TECHNOLOGY EXPLOITATION FOR IN-SERVICE SUPPORT OF FUTURE ROTORCRAFT

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INTRODUCTION

1. Support has always been an important topic in the aircraft business, but the cost of it may have been incidental to the Armed Forces, owing to the need to meet demanding operational requirements. However, unreliable and unmaintainable equipment can be extremely expensive in terms of reduced availability and excessive use of increasingly slender resources. Thus, the Armed Forces must look at ways in which to reduce the support costs of the in-service and future equipments.

2. Support is an area of great expense that is common to fixed and rotary winged aircraft. Much of the work that is being undertaken by the MoD, in conjunction with the defence industries, applies to both categories of aircraft, which are sharing the increasing levels of technology in very sophisticated systems. Therefore, the use of advanced technology to increase the supportability of equipments is applicable throughout aerospace industries.

AIM

3. The aim of this paper is to provide an understanding of the way in which the Armed Forces, particularly the Royal Air Force (RAF), envisage using technology to increase the levels of supportability of their rotorcraft.

BACKGROUND

4. Historically, the driving force behind the procurement of any Service rotorcraft, or indeed fixed-wing aircraft, has been performance. However, the Ministry of Defence (MoD) has recognised that the cost of ownership of rotorcraft has risen inexorably since the end of World War II. In fact, the cost of ownership has risen by some 8%, in real terms, every year since the end of the war, whilst the Defence Budget, and as a consequence the Air Vote, has increased by, approximately, only 2-3%. It is, therefore, obvious that the support costs of the Royal Air Force's rotorcraft have continually outpaced the increase in Budget. Fortunately, these facts are now fully appreciated, and the Armed Forces are making life cycles costs (LCCs) a primary driver in future procurement projects and will be vigorously pursuing means of reducing considerably the cost of ownership.

5. The in-service support of the Royal Air Force's aircraft cost some £1.25 billion for the 1990/91 financial year, which was almost 6% of the Defence Vote of £21 billion; a very significant proportion! The Royal Air Force's fleet of helicopters took a sizeable

proportion of this figure; about £120 million, which equates to about 10% of the support costs for approximately 10% of the RAF fleet of aircraft. However, this figure is disproportionate to the rest of the fleet when considering that our rotorcraft are old and relatively simple helicopters; Wessex, Puma, Gazelle and Chinook.

SUPPORTABILITY AND PERFORMANCE

6. Rotorcraft industries and operators realise that LCCs far exceed those of the initial procurement of an equipment. Studies carried out by companies such as Boeing, and the United States Department of Defence (USDoD) indicate that the support costs of equipments outweigh the cost of procurement by some 5 to 10 times as shown diagrammatically in Figure 1. Studies have also shown that up to 80% of LCCs are committed by the end of the full scale development phase, and some 60% are committed by the end of the design stage because the design has been 'frozen'. It would, therefore, seem obvious that the area of LCCs should be addressed at the design and development stages of an aircraft's life in order to reduce the support costs of future systems. However, previous Air Staff Targets (AST) have been based on the need for a new equipment to meet a particular operational role, and consequently performance has been a primary driver alongside initial cost and in-service date. Nowhere in the list of priorities has the area of support appeared. Fortunately, recent changes of policy have placed supportability on an equal priority with performance cost and time, which falls in line with recent defence expenditure cuts and with the expectation that the Defence Budget is likely to continue to follow a trend of reducing, in real terms. Therefore, the Armed Services want more value for money from future rotorcraft.

TECHNOLOGY EXPLOITATION

7. With few exceptions, new technology has been used by designers to increase the performance of new equipments. However, some of these types of equipments have been renowned for having exceptional performance but have been plagued with poor supportability characteristics; for example the Tornado and the Jaguar are different generations of aircraft and the Tornado has considerably better performance than the Jaguar, but their levels of reliability are extremely similar. In my opinion this is a sad waste of opportunity over a number of years of continued technology advances. Fortunately, the recent change of policy will ensure that technology will be exploited to increase the supportability of future equipments, in addition to the accepted practice of increasing performance. To this end the RAF is committed completely to this approach and has formed the Deputy Directorate of Support Policy (Operational Requirements) (DD Spt Pol (OR)(RAF)) to examine new and emerging technology, with the sole aim of increasing the support of our future equipments. The following examples detail a select number of projects that are being examined by the RAF, with the Defence Research Agency and industry:

a. Modular Avionics Packaging. Modular avionics architecture is based around a range of common line replaceable modules (LRMs), which are linked by high speed databuses. Most LRMs will have a common function, but each sub-system would have one or more unique sensor LRMs; but, rather than analyze and process the information within a specific sub-system, it will be done by any combination of shared common LRMs. The system would also be self-healing , which means that, should a module fail, the system would be reconfigured automatically under the guidance of software. As a result of this, the overall system reliability should be extremely high. Further spin-offs could be yet increased reliability by the introduction of high reliability modules, reduced levels of maintenance, high levels of fault tolerance, and high levels of helicopter availability for the operators. The major European programme, which also involves the USA, is the Allied Standard Avionics Architecture Council (ASAAC), the aims of which are to reduce the LCCs of advanced avionics architecture and produce a set of standard agreements (STANAGS) for use within NATO. ASAAC has recently embarked on a 2 year feasibility study, which should, ultimately, produce an avionics architecture definition and a core architecture demonstrator to provide the avionics for the proposed UK battlefield helicopter.

b. Vibration Control. Vibration control can be achieved in a number of ways from the simple weight on the rotor head to highly sophisticated active vibration control systems. Stewart Hughes Limited have been working extensively on a Rotor Analysis Diagnostic System (RADS) to measure blade displacement and vibration, which can then be used to combat the associated problems. Westland Helicopters, on the other hand, have been working on active vibration control. The benefits of vibration control have been experienced by the British Army on the Lynx helicopter. Figure 2 shows the reliability difference on the Aircraft Flight Control System (AFCS) between the Lynx Mk1 and Mk7. The Mk1 had a fault rate of about 4.5 per 1000 flying hours, but the Mk7 experienced a 25% reduction in this figure, without any specific attention being paid to the AFCS. Both the Army and Westland Helicopters have attributed this to the reduction in levels of vibration.

c. Engine Health Monitoring. The operation of every aircraft is dependant on the engines working at peak levels of performance and having high levels of reliability and life. Stewart Hughes Limited have been working on 2 systems for monitoring the health of gas turbine engines; the Engine Distress Monitoring System (EDMS) and the Ingested Debris Monitoring System (IDMS). Each of these methods involves analyzing the exhaust and intake gases, respectively and sending the information to a data retrieval unit for analysis by the aircraft engineers. To date, the EDMS has been successfully tested on a Sea King at the DRA, Farnborough. However, although each system has its benefits in isolation, they should be coupled to a central processing unit so that ingested and exhausted material can be compared to give an accurate picture of the health of the engine. The RAF and Stewart Hughes Limited are now in the process of trialling this type of system onto the Allison T-56 on the Hercules aircraft.

d. Surface Modification Treatments. AEA Technology is working on a number of surface treatment processes, one of which is Ion Assisted Coating (IAC). The process involves the bombardment of the parent material with a beam of ions, of various substrates depending on the requirements, which will alter the structure of the surface layers. This process has been tested successfully by a number of companies, of diverse industries such as the motor industry and tool makers, and by the US Army to cure some wear associated reliability problems on the AH-64 Apache attack helicopter. Although this process is not claimed to be a great panacea for all surface material treatments, it can be used with selective use to cure many problems related to erosion, corrosion, abrasion etc, and on a diversity of parent materials including metallics, polymers, and ceramics. The process can be used to treat, retrospectively, components that have been identified as having particular problems, or contracts can be placed with manufacturers to ensure that this treatment is included in the design of such components in new systems.

e. Advanced Materials. Many companies are working on advanced materials such as composites, ceramics, advanced metallics etc, particularly to meet the drive for greater performance from aircraft and their associated systems. Moreover, there is a realisation that these materials present companies with the opportunity to manufacture materials that are fatigue, creep, temperature etc resistant, which can be used to boost the reliability and life of components, airframes and engines in addition to the performance, albeit that some performance may have to be offset to achieve the specified levels of life and reliability (provided that the specified levels of performance have been achieved). Extra performance should not attained to the detriment of supportability.

This list of examples of some of the MoD involved projects is by no means exhaustive, but serve as a flavour of the type of work that is being undertaken by the MoD in conjunction with defence industries. Some other work includes smart actuation systems (actuators with digital electronic controls that can monitor the health of the actuator), structural health monitoring and smart materials and structures (materials and structures that react to their environment). All the work in the listed fields that is driven by DD Spt Pol (OR)(RAF) is purely for increasing the supportability of future aircraft.

8. In an ideal world supportability and performance would be mutually compatible, with neither affecting the other. However, we do not exist in Utopia, and conflicts of interests occur between the rotorcraft operators and the maintenance engineers. The former would like to have all their equipments designed around performance and reliability (thereby increasing availability), while the latter would like to have inherently reliable equipment that only requires minimal maintenance before flying on the next sortie, and maintenance at scheduled intervals. Therefore, the use of new and emerging technology presents an ideal opportunity to obtain rotorcraft that will be procured within an Integrated Logistic Support (ILS) strategy, which will have the specified levels of performance, and optimum levels of supportability.

9. With such an array of technologies and equipments becoming available the Service must assess each area before considering the potential effects of their inclusion on our future helicopters, with particular emphasis being placed on support. This is where the maintenance engineer becomes an invaluable commodity. He/she has a wealth of experience and knowledge associated with the in-service problems of aircraft, and usually has ideas about possible remedies. However, there is a cynical view from many

of military engineers that the designers are shut away from the real world with no conception of the operation of the equipments, and certainly no idea about some of the problems that arise. On a recent visit to a leading aero-engine manufacturer, for example, I asked about the design problems of bearings and abradable seals and was quizzed by the designer about in-service problems on gas turbine engines, which he knew nothing about. The biggest hurdle that must be overcome is that of communication. Designer and end users must get together to discuss the implications of the design, and rectify faults at this stage of the rotorcraft life cycle. An excellent example of this is known as the Ten Times Rule that is often applied to reliability problems. Figure 3 highlights the problem of costs extremely well. If, for example, a design feature that would increase reliability would cost £1 in design, this would increase to £10 by development, £100 by production, and £1000 if an in-service modification has to be carried out. Therefore, support must be considered in the design stage, and equally with performance.

TECHNOLOGY DEMONSTRATION PROGRAMMES

10. There is little benefit to be gained by using immature technology. To introduce such technology onto a flying platform and attempt to mature it would be an extremely risky proposition. The use of ground-based technical demonstration programmes (TDP) represents a safe way of increasing the support aspects of new systems. Historically, TDPs have been used to prove the performance capability of new technology before introduction onto a specified system with proven performance, but with little consideration for support. The Service is becoming more involved with ensuring that support is considered alongside performance on TDPs. This has been welcomed by manufacturers , in particular the Utilities Systems Demonstrator Rig at British Aerospace, because it also helps them to sell a product as having supportability considered and matured. Therefore, the ultimate aim is to build a common understanding of in-service support problems and rectify them long before any prototype is developed.

CONCURRENT ENGINEERING AND THE USE OF INFORMATION TECHNOLOGY

11. Although the on-aircraft technology is an exciting way in which to reduce LCCs, support costs are not only a function of design and the technology employed in the equipment. They are also a function of the information flow during the procurement of the equipment and its subsequent life cycle. The USDoD has identified that a very significant part of the LCCs of an aircraft involves the expensive process of transferring information, particularly on paper. It is extremely inefficient and is becoming outdated. The magnitude of the problem is so great that, for example, the documentation that is carried around in the field to support the Abrahams tank, when stacked on the ground, stands higher than the average tank commander. When all the paperwork is removed from a US destroyer, it rises in the water by over 1/2". Perhaps the most significant example of this is the fact that approximately 5% of all US Forces operational fatalities can be linked to inaccurate documentation. The alternative to paper is the storage and transfer of information in digital electronic form. This is commonly known as Electronic Data Interchange (EDI).

12. In 1985 the USDoD started work towards achieving paperless acquisition, and support, of its weapon systems. This initiative was referred to as Computer-aided Acquisition and Logistics Support (CALS). This has only been made possible because of the advances in Information Technology (IT) over the last ten years. However, the CALS initiative extends beyond the original purpose of reducing or eliminating paperwork. It provides the standards required for a fully integrated design/production/support environment, where the designer, prime contractor, sub-contractors, and customer are able to work concurrently and have access to a common database. This allows information to be distributed swiftly and accurately throughout the life of a weapon system, from design to disposal. The stated advantages/expectations are: the systems will be developed more quickly, enter service sooner, and will be proportionately cheaper to buy. Indirectly, CALS should help to increase reliability and maintainability because it will provide an environment of freely accessible data that will enable more reliability and maintainability to be designed in because of the concurrent engineering (CE) involved. CALS is seen as the tool that will enable CE to be an efficient process. The diagram at figure 2 shows how the USDoD envisages the progression of CALS from paperwork to full EDI. The intermediate step is a phase where the data will be transferred by a media such as magnetic tape, floppy disc, CD-ROM etc. The prime objective of CE is to ensure that the aircraft is designed correctly the first time. All design changes will be made before the equipment is produced, thus reducing costs; both acquisition and LCCs.

INTEGRATED LOGISTIC SUPPORT

13. Everything that has been covered by the paper falls within ILS, which is a management and technical process through which supportability and logistic support considerations of weapon systems and equipments can be designed in at the earliest stage of a project. All elements of logistic support can be planned, acquired, tested and provided in a cost effective manner. Application of the ILS process continues throughout the life cycle of the weapon system or equipment from the identification of the need for a new equipment to its final disposal, which is commonly known as "lust to dust", and can be defined by a series of milestones. Such milestones are related to the project and are subject to approval by the Equipment Policy Committee. This will be achieved using the tool of Logistic Support Analysis (LSA) which sets the milestones and report structure to be fulfilled by industry, under contract. The LSA will be monitored in the RAF by the ILS manager and his team of LSA specialists, who will then be in a position to influence the design, and subsequently influence the maintenance policy.

THE PROOF?

14. There have been 2 projects in the USA that have demonstrated that supportability has been considered equally with performance, time and cost; the award of the ATF to the YF22 consortium of Lockheed, Boeing and General Dynamics, and the award of the Light Helicopter (LH) development contract to the Boeing-Sikorsky consortium. In each competition the competing aircraft had very similar performance characteristics along with procurement costs. However, the deciding factor rested on the supportability of each aircraft. Of the LH project, Major General Ronald K Anderson, the US Army's LH programme manager said the 2 competitors were judged to be very close to each other in their technical and producibility proposals, 2 major factors in the evaluation. He said

that there were significant differences in favour of the Boeing-Sikorsky LH in other categories; cost, reliability, maintainability, logistics support, training and man-machine interfaces. The latter group accounted for 55% of the US Army's scoring of the development proposals. Supportability has been the key to 2 major US programmes, and will be driving factors in future British and European collaborative projects.

CONCLUSION

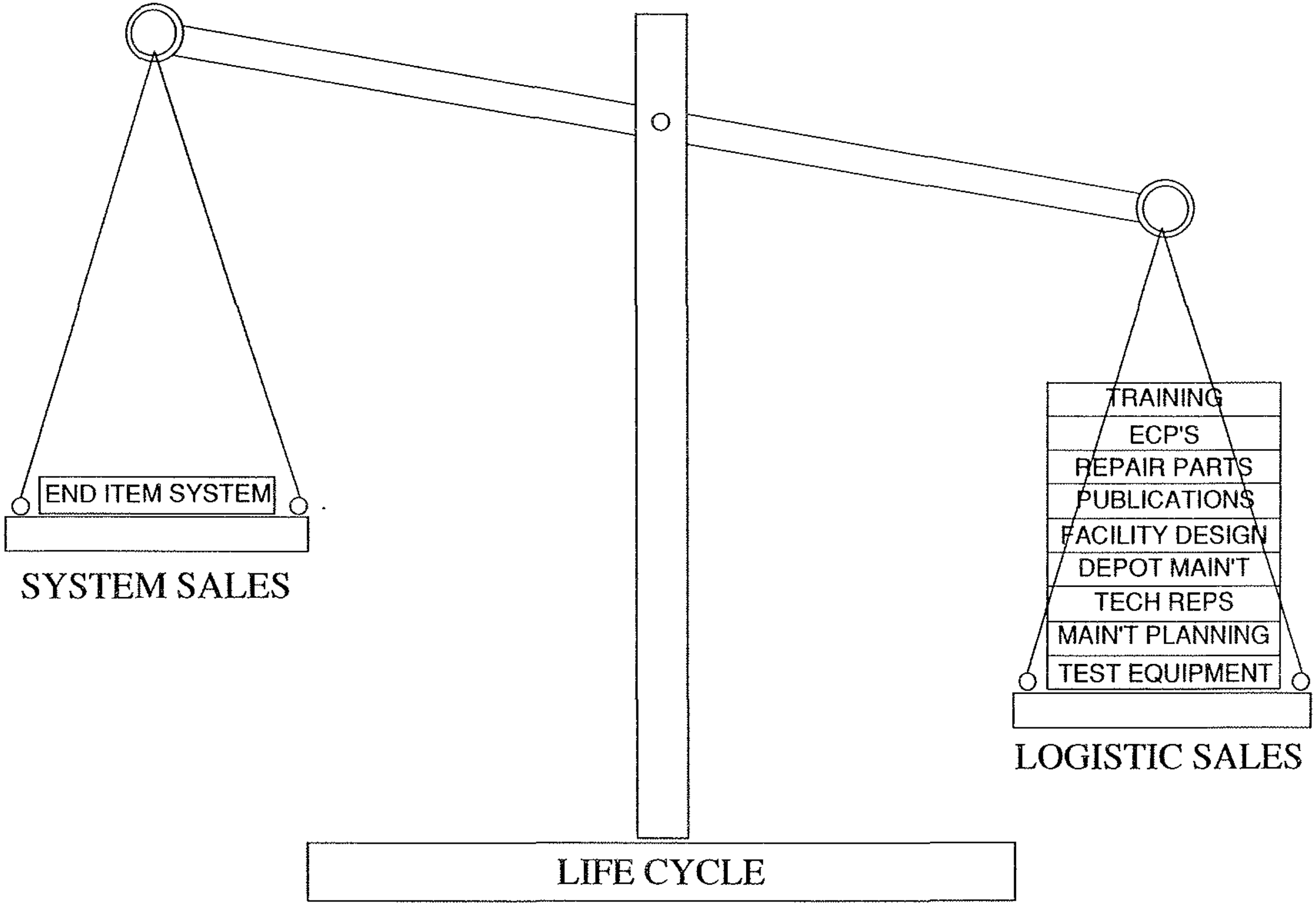
15. The paper has explained, throughout, the rationale behind the drive for supportability by the MoD, and has given a favour of how the RAF will be using advanced technology to increase the support factors of future aircraft, within the ILS strategy. Advanced technology, itself, will not increase supportability, but through greater co-operation between industrial and military engineers, particularly through the use of the LSA tool, designs will be influenced by the customer at the earliest stages of projects where the greatest cost savings can be made. Undoubtedly, the change in policy which has placed supportability alongside performance, time and cost will be a permanent feature of all future contracts, particularly as Defence Budgets continue to shrink in real terms. Therefore, the ultimate aim of future aircraft programmes will be to produce aircraft that have stunning levels of performance and SUPPORT!

Acknowledgements:

This work has been carried out with the support of:

A. Procurement Executive Ministry of Defence.
B. Stewart Hughes Limited.
C. Westland Group Plc.
D. AEA Technology.
E. British Aerospace Plc.

SUPPORT COST = 5 TO 10 TIMES SYSTEM COST



LOGISTIC SALES MUCH LARGER THAN SYSTEM SALES

FIGURE 1

Lynx Mk No	1		7	
Year	88/89	89/90	88/89	89/90
Sorties Affected	97	74	21	39
Flying Hours (FH)	21849	15958	5825	12897
Failures/1000 FH	4.4	4.6	3.6	3.0

Figure 2

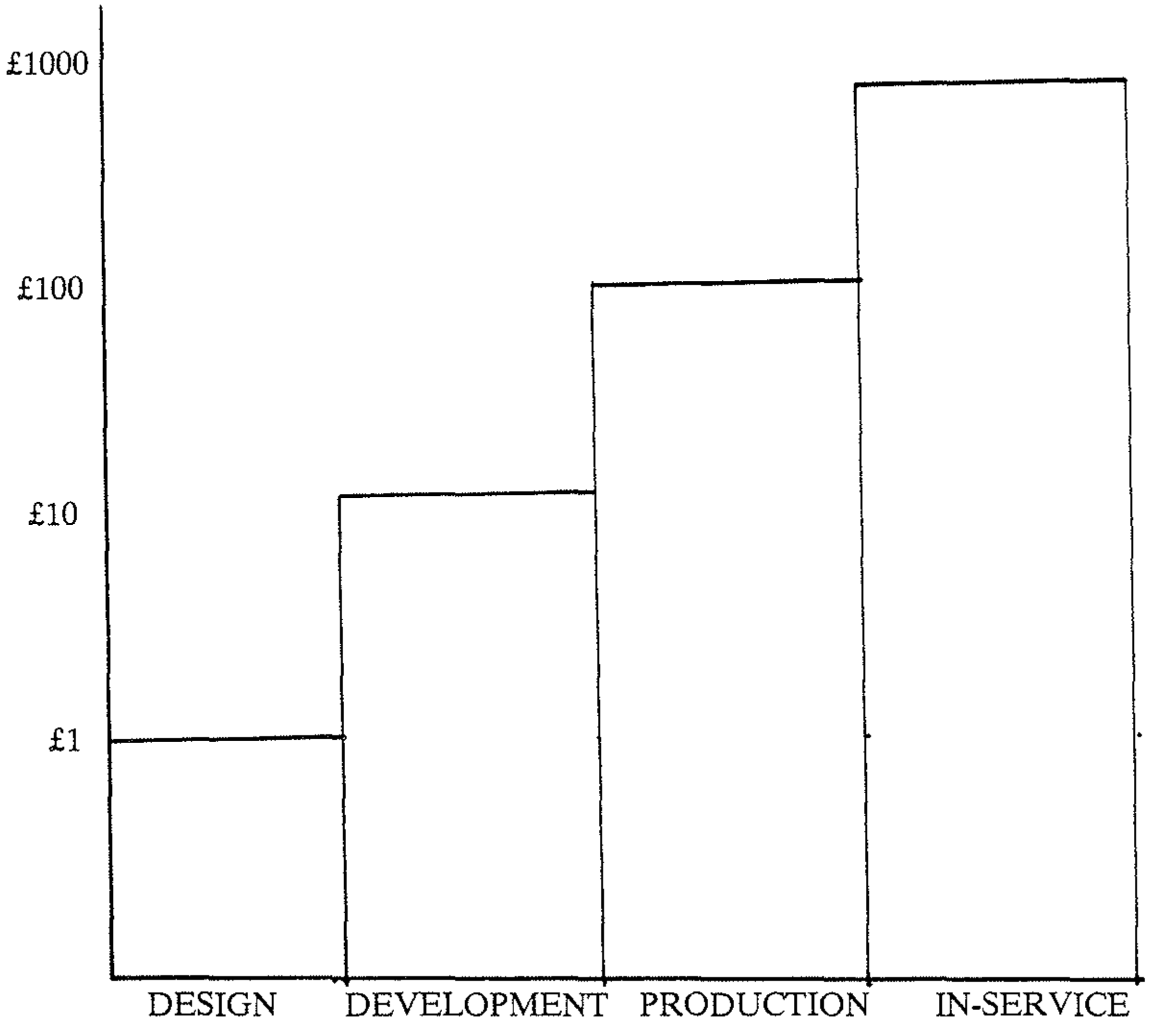


Figure 3 - The 10 Times Rule