systems) under the heading 'Required Equipment' and DOR (ICS) with the title 'Implementing Smart Procurement'. These factors, some of which are in effect tautological, will be impacted by the use of COTS IT. In some cases the use of such a solution will help these factors, while in others it will prove to be a hindrance. These are shown in below.

Factor	**Impact of using COTS IT**
Increase	
Stretch potential	A fundamental part of COTS IT.
Reliability	MTBF figures rarely given and no audit trail.
Robustness	COTS IT is not designed for the military market.
Time to service	COTS IT is usually available literally off-the-shelf.
Affordability	Initial cost of COTS IT is low; through life costs may not be.
Interoperability	COTS IT uses de facto standards but is not renowned for interoperability.
Reduce	
Vulnerability	COTS IT is vulnerable to EMP, IT warfare and lacks ruggedness.
Cost	Initial cost of COTS IT is low; through life costs may not be.
Slippage	The availability of COTS IT off-the-shelf should reduce slippage.
Maintenance	COTS IT is designed to be thrown away, not maintained.
Mass	Constant market pressure to reduce weight of portable COTS IT hardware.
Support in the field	COTS IT is designed to be thrown away, not maintained.

DG ICS said that information trends are driving society, business and defence towards:

1. Greater integration of information capabilities with process.
2. Coherent information integration is becoming a dominant benefit.
3. Technology development is still accelerating – there is an unprecedented rate of change; this latter referring particularly to the COTS IT field.

A further reference to a presentation at this conference can be found in Paragraph 5.7.7.

4.22.1 Review of information

The importance of this source is that it is 'straight from the horse's mouth'; two senior members of MoD – DCDS (Systems) and DOR Information and Communications Services. Their view is that COTS IT gives increased stretch potential and reduced time to service, with commercial pressures driving down its weight. It is more vulnerable, less robust and lacks a reliability trail. It is not designed to be maintained. Its initial cost is low but through life costs may not be.

There must be concern about whether there is truly an unprecedented rate of change. Ignoring the rate of change that occurs in war, consider what happened at the end of the 19th century. David Nye has written [liv] that electricity-generating plant was obsolescent in six months and obsolete in twelve, due to efficiency improvements and the need for machines of greater capacity.

Benefits

Increased stretch potential, reduced weight and time to service are all important.

Problems

COTS IT is more vulnerable, less robust, lacking reliability trail and less prone to time scale slippage. It is not designed for maintenance and there are doubts about interoperability.

Other issues

Initial cost is low but through life costs may not be.

4.23 The Ruthless Pursuit of COTS [lv]

At this NATO symposium twenty-five papers were presented, of which nineteen were relevant to this thesis. Hard copy of two further unread papers was provided and also proved germane. There were inputs from Australia, Belgium, Canada, France, Germany, Holland, UK and the US, and together they confirmed that the contents of this thesis do not conflict with current COTS IT thinking. The main thrust of the papers was aimed at COTS software, with the US and Dutch giving feedback on experiences using COTS IT. A summary of the papers of interest follows.

4.23.1 Robust Non-proprietary Software [lvi]

This paper looks at the goal of developing robust systems and applications, despite commercial systems being decidedly sub-optimal in meeting stringent requirements. It defines 'black-box' where source code is unavailable and 'open-box', where it is. The former makes it difficult for anyone but the developer to discover vulnerabilities and provide fixes. It also distinguishes between 'proprietary' and 'non-proprietary' software; the latter increasingly found in open-box form in the Free Software and Open Source Movements [lvii]. Open-box software can potentially improve system security, but many other factors need considering; not the least the unrealistic target of building secure systems out of less trustworthy sub-systems. The need for discipline and good software engineering are highlighted, as are inherently robust and secure evolvable interoperable architectures that avoid dependence on untrustworthy components.

Review of information

The author of this paper works for SRI International in the US, has an exceptional reputation in the COTS IT field and was a keynote speaker at the symposium [11]. His views on 'open box'

[11] NATO Symposium 'The Ruthless Pursuit of COTS'. Brussels 3 – 5 April 2000

software should thus be taken seriously. He says that COTS IT is not optimised for use in robust systems but COTS open box source code availability is growing and can improve robustness.

Benefits

Open-box software has potential to improve system security.

Problems

COTS is sub-optimal in meeting stringent requirements. Black boxes make it difficult for anyone but developer to find and fix vulnerabilities.

Other issues

Avoiding the unrealistic target of building secure systems out of less trustworthy sub-systems is an issue as is the need for architectures that avoid dependence on untrustworthy components.

4.23.2 Wrapping, The COTS Dilemma [lviii]

This paper first reviews problems using COTS, notably product assurance, continuity and vulnerability. The concept of wrapping COTS software inadequacies is then introduced. Wrapping is a concept to mitigate COTS limitations, and may be applied to any of the acquisition, design and implementation phases of a system. It is a fundamental assumption that COTS items being wrapped are not themselves amenable to any significant changes in their design or function.

It also mentions the impracticability of reverse engineering COTS software. Architecture and standards are shown not to address the problems of using COTS IT in military equipment. It highlight the Carnegie Mellon University's Ballista COTS software 'black-box' testing program and ongoing development of a family of wrappers to improve the reliability of operating systems, albeit with possible speed penalties.[lix] Functionality can be added with wrappers to provide items such as crypto and communications protocols. Hardware wrappers can provide physical robustness and mitigate the effects of radiation and Tempest standards.

Review of information

The author has been working in DERA for a number of years on CIS research and is a member of the NATO Information Systems Technology Panel. He has wide experience of using COTS IT and rightly sees wrapping as something that can mitigate the highlighted problems of using COTS items, if they are not amenable to change. He states that reverse engineering of COTS software is impracticable but black box testing and a family of wrappers improve performance.

Benefits

The inadequacies of COTS software can be wrapped, and crypto and communications protocols can be added to wrappers.

Problems

Product assurance, continuity and vulnerability are obstacles.

Other issues

Reverse engineering of COTS software is impracticable

4.23.3 *Standards – Myths, Delusions and Opportunities* [lx]

This paper describes how a new approach to defence standardisation could deliver, for the first time, the benefits that defence standards and Open Systems have for so long promised. It traces the history of defence computing standards and examines the original benefits that standardisation promised. It examines why so many defence standardisation efforts have failed to deliver on these promises. It then goes on to examine why the original efforts to create a standards-based computing market (the Open Systems movement) also failed. The limitations of a standards-based approach are described both from a technical and commercial viewpoint. The paper concludes with an optimistic message, that the Internet Standards and the Open Source movement have the potential to deliver on the original promise of the Open Systems movement.

It discusses and compares the UK and US approach to Common Operating Environments (COEs) and suggests that, despite some success, future challenges include:

- Evolving at a sufficient speed to match the rate of change in the COTS IT market place.
- Keeping defence systems up to date with the latest COEs.
- Clarifying whether a pragmatic approach that includes de-facto and proprietary standards is consistent with guidelines for open competition.

Review of information

These two DERA authors, who work in the CIS area, usefully examine past problems of defence standardisation and Open Systems, with optimism that the latter have the potential to deliver improvements. They also characterise some of the issues in a Common Operating Environment approach. Their paper is worthwhile in terms of providing a background to the problems of defence standardisation.

Benefits

Defence standardisation and Open Systems promise advantages.

Problems

Can standards evolve fast enough to match rate of COTS IT change? Is it possible to keep defence systems up to date with the latest COEs?

Other issues

Clarification is needed on whether a pragmatic approach is consistent with open competition.

4.23.4 *United States Army COTS Experience – The Promises and the Realities* [lxi]

The US Army Communications-Electronics Command (CECOM) has been aggressively pursuing COTS solutions for well over a decade. With that experience, CECOM has developed a strategy of 'Adopt, Adapt, Develop'. Through a series of case studies, this paper explains why CECOM adopts COTS directly, adapts COTS products (by modifying as necessary to meet operational needs), and develops solutions where no COTS products will meet the Army's needs.

Adopting COTS is the aim but is not always straightforward or risk free. It cites the suitability of a laptop computer for use in a command post where environmental conditions are controllable within the specification of the laptop but notes that it cannot survive extremes of temperature or vibration. There is wide use of commercial components, much more robust than they were twenty years ago, in custom-built military products. However, it points out that such components in orbiting satellites are subject to electromagnetic damage that has proved expensive for some commercial companies and could prove fatal for the military.

Adaptation is used where the COTS product cannot meet the military requirement such as environmental conditions, security standards, reliability or interoperability. CECOM only takes the develop approach when commercial industry cannot or will not provide appropriate solutions.

There are four case studies; the Common Hardware/Software program, software development, battery technology [12], and the Land Warrior program. The lessons learned by CECOM are:

1. Blind adoption of COTS is neither technically desirable nor financially sound. There must be a balance between adopting, adapting and developing.
2. Adopting is not free, as COTS to be adopted must first be tested. It must also be capable of fitting into the current system constraints, but will increase user satisfaction.
3. Adapting COTS to the military environment is the commonest solution and will usually include a degree of adopting at the component/sub-system level. It provides the best mix of leveraging commercial investment but is neither as quick nor inexpensive as adopting.
4. Developing must be reserved for those unique circumstances where no commercial solution can form either the total solution or a foundation for the answer.

Review of information

The significance of this US army paper is that it comes from the Director of the organisation that pioneered the military application of COTS IT. It is based on ten year's experience and describes the lessons learned from four case studies, three of them highly relevant. It concludes that, with the reality of the commercial investment in IT being orders of magnitude higher than that of the US military, CECOM has embraced an adopt, adapt, develop philosophy but recognises that this approach may well need to change 'tomorrow'. There always has to be a compromise between being an early-adopter and standing still. It is difficult to argue with the hard evidence presented.

Benefits

Increased user satisfaction. Adapting COTS to the military environment provides best mix of leveraging commercial investment.

Problems

Adopting is not free, as adopted COTS must first be tested. Modifying COTS is neither as quick or inexpensive as adopting. Developing is most expensive.

[12] While not directly IT, the importance of batteries in portable IT makes it relevant.

Other issues

Blind adoption of COTS is neither technically desirable nor financially sound. There must be a balance between adopting, adapting and developing.

4.23.5 The Co-ordinated Defence Role in Civil (Telecom) Standardisation [lxii]

The penetration of unmodified COTS technology and standards is increasing in the military domain. Thus, as the defence community becomes more reliant on COTS products and standards, it is increasingly a stakeholder in the results of the civil process. This should lead to a motivation to be a proactive participant in the process of developing civil standards and technology.

This paper presents the outcome of a November 1999 workshop organised by the NATO C^3 Agency and hosted by the European Telecommunication Standards Institute (ETSI) [lxiii]. The paper discusses ETSI specifically, but the arguments and principles also apply to other standards organisations.

It was proposed that there should be a co-ordinated action within the defence community of the Alliance with respect to civil standards, which will encourage the emergence of a harmonised defence market for COTS telecommunication products. This paper discusses the possibilities and significance of defence requirements capture within the context of civil telecommunication standards development.

Review of information

This paper from a member of the influential NATO C^3 Agency looks at the use of COTS telecommunications in the defence field. It is significant because it represents the consensus of views from a joint NATO/ETSI workshop in this specialised field. It confirms that COTS telecommunications are developing at a fast pace, particularly in the civil domain. Defence users are increasingly making use of civil standards and equipment, as their resources to invest in custom solutions diminish. Co-ordination within the defence community in working with standards will result in efficiency gains and increased effectiveness. Standards organisations provide a consensus-building forum with industry and the NATO nations should involve themselves in this area.

Benefits

Use of civil telecommunications standards and equipment.

Other issues

The defence community is a stakeholder in results of civil process as civil products/standards reliance increases.

4.23.6 Risks by Using COTS Products and Commercial ICT Services [lxiv]

Among the requirements influencing today's procurement of new information and communications systems, the most prominent through the whole lifetime of a system are:

- Cost effectiveness
- Use of the latest developments in information and communications technology (ICT)

This can no longer be achieved by using past procurement procedures, with long planning and development phases, resulting in custom products increasingly often based on out-dated technology when they become operational. Also, storage and provision of spare parts for and maintenance of such totally or mainly custom systems, as well as the training of personnel for their operation and maintenance, are increasingly cost intensive.

The alternative, inevitable approach is the use of COTS products, allowing for easy and timely release changes and the introduction of new hardware and software versions when they come to market, paired with the consequent outsourcing of all those services which are available with comparable or higher quality from competing non-military providers.

However, while at first sight this new way of procurement seems perfectly to meet these requirements for cost effectiveness and application of the latest ICT developments, a new class of risks needs to be identified and resolved. After summarising the clear advantages of the use of COTS products and outsourcing, this paper addresses the risks that have to be considered and finally point out methods to improve confidence in how to use 'insecure' products and services. These classes of risks originate from:

- System inherent risks due to complexity and heterogeneity of system components, including bugs, backdoors, and manipulated chips.
- Increasing vulnerability and attack options by interconnecting systems with one another and with commercial open networks.
- Dependence on products not implemented under military control, which must operate as 'black boxes'.
- Dependence on suppliers that operate worldwide and whose performance may be unpredictable.
- Political risks when a product is completely or partly produced in foreign country.
- Risks using or integrating products into existing systems that do not meet all the original requirements.
- Loss of support and continuity when a manufacturer or a product line ceases to exist.

Similar problems must be considered when commercial services are used as essential components of a military system or service. It is crucial to recognise and apply appropriate measures against problems from:

- External maintenance personnel having direct or indirect access to military systems.
- External personnel perverting military staff.
- Risks introduced by sporadic unavailability of services supposed to be 'always' available.
- Risks caused by attacks on normally highly reliable services indirectly affecting systems or services.

The paper concludes that for successful risk management, an important prerequisite is to achieve interaction and co-operation between people at all levels. Reports should be encouraged both positive and negative of:

- Obvious incidents or unusual behaviour – no report should be laughed at or carelessly put aside.
- Human induced events – helping to reduce or solve a problem should be valued more highly than 'finding and punishing the culprit'.
- Successful integration of 'insecure' products – how to configure them, what extra measures are used
- New measures that improve early detection of events or increase the number of successfully rejected attacks

Accepting that the use of COTS products and commercial services will continuously increase in the military environment, the obvious benefits have to be matched with rather less obvious risks on one hand and, on the other hand, with the ways and means of actively managing these risks.

Review of information
This paper, presented by a member of German industry, is informative in that it looks not only at COTS products but also at COTS services, thus giving a rather different perspective. It points out that new IT-based systems require a novel approach to whole-life acquisition to gain cost and technology benefits. Seven risks of using COTS IT and four of using commercial services are identified and these must be overcome in order to achieve successful risk management.

Benefits
Cost effectiveness and use of the latest COTS IT developments are advantages as are easy and timely release changes and introduction of new COTS IT versions. Outsourcing of services is available from competing non-military providers.

Problems
Concerns are increasing vulnerability, loss of product control, obsolescence, dependence on overseas suppliers whose performance may be unpredictable and COTS products that do not meet original requirement as is the use of non-military support personnel.

Other issues
A prerequisite for good risk management is achieving interaction/co-operation between people at all levels.

4.23.7 C^3I Systems acquisition and maintenance in relation to the use of COTS products [lxv]

The paper highlight the main pros and cons of embedding COTS products in military C^3I systems, in the overall framework of systems acquisition and maintenance, based on industrial experience. Significant programmes are briefly outlined, providing an opportunity to consider the issue from a practical perspective.

The use of international standards is the way to achieve C^3I systems scalability, modularity, flexibility and interoperability, allowing such systems to operate with other national C^3I systems, in different and stressful operative conditions and for different applications. Since C^3I military and civil systems have been designed following common standards, the use of COTS components has been increasing and dual-use and re-use potential enhanced.

Use of COTS information technology in military systems offers reduced development and support costs, improved interoperability, reduced technological risk, accelerated deployment, and supports the evolutionary development concept. In addition, the continuing trend to use and establish updated technical standards is pushing modern $C^3 1$ systems to be based on COTS products but these are effectively black boxes and raise risks and concerns that must be handled properly. However, there are problems with electromagnetic emission control, environmental conditions, security and mobility. Furthermore there are difficulties with evaluating COTS IT, keeping products under control, procuring and supporting them. Other issues include the need for software portability, interoperability and flexibility.

Major defence companies are adding to their capability of bespoke military systems development and manufacturing, the skills needed to offer COTS oriented, system of systems integration. This involves evaluation of technologies and products available on the market, together with innovative system design and engineering methodologies. Technical and commercial knowledge is required to determine when a system or a system component is a good candidate for migration toward a COTS approach.

Review of information

Two members of a dominant Italian defence company produced this paper. Its importance lies in the fact that it is based on practical experience in a number of programmes. It examines the acquisition and maintenance of COTS products in C^3I Systems. It highlights that such use of COTS IT offers benefits and problems. Six of the former are mentioned and eight of the latter, as well as three key software pre-requisites. It states that industry must gain the requisite technical and commercial knowledge if COTS IT is to be applied successfully to C^3I systems; a truism that clearly not all companies have yet learned.

Benefits

Reduced technological risk, development and support costs, improved interoperability and faster deployment are all beneficial.

Problems

Electromagnetic emission control, environmental conditions, security, mobility, problems evaluating COTS IT, keeping products under control, procuring and supporting them are all snags.

Other issues

There is a need for software portability, interoperability and flexibility.

4.23.8 COTS Software Evaluation Techniques [lxvi]

Employing COTS software products as components in large-scale long-lived systems has been proposed as a way to reduce implementation and operating cost. While this may be the case, the actual benefits have not been confirmed. There is factual evidence that some of the suggested cost savings will be offset by the need to address a new set of issues that are raised by the inclusion of COTS components. One of these is the need to evaluate candidates COTS systems early in the development life cycle by actual testing of the products.

The paper outlines a number of proposed evaluation and selection techniques for choosing appropriate COTS software products for incorporation in large-scale systems. The advantages and disadvantages of each are outlined. A process is proposed for the evaluation of COTS software products that takes advantage of the best processes of the different methods as well as introducing new techniques.

Current testing practices, as applied to conventional development, were examined and their applicability to COTS development highlighted. It is obvious that black box techniques are mandatory during in-context evaluation of software but also that the goals of testing are somewhat different from the traditional ones. Scenario-based testing provides a good basis for evaluating candidate products. The results obtained from evaluation testing can be used as validation data for system testing.

Review of information

Co-authored by two members of the Canadian National Research Centre, this paper usefully concentrates on software and cost issues, suggesting that testing needs may offset potential savings using COTS software. Evaluation techniques are considered that should help in selecting the right COTS IT products. It cross-relates with the paper reviewed in Paragraph 4.23.21.

Benefits

Reduce implementation and operating cost may result.

Problems

New issues are raised by the inclusion of COTS components may offset cost savings. There is a need to evaluate candidates COTS by testing.

4.23.9 Reliable Tailored-COTS via Independent Verification and Validation [lxvii]

An important class of COTS applications is the adaptation of an established COTS product to an operational environment for which it was not originally intended. This tailoring can provide the expected cost reduction benefits associated with COTS and still meet system reliability requirements when augmented with an appropriate Independent Verification and Validation (IV&V) activity.

This paper illustrates the successful tailored-COTS IV&V approach using the integration of a COTS Global Positioning System (GPS) receiver into the Space Shuttle onboard avionics system. The COTS GPS receiver chosen is a proven, reliable navigation aid that has been successfully integrated in numerous military aircraft. However, integration of this COTS receiver into the Space Shuttle avionics system required many changes due to the different avionics hardware environment and the dramatically different flight environment. The key part of tailored-COTS IV&V is the need to identify and verify portions of the software that are not changed but that are operationally affected by the new environment. The techniques that proved most beneficial were a modified criticality analysis and risk assessment process, custom source code analysis tools, software scenario analysis, and model checking. Finally, historical databases were found extremely valuable sources of information.

Review of information

Two members of the US company involved in the work presented this case study of the application of a GPS system, widely used in military aircraft, to the Space Shuttle. It stresses the importance of independent verification and validation of software when applied to a use for which it was not intended. The fact that they deal with the application of COTS technology to the Space Shuttle does not make the lessons learned any less relevant to the application of commercial technology to the military field.

Benefits

Adaptation of established COTS products to an unintended operational environment gives cost reduction. System reliability requirements are met by IV&V activity.

Problems

The cost of IV&V activities.

4.23.10 Maintaining COTS-Based Systems [lxviii]

After deployment, software systems enter a phase of maintenance, management, and evolution that can last many years until final decommissioning. This post-deployment phase is the longest and hence the most expensive phase of the software lifecycle. Success during this phase is often the determining factor as to whether a software system is cost effective over its lifetime.

Building a software system from COTS products does not change the importance or the expense associated with maintenance, evolution and management. COTS-based systems must continue to satisfy evolving user requirements, failures of the system must be dealt with, the system must adapt to the ever-changing environment, and managers must be able to monitor and control the deployed system.

The nature of the post-deployment activities changes when dealing with COTS-based systems rather than with custom-built systems. If the former are to be successful (better and more cost-effective) over the many years that they are expected to be in service, organisations involved in building or acquiring COTS-based systems must understand and accommodate these differences.

Review of information

Co-authored by the same two members of the Canadian National Research Centre who presented the paper in Paragraph 4.23.8, they examine here a valuable but different COTS software issue; software maintenance including the cost of such maintenance. They indicate that although COTS-based software systems provide many advantages, designers and users must expect that the majority of the lifecycle cost will be incurred after initial deployment of the system. Reducing this cost, and easing the maintenance and management effort, requires consideration of the post-deployment activities during the earliest stages of software development. By identifying the COTS-based system support activities that maintenance and management personnel perform, and using a design that supports these activities, systems can be made more cost-effective.

Problems

The majority of life cycle costs are incurred after initial deployment.

Other issues

Post-deployment activities change when dealing with COTS-based rather than custom-built systems.

4.23.11 Detection of Malicious Code in COTS Software via Certifying Compilers [lxix]

IT is increasingly a vitally important underpinning to economies and to societies. It is embedded in everyday applications and animates a wide class of systems from small to large and from simple to extremely sophisticated. Among the probable threats for military information systems, the presence of malicious code within COTS applications has been identified as a major risk that has not received a lot of attention.

Malicious code integrated into a commercial application could remain undetected and present a major risk for the safety of information within a military system. Techniques to detect malicious code within commercial applications are reviewed. Emphasis is placed upon the certifying compiler, which enforces a formal security specification while compiling the source code. This emerging technology offers the most comprehensive and sustainable approach for large applications and for the periodic certification of upgrades.

Review of information

This is one of a pair of informative papers by two enthusiastic members of the Canadian Defence Research Establishment dealing with malicious code. They have been carrying out novel research into the subject and realise that malicious code represents a serious problem when COTS software is used in military equipment. They see emerging technology offering a solution to this problem.

Benefits

Emerging technology offers a comprehensive and sustainable way of detecting malicious code.

Problems

The presence of malicious code within COTS applications is a risk for safety of information within military systems.

4.23.12 Dynamic Detection of Malicious Code in COTS Software [lxx]

COTS components are very attractive because they can substantially reduce development time and cost, but they pose significant security risks. These types of attack are not detected by standard virus detection utilities, which are essentially the only commercially available tools that work directly on binaries. This paper presents a dynamic approach that addresses this problem.

The complexity of a real time-bomb attack that disables a program after a fixed time is shown. Building on this example, a method that works at the binary level and could be used to facilitate the study of other time bombs – and hopefully of all types of malicious actions – is presented. This is the first step toward a fully automated tool to detect malicious actions in all their forms. The method is currently intended specifically for Windows NT running on an Intel processor. It could easily be extended to other platforms. This paper also discusses the possibility of using dynamic analysis techniques to overcome the inadequacy of the static methods.

Finally, a brief survey is presented of commercial tools that attempt to address this issue, considering where these products are today and what is needed to obtain a credible sense of security, as opposed to the often false sense offered by some commercial tools.

Review of information

This second revealing paper by the same two members of the Canadian Defence Research Establishment Valcartier on the subject of malicious code looks at potential solutions to the problem. Despite the attractions of COTS software, it incurs significant security risks from the inclusion of malicious code in programs. They state that these are not detected by COTS anti-virus utilities. They have developed a method to overcome this weakness, as part of a comprehensive research programme, and further improvements are likely.

Benefits

Reduced development time and cost result with a solution for Windows NT on Intel processors.

Problems

Detection of malicious code is difficult and there are significant security risks. Attacks are not detected by standard virus detection utilities.

4.23.13 Application of COTS Communications Services for Command and Control of Military Forces [lxxi]

This paper describes issues related to the use of commercial communication systems in support of military command and control. These systems provide messaging and telephony services with global reach using small, autonomously powered terminals. New commercial telephony and messaging systems offer ready access to advanced communications technology for a range of benign and hostile forces including the military, insurgents and terrorists. The size, cost, coverage and ubiquity of these systems combined with the availability of tools targeting Internet application development creates an interesting mix of threat and opportunity for military organisations.

One of the key advantages offered by the group of new telecommunications networks is diversity of supply that may enable a future adversary to use five different systems in order to provide a voice service, using only three terminals that could easily fit into a briefcase. These systems would operate in five different frequency bands and are highly independent of each other in terms of the supporting network.

This paper describes some high level attributes required of these commercial systems in order to operate in a military communication environment. It highlights the differences that would typically exist between the commercial and military communication markets and their associated procurement strategies. It provides some examples of COTS solutions for military applications, which include Command and Control Warfare (C^2W), and the application of COTS for Australian Defence Force (ADF) communications. The danger is that some C^2W techniques may inadvertently deny or degrade the communications of benign parties present in conflict scenarios and by doing so the results could well be counterproductive for the military effort. It concludes that new commercial satellite communications systems will be used for C^2 in military conflicts of the future. The precedent was set in the Gulf war and has followed in most major conflicts since.

Review of information

Two members of the Australian DSTO produced this realistic paper dealing with the application of COTS communications services for command and control of military forces. They have usefully examined a range of available COTS services and give practical examples of their use in a vast country with low population density. They explain that COTS communications services are increasingly being used for military C^2, offering diversity of supply and operation. This must have relevance worldwide. They also show some disparity between military and commercial markets.

Benefits

New commercial communication systems are available to the military based on multiple independent networks.

Problems

The same systems are available to insurgents and terrorists.

Other issues

Command and Control Warfare is an matter to be managed.

4.23.14 The Convergence of Military and Civil Approaches to Information Security [lxxii]

The motivation for this paper is the about-turn in defence computing that came with open systems interconnection and ADA. Defence specific products and bespoke development were discarded due to the far superior cost-benefits of mainstream COTS systems. A similar situation is developing in information security and suggests that the defence approach to security may need to adapt in order to benefit from the rapidly growing commercial market.

The paper shows that in areas of IT where defence and civil sector requirements significantly overlap, defence has been persuaded that it must adopt the COTS IT approach to keep pace with technology. Trends demonstrate that information security is heading in this direction. This implies that COTS technologies will become the default for many defence information security applications and that the defence and civil sector approaches to information security will converge. The highest classified defence information has no civil counterparts and there is unlikely to be any alternative to restricting such information to paper or isolated, physically-protected systems. However, there are several difficult issues that defence now faces:

- How to manage risk more pragmatically.
- How to reduce its dependence on security by obscurity.
- How to gain confidence in software without a large formal assurance overhead.
- How to manage security on the time scales of the civil sector.
- How to address document marking.
- How to manage secure systems federation.

In some of these aspects, such as the protection of information at the highest levels and the use of protectively marked documents, it is unlikely that defence will find commercial solutions. In other areas, such as assurance, careful consideration is required to manage the mismatch between the defence and civil approaches. Finally, in its approach to issues such as risk assessment, static security, and security by obscurity, there are no technical reasons against using the civil approach.

Review of information

This DERA paper accepts that defence already benefits from COTS IT and sees security moving the same way. It rightly suggests that the approach to defence security must change to profit from the fast growing commercial sector. It shows areas of overlap where COTS solutions are likely for many defence requirements. However, it says there is no civil equivalent to the top military security levels. Whether, with reduced superpower threats and increased competitive economic tension, this is realistic is open to debate. The paper ends by exploring six difficult security issues.

Benefits

Convergence of military and civil information security.

Problems

Information security is still a major issue for the military. Ways must be found to reduce dependence on security by obscurity, manage security on time scales of the civil sector and gain confidence in software without large assurance overheads. The best way must be established to address document marking and manage secure systems federation.

4.23.15 The Ruthless Pursuit of the Truth about COTS [lxxiii]

Some of the truths about COTS are exposed, discounting some exaggerated claims about the applicability of COTS, particularly with regard to using COTS in safety critical systems. Although agreeing that COTS has great potential for reduced development and maintenance time and cost, perhaps the advocates of COTS have not adequately addressed some critical issues concerning reliability, maintainability and availability requirements, risk analysis, and cost. These issues are illustrated, suggesting answers in cases where solutions are feasible and leaving some questions unanswered due to the inherent limitations of COTS, because there is inadequate visibility and documentation.

Review of information

This US academic paper is somewhat sceptical about the military application of COTS IT. It suggests that the decision to employ COTS on mission critical systems should not be based on development cost alone. Rather, it suggests that costs should be evaluated on a total life cycle basis and that reliability, maintainability and availability should be evaluated in a system context. It thinks COTS suppliers should also consider making available more detailed information regarding the behaviour of their systems, and certifying that their components satisfy a specified set of behavioural properties. This proposition is hardly likely to have an impact; only market forces are likely to cause COTS suppliers to change. In addition, the paper suggests performing a formal risk assessment of requirements taking into account the characteristics of host system environments.

Benefits

Reduced development, maintenance time and cost.

Problems

RMA requirements, risk analysis, and cost need to be addressed.

Other issues

The lack of suitability of COTS to safety critical systems is a specific question.

4.23.16 Determining the Suitability of COTS for Mission Critical Applications [lxxiv]

COTS products are being considered for inclusion in ever more complex and critical systems. There are known advantages and risks for considering using COTS in complex systems. Yet, given the rigorous needs of mission critical systems, concerns and risks have begun to emerge about the suitability of COTS for such applications. Some characteristics of mission critical systems (e.g. reliability, availability, maintainability, correct functionality) make the selection process of COTS IT an increasingly important factor in total system life cycle phases (design, development, acceptance, operations/maintenance and disposal).

This paper presents risk areas related to the use of COTS, in general, and specifically for mission critical systems, that would assist both the acquisition and development/integration communities in determining the suitability of using COTS in mission critical systems. A set of risk mitigation approaches is identified; some of which have been applied to certain National Aeronautics and Space Administration programs. Lastly, steps that could lead to the establishment of a set of procedures, and perhaps even an enterprise policy if and when COTS products are suitable for certain mission critical applications.

Further validation of the practices suggested here and the emergence of new practices will improve the ability of systems developers to incorporate COTS products while still satisfying the critical demands of large, complex systems.

Review of information

This US industrial author importantly examines the use of COTS IT in mission critical systems; one of the key factors in military usage. Both the advantages and the risks highlighted. A number of risks are described and possible procedures that could mitigate these risks are identified. However, the paper makes the vital point that there is much still to be learned about applying COTS to mission critical systems.

Benefits

Reduced costs and time scales

Problems

Reliability, availability, maintainability, obsolescence and correct functionality are all problems.

Other issues

There are risks and concerns about suitability of COTS for mission critical systems.

4.23.17 Six Facets of the Open COTS Box [lxxv]

Although procurement of COTS software for defence applications has long included evaluation in terms of the products specification, actual experience has often revealed shortcomings in the ability to deploy solutions based on these packages widely over a period of time. Six aspects are considered in order to make the use of COTS software more likely to bring continuing benefits over the life of an application system:

- Presentation interfaces.
- Release compatibility.
- Portability.
- Programming interfaces.
- Security interfaces.
- Management interfaces.

By considering these various facets of openness, IT architects can improve the use of COTS components in complex IT projects. It took some time for software companies to embrace the open movement. Today, with companies increasingly responsive to customer needs, and new technologies addressing a broader range of interfaces, the time has come to move to a more comprehensive definition of openness, and, as shown by a few examples, it is likely that the companies providing COTS software will be prepared to respond.

Review of information

This paper, prepared by a member of IBM Europe, provides a helpful model of six software aspects; mainly dealing with interfaces and portability. It reviews the use of COTS software in military systems and indicates some of the shortcomings. The six aspects that require serious consideration are described in detail. It considers openness to be a key factor in the successful integration of COTS software in complex IT systems.

Problems

There are shortcomings in ability to deploy solutions based on COTS software and difficulties with interfaces including security interfaces, release compatibility and portability.

Other issues

The requirement for COTS IT is to be responsive to commercial customer needs.

4.23.18 Lotus White Paper on COTS for Military Crisis Applications [lxxvi]

As businesses evolve to e-businesses, it is interesting to observe how the civilian requirements related to COTS software increasingly resemble the military crisis-mode requirements in terms of continuous operation (100% availability), vast scalability (Internet community), absolute reliability (transactional integrity), total security (numerous 'enemies' with malicious intent in a 1B user-wired community), flexible and manageable interoperability (alliances, mergers and acquisitions must be almost instantaneous and fully controlled). As COTS software vendors satisfy these civilian requirements, it will eventually facilitate military use. Inadequate software will naturally be supplanted in the marketplace by capable technologies.

Review of information

An employee of Lotus [13] presented this constructive paper dealing with its COTS software. It points to the convergence of military and civilian needs. It interestingly explains that although the specific intents of software applications for civilian versus military use are very dissimilar, the overall requirements are converging as a result of the increasing role of the Internet in connecting all businesses and consumers. COTS software with appropriate military amendments can play a significant role in military crisis applications.

Benefits

COTS IT provides improvements in continuous operation, extensive scalability, absolute reliability, total security, and flexible and manageable interoperability.

Other issues

Civilian COTS software and military crisis-mode requirements are converging.

4.23.19 Modernising OMIS, an operational air force C^2 system using COTS hardware and software products [lxxvii]

Modernisation of OMIS showed the successful application of COTS products for a functional re-hosting. The re-hosting resulted in a system with the same functionality, but based on leading edge technology and with improved capabilities for future extensions and an improved ease of operation and management. The application of standard PC hardware for the modernised OMIS showed that an assurance level at least equal to that of the original OMIS is possible.

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[13] Owned by IBM.

OMIS showed that not all functionality could be realised directly by the COTS products. It was not possible to meet security, logging and survivability requirements using COTS products alone. These were satisfied by small modifications to COTS products or by successfully using COTS software development tools to implement missing functionalities.

Using the ATCCIS standard for the data model satisfied the requirement for interoperability. The resulting model was implemented using COTS data management products without any problem.

In mid 1999, OMIS-2 was installed and operational at Volkel Air Force Base in the Netherlands. The configuration consists of multiple servers at secure locations, and client workstations all over the base. Minor problems were encountered during the installation, mostly related to the scaling of the system. After the installation it took only three days to get OMIS-2 operational. Since mid October 1999 the modernised OMIS has run smoothly. Intensive usage during large exercises has not resulted in any problems.

Review of information

This paper outlines some experiences gained with modernising an existing, operational Dutch air force C^2 system using COTS IT, and the adoption of standards, from a practitioner's perspective. It describes examples of functional areas where requirements could be met using COTS products alone, where they could not and what strategies were followed to meet these requirements. It is one of the few sources to actually describe the upgrading, in this case successful, of an existing legacy system with COTS IT.

Benefits

COTS IT gives the same functionality based on leading edge technology with improved capabilities for future extensions. It also provides ease of operation and management, at the same time providing interoperability and reducing commissioning time.

Problems

Security, logging and survivability are all snags.

Other issues

This is a practical example of the deployment of COTS IT in operational military equipment.

4.23.20 Using COTS Components in Safety-Critical Systems [lxxviii]

Risk is a broad ranging and multidimensional topic, including both management and technical risks. Management risks for COTS are well known, such as loss of market control, rapid obsolescence, and the shift from a buyer's market to a seller's market. Technical risk factors are less well understood. These include interoperability and performance issues as well as safety. This paper concentrates on risks related to safety, where safety is defined broadly as related to a significant accident involving human life or health, environmental damage, money, or system mission. The risk becomes a safety issue when the loss is significant enough that it becomes necessary or worthwhile to devote resources to reducing the risk.

One key driver for using COTS software is to save money. Much, if not all, of the savings may be offset by the activities needed to ensure an acceptable level of risk. This assurance might involve additional testing or analysis procedures. In some highly critical systems, COTS may raise the cost of certification or ensuring safety to the point where using COTS products is no longer feasible or cost-effective; any potential savings being eliminated by additional assurance costs.

In many cases, using COTS components in safety-critical systems with acceptable risk are not feasible. In these cases, it will be cheaper and safer to provide special-purpose software. In some situations, COTS components can be assured to have adequate system safety. In these cases, either the system design must allow protection against any possible hazardous software behaviour or the component producer must provide a complete black box behaviour specification in order to perform a system hazard analysis.

Review of information

This was another significant academic paper by an American keynote speaker. It concentrated on the use of COTS IT in safety critical systems; an issue of importance for a number of military applications. It points out that some of the risks of using COTS software in such systems are not well understood. Particular risks are identified and it states that the potential cost of their mitigation may outweigh any cost savings arising from COTS usage. It also states that steps must be taken to protect against hazardous software behaviour.

Benefits

Saving money.

Problems

Loss of market control, rapid obsolescence, and the shift to seller's market, interoperability, performance and safety issues are all COTS IT obstacles.

Other issues

Cost savings may be offset by activities to ensure acceptable risk level – additional testing, analysis procedures or cost of certification.

4.23.21 Certifying Off-the-Shelf Software Components [lxxix]

The cost and development time of software could be significantly reduced if there were a widely used component industry. Even the best programmers only produce 10 lines of code per day. With systems like those in cellular telephones – up to 300,000 lines of code – custom software development can be very expensive. If developers could purchase 100,000 lines of code, they could create less expensive software and move it more quickly to market. The development savings could be staggering; $5 million (less licensing fees) for 100,000 lines of code. Companies producing components would also see great rewards. Five licenses could pay for development with profit on subsequent sales. Admittedly, this simple analysis ignores several variables, but it does show the potential for components in the software industry.

Many industries use components and products rely on interchangeable parts. The software industry is analogous because most software today is built from smaller software objects. The software industry differs, however, in its in ability confidently to swap components in and out of systems. Developers are unsure of the reliability of a replacement component. If this could be gauged, software component commerce would flourish, reducing system design and repair costs. Developers need to know component reliability and whether a system will tolerate it. When this reliability cannot be determined, the assumption is that more expensive components are more reliable since they have undergone more testing. Sometimes less expensive components are more reliable simply because they have seen more use. However, even if component reliability could be known, there is never assurance that it will fit smoothly into a system and not cause problems. Software components are often delivered in 'black boxes' whose licenses forbid decompilation back to source code. Often source code can be licensed, but the cost makes doing so prohibitive.

A methodology has therefore been developed for determining the quality of COTS components using a set of black-box analyses. This methodology will provide developers with information useful for choosing components and for defending themselves legally against someone else's imperfect COTS components.

Review of information

The writer, who works for a US software company, quotes some interesting examples show how a widely used software component industry could reduce software costs and development time scales. The benefits and problems are discussed and a methodology proposed for determining the quality of software components. However, while the idea is interesting, the author does not address many of the practical difficulties that are likely to hold back such an approach. Furthermore, the paper reviewed in Paragraph 4.23.8 suggests that the cost of suitable testing may offset potential cost savings.

Benefits

A reduction in cost and development time of software would result from a software component industry. This needs reliability and assurance that software will fit smoothly into systems.

Problems

Black boxes software licenses forbid decompilation and the cost of licensing source code is prohibitive.

Other issues

A methodology is needed to help choose software components.

4.24 Rapid Development – Taming Wild Software Schedules [lxxx]

Chapter 5 of this informative 650-page tome deals with risk management when developing new software and highlights the dangers of runaway time schedules and costs. The two clear implications are that using already developed COTS software effectively mitigates both these risks, and that attempting to modify COTS software is fraught as it reintroduces these risks.

4.25 Exhibitions

Although not strictly written sources, both Farnborough air shows and DSEI 99 were opportunities to view COTS IT and see its application to military and aerospace equipment. They were also opportunities to hold brief discussions with members of industry and make contacts for future information gathering.

4.25.1 Farnborough

Organisations visited at these shows included:

Airbus Industrie	Marconi	Modemetric	Thomson
Boeing	Martin Baker	Racal	Ultra Electronics
DM Aerospace	Meggitt	Smiths Industries	Vinten

The first two companies, the key manufacturers of civil airliners, established that any COTS IT used in safety critical applications is only upgraded when aerodynamic or other significant changes are made, that in any case require the design to be re-certified. Martin Baker confirmed that early in any programme for a new ejection seat, they make a life time buy of any COTS chips they embed in their ejection seats.

4.25.2 DSEI 99

DSEI covers land, sea and air systems, but there was scant sign of air systems. Exhibitors visited included:

Caplin	HVR Consulting	Janes	Quadrant
Cogent Defence Systems	ILOG	MoD ICS	Racal Defence Systems
Cornwell Affiliates	Iridium	Parametric Technology	Tenet

The show contained few signs of COTS IT-based military equipment in terms of kit on display. For weather reasons, access to the show was much delayed and viewing of the external exhibits limited. What was clear was the proposed increasing application of COTS IT to operational military equipment demonstrated by the brochures gathered from the stands visited.

The contents of the MoD ICS catalogue was viewed and clearly is aimed at providing MoD users with COTS IT and related items only for 'business' applications.

4.26 Conclusions from written sources

This section has examined data from some fifty different written sources. To avoid introducing bias, as far as possible an objective view has been taken rather than a judgemental one. The conclusions fall into three general categories. These are the potential benefits of COTS IT, the problems of using COTS IT in military equipment and the issues to be addressed.

4.26.1 Cost and time scales

Lower costs and shorter development times are cited as a benefit of using COTS IT in as many as thirteen sources, while saving money occurs in a further two. The reduction of initial acquisition costs is brought up twice as opposed to reducing long-term maintenance costs which is referred to four times. There is one reference each to reducing testing costs, adapting COTS IT to the military environment as the best way of leveraging commercial investment, obtaining significantly better performance at potentially lower costs, and reducing time into service. The final comment in this area is that convergence between military and civil technologies reduces costs.

Balanced against these cost benefits are comments that savings using COTS items can largely be lost in costs of testing and protection, new issues raised by the inclusion of COTS components may offset cost savings, and that no examples exist of systems using COTS software where through-life cost savings have been demonstrated. These costs may actually be higher. There are four references to the potential for COTS-based systems to increase overall whole life costs.

Other problems pointed out for COTS-based systems are that cost estimating is complex and unreliable, and that it seems impossible to obtain accurate whole life cost predictions. Mention is also made twice of the need for a more linear spend profile funding where COTS IT is employed.

4.26.2 Risk

Two papers suggest that the use of COTS IT is beneficial in reducing programme risk. One book highlights programme and cost risks when developing COTS and other software; risks that do not exist when using COTS software. A third paper commented that using COTS IT in a system can provide reusable components for other systems and fourth used the term in its title[14].

4.26.3 Latest technology and obsolescence

Nine references occur showing the benefits that the use of COTS IT allows – easy upgrades and the capacity to remain close to the state-of-the-art, but twelve point out the problems of keeping up with the rapid rate of change of technology.

There are a further eleven references to problems of obsolescence and twice there is a further comment contrasting the short life of COTS IT with the long-life of military systems. Suggestions are made that a systems engineering approach is needed to obsolescence management, and that centralised COTS component monitoring could provide a way of managing obsolescence.

4.26.4 Specification

The fact that COTS products rarely match the military requirement occurs three times while two state that such products normally contain undocumented features. Furthermore, one source mentions that COTS IT is more vulnerable and less robust, while another suggests that suppliers exaggerate product capabilities making their assessment difficult. However, the continuing reduction in weight of COTS IT is seen as a benefit. The problems involved in the use of COTS IT in safety critical systems also come up twice.

Eleven sources point to the problem that COTS is unsuitable for many of the more severe military environmental conditions, while just one examines protection and hardening methods,

[14] Facing the risks in COTS IT – Page 49

and two mention wrapping any inadequacies of COTS IT. Ease of operation and management of COTS IT is mentioned once, as is the benefit of increased user satisfaction.

4.26.5 Security

There are thirteen references to the security problems likely to occur with COTS IT, while two see COTS IT security providing benefits. The convergence of military and civil information security is also noted. Two individual sources suggest COTS security can be improved; one by adding crypto and communications protocols to wrappers, and the other by highlighting that emerging technology offers an approach to detecting malicious code.

4.26.6 Product control

Eight sources mention that going the COTS IT route means that MoD effectively loses product control. A further three highlight the problem of lack of configuration control of COTS products.

4.26.7 Standards

There are four references to the benefits of open standards and open systems that the use of COTS IT brings to military solutions. Commercially favoured architectures and standards are considered important in allowing compatible upgrades, as well as providing system flexibility. A further three references are made to improved interoperability (and one to doubts about it) as a benefit of using COTS IT, but a similar number refer to interfacing difficulties.

4.26.8 Modifications

Major systems will include COTS IT and require some modification or bespoke hardware and software. Two sources point to the need to avoid modifying COTS IT, and another says that modifying COTS IT will increase support costs and in time divorce the modified solution from standard COTS.

4.26.9 Support

Product support is seen as a problem in four papers, difficulties with availability are mentioned three times, reliability five times (one source thinks reliability will improve), maintainability twice and certification just once. A further one highlights that COTS IT is not designed for maintenance.

4.26.10 Conclusions

The review of the literature indicates benefits of COTS IT in initial acquisition costs, timescales into service, reduced programme risk and the ability to stay close to the state-of-the-art. Against these benefits are concerns about through life costs, obsolescence, inability to meet military specifications, poor security, lack of product control, problems with modifications and difficulties with product support. Thus, the view is that there are considerable advantages to the use of COTS IT provided that the various snags can successfully be overcome.

5 COTS IT IN MILITARY SYSTEMS AND WEAPONS

This section scrutinises military innovations to try and establish where IT fits in the pattern of other advances. It then examines the boundaries between military and civil usage. It considers the finance available to the UK MoD and also looks at some industrial issues. It explores the use of IT by MoD, and the different categories of COTS IT, as well as the different types of military uses to which they might be applied. Finally, it considers the position of the UK MoD and US DoD in applying of COTS IT to their military equipment.

5.1 Innovations

Before looking at information technology, including COTS IT, and its military uses, it is useful to examine briefly the other innovations in military technology during the last century that have had a dramatic effect on the way the armed forces operate. Are there useful parallels that can be applied to information technology? In Chapter 2 of ***The diffusion of information and communication technology in the world economy in the 1990s*** [lxxx], Christopher Freeman quotes Mensch (1975) who defined radical innovations as those:

> *'which require a new factory and/or a new market, whereas incremental innovations take place within existing workplaces and existing markets, that is, they are simply improvements to existing processes and the existing product range. However, much as engineers tried to improve cotton or woollen factories they would never have got nylon or acrylics.'*

Using this definition, the list of innovations first used by the military in the last century, include:

Tanks	Aircraft	Nuclear weapons	Satellites
Radio	Radar	Guided missiles	Information technology

Each of the first seven innovations has had a radical impact on warfare. The combination of the tank and the radio, supported by aircraft were the basis of the German Blitzkrieg technique used so successfully during the first half of World War II, while radar allowed the meagre resources of RAF Fighter Command to achieve a memorable victory in the Battle of Britain in 1940. Nuclear weapons, in the form of the first atomic bombs, brought World War II to a premature close and then produced a deterrent effect that has maintained peace in Europe, at an international level, ever since.

The guided missile has had some notable successes, but none more than in the Vietnam War where it accounted for a significant proportion of the US air losses, and in the Falklands conflict where superior missile technology helped the sub-sonic Harrier outfight the supersonic Dagger. The satellite is dominant as the super powers' main reconnaissance tool, a key part of their communications chain and the source of the global positioning system. Perhaps its major impact has been in bringing live pictures from the battlefront into the living rooms of the world, resulting in major changes to popular support for governments and armed forces involved in conflict.

There is little reason to think that information technology will not have a similar impact. Already a triumph in the UK for providing a level of assistance in the decoding of the German Enigma codes, its first employment in the US was to solve artillery trajectory problems, while in Germany it was to help in aircraft stress analysis [lxxxi]. Its uses have continued to widen to the stage where it is possible to simulate nuclear explosions instead of carrying out real tests; a key factor in persuading nations to sign the nuclear test ban treaty. It is now found in applications as diverse as command and control systems, digital signal processing, communications and engine management in ships, land vehicles and aircraft.

There are, however, significant differences between information technology and the other seven innovations. Tanks, radio, aircraft, radar and guided missiles have been manufactured by the industrialised nations and sold, subject to export control, to the world's armed forces. On the other hand, the availability of nuclear weapons and satellites has been limited to a handful of nations. Information technology, however, is universally available both for civil and military use.

In ***The Relations between Defence and Civil Technologies*** [lxxxii], the editors looked at civil and military uses, noting three categories of technology which were agreed at the Wiston House Conference in 1987: Military – Multiple use – Civil. They stated that:

> *'The multiple-use category is clearly the most important for a number of policy issues, ranging from the effect of military spending on civil economic performance to the availability of civil-funded technologies for the defence industrial base.'*

Looking at the list of innovations, it is clear that tanks, nuclear weapons and guided missiles are at present only suited to military use, while radio, aircraft, radar, satellites and information technology all fall into the multiple use category. In this latter category at least, some of the uses are very similar, resulting in similar design and production techniques. Some of the lessons learned from these areas are applicable to information technology. Furthermore, as will be shown, many civil and military environmental requirements are rapidly converging. Is military security really of more vital importance than security of a nation's financial systems?

The same source went on to add that:

> *'There are few civil analogues for the lethal characteristics of weapons systems, but at the components and sub-component level similarities abound ... solid-state electronics, microcomputers ... will find both military and civil applications.'*

However, in the same paragraph they suggest that:

> *'The extent, however, that specialised military requirements drive technology towards designs or manufacturing processes that are not cost-effective in a civil context, the realm of multiple-use technology will be lessened, even at the component level.'*

It is important to remember that this was written before the fall of the Berlin Wall in 1990, before the nineteen-nineties recession and Asian collapse and slow recovery had started to grip the world economies and before the demand for a peace dividend had savagely hit at military budgets. The potential attractions of using COTS IT, whether at a systems or a component level, to save money and to provide a battle winning advantage have never been greater than they are today.

5.2 The vertical hierarchy of military systems

Any C^3I or weapon system and its constituent components can be categorised in a vertical hierarchy that is useful in a number of ways. It can assist in the development of functional models and in deciding which parts may be amenable to the application of COTS IT. It can also help to decide where military systems have civil counterparts. In their book [lxxxiii], Messrs Walker, Graham and Harbor propose a classification of systems in a vertical hierarchy from materials at the bottom to the most complex systems at the top [15].

- *Integrated weapon and **information systems***
- *Major weapon platforms and communication systems*
- *Complete weapons and communications kits*
- *Sub-systems (e.g. gyroscopes, terminals, **work stations**)*
- *Sub-assemblies (e.g. sights, fuzes, amplifiers, **monitors**)*
- *Components (e.g. **integrated circuits**, connectors)*
- *Materials (e.g. carbon fibres, **semiconductors**)*

They note the tendency to increasing product uniqueness the further up the hierarchy, quoting UK Air Defence Ground Environment as an example at the top with no military or civil equivalents. However, they suggest that this type of system's components, design principles and architecture have much in common with other large-scale systems and similarities to large telecommunications and electricity grid systems.

They highlight the need to understand the main structural characteristics of the systems at each level of the hierarchy, particularly towards the top. They stress, when examining civil/military interactions, the need to consider how the systems structures are continuing to evolve as this determines technological divergence or convergence between the military and commercial sectors.

They hold the view that rapid advances in materials and information technologies are the main drivers of radical system changes. These structural changes also depend on institutional settings, political preferences and other environmental factors. Any discussion of technological changes must take account of developments in producer/user relations and other factors that affect outcomes in both the military and commercial sectors.

They mention that the changes almost all depend on microelectronics-based hardware and software. These are pervasive because they perform, at rapidly reducing cost and increasing efficiency, three vital functions:

1. Data processing and storage
2. Data gathering and transmission
3. Machine and network control

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[15] I have emboldened those items that are IT. I have not done this for communications systems and communications kit although they are often IT dominated.

They note that a wide array of products and processes has grown up around each and that distinctions are blurring. Computers communicate with each other as do control systems, so they are no longer separate branches of technology. Both computers and control systems cut horizontally across many of the vertical levels of the 'materials to complex systems' hierarchy, and are deeply embedded within it. In fact they are hierarchical in their own right. Their effects are seen in four ways.

1. Computers embedded in existing mechanical/electromechanical products allow significant advances in control techniques. They are also becoming programmable, facilitating automation and adaptation as circumstances change. Typical examples include fire and forget missiles and fly-by-wire aircraft.
2. Labour intensive information handling is being automated at the same time as the rapid expansion in the quantity of available information, its speed of transmission and its uses. The Internet and e-mail are typical illustrations of this.
3. Design and production techniques are changing as a result of the widespread use of computers in these areas. 'From CAD (computer aided drawing) straight to numerically-controlled machine tools' is having a major impact on the defence industries.
4. Data processing, combined with advances in sensors and communications, is allowing integration of previously discrete or weakly coupled products and processes. The form of integration is also changing with developments in distributed computing and networking. Sensor fusion is a typical application in this area.

Items 1, 2 and 4 are particularly important in terms of the application and use of COTS IT for military purposes.

Their conclusions include the following points:

1. Assessing the degrees and types of differentiation between military and civilian technologies is no easy task. It is worth identifying those products that are identical in civilian and military contexts and those that are uniquely or predominantly military (although aspects of them and their manufacture may still be common with civilian products and processes, and that uniqueness can be transitory).
2. A greater understanding of the types of market that exist in the civil and military field is important. The crude split into civil and military markets fails to capture the variety that exists in both markets. There seems to be much similarity between civil and military markets for large systems.
3. Little is understood about the structures of the large military systems and how they may relate to their civilian counterparts. Understanding their component parts, linkages and architectures is important to the large companies dominating defence contracting.
4. The way the interplay between innovations in generic technologies and military systems is shaping and being shaped by changes at the systemic level is poorly understood.

The effects and conclusions of Messrs Walker, Graham and Harbor's book are at the heart of the issue facing MoD in C^3I systems and battle space digitization. It is also worth noting that new military requirements may often be met by new information services rather than new systems.

5.3 Defence spending

The UK defence estimates [lxxxiv] quote the following figures for total expenditure, which show the pressure on future defence spending. The reduction in year on year funding allocation during the second half of the nineteen-nineties, amounting to around twenty percent, without a significant reduction in the tasks placed on MoD by its political masters must alone be a real cause for concern. The drive to reduce overall costs, and one example is by using COTS IT, has been essential in every aspect of the work of MoD. What is a long-term concern is the risk that the life cycle costs of COTS IT may actually cause the opposite effect.

All figures £K	93/94	94/95	95/96	96/97	97/98	98/99	99/00
Defence Budget	23,424	22,519	21,517	22,041	20,910	22,240	22,280
% of GDP	3.8%	3.3%	3%	2.7%	2.7%	–	–
Budget at 97/98 prices	26,455	24,658	22,725	22,897	21,610	21,999	21,207
Real change on 1993/94	–	-6.8%	-14%	-13%	-18%	-16%	-19%
Equipment spend	9,200	8,819	8,537	9,100	9,003	9,785	9,803
Sea	2,589	2,441	2,110	2,190	2,142	2,351	2,299
Land	1,806	1,642	1,576	1,806	1,658	1,702	1,652
Air	3,245	3,184	3,356	3,507	3,843	4,394	4,532
Other	1,559	1,552	1,495	1,597	1,360	1,339	1,321

'Realising our Potential A Strategy for Science, Engineering and Technology', presented to Parliament by the Chancellor of the Duchy of Lancaster in May 1993 [lxxxv], while commenting on the decisive edge technology can give in situations such as the Gulf Conflict and the vital need for substantial investment in defence research and development, quotes the following figures:

1. Planned defence R&D expenditure for 95 - 96 is 20% lower in real terms than 87 - 88.
2. By 2000 the reduction is expected to be about 33%. [16]
3. Of the 93-94 MoD R&D spend of £2.6B, 75% is development, 25% research.
4. Research spending is planned to reduce by 15% over the next five years with substantial efficiency improvements in DERA. Development expenditure will reduce proportionally more than research.

It also stated that MoD buys commercial technology when it offers best value for money. This produces opportunities for 'spin-in' from the commercial to the defence sector. Microelectronics and IT are areas in which this has happened. Companies have every opportunity to offer their technology in bidding for defence equipment projects. All this is occurring at a time when the R&D budgets of the largest international companies are clearly greater than those of UK MoD.

[16] It is actually down 45% (16% down on 95 – 96)

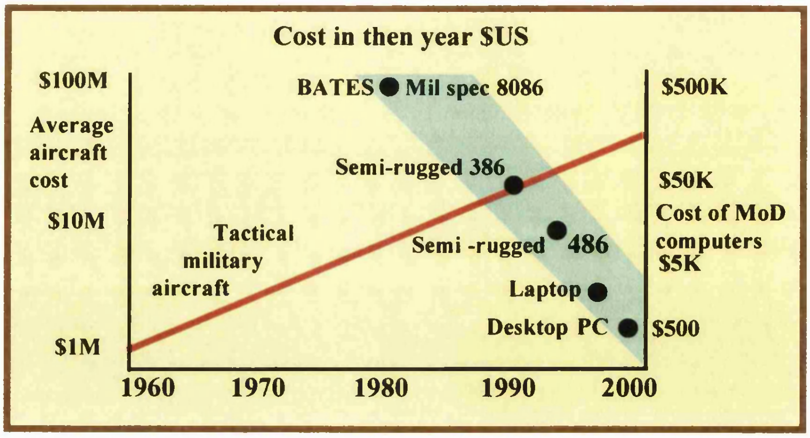


Figure 4. Typical price changes over the last four decades of military aircraft and commercial computers – all in then year US$ [lxxxvi].

Figure 4 shows the change that has occurred in the price to MoD of obtaining a given amount of computer power over the past 20 years and contrasts it with figures for military aircraft over the same period. The figures suggest, not only that military equipment procurement is becoming increasingly unaffordable in real terms, but also that COTS IT is becoming rapidly more affordable. The advantages of this increased cost effectiveness should offer great benefit to the military procurer. However, while the capital investment in IT per white-collar worker has increased one hundred fold since 1978, there has been no accompanying increase in white-collar productivity [lxxxvii]. Whether there is a read across to military applications is considered in the response to the questionnaires.

Furthermore, Figure 5 contrasts the change in performance of high-performance military aircraft and computers, indicating the remarkable rate of performance increase in the latter sector. The steep rise in military aircraft performance arose during two world wars and when supersonic flight was first achieved.

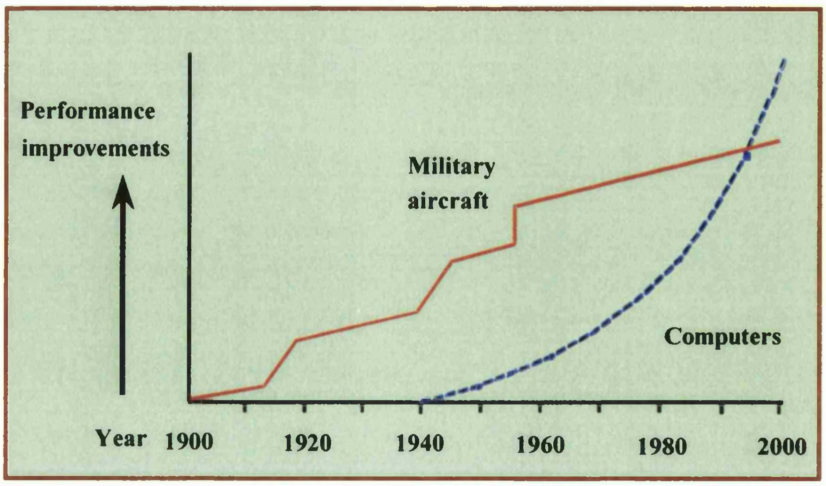


Figure 5. While the performance of computers is rising dramatically, leading edge aircraft performance has been driven by two world wars and the achievement of supersonic flight.

The cost of implementing IT systems seems to be increasing rather than decreasing, though certainly the price of a personal computer and associated software is presently still reducing. This is because of volume increases and market pressures. However, while the cost of a unit of processing power and memory is reducing, the amount of both needed in a personal computer is increasing at a rate that negates any cost saving from that particular source.

The normal reason given for the exceptionally high rate of escalation in the price of military equipment is the paramount need to achieve the best possible performance. A similar reason is given for the rapid rate of change in the IT industry with the apocryphal statement that *'What Intel giveth, Microsoft taketh away'*.

The increase in performance of microprocessors is dramatically indicated in Figure 6, which shows how Moore's law has continued to apply over the first 30 years of this component's life. The law states that the performance of microprocessors doubles every 18 months for no extra cost. This performance increase looks set to continue until at least 2010.

The problem is that unless a solution is found to the integration of the latest IT technology in future systems and a way of regularly, speedily and affordably updating them, there is a distinct danger that these systems may prove inferior to those of a potential enemy.

Addressing the impact of federal industrial R&D expenditure on private R&D activity in the US, Frank R Lichtenberg [lxxxviii] is certain that some of the most important US technological developments result from research first sponsored by government. Such early research funding on computers fundamentally affected the entire course of development of the computer industry. He mentions the difficulty of determining whether it is direct government support or government demand for products to be developed which influences private R&D investment.

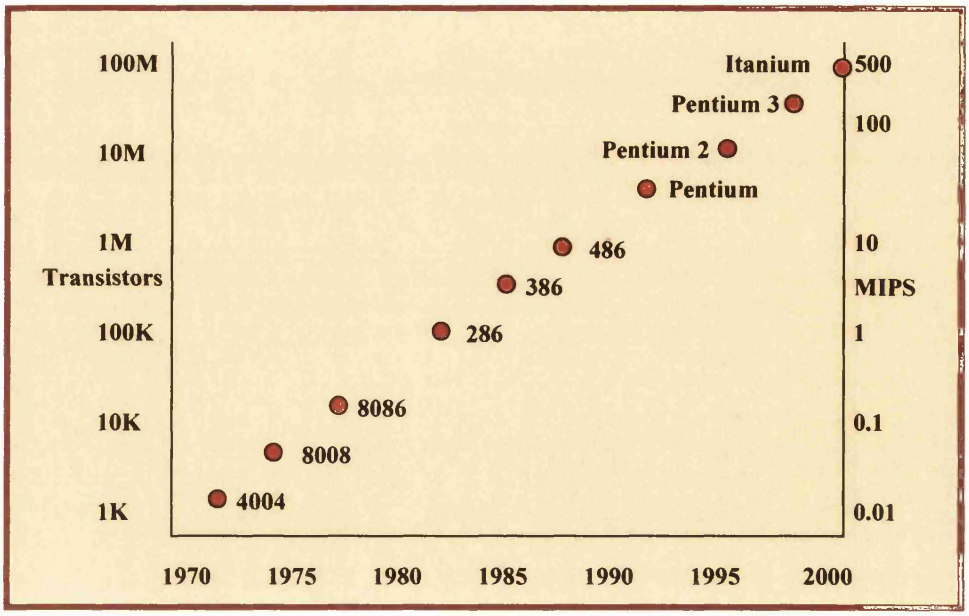


Figure 6. Moore's Law [lxxxix] *showing the regular increase in microprocessor speeds since 1972.*

5.4 Industrial issues

The rationalisation of the defence industry, as typified by the recent acquisition of Marconi by BAE Systems suggest that defence contractors are concluding that vertical integration is currently the best policy. The resultant difficulty of providing sufficient investment at all vertical levels remains a major issue. The rapid rate of change of IT is another disincentive.

At the integrated weapon and information system level, IT sub-systems, sub-assemblies and components are almost certain to become obsolete within a new system's development time scale. Even at the sub-assembly level, there is experience of components, such as ASICs and their design tools, becoming obsolete during development programmes. Where an item has to be qualified prior to production this results in significant problems and may only be solved by a life-time purchase of the component; difficult if MoD calls for batch production over several years with no guarantee that a contractor will continue with production.

Some contractors are producing ruggedised COTS-based computers. Milper Ltd [xc] is a typical company involved in producing ruggedised electronic equipment, using products such as COTS computers, workstations and computer peripherals. Its services include the design, development, manufacturing, testing and qualifying of products to meet military specifications. A typical product advertised in May 2000 is its MRC-150 rugged computer. This uses a Pentium II microprocessor operating at 450 MHz, up to 128 Mb of RAM, a 6 slots passive back plane, a 3Gb removable hard disk, a MIL-STD-1553 - MUX BUS interface and a complete array of rugged peripherals. It is claimed to be *'a high performance, rugged computer designed specifically for military airborne applications demanding toughest environmental conditions'.*

5.5 Use of IT by MoD and potential for use of COTS IT

To decide where COTS IT might be applicable to UK armed forces' equipment, a list of major items has been prepared, all of which are likely to employ IT [xci]. They have been examined and functional block diagrams developed to see how far COTS IT could be used in future.

5.5.1 Platforms

Platform		**Areas requiring IT**
Missile and fleet submarines	)	Command, control and communications,
Destroyers and frigates	)	radar, sonar, infra red and EW, fire control,
Single role mine hunters	)	engine control and navigation systems.
Main battle tanks	)	Communications, navigation, sensors, fire
Reconnaissance vehicles	)	control and engine management systems.
Combat aircraft	)	Engine control, stability and flight control,
Support aircraft	)	weapon aiming/release, radar, infra red and EW,
Helicopters	)	navigation and communications systems.
Remotely piloted vehicles		Airborne and ground control systems.

5.5.2 Weapons		**Areas requiring IT**
Missiles: surface to surface, surface to air,	)	Navigation and guidance systems,
air to air, air to surface, air to sub-surface	)	flight control system, motor
sub-surface to surface, surface to sub-surface	)	control system, warhead activation
Smart bombs	)	
ASW missiles/torpedoes	)	

5.5.3 Command/control/communications/intelligence systems

Air defence systems	)	Central processing system,
Artillery engagement systems	)	display consoles,
C^2, C^3 and C^3I Systems [17] and JOCs	)	MMIs, modems,
Command information systems	)	operating system, data bases,
Intelligence systems	)	front-end processors,
Communications systems	)	signal processors,
EW systems	)	other application programs,
Satellite systems	)	BITE

Most platforms, weapons and systems will utilise some or all of the following sensors: microwave and other RF, electro-optical and acoustic sensors (both active and passive). These sensors normally make extensive use of IT at component/sub-system level in their control systems, signal processing and displays.

5.5.4 Typical COTS IT applications

There are many COTS IT application programs that are likely to be required by military users. The following list details the majority of them. They are widely available from a number of commercial vendors.

Text processing	Multimedia processing	Computer conferencing
Document processing	Personal messaging	Spreadsheet
Electronic publishing	Organisational messaging	Data bases
Geographic information systems	Enhanced telephony	Project management
Image processing	Shared screen teleconferencing	Calculation
Video processing	Video teleconferencing	Calendar [xcii]
Audio processing	Broadcast communications	

5.5.5 Training and simulation systems

The requirement for training and simulation systems is rapidly growing for a number of reasons. The main aims of increasing the use of such systems are to:

- Reduce costs through minimising expensive equipment use. This can have a positive impact on equipment maintenance, spares usage and fuel consumption.
- Reduce the number of training accidents.

[17] The term C^4I has deliberately not been used – see Paragraph 2.5.1.

- Improve both the quality and the quantity of training.
- Reduce any adverse environmental impact from conventional training.

Virtual Reality

The recent development of virtual reality systems is being led by the civil sector but military uses include simulation, training, systems design and options evaluation, as well as war gaming.

Figure 7. One of the audience walks in front of the speaker on his way out of the room.

Figure 7 shows a virtual audience, used for training people to give lectures. It is taken from ***Public Speaking in Virtual Reality: Facing an Audience of Avatars*** [xciii], which has been developed at University College London. It represents what will shortly be the state of the art in COTS virtual reality. Virtual reality for military use is classified into three groups:

Live

Real people use real weapons in the real world, together with virtual reality. A typical example is the rifle fitted with a laser scoring system for infantry exercises.

Virtual

Real people work directly with virtual reality as, for example, in a combat simulator. An example is shown in Figure 8.

Constructive

Virtual reality is used alone. War games played on a computer screen fit into this category. A constructive system is shown in Figure 9.

Figure 8. Left, a pilot's virtual reality view of an enemy aircraft returning to its base.

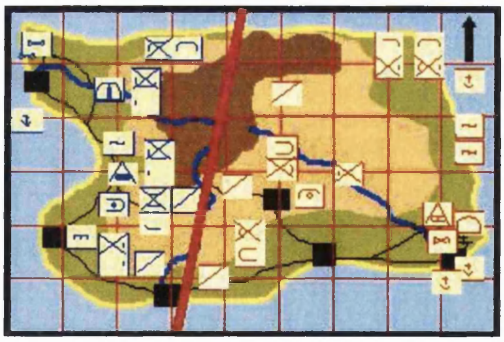


Figure 9. Right, the type of display used in war games.

COTS IT-based virtual reality systems for military use [xciv]

A typical example of a COTS IT-based virtual reality system is the SIGMA system from Data Sciences UK. It is a cockpit part-task trainer built around a COTS requirement, which can emulate a variety of fixed-wing aircraft. The personal computer-based SIGMA, which is designed for easy reconfiguration of displays and flight models, has a 120° high-resolution out-of-cockpit visual system with real-time interaction. Training scenarios include instrumented flight and navigation, in-flight refuelling, emergency procedures, use of air-to-air and air-to-ground weapons, and electronic warfare. Another example is Digital Equipment Corporation's Alpha VME 2100 system, a symmetric multiprocessor based on RISC (reduced instruction-set computing) technology. The VME 2100 consists of one to four 190MHz DEC chip 21064 microprocessors and an on-board Ethernet interface. It is targeted at military and aerospace embedded training and real-time simulation markets and is currently being used in several applications, including flight trainers and prototype shipboard training systems.

5.6 IT in military systems and weapons

The armed forces' utilisation of information technology fall into four main categories and it is important to recognise these different applications.

1. The use of personal computers as stand-alone or networked items. Many of these applications fall outside the scope of this research because they are 'business applications' but a commander's use of a lap top computer for C^2 or command information functions is both relevant and typical both on the battlefield and at sea.
2. Embedded IT is very different from the freestanding application. It includes the IT found, for example, in an aircraft's flight control system or at the heart of a guided weapon. The user will normally either be unaware of or have no direct access to or control over such IT.
3. Standard items of IT are found in large systems. Thus, a C^3I system may contain numerous computer-like consoles for the system users, as may training and simulation systems.
4. Systems that use Virtual Reality aim to make the users' view as realistic as possible, particularly in terms of visual, aural and touch senses. It is a new and rapidly emerging branch of IT that needs further investigation. Military applications include war gaming, vehicle and aircraft simulators, as well as equipment system design and maintenance.[xcv]

5.6.1 COTS IT

'Spin off' is the term usually used for 'Swords to ploughshares', but 'Ploughshares to swords' is fundamental for the application of COTS IT to operational military equipment. Because the commonest military use of COTS IT is in 'business applications' this area has already seen rapid implementation of a COTS procurement policy. Typical is the DAWN system for the MoD DPA at their Bristol Abbey Wood site; a system using standard personal computers with Windows NT4. There are discretionary access controls, multiple security levels and user authentication.

How far a similar policy can be applied to C^3I and weapon systems requires an examination of how COTS IT might fit into these systems and also the original application for which the COTS IT was designed.

5.6.2 Potential uses of COTS IT

Figures 10 - 14 were specially developed to show examples of embedded IT and the use of IT in large systems. These five diagrams show functional diagrams of a naval warship combat centre, a main battle tank and an airborne early warning aircraft, as well as a guided missile and an air defence system. The naval combat centre includes a diagram of a display, indicating the individual constituent parts. The airborne early warning aircraft only looks at the functions associated with its primary role, not the basic systems needed to fly the aircraft. Possible applications for COTS IT are coloured red; with wrapped COTS IT hardware is outlined in green.

It is apparent from this brief examination of the potential use of COTS IT in a platform from each of the three branches of the armed force, a generic guided missile that might be used by any of them, and a command and control system, that the use of COTS IT is likely to be widespread throughout the vast majority of the purchases of UK MoD. Furthermore, although much COTS IT hardware will have to be wrapped, much can also be used as supplied. A great deal of COTS software can also be used as supplied, rather than wrapped.

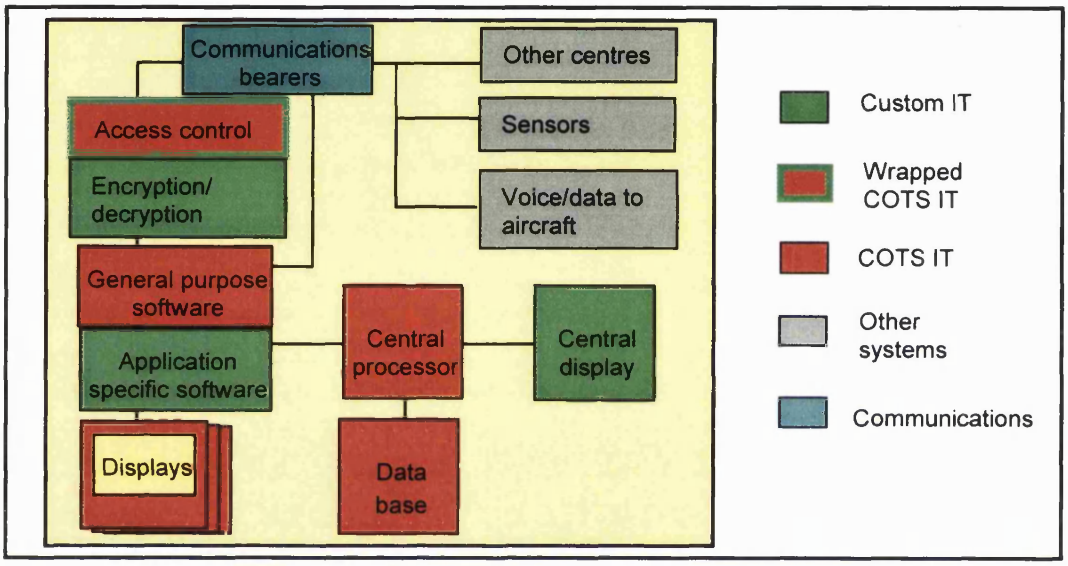


Figure 10. Functional diagram of a typical air defence centre.

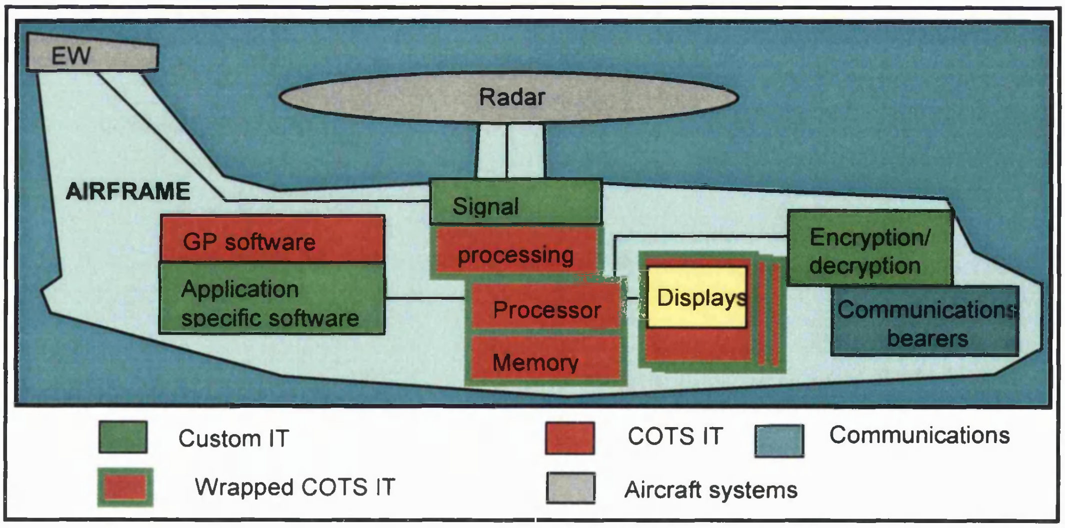


Figure 11. Functional diagram of an airborne early warning aircraft, excluding basic aircraft systems.

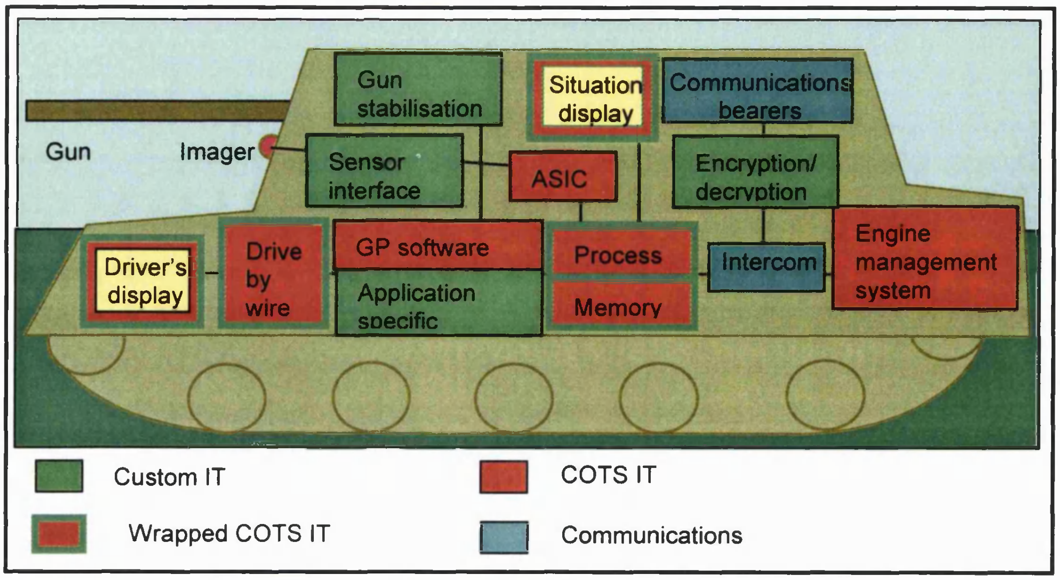


Figure 12. Functional diagram of a typical main battle tank.

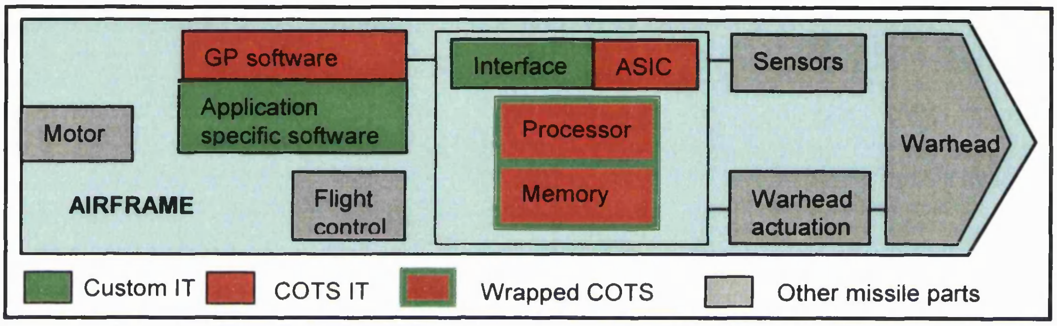


Figure 13. Functional diagram of a typical generic guided missile.

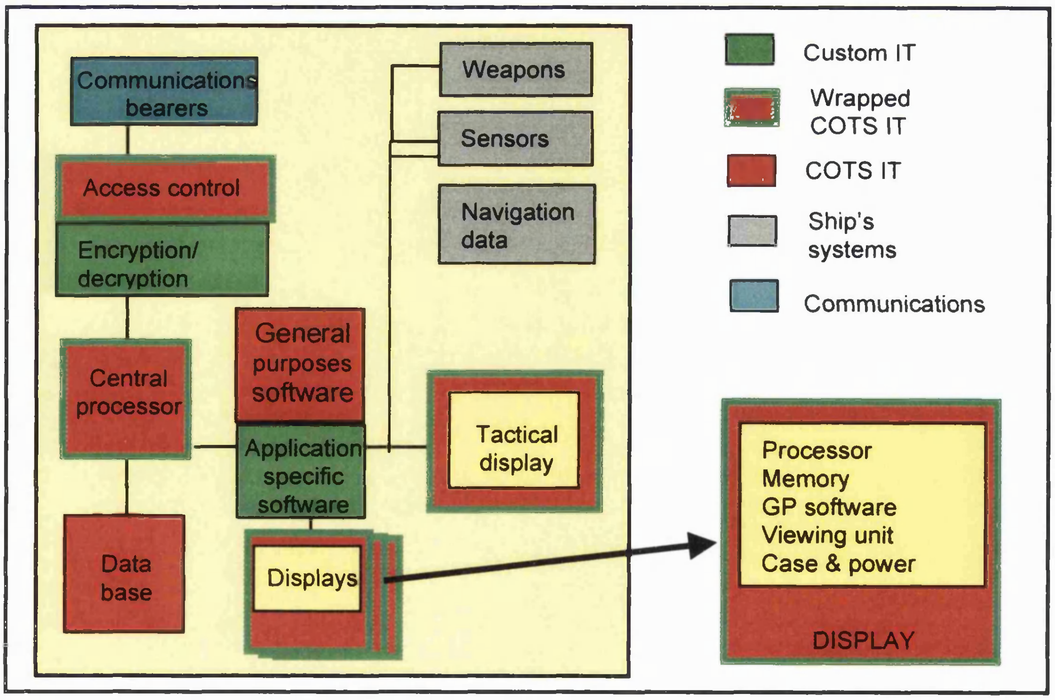


Figure 14. Functional diagram of a warship's combat centre.

5.7 MoD current position

Preliminary visits in 1996 to MoD and DERA staff to cull an initial military view of the use of COTS IT made it clear that:

1. There was a significant interest in the subject.
2. Most of the work that had been done already (by mid 1996) involved business applications, which are excluded from this thesis.
3. A pilot joint operations centre project was being used as a test bed for COTS IT.
4. As well as significant potential cost savings, there are also significant difficulties in the use of COTS IT based solutions.

Even at that early stage, it was clear that the UK MoD recognised the importance of COTS IT to its future and had already grasped its use for 'business applications'. It was keen to avoid past mistakes, such as the expensive customised CHOTS (Corporate Headquarters Office Technology System) system used in the Main Building, in its COTS IT based DAWN system for DPA at Bristol. Investigation uncovered the COTS IT activities shown below, which are typical of MoD projects, involving COTS IT, in the mid 1990s. Since that time, interest in COTS IT has blossomed and many projects are now incorporating COTS IT. Some of these projects are also outlined.

5.7.1 C^2I Common Operating Environment

MoD was establishing, in conjunction with DERA, a C^2I Common Operating Environment (COE) to try and establish standards for:

1. Application portability
2. Interoperability
3. Communications interfaces
4. Security
5. Deployment and ruggedness
6. Simple technology refresh
7. Data consistency and replication

The aim was to deal with management and procurement issues while providing a COE definition and rationale. In terms of COTS IT, it would also consider the rate of change, defence applicability and market availability. Unfortunately, recent discussions reveal that individuals feel that the COE approach is not producing the expected benefits. However, this is not a formal MoD view.

Figure 15. COTS IT flat displays in the trial JOC at RAF Northwood.

5.7.2 Trial Joint Operations Centre (JOC)

EDS have produced a trial JOC. The aim was to try out part of the system, using COTS IT as far as possible, and then use the experience gained to purchase state-of-the-art IT for the next two phases. It did represent a new methodology for tackling IT systems. Issues for MoD were the need to procure smaller increments faster, evolve systems, find suitable financial controls and establish ways of avoiding contractor lock in.

5.7.3 Security in Open Systems (SOS) Technology Demonstrator Project [xcvi]

During the three year period 1994 -96, a consortium led by Microsoft, Novell, Digital, EDS and Nortel had been studying ways of intercommunicating between competing products at acceptable security levels. The security in open systems technology demonstrator project was demonstrated in 1996 using COTS IT.

Once both the trial JOCS and the security in open systems demonstrator were complete, their implementation and operation would be examined to see what lesson had and could be learned.

5.7.4 Software integration [xcvii]

Data Sciences, now part of IBM, will provide 4,000 army users at 56 sites with office automation and logistics as well as C^2 applications under a multi-million pound software integration contract.

5.7.5 SMCS [xcviii]

The Royal Navy's Submarine Command system (SMCS) for the S&T final phase update exploits COTS IT hardware and software by porting the existing common infrastructure to UNIX®. In addition, new SMCS consoles are based on SPARC 20 boards and present the user with a standard Windows graphical user interface. The COTS IT hardware is ruggedised by wrapping to withstand the submarine environment.

5.7.6 Chinook GHUMS [xcix]

The generic health and usage monitoring system (GHUMS) supports the RAF Chinook helicopter fleet. It uses a rugged portable ground station with Pentium and Pentium Pro rugged computers, together with commercial personal computers and rugged printers. Its innovative environmental processor allows COTS technology to operate in harsh and extreme climatic environments. It is intended that in due course GHUMS will support all of the existing UK military helicopter fleet.

5.7.7 Digitization of the battle space [c]

The purpose of Joint Battle space Digitization is to enhance military capability in the conduct of joint and combined operations by achieving information superiority based upon the integration of information across the whole battle space. It is expected to be 'open for routine business' in the period 2005 – 2008.[ci]

Pre-Bowman, this provides an embryonic battle management system using Ptarmigan communications. Stage 2, with Bowman, provides increased capability and includes formation battle management system, battle group battle management system and battlefield information system applications. Its aim is: *'subject to security, communications, and rights of access, any authorised user will have access to relevant, timely and accurate information, wherever it may originate,*

Figure 16. The new British army tactical computer systems, a key component of battle space digitization.

and have it presented in the form most appropriate to the level of command or activity concerned.' Its challengers include:

- Robust secure systems.
- Sensor to weapon connectivity.
- Data input only once but read by many.
- Common interface to give reduced training needs.
- Information to 'right person in right format at right time'.
- Minimal manual intervention but humans where necessary.
- A single terminal for all purposes.
- Battlefield to highest headquarters/sustaining base connectivity.

It is the UK army's top equipment priority and involves the use of 55,000 radios, 40,000 computers and 22,000 vehicles. Its implications and effects will be felt throughout the army.

5.8 US Department of Defence (DoD) position

The US Defense Secretary William Perry's 'Specifications & Standards – A New Way of Doing Business' June 29, 1994 paved way for the US DoD acquisition reform and the use of COTS IT in their military equipment. To this can be added the following quote from President Clinton's Executive Order 12931 [cii]

> *'Increase the use of commercially available items where practicable, place more emphasis on past contractor performance, and promote best value rather than simply low cost in selecting sources of supplies and services.'*

The DoD's policy is to use COTS IT wherever possible and in this they lead the world. They are some one to two years ahead of the UK in its implementation. They are widely employing COTS IT for 'business application'. They do, of course, have fewer problems having to obtain their COTS IT from overseas suppliers. They are also implementing an ambitious program under the banner of 'Joint digitization of battle space'.

The US Army Communications Electronics Command (CECOM) reports that the US military has embraced COTS [18] solutions, to varying degrees, to realise cost savings and to speed up equipment fielding. Over the last twenty years the use of COTS products and components in military systems and platforms has gradually increased. In ground vehicles and missiles, this use has grown slowly. In CECOM's products, the use has been surprisingly expansive. The report mentions the US military's change from being a significant customer in the electronics market two decades ago to today's position where its business represents a small fraction of the overall electronics market. However, its buying power has increased in the IT sector, enabling it to enter into arrangements with major COTS IT companies to obtain very competitive pricing arrangements. [ciii] US military programmes utilising COTS IT include:

[18] COTS but not necessarily always COTS IT.

5.8.1 US DoD programmes using COTS IT [clv]

Army programmes

1. The U.S. Army's future efforts to detect buried mines and enemy equipment hidden in foliage are expected to reap the benefits of a new radar research project that uses advanced COTS technology including state-of-the-art multiprocessors, transmitters, and analogue-to-digital converters.

2. The US Army CHS (Common Hardware/Software) program will equip its battle command systems, from echelons above corps to foxhole, with common hardware and software. It aims to improve interoperability and lower life-cycle costs by standardising battlefield C^2 automation through centralised buys of NDI, standardised protocols, and reusable common software. The program provides common hardware and software to over 80 Army and DoD customers. Four hardware versions are available using RISC or 486 processors. The CHS contract was awarded to GTE in April 95 and extended to August 97. CHS-2 is a follow-on to the CHS-1 contract and version 2 equipment began delivery February 96.[cv]

3. The U.S. Army is underwriting a COTS program to develop future digital radio. This programme is expected to emerge after the year 2000 and is to evolve from three more immediate communications programs: the near-term digital radio, the surrogate digital radio, and the Speakeasy.

4. The U.S. Army's intelligence and electronic warfare common sensor program (IEWCS), through the use of COTS is putting in place a basic system that can be changed over time. An open architecture using commercial standards has been adopted to provide the flexibility of changing the system over time by replacing parts as opposed to complete new replacement. The IEWCS system consists of four subsystems providing electronic support measures, electronic countermeasures, precision location, and electronic intelligence. While the sub-systems themselves are custom designs, many of their components are commercial items. The system will be installed on the Army EH-60L Blackhawk helicopter and high mobility multi-purpose wheeled vehicles (HMMWV's). In addition to being common across platforms, the IEWCS program is common across military services.

5. The combat terrain information system (CTIS) program is an open system solution to the need to provide army terrain analysts with computer-based tools that combine COTS hardware and software, government-developed analytical models, and existing software. The COTS packages form the core of CTIS: ARC/INFO, the leading GIS package, and ERDAS IMAGINE the leading image-processing package. One of the most important and challenging aspects of the CTIS is that the resulting system will comply with Army and DoD standards for software development and also with emerging commercial standards.

Air Force programmes

1. The electro-optical subsystem for the E-3 AWACS extended airborne global launch evaluator program is an integrated suite of NDI hardware adopted to meet the mission requirements for detection and tracking of theatre ballistic missiles. In this program, existing infrared/electro-optic system and processing hardware and software for object tracking and system management are being customized and integrated with multiple sensors.

2. The Air Force Wright Laboratories has contracted for a 'COTS-based real-time avionics parallel computer.' The aim of this two-year program is to build and demonstrate a prototype multiprocessor for use in real-time avionics applications. The prototype will use as far as possible COTS software and hardware, including hardware based on the IEEE Scaleable Coherent Interface 1596-1992 standard.

3. The U.S. Air Force and National Weather Service are developing a new 449MHz profiler radar technology using COTS components as much as possible. The system will replace an existing radar at Vandenburg air force base with the Weather Service deploying the next three systems in Alaska. The COTS components will interface with post processing and instrument control developmental items not accommodated by existing COTS profiler system designs.

4. The U.S. Air Force has initiated a COTS program called Digital Warrior which integrates the gathering of intelligence, planning of missions, mission preview and debriefing in an electronics suite that consists of hardware available from an average suburban computer store.

Navy programmes

1. The signal processing capacity of current submarine sonars has been exhausted, and this limits the Navy's ability to implement available acoustic improvements. The process of developing military hardware to give these systems the needed processing capacity will take too long and is too expensive. Instead, the Acoustic Improvement Program for submarine sonar systems takes advantage of new technologies available in COTS and other NDI hardware and software products rapidly to develop and deploy new operational capabilities. This approach will also provide substantial growth capacity for future upgrades. The Acoustic Rapid COTS Insertion program is a four-phase evolutionary development program that ensures acoustic superiority for the SSN 688, 688I and SSBN 726 classes of submarines through the rapid introduction of new development capabilities.

2. In the command centre for the U.S. Navy's new attack submarine, 78% of the hardware and software will be COTS and is being projected by the prime contractor to result in a five-to-one reduction in development and acquisition costs. Of the 5.4 million lines of code required for the submarine's onboard computers, 4.1 million will be COTS. Use of other NDI software is expected to reduce the total software for the new submarines' UNIX®-based system to 485,000 lines of code. An 'open system architecture' along with COTS also allows a substantial reduction in electronic modules in the command centre.[cvi]

3. MSTRAP provides the Navy's surface ships with a highly capable torpedo alert system to defend against torpedo attack. The system design is based, in large part, on the use of COTS electronics and existing cabinetry. MSTRAP also features an 'open architecture' approach to surface ship combat design which translates into reduced costs and shorter time frames to incorporate future combat system upgrades.
4. The LEAD defensive subsystem integrates existing submarine countermeasures with proven chaff and infrared launching systems. The LEAD design is totally based on existing systems and is truly an NDI item. The approach taken with LEAD makes it instantly compatible and launchable from every surface ship in the U.S. Navy and virtually all allied navies.

Strategic Computing Initiative

In ***Computer Ethics*** [cvii] Tom Forester and Perry Morrison discuss artificial intelligence and expert systems. They highlight wasteful DARPA (Defence Advanced Research Projects Agency) funding to develop key weapons and systems as part of the US Strategic Computing Initiative. These include:

- An intelligent fighter pilot's assistant to help, under the stress of high-g manoeuvres, plan target approaches and evasive actions while monitoring threats.
- Development of prototype autonomous reconnaissance vehicles to operate in enemy territory and transmit tactical information to a computerised headquarters.
- Expert systems to help generals facing the complexity and speed of modern war make correct decisions.

The authors are sceptical about such programmes, highlighting the problems of machines recognising objects in dynamic environments with camouflage, poor visibility and seasonal variations. They do not believe a twenty-ton intelligent monster blundering around a forest can run into tank and aircraft mock-ups and distinguish them from the real thing, especially in a hostile situation demanding real time decisions. They conclude that such solutions cannot be cost effective and are tantamount to burning money.

However, people were sceptical about the telephone and the UK initially predicted the need for only six computers. Thus it is clearly dangerous to pre-judge situations as the benefits are often unpredictable. How far COTS IT is being used in these programs and the extent to which COTS IT may bring early solutions to such applications is also a key factor.

5.9 Conclusions

IT is likely to be more pervasive in the armed forces than any other twentieth century innovation and will affect most aspects of military procurement and operations. With government pressures driving down military budgets, COTS IT is seen as a key factor in economically maintaining equipment capabilities and UK MoD and US DoD are committed to its use. Both already have numerous COTS IT-based programmes and diagrams illustrate how widely COTS IT can be deployed in equipment. Industry is reacting positively to the resultant changes.

6 THE COTS IT CIRCLE – A TRAINING AID FOR PEOPLE IN MOD [cviii]

This section presents a specially developed circular model of the issues faced by those considering using COTS IT in operational military equipment, the decisions that need to be made, and the organisation which will have to make the decisions.

The purpose of designing the COTS IT circle is to provide those staff in MoD involved in specifying or procuring equipment utilising COTS IT with a practical tool to enable them to recognise the issues, face the decisions that have to be made, and decide where those decisions must be made. A copy of the whole of this section has been passed to Procurement Development Group, Project Management 1a, DPA and interest has been shown in using this as a training aid for DPA staff. The problems facing UK MoD are shown in Figure 16 on page 107. Each issue has been examined during interviews with staff, both from military and industrial organisations. Typical of the issues is that of rapid obsolescence. This is well illustrated by the Eurofighter 2000, due in RAF service early this century, using micro-processors with a capability dating back to the late 1980s. Testing of safety critical systems involving the processors makes their regular update during the development and production programme impracticable. Commercial airline suppliers like Boeing and Airbus deal with this difficulty by only incorporating electronic updates when either aerodynamic or changes to the engine configuration are also being made.

Vulnerability is another issue. Some notable weaknesses of COTS are [cix]:

- The lack of strong protection in terms of integrity, security and EMC.
- Susceptibility to erroneous functions and to viruses such as Trojan Horses and Easter Eggs, due to wide dissemination over the Internet.
- Easier for non-specialists to make accidental or deliberate intrusions.
- Difficulty in establishing conformance, particularly for software needing regular patches to fix defects.
- Procurement pressures to adopt COTS IT, even if the vulnerabilities are unclear, because of its low cost and rapid time to service.
- Maintenance problems in some operational scenarios.
- Unexpected inter-system interactions.

It appears that most commercial software programmes have trap doors to give the original designers access to the programmes for updating purposes. While this may be admirable from a commercial point of view, it is far from ideal for military applications; particularly if the software is used in an on-line situation.

The COTS IT circle looks at the decisions about the use of COTS IT that have to be made, the organisations involved in the decision-making process and the issues arising from these decisions. It is a circle because a planned upgrade involves going around the decision-making chain afresh. The circle starts at Segment 1 with a decision to purchase a new piece of equipment and continues through its life until it is upgraded or replaced (Segment 11), when the process starts all over again at Segment 1.

The following paragraphs examine the various issues in Figure 16 overleaf in rather more detail, starting from the 12 O'clock position at Segment 1. Each segment is numbered sequentially.

6.1 Potential to use COTS IT

It is at the earliest stage that a decision must be made on the possibility of using COTS IT. Such a decision is likely to impact on the equipment specification, which must reflect its proposed use.

6.2 Operational considerations

There are a number of operational factors that need to be considered in the early stages of any project. Four of them have been chosen, as they are relevant to the utilisation of COTS IT.

6.2.1 Safety implications

Does the use of the equipment have any safety implications and is it classified as a safety critical system? Such criteria demand the provision of a safety case; something that is extremely difficult with a COTS IT-based system. Traceability is one of the key factors missing from virtually all COTS IT and there is little indication from the main suppliers that this situation is likely to change.

6.2.2 Mission critical

While the equipment may not have a safety role, it may well be critical to the completion of a mission. Such roles include COTS IT embedded in key sensors, weapons and platform control systems. Clearly, duplication of low reliability parts increases the chances of successful functioning throughout any mission.

6.2.3 Total design life

The design life of almost any piece of military equipment is far longer than for most of its COTS IT. A few aircraft and ships may remain in service, after a mid-life update, for as long as fifty years and a period of twenty-five years is commonplace. COTS IT, on the other hand, is obsolescent in eighteen months, obsolete in three years and mostly replaced within four years, even by the most cost conscious users.

6.2.4 Interoperability

Interoperability mainly revolves around the question of standards and in the case of COTS IT these are largely de facto standards. However, experience with popular programs such as Microsoft Office show the difficulty of interoperability between different versions of the same programme. The problem may become significantly harder and more expensive to deal with when upgraded COTS software has to interface to custom military hardware with an interface to the original version of the COTS software.

Considerations affecting the use of COTS IT in military equipment

Abbreviations

MTBF – Mean time between failures
MTTR – Mean time to repair
IPR – Intellectual property rights

DLO – Defence Logistics Organisation
DPA – Defence Procurement Agency
ECC – Equipment Capability Customer
Prime – Prime contractor

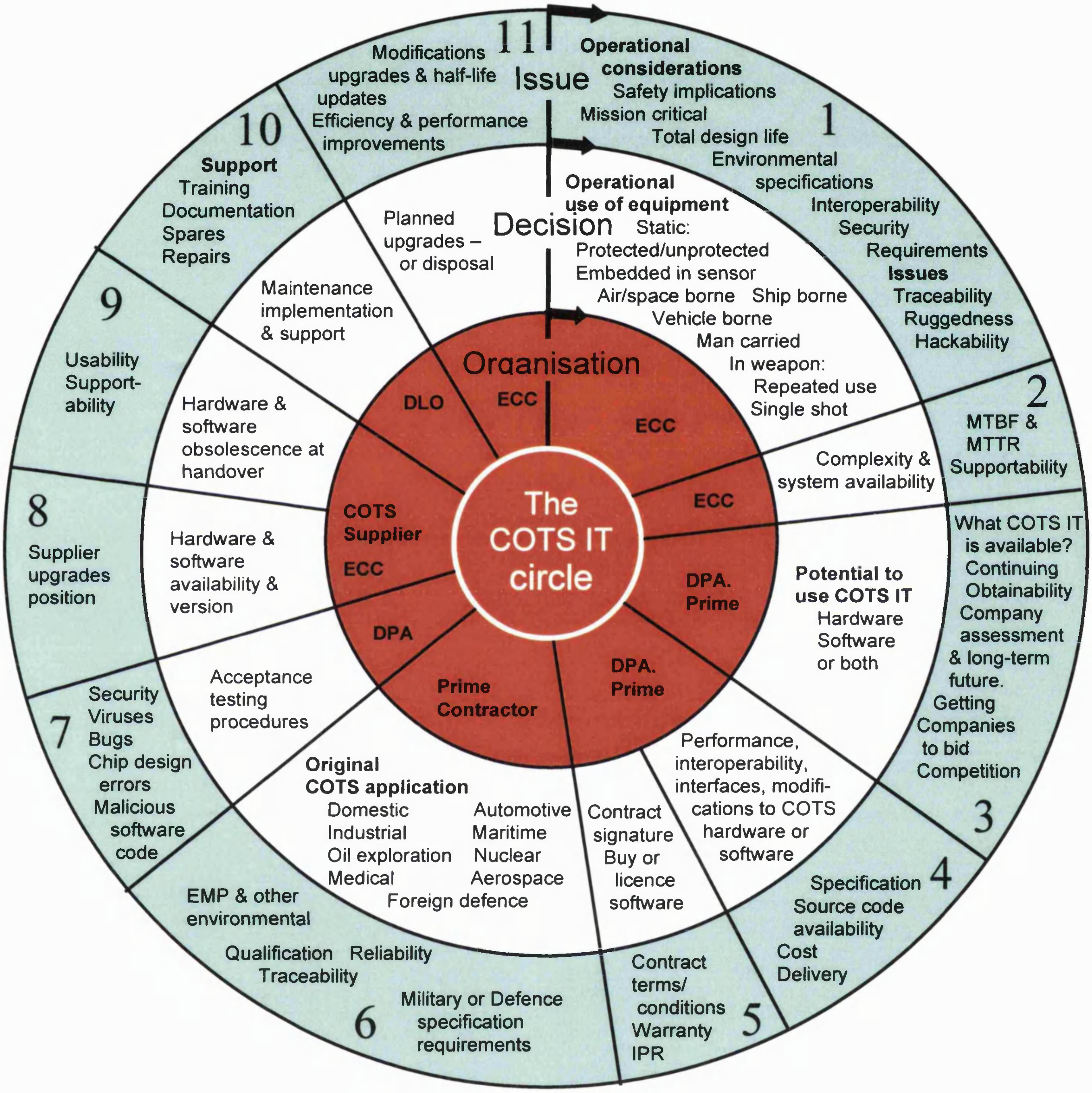


Figure 16. The COTS IT Circle helps identify issues using COTS IT, decisions to be made and who has to make them.

6.3 Operational use

The type of operational use will affect the requirements facing any COTS IT used. Any military equipment may experience a wide range of different environments depending on the particular application. It may be:

Static and protected – Office
Base unit/Headquarters
Bunker

Static and unprotected – Temporary headquarters

Portable and unprotected – Man carried
Slit trench
Tent

Embedded – In a sensor
In a weapon – single shot use – torpedo, shell, bomb, missile, mine
– repeated use – gun, missile launcher

Airborne – Combat aircraft
Support aircraft
Helicopter
Unmanned air vehicle

Space borne

Ship borne – Warship
Submarine
Support ship

Vehicle borne – Armoured fighting vehicle
B vehicle

Transportable – Container

While historically defence specifications have carefully defined these different environments, COTS IT has less care taken specifying the environment and suppliers to defence end users have made extensive use of wrapping to protect what would otherwise be very vulnerable items. The main area of COTS IT hardware differentiation has been between portable battery-powered items and mains-powered static ones.

6.3.1 Static

By far the most benign environment is that which is static and protected. Examples include COTS IT installed in MoD Main building, DPA at Abbey Wood and at the JOC in the bunker at Northwood. More demanding is the use of equipment in a static but unprotected environment. These are increasing found when the armed forces are deployed overseas and will locate equipment in existing buildings that may or may not have central heating, air conditioning or sealing from damp, dirt and dust.

6.3.2 Embedded in sensors

Sensors themselves may require some or a great deal of IT to function successfully. At the top end are the requirements of electronic warfare sensors, while at the bottom are relatively simple sensors such are thermal imagers. Embedding may take the form of wrapping, but consideration also needs to be given to the likely deployment of the sensor. The radars in the UK Air Defence Ground Environment are relatively static, while a sonar buoy has to withstand impact with the sea when dropped by an aircraft, not to mention exposure to the maritime environment.

6.3.3 *Air/space borne*

The nature of the unprotected environment in aircraft is severe. Low temperatures and pressures are often allied to high vibration and 'g' levels. There is, however, increasing pressure on the aerospace industry to provide pressurised, temperature-controlled compartments for avionics equipment, with equipment mounted on suitable anti-vibration mounts.[cx] The situation in spacecraft can be even most severe. Not only must the equipment survive the launch, but it must also cope with the wide range of temperatures, vacuum conditions, micrometeorite impact and various types of radiation.

In both cases, weight and volume are major considerations as are heat generation and power consumption; the last particularly in space applications. Furthermore, in aircraft, the production of poisonous fumes in the case of fire in the air must be avoided for the safety of the crew.

6.3.4 *Ship borne*

Areas of problem arise on board ships and submarines for a variety of reasons. The first is the presence of a salt-laden environment. Low frequency vibration is a particular issue and equipment must be able to survive exceptional levels of shock should the vessel be hit by enemy action. The generation of smoke or poisonous fumes must be avoided, particularly in the case of submarines. While power consumption is less of an issue than in aircraft, the generation of excess heat below decks often calls for a water-cooled heat exchanger. A particular issue is the need for availability throughout a mission that can exceed 90 days, relying only on on-board support for maintenance.

6.3.5 *Vehicle borne*

Any equipment installed in a vehicle leads a tough life. Exposed to the ravages of the weather, it is also expected to survive very high levels of shock and vibration. Maintenance usually takes place in a less than ideal environment.

6.3.6 *Man carried*

Any man-portable equipment has to survive a large degree of rough and tumble, particularly in wartime. Exposure to the elements, dust and mud, being dropped or thrown into a vehicle are all the lot of man-portable equipment. Size, weight, silent operation and low power consumption are important issues.

6.3.7 *In weapons:*

Weapons include guns, rockets, guided missiles, mines and torpedoes. Almost all experience serious stresses at launch.

Single shot

Any single shot equipment must operate the first and only time after a storage period that may last for decades. The increasing trend towards 'sealed' rounds avoids any checking or maintenance.

Repeat use

The repeated shock on any item of equipment that is part of a multiple firing weapon system is bound to be severe.

6.4 Complexity & system availability

The complexity of any proposed military equipment will affect its availability, as will measures taken to increase availability such as redundancy. These issues, together with the type of deployment of the equipment will be reflected in supportability demands and required MTBF and MTTR figures. Unfortunately, such figures are rarely available for COTS IT and difficult for the military user to gauge. Large software programs are known to contain large numbers of bugs, but probably not the 4bugs/Kloc (thousands of lines of code) commonly cited, as this would suggest as many as 250,000 bugs in modern personal computer operating systems.[cxi]

6.5 Sectors 1 and 2 decisions

Up to this point in the COTS IT Circle, staff in the Equipment Capability Customer (ECC) area have to make all these decisions and it is essential for these staff to recognise from the start the possibility of using COTS IT and reflect this fact in the equipment requirement specification.

6.6 What COTS IT is available

People working in MoD and defence contractors are finding it increasingly difficult to keep up to date with what is being offered in the market place. The main reason for this is that the range of products is increasing rapidly as the market grows and this is allied to speedy product obsolescence; the result of the rapid changes in technology.

6.7 Company assessment & long term future

Many commercial IT companies are both young and small in size. Some like Microsoft are enormous, yet still relatively young. Most are following the industry norm and growing very fast. The vast majority are located outside the UK and it is commonplace for the larger companies to sub-contract to workers in countries like Russia, China and India. This implies that UK MoD or their prime contractors must manage these predominantly overseas suppliers, with the risk that support may be embargoed in times of tension or war. As for the long-term future, who in 1980 would have predicted the fall from the top spot of IBM?

6.8 Getting companies to bid

The commercial IT market is huge while the military IT market is very small and represents only one percent of the total. This, in itself, is not a great incentive for commercial companies to bid. The attractions of bidding are further reduced by the aggravation involved in bidding against the qualifying, bidding and contracting hurdles put in place by UK MoD as a typical government purchaser.

6.9 Competition

There are monopolies, or near monopolies in some areas, and the dominance of Microsoft and Intel in the software and microprocessor markets is well established. This can mean that it is sometimes hard to find true competition and this gets worse, once a project is locked into a particular IT solution. In the case of hardware, there is a plethora of 'IBM personal computers' but the performances of these look alikes is by no means the same. Nor are they necessarily always suitable in terms of form, fit and function.

6.10 Continuing obtainability

In the time from deciding content of tender to the award of a contract, a piece of COTS IT hardware or software may no longer be available. A year is a long time in the commercial IT industry, but only a short time in the military acquisition process, the more so if platform (ship, tank or aircraft) time scales are taken into account. It may well be that the COTS item can only be obtained as an upgraded version, which may or may not meet the requirement. It is difficult to keep up to date in terms of knowing what COTS IT is on the market and matching this against what will be needed. For some military requirements, Mil spec equivalents will be essential and COTS IT may not be able to be wrapped or otherwise modified to meet these requirements. In these cases, it will be essential to fund specifically these military areas of IT.

6.11 Potential to use COTS IT hardware, software or both

Having looked carefully at all the issues, a decision needs to be made about whether it is possible to use COTS IT. DPA will have to work in conjunction with potential prime contractors to provide a tender specification that can be met by the use of COTS IT.

6.12 Sector 3 decisions

While it might appear that the decision can be taken by DPA alone, consultation with industry prime contractors will be necessary to ensure practical decisions are made. Integrated Project Teams (IPTs) should be an ideal vehicle for this joint decision-making process.

6.13 Specification

It can be difficult, if not impossible, to obtain an exact specification for any item of COTS IT, regardless of whether it is hardware or software. Furthermore, suppliers are in the habit sometimes of exaggerating the capabilities of their products, while at other times, to prevent litigation, understating them. It is also unusual to find performance guarantees provided. Formal software evaluation technology cannot test for conformance to specification even if such a specification is available. Problems with unwanted functionality are outlined in Paragraph 6.26.1.

6.13.1 Source code availability

Much COTS software, such as operating systems and office aids are complicated programs of several million or even several tens of millions of lines of code. Source code for software is rarely available, though some companies do allow their code to be inspected on their premises. Open source software, of which UNIX® and LINUX® are examples, are gaining popularity due to the dissatisfaction with closed-source products.

6.14 Delivery

The delivery of COTS IT is remarkably short. It may often be literally off-the-shelf and may, in any case, be too quick for the purchaser. On the other hand, it may no longer be available when required. Continuity of supply and build standard are both issues that cannot easily be resolved. Furthermore, once the COTS IT has been delivered, there may be significant system integration problems, both in terms of the need for protecting hardware, and in both hardware and software interfacing.

6.15 Cost

It is clear that bespoke systems are largely unaffordable from MoD's current level of defence equipment budget. The same factor applies to the other industrial nations, even the US. There is a significant cost of testing COTS IT to prove that it is 'problem free', and this may need to be added to the actual purchase price. It should be noted that the US DoD is carry out a great deal of COTS IT testing at its own expense. The life cycle cost implications of using COTS IT are largely unknown, but may be higher, since no major platform or system has had time to pass through more than a fraction of its life since COTS IT started to be used.

Competitive policy tends to be anti COTS IT, since once a particular supplier, for example of some software, has been chosen, that supplier will be the sole potential supplier of software upgrades.

6.15.1 Modifications

COTS IT is available at remarkably low prices for standard items, though these low costs rise to ridiculous levels if modifications are demanded. It is clear that the initial operational requirement must reflect the potential for COTS IT use if major modifications to standard items are to be avoided.

6.15.2 Interoperability and interfaces

The need for interoperability between different COTS IT-based equipment and between COTS IT-based and bespoke military equipment is largely an issue of cost. Careful though about the architecture and the use of interfaces early in any programme is key to minimising costs at later stages.

6.15.3 Performance

The performance of the final solution being acquired is a major driver, with complex, high-performance systems demanding the most from COTS IT and other system components, while simpler equipment is usually well within the state-of-the-art of COTS IT.

6.16 Contract terms and conditions

The terms and conditions of contract offered by DPA are not attractive and often not acceptable to most COTS IT suppliers. With most of these suppliers located in the US or Pacific Rim, these foreign firms are usually reluctant to send a negotiating team to the UK for what they see as a contract in an irrelevant or sidelined market. Defence prime contractors are in no position to be able to flow down MoD terms and conditions to commercial IT companies and face a 'take it on our terms or leave it' attitude. Three particular issues are warranty - not unreasonable for hardware but usually quite inadequate for software - intellectual property rights for software, and the associated availability, or not, of source code. Warranties for hardware provide for physical failure but not for design faults. Software warranties usually disclaim liability for their use and do not undertake to correct any faults that are discovered.

A decision must be made on whether to purchase outright or take out a licence for any COTS software, and the timing of contract signature may need to take into account new or upgraded COTS IT release time scales.

6.17 Sector 4 and 5 decisions

As with Sector 3 decisions, Sector 4 and 5 decisions will involve both DPA and its industry prime contractors. Again, IPTs should be an ideal vehicle for this joint decision-making process.

6.18 Military or defence specification requirements

No COTS IT meets UK defence specification or US military specifications and, worse, there is no audit trail. However, the specifications that COTS IT can meet are increasingly severe, usually not guaranteed by the supplier but often better than the supplier suggests. A popular solution is to wrap COTS IT to mitigate its limitations. This technique is suitable both for COTS IT hardware and software.

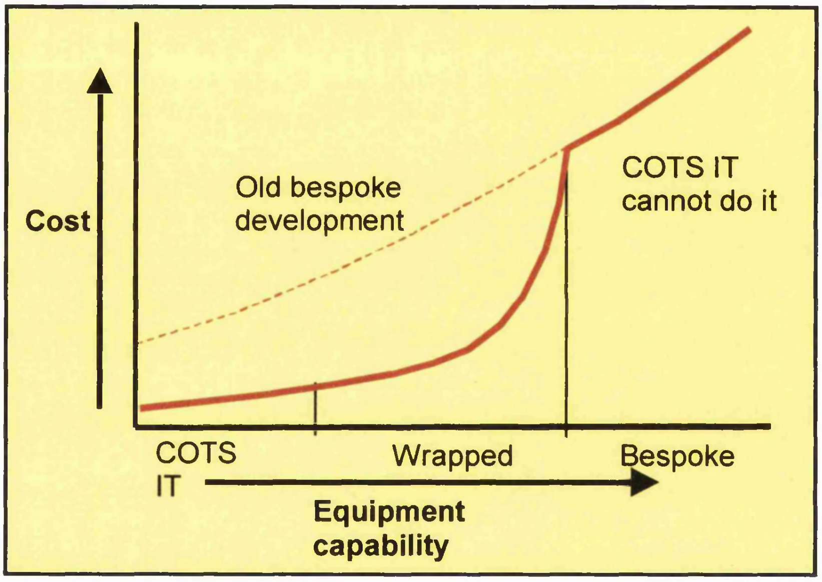


Figure 17. Costs escalate as equipment capability increases, whether using a COTS IT based or bespoke solution. However, there is some trigger point in equipment capability above which COTS IT cannot effectively meet the requirement.

6.18.1 EMP and other environmental

COTS IT hardware is not radiation hardened and for many military applications, ruggedness is still an issue, leading to the need for wrapping to provide the required level of protection. While environmental requirements in the commercial sector are increasing, and much COTS IT is built to avoid RFI, there is little actual testing and there are no Tempest proof items. Fire in a confined space, such as on board a submarine, could be worsened by the toxic products of combustion from some of the plastics and batteries found in COTS IT. However, there is convergence as commercial environmental specifications toughen and military ones, such as the need for equipment to be EMP proof, relax.

6.19 Qualification

Qualification may be as fit for purpose, mission critical or safety critical. This usually requires testing to prove usability, environmental survival, reliability, maintainability and types of failure mode.

6.20 Traceability

While military equipment is normally traceable, in the sense that each part and each work package is carefully referenced, by and large such traceability does not exist in COTS IT products. It is noticeable, however, that certain industries are now converging on this military requirement and demanding traceability from the component suppliers and sub-contractors. Typical is the vehicle industry, which needs to know which particular vehicles to recall for safety checks. Much of this change is being driven by litigation concerns and is likely increasingly to apply to COTS IT, particularly hardware.

6.21 Reliability

Software is notoriously unreliable and prone to regular crashes, although it may well be better than certified custom software of similar complexity. As an example, the much delayed new air traffic control centre at Swanwick is reported to have roughly the same number of lines of code as Microsoft Office 2000, but is proving much more intractable to get into service. There is no database of failures and no traceable records for COTS IT, though the wide user base and extensive Beta testing of some software does provide a degree of confidence. However, where safety is an issue, it is very difficult to provide proven safety cases. At the same time, there are problems with product liability and virtually valueless warranties for software. As mentioned earlier, the US DoD does prove COTS IT by both board and equipment level testing.

Acceptable MTBF and MTTR are key issues normally considered in the very early stages of the procurement cycle. The actual figures required will depend on a number of issues including the operational role, the operational environment, the consequences of failures and the ease of maintenance. Showing they can be met with COTS IT is another problem.

6.22 Original COTS application

While there are many differing definitions of COTS IT, none has been discovered that look at the original application for which the COTS IT was designed. Each application will have different requirements in terms of factors such as reliability, ruggedness and security.

Domestic

Equipment designed for use in the home, such as washing machines, microwave ovens and video recorders, contain microprocessors and memory circuits. Their environment is relatively benign, static and with a narrow operating temperature range. Electro-magnetic compatibility is important but design life for white goods is only five years. Mobile products, such as video cameras are pushing a trend towards increasing physical robustness.

Commercial

Information technology designed for commercial use operates in a similar environment to domestic equipment but is usually required to be more reliable as the consequences of failure for any reason usually have financial implications. In addition, the consequences of a hacker accessing, for example, a banking or other financial system can be extremely serious. Anything from a personal computer-based system, through a server to a mainframe system may be crucial to the operation of any commercial concern.

Industrial

Industrial systems, particularly those operating on a continuous basis, such as production line equipment in a steel or glass works, or undertaking robotic tasks, must have the highest availability. The environment can be remarkably demanding and wrapping of delicate electronic equipment is widespread.

Oil Exploration

Many of the areas where oil companies are exploring for new finds have hostile environmental conditions. These include rigs in the North Sea, South Atlantic and Gulf of Mexico, land-based equipment in Alaska and Siberia, as well as in tropical and desert regions. The application of IT in this industry has provided some exceptional wrapping issues, with a salt-laden atmosphere common and extremes of temperature as wide as any experienced by military equipment.

Medical

Information technology may just be commercial or industrial adapted for a medical role but it may operate equipment, such as X-ray machines, where incorrect operation has the capacity to kill. Thus some applications involve safety critical operation; a fact which may be particularly applicable to some military requirements.

Automotive

Not only are some automotive applications of IT safety critical, such as drive by wire, but the equipment also has to operate in a much tougher environment. A wide range of operating and survival temperatures and humidities is essential and the mobile environment implies a high level of shock and vibration. Engine management systems are often fitted close to high revving internal combustion engines and must operate reliably through the design life of the vehicle – typically ten years. Much of the standard IT used on commercial vehicles is already being applied to military variants as well as to new military vehicles.

Maritime

In some ways more benign that the automotive environment, the salt atmosphere and low frequency vibration levels must be survived. Some systems are safety critical, particularly those that control the engines and steering, while others, such as navigation systems may be mission critical. With long periods spent at sea, the only maintenance that can be carried out is by the ship's engineering staff using on board spares.

Nuclear

Much of the equipment operating in the nuclear industry is actually used to control or monitor the operation of nuclear reactors. This is a very safety critical function and equipment failures or crashes cannot be tolerated. Historically, custom-built systems were the norm but, as with military IT, the nuclear industry is being forced to embrace COTS IT.

Aerospace

The ultimate safety critical environment, flight control systems have to survive a pretty tough environment, in many ways similar to that found in military aircraft. These and other IT-based systems can be exposed to a trying environment including a very wide range of temperatures, low pressures and a broad span of vibration and humidities.

Spacecraft, while mostly less safety critical, have exposure to a wide range of severe environmental conditions both during launch and in the hostile environment of space itself. Furthermore, the cost of getting a satellite into Earth orbit or beyond is extremely expensive, making reliable performance a key criterion.

Foreign defence

As mentioned in the exclusions in Section 3, military equipment and systems supplied to overseas armed forces and then purchased off-the-shelf are not considered here.

6.23 Sector 6 decisions

Decisions on the source of COTS IT to use in any solution lies directly in the prime contractors hands, and will depend on the demands of the military specification.

6.24 Security

The requirements of military security are currently different from commercial requirements, though the latter are being driven by the need for financial transaction security. Unfortunately, military crypto requires modification to standard COTS software and re-modification each time the software is upgraded.

The greatest problem lies with transmissions to and from platforms, where radio links are essential and can be intercepted. There are, however, signs of military/civil convergence, driven by problems on the Internet with financial assurance and viruses. Commercial crypto is a possible solution, but takes 2 - 3 years to get accredited for military use and is, of course, also available to potential enemies.

6.24.1 Hackability

Designers leave built-in trap doors in their software to allow future access. Hackers familiar with COTS software may more readily exploit these entry points. A further issue is the indiscipline in the use of passwords, a trend that has been accelerating with the increasing number of passwords and pin numbers that each individual has to remember.

6.25 Viruses

One or more viruses may already be resident in COTS software, while world familiarity eases its infection. Even worse is the possibility of binary viruses, where one part is already resident and the trigger does not actually look like a virus. In general, viruses written to work in custom military software are only likely to be generated by professionals employed by potentially hostile nations.

A survey in 1996 by the US National Computer Security Association provided the following information:

- Despite increasing use of anti-virus software, computer infections tripled in 1996.
- The infection rate is 3.3% of computers in any one month.
- For organisations with over 500 personal computers, 90% found a virus every month in one of their computers.
- Complete recovery from a virus involves an average of one person working for 10 days.
- Average downtime per server virus incident was 5.8 hours for 33% of respondents.

6.26 Bugs

All software contains bugs. These may occur at different frequencies and with different impact on users. There are bugs that may occur daily, weekly, monthly, yearly or even once a decade. One of the major difficulties is testing for bugs and in this area, COTS IT fairs well with large numbers of Beta testers, not to mention the often-large installed base. However, removing bugs has the unfortunate habit of introducing new ones, so that it may well be better to live with a number of bugs if their consequences are not severe.

6.26.1 Malicious Code

In addition to bugs, there is the problem of malicious code that can affect confidentiality, integrity, data and control flow, and functionality. At one extreme of unwanted functionality are the benign examples of the flight simulator and the pinball machine, carefully buried in widely used office programs by those who wrote them. At the other end are the problems associated with licence expiration logic, trapdoors found in operating systems and hidden communications back to vendors. Furthermore, there may be other undeclared features.

6.27 Chip design errors

The design of complex chips, such as microprocessors, contains many millions of transistors, which can easily lead to design errors. Notable was the fault in the early Intel Pentium chip, but such faults are rare, due to rigorous testing to ensure functionality is sound as well as emulation testing. Regardless, the integrity of chips and their reliability are normally several orders of magnitude better than equivalent software and chip designs from the major suppliers are likely to be satisfactory for use in most military equipment.

6.28 Acceptance testing procedures

Acceptance testing for COTS IT differs significantly from custom military IT. For a start, there may be no specification against which to carry out the tests and, furthermore, the complexity of current COTS software makes comprehensive testing impractical both from economic and time scale points of view.

6.29 Sector 7 decisions

Decisions on the acceptance testing procedures will have to be made by DPA staff, and will depend on the complexity of the equipment as well as the amount and type of COTS IT included.

6.30 Supplier upgrade position

No COTS IT supplier can continue to offer a standard product in the market place for very long without upgrading it. There are a number of drivers for this approach:

- Competition from other suppliers.
- Inadequacies in the existing product.
- The need to broaden the capabilities of the existing product.
  - For software suppliers, to take advantage of improvements in hardware speed and memory.
  - For hardware suppliers, to take advantage of improvements in component/sub-system technology.

The result is that improved hardware comes on the market in a matter of months, while upgrades to software come about every one to two years. What is available and its version or specification will thus continuously change.

6.31 Usability and supportability

The general familiarity of people with COTS IT helps usability as does market competition. Supportability usually depends primarily on the degree of obsolescence when the equipment is handed over to the user. Because of short COTS IT product lives, supportability will often depend on the prime contractor leaving the actual choice of COTS IT hardware and software as late as possible in the delivery programme. Regardless, through life support will call for plans to replace COTS IT elements frequently during the life cycle.

6.31.1 Rapid obsolescence

Two years seems to be the time span before the issue of any particular major software program upgrade. From that point on, the older version ceases to be supported. The appearance of new hardware models is measured in months rather than years. Thus, the use of COTS IT means that hardware and software may be obsolescent at hand over and, in any case, forces the upgrade route on the purchaser when the supplier ceases support. A useful approach is to upgrade only that hardware necessary to support new software needs.

6.32 Sector 8 and 9 decisions

While much of the decision-making in these two sectors lies with the Equipment Capability Customer, many decisions are outside the control of MoD and will be made by the COTS IT supplier.

6.33 Support

The term support is used here to describe activities necessary to enable equipment to be kept available for operational use. It includes training and provision of documentation for users and maintenance staff as well as the supply of spares and test equipment. Such a package can be provided by industry to support COTS IT.

6.33.1 Training

On the whole, COTS IT suppliers do not provide training in their products. This task is largely left to established training companies and can sensibly be incorporated in the equipment prime contract.

6.33.2 Documentation

COTS IT documentation is very thin, the choice of all suppliers being to provide the vast bulk of the information on CD ROMs. This format may change as DVDs and other new media replace CD ROMS. Some software suppliers also provide on-line support for registered users to download updates from their web sites. All this help may be printed out, but is in the form of basic word processing pages, largely without illustrations, rather than the excellent standard of most custom (and very expensive) military handbooks.

6.33.3 Spares and test equipment

Much COTS IT hardware is not designed for repair and thus spares support is limited both in extent and duration. In the commercial market, failed hardware is normally discarded if it fails outside the extended warranty period - normally three years. In any case, manufacturers' warranty repairs are likely to be of a form fit and function nature, where the failed unit may simply be replaced rather than repaired. However, COTS IT hardware usually includes diagnostic software to facilitate faultfinding.

6.33.4 Repairs

The support of COTS IT demands a different maintenance policy to that in place for existing military equipment. COTS IT hardware is relatively reliable and, in the event of a failure, much of it is designed to be thrown away, rather than repaired. Spares at board level are available only for a short period for current products and are not NATO codified. Repair work is largely sub-contracted by IT suppliers. Whether, in these circumstances, prime contractors can provide long-term logistic support remains to be seen.

6.34 Sector 10 decisions

Decisions on how maintenance and support are going to be implemented for any particular piece of equipment must be made by the relevant members of the Defence Logistics Organisation.

6.35 Modifications, upgrades and half-life updates

6.35.1 Modifications

Contractors are very reluctant to undertake modification to in service COTS IT, and government financiers are rather reluctant to accept the standard upgrade process. There is a need for transparent interfaces and architecture at the start of any COTS IT based programme to support future growth. Furthermore, it should be remembered that any modification to standard items will be expensive and may introduce new bugs.

6.35.2 Upgrades and half-life updates

Half-life updates historically happened to custom-built military equipment and still do for items such as platforms and weapons. However, COTS IT-based solutions require much more frequent upgrades to maintain state of the art by technology insertion. This can make the planning of upgrades closer to a continuous development activity. This different approach also requires a more linear funding spend profile.

6.36 Performance and efficiency improvements

There are two main purposes for using any IT. The first is to improve the way of undertaking a task to provide improved performance. The second is to do the task more efficiently. The fact that the equipment contains COTS rather than custom IT should not reflect on these issues. Efficiency improvements can be obtained by using, for example, a standard COTS human-machine interface to avoid the need for retraining operators before they move to a new role.

6.37 Disposal

The decision to dispose of a piece of COTS IT is generally straightforward. However, care must be taken to ensure that any classified data are entirely and effectively removed from any storage medium, such as floppy and hard disks, CDs and tapes. Special care must then be taken with their declassification or destruction.

6.38 Sector 11 decisions

Decisions on whether to modify or upgrade equipment, or to dispose of it, lie with the Equipment Capability Customer.

6.39 Validation of COTS IT Circle

The COTS IT Circle was developed from the pre-briefing diagram sent to the people interviewed.[19] The content of the diagram was discussed and subsequently developed into the Circle. A modified version was presented to the Civil Aviation Workshop for the Avionics Industry and in virtually its final form at the NATO Ruthless Pursuit of COTS Symposium in April 2000. It has been discussed with a number of people from MoD. The reaction has been that it offers a useful training aid for those in any way involved with the application of COTS IT to operational military equipment, and should prove particularly beneficial to new members of IPTs.

[19] Figure 26 on Page 176.

7 DATA GATHERING

This section looks at how the populations in MoD and industry, to which the questionnaires were sent, were established. It also carefully examines the likely accuracy of the results and the extent to which bias might affect the outcome of the research.

To survey the attitudes of UK MoD and the UK defence industry, two distinct methods were used for gathering views. First, some 1200 questionnaires were mailed to named individuals. The analysed results are shown in Section 8. Second, a small percent of those who responded, and subsequently agreed, were interviewed for a period of roughly one hour. Information on the interviews is contained in Section 9.

7.1 Confidentiality

In order to try and achieve unbiased results, the names and addresses of those sent questionnaires as well as those interviewed, have been kept confidential. All questionnaires have been retained but are not included in any appendix for this reason. The covering letter sent out with each questionnaire contained the sentence: '*The answers you provide will not be disclosed to any other person*'. A similar statement was made at the start of each interview and the subsequent written reports of these interviews have been retained but are also not included in the appendices. In some cases, the summary of the visit report content has been slightly abbreviated to protect the identity of the individuals involved.

7.2 Questionnaire development

The questionnaires were developed using one-year DEG MSc students as guinea pigs. At the start of 1996, a first simplistic questionnaire led to the use of multiple-choice answers as well as removal of an irrelevant sexist question. A year later, a further test on a questionnaire, close to the final one used, produced a favourable response. However, one further question was added. Changes, once the questionnaire had been sent to DPA, resulted from feedback from the forms received – the need to break the 30-50 age group in half, and from follow up interviews – the need to provide a definition of COTS IT. There were also two further questions relevant to DERA and some changes to the questionnaire to orientate it towards industry. The final questionnaires used for MoD and industry are shown in Appendices 1 and 2.

7.3 Identification of populations and samples

7.3.1 MoD including DERA

The MoD telephone directory was the source of names, appointments and addresses for selecting MoD and DERA personnel approached. This is now available quarterly on CD ROM, significantly reducing the 'out of date' factor compared to the hard copy directory. Both have the benefit of giving a brief listing of the job responsibilities of those named in the directory, and the

CD ROM, provided by MoD, allows searches to be made by name, appointment or location. This directory should include all but 'blue collar' workers.

A major attempt was made, with the DPA, MoD and DERA to approach everyone who was involved with work on electronic systems and electronic equipment, whether embedded, installed in platforms or stand-alone. Typical of those excluded were people involved in the specification or procurement of uniforms, small arms and their ammunition, purely mechanical hardware such as bridging equipment and, of course, all civil works whether for peace time or war time use.

All questionnaires were mailed to named individuals, rather than just to appointments, and all individuals thought likely to have even the vaguest contact with requirements for COTS IT were included.

Despite this, even the CD ROM names and addresses are out of date; a fair guesstimate being six months. This suggests that some 15% of those to whom questionnaires were sent are no longer in post, based on an average three-year tenure of post. For this reason, a conservative assumption is that 10% of questionnaires sent were to individuals who had already moved to a new post.

Initial investigation identified several key departments in MoD and DERA where contact was made. These areas are shown in Figures 18 - 20. These charts do not represent the present organisation of these departments. They are the organisations that were in place when data were gathered from them.

MoD DPA

In terms of total population, MoD PE, the DPA predecessor, employed 6,500 service and civilian staff [cxii]. However, each individual included in the list was handpicked from the MoD telephone directory. Among those excluded were DESO and those involved with nuclear systems, naval architecture, crypto, uniforms, small arms and ammunition as well as secretarial, clerical, administration and registry staff. In addition, care was taken to select from those involved in platform procurement, only those who would be impacted by the use of COTS IT on the platforms. Thus a selected sample numbering 278 was sent questionnaires.

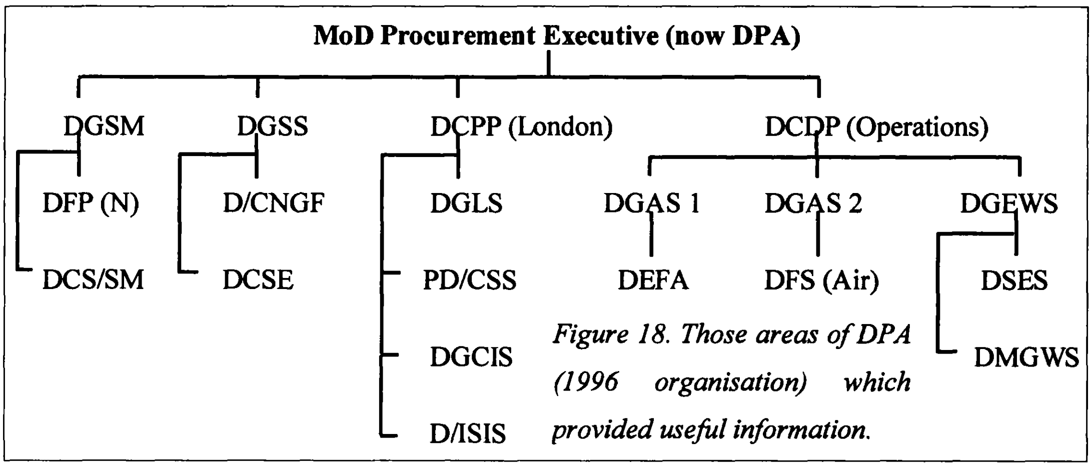


Figure 18. Those areas of DPA (1996 organisation) which provided useful information.

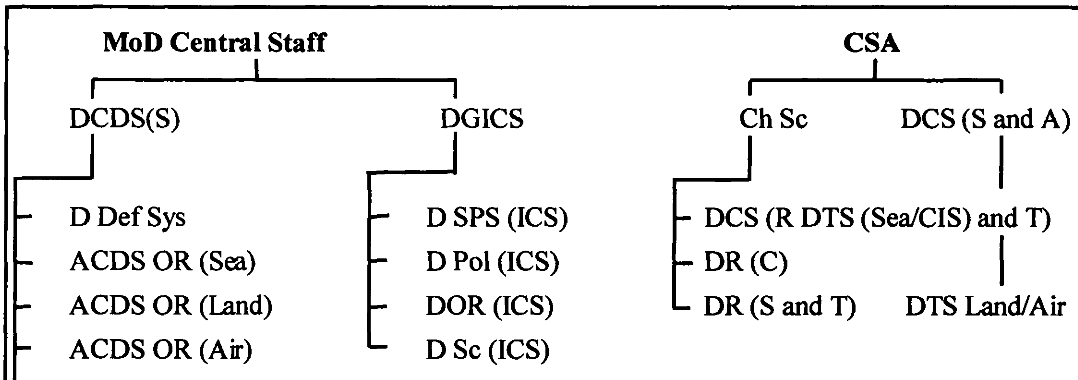


Figure 19. Those areas of MoD OR (1996 organisation), now ECC, that provided useful information.

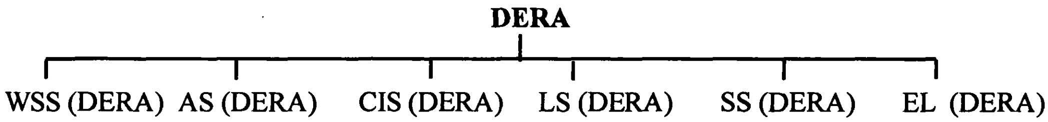


Figure 20. Those areas of DERA (1996 organisation) which provided useful information.

MoD OR (now ECC)

MoD OR, the Equipment Capability Customer predecessor had 501 staff listed in the MoD telephone directory at the time the questionnaires were dispatched. 174 were not selected for a variety of reasons; those involved in specifying nuclear systems, crypto, uniforms, small arms and ammunition as well as those not named or working in secretarial, clerical, administration and registry posts. This left a total of 327 who were mailed the questionnaire. At worst, this represents 65.3% of the population of this group and at best, assuming 25% of those excluded were done so incorrectly, 88.3%. With a response rate of 55%, this implies that between 36% and 49% of the total absolute population of this group completed and returned their questionnaires.

DERA

DERA employed some 12,000 staff [cxiii] and was divided into sixteen sectors. However, those working in ten sectors were not approached as they dealt with biological and chemical agents, human sciences, materials, test and evaluation. The excluded areas account for some 45% of DERA employees. Again, the names were listed in the MoD directory and those doing research into nuclear systems, crypto, uniforms, small arms and ammunition were excluded, as well as those not named or working in secretarial, clerical, administration and registry posts. Thus, a sample of 274 named staff was sent questionnaires.

MoD overall

It is reasonable to suggest that for the three MoD groups, a very high percentage of those whose work does or may involve the application of COTS IT to military equipment, were sent the questionnaire. However, the accuracy figures quoted for the survey do not depend on the size of the population of interest.

7.3.2 *Defence Industry*

MoD gives work to 70,000 people in the UK defence equipment industry. An approach to DESO Head of Technical Services elucidated that the number of defence industry employees was 110,000 ± 5,000 for the latest year of DESO statistics (97/98), of which 70,000 were involved in MoD equipment expenditure; the remainder in exports. MoD's purchase of electronic equipment in the same year was £982M, out of a total spend of £10,159M, but this excludes electronics embedded in platforms. In 1993 a Seaking airborne early warning helicopter comprised by value 25% airframe, 25% engine and 50% electronics. The tin box of an MBT represents only 25% of the total of £2M Challenger 2 cost. The remainder covers the engine, armament and electronics. It is thus reasonable to suggest that as much as half of platform costs are for electronic equipment. As platform cost for that year, including guided weapons, amounted to £3,840M, 50% suggests a further electronics expenditure of £1,920M, giving a grand total for all MoD electronic equipment of £2,902M (£982M + £1,920M) – 28% of the total procurement budget.

70,000 people work on MoD defence equipment, at an average turnover of £100K per employee, gives a total turnover of £7B. The out turn for defence production and repair in the UK was £7,200M - a good level of agreement. Thus it is reasonable to assume that the defence electronics industry (including COTS IT suppliers) employs some 28,000 people (2,902 ÷ 7,200 x 70,000). Making an assumption that around 10% of those employed in industry are engineers, this suggests a total engineering population of 7,000 ± 330. Looking at the value statistics, if 28% of the total budget is spent on electronic, this suggests that 28% of 70,000 (19,600) of the population were involved in electronics, of which some 1,960 are engineers. This suggests that some 16% of the total electronic engineers were sent questionnaires and some 5% responded.

For the defence industry, there is no possibility of taking a large sample; the numbers involved are simply too great. In this case, the 319 sent questionnaires represents only a small percentage but can still provide a reasonable level of accuracy.

7.4 Analysis methodology

All analysis of the data gathered from the returned questionnaires involved the use of the computer program SPSS for Windows, release 7.5.1. This was an invaluable tool used for the calculation of mean values, variances and standard deviations as well as the automatic production of bar graphs and pie charts. A very few graphs had to be done in Excel 2000. It is also worth reiterating that the term OR is used in place of Equipment Capability Customer throughout this section and Section 8, as the change in title came only after all the graphs had been produced.

Missing data are included in the database, including the 'insufficient knowledge' category, but have been excluded in the analysis. At one extreme, there was only 4% missing data in response to the statement 'an advantage of COTS IT is that it is familiar and thus easy to use' while the percentage for 'COTS IT can be used in satellites' was 30.3%. For platforms, many people only filled in boxes relevant to their particular role. In the case of terms and conditions, those isolated from contractual work – OR staff – had an above average missing rate, while on technical issues, it was those with the least engineers – again OR – which had the largest ratio of missing data. Typical missing data values are shown graphically in Figure 21.

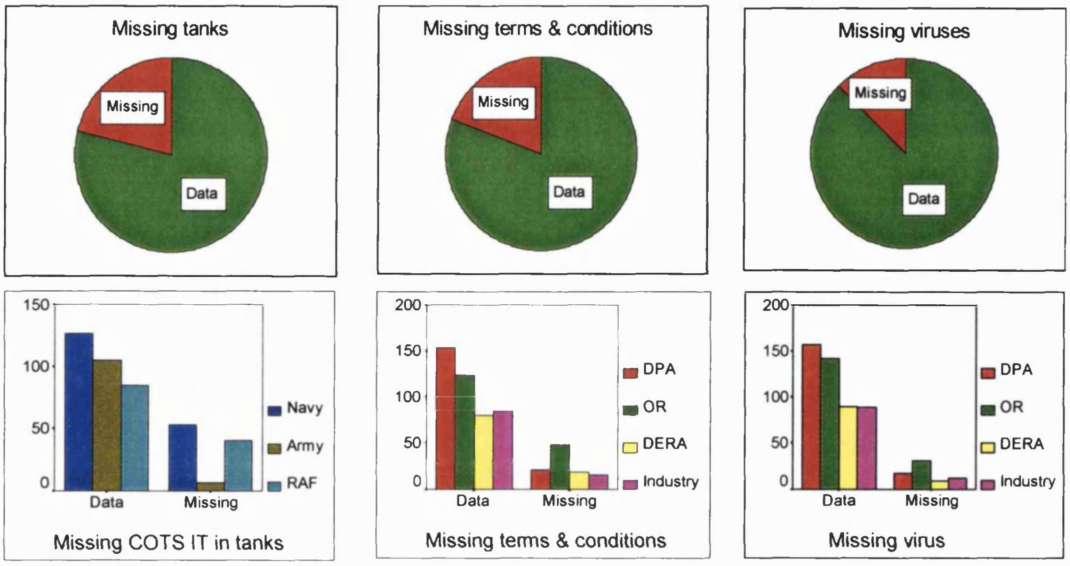


Figure 21. Samples of missing data rates.

7.4.1 Bias

One of the key problems to be faced is that of bias. Bias applies in terms of the author, who has spent most of his working life in industry, following a period as an RAF pilot. There is also the problem of bias in gathering data from people who are to be interviewed or sent a questionnaire. In particular, the following points are recognised as areas where bias is likely to arise:

Bias issue	**Response**
Selection of the audience to be questioned.	Almost everyone in MoD departments selected.
Responses only from those who have time.	High rate of return makes this fairly unlikely.
People saying what they think answers should be.	Not found in subsequent interviews.
Reluctance to discuss problems in current systems.	A surprising degree of openness found in interviews.
Go-away responses.	Unlikely from armed forces/civil servants.
Mischievous answers.	Unlikely from armed forces/civil servants.
Self-fulfilling prophecies.	Always a risk.
Bias when interpreting the responses.	A logical statistical approach has been taken.

Each point has been examined in turn although it is recognised that any bias review is both subjective and judgmental. To minimise this, a senior member of DEG staff, not involved in supervision of this research, assisted in the review and made some constructive suggestions.

The approach to data gathering for this research has been to send people a questionnaire to complete and to interview a small sample of those who returned the questionnaire to provide an extended range of views on the subject. People in four different organisations were mailed the questionnaire between autumn 1997 and summer 1999. Each questionnaire carried an individual reference number to provide anonymity, apart from my own 'confidential' reference table of names against reference numbers. This is excluded from the thesis to maintain the promised confidentiality to those who completed the questionnaire. The number of questionnaires mailed to each group is shown in Figure 22, together with the return rates.

Organisation	Sent	Estimated received	Replied	% replied	% of estimated received
MoD DPA	278	250	174	62	70
OR	327	284	173	55	61
DERA	274	247	99	36	40
Industry	319	287	101	32	35
Total	**1198**	**1068**	**547**	**46**	**51**

Figure 22. Questionnaires sent out to and received back from the various organisations.

One difficulty is that individuals in MoD are typically posted/promoted to a new position every three years and, in addition, frequent re-organisations add to the rate of staff change. Because of these factors, it has been assumed that 10% of those addressed have changed jobs and their successor has forwarded rather than looked at the questionnaire, and 2½% are not involved in work where COTS IT is employed. Thus 12½% of questionnaires sent are unlikely to have produced any response.

Since the defence industry mailing list was compiled from a more diverse series of sources than the MoD one, it is likely that the addressees will have not received some letters because:

1. The address is incorrect because the company has moved or been taken over.
2. They have moved to another company.
3. They have changed jobs within their existing company.
4. They are not involved in military projects
5. They are not involved in projects using COTS IT.

Because of these factors, it has been assumed that 2½% of addresses are incorrect, 12½% of those addressed have changed jobs or their job no longer exists and 10% are not involved in military work. As a result, it is assumed that 25% of questionnaires sent are unlikely to have provoked any response. Figure 22 shows the response rates both on the basis of questionnaires sent and on the estimate of questionnaires that are assumed actually to have reached the addressee. In calculating the error rates, the former figures only were used.

The difficulties of avoiding bias in gathering data start with the list of questions to be asked. These problems are accentuated by the very different backgrounds, experience, motivations and understanding of the issues of the people involved.

A total of eighteen questions (20 for the people in industry) were arranged into three distinct groups. The first deals with the use of COTS IT by UK MoD and considers the possible areas where COTS IT might have an application. The second examines its purchase and the third looks at the impact this use will have. Thus the following list of statements was used to prompt people to indicate their views. These views allowed five possible responses from 'strongly agree' to 'strongly disagree'. An additional category – insufficient knowledge – was also included. When looking at means, standard deviations and variances, the following numerical values were used:

Strongly agree	5	Slightly disagree	2
Slightly agree	4	Strongly disagree	1
Neither agree nor disagree	3	Insufficient knowledge	0

8 DATA ANALYSIS

This section shows the outputs of analysis of the data from the questionnaires, in terms of the background of the people from MoD and industry who provided the data and their views on the use of COTS IT in military equipment. It ends with a summary of their opinions.

8.1 Those who responded from MoD

In order to obtain some statistics about the nature of those who responded, each questionnaire asked for some personal information about the person who completed it. The military questionnaire [20] asked:

Please provide some brief information about yourself

My rank/grade is

My age is Under 30

30-40) in the DPA questionnaire, these two age

40-50) groups were combined in a single 30-50 age group.

Over 50

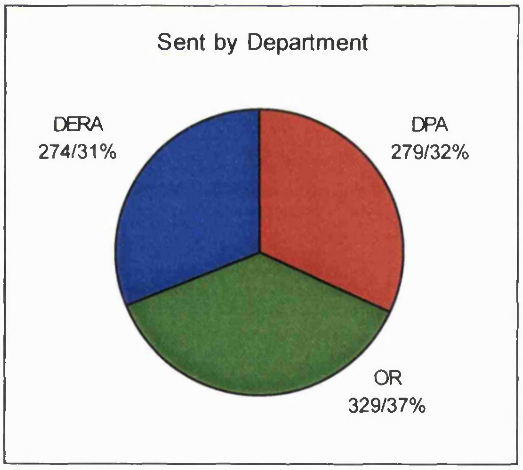
I use a computer at work

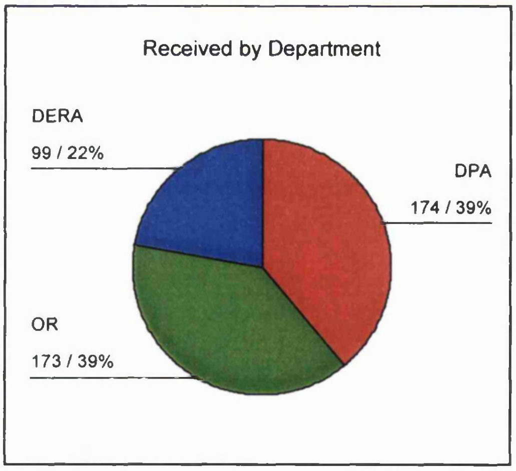
I use a computer at home

I am involved in specifying/purchasing IT

8.1.1 MoD department

The details of the people in DPA, MoD OR and DERA who completed the questionnaires, were analysed as a single group. The results are shown in the following twelve charts.





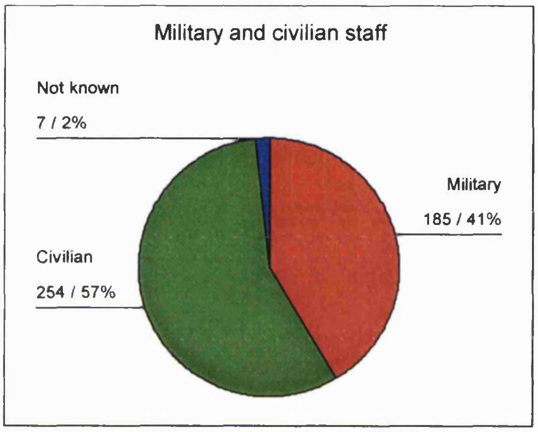
Some 880 questionnaires were sent to the three departments of MoD – DPA, OR and DERA – in roughly equal numbers but with a slight preponderance in favour of OR. The response rate from those in DPA was slightly higher than from those in MoD OR, while the response from DERA

[20] The questionnaire is included as Appendix 1.

was around 60% of that from the other two MoD organisations. This is not surprising since DERA is least impacted in the results of using COTS IT in military equipment. Furthermore, the agency status of DERA has resulted in a new cost consciousness, which means that those who filled in the questionnaire would have to find a code to charge it to. Despite this, a far higher response rate was achieved than could reasonably have been expected, with some 40% of completed questionnaires coming each from DPA and OR with 22% from DERA.

8.1.2 Civilian and military personnel

	Total sent	Sent to civilians	Sent to military	Civilian returned	Military returned
DPA	279	79%	21%	76%	24%
MoD OR	329	31%	69%	18.5%	81.5%
DERA	274	97%	3% [21]	93%	7%
Total	882	67%	33%	57%	43%



Questionnaires were sent to people in MoD DPA, OR and DERA in the proportion 67% to civilians and 33% to military staff. This compares with the questionnaires returned, of which 57% of were from civilian staff and 43% from military personnel.

In all three organisations, as well as in total, the response rate from military personnel was higher than from their civilian counterparts. This is assumed to be a result of the more disciplined training of military personnel. It could, however, be due to a greater workload being placed on civilian staff. The result is a skew in the direction of the views of military staff. The Pearson coefficient of skewness can be computed from the formula:

$$Sk = \frac{3\,(\text{Mean} - \text{Median})}{\text{Standard deviation}}$$

For those sent the questionnaire, the skew is = 3(1.67 – 2.00) ÷ 0.4726 = - 2.09

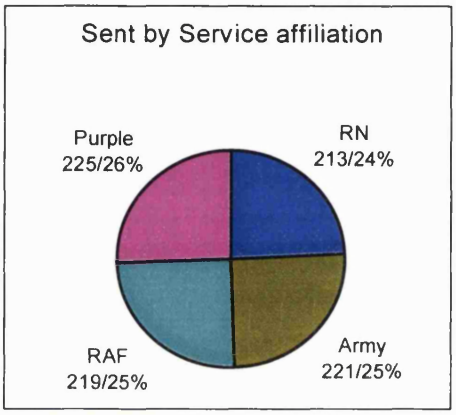
For those who returned the questionnaire, the skew is = 3(1.60 - 2.00) ÷ 0.520 = - 2.30

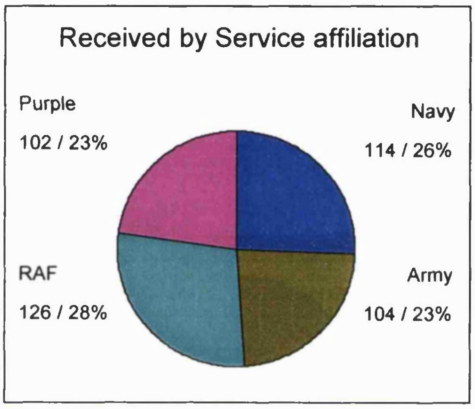
The difference in skew is therefore - 0.21; the negative sign indicating that a skew towards the military. This means that all the results from the questionnaires are slightly skewed towards a military view. Because of the two-thirds percentage of civilians in the MoD population, this is probably even a positive effect in that it reduces what would be a predominantly civilian view to one that is only 57% civilian to 43% military.

[21] DERA is almost entirely civilian staffed.

8.1.3 Service affiliation

Questionnaires were sent in almost equal number to the three armed forces branches and tri-service (purple) staff. This was not by design, but rather the way things turned out after names/job titles had been gleaned from the MoD telephone directory. The service affiliations of those who responded were also roughly equally split between the Royal Navy, the Army, the RAF and those in purple roles. There was a slight predominance of responses from the RAF, but this is judged insufficient to cause significant bias.





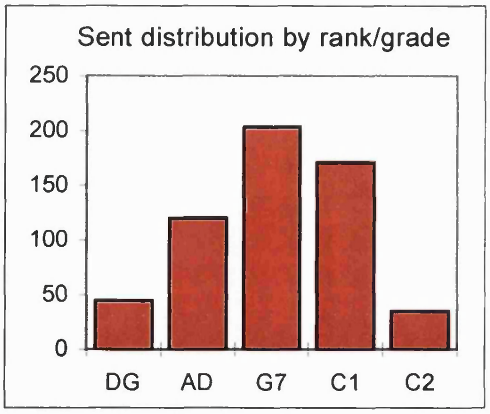
8.1.4 Rank or Grade

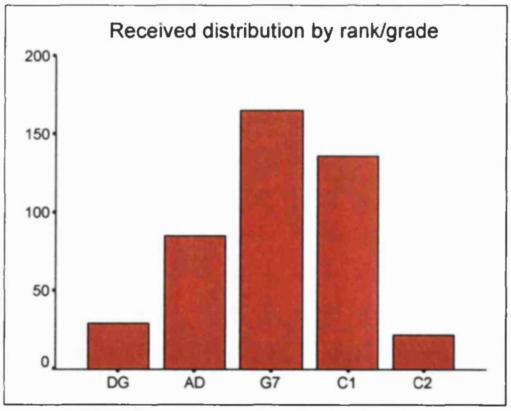
The ranks or grades of those who returned questionnaires were clustered into five groups. These groupings are shown in Figure 23 below.

Rank/grade – DG	Rank/grade – AD	Rank/grade – G7
Director General	Assistant Director	Grade 7
Director	Grade 6	Commander
Two star rank	Captain RN	Lieutenant Colonel
One star rank	Colonel	Wing Commander
Grade 5	Group Captain	

Rank/grade – C1 or SSO	Rank/grade – C2 or HSO & below
Senior Scientific Officer	Higher Scientific Officer
Lieutenant Commander	Lieutenant RN
Major	Captain - Army/RM
Squadron Leader	Flight Lieutenant

Figure 23. The five groupings used for the various military ranks and civil service grades.

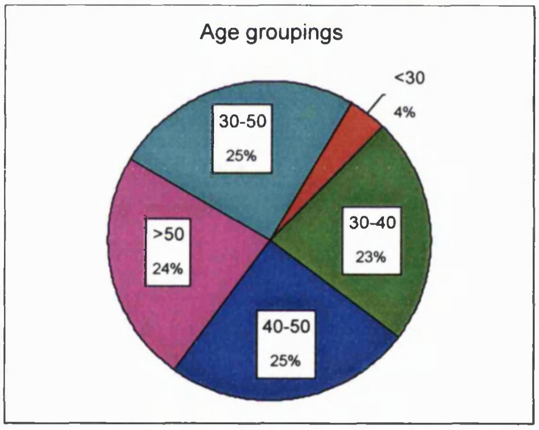


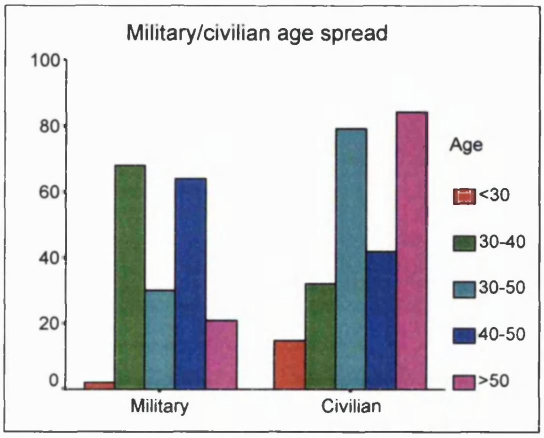


The questionnaires were sent out to named individuals holding particular posts and without particular consideration of the rank/grade of the person to whom they were sent. The dispatches and responses by rank or grade showed a typical Gaussian distribution. At the senior levels, this is not surprising. At the lowest grades, this has come from the lack documentation of the most junior posts in the MoD directory. This has caused a bias, which seems to be all but insuperable. Further work could be done to poll those in the fifth and lowest grouping of ranks/grades. However, at this level, there are few military officers working in DPA, MoD OR, or DERA. Interestingly, fewer senior members (two and one star level) of OR replied than of DPA or DERA.

8.1.5 Age groups

The age distribution highlights a change in the questionnaire used, following the DPA survey, where the middle 'age group' was 30 – 50 years old. Because the vast majority of responses came from people in this age group, for the other two organisations, it was broken down into two separate age groups; 30 – 40 and 40 – 50. What is clear is that MoD OR has a significantly lower percentage of people below 30 or older that 50. This was not expected but does not appear to indicate bias, as the organisation is predominantly uniformed. People below 30 are unlikely to have has sufficient field experience and a retirement age of 55, rather than 60 for civil servants, is likely to give a lower population in the over 50 group.



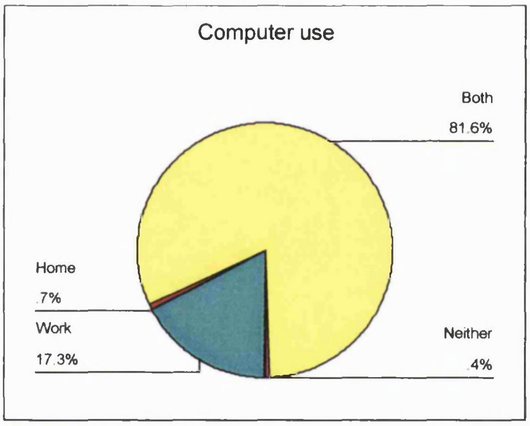


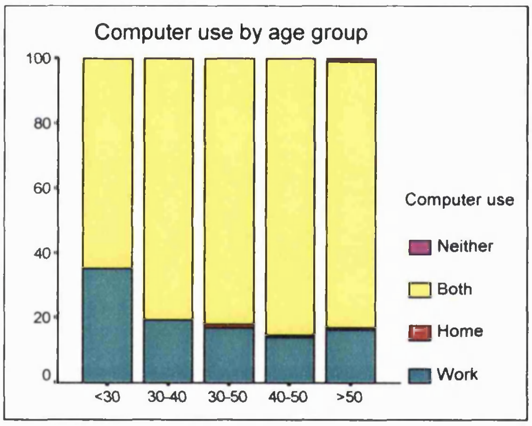
Only 4% of the responses were from people aged 30 or less, while 24% came from those over 50. Not surprisingly, the bulk of replies came from those in the 30-50 bracket and, where this age category was further split down (following the responses from DPA) the split was roughly equal between the 30 – 40 and 40 – 50 age groups. Clearly, there was no way of knowing the distribution in this age group of those to whom the DPA questionnaires were sent.

What is noticeable is that the average age of the military people who responded is significantly lower than that of their civil service counterpart. It is assumed that this is because the compulsory retirement age for all but the most senior members of the armed forces is 55, while the equivalent for civil servants is 60.

8.1.6 Computer use

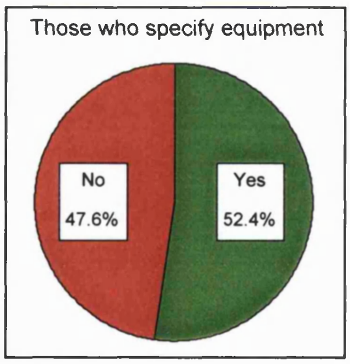
Computer use was assessed as it was felt that computer literacy could affect the views expressed on the use of COTS IT. 82% of responses were from people who used a computer both at home and at work, while a further 17% used a computer only at work. Only 0.7% owned a computer at home but did not use one at work and this ownership was mainly among older people. Just 0.4% had no access to a computer and this small group was exclusively among the over fifties. It is therefore felt that the data has not been of particular value, except in showing the high level of computer usage by staff in MoD and DERA.





8.1.7 Those who specify equipment

Finally, responses were just about equally divided between those who said they were involved in specifying equipment and those who were not. This is useful in that it allows a check to be made as to whether actual involvement in specifying equipment changes the responses.



8.2 Those who responded from industry

UK industry is estimated to employ some 355,000 people on defence-related work, excluding MoD employees. The impact of COTS IT on the major defence equipment prime contractors, and their sub-contractors, supplying the UK MoD (some 70,000) is probably just as significant as it is on UK MoD itself.[cxiv] The same source shows that approximately 30% of expenditure would definitely not involve the use of any IT.

Thus a questionnaire similar to that used for MoD, was sent to selected individuals from divisional chief executive, engineering director and chief scientist level down to ordinary engineers. These companies are involved in the use of COTS IT in what they sell to MoD and already foresee a number of difficulties to be overcome. Some specialist smaller defence contractors were also approached.

Obtaining a suitable mailing list proved more difficult than for MoD. Eventually, a list was combined from several sources including UK INCOSE, attendees at the Defence Information Capability Conference 99 and individuals contacted at Euromilcomp 97 and Farnborough 98. This produced a rather random list but with a good spread of people in a range of important defence contractors, as shown in Figure 24. Note that this took place before the amalgamation of British Aerospace and Marconi into BAE Systems.

Company Name	Number sent	Company Name	Number sent
British Aerospace	61	Matra	10
Boeing	2	Pilkington	3
British Telecom	1	Racal	13
CDC	12	Rolls Royce	4
DEC	2	Shorts	2
EDS	8	Siemens	9
GEC/Marconi	40	Thomson	6
Lockheed Martin	4	Ultra	5
Lucas	6	Vickers	1

Figure 24. The number of questionnaires sent to people in MoD's main defence contracting companies.

Of the list of UK MoD top defence equipment contractors in 1995/96 [cxv], shown below, employees from approximately two-thirds were approached.

Alvis	British Telecom	IBM	Thomson
BAe	GEC Marconi	Lockheed	Vickers
Boeing	GKN	Racal	Vosper Thorneycroft
Bombardier	Hughes	Siemens	VSEL

Of the list of nine contractors (excluding DERA because they are an agency of MoD) shown below that were paid over £250M in 98/99 by UK MoD [cxvi], over three-quarters were approached.

BAe	GKN	Matra BAe Dynamics
Devonport Royal Dockyard	Hunting	Rolls-Royce
GEC	Lockheed Martin	Vickers

To obtain some statistics about the nature of those who responded, each questionnaire asked for personal information about the person who completed it. The industry questionnaire [22] asked:

Please provide some brief information about yourself

My job title is

My age is Under 30

30-40

40-50

Over 50

I use a computer at work

I use a computer at home

I am involved in specifying/purchasing IT that is incorporated into what we market

The main business of the company I work for is (tick all that apply):

Defence

Commercial

A systems house

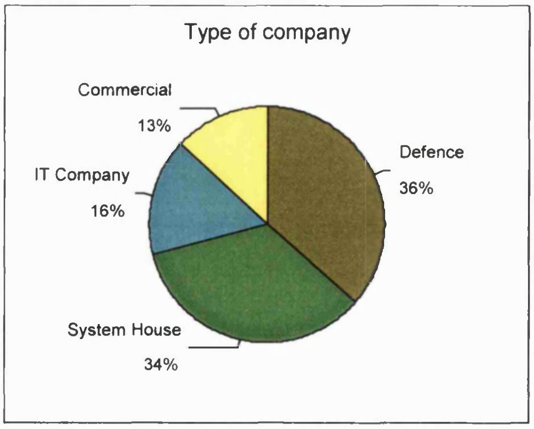
An IT company

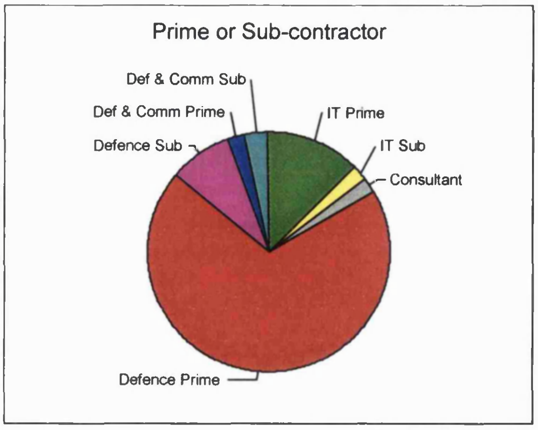
A prime contractor

A sub-contractor

8.2.1 Type of Company

One way at looking at the responses is to classify them into one of four categories; defence companies, system houses, IT companies or commercial companies. About one-third worked for defence companies, one-third for systems houses and the remainder for IT or commercial companies. From these figures, it appears that the systems-house companies were all also defence prime-contractors since approximately 70% of the people who returned their questionnaires worked for a defence prime-contractor and a further 8% for a defence sub-contractor. Another 5% worked for a prime or sub-contractor operating in both the defence and commercial fields. 15% worked for an IT prime or sub-contractor and just 2% were working as consultants.

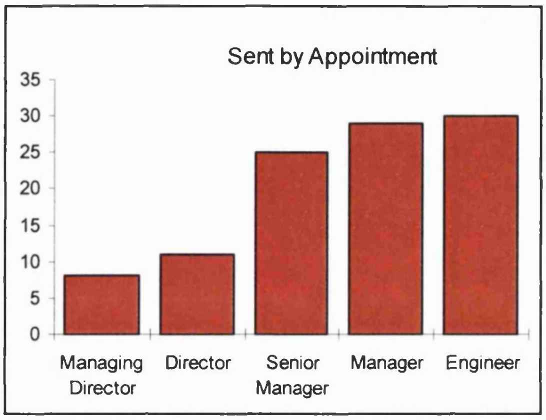




[22] A sample of the document sent to commercial organisations is shown in Appendix 2.

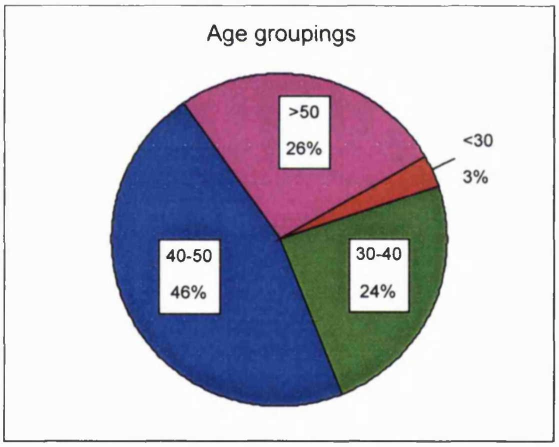
8.2.2 Appointment

The spread of industry responses was typical of industrial pyramid organisations but the responses tended to come from the more senior people, with a disappointing shortfall from engineers. It has to be admitted, however, that the grades of those questioned was only known in about one-third of cases, so that it is difficult to draw serious conclusions from these results.



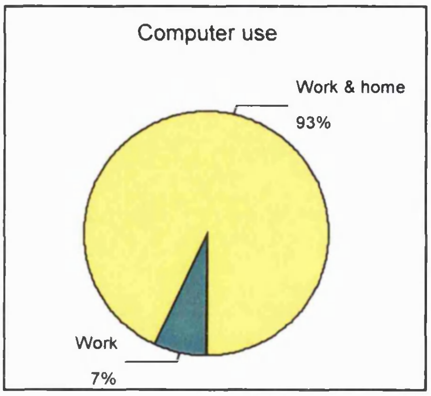
8.2.3 Age groups

The age distribution was broken down into four separate age groups; <30, 30 – 40, 40 – 50 and >50. Inevitably, there was no information about the ages of the people who were sent questionnaires. Only 3% of the responses were from people aged 30 or less, while 26% came from those over 50. Slightly surprisingly, the bulk (nearly half) of replies came from those in the 40 – 50 bracket, with only a quarter in the 30 – 40 age group. More surprising is that, although the compulsory retirement age in industry is 65 compared to 60 in the civil service and 55 in the armed forces, the percentage of responses from those over 50 is about the same. Perhaps the current 'youth culture' is forcing early retirement on people in industry [cxvii].

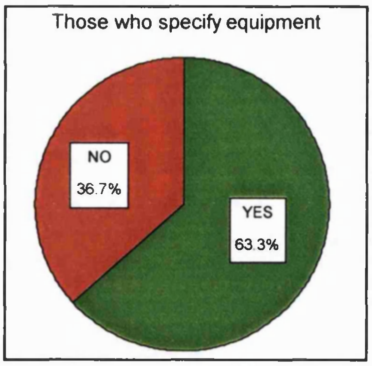


8.2.4 Computer use

Compared to MoD and DERA where only 82% of staff use a computer at home and work, with a further 17% using one only at work, the equivalent figures for industry are 93%, with the remaining 7% using a computer only at work. This suggests only that people in industry are more likely to use a computer at home than those in MoD. No one in industry had no access to a



computer at all, or only had access at home. This compares with MoD staff percentages of 0.4% and 0.7%. Thus, the responses to the question only demonstrated the total pervasiveness of IT in the working lives of those who responded.



8.2.5 Those who specify equipment

Roughly two-thirds of those who took the trouble to respond are involved in specifying equipment, while the remaining third are not. This is useful in two ways; first to establish whether people involved in specifying equipment had different views from those who did not and secondly, in showing that two-thirds of those who responded were in the direct area of interest, as far as obtaining information about COTS IT was concerned.

8.3 Answers about potential MoD use of COTS IT from DPA, MoD OR & DERA

A great deal of effort was put into developing the individual statements incorporated into the questionnaires. The responses to the following thirteen statements were analysed to show the MoD attitudes towards the use of COTS IT in particular types of equipment. Before answering these questions, people were asked to:

First, think about the potential use of COTS IT by UK MoD.

1. COTS (commercial off-the-shelf) IT (information technology) has a place in MoD purchases.
2. COTS IT only has a place in non-combat systems.
3. Compared with military IT, COTS IT will perform equally well in war.

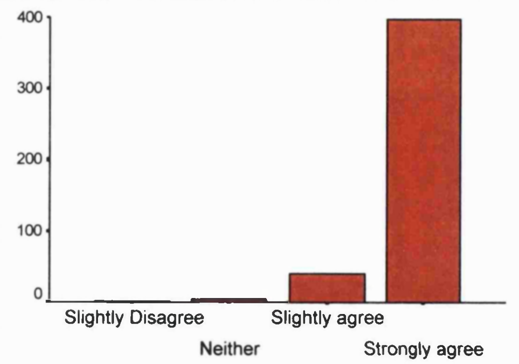
COTS IT can be used in:

4. Business systems (word processing, accounting systems etc.)
5. Warships or submarines
6. Battle tanks or recce vehicles
7. Combat or support aircraft or helicopters
8. Weapons
9. Weapon launchers
10. Sensors
11. C^2, C^3, C^3I, Intelligence or Air Defence Systems
12. Communications or Electronic Warfare Systems
13. Satellites Systems

There is a graphical representation of the responses to each statement, supported by the calculated mean value between 1 – strongly disagree and 5 – strongly agree, as well as the standard deviation and variance. Where group responses (military/civilian, age, grade/rank, service and department) vary from the average, then individual graphs showing these variations are also presented. The absence of any of these graphs indicates the same pattern of responses as the total group.

8.3.1 COTS IT has a place in MoD purchases

The first statement asked was whether those questioned agreed or disagreed that 'COTS IT has a place in MoD purchases'. It should be remembered that this is MoD policy. 89.4% of responses fully supported the MoD policy, 9% slightly agreed with the policy, 1.1% neither supported nor disagreed with the policy, while a small minority) – 0.5% (two people, both in DPA) slightly disagreed with it. With a mean value of 4.87 out of 5, and a standard deviation of only 0.4, this does indicate that the policy to use COTS IT wherever possible is widely understood throughout MoD DPA, OR and DERA – or at least among those sections of the organisations which were questioned. [23]



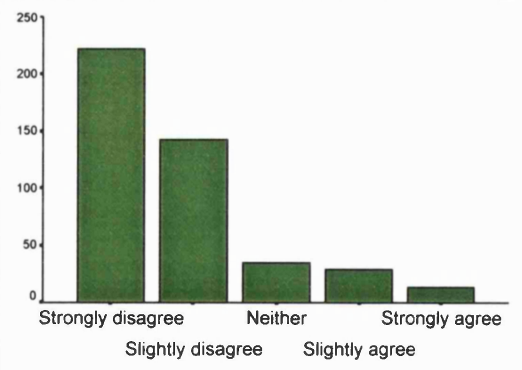
COTS IT has place in MoD purchases

Variable	Calculation	No	*Factor*	*Score*
COTS IT has a place in MoD purchases	Mean value	4.87	*Strongly agree* ——▶	*5*
	Standard deviation	0.4	*Slightly agree*	*4*
	Variance	0.16	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.2 COTS IT only in non-combat systems

There is rather less unanimity on whether 'COTS IT is suitable for use only in non-combat systems'. Only half the responses strongly disagreed with the proposition but 82.3% either strongly or slightly disagreed. The mean value of 1.8 equates to 'slightly disagree', with a significant variance of 1.09.

Only the Navy had no 'strongly agree' responses but, in any case, the overall numbers in this category were small. Thus, it is clear not only that almost everyone in MoD supports the use of COTS IT, and that the vast majority do not think this use should be limited only to non-combat systems. The counter assumption, which suggests that half of those who responded think COTS IT is positively suitable for use in combat systems and a total of four out of five think is positively or probably suitable, is a reasonable view to take.



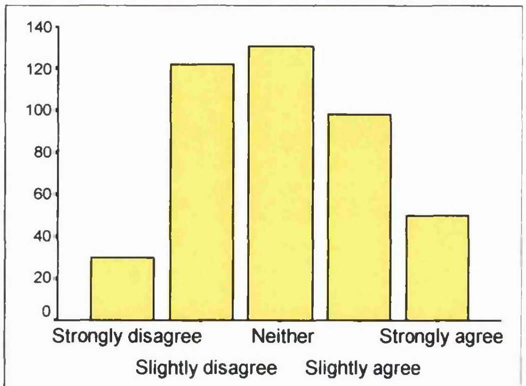
COTS IT only in non-combat systems

[23] One elderly interviewee, in a relatively junior (SSO) post was 'died-in-the-wool' anti-COTS and unwilling to change his views.

Variable	Calculation	No	Factor	Score
COTS IT only has a place in non-combat systems	Mean value Standard deviation Variance	1.8 1.05 1.09	*Strongly agree* *Slightly agree* *Neither agree nor disagree* *Slightly disagree* → *Strongly disagree*	5 4 3 2 1

8.3.3 Compared with military IT, COTS IT will perform equally well in war

There was no agreement (mean value of 3.04 equivalent to 'neither') on the likelihood that 'Compared with military IT, COTS IT will perform equally well in war' being true. The general opinion was ambivalent with a high variance of 1.25. However, slightly more people strongly agreed than strongly disagreed but, on the other hand, rather more slightly disagreed than slightly agreed.

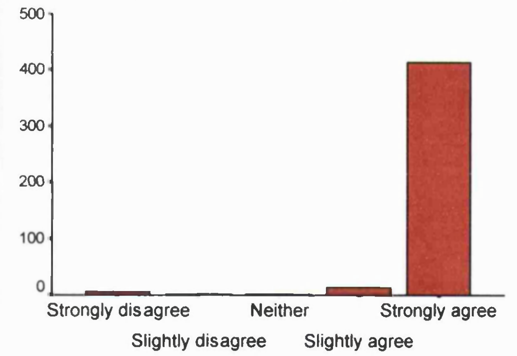


COTS IT will perform equally well in war

Variable	Calculation	No	Factor	Score
COTS IT will perform equally well in war	Mean value Standard deviation Variance	3.04 1.12 1.25	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	5 4 3 2 1

8.3.4 COTS IT in business systems

There is almost total unanimity about the use of COTS IT by MoD for business systems. Only five people strongly disagreed, (again one in DPA, but also 4 in DERA). One (in DERA) slightly disagreed and one neither agreed nor disagreed out of a total sample of 446. Of the remainder, 13 slightly and 413 strongly agreed.



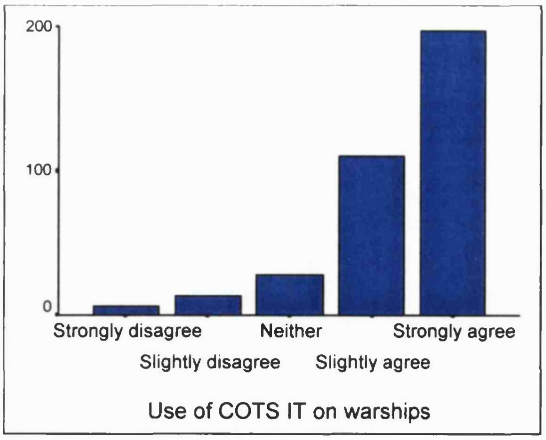
Use of COTS IT in business systems

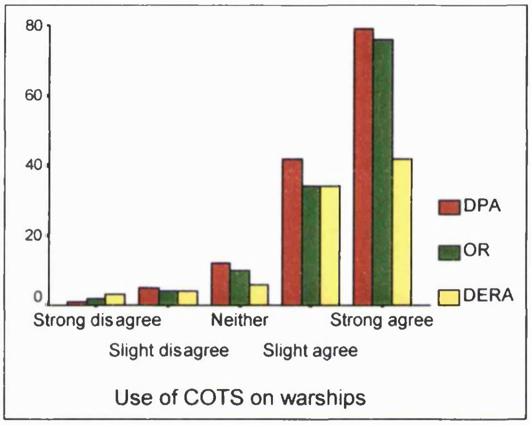
These figures were more positive than those who felt COTS IT has a place in MoD purchases and provide a useful cross-check, on people's attitudes and on their ability to fill in the questionnaire correctly. The view that business systems are needed on the battlefield as much as in headquarters in the UK should be noted.

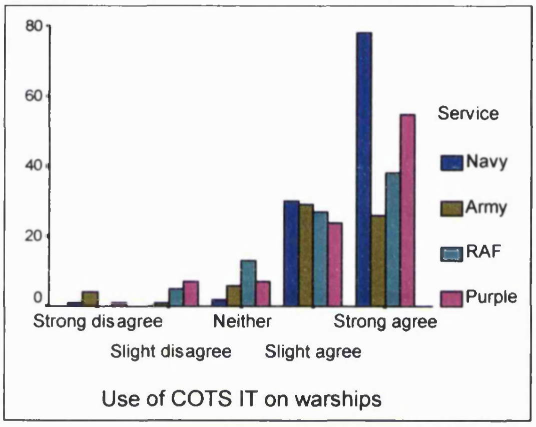
Variable	Calculation	No	Factor	Score
COTS IT can be used in business systems	Mean value Standard deviation Variance	4.91 0.49 0.24	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	5 4 3 2 1

8.3.5 COTS IT in warships

The results show that there is strong support for the deployment of COTS IT on board both warships and submarines, with nearly 87% strongly or slightly agreeing and almost twice as many in the former category. In DPA and MoD OR, about twice as many strongly agree as slightly agree, whereas in DERA, less than 10% more strongly agree. When examined on an individual service basis, the Royal Navy staff are the strongest supporters of putting COTS IT on board ship, while the army has more people slightly than strongly agreeing. There seems to be no particular reason for this, apart from the army's ambivalence about using COTS IT in military equipment.



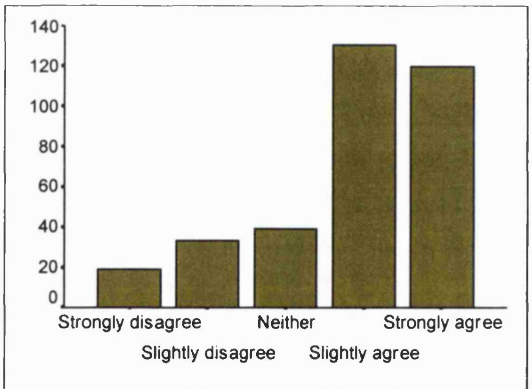




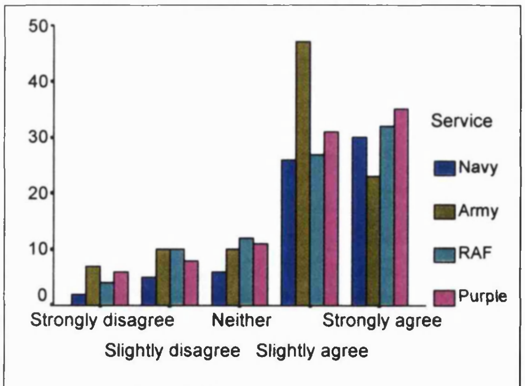
Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in warships	Mean value Standard deviation Variance	4.35 0.9 0.24	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.3.6 COTS IT in battle tanks and recce vehicles

It is clear that the majority slightly or strongly agree that COTS IT is suitable for use in armoured fighting vehicles. A similar pattern is apparent across DPA, MoD OR and DERA. However, the bias is towards strong agreement in all arms except for the army, where a large number only slightly agree. This may arise from the army's view of the harshness of their environment, which many have personally experienced.



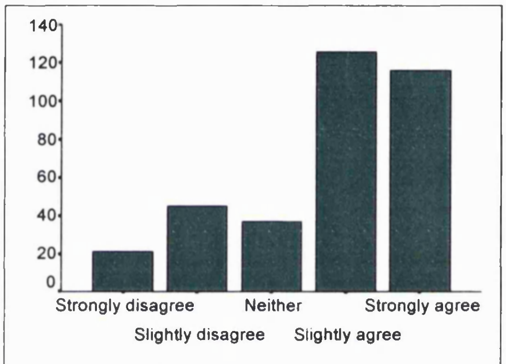
Use of COTS IT in tanks



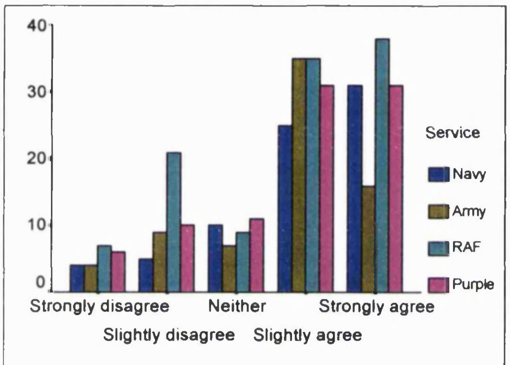
Use of COTS IT in tanks

Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in battle tanks and recce vehicles	Mean value	3.88	*Strongly agree*	*5*
	Standard deviation	1.16	*Slightly agree* →	*4*
	Variance	1.34	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.7 COTS IT in aircraft



Use of COTS IT in aircraft



COTS IT in aircraft

There is a majority in favour of deploying COTS IT on aircraft, though a significant minority disagrees. From an individual service point of view, bearing in mind there is a Fleet Air Arm, an Army Air Corps and the RAF, the army is again out of kilter with the other branches of the armed forces and less in favour of the use of COTS IT in aircraft.

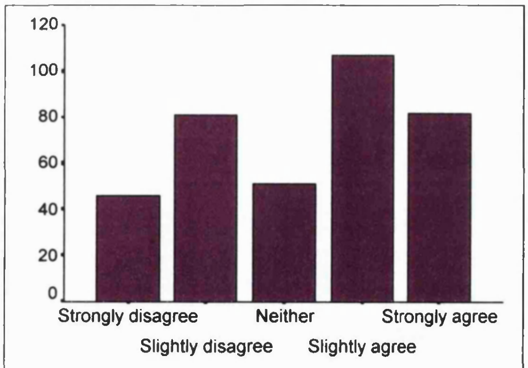
Could this be because the Army Air Corps only uses helicopters or is it because of the tough environment found on the battlefield? It is also noteworthy that those in MoD OR are rather more in favour of COTS IT in aircraft than those in DPA or DERA.

Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in aircraft and helicopters	Mean value	3.79	*Strongly agree*	*5*
	Standard deviation	1.21	*Slightly agree* →	*4*
	Variance	1.47	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.8 COTS IT in weapons

The view of the use of COTS IT in weapons is fairly well polarised. The mean value is 3.27, but the variance is 1.84. This same pattern shows for each branch of the armed forces and for those serving in purple positions. There is also the same distribution between DPA, MoD OR and DERA personnel. A check has shown that there is also the same distribution by age and by grade. It is thus clear that the difference in views is universal throughout MoD.

Thus it seems unlikely that people might be considering different weapons types when answering this question. Yet if they were, then for example, IT in a guided shell must survive a far harsher launch environment than in a torpedo.

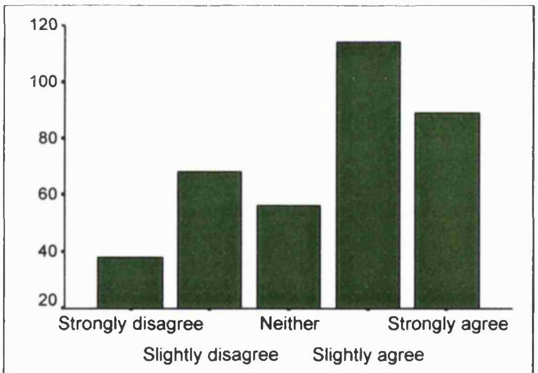


COTS IT in weapons

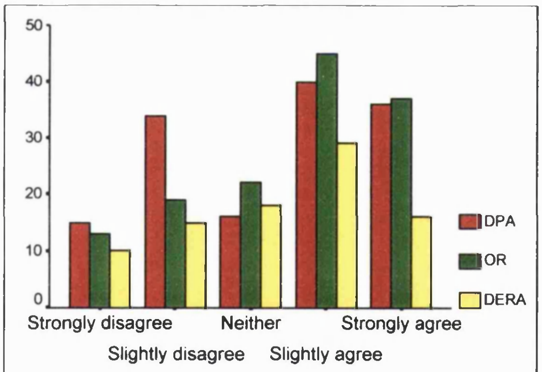
Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in weapons	Mean value	3.27	*Strongly agree*	*5*
	Standard deviation	1.26	*Slightly agree*	*4*
	Variance	1.84	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.9 COTS IT in weapon launchers

There is rather less polarisation of views on weapons launchers and, furthermore and the views hardly vary from service to service. However, it is clear that the slight polarisation emanates almost entirely from the views of DPA, while in OR and DERA there is a fairly strong bias towards agreeing with the statement. No particular reason has been established for this anomaly.



COTS IT in weapon launchers



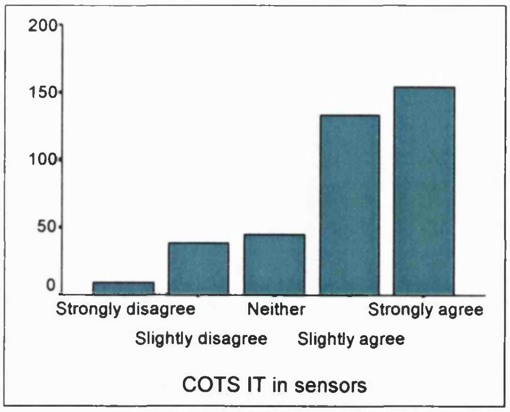
COTS IT in weapon launchers

Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in weapon launchers	Mean value	3.41	*Strongly agree*	*5*
	Standard deviation	1.32	*Slightly agree* →	*4*
	Variance	1.73	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.10 COTS IT in sensors

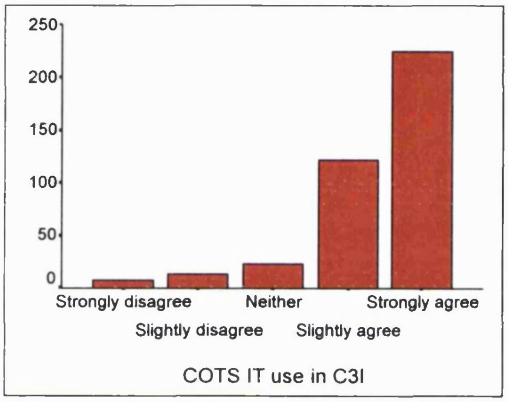
There is pretty clear support for the use of COTS IT in sensors, and this support does not vary either by service or by department. The fact that sensors have to survive many different environments and the actual environment experienced varies with the different branches of the armed forces does not seem to have influenced the response.

Exposure also depends on whether the sensor is static, hand carried on the battlefield, or fitted to one of the very wide range of platforms, making this result slightly puzzling. What is clear is that IT is sensors is embedded and this can be expected to provide a significant degree of protection for any COTS IT hardware.

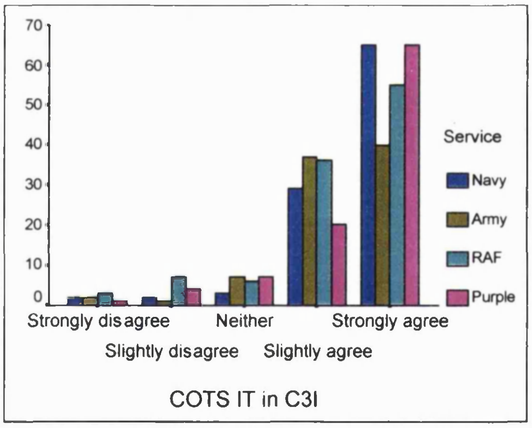


Variable	Calculation	No	Factor	Score
COTS IT can be used in sensors	Mean value	4.01	*Strongly agree*	*5*
	Standard deviation	1.07	*Slightly agree* →	*4*
	Variance	1.15	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.11 COTS IT in C^3I, intelligence or air defence systems



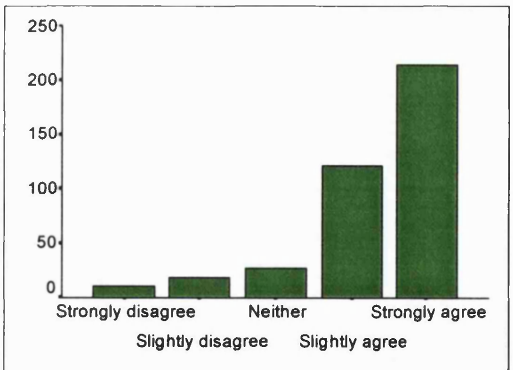
The use of COTS IT in C^3I, intelligence and air defence systems has broad support, particularly by Navy, RAF and purple staff, with a mean of 4.38 and a variance of only 0.81. The positive army responses, which agree with the statement, are almost equally divided between those who strongly and those who slightly agree. This could well be because, when the army uses these systems, they may be deployed in vehicles or even tents.



Variable	Calculation	No	Factor	Score
COTS IT can be used in C^3I, intelligence or air defence systems	Mean value	4.38	*Strongly agree*	*5*
	Standard deviation	0.9	*Slightly agree* →	*4*
	Variance	0.81	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.3.12 COTS IT in communications or electronic warfare systems

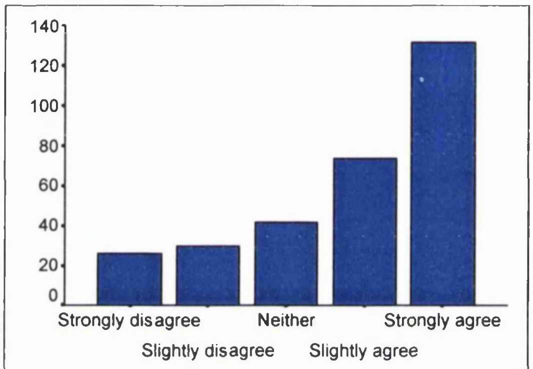
The positive support that exists for the use of COTS IT in communications and electronic warfare equipment does not vary between services or departments. The mean value is 4.38 and the variance just less than one. Again, as with sensors, these systems may or may not be fitted to land, sea, air or space platforms, may be statically installed or even man carried. However, these many different categories do not appear to significantly affect the views of those who responded to this particular statement. Perhaps there is a bias caused by the high profile Bowman system and its entry into service.



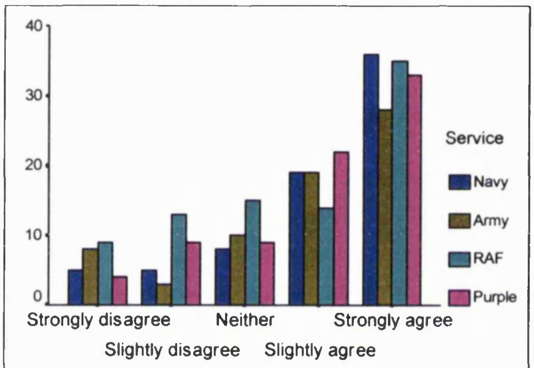
COTS IT in comms & EW

Variable	Calculation	No	Factor	Score
COTS IT can be used in communications or electronic warfare systems	Mean value Standard deviation Variance	4.30 0.98 0.97	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.3.13 COTS IT in satellites

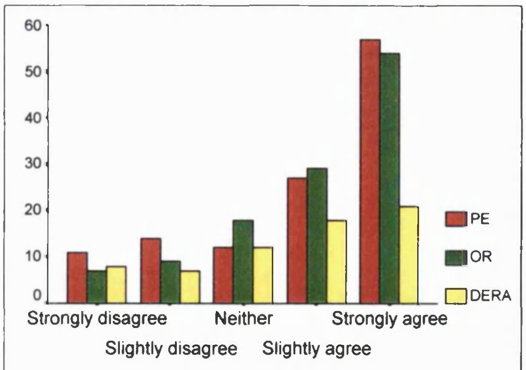


COTS IT in satellites



COTS IT in satellites

There is a reasonable support for the use of COTS IT in satellite systems with a mean value of 3.84. However, while the largest percentage of people strongly agreeing with the question lie in the RAF, that service also has the most people who slightly or strongly disagree. For no clear reason, DERA support is not less positive than DPA or OR. With hindsight, the question was badly phrased and should have divided satellites from earth-based terminals.

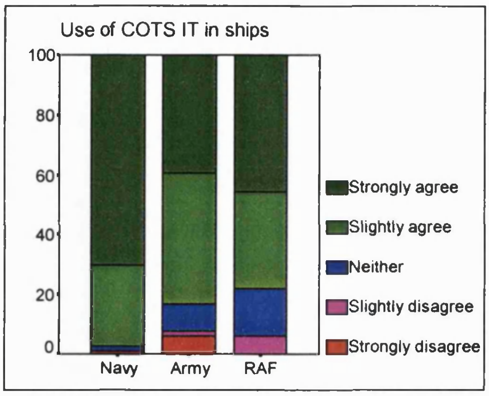


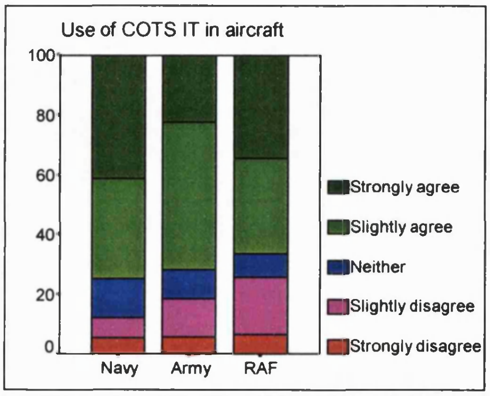
COTS IT in satellites

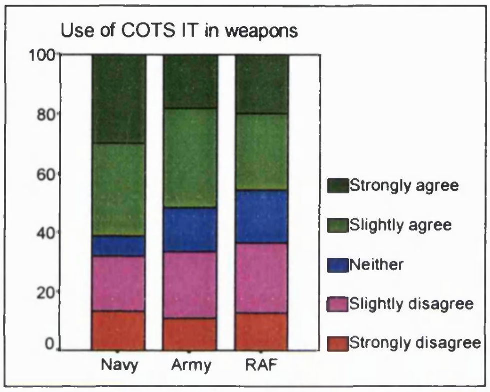
Variable	Calculation	No	Factor	Score
COTS IT can be used in satellites	Mean value Standard deviation Variance	3.84 1.31 1.72	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

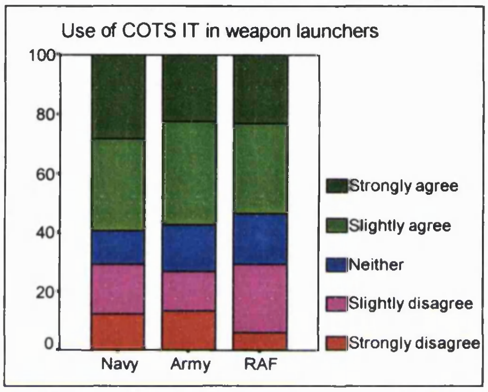
8.4 The three different services' view of COTS IT in equipment

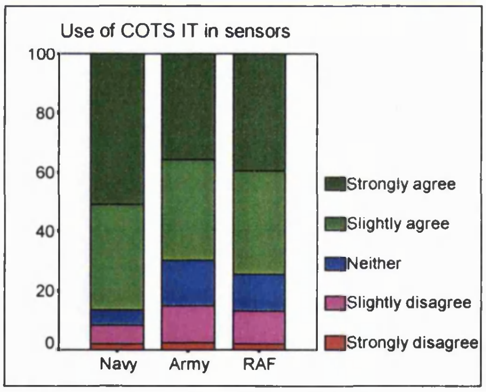
The answers to some of the thirteen questions above show variances between the answers from the different branches of the armed forces. The following eight graphs demonstrate that the army is generally least likely to strongly agree with the use of COTS IT in any military equipment or systems, but in five cases the RAF is most likely to disagree with its use, and in three cases it is

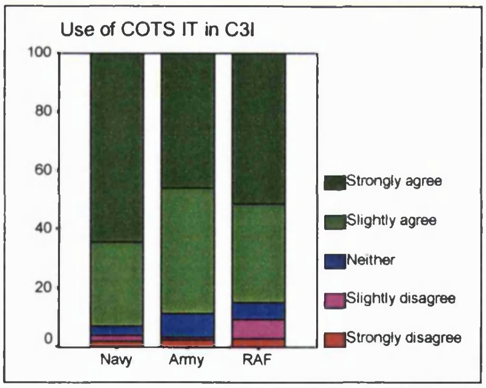


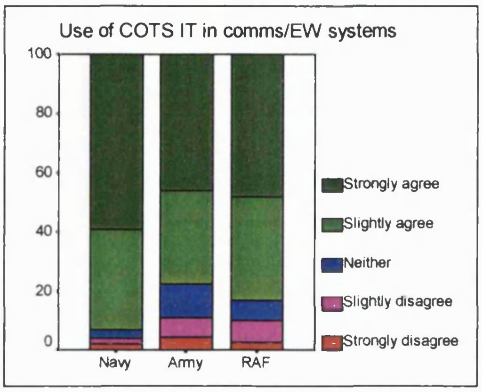


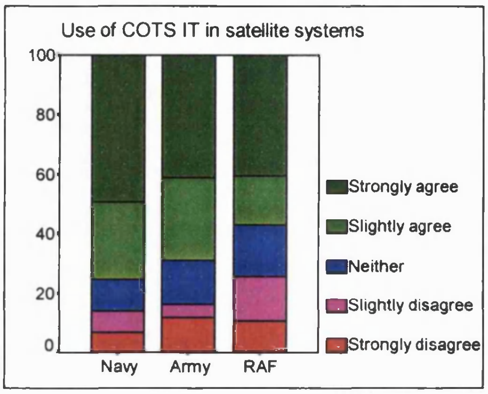












the army. The navy, however, are the most positive about agreeing with the use of COTS IT in every category.

8.5 Answers about purchase of COTS IT by MoD from people in DPA, OR & DERA

The answers to the following 14 questions were analysed to show attitudes towards the purchase of COTS IT by UK MoD. This section in the questionnaire started with the following statement: *Now consider the purchase of COTS IT by UK MoD.*

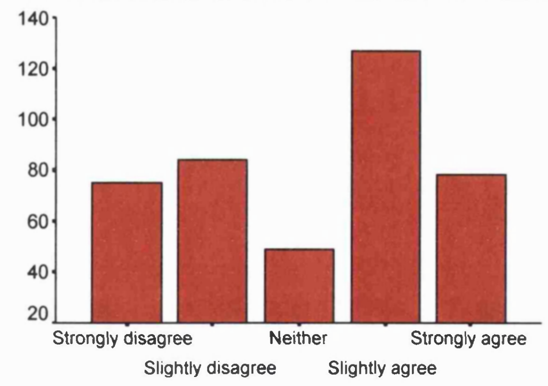
1. Commercial IT companies, as suppliers to MoD, are different from other potential defence contractors.
2. Commercial IT companies will bid for military work and accept MoD contract terms/conditions.
3. There will be a lack of competition in the COTS IT field.
4. COTS IT will be available long enough to be purchased in normal MoD procurement time scales.
5. The price of COTS IT will be lower than that of specially developed military IT.
6. Mil/Def spec requirements will cause problems with the purchase and use of COTS IT.

Think about how the use of COTS IT will impact on UK MoD.

7. The use of IT will improve efficiency or performance.
8. Viruses are likely to be more of a problem with COTS than military IT.
9. Security likely to be more of an issue with COTS than military IT.
10. The need for long-term support for COTS IT (spares, test equipment, maintenance, documentation, training) is likely to cause difficulties.
11. Bugs are likely to be more of a problem with COTS than military IT.
12. Reliability is likely to be more of a problem with COTS IT than with IT specially developed for military use.
13. Obsolescence is likely to be a more of a problem with COTS IT than with IT specially developed for military use.
14. An advantage of COTS IT is that it is familiar and thus easy to use.

8.5.1 Commercial IT companies differ from defence contractor

The views about whether commercial IT companies differ from defence contractors are polarised, with a slight majority of those who were polarised – 56% agreeing strongly or slightly and 44% disagreeing strongly or slightly. This is not clear from the mean value of 3.12 (close to 'neither') but becomes clear when looking at the



Commercial IT companies differ from defence contractors high variance of 1.98. This polarisation reflects across the responses from the three branches of the armed forces and those in purple roles, regardless of age and rank/grade. However, MoD DPA was much more polarised than OR, and DERA tended to agree that the two are different. Civilian who responded, though divided, agreed with the statement more than military staff.

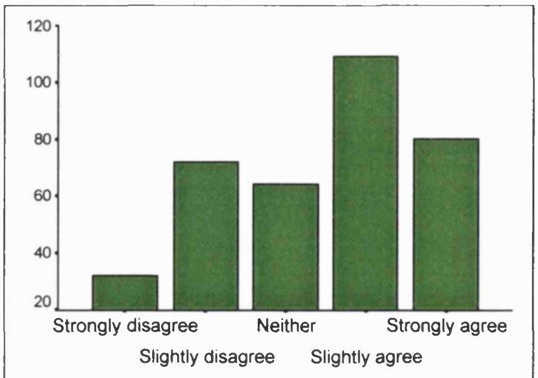
Variable	Calculation	No	*Factor*	*Score*
Commercial IT companies differ from defence contractors	Mean value	3.12	*Strongly agree*	*5*
	Standard deviation	1.41	*Slightly agree*	*4*
	Variance	1.98	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.5.2 Commercial companies will bid for & accept MoD terms and conditions

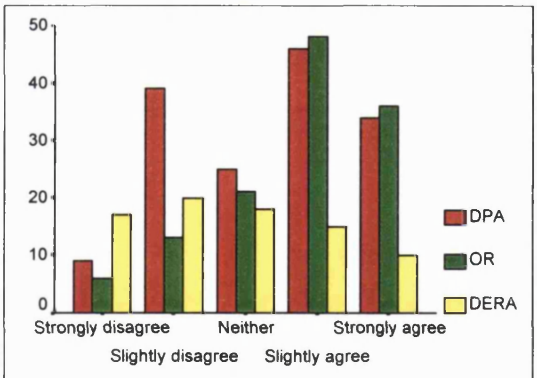
When it comes to whether 'commercial IT companies will bid for military work and accept MoD terms and conditions', there is, unusually, a considerable spread of views shown in the six graphs below.

As a group, people in MoD show a bias towards agreeing with the statement. However, the views by different groups vary very considerably. Examining the three departments of MoD, within DPA views are polarised, within OR there is a tendency to agree, while in DERA the tendency is to disagree. When examined by service, the Royal Navy, RAF and purple responses were all polarised, while the army tended to agree. When considering views by rank or grade, the senior staffs were polarised, while at the two junior levels, the view tended towards agreement. Civilians and those who specify equipment were polarised while uniformed personnel and those who don't specify equipment tended to agree with the statement

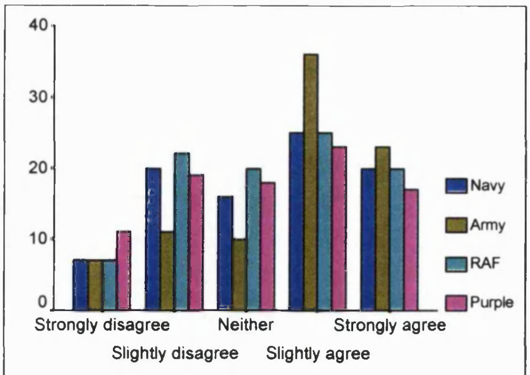
Whatever MoD's view, it is difficult to persuade industry to bid to MoD because there are too many hoops to jump through. This is shown by industry's view to the same question shown in Paragraph 8.9.1.



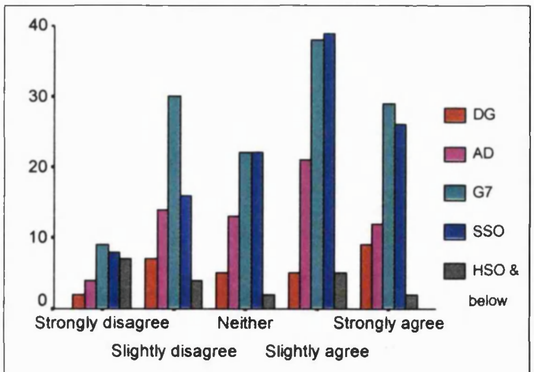
Bid & accept MoD terms & conditions



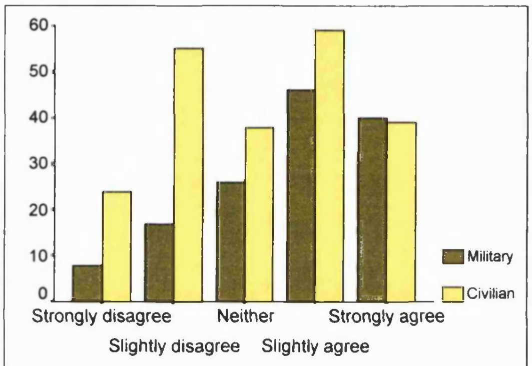
Bid & accept MoD terms & conditions



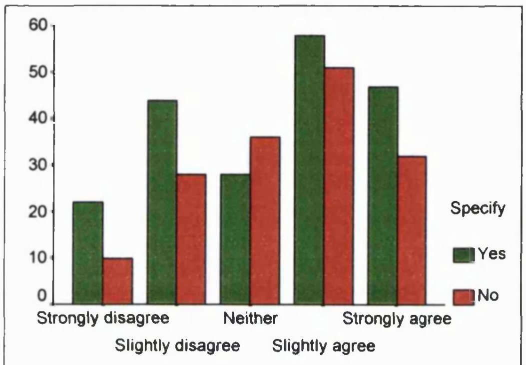
Bid & accept MoD terms & conditions



Bid & accept MoD terms & conditions



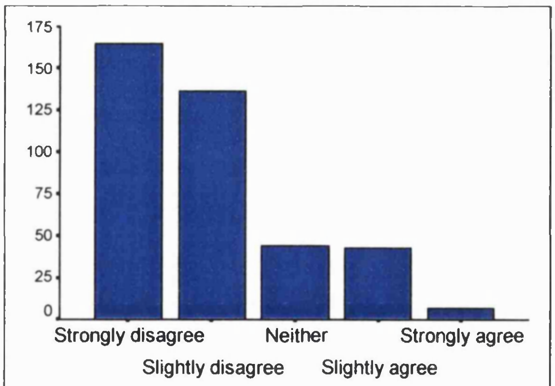
Bid & accept MoD terms & conditions



Bid & accept MoD terms & conditions

Variable	**Calculation**	**No**	***Factor***	***Score***
Commercial companies will bid for & accept MoD terms & conditions	Mean value Standard deviation Variance	3.37 1.28 1.63	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.3 There will be a lack of competition in COTS IT field



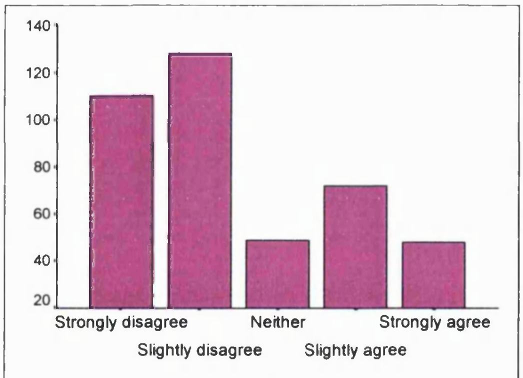
There will be lack of competition in COTS IT field

Over three quarters, 76% of those questioned either strongly (42%) or slightly disagreed that there would be a lack of competition in the COTS IT field. The mean value of 1.96 indicates a mean response of 'slightly disagree', but the variance of 1.13 indicates quite a spread in the responses. These levels were reflected when the responses were examined by grade/rank, age, service affiliation, department, computer use and whether involved in specifying/procuring equipment or not. It is thus clear that there is a near consensus that lack of competition is unlikely to be a problem for MoD in its purchase of COTS IT.

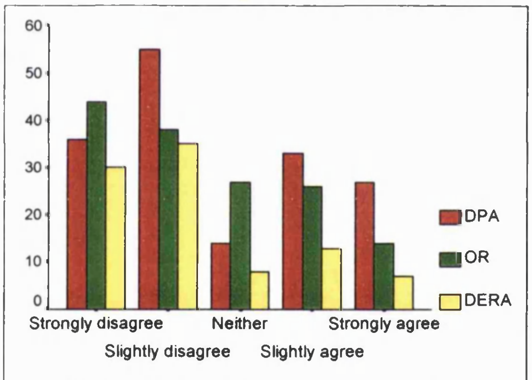
Variable	Calculation	No	Factor	Score
There will be a lack of competition in the COTS IT field	Mean value Standard deviation Variance	1.96 1.06 1.13	*Strongly agree* *Slightly agree* *Neither agree nor disagree* *Slightly disagree* ⟶ *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.4 Availability of COTS IT

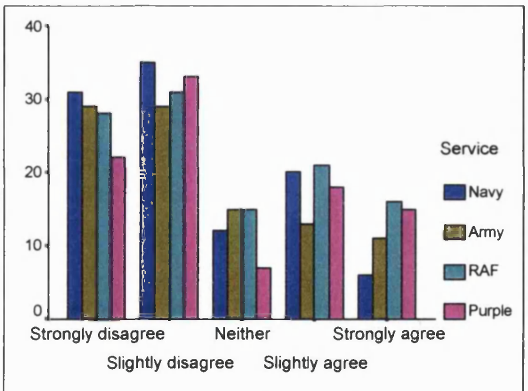
To the statement 'COTS IT will be available long enough for normal MoD procurement time scales' a majority tended to disagree either strongly (27%) or slightly (31.5%), but approximately 30% agreed either slightly (17.7%) or strongly (11.6%). This pattern was irrespective of age. However, while DPA and DERA followed similar trends, the MoD OR responses showed a smooth pattern with 30% strongly disagreeing reducing to just under 10% strongly agreeing. A similar pattern emerged when the results were viewed service affiliation, with only the army breaking the pattern and showing 30% both strongly and slightly disagreeing, reducing to 13% and 11% for those who slightly and strongly agreed. Significantly more of those in Grade 7 (also Commander, Lieutenant Colonel or Wing Commander) strongly disagreed with the statement than in any other grade/rank.. Those who specify equipment are less in disagreement with the statement than those who do not, and a similar pattern is true for the responses from civilian and uniformed personnel.



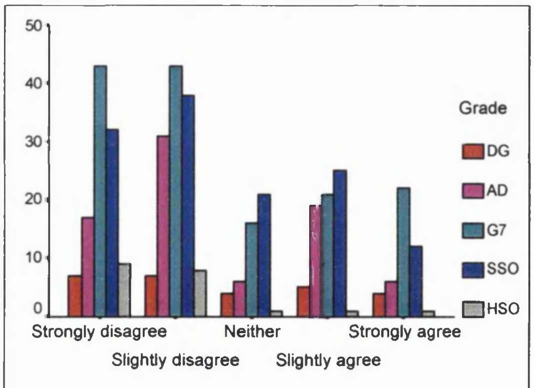
COTS IT available for MoD procurement time scales



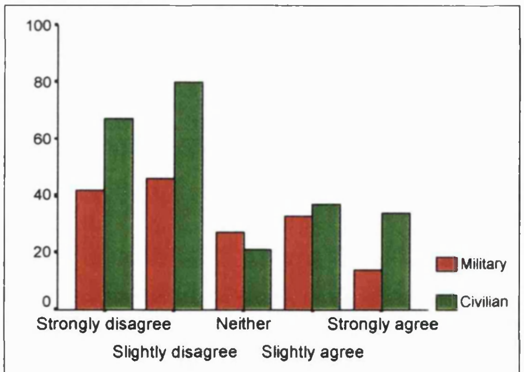
COTS IT available for MoD procurement time scales



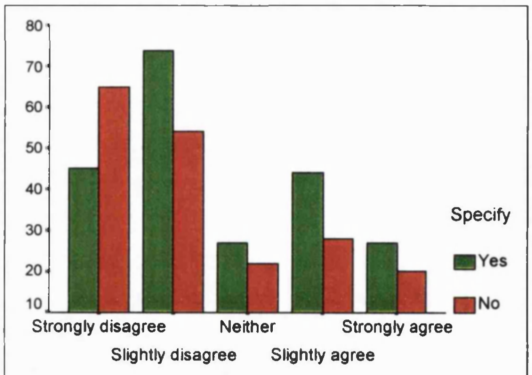
COTS IT available in MoD procurement time scales



COTS IT available for MoD procurement time scales



COTS IT available in MoD procurement time scales

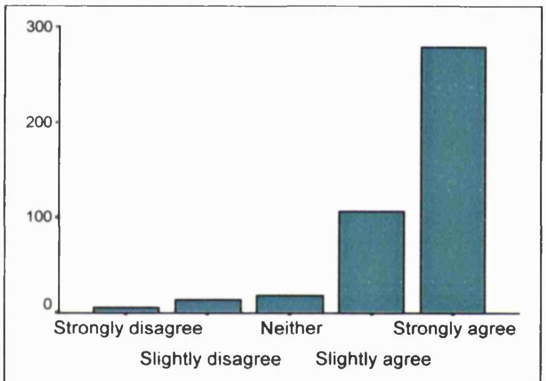


COTS IT available for MoD timescales

Variable	Calculation	No	Factor	Score
COTS IT will be available long enough for normal MoD procurement time scales	Mean value Standard deviation Variance	2.56 1.36 1.85	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.5 The price of COTS IT will be lower than that of specially developed military IT

A strong majority agreed that the price of COTS IT would be lower than that of specially developed military IT. Only 4.7% either slightly or strongly disagreed. This spread applied regardless of sub-group. With a standard deviation of 4.5 and a variance of only 0.71, there is a strongly held feeling that the price of COTS IT will be lower than that of specially developed military IT. Once again hindsight suggests that two questions would have been better than one, the first dealing with the initial purchase price and the second with the price of through-life support. As it turned out, this topic was thoroughly covered during the subsequent interviews.



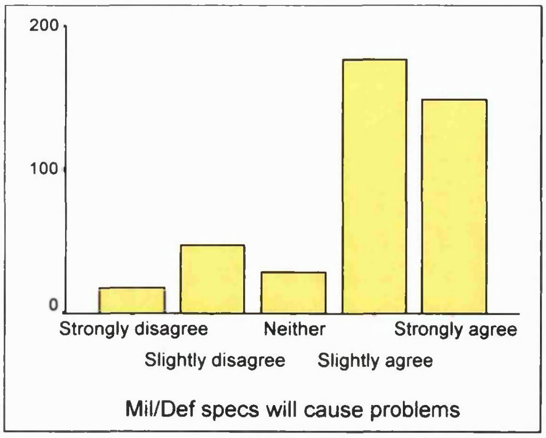
Price of COTS IT lower than custom military IT

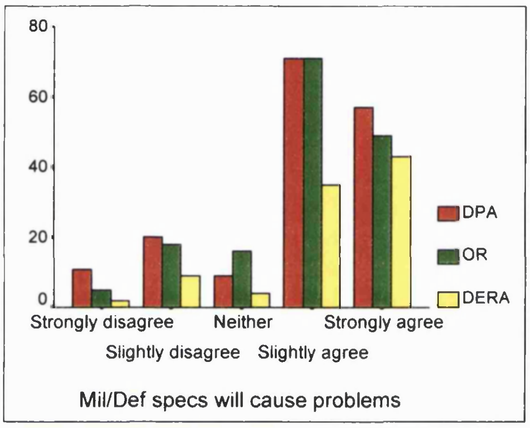
Variable	Calculation	No	Factor	Score
The price of COTS IT will be lower than that of specially developed military IT	Mean value Standard deviation Variance	4.5 0.84 0.71	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

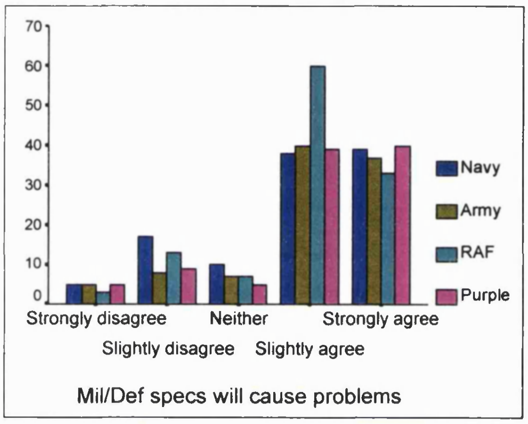
8.5.6 Mil/Def specifications will cause problems with purchase & use of COTS IT

More people slightly agree than strongly agree that Military or Defence specifications will cause problems, with some 15% slightly or strongly disagreeing with the proposition. The mean value of 3.93 indicates an overall slight agreement but the variance of 1.26 is indicative of the smaller number that disagrees. This pattern remains the same when examined by age and grade.

However, there is a much greater level of agreement amongst DERA staff than those in DPA and OR. When looked at by branch of the armed forces, it is clear that those associated with the RAF are much less strongly in agreement than those in either of the other two services or those in purple roles.



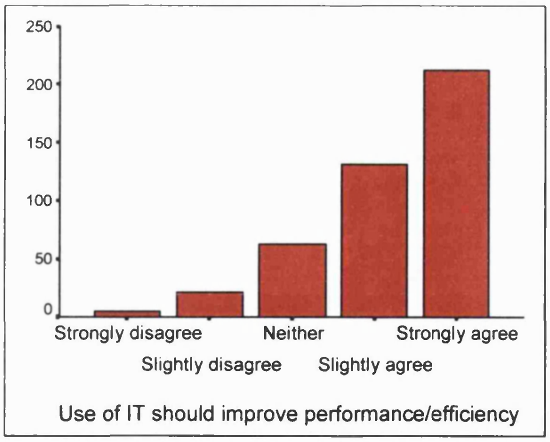




Variable	Calculation	No	*Factor*	*Score*
Mil/Def specs will cause problems with purchase & use of COTS IT	Mean value	3.93	*Strongly agree*	*5*
	Standard deviation	1.12	*Slightly agree* →	*4*
	Variance	1.26	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

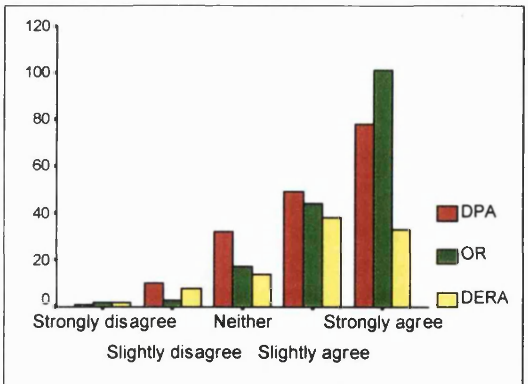
8.5.7 *The use of IT should improve MoD's performance/efficiency*

The bias towards agreeing that IT (not just COTS IT) should improve performance/ efficiency is clear, with a mean value of 4.21, lying between slightly and strongly agreeing with the statement. The variance is only 0.89. Inevitably, the response to this statement introduces two further questions. First, how does the view impact on COTS IT, and second, how is it possible to measure performance and efficiency improvements in an organisation like MoD? These two questions are further examined in Section 12.

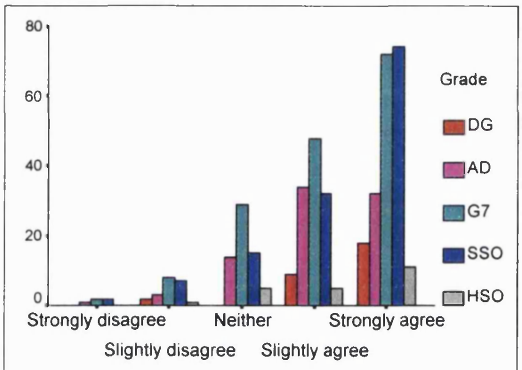


This, however, is not true of staff in DERA, who are significantly less in agreement, nor among those at the assistant director/captain RN/colonel/group captain level.

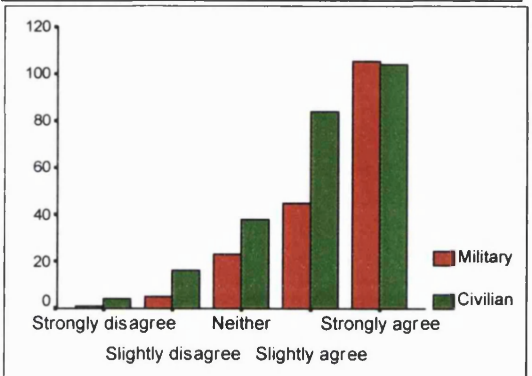
It is also interesting to note that while roughly the same numbers of military and civilian personnel strongly agree, only half as many military people agree as civilians. This is probably because military personnel get experience of operating operational military equipment containing IT whereas civilian staff does not.



Use of IT should improve performance/efficiency



The use of IT will improve performance/efficiency

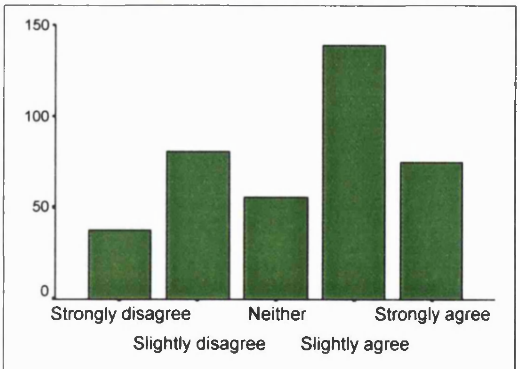


Use of IT should improve performance/efficiency

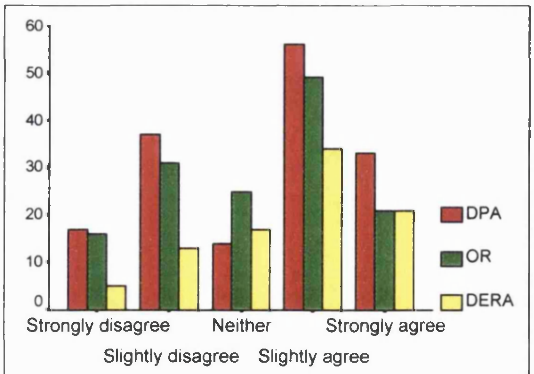
Variable	Calculation	No	*Factor*	*Score*
The use of IT should improve MoD's performance /efficiency	Mean value	4.21	*Strongly agree*	*5*
	Standard deviation	0.94	*Slightly agree* →	*4*
	Variance	0.89	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.5.8 Viruses are likely to be more of a problem with COTS than military IT

There is some polarisation of views on whether viruses are more likely to be a problem with COTS IT than bespoke military IT, with a near median mean value at 3.34 but a wide (1.62) variance of views. This polarisation is more marked in DPA and MoD OR, but in the DERA case, the average view is to slightly agree. However, all the other sub-groups show a virtually identical polarisation.



Viruses more likely to be problem with COTS IT

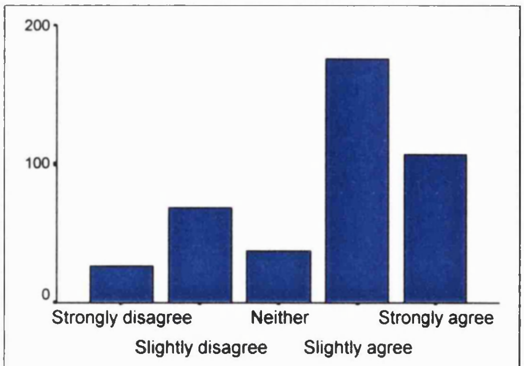


Viruses more likely to be problem with COTS IT

Variable	Calculation	No	Factor	Score
Viruses are more likely to be a problem with COTS IT than military IT	Mean value Standard deviation Variance	3.34 1.27 1.62	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.9 Security is likely to be more of an issue with COTS than military IT

There is slight polarisation of views, though the dominant one is that 68.3% slightly or strongly agree that security is likely to be more of an issue with COTS IT than custom military IT. A near identical pattern occurs when the response is examined by each possible sub-group. The mean value of 3.65 shows an overall trend towards slightly agreeing with the question, but the variation of 1.45 indicates the lack of consensus.



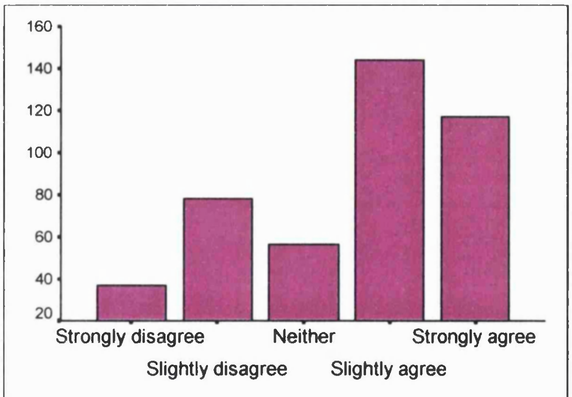
Security more of an issue with COTS than military IT

Security is an area identified later in this thesis as one where significant problems need to be resolved if COTS IT is to be used in a really cost-effective manner.

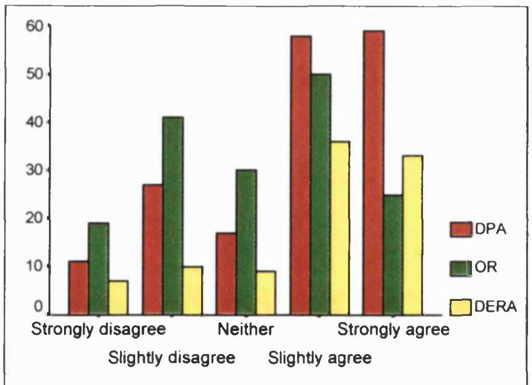
Variable	Calculation	No	Factor	Score
Security is likely to be more of an issue with COTS than military IT	Mean value Standard deviation Variance	3.65 1.21 1.45	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.10 The need for long-term support for COTS IT is likely to cause difficulties

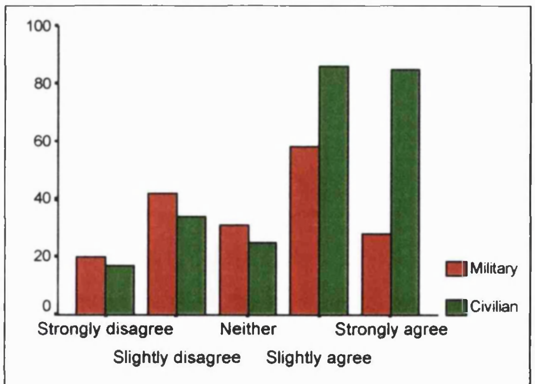
There is again a slight polarisation of views about whether the need for long-term support of COTS IT is likely to cause problems. Civil servants agree much more strongly with the statement than their uniformed counterparts, as do those in DPA and, to a point, those in DERA, compared to those in MoD OR. In fact, OR is much more strongly polarised than any other group. The mean value of 3.52 shows a tendency to slightly agree with the proposition, but the variance of 1.67 shows the lack of consensus. Support is another area identified later that requires a change of approach if COTS IT is effectively to be employed in military equipment.



Long-term support for COTS IT may cause difficulties



Long-term support for COTS IT may cause difficulties

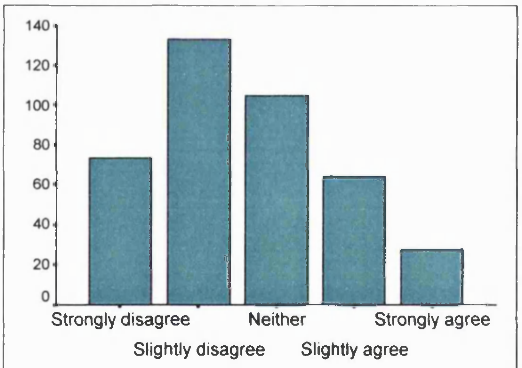


Long-term support for COTS IT may cause difficulties

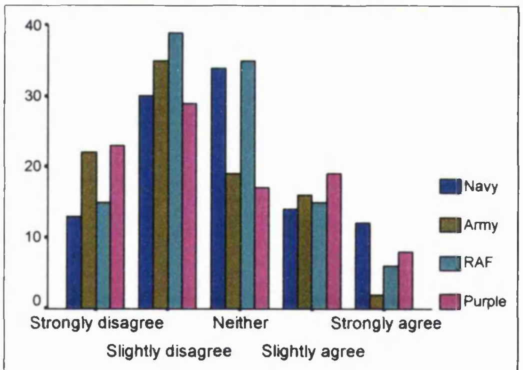
Variable	Calculation	No	*Factor*	*Score*
The need for long term support for COTS IT is likely to cause difficulties	Mean value	3.52	*Strongly agree*	*5*
	Standard deviation	1.29	*Slightly agree* →	*4*
	Variance	1.67	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.5.11 Bugs are likely to be more of a problem with COTS than military IT

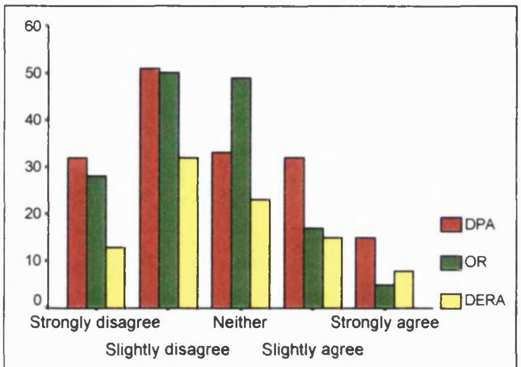
While there is no marked agreement on the likelihood of bugs being causing more problems with COTS than military IT, general opinion is biased towards slight disagreement with a mean value of 2.61. When viewed by grade/rank, junior staff disagree less strongly than senior ones. Similarly, the navy disagree less strongly than the other services or those in purple roles as do those in OR compared with DPA and DERA. Why junior staff, those who are involved with naval programmes and those in OR are more concerned about bugs in COTS IT is unclear.



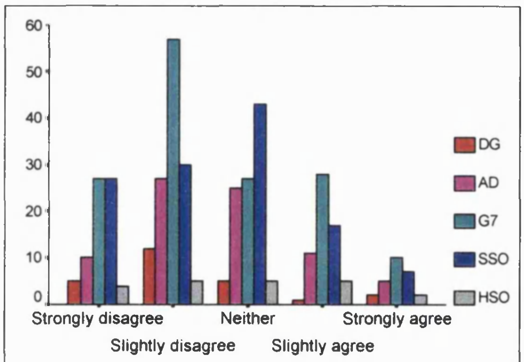
Bugs more problem with COTS than military IT



Bugs more problem with COTS than military IT



Bugs more problem with COTS than military IT

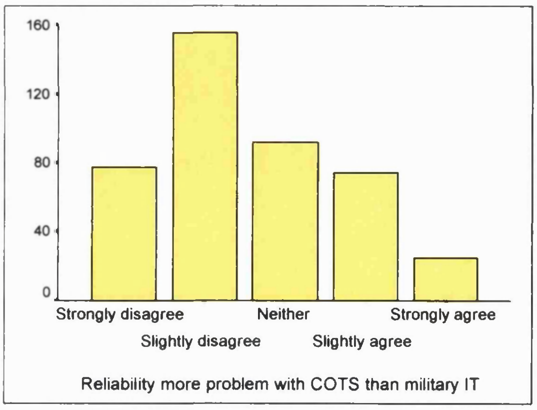


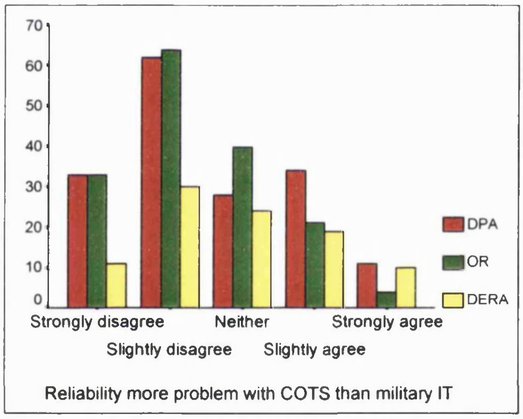
Bugs more problem with COTS than military IT

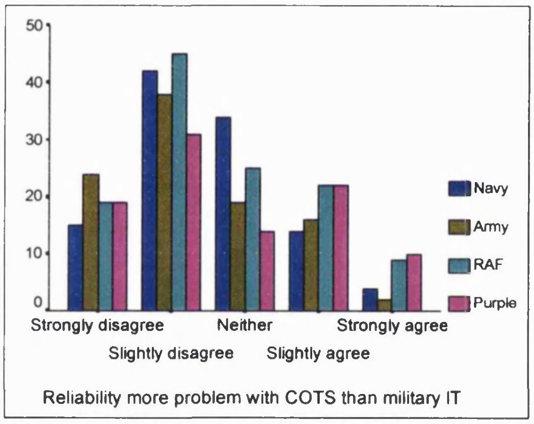
Variable	Calculation	No	*Factor*	*Score*
Bugs are likely to be more of a problem with COTS than military IT	Mean value Standard deviation Variance	2.61 1.16 1.34	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.12 Reliability is likely to be more of a problem with COTS IT than with custom military IT

There is overall slight disagreement (mean value 2.56) with the view that reliability is likely to be more of a problem with COTS IT than with bespoke military IT. The standard deviation of 1.25 indicates quite a wide spread of views. When looked at by service, those in purple roles are, however, polarised in their views, as are those in DPA. No clear answer has been found to why only purple staff and DPA show polarisation, with a rise in the number agreeing.



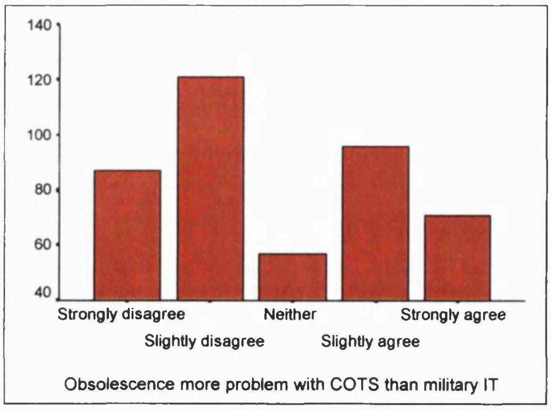


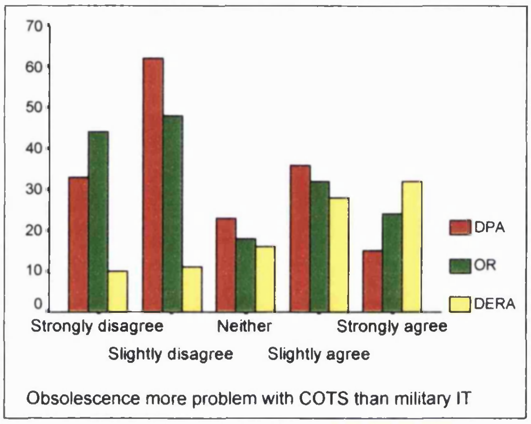


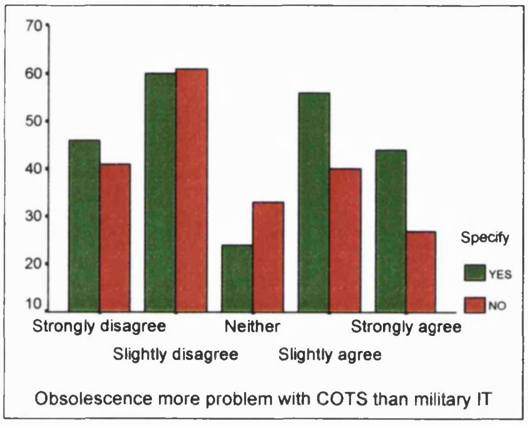
Variable	Calculation	No	*Factor*	*Score*
Reliability is likely to be more of a problem with COTS IT than with IT specially developed for military use	Mean value Standard deviation Variance	2.56 1.15 1.32	*Strongly agree* *Slightly agree* *Neither agree nor disagree* → *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.5.13 Obsolescence is likely to be more of a problem with COTS IT than with custom military IT

There is marked polarisation of views about whether obsolescence will be more of a problem with COTS than bespoke military IT. 48.1% strongly or slightly disagree while 38.6% strongly or slightly agree. The mean value is 2.87 (near to 'neither') but with a variance approaching 2. When examined by groups, those in DERA are not polarised and show a trend towards agreeing with the statement. Perhaps this is because they are often close to the purchase of equipment and therefore more aware of obsolescence problems. It is unclear is why those who specify equipment are more polarised than those who do not.



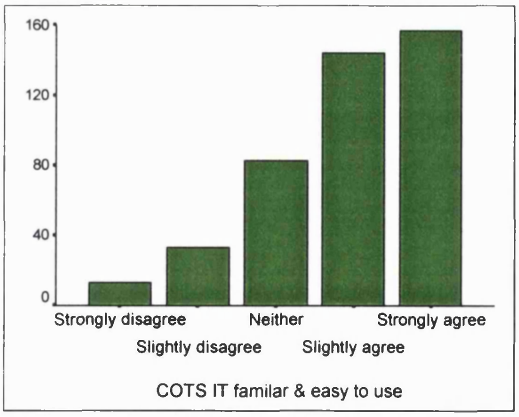


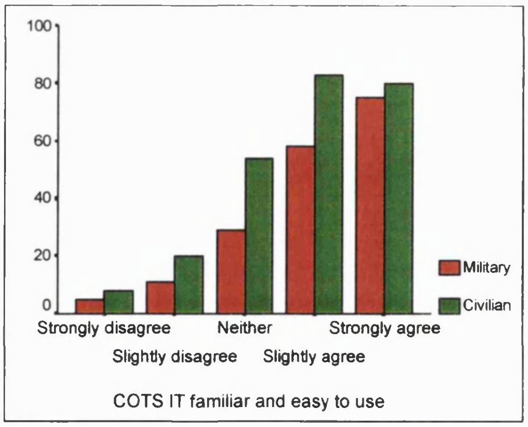


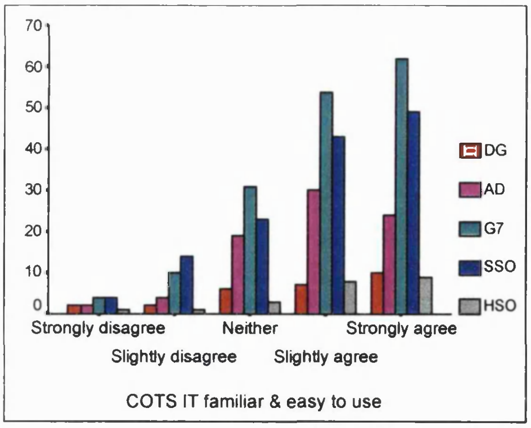
Variable	Calculation	No	*Factor*	*Score*
Obsolescence is likely to be more of a problem with COTS IT than IT specially developed for military use	Mean value	2.87	*Strongly agree*	*5*
	Standard deviation	1.40	*Slightly agree*	*4*
	Variance	1.95	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

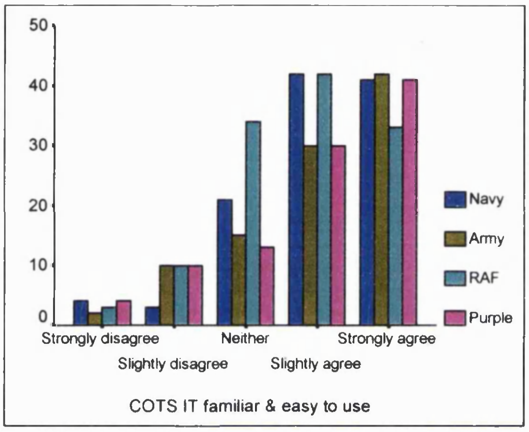
8.5.14 An advantage of COTS IT is that it is familiar and easy to use

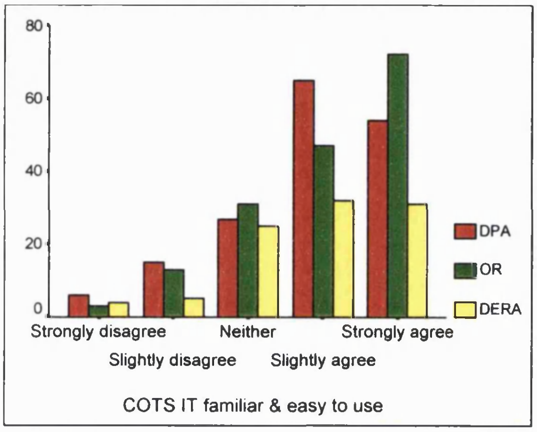
The response to the statement that an advantage of COTS IT is that it is familiar and easy to use showed that the majority either strongly or slightly agree, with only just over 10% either strongly or slightly disagreeing. The mean value of 3.97 approximates to slightly agreeing. The standard deviation of 1.07 indicates quite a broad spread of views. Civilian staffs less strongly agree than military staff and the same is true of the Assistant Director/Captain RN/Colonel/Group Captain grade/rank when compared with other rank/grades. When examined by service affiliation, the Navy and the RAF showed less strong agreement than those in the army or purple roles as do DPA compared to OR and DERA.











Variable	Calculation	No	*Factor*	*Score*
An advantage of COTS	Mean value	3.93	*Strongly agree*	*5*
IT is that it is familiar	Standard deviation	1.07	*Slightly agree*	→ *4*
and easy to use	Variance	1.13	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.6 Overall conclusions of the MoD/DERA questionnaires

Looking at all the data gathered from MoD, there is overwhelming support for widest use of COTS IT both in business systems and in operational military equipment. There is slightly less unanimity against the use of COTS IT only in business systems. There is some ambivalence about its potential performance of COTS IT in wartime, when compared with custom military IT and it is noticeable that those employed with army requirements were least happy with the likely performance of COTS IT in war.

8.6.1 COTS IT in operational equipment

There is wide support use of COTS IT.

87% agree with its use in ships, particularly by those with a naval affiliation.

73.4% agree with its use in tanks, with least support from those dealing with land-based equipment.

70.1% agree with its use in aircraft, though support is least strong from those with army affiliations.

There is a strong consensus of opinion that COTS IT is well suited to use in C^3I, communications systems, electronic warfare systems, intelligence systems and air defence systems. That consensus is slightly less marked for its use in sensors and satellites. Its use in weapons and their launchers provoked a markedly polarised view, which cannot readily be explained. For example, 34.6% disagree against 51.5% who agree with its use in weapons.

8.6.2 The purchase of COTS IT by UK MoD

The views about whether commercial IT companies differ from defence contractors are polarised, with 56% agreeing and 44% disagreeing. Views are also distinctly polarised about whether the IT industry will accept MoD terms and conditions and these views vary depending on seniority, service affiliation, department, whether the person is military or civilian and whether they are involved in equipment specification.

On availability of COTS IT in MoD time scales, there is polarisation with a majority, 58.5%, tending to disagree, but approximately 30% agreeing, while on the issue of obsolescence, the polarisation is even more marked with 48.1% who disagree while 38.6% agree.

76.2% agree that there is unlikely to be a lack of competition. A strong majority agreed that the price of COTS IT would be lower than that of specially developed military IT; only 4.7% disagree. 85% think that military specifications will cause problems. Furthermore, 79.4% agree that the use of COTS IT will improve MoD's performance and efficiency. There is only slight disagreement that COTS IT will be less reliable that custom military IT.

There is considered to be a slightly lower chance of bugs in COTS IT than custom military IT but a slightly larger chance (although some disagree) of viruses. Finally, although there is some polarisation of views, 68.3% agree that security is likely to be more of an issue with COTS IT than bespoke IT, and 60.4% agree that long-term support is likely to cause difficulties. There is slight agreement that COTS IT is familiar and easy to use.

8.7 Answers about the potential MoD use of COTS IT by people in industry

In addition to all the statements put to those in MoD (the statement to industry about satellites specifically excluded ground stations), four additional statements were also put of people in industry, in the second section of the questionnaire, which also carried a slightly different header.

Now consider the purchase of your company's systems/products by UK MoD or a prime contractor.

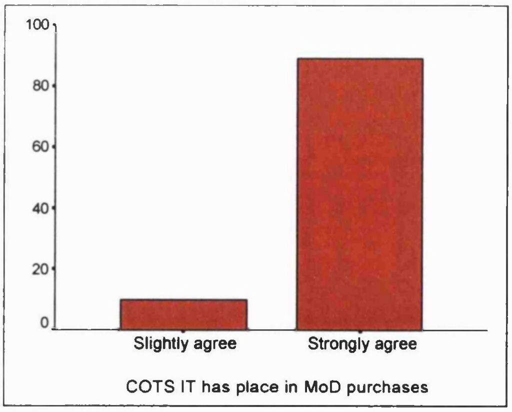
We specify/use COTS IT in our military systems/products.

We build COTS IT into what we sell to MoD.

For many applications, COTS IT hardware will not need any modification.

COTS software can easily be interfaced with military specific software.

8.7.1 COTS IT has a place in MoD purchases

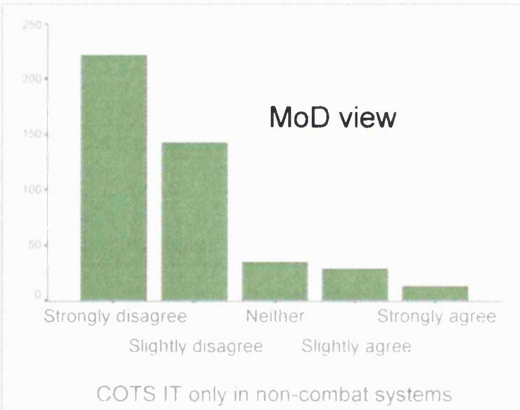


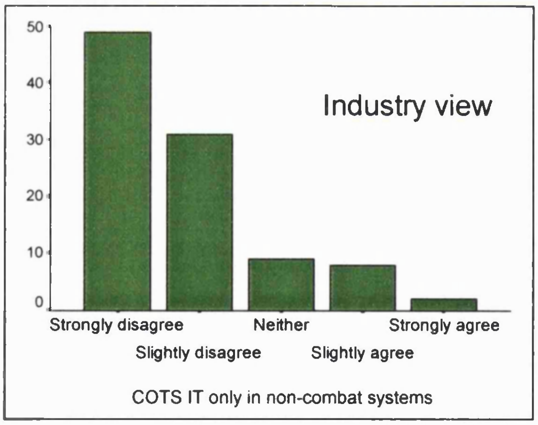
Ninety percent of responses from people in industry strongly agree that COTS IT has a place in MoD purchases, while ten percent slightly agree. These are almost identical to the percentage responses from people in MoD. The mean value is 4.9 with a standard deviation of only 0.3, indicating an even stronger level of support than within MoD itself. This increased support for COTS IT probably emanates from the understanding of the lack of alternatives and the view that at least the initial purchase price (essential to win a competitive tender) will be lower.

Variable	Calculation	No	*Factor*	*Score*
COTS IT has a place in MoD purchases	Mean value	4.9	*Strongly agree*	→ *5*
	Standard deviation	0.3	*Slightly agree*	*4*
	Variance	0.09	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.2 COTS IT only has a place in non-combat systems

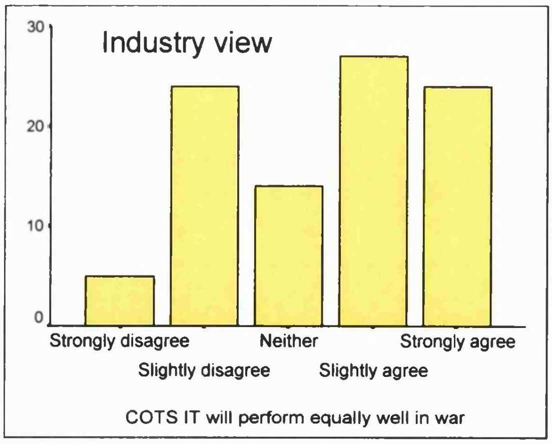
In industry, 82.3% of people strongly or slightly disagree that COTS IT only has a place in non-combat systems. It is interesting to note that the profile of industry responses is virtually identical with those from MoD, with a mean value of 1.82 and a standard deviation of 1.03, compared with the MoD figure of 1.8 and a standard deviation of 1.05.



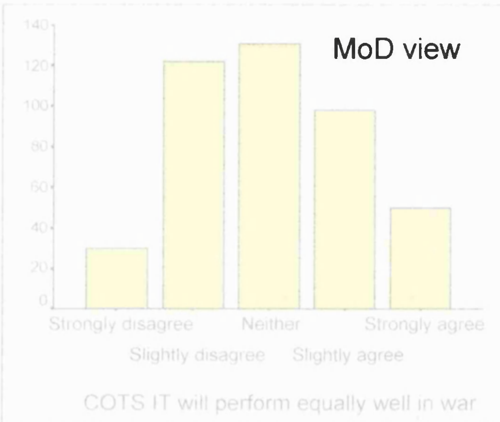


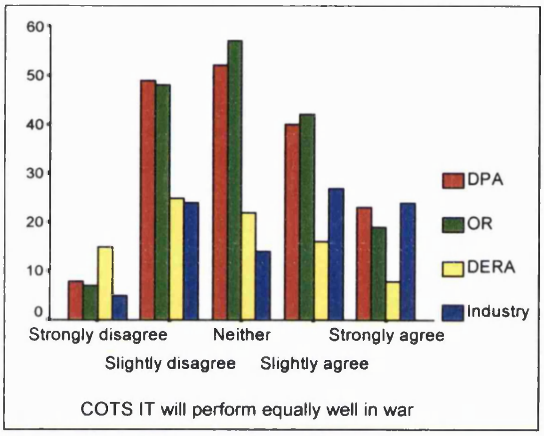
Variable	Calculation	No	*Factor*	*Score*
COTS IT only has a place in non-combat systems	Mean value	1.82	*Strongly agree*	*5*
	Standard deviation	1.03	*Slightly agree*	*4*
	Variance	1.07	*Neither agree nor disagree*	*3*
			Slightly disagree	→ *2*
			Strongly disagree	*1*

8.7.3 Compared with military IT, COTS IT will perform equally well in war



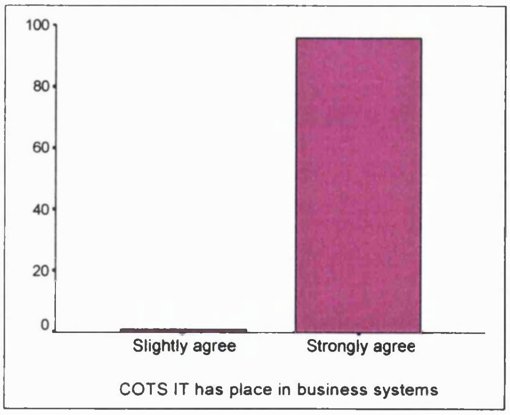
Views were polarised in industry about whether, compared with military IT, COTS IT will perform equally well in war. The mean value was 3.44 but with a variance of 1.06. This was true of all the groups within industry. However, industry's view is quite different from the MoD profile, with which it is compared. This could be explained by industry's relative detachment from the actuality of war, with the polarisation explained by the views of former military personnel now employed in industry.





Variable	Calculation	No	*Factor*	*Score*
Compared with military IT, COTS IT will perform equally well in war	Mean value	3.44	*Strongly agree*	*5*
	Standard deviation	1.27	*Slightly agree* →	*4*
	Variance	1.06	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.4 COTS in business systems



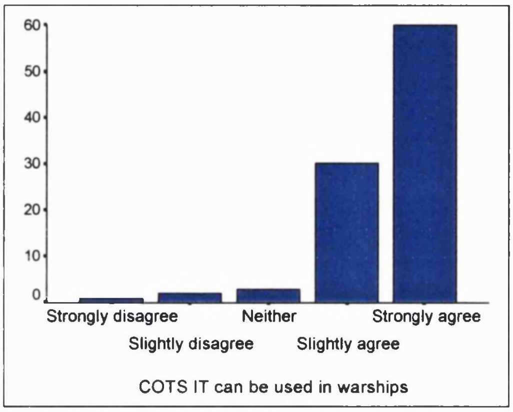
Only one single person in industry failed to agree strongly that COTS IT has a place in business systems, and that person agreed slightly. This is overwhelming support for the use of COTS IT in business applications and is very similar to the view expressed by those in MoD. However, there may be a degree of self-fulfilling prophecy here. Who in the defence equipment field would not want COTS IT to be used by MoD in business systems?

The responses to this statement provided the highest mean value and lowest variation of any parameter measured by the survey.

Variable	Calculation	No	Factor	Score
COTS IT can be used in business systems	Mean value Standard deviation Variance	4.99 0.1 0.01	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.7.5 COTS IT can be used in warships

There is strong support in industry for the use of COTS IT in warships and submarines with 93.8% strongly or slightly agreeing.

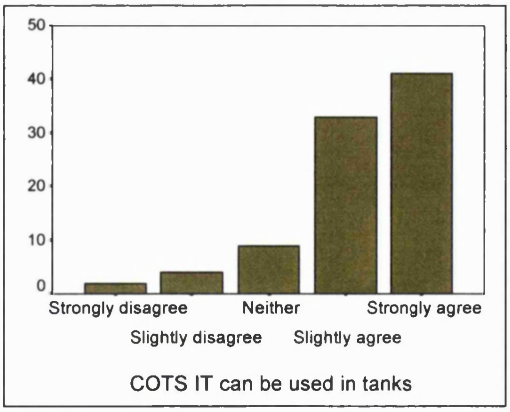


This view is held regardless of industry group. It also almost exactly matches the profile for MoD users. The mean value of 4.52 is almost exactly half way between slightly and strongly agreeing, while the variance of 0.57 is comparatively low.

Variable	Calculation	No	Factor	Score
COTS IT can be used in warships	Mean value Standard deviation Variance	4.52 0.75 0.57	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.7.6 COTS IT can be used in land vehicles

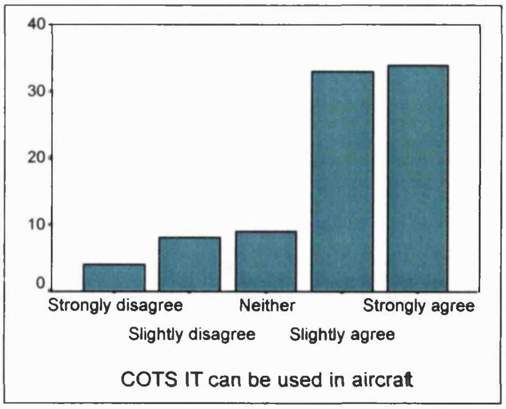
There is a strong agreement that COTS IT can be used in battle tanks and recce vehicles, with 83.2% either strongly or slightly agreeing. This support is stronger than that within MoD, where the 'slightly agrees' exceeded the 'strongly agrees'. There is a closer match with those of MoD by those in IT companies, but the sample is too small for the result to be considered significant.



Variable	Calculation	No	Factor	Score
COTS IT can be used in battle tanks and recce vehicles	Mean value Standard deviation Variance	4.2 0.96 0.91	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.7.7 COTS IT can be used in aircraft

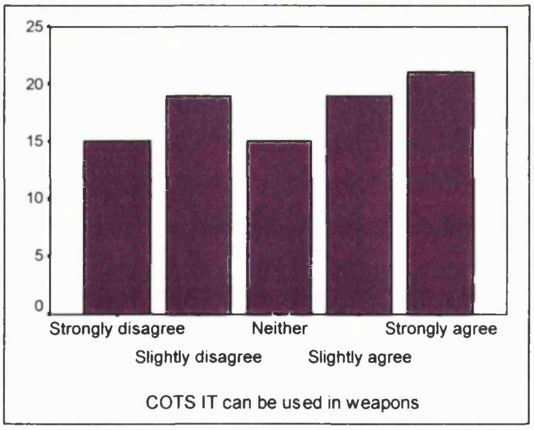
Industry's view supports the use of COTS IT in aircraft, though rather less strongly than is the case for ships and tanks, with 76.1% either strongly or slightly agreeing. However, it is clear that there is less strength of agreement in systems houses, commercial companies and IT companies than in other military companies.

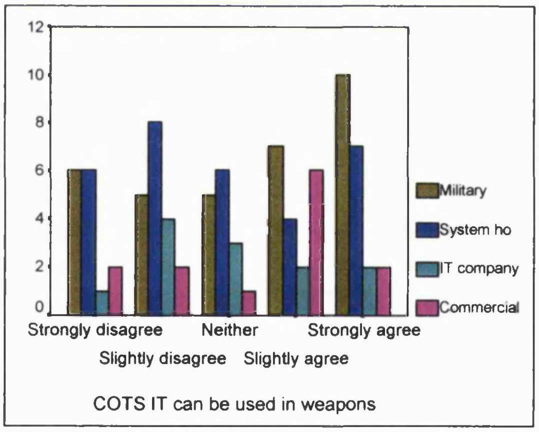


Variable	Calculation	No	Factor	Score
COTS IT can be used in aircraft	Mean value	3.97	*Strongly agree*	*5*
	Standard deviation	1.13	*Slightly agree* →	*4*
	Variance	1.27	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.8 COTS IT can be used in weapons

There really is no consensus of views amongst members of industry on the use of COTS IT in weapons. The mean value is 3.17 but 16.3% strongly disagreed while 23.6% slightly disagreed. This is reflected in the very high variance of 2.12. The views also vary depending on the type of company, with those employed by defence or other commercial companies more in favour than those in system houses or IT companies.

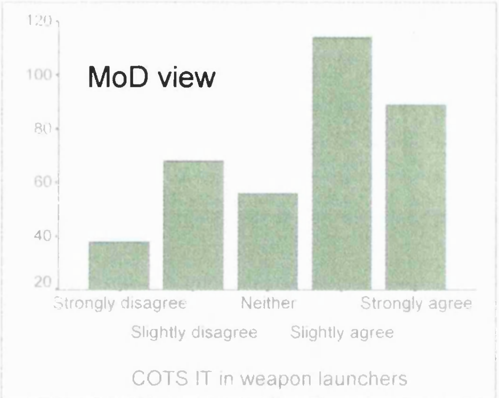


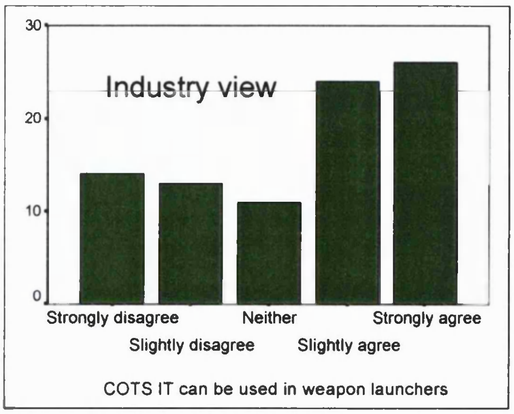


Variable	Calculation	No	Factor	Score
COTS IT can be used in weapons	Mean value	3.17	*Strongly agree*	*5*
	Standard deviation	1.46	*Slightly agree*	*4*
	Variance	2.12	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.9 COTS IT can be used in weapon launchers

There is a balance of views agreeing that COTS IT can be used in weapon launchers with 56.8% either strongly or slightly agreeing. However 30.7% either strongly or slightly disagree, and the variance is even greater than for weapons at 2.16. When viewed by type of company, the balance varies little. Furthermore, the profile differs considerably from that of MoD.

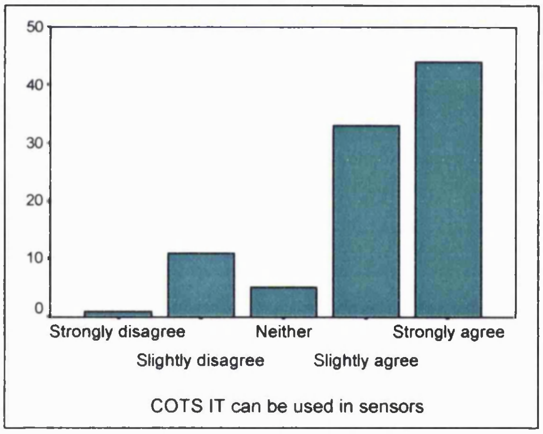




Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in weapons launchers	Mean value	3.43	*Strongly agree*	*5*
	Standard deviation	1.47	*Slightly agree*	*4*
	Variance	2.16	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.10 COTS IT can be used in sensors

There is strong support for the use of COTS IT in sensors with 83% of responses either strongly or slightly agreeing. The mean value is 4.15. This is very similar to the response to that obtained from those in MoD. There is, however, a minority of 12.8% who either slightly or strongly disagrees.

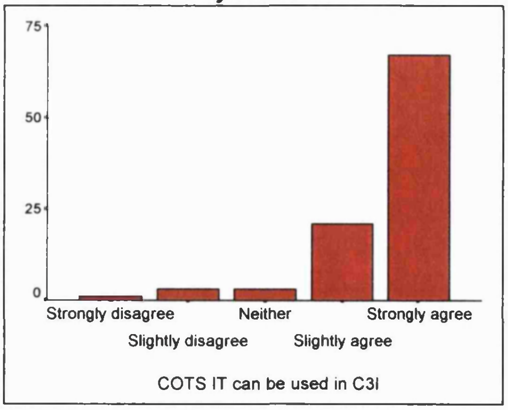


This may be due to the fact that sensors have to survive many different environments depending on whether they are static, hand carried on the battlefield, or fitted to one of the very diverse range of platforms.

Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in sensors	Mean value	4.15	*Strongly agree*	*5*
	Standard deviation	1.04	*Slightly agree*	*4*
	Variance	1.07	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.7.11 COTS IT can be used in C^3I, intelligence or air defence systems

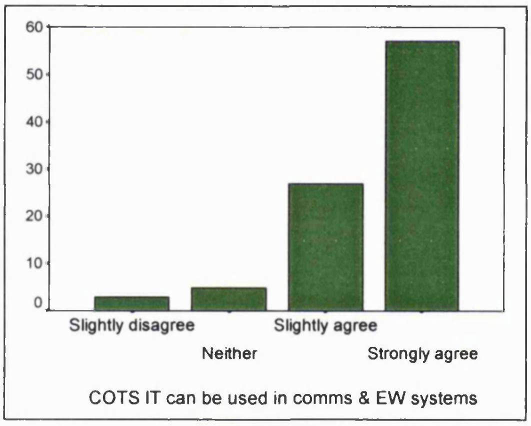
There is very strong support for the use of COTS IT in C^3I, or other systems with nearly two-thirds of those who responded strongly agreeing and a further 22.1% slightly agreeing. The mean value is 4.58, with less than five percent disagreeing. There is a definite consensus for the use of COTS IT in C^3I, intelligence and air defence systems. This response is very similar to that from the people working in MoD.



Variable	Calculation	No	Factor	Score
COTS IT can be used in C^3I, intelligence or air defence systems	Mean value Standard deviation Variance	4.58 0.79 0.63	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.7.12 COTS IT can be used in communications or electronic warfare systems

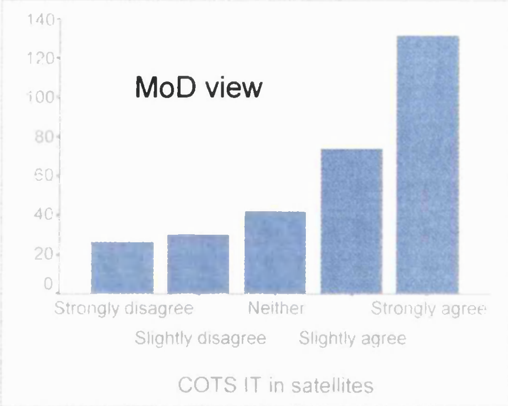
There is support for using COTS IT in communications and electronic warfare systems, with 91.3% either strongly or slightly agreeing. The mean value of 4.5 is indicative of the strength of the support, while the standard deviation is only 0.75. This is a similar profile to that obtained from MoD responses, but with a rather higher level of agreement – industry mean of 4.5 compared to 4.3 for MoD. Furthermore, no one in industry strongly disagreed, whereas 2.8% did in MoD.

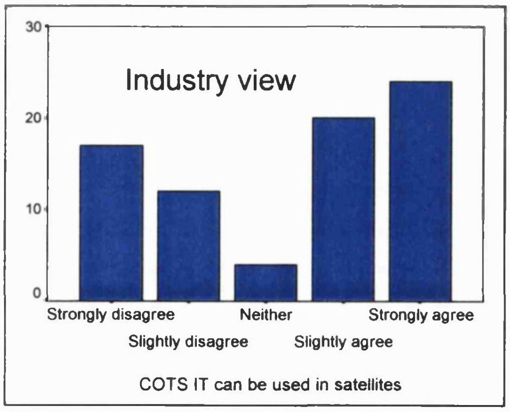


Variable	Calculation	No	Factor	Score
COTS IT can be used in communications and electronic warfare systems	Mean value Standard deviation Variance	4.5 0.75 0.56	*Strongly agree* → *Slightly agree* *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.7.13 COTS IT can be used in satellites

There is a serious polarisation of views about whether COTS IT is suitable for use in satellites. 37.7% strongly or slightly disagree but 57.2% strongly or slightly agree, resulting in a mean value of 3.29 but a very high variance of 2.5. This probably results from an ambiguity in the question and depends on whether the person responding was considering the satellite ground equipment or the actual satellite itself. This result is in marked contrast to the views of MoD.





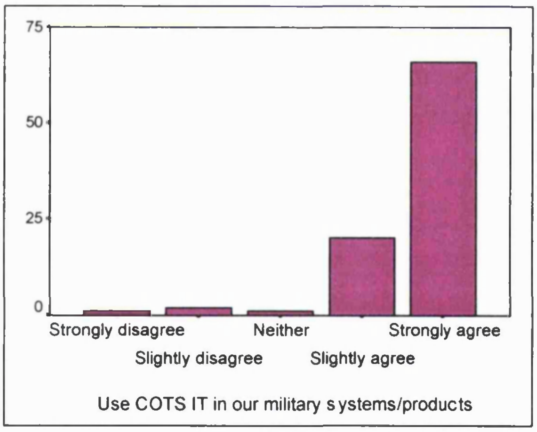
Variable	Calculation	No	*Factor*	*Score*
COTS IT can be used in satellites	Mean value	3.29	*Strongly agree*	*5*
	Standard deviation	1.58	*Slightly agree*	*4*
	Variance	2.5	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.8 Answers to statements solely for people in industry

As mentioned earlier, the following four additional statements were put only to people in industry.

1. We specify/use COTS IT in our military systems/products.
2. We build COTS IT into what we sell to MoD.
3. For many applications, COTS IT hardware will not need any modification.
4. COTS software can easily be interfaced with military specific software.

8.8.1 COTS IT in our military systems/products



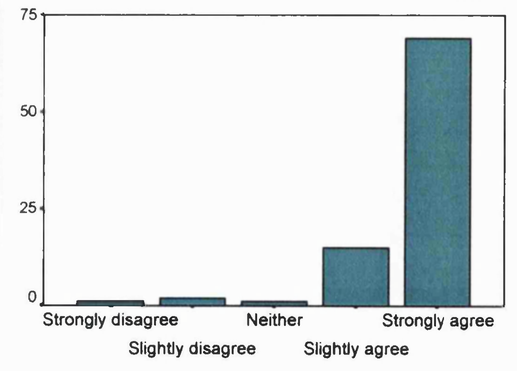
Nearly 96% of those who responded strongly or slightly agreed that their companies use COTS IT in the military systems/products that they produce and sell. A check was made to see if a purely commercial company had been included in the list. Interestingly, the person who strongly disagreed worked for GEC Marconi at Great Baddow, the two who slightly disagreed work for Thomson Marconi Marine, the one who neither disagreed nor agreed worked for the defence sector of Smith's Industries. It thus appears that the 3.3% who disagreed were clearly not using COTS IT.

Variable	Calculation	No	*Factor*	*Score*
We use COTS IT in our military systems/products	Mean value	4.64	*Strongly agree* →	*5*
	Standard deviation	0.72	*Slightly agree*	*4*
	Variance	0.52	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.8.2 COTS IT in what we sell to UK MoD

A virtually identical set of results suggests that the companies that use COTS IT in their military systems/products all sell to UK MoD. The mean value was just marginally higher at 4.69, but the standard deviation is identical.

This is no surprise as export defence equipment is unlikely to differ in this aspect from similar equipment supplied to UK MoD.

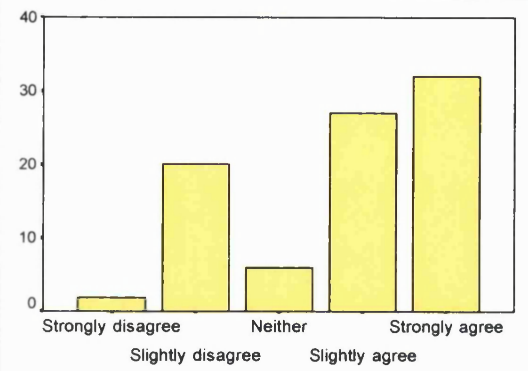


Use COTS IT in what we sell to UK MoD

Variable	Calculation	No	Factor	Score
We use COTS IT in what we sell to UK MoD	Mean value	4.69	*Strongly agree* →	*5*
	Standard deviation	0.72	*Slightly agree*	*4*
	Variance	0.51	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.8.3 For many applications, COTS IT hardware will not need any modification

There is a degree of polarisation in the responses to this statement and the profile remains regardless of the sub-group to which the person responding belongs. 69.8% strongly or slightly agreed that for many applications, COTS IT hardware will not need any modification. However, 25.3% slightly or strongly disagreed. The resulting mean value is 3,77, but with a variance of 1.53. Why this polarisation exists is not clear, but may well relate to which particular applications of COTS IT the person works on. Those disagreeing may well work on the more awkward applications.

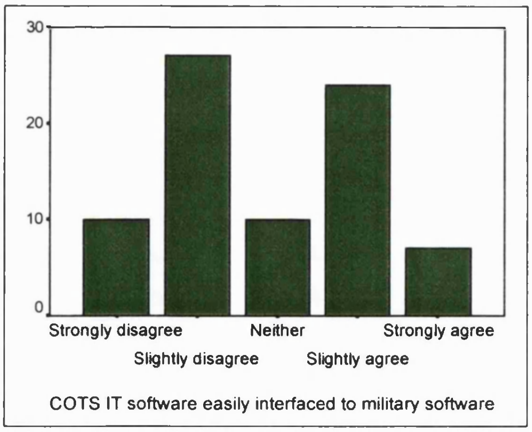


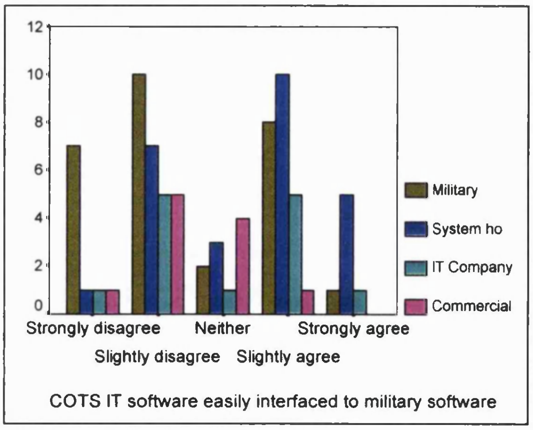
COTS IT hardware will not need any modification

Variable	Calculation	No	Factor	Score
For many applications, COTS IT hardware will not need any modification	Mean value	3.77	*Strongly agree*	*5*
	Standard deviation	1.24	*Slightly agree* →	*4*
	Variance	1.53	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.8.4 COTS software can easily be interfaced with military specific software

The response to the statement that COTS software can easily be interfaced with military specific software was very clearly polarised. 47.4% either strongly or slightly disagree with the statement while 39.8% either strongly of slightly agree. This gives a mean value of 2.88, but a large variance of 1.53.





Obviously, rather more people find interfacing difficult than easy. This may depend on the COTS software and the legacy system involved.

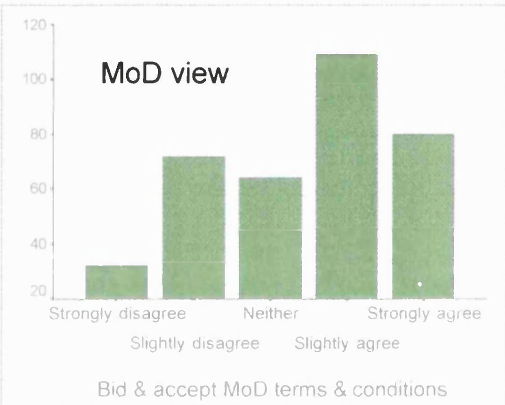
What is interesting is that the military defence contractors, though polarised, are biased towards disagreeing with the statement while the systems houses, also polarised, are biased in the opposite direction. This may be because of the increased importance of software in system house solutions.

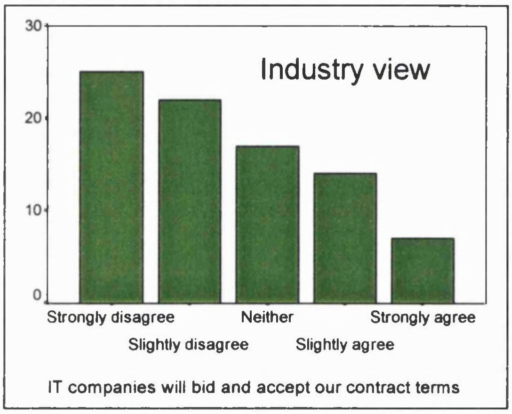
Variable	Calculation	No	*Factor*	*Score*
COTS software can easily be interfaced with military specific software	Mean value	2.88	*Strongly agree*	*5*
	Standard deviation	1.24	*Slightly agree*	*4*
	Variance	1.53	*Neither agree nor disagree* →	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9 Answers about the purchase of COTS IT by MoD from people in industry

8.9.1 Commercial IT companies will bid for military work and accept MoD contract terms/conditions

There is quite a contrast between the views of industry about the likelihood of commercial IT companies bidding and accepting MoD's terms and conditions and the view of MoD towards the same issue. Industry disagrees with the statement as the mean value of 2.48 indicates. This compares with MoD's polarised view and mean value of 3.37. This difference in view clearly indicates the relative optimism of the buyer and the comparative pessimism of the seller.

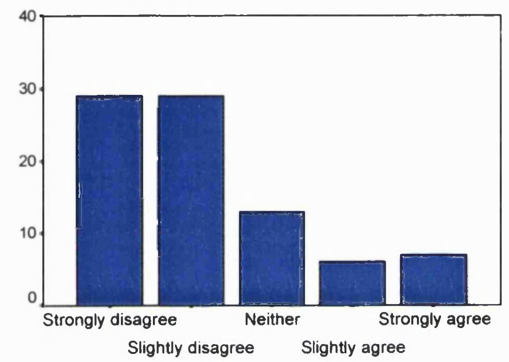




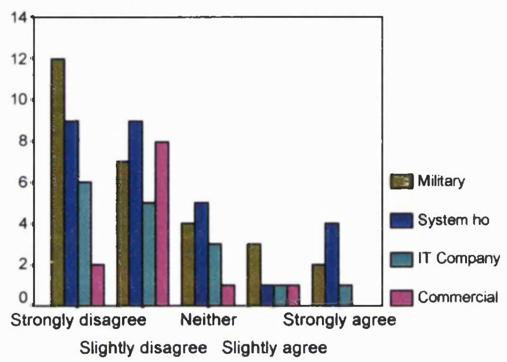
Variable	Calculation	No	*Factor*	*Score*
Commercial IT companies will bid for military work & accept our contract terms/conditions	Mean value	2.48	*Strongly agree*	*5*
	Standard deviation	1.30	*Slightly agree*	*4*
	Variance	1.68	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.2 There will be a lack of competition in the COTS IT field

Almost seventy percent of the responses were from people who either strongly or slightly disagree with the statement, resulting in a mean value of 2.2. However, 15.4% either strongly or slightly agree; a significant minority, resulting in a variance of 1.51. It is noteworthy that while the profile for system houses follows the overall result, military and IT companies disagree more strongly but commercial companies disagree less strongly. However, the statistical sample is very small.



There is a lack of competition in the C OTS IT field

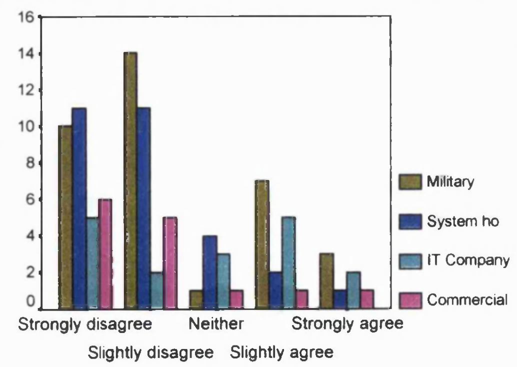


There is a lack of competition in the C OTS IT field

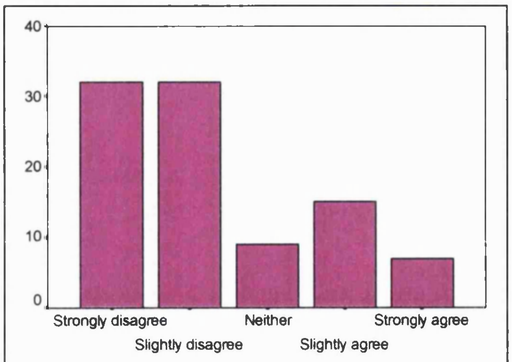
Variable	Calculation	No	*Factor*	*Score*
There will be a lack of competition in the COTS IT field	Mean value	2.20	*Strongly agree*	*5*
	Standard deviation	1.23	*Slightly agree*	*4*
	Variance	1.51	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.3 COTS IT will be available long enough to be purchased in normal MoD development and production time scales

While two-thirds of responses strongly or slightly disagreed with the statement that COTS IT will be available long enough to be purchased in normal MoD development and production time scales, nearly a quarter strongly or slightly agreed. This gave a mean value of 2.29. Once again the views of the different sectors of industry



COTS IT available long enough for MoD purchase

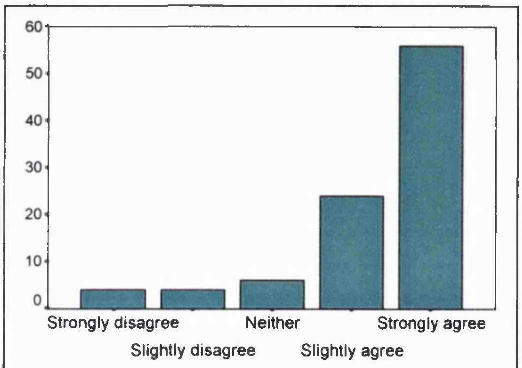


COTS IT available long enough for MoD purchase vary with military companies less in disagreement, while IT and other commercial companies are more in disagreement.

Variable	Calculation	No	Factor	Score
COTS IT available long enough to for purchase in normal MoD development/ production time scales	Mean value	2.29	*Strongly agree*	*5*
	Standard deviation	1.29	*Slightly agree*	*4*
	Variance	1.66	*Neither agree nor disagree*	*3*
			Slightly disagree →	*2*
			Strongly disagree	*1*

8.9.4 The price of COTS IT will be lower than that of specially developed military IT

Sixty percent of responses strongly agree that the price of COTS IT is lower than that of specially developed military IT, while a further twenty-five percent slightly agree. This results in a mean value of 4.32 and a relatively modest variance of 1.12. The results and profile are very similar to those obtained from MoD, but with a slightly lower mean value and a somewhat higher variance.

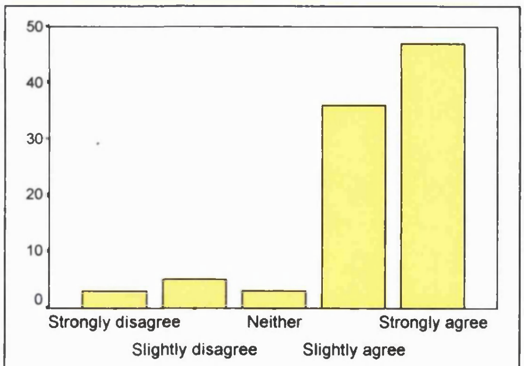


COTS IT price lower than military IT

Variable	Calculation	No	Factor	Score
The price of COTS IT will be lower than that of specially developed military IT	Mean value	4.32	*Strongly agree* →	*5*
	Standard deviation	1.06	*Slightly agree*	*4*
	Variance	1.12	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.5 Mil/Def spec type of requirements will cause problems with the purchase and use of COTS IT

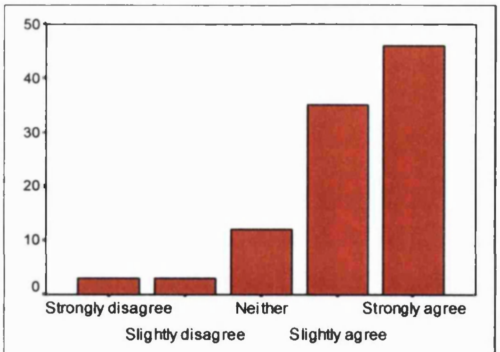
Half the responses strongly agree that Mil/Def specs will cause problems and a further thirty eight percent slightly agree. This results in a mean value of 4.27 and a relatively low variance of 0.97. The profile is similar to that of MoD, although in the MoD case, more people slightly agreed than strongly agreed. The result is that industry has a noticeably higher mean value; 4.27 compared to 3.93, and a slightly lower variance.



Mil/Def specs will cause problems with COTS IT

Variable	Calculation	No	Factor	Score
Mil/Def spec type of requirements will cause problems with the purchase and use of COTS IT	Mean value	4.27	*Strongly agree*	*5*
	Standard deviation	0.99	*Slightly agree* →	*4*
	Variance	0.97	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.6 The use of IT should improve MoD's efficiency or performance



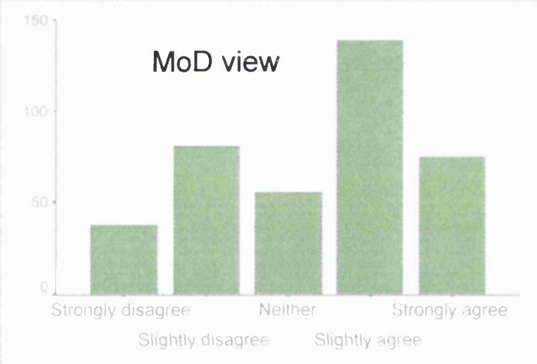
Use of IT should improve MoD's efficiency/performance

The view of industry is that IT, and not just COTS IT, should improve the efficiency or performance of MoD. 81.9% either strongly or slightly agree, giving a mean value of 4.19 with a less than unity variance. In this view, they are virtually identical to that of MoD, where the mean value is 4.21. This exceptionally close similarity shows the optimism of all concerned about the benefits of IT.

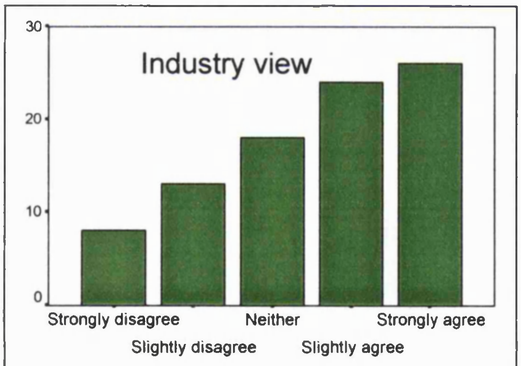
Variable	Calculation	No	*Factor*	*Score*
The use of IT should improve MoD's efficiency or performance	Mean value	4.19	*Strongly agree*	*5*
	Standard deviation	0.98	*Slightly agree* →	*4*
	Variance	0.95	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.7 Viruses are likely to be more of a problem with COTS than military IT

Industry's view has a definite bias towards agreeing that viruses are more likely to be a problem with COTS than military IT, with more than half the people agreeing strongly or slightly and less than a quarter similarly disagreeing. The mean value is 3.53 with quite a wide variance at 1.68. This is quite different from the polarised view of MoD even though the mean value of 3.34 is very close to that of industry.



Viruses more likely to be problem with COTS IT

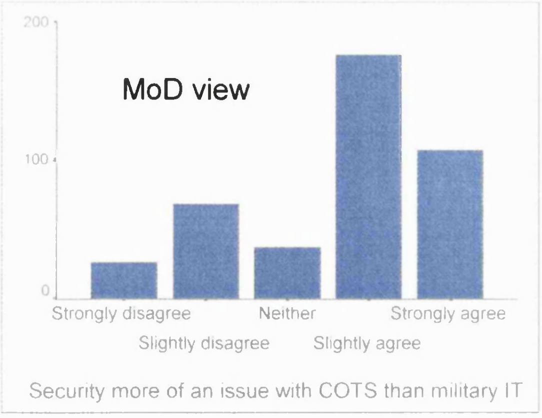


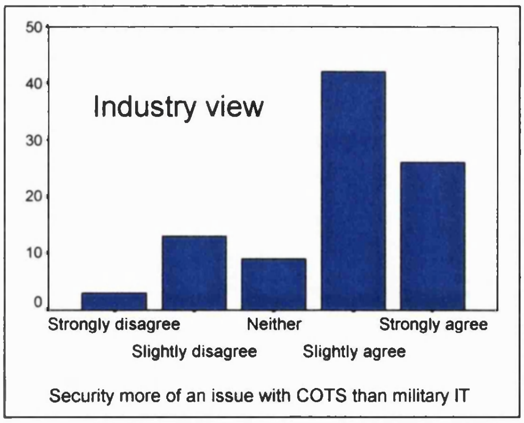
Virus problems more likely with COTS than military IT

Variable	Calculation	No	*Factor*	*Score*
Viruses are likely to be more of a problem with COTS than military IT	Mean value	3.53	*Strongly agree*	*5*
	Standard deviation	1.30	*Slightly agree* →	*4*
	Variance	1.68	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.8 Security is likely to be more of an issue with COTS than military IT

While approaching half the responses slightly support the statement and nearly three-quarters strongly or slightly support it, there is a 17% minority that take the opposite view. This results in a mean value of 3.81 that is quite remarkably similar to the MoD profile. It is thus clear that the vast majority of people in both organisations view COTS IT security as an issue.

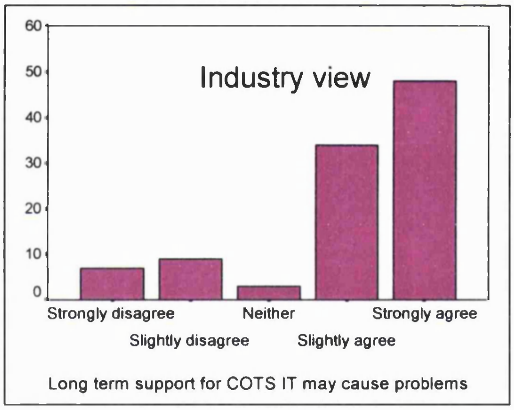


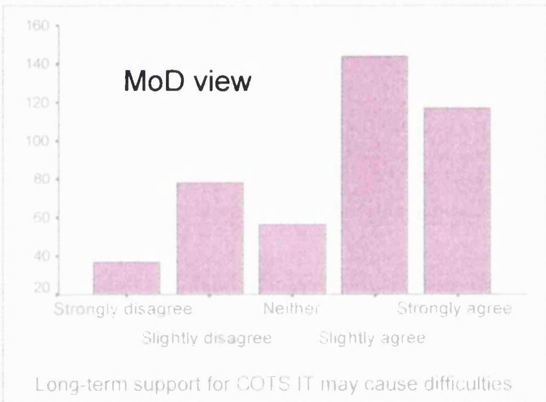


Variable	Calculation	No	*Factor*	*Score*
Security is likely to be more of an issue with COTS than military IT	Mean value Standard deviation Variance	3.81 1.10 1.20	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.9.9 The need for long term support for COTS IT is likely to cause difficulties

Nearly half those who responded strongly agreed that the need for long term support for COTS IT



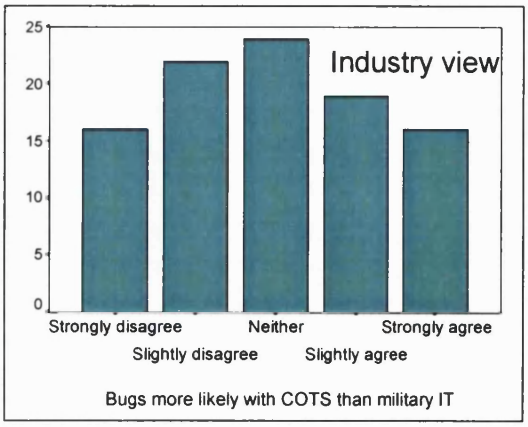


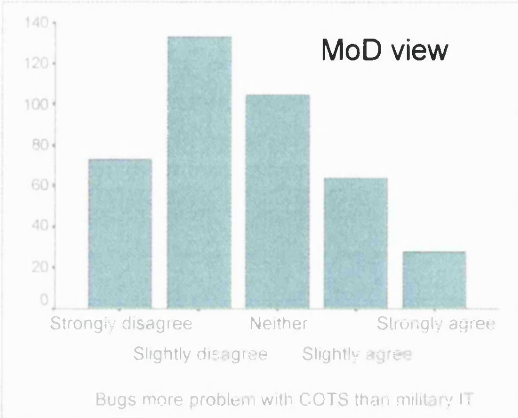
is likely to cause difficulties and this total rose to over eighty percent when those who slightly agreed were added. However, a small 8.9% minority disagrees. The profile is not dissimilar to that of MoD, but more people strongly agree, less people slightly agree and the minority is smaller. This mean value of 4.06 compares with the MoD mean of 3.52.

Variable	Calculation	No	*Factor*	*Score*
The need for long term support for COTS IT is likely to cause difficulties	Mean value Standard deviation Variance	4.06 1.22 1.50	*Strongly agree* *Slightly agree* → *Neither agree nor disagree* *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.9.10 Bugs are likely to be more of a problem with COTS than military IT

With a mean value of 2.97 and a variance of 1.76, there is clearly no consensus in industry as to whether bugs are more or less likely to be a problem with COTS IT than with specially developed IT. What is clear is that MoD with a mean value of 2.61 is more optimistic than industry. This is probably because of the higher industry exposure to bugs in COTS IT.

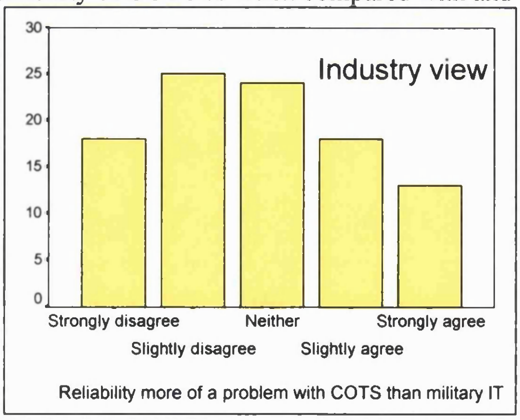


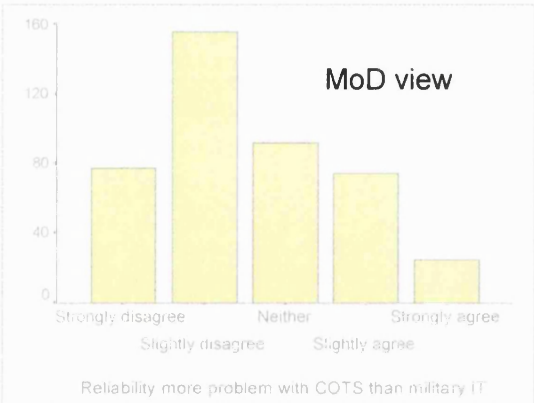


Variable	Calculation	No	*Factor*	*Score*
Bugs are likely to be more of a problem with COTS than military IT	Mean value Standard deviation Variance	2.97 1.33 1.76	*Strongly agree* *Slightly agree* *Neither agree nor disagree* ⟶ *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.9.11 Reliability is likely to be more of a problem with COTS IT than with IT specially developed for military use

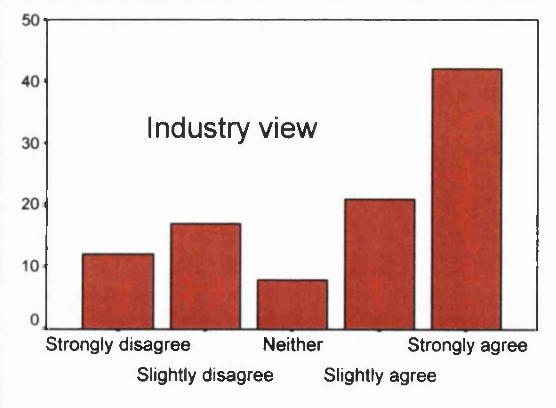
Again, there is little consensus about the relative reliability of COTS IT when compared with and specially developed military IT. The mean value is 2.83, with a wide variance of 1.69. There is less concern with reliability in MoD and this reflects in the lower mean value of 2.56.





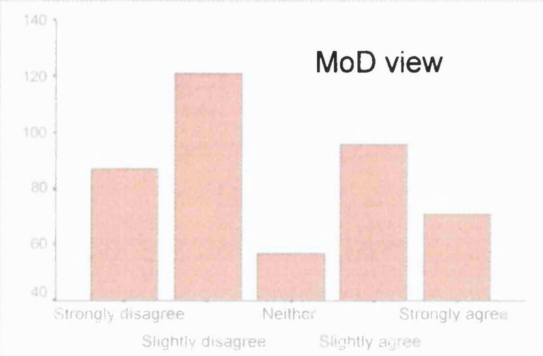
Variable	Calculation	No	*Factor*	*Score*
Reliability is likely to be more of a problem with COTS IT than with IT specially developed for military use	Mean value Standard deviation Variance	2.83 1.30 1.69	*Strongly agree* *Slightly agree* *Neither agree nor disagree* ⟶ *Slightly disagree* *Strongly disagree*	*5* *4* *3* *2* *1*

8.9.12 Obsolescence is likely to be more of a problem with COTS IT than with IT specially developed for military use



More obsolescence problems with COTS than military IT

Over forty percent strongly agree that obsolescence is more likely to be problem with COTS IT and when those who slightly agree are added, the total reaches nearly two thirds. Despite this, nearly a quarter either strongly or slightly disagrees. The result is a mean value of 3.64, with a very high variance of 2.15. This polarisation is matched by MoD, but in the opposite direction, resulting in an MoD mean of 2.87. Industry is clearly more concerned about the issue of obsolescence that its customer.

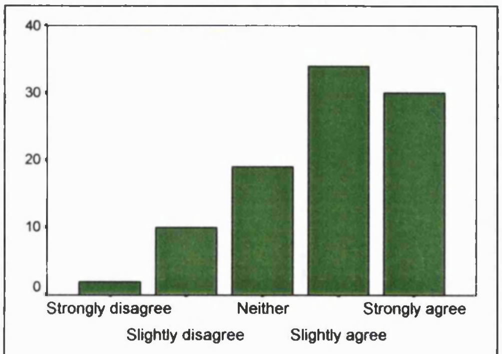


Obsolescence more problem with COTS than military IT

Variable	Calculation	No	*Factor*	*Score*
Obsolescence is likely to be more of a problem with COTS than with IT specially developed for military use	Mean value	3.64	*Strongly agree*	*5*
	Standard deviation	1.47	*Slightly agree* →	*4*
	Variance	2.15	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.9.13 An advantage of COTS IT is that it is familiar and thus easy to use

Just under one third of responses strongly support the view that COTS IT is familiar and thus easy to use, while just over one third more slightly agree. Only a total of twelve and a half percent strongly or slightly disagree. The mean value is 3.84 with a standard deviation of 1.06. This slight agreement is similar to that of MoD, where slightly more people strongly agree than slightly agree, giving a slightly higher mean value of 3.97.



Advantage of COTS It is familiarity & ease of use

Variable	Calculation	No	*Factor*	*Score*
An advantage of COTS IT is that it is familiar and thus easy to use	Mean value	3.84	*Strongly agree*	*5*
	Standard deviation	1.06	*Slightly agree* →	*4*
	Variance	1.11	*Neither agree nor disagree*	*3*
			Slightly disagree	*2*
			Strongly disagree	*1*

8.10 Overall conclusions of industry questionnaires

It should be remembered that both the sample and the response from industry were much lower than those from MoD.

8.10.1 COTS IT in operational equipment

There is overwhelming support (everyone strongly or slightly agrees) for the use of COTS IT not only in business equipment but also in all MoD purchases. The disagreement with the use of COTS IT only in non-combat systems exactly matches MoD's view. As to whether COTS IT will perform as well in war as custom military equipment, there is a polarised view with a bias towards slightly agreeing.

Again, as with MoD, there is wide support for the use of COTS IT in:

Ships – 93.8% strongly or slightly agree.

Land vehicles – 83.2% strongly or slightly agree.

Aircraft – 66.4% strongly or slightly agree.

There is absolutely no consensus on the use of COTS IT in weapons. 16.3% strongly disagree while 23.6% strongly agree. For weapon launchers, there is still no consensus, though 56.8% strongly or slightly agree. There is strong support for the use of COTS IT in sensors, C^3I, intelligence and air defence systems, as well as communications and electronic warfare systems. There is a polarisation of views about whether COTS IT is suitable for use in satellites, although in this case only the actual satellite itself was considered.

8.10.2 Industry use of COTS IT

Some questions specific to industry use of COTS IT produced the following results. Over 95% of those responding said that their companies use COTS IT in the military systems/products that they produce for MoD and other customers. There is a degree of polarisation of views in the responses to the statement that for many COTS IT applications, hardware will not need any modification. The response to the statement that COTS software can easily be interfaced with military specific software was also very clearly polarised; military defence contractors are biased towards disagreeing with the statement while systems houses are biased towards agreeing.

8.10.3 The purchase of COTS IT by UK MoD

There is quite a contrast between the views of industry (the seller) towards companies bidding and accepting their contract terms and the views of MoD (the buyer) about the same statement. Industry feels that acceptance of MoD terms is much less likely than does MoD itself.

Almost 70% of the responses disagree that there will be a lack of competition in the COTS IT field. While two-thirds of those who responded agreed COTS IT will be available long enough to be purchased in normal MoD development and production time scales, nearly a quarter disagreed.

Sixty percent of responses strongly agree that the price of COTS IT will be lower than that of specially developed military IT, while a further twenty-five percent slightly agree. Half the responses strongly agree that Mil/Def specs will cause problems with the purchase and use of

COTS IT while a further 38% slightly agree. The view of industry is that IT, and not just COTS IT, should improve the efficiency or performance of MoD. In this view, industry is slightly more positive than MoD itself.

There is a definite bias towards agreeing with the view that viruses are more likely to be a problem with COTS than bespoke IT, with more than half the people agreeing and less than a quarter disagreeing. On the other hand, there is no clear consensus as to whether bugs are more or less likely to be a problem. Nearly three quarters of the responses take the view that security is likely to be more of an issue with COTS than military IT. However, there is a 17% minority that take the opposite view. This is a quite remarkably similar profile to that of the people in MoD.

Eighty percent of those who responded agreed that the need for long-term support for COTS IT is likely to cause difficulties. There is little consensus about the relative reliability of COTS when compared with that of custom military IT, with a wide variance. Two thirds agree that obsolescence is more likely to be a problem with COTS IT. Despite this, nearly a quarter disagrees. About two thirds of responses support the view that COTS IT is familiar and thus easy to use. Only 12½% disagree.

9 PERSONAL INTERVIEWS

This section provides an overview and summary of the conclusions of forty-six interviews with people in MoD, and in industry supplying MoD directly or as sub-contractors. It ends with the overall conclusions from both the questionnaire analysis and the interviews.

A compromise was clearly essential in the questionnaire between asking sufficient questions to get a clear and unambiguous response and asking few enough to get a reasonable response rate. Having compromised on a questionnaire consisting of only two sides of A4 paper, a series of interviews were set up with a selection of people who had returned their questionnaires. This was in addition to a number of people who were interviewed prior to receipt of the questionnaires during the initial data-gathering stage of the research.

It was decided to approach all those who indicated reservations about whether the questions were sufficiently detailed, as well as those who offered to discuss the questionnaire further. While this does represent a clear bias, it was felt to be reasonable in terms of obtaining agreement to sufficient interviews without spending too much time in getting that agreement.

A letter was sent to the selected people asking if they would agree to an interview and stating that a follow-up telephone call would be made to agree, or not, to meeting and to set up a date and location. With a single exception, all interviews were held at the location of the individual, the exception being a person based in the North of England who regularly travels to London and who was interviewed in an office at UCL.

Even using these criteria, some people declined to agree to meet. Clearly some immeasurable further biases were built in at this stage. The low number of DPA interviews was based on two factors; the initial view that some twenty-five to thirty interviews were all that could be accommodated and the cost and time involved in travelling to DPA at Bristol. In the event, a total of 46 interviews were held, and Figure 25 shows how many meetings were held with each group and when.

DPA	7 – Nov 97	7
OR	1 - Aug 96, 1 – Nov 96, 1 – Dec 96, 1 – Feb 97, 9 – Sep/Oct 98	13
DERA	2 – Mar 96, 1 – Nov 96, 1 – Nov 98, 9 – May 99	13
Total MoD		33
Industry	1 – May 96, 2 – Apr 97, 5 – Jan/Feb 98, 1 – Sep 98, 1 – Aug 99, 1 – Sep 99, 2 – Oct 99	13
Total		46

Figure 25. Dates and numbers of meeting held with MoD and industry.

Face to face interviews were held with people from the four groups. Each interview lasted about one hour and, in order to avoid bias, the aim was not to ask questions, but rather to get the interviewee to talk about their response to the questionnaire. Typical of the letters sent as brief before each interview is the following:

'Following our telephone conversation, I confirm that I look forward to meeting you in your office at <time> on <day/month/year>. I am enclosing a diagram (See Figure 26) *that shows the various issues that I am considering in my research. I would not necessarily expect you to have views on all topics, particularly those more appropriate to MoD <department>, but find the chart provides a useful basis for discussion.'*

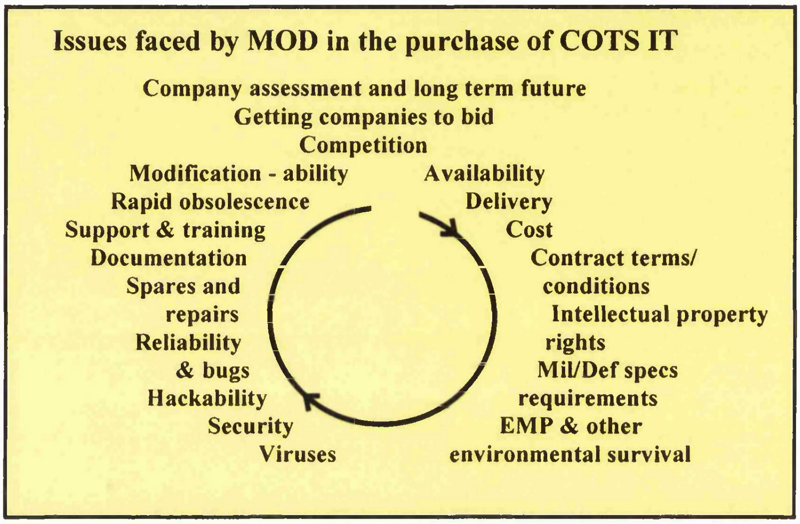


Figure 26. The document used to guide the interviews.[24]

The statements made below are taken from the forty-six summaries of **the words actually spoken by the various individuals interviewed**. Sometimes they are contradictory; sometimes they deal with very specific issues. Some general points are grouped together in a number of separate categories. There are two separate headings covering the MoD and industry groups.

9.1 Summary of interviews with MoD/DERA staff

9.1.1 General

Non-operational and operational use of COTS IT should not be divided as MoD's core business is defence and this requires word processing and financial systems. COTS IT is inescapable at least at the electronic component level.

The military may not be invited to the next war. If an enemy is attacking IT, it is easier to attack vulnerable commercial systems than custom military ones. Professional hackers, such as a team in Microsoft, exist and a war on a nation's IT is a distinct possibility.

[24] This diagram was an early prototype for what was developed into the COTS IT Circle.

Land and joint battle space digitization is driving towards a reduced number of platforms and more C^3I. The impact of increased information on people needs researching. Data fusion is crucial for sensor data.

Reconnaissance requirements in peacekeeping operations are different to those in war. Such needs may hold back the tide of automation. There is also the question of the level of authority to be given to a machine; however, time constraints may drive people out of the loop.

The DG ICS was seen to be out of date with the latest developments in the IT industry.

9.1.2 Attitudes

IT is not viewed as interesting by the armed forces and senior officers are frightened that it will cause them to lose control to technologists. The IT in current military systems lacks interest to users because it uses old-fashioned technology. The use of COTS IT is supported as MoD policy, but there is a belief that solutions will almost invariably be a mix of COTS and bespoke IT. A few of those interviewed were very anti COTS and thought solutions would be fudged, giving unrealistic through life costs.

The military can search for perfection or accept what is just good enough. The best is the enemy of the good and this is particularly true when using COTS IT. EMP is not in the front of people's mind and MoD has largely discarded this risk.

There are problems caused by the military stating what is wanted. This is partly a culture issue, partly cost counting. Managers are not trying to work smarter particularly as, at the unit level, soldiers are (to them) cheap and equipment is expensive.

Land systems are incredibly crude – 25 years behind air systems. A soldier relies on a big gun and thick armour. To change into a more efficient fighting machine, by using techniques such as stealth, will require a change of custom and practice in the army.

The Internet is useful, particularly e-mail, with strengths and weaknesses, requiring authentication, accuracy and reliability of information. It can put a gloss on doubtful information, particularly as it is so cheap to produce and there are no checks and balances. The Internet is only satisfactory for non-real time applications. Quality of service is important. Search engines are still very poor.

9.1.3 Usability

1 UK Brigade uses a lot of COTS IT in its static headquarters, typically deployed in tents within a barn. It appears to be efficient use of office equipment in the field, including personal computers, laser printers, faxes and similar COTS IT peripherals. The ease of use of COTS IT is brilliant for a conscript army. IT improves performance but not necessarily efficiency in the armed forces.

There is a problem of unnecessary padding with commercial software – the military doesn't need to be able to customise a desktop! Modern word processors waste people's time on format rather than content. However, buttons on any equipment give user flexibility. Losing a file on a personal computer is still a problem. Compatibility between old legacy bespoke and COTS IT systems can also be a problem.

Senior people find new technology harder to use than the young and the same may be true of maintenance staff. Mention was made of operators misusing the MMI or even the whole equipment.

9.1.4 Cost

COTS IT use is being driven by the relative decline in military budgets and the expense of custom developments. However the cost of ownership could equal that of developing specialised military IT solutions and some feel that it was a misnomer that COTS IT is cheaper. There is also a significant cost of testing COTS IT to prove it is problem free.

One person quoted a COTS IT-based ship-borne system that has been in service for five years and is viewed as 'working better than if it had been designed from scratch and with a lower capital cost'. Yet others felt that the use of COTS IT was OK if it was the right tool for the job.

Licensing software

The Australian Defence Forces have taken out a Microsoft global licence, which seems to be a good and economic idea. However, licences for extensive networks are expensive.

9.1.5 Procurement

There are effectively three military procurement leagues:

US –	Buy special equipment.
Leading industrial and military nations –	Buy near off-the-shelf.
Rest of the world –	Buy what exists.

MoD, by using COTS IT, is seeking quicker technology insertion at a lower cost. Historically the military share of the IT market was the dominant one. Today the market can only offer military applications of commercial developments and this position that has been forced on the military.

It is clear that the military accepts the need for COTS IT but this requires a re-evaluation of requirements and some reorganisation to match what COTS offers. IT knowledge is crucial for those involved with specifying equipment but is often lacking in Equipment Capability Customer. MoD procurement volumes are low compared with the commercial IT market. Even Bowman comprises only some 100,000 units of five different types. Tracer will use little COTS IT – just at board level and in some of its sensors.

The best solution for IT systems or embedded IT is to get the software developed, then get the prime contractor to recommend COTS IT hardware with stretch potential on which to run the software. To reduce the risk when developing airborne IT, it is important to check out the hardware and software needed in an airborne laboratory.

The number of suppliers in the IT market is likely to reduce, as companies grow bigger. Finding commercial competition is hard for MoD as it tends to get tied to one supplier after the initial purchase. Going the COTS IT route means MoD must follow the upgrade route when suppliers cease support. For new equipment, current practice is:

1. Write the fullest possible specification.
2. Circulate the specification to all possible interested parties for comment.
3. Add the cost and burden of security.
4. Finish with a monolithic giant that cannot be changed without great difficulty.
5. Send the specification out to industry and ask how much. It is always non-standard.

This very long procurement cycle is not matched to the rate of technology change. From the field army point of view, the procurement system is poor and bureaucratic. E.g. Clansman radio was outdated before it entered service and at £3000 compares unfavourably with a policeman's £100 Motorola equivalent.

Smart Procurement is driving towards common sense but is unlikely to achieve instant success. Security of tenure for civil servants does not help in changing attitudes. From a testing, debugging and training point of view always use COTS IT.

9.1.6 Military/civil convergence

Military and civil requirements are increasingly converging as commercial specifications get tougher, particularly the mobility, environmental and security characteristics. MoD no longer 'EMP proofs' all its equipment. Defence specifications should be kept only for a tiny core of requirements. An unmodified Apple Mac has survived a naval shock test and laptop computers can survive on board a minesweeper – a tough environment. Commercial disruption of IT is rife, so ruggedisation is coming automatically. Civil crypto is being driven by mobile telephones and banking requirements. However, the civil market is not catering for overt jamming. Oil exploration C^3I is a converging civil market.

9.1.7 Standards

Standards are evolving, but the lack of specifications and performance guarantees for COTS IT is a problem. MOD tries to impact commercial standards by lobbying committees and in any case, standards are slow to change because of commercial reluctance and technology upgrades. There is no interest in requirements where the interface is not 'open' as open standards will be used wherever possible. Some of those interviewed see a growing convergence of military and civil mobility and security characteristics and stressed that MoD must continue its efforts to impact commercial standards. There are de-facto commercial standards, such as operating systems and Microsoft Office, and for communications.

There is a general lack of guidelines for COTS IT. It is left to DPA/Equipment Capability Customer to decide on the standards, depending on the importance of the equipment/feature. This then results in exclusions from passing tests. There are differences in EMC standards between Mil specs and NES standards. However, commercial standards are far from military standards. There are doubts about whether Tempest is really necessary for equipment in the field.

Cartels drive standards but military standards are important for inter operability. COTS IT-based systems result in problems with both product liability and interoperability. COTS IT systems are not being NATO codified but are relying on industrial code numbers.

It is debatable whether the military could accept the use of commercial communications networks. By the early 90s, privately owned laptops and cell phones could be found in numbers on board RN ships. SMC radios and GPS systems were purchased off-the-shelf for the Gulf war.

9.1.8 Specification

MOD EC may need to change their requirement in order for a COTS solution to be acceptable and there is a need for early compromise in the requirement. However, not all the needed changes are apparent early in a programme. Insistence on an NBC environment makes the use of COTS IT unlikely and, for some systems, there is the problem of trading down on EW resilience. COTS IT is seen as a problem for satellites due to the necessity for space qualification.

There is a need to establish a MILCOTS specification. This must be done in conjunction with the US. Note that the commercial market for high specification COTS IT is increasing.

Bandwidth

There is pressure to increase the amount of data in the battle space. This is more about technology than COTS IT, which is not designed for a lean bandwidth; COTS software is very bandwidth hungry. This can be a real problem with radio transmission especially those that demand encryption and only have limited bandwidth. It is essential to explore the trade off of high-v-narrow bandwidth, and it is possible to strip out facilities, use special procedures or employ lean application software. Also, increased bandwidth can always be achieved at a price.

9.1.9 Environmental stress

COTS IT is inescapable at electronic component level and mounting is a risk area – board level is the starting point. Modules of COTS IT can include built-in hardening. The cost increase of putting in it in a rugged box is 1½ – 2 times.

COTS IT is all right if it is used in the normal environment for which it was designed. Hardware has to survive high shock levels and there will be problems with toxicity and smoke produced by plastics and other toxic materials used in some COTS IT hardware. Knowing where problems are likely to occur helps to find solutions and the example of using of special fire fighting equipment to deal with the generation of toxic smoke from personal computers in a fire was quoted. However, COTS display monitors present more risk of screen debris hitting individuals.

COTS IT specs are formed project by project to meet the particular environmental requirements. In DPA's ship procurement programmes, all equipment must satisfy all the requirements. C^3I is the least stressed environment for COTS IT. Improved communications and longer range weapons mean C^3I is located further back from the enemy. The US are putting COTS IT-based field headquarters in air-conditioned containers.

There are two key uses for IT – one bespoke, the other COTS. The environment drives which is chosen. The environment can be more strenuous in peacekeeping than in war for CIS and needs interoperability with non-military organisations. There is still a requirement for some mil spec components and a few companies are working on hardened components.

A military prime contractor is essential. If commercial components are used, then either lower reliability or a lower performance spec must be accepted. Better integration can help. The environmental specification is different for each equipment. It is difficult to know the exactly physical extremes that COTS IT can survive as it may well exceed the maker's specifications.

In some cases, defence standards can be reduced but health and safety needs may well dominate. There is some evidence of more ruggedised COTS but the methods of policing are getting worse – rough and ready. Some manufacturers just stick on an approval label. New COTS IT to higher standards is not tested, though some companies do carry out COTS IT testing.

EMP

There is a concern about nuclear conflict and the ability of COTS IT to survive EMP, particularly at greater ranges from ground zero. EMP and directed energy weapons can both damage COTS. IT. The problem will be more severe in a tent than in a metal skinned vehicle. The military should plan to be able to operate after EMP has destroyed COTS IT and thus reversionary working modes are important. The solution is wrapping hardware. However, sealed screened boxes tend to become ineffective after they have been serviced. EMP survival is no longer specified for some equipment but testing is still expensive.

9.1.10 Reliability

COTS IT has no traceable record. COTS IT hardware and software are not necessarily less reliable and could be more reliable than bespoke IT. Some felt that COTS IT is more reliable but pointed out that there is no database of COTS IT failures and no traceable records. There is the danger of unprovable safety cases. Others view COTS IT as having a higher risk of failure, but not much higher. Views vary because it is thought that hardware is, by and large, reliable but software is unreliable. System redundancy can be key to improving COTS IT availability. It was noted that the use of COTS IT in weapons demands the highest reliability and packaging to survive the high accelerations etc.

COTS IT is generally all right if it is employed in the environment for which it was designed and if it is the right tool for the job. Reliability growth programmes are important and MoD should be prepared to invest in system upgrades.

Testing

The US DoD does a lot of testing at board/equipment level to prove COTS IT. Sensible compromises are needed and software testing, which is quite as feasible, is just more expensive than hardware testing. MoD needs to do research on wrappers e.g. crypto and bit error correction. The Ballista programme in the US looks at UNIX inputs – some legal, some illegal – which can cause failure. It fires different parameters at the computer and examines the results. There is typically a crash on 10% of inputs! The results will be used to create wrappers that reject inputs, which are known to cause crashes. Operational training can also mitigate some problems.

9.1.11 Security

The armed forces need to think through security issues. Security is a big problem for transmissions to and from the platform. COTS software is straightforward to protect. However, fast crypto is very expensive and commercial crypto takes two to three years to get accredited.

Security requirements of commercial organisations are converging with military needs and civil products would be all right if only they were accredited. There will be a balance of technologies between opposing forces. Recognising vulnerabilities is important. With the numbers of military computers deployed, it is all but impossible for an enemy to know which to hack into. COTS IT is less EW resilient than custom military IT and is more vulnerable to information warfare that custom military IT. COTS software is seen as straightforward to protect and no more likely to be hacked into in war because of changes resulting from wide peacetime hacking attempts.

Viruses

There is concerned about binary viruses in application programs or operating systems where an apparently harmless message that doesn't look like a virus triggers the binary part already implanted. Viruses in COTS IT are likely to be worse than in bespoke systems.

9.1.12 Integration

Integration of COTS IT is a critical function and a key challenge. If COTS IT interfaces to military equipment, there must be a well-defined interface. The human/computer interface is an area that definitely needs improving. Integrating modular avionics needs a custom operating system. Potential problems arise when inter-linking COTS software with other software. There must be a well-defined interface. Form fit and function does not always provide a workable solution. Future equipment solutions will be a mix of COTS hardware and software together with bespoke software. Transparent interfaces and architecture to support growth are both required.

Modification

COTS IT products have short life and COTS IT is always modified for military use to some degree. There are dangers and problems in modifying COTS IT.

9.1.13 Support

MoD always wants to repair equipment. This policy dates back to World War II. It is unlike the commercial car where all the components are remarkably lifed to wear out at the same time and then the whole vehicle is thrown away.

DLO handles spares while the main equipment is in the hands of DPA. Some systems are being logistically supported long term by the contractor, with software support for 5 to 7 years. Some platforms, and submarines are a worst case, have a 90-day mission without any outside support for COTS IT or any other equipment. COTS IT needs a different maintenance policy from other military equipment and a suitable maintenance organisation. In practice, less flexible and less well-trained civilians often do the maintenance.

Obsolescence is a key factor as is long-term logistic support by contractors. There should be a lifetime purchase of COTS IT spares with the main equipment. There is an effective automatic technology upgrade as obsolescent printed circuit cards are updated. Primary upgrades should be only of that hardware necessary to support new software needs. Technology upgrades come automatically as obsolescence means that cards are updated automatically.

Could COTS be 'painted red' to identify it as needing special care? The burden of taking care is an issue, as is the burden of additional maintenance to meet the military requirement.

9.2 Key themes from the MoD/DERA interviews

So what were the important issues highlighted by people from the three different MoD organisations?

1. The use of COTS IT is rapidly becoming inescapable, and is already so at the component level. While the vast majority of MoD employees understand the policy of using COTS IT wherever possible, there are still some people, particularly those elder people still in junior posts, who do not support its use. The majority of people see many problems that need to be overcome before COTS IT can be employed widely. A change of culture is needed; particularly in ensuring requirement specifications are suited to the use of COTS IT. Furthermore, IT is generally not viewed as an interesting subject and senior officers are still afraid of it.

2. There are significant concerns that, although the initial cost of COTS IT is lower than of equivalent specially developed military IT, the total life cycle cost may not be lower. A benefit is that civil and military specifications are increasingly converging as the commercial market progressively embraces such features as mobility, ruggedness, non-toxicity and EMC.

3. Despite an initial wide choice, once locked into an actual COTS-based solution, finding competition can be difficult.

4. The way in which COTS IT should be maintained is different from the existing system for military equipment and requires a change of approach. The fact that MoD isolates its initial procurement budget from its support budget is seen as an obstacle to achieving minimum life cycle costs.
5. Open and commercial standards increasingly have to be accepted for COTS IT and this has meant some reduction in defence specifications in areas such as EMP. Wrapping solves many hardware and software problems but modifying COTS IT tends to be very expensive.
6. Security is seen mainly as a cost issue with the software interface, for example to crypto equipment, having to be changed every time an operating system or application program is upgraded.
7. Three major factors working against COTS IT are its unsuitability for safety critical applications, its demand for excessively wide bandwidths for radio transmission and its lack of robustness.

9.3 Summary of industry interviews

There is a noticeable lack of historical industrial experience of putting COTS IT into systems, though it is being widely applied to new projects for all three services. COTS IT modification is being avoided as far as possible. A key issue raised is the difficulty of system integration. It is still true that for most of the defence industry one thousand units represent a large volume, whereas millions are not uncommon in the commercial market place.

The emerging pattern seems to be:

- Prime contractors produce military solutions for MoD.
- Sub-contractors convert civil technology to meet military requirements
- Commercial suppliers offer COTS IT to prime and sub-contractors.

There is a growing acceptance that COTS IT is familiar to users and maintainers, and this is a clear advantage. However, MoD has just [25] procured a system with thousands of green screen terminals despite the fact that users want Windows®.

9.3.1 Industry's view of MoD

Inflexibility in MoD gets worse the further down the structure. People find it hard to change from their old system to a new one. ILS problems specified for COTS IT are totally impractical. MoD is not good at preparing requirements. The requirements keep creeping and take a long time to form. They are also very rigid. An early commitment to COTS IT parts is needed on large systems. Smart procurement and PFI may help solve some of these problems. There is a question as to why MoD doesn't fall in line with US DoD on COTS IT.

[25] In February 1998.

9.3.2 *Defence industry culture*

It is difficult to change the culture in large defence contractors, which accept that MoD does not pay for everything. Such organisations are tuned to MoD and resist change. Even a change of process may need a director to drive it through. The UK work culture and the lack of mobility of the work force do not help this. The defence industry needs to move into more rapid prototyping and paperless systems. Smart Procurement gives no relief to documentation, proof and testing.

9.3.3 *Company assessment and long term future*

Microsoft is recruiting 1,500 IT graduates per year and there are doubts whether US universities can keep up the rate of supply. There is a general acceptance that everyone is in the hands of Microsoft, but this is not seen as a problem and any could well change in the future. Several companies reported moving to NT-based systems.

9.3.4 *Availability*

Companies find it difficult to keep in touch with what COTS IT is available as each project deals with the market independently. If the US DoD changes a particular supplier of COTS IT, it is almost certain that UK MoD will have to follow suite. There is no continuity of supply or support.

9.3.5 *Standards*

A common approach revolves around the layered use of standards – open or Microsoft ones. Hardware is selected as late as possible in production of any system. The use of COTS IT in the UK's Battlefield Digitization Project is driving MoD towards layered standards.

The performance requirements of COTS software are still not well characterised. Specifications are unprovable as are requirements like bus loading.

9.3.6 *Differences in military and civil markets*

The growth of requirements in the military and civil markets differs as do the development cycles – military 7-10 years, civil 1½ years. The military are still widely tied to legacy systems. Only a small percentage of military systems require the latest IT.

9.3.7 *Operational considerations*

Three typical views are: COTS IT is a 60% -70% fit. COTS IT provides 95% of performance for 60% of cost but the other 5% of performance is very expensive. COTS give 85% of what is required. Facilities above the specification are inevitably included in COTS IT and it sets user expectations that may be too high for bespoke software. There is a strong feeling that COTS IT must be eliminated from safety critical systems. Bandwidth is a problem for remote armed forces and COTS IT is hungry for bandwidth. As an example quoted by someone interviewed, and subsequently verified, showed the word '**Attack**' (or any other six letter word) needs only 48 ASCII bits. However, a high overhead is imposed by COTS programs like Word and PowerPoint in providing information such as page size, orientation, margins, font types, sizes and colours, styles, spelling and language, particularly for short messages. An exercise for 1, 10, 100 and 1,000 words produced the results shown in overleaf.

Format	1 word	10 words	100 words	1,000 words
ASCII uses	48 bits	560 bits	5,100 bits	51,000 bits
MS Word 2000 uses	152,000 bits	152,000 bits	152,000 bits	192,000 bits
MS PowerPoint 2000 uses	64,000 bits	72,000 bits	96,000 bits	320,000 bits

9.3.8 Development issues

A faster way of developing military solutions is needed. Iterative deliveries of functionality can help but there is the danger of lagging one or two steps behind the latest COTS IT. Software size is no longer limited by hardware issues, but rather by new sensors with high data rates. There is no choice but to use COTS IT hardware at the component level, however lifetime component buys are usually out of the question because of production quantity uncertainties. There are major upgrades to the core kernel of COTS platforms [26] every 18 months. The size of Sun's operating system has grown 10 fold.

Modifying COTS IT

There is a high cost of modifying COTS IT but some companies are happy to do the modifications, which are still cheaper than developing from scratch. However, modifying COTS IT increase costs, time scales and requires repeating for system upgrades. Thus, it is better to choose COTS IT that can be tailored.

Updates

For platform [27] upgrades, the shape and size of the enclosure has to match existing space. The ASARC study of modular avionics is looking at hardware/software independence and also incremental certification. Both ease system upgrading.

9.3.9 Delivery

It is difficult to define hand over for IT intensive systems – functionality can be traded off against timescale. COTS IT suppliers deliver to suit themselves and may divert items to bulk purchasers.

9.3.10 Cost

Initial procurement of COTS IT is cheap, but its use in military projects leaves a number of issues to be solved. A real issue is the MoD separation of procurement and repair budgets. The cost of modifying software is a repeat cost. It is possible to trade off failure rate against initial cost but this is difficult, as MoD still does not look at life cycle costs. Several companies mentioned the need to spend more up front to keep whole life costs low.

9.3.11 Risk

Both MoD and industry want to minimise risk. However, DPA is very risk averse and the nature of defence projects involves risk, especially in company-funded developments. Large organisations are now using the latest risk assessment tools and are facing up to the need to take risks. Smart procurement could solve the problem by co-operative risk sharing. The US are now

[26] Used in the sense of computer platforms.
[27] Used in the sense of ship, vehicle and aircraft platforms.

co-operating with contractors up to the start of the competitive phases. Typical project failures lack front loading and are under planned, under resourced and under modelled.

9.3.12 Contract terms/conditions

Large IT companies sell to standard terms and conditions. Niche companies will accept buyer's terms. Suppliers, particularly dealers, will sometimes make commitments that cannot be met. Contractors often have to deal with middlemen because of distance to USA and Far East, also because of lack of volume. They often find it hard to get a response to technical queries.

The defence industry is unable to flow down MoD terms and conditions to COTS IT suppliers. The smaller defence contractors only require small quantities of COTS IT and as a result have little pull with suppliers. They try and build supplier/purchaser relationships because of their lack of sway with the supplier unless they are the first purchaser of a new model or the supplier is a niche one. Defence contractors normally require certificates of conformance, which large suppliers are not prepared to provide. Specifications are negotiated for COTS IT. Sub-contracting must be done to careful specifications, avoiding the use of many inspectors by both parties.

9.3.13 Mil/Def spec requirements

Environmental specifications need the contractor to work with MoD to see the environment itself. It is critical to avoid over specification. EMP is a problem, particularly with the growing replacement of metal with composites. MoD is prepared to relax EMP requirements but is still concerned about the effect of electro-magnetic weapons. At least one company implied that MoD are not prepared to relax standards on EMC or Tempest.

COTS IT is getting smaller and more rugged but there is still a need to look at robustness. The use of COTS IT in weapons and satellites is low because of the tough physical environment. Some companies take a pragmatic view of survivability of COTS IT hardware, but wrapping COTS IT hardware in containers and/or using shock mounts is widespread. Cost effective turnkey enclosures to protect commercial circuit boards are available that deal with thermal management, shock and vibration, EMC, power supplies and connectors and cabling. Less than half of commercial circuit boards need stiffeners or coatings. It is possible to get COTS processors mounted on COTS boards manufactured to more demanding standards. Only extreme shock on, for example hard disks, remains a problem.

9.3.14 Efficiency/performance improvements

In efficiency terms, information presentation is much improved. Proof of full COTS IT performance at delivery is impossible and should be based on a certificate of conformity.

9.3.15 Security

Security is the biggest problem and relaxation by MoD on security does not seem possible. MoD requires security in the sense of ticks in boxes and is starting to think about placing trust in the user's hands. Security audits limit the range of suitable operating systems, usually to obsolescent ones. There is the possibility of contamination if using a COTS operating system. This needs physical, design and architectural security.

Modification of each new or updated application, to meet the security interface, takes time and is expensive. The same is true each time the operating system changes. Thus there is the question of the affordability of maintaining the applications, operating and security systems each time any of them is changed or updated. However, security provides good revenue for some IT companies.

Encryption is implemented outside the system. Classified secure systems are not connected to any open network [28]. However, open systems are more open to hostile attack. At present, data and software are separate, but this is likely to change with intelligent systems. Large chunks of any aircraft will be electronically connected to the service organisation. All avionics and sensors will input and output a great deal of data. An infrastructure is needed to handle the data with integrity.

Viruses

Viruses are a worry to industry, are not well dealt with and are an equal risk for military and COTS software.

9.3.16 *Qualification*

Qualification of COTS IT must be done on a different basis to bespoke IT. It must be done at the start and requires a change in the ways of operating. There is still a legacy approach to requirements for testing. Both test and qualification are considered to be key issues.

9.3.17 *Traceability*

Configuration control and traceability are issues, particularly on COTS IT. Manufacturers change their designs without telling their customers. Build standards change from item to item which are supposedly identical, and suppliers are reluctant even to say that they have made changes.

9.3.18 *Reliability*

Old Mil D standards gave horrendously poor reliability figures for COTS IT, but it is not seen as less reliable than bespoke IT. It has been well tested. However, it can be difficult (near impossible) to get adequate reliability calculations for commercial components.

Bugs

Microsoft won't fix bugs but niche software suppliers will. New bugs are found in COTS software as military requirements push the boundaries. Sun's Solaris has a monthly CD ROM with bug fixes. The US is investing to reduce bugs and increase reliability. Army bespoke software is full of problems.

9.3.19 *Support*

There is a high cost of supporting COTS IT and an issue already covered under 'cost' is the separation of the procurement and repair budgets in MoD. Furthermore, the complexity of many systems is not immediately apparent.

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[28] This is beginning to change at the Restricted level.

Support is also a concern due to COTS IT obsolescence and conservative buying. The real life of electronic equipment is only about five years because of performance improvements, obsolescence and lack of support for COTS IT beyond this time. There is also a lack of continuity amongst suppliers' staff. It is thus important to keep in the mainstream of COTS IT developments. COTS IT requires much more care with its interfaces to allow later replacement. Some companies purchase lifetime supplies of components, mainly for older equipment.

There is a need for a close relationship between the supplier and MoD if effective support is to be provided, and contractors can maintain equipment permanently based in the UK or that never deployed into war zones. There is an opportunity to follow the example of the automobile industry that has a harsh operating environment and large volumes but still offers qualified spares for 10 years that are form, fit and function compatible. Low volume makes repair cost effective and 'throw away' too expensive. With engineering time at £50/hour, a throwaway and replace policy for cheaper items looks cost effective.

Documentation

On line help is satisfactory. However, there is still a legacy approach to requirements for documentation and testing. Bug fixes cause documentation problems. Even small changes may impact on handbooks and other documentation. The cost of PDS to change handbooks is disliked by MoD and each cost has to be justified. MoD's attitude is considered inflexible.

Training

There is an issue in providing training for large scale COTS IT. The training problem is mainly a handbook one.

9.3.20 Rapid obsolescence

The life cycle of COTS IT makes availability an issue. Electronic obsolescence is already a problem with Eurofighter even before it enters service. The rate of change of hardware is a problem. A system for the army, five years ago used 386s: last year [29] it used Pentiums.

A missile for MoD used three different processor chips during development. An ASIC design for a processor can disappear in three years and the design tools become obsolete as well. ASICs become obsolescent during qualification, which is a real issue for subsequent production. ASIC foundries are being driven by the rate of change of commercial IT. One time buys are a possible solution, but only if a production contract with firm quantities is guaranteed. Some companies may make a large buy with obsolescent parts in store. This is still a problem if items change between tranches. It could be possible for the defence industry to use their trade associations to purchase items in bulk for the whole industry. Late spares orders can be a particular problem due to obsolescence. Manufacturers have different NATO stock numbers for identical items and this applies even for a firmware change on a card with the same processor and memory modules.

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[29] 1997

The typical service life of military aircraft is forty years and a manufacturer may have a product range of ten different aircraft. Major upgrades may or may not involve altering the avionics.

9.3.21 Disposal

Failed hard disks have to be physically destroyed if security is to be maintained.

9.4 Key themes from industry interviews

So what were the important issues highlighted by people from industry?

1. The use of COTS IT is becoming inescapable and is already so at component level. However, it is unsuitable for safety critical applications and demands excessively wide bandwidths. The life cycles of military and civil markets differ. COTS IT maintenance requires a change of approach.

2. Although the initial cost of COTS IT is lower than military IT, total life cycle cost may be higher. Wrapping COTS IT hardware in containers is widespread but MoD must relax EMP and Tempest despite electro-magnetic weapon concerns. Modifying COTS IT is expensive and time consuming but is still cheaper than bespoke development. MoD separation of initial procurement and support budgets is an obstacle to minimising life cycle costs.

3. COTS IT has a short life cycle with no continuity of supply or support. It is difficult keeping in touch with what COTS IT is available. Lifetime component buys are impossible due production quantity uncertainties.

4. Civil and military specifications are converging due the civil importance of mobility, ruggedness, non-toxicity and EMC. Open and commercial standards must be accepted for COTS with some reduction in defence specifications. Configuration control and traceability are both problems and there is still a legacy approach to testing and documentation

5. The inflexibility of both MoD and large defence contractors is hindering the widest use of COTS IT in operational military equipment.

6. Security is a huge problem and any relaxation by MoD seems unlikely [30]. The issue is mainly one of cost.

9.5 Overall conclusions from the questionnaires and interviews

In an effort to provide a homogeneous view of the information gained from MoD DPA, ECC and DERA, and industry, the analysed data from the questionnaires and the summaries of the various interviews were matched together leading to the following conclusions:

1. There is overwhelming support for the widest use of COTS IT, although a few people in MoD are still against it. There is acceptance that its use is becoming inescapable despite many problems to be overcome. Requirement specifications must reflect the potential to use COTS IT. A culture change is needed, both in MoD and the defence industry, to obtain

[30] Significant changes are presently being planned by MoD.

the maximum benefit from COTS IT. Furthermore, IT is generally viewed as an uninteresting subject and senior officers are still afraid of it.

2. Almost all companies use COTS IT in military equipment for MoD as well as other customers. There are polarised views on whether COTS IT hardware will need modification for many applications and whether COTS software can easily be interfaced with bespoke software. Industry has difficulty keeping in touch with what COTS IT is available.

3. Although the initial cost of COTS IT is lower than bespoke IT, the total life cycle cost may be higher than that of specially developed military IT, particularly the cost of implementing military security standards. Modifying COTS IT is very expensive and time consuming but still cheaper than scratch development. However, its lack of military specifications will cause problems. MoD separation of initial procurement and support budgets is seen as an obstacle to minimising life cycle costs.

4. COTS IT is better suited to use in sensors, C^3I, electronic warfare systems, intelligence systems and air defence systems than in weapons and their launchers. It is unsuitable for safety critical applications, but there is wide support for its use on platforms:
   - 90% of responses support using COTS IT on board warships and submarines.
   - 80% of replies back the use of COTS IT in tanks and reconnaissance vehicles.
   - 67% of responses support the use of COTS IT in all types of aircraft and helicopters.

5. Industry feels that companies bidding and accepting MoD contract terms is much less probable than does MoD. There is unlikely to be a lack of competition until a particular solution has been chosen, and IT companies differ little from defence ones. However, views are polarised about whether COTS IT will be available long enough to be purchased in normal MoD time scales.

6. Maintaining COTS IT requires a different approach from military equipment. COTS IT has a short life cycle, especially compared with military equipment, with no continuity of supply or support, and production quantity uncertainties prevent lifetime component buys. COTS IT is thought to be marginally more reliable than its custom counterpart. There are likely to be problems with COTS IT obsolescence giving long-term support difficulties.

7. A benefit is that civil and military specifications are increasingly converging. Open and commercial standards must be accepted for COTS IT with some reduction in defence specifications but with a need for further relaxation. Configuration control and traceability are both issues and there is still a legacy approach to testing and documentation. Wrapping solves many hardware and software problems but modifying COTS IT tends to be very expensive. Furthermore, there are worries about COTS IT bandwidth demands at a time when data transmission is mushrooming, and doubts about its performance in war.

8. Security is likely to be a key problem despite a minority in MoD and industry disagreeing. It is seen mainly as a cost issue, with interfaces having to change every time an operating system or application program is upgraded. Industry views any security relaxation by MoD as unlikely. Viruses will be more of a problem and bugs will probably be less of one.
9. Industry is slightly more positive than MoD that IT, not just COTS IT, should improve the efficiency or performance of MoD, and most support the view that COTS IT is familiar and thus easy to use.

10 US NAVY EXPERIENCE WITH COTS IT

This section examines the US Navy's background in using COTS IT in operational military equipment and how it is tackling its procurement. The information has all been gathered from data published on the Internet. Some conclusions are drawn about the Navy's approach to COTS IT.

10.1 Data gathering

A search was made of the Internet using a number of 'words', such as US, Navy, COTS and IT. These searches not only produced useful facts and figures in themselves, but also led to US Navy web sites that were also a productive source of information.

10.2 COTS Steering Board [cxviii]

A COTS Steering Board has been set up to guide the US Navy Sea Systems Command in the rapid introduction, maximisation of opportunities, and minimisation of risk associated with COTS IT product utilisation. This guidance includes identifying the most efficient tools and processes for use through the life cycle.

10.3 Software [cxix]

The US Navy plans to use COTS operating systems such as UNIX, VMS, and the ADA[31] operating environment. It does not plan to use custom operating systems when it is possible to use commercially developed products. The Navy will have greatest use for operating systems that support Multi-Level Security (MLS). However, it also needs to process unclassified information and may choose non-MLS operating systems in these environments for cost reasons.

By using a standard human-machine interface, based on COTS IT products, the Navy will greatly improve the productivity and accuracy of personnel by avoiding the need for extensive retraining before moving to a new duty station.

The US Navy intends to use COTS IT products extensively for generally needed applications such as word processing, spreadsheet, text search, data base maintenance and query, and graphics. The Navy may require specialised COTS or GOTS for functions such as computer-aided analysis, managing specialised or multi-level secure data bases, manipulating and displaying high-resolution imagery, and preparing reports in joint and allied formats.

COTS IT can be used for the following typical functions, though some may require adaptation:

- Theatre and regional situation monitoring.
- Map and chart display and editing.
- Land, air, and maritime order of battle and technical databases.
- Campaign plan simulation and modelling use of scarce logistic and repair resources.
- Situation assessment and alternative assessment briefings to decision makers.

[31] MoD no longer prefers ADA.

Most application software services require GOTS application software because of limited commercial application or a degree of trusted software certification not encountered in commercial uses. Other application software services, such as word processing, may be COTS IT. The Navy will employ COTS IT as much as possible, both as a cost saving measure and to benefit from commercially produced upgrades.

10.3.1 IT-21 Databases [cxx]

Relational databases that can support web technology as well as the COE (Oracle, Sybase, SQL server, Access, etc.) will be used to support data requirements and application development. All process engineering initiatives that result in design/redesign of a data collection/capture system must use COE-compliant relational database management systems software. This requirement should ensure relational database management systems initiatives use COTS application software.

10.4 $C^4$1 [cxxi]

Four building blocks, network services, hardware, operating systems, and software applications/utilities, will provide $C^4$1[32] capabilities for naval forces operating at all levels in the spectrum of conflict. The design and implementation of building blocks in a modular, open system design and using COTS and GOTS IT products will provide a pathway for frequent modernisation at low cost. Operational users will move from afloat to ashore without the need for retraining.

C^4I systems that do not utilise high percentages of COTS software are strong candidates for cancellation as non-supportable. However, all new software that is written will be in ADA.

10.5 Mine warfare ships [cxxii]

The Mine Warfare community implemented an innovative acquisition reform approach in its equipment upgrade and ship modernisation efforts, including an accelerated COTS replacement of the Mine Countermeasures Machinery Control System. Using proven Smart Ship equipment design, plans were initiated to replace the existing 1970's era analogue control systems with a commercially supportable digital Integrated Ship Control System (ISCS). Installation of new ISCS units was projected for FY 1999 on eight ships of the Class.

10.6 New attack submarine [cxxiii]

Acquisition reform continued to pave the progress of the Navy's New Attack Submarine towards lead ship construction in FY 1998. Key to the success of the program has been the use of Integrated Product and Process Development Teams to ensure the most efficient design early in the development process. In addition, the use of Open Systems Architecture, the insertion of advanced COTS IT technologies, and the application of modelling and simulation will reduce risk and total ownership costs.

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[32] C^4 is only used here as a direct quote from Military Review.

The command centre for the U.S. Navy's new attack submarine will use 78% COTS IT hardware and software. The prime contractor expects this approach to reduce development and procurement costs by 80%. 4.1 million of the submarine's total of 5.4 million lines of code will be off-the-shelf. Other non-developmental software should help reduce the total for the submarine's UNIX-based software system to 485,000 lines of code. The use of an open system architecture in conjunction with COTS IT should substantially reduce the number of electronic modules in the command centre.

10.7 Acoustic Improvement Program [cxxiv]

The Acoustic Improvement Program for submarine sonar systems takes advantage of new technologies available in COTS and other non-developmental hardware and software rapidly to develop and deploy new operational capabilities. This approach will allow substantial growth capacity for future upgrades. The Acoustic Rapid COTS Insertion program is a four-phase evolutionary development program that ensures acoustic superiority for the SSN 688, 688I and SSBN 726 classes of submarines

10.8 Multi-Sensor Torpedo Recognition and Alertment Processor (MSTRAP) [cxxv]

MSTRAP gives the US Navy surface ships a high capability torpedo alert system for defence against torpedo attack. The MSTRAP system features an open architecture approach and is largely based on the use of COTS electronics and existing housings. This approach should result in reduced costs and shorter time scales when incorporating future combat system upgrades.

The first of 20 MSTRAP systems was delivered in June 1995 and a further 14 will be delivered early in 2000. MSTRAP is a torpedo defence system designed for surface ships that processes ship sensor data to detect, classify and localise threat torpedoes. The system includes a high-power digital signal processor with advanced software algorithms and can display the results on any Windows-based multi-function console. MSTRAP uses COTS and NDI components that reduce overall system costs by a factor of four compared with previous systems.

10.9 Aegis cruiser modernisation [cxxvi]

The Aegis program is firmly focused on the introduction of technology initiatives to streamline fleet modernisation efforts. The Aegis Cruiser Conversion Plan extends the service life of Ticonderoga Class Cruisers and introduces significant new war fighting capabilities, beginning in FY 2003. Driven by the increased processing requirements of a modern, state-of-the-art combat system, the Naval Sea Systems Command expanded the use of COTS subsystems, equipment, and components in AEGIS Weapon System development, ending its long-standing reliance on standard, embedded computing resources.

10.10 Accelerated business process improvements [cxxvii]

Accelerated Business Process Improvement is the last phase in the Naval Tactical Command Support System program. Execution of this program is evolutionary, starting with the legacy systems on proprietary hardware and software. The legacy systems are replaced with 'state of the shelf' COTS IT hardware and software operating systems that comply with the COE standards. The legacy software is 'ported' to a form that will run in the new environment, or emulators are used. No change in functionality occurs at this point, however, system speed is greatly increased and hardware maintenance costs are greatly reduced. In the next phase, the software is 'optimised'. Again, no change in functionality occurs; however, operator productivity is increased and software maintenance costs are greatly reduced. At this point, the foundation has been laid for changes in functionality via Business Process Improvements.

This approach was first used with the Automated Maintenance Environment effort, which is an improvement to the business processes supported by the Optimised Naval Aviation Logistics Command Management System. It is a reengineering of the maintenance process used to support F/A-18 aircraft with future applicability throughout the Fleet. There were prototypes in the Fleet, which have been used to measure benefits and estimate the future value of the improved business process. The Naval Tactical Command Support System Program Office has performed an analysis of the prototype and delivered a Business Process Improvement Management Plan that is estimated to result in cost avoidance totalling $345M over the system life cycle.

10.11 Defense message system (DMS) [cxxviii]

10.11.1 General Description

The Defense Message System (DMS) will be the primary means of electronic messaging within the US DoD in the 21st century. It comprises the hardware, software, procedures, standards, facilities and personnel used to exchange messages electronically within DoD and among other authorised users. It provides an integrated, global information COE for the US DoD for peacetime operations, and both tactical and mobile crisis situations. The DMS program must respond to the dramatic changes in technology and the evolving needs of its users. Flexible system architectures are key to implementing evolutionary systems. They allow a blend of COTS IT and developed capabilities to meet DoD needs, and through this leveraging of the commercial technology and industrial base, provide a range of economical and effective services.

By accepting a flexible architecture, with implementation tailored to provide the different levels of service required by specific user communities, DMS can receive the advantages of commercial technology development surrounding the Internet and move closer to COTS technology without impacting the capability required to support C^2 and allied messaging. The DMS will evolve into a flexible, COTS-based service that provides a full range of message security/assurance levels and grades of service to the C^4I user.

To reduce life cycle costs, DMS hardware will use standardised components where possible, employ modular design, use COTS/NDI products, and use 'design to discard' where repair is not economically feasible. The Management Workstation is the primary tool for network management at all management levels and includes a suite of COTS products.

In considering the type of service required, DMS users, are considered to fall into two basic classes, both of which can be met by COTS products:

- Critical C^2 users (high-grade messaging with high security assurance).
- General users with less stringent performance requirements.

The DMS is, as far as possible, a COTS/NDI item using COTS/NDI acquisition. No ILS studies have been required of the vendor. There are no requirements for parts standardisation or commonality with items provided through the defense supply system, since there is complete dependence on contractor logistics and maintenance support. There is, however, a requirement for commonality of contractor-supplied components. The DMS will also use hardware that is already installed where compatibility can be maintained.

10.11.2 The Convergence of DMS and Commercial Communications

The DMS uses COTS products to the maximum extent possible to exploit commercial trends. The emergence of the World Wide Web sparked a rush by commercial companies to provide Internet based products. The extension of Internet messaging capabilities to provide functional equivalents of many X.400 services is enabling many users to choose Internet mail as their 'business grade' messaging system. DoD needs, especially for C^2 users, may still exceed COTS IT capabilities, but over time that gap grows smaller.

While COTS products will serve many DoD requirements, it cannot depend on commercial evolution to provide essential capabilities for C^2 grade messaging. Some features are simply of insufficient interest to the market to warrant investment by commercial IT suppliers. Other capabilities may be addressed eventually, but DoD users may not be able to wait. Key activities for DoD to speed the convergence process are to:

1. Review DMS functionality and requirements to determine where Internet technology might come closest to meeting DMS needs.
2. Review requirements process to determine what is driving customisation, and revise original requirements wherever possible to meet COTS.
3. Create a flexible architecture that can accommodate a range of protocols and services and selected vendor native protocols.
4. Develop a tiered architecture of security requirements. Especially where unclassified data are concerned, this should map to electronic commerce and commercial cryptography services.
5. Revise the overall product acceptance methodology to foster more rapid prototyping, procurement, and deployment of new technologies.
6. Participate in industry forums to influence standards, communicate DoD requirements and experiences to the marketplace, and form alliances with the commercial sector.

The key element to achieving commercial convergence and rapid integration of new technologies is a flexible architecture that can adapt to changes in user requirements and technologies. Technologies may be updated and introduced as needed, without disrupting services. The DMS goal is to converge commercial business grade and high-grade/high assurance messaging. Flexible architecture supports this by:

- Providing a path for the introduction of multiple Internet and commercial products.
- Developing operational experience with large-scale deployments of COTS IT products.
- Deployment of local/backbone infrastructure for both high grade and COTS messaging.

To take advantage of the rapid pace of technological advancement for the DoD, DMS must evolve along with COTS IT products, while meeting the diverse requirement and cost efficiencies that community. It supports the use of products from multiple suppliers, and allows for the rapid introduction of new technologies and products.

10.12 Navy ILS implementation plan for TC AIMS II [cxxix]

TC-AIMS II will be integrated into all facets of transportation operations within the Navy and will provide a suite of systems capable of supporting day-to-day sustainment, and contingency transportation planning and execution. It will provide Navy users with the capability to use a joint system to effect transportation planning and execution during peace and war.

Navy fielding concept provides for TC-AIMS II software to be submitted (with easy loading instructions) for loading on stand-alone workstations computers, LANs, deployable notebooks, and robust servers. The software will be designed to provide each user with the ability to create, print, and exchange documentation on workstations and/or deployable notebooks. Robust servers will be used for data storage and replication.

COTS/NDI hardware and associated software will be used. Unit level applications will reside on workstations and deployable notebook computers. Units will be connected to one robust server and one backup server for data replication and storage.

10.13 Submarine countermeasures [cxxx]

The LEAD defensive subsystem integrates existing submarine countermeasures, the US-ADC MK2 and UK-2066 with proven chaff and infrared launching systems. The LEAD design is totally based on existing systems and is truly an NDI item. The approach taken with LEAD makes it instantly compatible and launchable from every surface ship in the U.S. Navy and virtually all allied navies.

10.14 US Marine Corps policy on IT procurement [cxxxi]

The Marine Corps has delegated procurement authority to the commanding general, commanding officer and headquarters Marine Corps flag/SES levels for the following it programs:

1. IT acquisitions with total program costs less than or equal to $10,000,000.00 where:
    a) There is no software development.
    b) All acquired IT assets comply with the US Marine Corps minimum desktop computer configuration and US Marine Corps COTS and GOTS software standards.
2. IT software development programs with total program costs less than or equal to $250,000.00.

10.15 Information warfare [cxxxii]

The US government reported that during 1995, there were 250,000 attempts to penetrate US military computers. It estimated that 65% of attacks were successful but that only 1 in 150 such attacks is reported. It also is extremely concerned about the success of its 1995 information war games in causing serious problems to transportation, banking and telephone systems, while a virus was used to paralyse weapon systems. It is taking action to assess vulnerabilities.

10.16 Legacy systems replacement [cxxxiii]

The US Naval Undersea Warfare Division has plotted the timescale for replacement of legacy systems by COTS-based ones over a twenty-two year period ending in 2017. Figure 27 shows just how long it will take for their systems fleet population to get COTS IT into service. Such a profile is typical of that likely to be found for the replacement of other legacy systems.

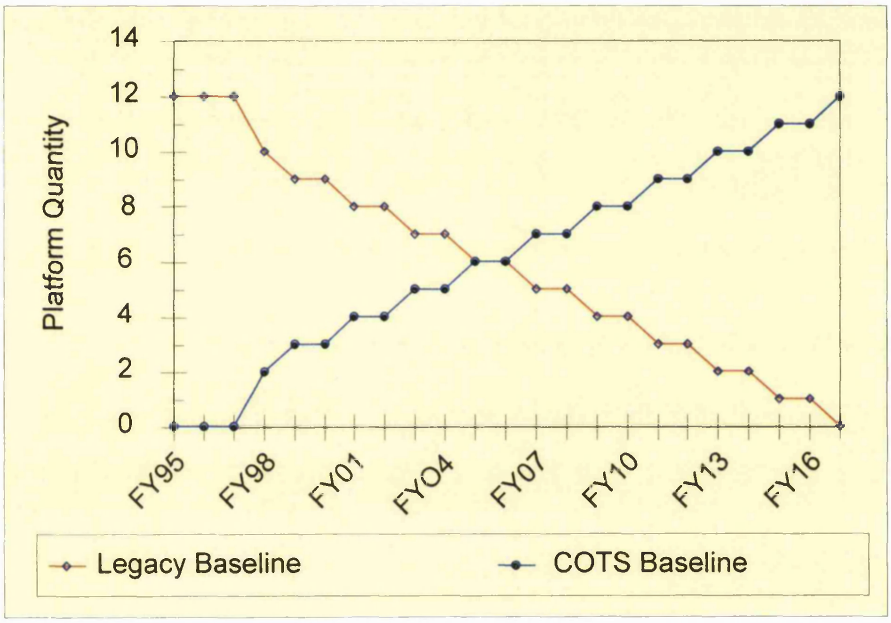

Figure 27. US Naval Undersea Warfare Division legacy & COTS systems fleet population.

10.17 Conclusions

It is clear that the US Navy has enthusiastically embraced the use of COTS IT and is already seeing a significant reduction in the initial acquisition cost of many programs. It is enthusiastic about the benefits of COTS IT and expects to see a significant reduction in through life costs as well. It does have the advantage of a wide range of COTS IT suppliers based in the US, where it can put on pressure, not only from a nationalistic point of view, but also as a result of the size of its budget. It has also set up a COTS steering board to help the Navy obtain the greatest advantage from its use of COTS IT.

11 IMPLICATIONS FOR MoD IN USING COTS IT

This section looks at the possible implications for MoD of using COTS IT in operational military equipment. The implications are based on an examination of all the data sources and analysis throughout Sections 4 – 10.

The inferences in this section are drawn from the information gathered from the literature search, the data obtained from the questionnaires and interviews as well as the experience of the US Navy in using COTS IT.

11.1 Attitudes to COTS IT

The policy that COTS IT should be used wherever possible in MoD purchases has overwhelming support, but there are doubts about its performance in war and concerns about its total life cycle costs. There is recognition of the need for a major change in maintenance policy and worries about the cost of implementing military security standards. It is accepted that COTS IT use is becoming inescapable.

Some older members of MoD, particularly those in more junior posts, do not want to see the use of COTS IT in operational military equipment. Many of these people are employed in support roles such as reliability, quality assurance and handbooks. As such, they have considerable influence in areas where COTS IT cannot meet existing military specifications. They may well fight an active rearguard action.

11.2 Where COTS IT might be used

There is most support for the use of COTS IT in ships, but also wide support for its use tanks and aircraft. COTS IT is better suited to use in sensors, C^3I, electronic warfare systems, intelligence systems and air defence systems than in weapons and their launchers. It is considered unsuitable for safety critical applications and there are concerns about its bandwidth demands.

11.3 The cost of COTS IT

The initial cost of COTS IT is lower than bespoke IT but modifying COTS IT tends to be expensive and time consuming though it is still cheaper than developing bespoke solutions. Furthermore, the total life cycle cost of COTS IT may be higher than specially developed military IT, despite a lower initial cost. Equipment using COTS IT needs to be maintained differently if through life costs are to be controlled.

A more linear through-life spend profile for programmes is essential for equipment incorporating COTS IT. This is due to the rate at which COTS IT becomes obsolete and therefore unsupportable, thus requiring replacement.

There is a need for MoD to establish ways of ensuring adequate security and EMC for COTS IT and managing the potential cost of ensuring this compatibility. Modifying COTS IT will increase support costs and in time divorce the modified solution from standard COTS. There are also significant problems and costs involved linking COTS software with other programs. However, most if not all major systems will require either some modification to COTS IT or the use of bespoke hardware and software.

11.4 Issues to be addressed

Rapid progress has been made and will continue to be made in all areas of IT. The impact of the defence sector has become relatively unimportant in terms of the overall development of IT and military-qualified components are rapidly disappearing. Thus there is no alternative but to use COTS IT though some tailoring of applications may be needed. These factors indicate that MoD will continue to depend increasingly on COTS IT for its information technology requirements.

Change is needed in the MoD's traditional approach to acquisition of COTS IT. There is a need for a set of guidelines on the use of COTS IT in military equipment. MoD's Smart Procurement initiative can help to get the best from the use of COTS IT.

COTS IT should be planned in basic system designs so that new technology insertion can readily be implemented and care taken in the architectural approach. COTS products rarely match the military requirement and normally contain undocumented features. Furthermore, COTS IT is more vulnerable and less robust, though many inadequacies can be wrapped. Suppliers tend to exaggerate product capabilities making an objective product assessment difficult. There are also problems involved in the use of COTS IT in safety critical systems.

11.5 Potential benefits of COTS IT

The reduction in initial purchase cost of COTS IT has already been mentioned. It also allows easy upgrades and the capacity to remain close to the state-of-the-art. Shorter project implementation time scales are made possible by COTS IT use. Equipment embodying it should also have improved flexibility and better interoperability with other systems incorporating it. Civil and military specifications are converging, providing improvement in areas such as ruggedness, weight reduction, EMC, portability, mobility and security. The use of COTS IT is also beneficial in reducing programme risk, should improve performance and is familiar and thus easy to use.

11.6 Problems using COTS IT in military equipment

11.6.1 Specification

Requirements trade-offs are needed if COTS IT is to be used, especially as military requirements often include very tough environmental conditions. This requires a change of thinking by Equipment Capability Customer staff. A consequence of the use COTS IT must be the acceptance of open standards, rather than military ones. They are important in allowing compatible upgrades, as well as providing system flexibility. Interoperability may be eased but there are still likely to be interfacing difficulties.

11.6.2 Product control

MoD will not have any product control over the continuity of support or the future development of COTS products it acquires. There are also problems with lack of traceability and poor configuration control; the former a particular issue for safety critical systems. At the same time there is an increasingly rapid rate of COTS IT obsolescence.

11.6.3 Security

Security is likely to be a costly problem and industry views any relaxation of security by MoD as unlikely. However, new technology in commercial areas such as banking and e-commerce is helping to overcome a number of COTS IT security difficulties.

11.6.4 Support

Maintaining COTS IT requires a different approach from other military equipment. It is not designed for maintenance and has a short life cycle with no continuity of supply or support. This short lifetime is in stark contrast to the long lifetime of military equipment, particularly platforms. Lifetime component buys by industry are impossible due to production quantity uncertainties. Thus long-term support is a significant issue that needs to be resolved. The establishment of a means of centralised COTS IT component monitoring might help manage obsolescence.

11.7 The procurement implications of using COTS IT

MoD needs to accept the industry view that getting companies to bid is more difficult and that MoD contract terms are less acceptable than MoD thinks. There is plenty of competition for new procurements in the COTS IT field, though it may be hard to find competition for COTS IT upgrades. IT companies are thought to differ little from defence ones. However, views are polarised about whether COTS IT will be available long enough to be purchased in using normal MoD processes and time scales.

The initial purchase cost of COTS IT will be less than for custom IT, but military specifications will cause problems. However, going COTS IT route forces MoD to follow the largely non-competitive upgrade route when suppliers cease support. MoD must be prepared to invest in system upgrades. Integration is a critical function and a challenge for military equipment employing COTS IT.

11.8 The operational implications of using COTS IT

The use of COTS IT should improve performance and efficiency. It is familiar to members of the armed forces and easy for them to use. There is a slightly lower chance of bugs in COTS IT than in bespoke military IT, balanced by slightly greater chance of viruses. COTS IT has about same or slightly better reliability than bespoke military equipment.

11.9 MoD budget

It is the view of the author based on the experience of three decades working in industry, that the splitting of the MoD budget between DPA and DLO will inevitably and increasingly drive DPA budget holders towards the purchase of equipment with the minimum initial procurement cost, even if the in service support costs are likely to be slightly higher. This view is supported both by those in MoD and those in industry.

11.10 Conclusions for MoD

There is no doubt that COTS IT is here to stay and that UK MoD must learn to employ it to best effect. This will require MoD to:

1. Set up guidelines on acquisition and through-life support of equipment incorporating COTS IT.
2. Manage the differing life cycles and development time scales of military equipment and COTS IT.
3. Continually update COTS IT-based projects by a different approach to funding.
4. Implement a different maintenance policy for COTS IT from that for existing bespoke equipment.
5. Avoid insisting on the application of many existing military requirements to COTS IT.
6. Manage the security issues and bandwidth requirements of much COTS software.
7. Research how to use COTS IT in safety critical systems.

12 CONCLUSIONS/RECOMMENDATIONS

This section looks at the outcomes of the research programme and provides answers to the eight questions posed in Paragraph 3.1. It summarises the issues that MoD needs to address and concludes with an unanswered question.

There are six main outcomes of this research:

1. Analysis of the information obtained from the various bibliographic sources.
2. The design of the COTS IT circle to assist those involved with COTS IT in military equipment.
3. The results of the analysis of the 547 completed questionnaires that were returned.
4. The outcome of the discussions during forty-six personal interviews.
5. The review of the experience of the US Navy with COTS IT.
6. The conclusions drawn from items 1-5 above.

One of the major issues has been the limited time and effort available for the wide scope of this research in a fast changing field. Inevitably it has not been possible to cover some areas. As a result, a number of items that could usefully be tackled in the future are listed in the final section.

In order to examine the use of commercial off-the-shelf information technology in operational defence equipment, the responses to a number of key questions have been established. Beneath each question is a summary of the answers to it:

12.1 To what extent does UK MoD envisage needing to rely on purchasing IT hardware and software, for what purposes and what efficiency improvements are likely?

It has been shown that MoD has pervasive requirements for both IT hardware and software. Furthermore, it has been demonstrated that there are few areas of military activity that do not rely, to a greater or lesser extent on the use of IT, whether stand alone or embedded in a platform or other piece of equipment. Furthermore, there is a strong feeling that the use of IT should improve both performance and efficiency.

12.2 What is the attitude of MoD to the use of COTS IT and what are the plans for its purchase and use?

There is overwhelming support among MoD employees for the use of COTS IT in military equipment wherever possible, and in business systems, although there are still just a few people who disagree with its use. Perhaps more important is the view that IT is generally a dull and tedious subject. Even worse, many junior officers see senior officers as afraid of IT.

There is wide support use of COTS IT in:

- Ships and submarines, particularly by those with a naval affiliation.
- Tanks and reconnaissance vehicles, though support is lowest from those working with land-based equipment.
- Aircraft and helicopters, though again support is lowest from those working with the army.

The consensus of opinion is that COTS IT is better suited to use in sensors, C^3I, electronic warfare systems, intelligence systems and air defence systems than in weapons and their launchers. The initial procurement of COTS IT will cost less but there are serious concerns about increased life cycle costs. Military specifications will cause problems but the use of COTS IT will improve efficiency, performance and the reliability of equipment. There is considered to be a lower chance of bugs but a larger problem with viruses. There is some ambivalence about the potential performance of COTS IT in wartime in comparison with the performance of custom-built military equipment.

MoD has already purchased much COTS IT for use in business applications in its permanent headquarters in the UK. It has a wide range of current and planned operational equipment programmes utilising COTS IT, including the joint operations centre at Northwood, and its plans for battle space digitization will see the widest application of COTS IT. While research is also looking at COTS IT opportunities, there are still some areas, such as weapons, their launchers and safety critical systems, where the use of COTS IT has yet to be embraced.

12.3 What problems are likely to affect such purchases?

It is accepted that using COTS IT is becoming inescapable; it is already so at component level. However, it is not well suited to safety critical applications because of lack of traceability. MoD cannot control the COTS products it acquires, which lack good configuration control and normally contain undocumented features. COTS software also requires excessively wide bandwidths.

COTS IT is vulnerable and far from robust, though wrapping can help. Requirements trade-offs, particularly on environmental conditions, and the use of open standards are needed if COTS IT is to be used, which Equipment Capability Customer staff must reflect in their requirements.

Providing military standards of security is likely to cause problems, as are viruses, and a special approach to COTS IT maintenance is needed to deal with its lack of design for maintenance and rapid rate of obsolescence.

12.4 Could more use be made by MoD of COTS IT and if so, how should this be done?

The use of COTS IT, while being actively encouraged, is being held back by several factors:

1. The major difference in development time scales of military equipment and COTS IT is made worse by the very different life cycles of the two.
2. COTS IT needs regular updates to maintain the 'state of the art' and for supportability reasons. This calls for a different approach to funding COTS IT-based projects through their life from the MoD's typical bespoke equipment.
3. Unlike the majority of bespoke military equipment, COTS IT has not been built to be repaired. This calls for a different maintenance policy to be implemented, based on the concept of replacement rather than repair.

4. There is still insistence on the application of many existing military standards. Examples include the need for military standards of documentation, the need for Tempest proof hardware, traceability and common build standards. Many of these standards must be relaxed for COTS IT.
5. The bandwidth requirements of much COTS software are far greater than that of basic text files. This is proving a real problem where COTS has to communicate off the platform on which it is working.
6. COTS IT is still felt to be virtually unusable in safety critical systems due to the difficulty in providing suitable safety cases.

12.5 What is the attitude of UK and foreign IT companies and defence contractors towards meeting both the general and the special IT needs of MoD?

Defence contractors are very positive about using COTS IT in what they supply to MoD but the attitude of IT companies is best described as 'take what we offer or leave it'. It is also clear that the IT industry finds MoD terms and conditions far less acceptable than MoD thinks they do.

12.6 How are defence contractors dealing with the procurement of COTS IT?

Defence contractors look for an early commitment by MoD to the use of COTS IT in military equipment. However, contractors do find it difficult to keep in touch with what COTS IT is available due to the rapid rate of change.

The life cycle of COTS IT makes availability an issue. There is no continuity of supply or support, and this has a real impact, due to the lengthy time scales of the vast majority of military procurements. Lifetime component buys are a possible solution to obsolescence during development or production. However, this is usually out of the question because of production quantity and contractor selection uncertainties. Some companies may make a large buy of obsolescent parts and store them, but this is still a problem if items change between tranches.

Large IT companies sell to standard terms and conditions, and are not prepared to provide certificates of conformance. Niche suppliers may accept buyer's terms and the smaller defence contractors attempt to build supplier/purchaser relationships with them. The defence industry does not try to flow down MoD terms and conditions to COTS IT suppliers.

Some companies take a pragmatic view of survivability of COTS IT hardware, but wrapping COTS IT in containers and using shock mounts is widespread. Wrapping software is also commonplace. Configuration control and traceability are still issues for COTS items. COTS IT suppliers change their designs without telling their customers. Build standards change from item to item, which are supposedly identical, and suppliers are reluctant even to say that they have made changes.

12.7 What is the likely impact and in particular the risks MoD faces in procuring COTS IT hardware and software?

It is felt that programme development risks can be considerably reduced by the use of COTS IT. However, rapid obsolescence and unsupportability are risks fundamental to the use of COTS IT. Moreover, requirement specifications must be relaxed in many cases, or equipment carefully wrapped, both of which may impact on equipment's fighting ability. The final risks lie in ensuring that military security is not compromised and that viruses do no result in equipment failure.

12.8 How does the US Navy experience match that of UK MoD?

The US Navy is rapidly embracing COTS IT, but there are few reports of its performance in service. The points below compare some key actions undertaken by the Navy with those of MoD.

1. A US Navy COTS Steering Board guides the rapid introduction, maximisation of opportunities, and minimisation of risk associated with COTS product utilisation.

   There is no equivalent organisation within MoD.

2. COTS IT is used whenever possible to save cost and to benefit from commercial upgrades. A standard COTS-based human-machine interface will greatly improve productivity and accuracy by avoiding the need for extensive retraining.

   This is similar to the MoD approach.

3. COTS products will be used extensively for straightforward standard applications. Specialised COTS may be needed for some functions and COTS products for certain dedicated functions may require application software adaptations.

   MoD plans similar use of standard, specialised and adapted COTS products.

4. Four building blocks will provide $C^4$1 capabilities in a modular, open system design and use COTS IT to provide a path for frequent, low cost modernisation. C^4I systems not utilising high percentages of COTS software are strong candidates for cancellation as unsupportable.

   MoD has made significant progress in this area.

5. Many DoD users are choosing Internet messaging capabilities, though some requirements still exceed COTS capabilities. With time the gap is growing smaller and DoD is working to speed the convergence process.

   MoD is already grasping Internet benefits and should further profit from DoD work.

6. The US Marine Corps has delegated procurement authority for IT with limited programme costs, restricted software development and compliance with its minimum COTS IT standards.

   There is, as yet, no sign of such a radical approach by MoD. However, whether such delegation is being considered has not been researched.

7. A number of very different US Navy programmes are using COTS IT. These are all reducing initial acquisition costs and time scales, provide state-of-the-art technology and are expected to reduce life cycle costs.

   MoD has a number of COTS IT-based programmes in service as well as projects for new equipment and upgrades to existing equipment, which are yielding similar benefits.

In summary, the US Navy has taken executive action in support of the procurement of equipment using COTS IT. Like MoD, it sees the key benefits as:

1. The reduction in development and procurement costs.
2. A reduction in cost and time scales for future upgrades.
3. Taking advantage of commercial technology development.
4. Allowing substantial growth capacity for future upgrades.
5. Removing the need for vendor ILS studies, parts standardisation and commonality with the defense supply system.

12.9 The key issues for MoD to address

1. MoD needs guidelines for the acquisition and through-life support of military equipment incorporating COTS IT.
2. The development time scales and life cycles for military equipment vary greatly from those of COTS IT. These factors require early consideration and call for a different approach to long-term funding, with a more linear spend profile through the life of this type of equipment, in order to allow for regular COTS IT upgrades.
3. There is a need for the Equipment Capability Customer to recognise the potential to use COTS IT at the earliest stage of any programme and to reflect this fact in the requirements specification. The specification will need to avoid insistence on application of existing military requirements. It will also need to consider, if relevant, problems involved in using COTS IT in safety or mission critical systems.
4. COTS IT requires a different maintenance policy from bespoke equipment. The two different classes of equipment need recognising, with separate maintenance policies for each.
5. Security is a COTS IT issue to be addressed and can significantly increase through life costs.
6. The bandwidth requirements of much COTS software are certain to cause transmission congestion, particularly between platforms and this must be borne in mind during solution trade-off studies.
7. The use of the COTS IT circle, or a similar model, could help to teach staff to consider all the issues associated with using COTS IT during the complete life cycle of military equipment.
8. US Navy experience suggests that UK MoD could, to advantage, consider:
    i. Setting up a COTS Steering Board to guide in the rapid introduction, maximisation of opportunities, and minimisation of risk associated with COTS product utilisation.
    ii. The delegation of procurement authority for IT with limited programme costs, no software development and compliance with its minimum MoD COTS IT standards. The same delegation could be applied for limited software development.

12.10 The unanswered question

There is an almost unanimous view that the initial purchase price of COTS IT will be lower than that of bespoke IT. However, there is considerable variation in the views about through life costs. Perceived wisdom has always been that early investment in reliability reduces life cycle costs and this is shown in Figure 28.

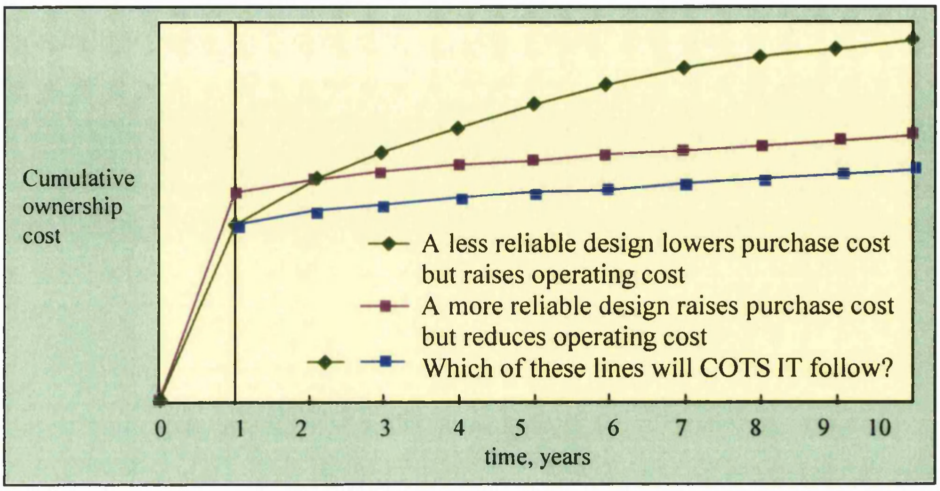

Figure 28. Early investment in reliability reduces total life cycle costs,[cxxxiv] *but what is the impact of COTS IT?* [33]

What is not clear is whether COTS IT will perform as a 'less reliable design' with relatively high life cycle costs or behave as a 'more reliable design'. Getting COTS IT into service to replace legacy systems is proving to be a relatively slow process as Figure 27 on Page 199 shows. Only when COTS IT has been in service for several decades will the answer to whether COTS IT reduces whole life costs become completely clear.

[33] The blue line addition relating to COTS IT has been added to the original diagram.

13 RECOMMENDATIONS FOR FUTURE WORK

This section describes possible future work it has not been possible to complete in this research programme, due either to time pressures, or to a lack of field experience with COTS IT in military equipment.

Inevitably, time scale limitation meant that a sub-set of the desirable work had to be selected if this thesis was to be completed in five years on a part-time basis. In addition, both the MoD and COTS IT are continually changing. The following work could be added to that already completed to provide a more comprehensive overview of the use of COTS IT in military equipment.

1. It would be a benefit to gather data about COTS IT life support costs in military equipment. A significant amount of COTS IT-based equipment has to have been fielded for a significant time. The next few years represent the first real opportunity to collect such data.

2. The Defence Logistics Organisation formed during the last few month of this research. It would be useful to gauge their corporate view on the use of COTS IT in military equipment.

3. The industry survey sample was much smaller than that of MoD. There would be significant benefit from sending questionnaires to a much larger sample, to increase the accuracy of results and to provide statistically significant samples for the various sub-sets of responses.

4. To deal with the impact of the continuing rate of change in COTS IT and the way it is being applied to operational military equipment, it would be useful to briefly revisit the views of MoD to provide a timely update to the data already gathered.

5. It is well documented that the London Stock Exchange and the Ambulance Service [cxxxv] both had serious problems when they installed IT systems to replace their manual systems. Similar difficulties beset the new Denver Airport baggage handling system. Access to large civil organisations, such as the public utilities, communications providers, police, air traffic control and meteorological services should establish how they procure large IT-based systems and whether a possible read-across can be applied to the military scenario.

6. The civil aviation industry is examining the application of COTS IT to avionics equipment. A paper, 'COTS IT for Defence – is there a read across to Civil Aviation?'[cxxxvi] was presented at a Civil Avionics Support Group workshop on 'The use of COTS items in Civil Avionics'. Further study of the work being carried out in this field could produce information of benefit to the military application of COTS IT.

7. The question 'Where are IT companies concentrating their investments in R&D?' was excluded from the original list of questions provided in the transfer thesis due to lack of time. The benefit of carrying out a similar task to look at the range of products in the market place as well as areas of innovation could indicate gaps in the market that may require investment by UK MoD and other departments/ministries of defence.

APPENDICES

Appendix 1 – Questionnaire sent to members of MoD

The procurement and use of Commercial Off the Shelf Information Technology in Operational Defence Equipment.

> **For the purposes of this questionnaire COTS IT comprises any of the following: Computers and peripherals; standard processing and memory devices; ASICs; operating systems; standard software packages and algorithms; comms interfaces and the Internet.**

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	Insufficient knowledge
First, think about the potential use of COTS IT by UK MoD						
1. COTS (commercial off the shelf) IT (information technology) has a place in MoD purchases.	□	□	□	□	□	□
2. COTS IT only has a place in non-combat systems.	□	□	□	□	□	□
3. Compared with military IT, COTS IT will perform equally well in war.	□	□	□	□	□	□
4. COTS IT can be used in:						
Business systems (word processing, accounting systems etc.)	□	□	□	□	□	□
Platforms						
Warships or submarines.	□	□	□	□	□	□
Battle tanks or recce vehicles.	□	□	□	□	□	□
Combat or support aircraft or helicopters.	□	□	□	□	□	□
Weapons.	□	□	□	□	□	□
Weapon launchers.	□	□	□	□	□	□
Sensors.	□	□	□	□	□	□
Systems for: C^2, C^3, C^3I, Intelligence or Air Defence.	□	□	□	□	□	□
Communications or Electronic Warfare.	□	□	□	□	□	□
Satellites.	□	□	□	□	□	□
Now consider the purchase of COTS IT by UK MoD						
5. For many applications, COTS IT hardware will not need any modification.	□	□	□	□	□	□
6. COTS IT software can easily be interfaced with military specific software.	□	□	□	□	□	□
7. Commercial IT companies, as suppliers to MoD, are different from other potential defence contractors.	□	□	□	□	□	□
8. Commercial IT companies will bid for military work and accept MoD contract terms/conditions.	□	□	□	□	□	□
9. There will be a lack of competition in the COTS IT field.	□	□	□	□	□	□
10. COTS IT will be available long enough to be purchased in normal MoD procurement time scales.	□	□	□	□	□	□
11. The price of COTS IT will be lower than that of specially developed military IT.	□	□	□	□	□	□
12. Mil/Def spec type of requirements will cause problems with the purchase and use of COTS IT.	□	□	□	□	□	□

PLEASE TURN OVER

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	Insufficient knowledge
Think about how the use of COTS IT will impact on UK MoD						
12. The use of IT will improve efficiency or performance.	□	□	□	□	□	□
13. Viruses are likely to be more of a problem with COTS than military IT.	□	□	□	□	□	□
14. Security likely to be more of an issue with COTS than military IT.	□	□	□	□	□	□
15. The need for long term support for COTS IT (spares, test equipment, maintenance, documentation, training) is likely to cause difficulties.	□	□	□	□	□	□
16. Bugs are likely to be more of a problem with COTS than military IT.	□	□	□	□	□	□
17. Reliability is likely to be more of a problem with COTS IT than with IT specially developed for military use.	□	□	□	□	□	□
18. Obsolescence is likely to be a more of a problem with COTS IT than with IT specially developed for military use.	□	□	□	□	□	□
19. An advantage of COTS IT is that it is familiar and thus easy to use.	□	□	□	□	□	□

Please provide some brief information about yourself

Personal details

My rank/grade is

My age is

Under 30	□
30-40	□
40-50	□
Over 50	□

I use a computer at work	□
I use a computer at home	□
I am involved in specifying/purchasing IT	□
I would like to receive a copy of your final thesis.	□

Any comments:

Please mail the completed questionnaire to:

Alex Weiss,
Defence Engineering Group,
University College London,
4th Floor, 66-72 Gower Street,
London WC1E 6BT.

Appendix 2 – Questionnaire sent to members of Industry

The procurement and use of Commercial Off the Shelf Information Technology in Operational Defence Equipment.

For the purposes of this questionnaire COTS IT comprises any of the following: Computers and peripherals; standard processing and memory devices; ASICs; operating systems; standard software packages and algorithms; comms interfaces and the Internet.

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	Insufficient knowledge
First, think about the potential use of COTS IT by UK MoD						
1. COTS (commercial off the shelf) IT (information technology) has a place in MoD purchases.	☐	☐	☐	☐	☐	☐
2. COTS IT only has a place in non-combat systems.	☐	☐	☐	☐	☐	☐
3. Compared with military IT, COTS IT will perform equally well in war.	☐	☐	☐	☐	☐	☐
4. COTS IT can be used in:						
Business systems (word processing, accounting systems etc.)	☐	☐	☐	☐	☐	☐
Platforms:						
Warships or submarines.	☐	☐	☐	☐	☐	☐
Battle tanks or recce vehicles.	☐	☐	☐	☐	☐	☐
Combat or support aircraft or helicopters.	☐	☐	☐	☐	☐	☐
Weapons.	☐	☐	☐	☐	☐	☐
Weapon launchers.	☐	☐	☐	☐	☐	☐
Sensors.	☐	☐	☐	☐	☐	☐
Systems for: C^2, C^3, C^3I, Intelligence or Air Defence.	☐	☐	☐	☐	☐	☐
Communications or Electronic Warfare.	☐	☐	☐	☐	☐	☐
Satellites (excluding the ground station).	☐	☐	☐	☐	☐	☐
Now consider the purchase of your company's systems/products by UK MoD or a prime contractor.						
5. We specify/use COTS IT in our military systems/products.	☐	☐	☐	☐	☐	☐
6. We build COTS IT into what we sell to UK MoD.	☐	☐	☐	☐	☐	☐
7. For many applications, COTS IT hardware will not need any modification.	☐	☐	☐	☐	☐	☐
8. COTS IT software can easily be interfaced with military specific software.	☐	☐	☐	☐	☐	☐
9. Commercial IT companies will bid for military work and accept our contract terms/conditions.	☐	☐	☐	☐	☐	☐
10. There is a lack of competition in the COTS IT field.	☐	☐	☐	☐	☐	☐
11. COTS IT will be available long enough to be purchased in normal MoD development and production time scales.	☐	☐	☐	☐	☐	☐
12. The price of COTS IT will be lower than that of specially developed military IT.	☐	☐	☐	☐	☐	☐
13. Mil/Def spec type of requirements will cause problems with the purchase and use of COTS IT.	☐	☐	☐	☐	☐	☐

PLEASE TURN OVER

Insufficient knowledge
Strongly agree
Slightly agree
Neither agree nor disagree
Slightly disagree
Strongly disagree

Think about how the use of COTS IT will impact on UK MoD.

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	Insufficient knowledge
14. The use of IT should improve MoD's efficiency or performance.	☐	☐	☐	☐	☐	☐
15. Viruses are likely to be more of a problem with COTS than military IT.	☐	☐	☐	☐	☐	☐
16. Security likely to be more of an issue with COTS than military IT.	☐	☐	☐	☐	☐	☐
17. The need for long term support for COTS IT (spares, test equipment, maintenance, documentation, training) is likely to cause difficulties.	☐	☐	☐	☐	☐	☐
18. Bugs are likely to be more of a problem with COTS than military IT.	☐	☐	☐	☐	☐	☐
19. Reliability is likely to be a more of a problem with COTS IT than with IT specially developed for military use.	☐	☐	☐	☐	☐	☐
20. Obsolescence is likely to be a more of a problem with COTS IT than with IT specially developed for military use.	☐	☐	☐	☐	☐	☐
21. An advantage of COTS IT is that it is familiar and thus easy to use.	☐	☐	☐	☐	☐	☐

Please provide some brief information about yourself.

Personal details
My job title is
My age is:
- Under 30 ☐
- 30-40 ☐
- 40-50 ☐
- Over 50 ☐

I use a computer at work ☐
I use a computer at home ☐
I am involved in specifying/purchasing IT that is incorporated into what we market ☐

The main business of the company I work for is (tick all that apply):
- Defence ☐
- Commercial ☐
- A systems house ☐
- An IT company ☐
- A prime contractor ☐
- A sub-contractor ☐

I would like to receive a copy of your final thesis. ☐

Any comments:

Please mail the completed questionnaire to:

Alex Weiss,
Defence Engineering Group,
University College London,
4th floor, 66-72 Gower St,
London, WC1E 6BT.

Appendix 3 – Overview of visits made

For confidentiality reasons, the names of those interviewed, though recorded, are not disclosed in this thesis. However, visits were made to the following organisations/functional areas and separate reports for each visit are stored in digital (MS Word 2000) format.

MoD DPA

Bowman project
Command Support Systems
Software reliability
Submarine electronic systems
Tracer project

MoD ECC

Naval CIS, CSS and navigation systems
Land CIS and engineering equipment
RAF CIS, avionics, sensors and communications equipment
Intelligence
Simulation and modelling

DERA

C^3I (Tri-service)
CDA
CIS
COTS policy
Environmental test
Naval combat management systems
Security systems
Software systems
STAR
Terrestrial and satellite communications
Weapons

Industry

British Aerospace (now BAE SYSTEMS) Military Aircraft
EDS
GEC Marconi (now part of BAE SYSTEMS)
INRI
Integris
Logica
Mektron
Siemens Plessey
Sun Federal International
Thomson -THORN Missile Electronics
Ultra Electronics

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