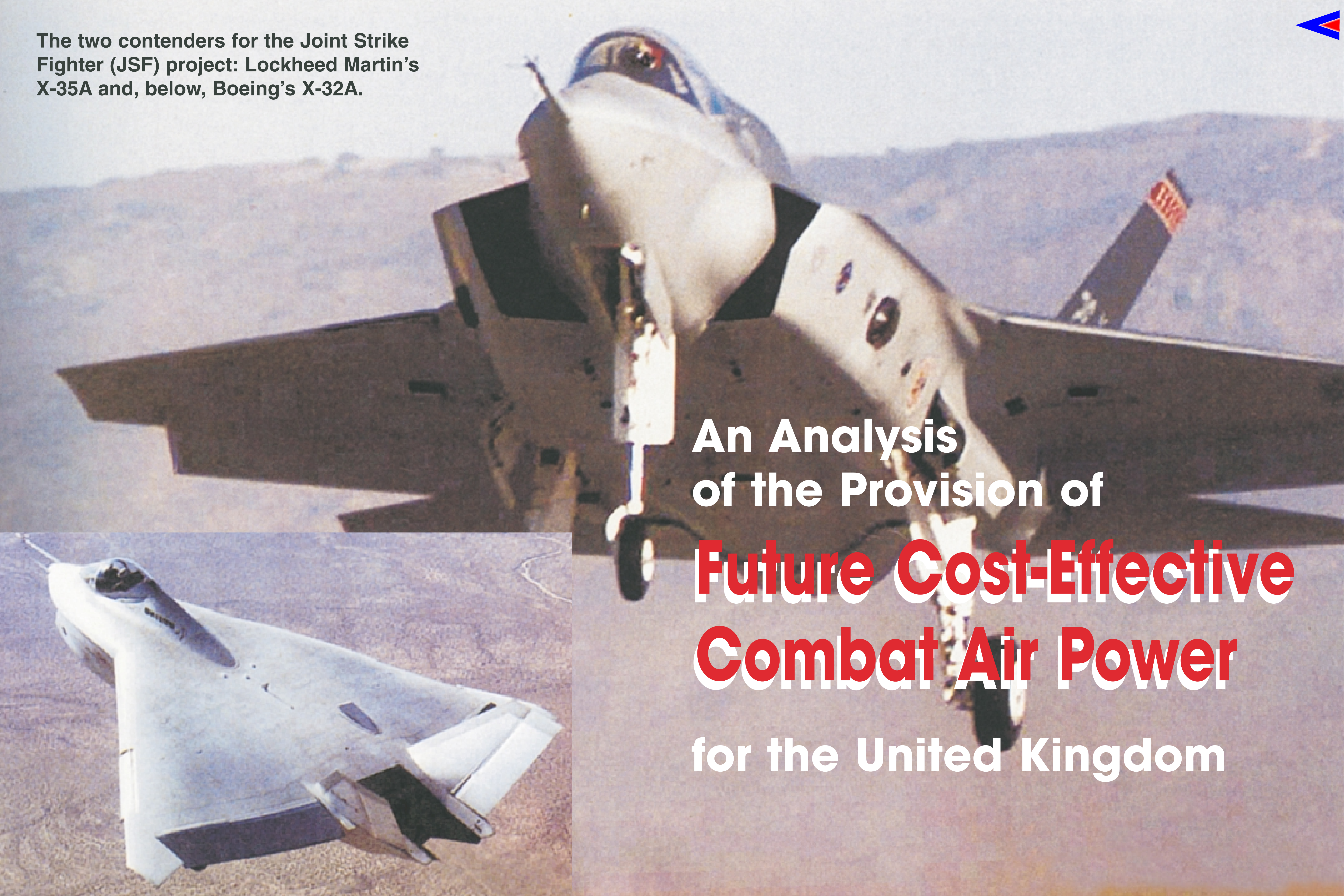


The two contenders for the Joint Strike Fighter (JSF) project: Lockheed Martin's X-35A and, below, Boeing's X-32A.

An Analysis of the Provision of Future Cost-Effective Combat Air Power for the United Kingdom

INTRODUCTION

The past 10 years have seen a variety of conflicts where Combat Air Power has been used to shape a battlespace for surface forces or to determine the outcome of a conflict in its own right. The efficacy of Combat Air Power is well proven by the results it has achieved, ranging from the aerial onslaught against the Iraqi forces before a ground invasion in 1991, to the ejection of Serbian troops from Kosovo in 1999. The wide range of capabilities that Air Power can provide, from air surveillance to the attack of surface targets, coupled with its reach and responsiveness, is unique. Current UK doctrine recognises these capabilities and that "air power is frequently the favoured option of first recourse in crisis management".[1]

Since the publication of the Strategic Defence Review (SDR) in 1998, there has been a clear focus on the need to provide defence capabilities within an ever dwindling budget and to strive for cost-effective solutions to military problems. Because of the increasing involvement and development of technology, Air Power is an inherently expensive commodity and is therefore likely to be particularly sensitive to any budgetary constraints. An initial, or superficial, approach to the problem suggests that the solution is to simply buy cheaper equipment and make it work. However, a deeper analysis of what is an extremely complicated issue shows that there is no easy solution to the problem: indeed, it is questionable as to what constitutes cost-effectiveness, depending upon the observer's perspective to the relevant issues.

This Paper will examine the possibilities for the cost-effective provision of Combat Air Power for the UK over the next 20 years, by firstly discussing the UK's security environment. The many factors that affect the provision of Combat Air Power, including the economic situation and the procurement processes, will then identify the requirements and constraints upon the operational use and development of Combat Air Power. This will contribute towards an understanding of the various views of cost-effectiveness.

British Air Power Doctrine defines Air Power capability as having 3 component parts:[2] physical, conceptual and moral. The physical component of Air Power is pivotal in the future cost-effective provision of Combat Air Power capability. Therefore, in-service and future equipment will be briefly examined to assess their suitability for the operational task before discussing the supporting doctrine. Several shortcomings of the current UK doctrine regarding the use of Combat Air Power will be identified. The examination of both the equipment and doctrinal issues raised here will lead to conclusions regarding the future provision of cost-effective Combat Air Power. Finally, the moral component, including those leadership and core values that do not rely upon equipment or doctrinal issues, will not be discussed in this Paper.

For clarity this Paper will focus upon the air/land battlespace, and will not consider the sea/air battlespace or littoral warfare. It must be noted that future operations are likely to take place in a joint battlespace with significantly reduced boundaries between the land, sea and air environments and this Paper's conclusions will be focused upon this future battlespace. Finally, personnel and training issues, and the provision of targeting and intelligence using ISTAR assets, will be common to all future possible Combat Air Power platforms so will not be discussed in any detail.

THE UNITED KINGDOM'S SECURITY ENVIRONMENT

The 1998 SDR clearly articulated the current and expected security environment that is likely to surround the United Kingdom during the next 15 years. It recognised that although there is little direct threat to our national survival, "today's security environment is not benign".[3] Given this instability, and the United Kingdom's desire to play a prominent role in international affairs,[4] British forces can expect to be operating in a wide variety of locations within many different scenarios. British Defence Policy has stated[5] that military forces can expect to be used in combat, ranging from high intensity warfare through intervention and counter-insurgency operations: as a deterrent; provide support to diplomacy; peacekeeping and peace enforcement or in support of the civil powers.

It has also been recognised that British forces can expect to operate as part of a coalition framework, within either NATO or a wider coalition, in any major operation[6] in the future. Additionally, there will be an increasing role for the military in support of peace support and humanitarian operations as part of a "force for good".[7] This theme echoes the Foreign Office view,[8] expressed by Mr Derek Fatchett MP (Foreign Office Minister) who said recently, that "in seeking to achieve the basic objective of security.......the nature of war is changing". As potentially hostile developed countries' military capability increases unconventional attacks may become more likely. Many current military forces have limited, if any, capability to counter these unconventional threats. This is the dichotomy facing future security posture: whilst military forces may be expected to fight in a conventional war, they may also be used in an asymmetric conflict, where their utility may be limited. The proliferation of military hardware around the world, in concert with this possible asymmetric warfare, will ensure that the future battlespace is increasingly complex. This will demand complex systems operating across land, sea and air as a single battlespace. The House of Commons Research Paper 98/91, published as part of the SDR, defined the future of Air Power as:

"....seen by the SDR as complementing ground and maritime operations but also having an offensive role in its own right. This will be further enhanced by the acquisition of further precision air-delivered weapons. Air Power will also have a role in non-war fighting missions, such as the enforcement of no fly zones and the provision of humanitarian aid. The SDR concludes that a balanced force, similar to the present forces structure, is required to meet these contingencies."[9]

...there will be an increasing role for the military in support of peace support and humanitarian operations as part of a "force for good"

INTERNAL FACTORS AFFECTING THE UNITED KINGDOM'S SECURITY ENVIRONMENT

In recent years it has become clear that budgetary pressure, focused by the Treasury, will continue to increase on the Defence Budget. The Ministry of Defence (MOD) Budget is in direct competition with all other Government spending departments for resources. In 1998-99 the Defence Budget of about £22 Billion was approximately 7% of the Government's overall expenditure, accounting for approximately 2.7% of the British GDP . In the next 3 years, this figure is projected to rise slightly in cash terms, although in real terms this will reflect a fall to approximately 2.4% of the GDP.[10] Remembering that Air Power is intimately linked with technology and thus particularly influenced by this ongoing increase in costs, this decrease in funding will be a significant factor for the future provision of Combat Air Power. This focus will be exacerbated by the continually rising costs in this sector. Each major new aircraft costs approximately twice its predecessor.[11] This is because of the increased costs of production and also due to the increasing demands upon the combat platforms in a more complex joint battlespace.

The purely economic costs of defence procurement and operations are difficult to define. The MOD spends approximately £9 Billion each year on equipment alone, within the overall Defence Budget of some £22 Billion. The SDR stated that the procurement budget should be reduced by £2 Billion. Although it is relatively easy to determine how much the defence budget is, in cash terms, it is more difficult to determine the true cost since it must include the unknown opportunity costs of not spending that money on defence.[12]

The SDR recognised that the British Defence Industry is viewed as a strategic asset, providing jobs for over 400,000 people and annually earning the country some £5 Billion in exports.[13] Furthermore, the Government plans to support the UK's Defence Industrial Base (DIB)[14] whenever it can do so. This policy is to ensure that the UK retains an indigenous military technology capability and the capability to continue its trade within the extremely competitive world-wide export market. Procurement decisions, both national and workshares from collaborative projects, have repeatedly shown that this policy will continue to be endorsed – whichever Government is in place. In short, the political view of "cost-effectiveness" relies upon supporting the UK DIB to maintain technical competence and provide both employment and export opportunities for it.[15] This political constraint may conflict with a purely military recommendation for procurement options for particular equipment.

The current rate of technological change will have a significant effect upon future military equipment.[16] The very pace and breadth of technological change make it impossible for the military to fully embrace all its aspects at all times.[17] This is especially true with regard to Air Power as noted by Professor Tony Mason as a "product of 20th Century technology".[18] The continual increase in Air Power capabilities seen over the past 100 years is set to continue in the future with ever-increasing accuracies of precision guided munitions (PGMs). The increase in precise weapons effects can allow smaller more efficient forces to be used and reduce collateral damage against previously untargetable areas. This capability fully supports the military requirement to achieve an end-state with minimum casualties and loss of equipment. It is also clear that this capability is particularly sensitive

The current rate of technological change will have a significant effect upon future military equipment. The very pace and breadth of technological change make it impossible for the military to fully embrace all its aspects at all times

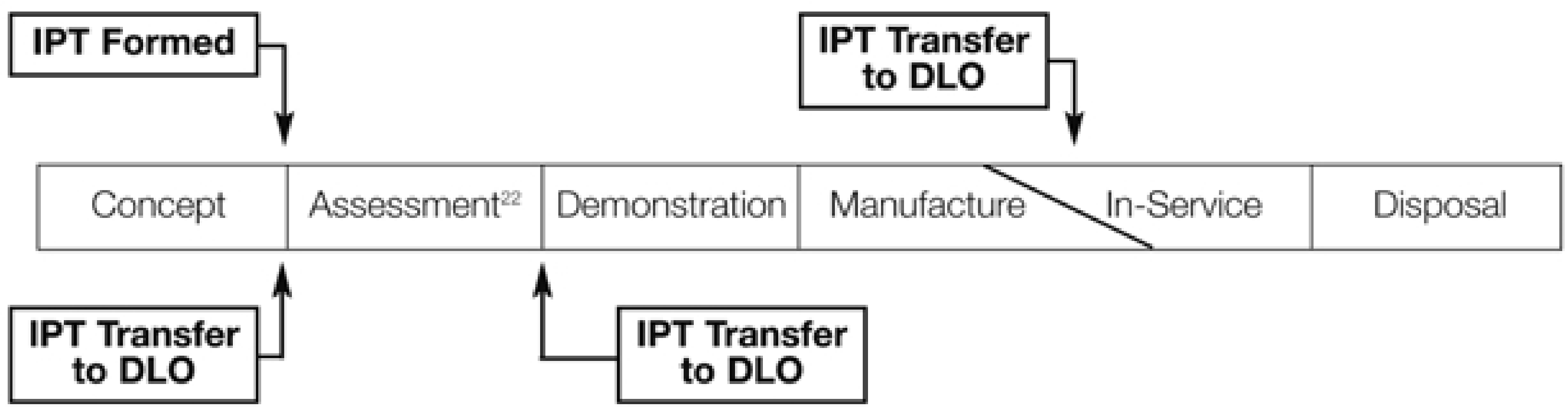
to technological change, so the choice of future Air Power platforms and sensors must be chosen with care and vision to capitalise upon technology rather than be a slave to it.

Additionally, technology has enabled world-wide, real time distribution of news, ensuring that all future operations are likely to take place in full view of the international media. This “CNN effect” and public sensitivity to its images will further focus this need for military operations with little, or nil, casualties and collateral damage. Therefore a concept of Precision Attack in future operations will be developed in attempts to ensure that a casualty-sensitive Government and public remain supportive of those operations.[19]

In sum, internal pressures upon UK Combat Air Power are a combination of the economic need for reducing costs; the political need to support the UK DIB; the military need complete the mission with minimum casualties and collateral damage under an over-arching need to ensure widespread public support by ensuring favourable media coverage, reflecting these aims, at all times.

THE PROVISION OF UK COMBAT AIR POWER

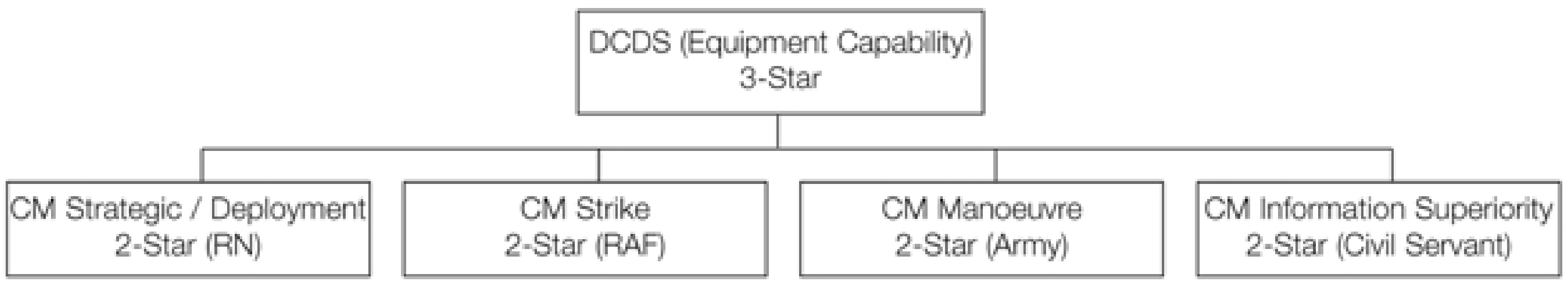
Having identified that Combat Air Power is required for current and future military operations, the next question that should be considered is how to provide the capability needed to do so? The procurement process has been repeatedly criticised in the past. The McKinsey report into Defence Procurement clearly identified the major failings: an average of 41 months' delay to delivery dates; an average increase of 10.7% in costs; significant in-service reliability and maintainability problems and constantly changing acceptance criteria to compound the problem.[20] In light of the budgetary pressure noted above, this situation could not continue. One of the key elements of the SDR is that of Smart Procurement[21] firmly based upon the McKinsey report findings. Smart Procurement seeks to realign the procurement process to reduce the unacceptable delays, and consequent increasing costs, currently experienced in defence procurement. In general terms the procurement process has been changed to reduce bureaucracy and the Equipment Approvals Committee submission requirements at the initial and main gates have been reduced to the minimum. Furthermore, Smart Procurement has adopted a through-life approach to defence procurement and increased the links with industry by both Partnership and Competition. This strategy is aimed at providing the widest possible ownership of the procurement process, with an incremental approach for new equipment and clear technical upgrade opportunities. Finally, Smart Procurement seeks to provide improved in-service support by the use of Integrated Project Teams (IPTs) and, with the creation of a joint Defence Logistics Organisation, streamline logistical support for all 3 Services. The new procurement cycle's phases and procedures are:



(Source: MOD Investment Strategy: Section 3)

The stated aim of Smart Procurement is to provide "faster, cheaper and better procurement with improved in-service support and savings in through-life costs".[23] This should allow full access to modern, and continuous technology insertion, within the expected financial constraints. Despite these aspirations, it remains to be seen whether the savings that the Smart Procurement seeks will materialise, but any improvement to the procurement system should be welcomed and provide significant savings in the process.

In association with the Smart Procurement Initiative (SPI), a reorganisation of the MOD Central Staff was recommended by McKinsey,[24] as a means of permitting a wider view of defence capabilities. In the past, the Central Staffs have been organised along strict Land, Sea and Air boundaries with little interaction between them. Within the newly identified security environment, this structure would be a poor basis for force development and sustainment. Accordingly, McKinsey recommended that the MOD Central Staffs should be reorganised along functional pillars to allow a broad view to be taken in any particular capability. The reorganisation has been completed by the MOD Central Staffs and the new joint approach has been warmly embraced. The revised Central Staff structure is:



Each capability pillar is headed by a Capability Manager (CM)[25] who may drawn from any of the Services, or may be a Civil Servant as shown, with a joint staff covering a variety of component parts. For instance, CM Manoeuvre's pillar contains Direct Battlefield Engagement, Indirect Battlefield Engagement, Tactical Mobility, Manoeuvre Support amongst others. Most importantly, Manoeuvre also includes Army assets, and Strike includes Naval TLAM capabilities. Since each pillar is functionally based, rather than Service orientated, the capabilities of all component parts will be able to complement each other, hopefully with reduced inter-Service rivalry. The focus of the revitalised staffs will be concentrated upon providing the best possible blend of systems to enable a capability rather than a particular weapon system.[26] Additionally, DCDS (Equipment Capability) has a responsibility to "develop, manage and own a balanced, coherent and affordable equipment programme". This new drive for balance and cohesion should allow synergy to develop between the Services to provide the optimum operational capability.

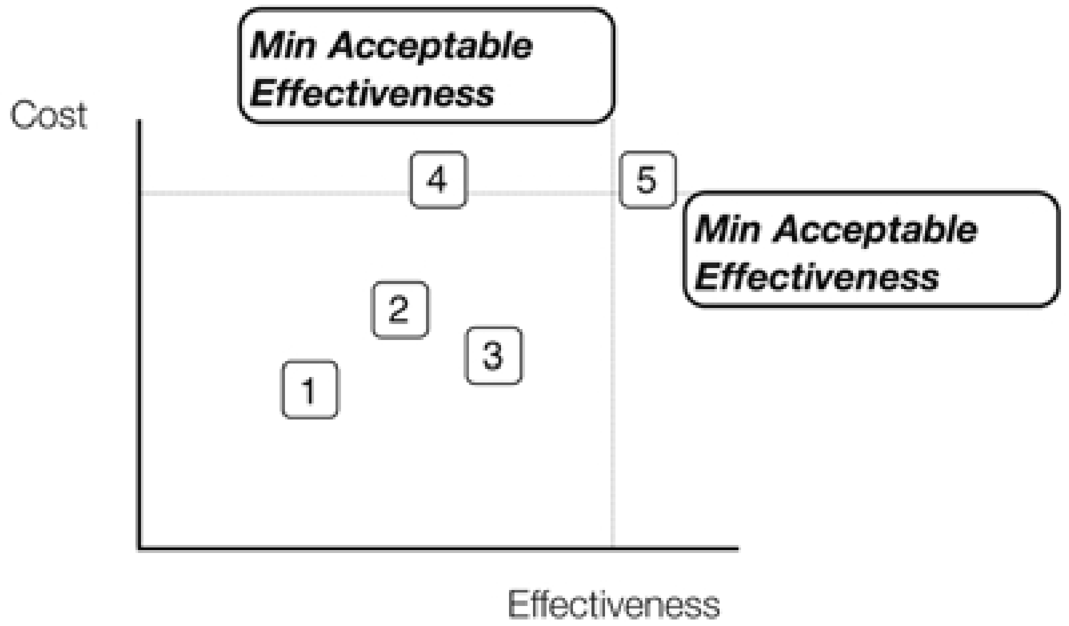
As well as aiding lateral approaches to military capability, the reorganisation of the MOD Central Staffs will also provide a focus for the procurement process. For the first time a clear customer can be identified for equipment needed for military use. The Central Customer, or Customer 1, is able to provide and receive strategic planning for military procurement. The front-line commands, known as Customer 2, hold an interest in the early stages of procurement and become the focal point when the system is in service.

For several years a vital part of the procurement process has been that of assessing the potential operational effectiveness of a new weapon system. The system in use is that of the Combined Operational Effectiveness and Investment Appraisal (COIEA).

The COIEA seeks to support the decision-making process not replace it. Within the COIEA several options are considered against each other and against the overall capability requirement, using Operational Analysis (OA) and Investment Appraisal (IA) techniques. The following options must be considered in every COIEA:[27]

- Do nothing.
- Do minimum.
- Refurbish current equipment.
- Replace with the same equipment.
- Buy follow-on.
- Buy off-the-shelf.
- Develop and procure new.

The COIEA attempts to compare all options within a common framework. The options, set as a comparison of Cost against Effectiveness, are then represented as:



(Reproduced from Choose Your Weapon, David Kirkpatrick. pp38-9)

The graph shows how a COIEA can also provide a means to identify what options may available at a particular cost, or indicate how the available options perform with respect to a distinct cost and what trade-offs may be needed to resolve the choice.

Whilst the COIEA strives for objectivity at all stages, there is scope for error or interpretation. The OA relies upon statistical analysis of the effectiveness of the equipment under consideration. The metrics are based upon numerical results,[28] such as how many tanks will be destroyed, with a limited capability to assess the wider effectiveness within a system of systems. These do not sit well with the concept of applying the manoeuvrist approach to warfare, in accordance with British Defence Doctrine,[29] as "…shatter the enemy's overall cohesion and will to fight, rather than his material…..". Furthermore, the IA allows for a variety of costs but must, almost by definition, have limited boundaries to where the costs are placed. The IA will seek to ignore costs that are common to all options and only consider costs that will be directly attributable to the each option under consideration. The IA does not, however, allow for any peaks and troughs in an option's expenditure within the Government's overall annual expenditure. It also has problems allowing for residual value of equipment, especially while it is still in service, and can only estimate the disposal value and plans at the end of its service life.[30] Thus the COIEA could not be really described as objective in all respects.

It has been shown that the COIEA process is a subjective tool; at the higher level there may be insufficiently articulated measurements of effectiveness, whilst lower level studies are unable to consider overall systematic effectiveness. Thus the context and results of a COIEA must be understood, interpreted and applied intelligently.

A further consideration for future procurement is the design and production strategy choice. The main procurement choices with the major advantages and disadvantages of each option, detailed by the National Audit Office in 1994 as being:[31]

Procurement Route	Advantages	Disadvantages
Individual National Development	• Control over specifications. • Control over time scale. • Ability to impose UK contractual practices. • Possibility of export sales.	• Costs likely to be very high for major platforms. • Developing a weapon from scratch as opposed to buying off-the-shelf carries greater programme and cost risk. • Can lead to a lack of commonality with NATO allies.
Individual National off-the-shelf	• Usually considered cheaper than funding development. • Equipment is proven when purchased. • Control over timescale. • Can impose UK contractual practices.	• Equipment may not meet requirement; leading to • Costly customisation of equipment.
Collaborative off-the-shelf	• Owing to economies of scale usually cheaper than national off-the-shelf. • Can enhance interoperability if equipment is used by allies. • Can lead to net inflow of technology from overseas. • Owing to economies of scale, usually cheaper than national development. • Usually cheaper than development.	• Risk of compromising on specifications. • Risk of project delays as a result of problems in partner countries. • Difficulties in imposing UK contractual practices. • Equipment may not meet requirement; leading to • Costly customisation of equipment.
Collaborative Development	• Commonality with equipment used by NATO allies. • Economies on in-Service support. • Can lead to net inflow of technology from overseas. • Owing to economies of scale, usually cheaper than national development.	• Risk of compromising on specifications. • Risk of project delays as a result of problems in partner countries. • Difficulties in imposing UK contractual practices. • Imposition of workshare between partners can inflate costs. • May result in a net outflow from UK to other industrial partners.

There has been much discussion regarding the “best” procurement strategy. Escalating costs within the aerospace industry suggest that both of the independent, national options may be unachievable for the UK in the future.[32] Conversely, collaboration procurement is generally held to be both economically and politically desirable.[33] However, there is evidence to suggest that the inefficiencies of collaborative programmes can increase development and production times. With expected increase in costs of approximately 8-10% per annum, any delay will produce an increase in the overall cost of a programme, but it is still considered that the national cost of a collaborative programme would be less than a purely national one.

In line with its parallel intention to maintain the UK DIB, development rather than off-the-shelf purchasing is likely to be the UK’s choice. Additionally, despite the listed disadvantages for collaborative developmental procurement, in the 1998 SDR the UK Government clearly stated its intention to use international collaboration to achieve economies of scale.[34] The Government must also be expected to attempt to support UK companies to the maximum possible extent within this international collaborative framework.

In addition to Smart Procurement, a significant effort to change the MOD accounting system that supports all its expenditure has been implemented recently. Previously the MOD used cash-based financial methods, in accordance with the Government’s need to maintain tight fiscal control, on an annual basis.[35] However, cash-based accounting does not allow for the value of stock, assets, or their depreciation.[36] Nor can cash-based accounting spread capital expenditure since liabilities and capital disposal are only accounted for when the purchase or disposal occurs. Therefore, it is difficult to appreciate the full, true costs involved in running the MOD. Project CAPITAL seeks to replace the old cash-based system with one based upon Resource Accounting and Budgeting (RAB) by 2001/2.[37] RAB uses accruals accounting methods,[38] supported by the concept of matching objectives and outputs, with a clear audit trail of cost communications[39] and measurable analysis of military outputs. Most importantly, RAB will spread the cost of an asset over its life, whilst levying an annual depreciation charge on that asset.[40]

Theoretically, RAB will provide a clear view of the true cost of ownership of military capability by providing the means to recognise procurement and ownership costs, with due allowance for the depreciation of capital assets, in public annual accounts. However, it must be noted that “[RAB] is not just an accounting system: it will fundamentally change the way MOD manages its resources and operations”[41] and management structures and procedures must change to embrace it. Whilst RAB has many obvious benefits, there are many concerns that once full through life costs of military equipment are seen, and available for public audit, the focus of examination will not be to ensure efficient procurement and operation, but may simply seek to reduce the total of the annual balance sheet.

UK COMBAT AIR POWER WITHIN THE "NEW" SECURITY ENVIRONMENT

Within the generic heading of Combat Air Power there are several major operational capabilities. These have been defined in AP3000 (Air Power Doctrine, 3rd Ed)[42] as:

1. Control of the air, using defensive fighter aircraft and surface to air missiles.
2. Operations for strategic effect.
3. Anti-surface force operations including air interdiction and close air support.

AP3000 provides a wide ranging discussion on the many factors that are needed for, or act as constraints upon, Combat Air Power operations. The major factors may be summarised as:

Key Attributes/Requirements	General Constraints
Reach Responsiveness Flexible Interoperable (each other & coalition) Survivable Sustainable Information Exploitation Precision Attack (day/night, all weather, air-air & air-ground)	Low Collateral Damage Low (Nil?) Casualties Legal Use of Force Restrictive Rules of Engagement

AP3000 also discusses the tactical roles that Combat Air Power must fulfil. These roles are a combination of some that are independent and ones that support land operations. In brief these roles are:

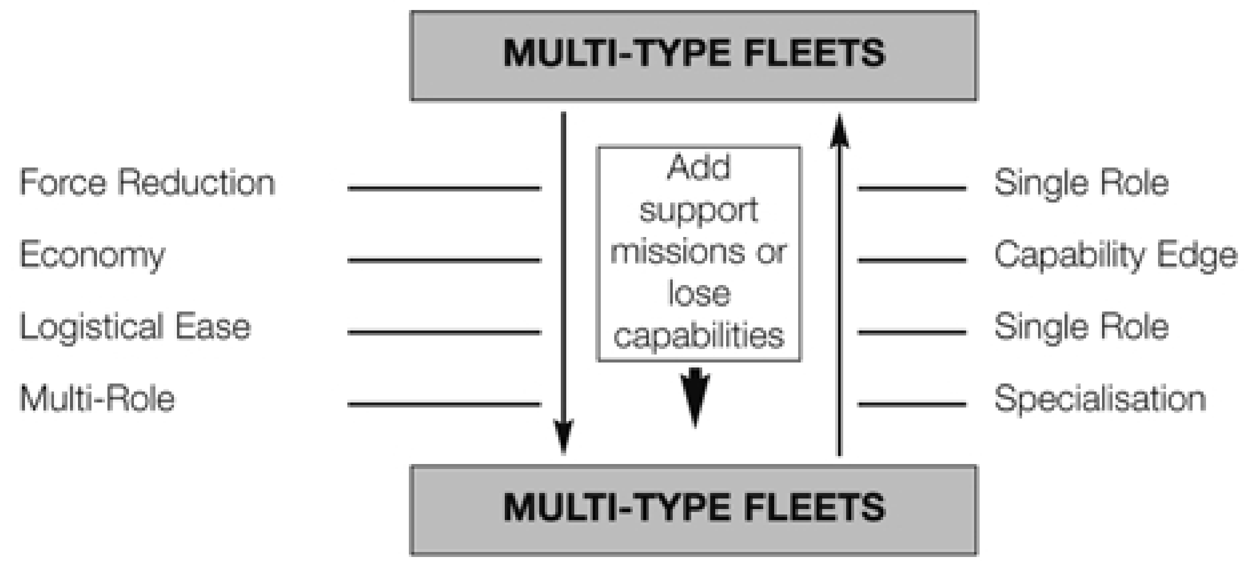
Ship-launched cruise missiles heading to Baghdad during the Gulf War.

Role	Comments
Control of the Air	Air action against enemy air power assets.
Offensive Counter Air (Airfield Attack)	Offensive air action against enemy fighters.
Fighter Sweep/Escort	Air action to neutralise or destroy enemy SAM systems.
SEAD	
Defensive Counter Air	Fighter and SAM defences against enemy air assets.
Operations for Strategic Effect	Air action against strategic targets.
Anti-Surface Force Operations	
Air Interdiction	Air action against enemy forces before they can attack friendly forces.
Close Air Support	Air action against hostile targets in close proximity to friendly forces.

It has already been noted that military, and hence Combat Air Power, assets can expect to be involved in a wide range of operations in the future. This range of operations, and the increasingly complicated joint battlespace, suggest that the current delineation of roles may not be adequate for future operations. Recalling the Kosovo air campaign, many Combat Air assets including the RAF Harrier GR7s were employed in a role reminiscent of CAS – yet there was no close contact battle in progress.[43] Similarly, the distinction between strategic effect targets and tactical targets is becoming increasingly blurred. For instance, despite being a nominally strategic weapon the RN TLAM may be the ideal weapon to use against a traditional tactical target. To ensure optimum target-weapon system matching in the future a re-examination of the interaction of Combat Air Power roles is needed to include a full appraisal of the joint battlespace.

…despite being a nominally strategic weapon the RN TLAM may be the ideal weapon to use against a traditional tactical target

The RAF has, in the recent past, tended to procure single role capable aircraft. Typical of this genre is the Tornado GR1 bomber, designed to penetrate enemy airspace at low level and in poor weather, possessing little self-defence capability that demands other fighters' protection against any competent Integrated Air Defence System. To compound the problems of the RAF procuring aircraft that are essentially single role, or providing a single capability, these aircraft are based and operated within type boundaries to ease logistical costs and requirements. This basing and operating policy severely limits any development opportunities for synergistic operations. Furthermore, the absence of any true multi-role aircraft has required, and will continue to do so, the deployment of different aircraft types to provide any particular blend of operational capabilities. This approach could never be argued to be cost-effective, either financially or operationally. The interaction between single and multi-type fleet of aircraft may be expressed as:



In the future, however, there is no doubt that logistical ease and associated economies will drive the choice towards multi-role aircraft, such as EFA. This will then present the operators with a training burden to ensure that crews are sufficiently practised in all roles, or adopt a common aircraft type with different squadron role specialisations.

Additionally, all current RAF aircraft were designed and built as standalone systems and were not considered as part of a linked system. The nearest contender for consideration as a “system” platform is the Tornado F3 fitted with the JTIDS/Link16 datalink.[44] The use of a secure, real-time datalink cannot be overstated. It allows formations of fighters to operate together with much greater tactical effectiveness than was previously available, and can provide system-wide sensor information. In short, the JTIDS/Link16 allows a dramatic reduction in “sensor-shooter” time scales. The Link16 datalink is becoming the standard for future operations and costly upgrade programmes are underway in the USA to fit it to all tactical aircraft. Regrettably, the UK MOD has not funded such a programme for its combat aircraft: indeed it is almost certain that EFA will enter service without its version of Link16. Much has been written about the significance of datalinks in future operations, and in 1998 it was suggested that “datalinks will provide the biggest gains for fighter effectiveness early in the next century”.[45] The addition of datalinks, as part of upgrade programmes, must be considered as vital to any systematic increase in capability for current and near-future combat aircraft.

DOCTRINAL ISSUES

Current RAF doctrine, as discussed in AP3000, articulates the requirements for the various roles but fails to explore the possibilities of alternative means of fulfilling those roles, for instance by the use of non-RAF assets. Indeed, AP3000 goes so far as saying:[46]

> *“Both the Royal Navy and the British Army operate rotary and fixed-wing air vehicles which offer highly capable specialist and organic support to their environment. Single-Service doctrine to explain the specialist requirements of the maritime and land environment is contained in British Maritime Doctrine and British Military Doctrine.”*

RN doctrine for the use of organic RN air assets, defined in BR 1806: British Maritime Doctrine,[47] only discusses the use of fixed wing RN aircraft in the roles of counter air, anti-surface operations and combat support air operations in direct support of the carrier task group. The RN doctrine suggests that RN air assets should be integrated with land-based air assets and it is recognised that RN air assets should be co-ordinated by the Joint Force Air Component Commander (JFACC). However, no detailed guidance on the doctrinal resolution to the operational problems associated with a complex, joint battlespace expected in the future is given. Furthermore, the TLAM is used in a purely strategic role and would not be under the command of the JFACC, but directly from the UK MOD.

There is a vast amount of doctrine available for the use of air assets by the Army.[48] However, the doctrine only concentrates upon the use of Army air assets as support to the close and deep contact battles. Similarly, RAF assets are seen in a purely supporting role. Whilst it is recognised that "Air Power has a vital role to play in modern warfare and will have a decisive influence on the outcome of any conflict"[49] there are no details on how the Army and RAF assets may be used to complement each other, and no articulation of how these Army assets may be used to fulfil the SDR aspirations of "[Air Power] having an offensive role in its own right" discussed above. In the near future, AH64 will offer a much deeper strike option for the Army and, more importantly, for any Joint Force Commander than has been previously available. The AH64, sharing many capabilities with the Harrier, must be a fully joint asset rather than simply providing battlefield support to the Army. Doctrine and training for its crews must follow these principles from its inception and develop appropriate doctrine to fully integrate all air assets into a joint battlespace to ensure effective use of the AH64.

The AH64, sharing many capabilities with the Harrier, must be a fully joint asset rather than simply providing battlefield support to the Army

The "stove-pipe" doctrinal approach seen here advocates joint, synergistic operations in the Combat Air Power arena but relegates RN and Army assets to a strictly supporting role within their respective environments rather than expound how they may be integrated into a recognised Combat Air Power role. Given that Air Power may be a combat-winning capability in its own right and with ever-decreasing resources, this failing cannot be allowed to continue. Effective application of Combat Air Power requires that a holistic view must be taken of all possible contributors in the future.

The creation of JF2000, as detailed in the SDR,[50] will effectively combine the RAF GR7 and the RN FA2 into deployable carrier air wings with reasonable air-ground and air-air capabilities, and overcome previous inter-Service rivalry and boundaries that have tended to reduce operational interaction between aircraft types. Similarly, the creation of the Joint Helicopter Force (JHF) should allow integration of the new AH64 into the mainstream of air power, although it has many more characteristics in common with the Harrier force rather than with its rotary-wing companions.

Emerging doctrine, in documents such as JWP 3-00 (1st Study Draft), does seek to integrate all Combat Air Power assets to a limited degree. Concepts such as Joint Fires within the battlespaces explored, and the relationship between the various elements of command, but the focus of this emerging doctrine remains at the tactical level in direct support of surface operations. In the future this doctrine must be expanded to encompass all aspects of Combat Air Power, including those where it is a combat activity in its own right, rather than a supporting capability, using all available assets to achieve optimum effectiveness. Additionally, revised doctrine must focus all efforts at seeing Combat Air Power over the entire joint battlespace with more flexible boundaries between the land, sea and air environments.

FUTURE POSSIBILITIES

The key question for future Combat Air Power is: how can the need be met, within acceptable cost and performance boundaries? There are many possibilities ranging from a continued investment in manned aircraft to the use of unmanned aircraft or other systems. A brief examination of the key contenders for future procurement will identify potential candidate systems for the UK. The future joint battlespace will mean that no individual platform will be able to provide a suitable operational capability in all arenas, or be able to do so as a "standalone" item: it is clear that the supporting systems must be fully integrated and considered with any future aerospace weapons options.

In the near future, EFA has been ordered to fulfil both the air superiority and ground attack roles within the RAF, replacing the Tornado F3 and Jaguar by 2010. EFA is expected to provide a quantum leap forward in capability, particularly in the air-air role, and will be the core aircraft for the RAF for some time. The approximate cost of the EFA programme will be £14.5 billion[51] for a total of 232 aircraft. When Integrated Logistic Support (ILS) and development costs are considered, the unit cost for each EFA will be £40.2 million.[52] The EFA programme is not without problems: it is late and costs are increasing. Some of these problems are caused by the technology involved, but the majority are a direct result of the collaborative nature of the programme.[53]

EFA is expected to provide a quantum leap forward in capability, particularly in the air-air role, and will be the core aircraft for the RAF for some time

Future Offensive Air System (FOAS)

The second major Combat Air Power project currently under development is the collaborative Joint Strike Fighter (JSF) planned to replace the Harrier and Sea Harrier in the UK in the 2010-2012 period. JSF will be built by a US/UK joint venture, although the winning companies have not yet been confirmed. Costs of the JSF are expected to be half that of EFA, and is likely to provide a relatively cheap fighter option, although not as capable as EFA. JSF is a primary contender for the Future Carrier Borne Aircraft (FCBA), and since the FCBA is likely to replace both the Harrier and Sea Harrier will aid the convergence of doctrine and operation discussed earlier in this Paper.
By the end of the next decade the Tornado GR4 will be replaced by the Future Offensive Air System (FOAS).

Procuring a new combat aircraft is an expensive business. An alternative option may be to upgrade those aircraft already in service. Key aspects that should be considered for such updates include the weapons system; the propulsion and flying characteristics and the provision of an increased self defence capability. Many aerospace companies, such as BAE Systems and Lockheed-Martin amongst others, are actively pursuing a market for upgrading in-service combat aircraft. For instance, Lockheed-Martin are about to complete the upgrade of European nations' F16 fighters at a cost of more than £5 million per aircraft.[54] Whilst an upgrade programme may seem to be an attractive option, the associated costs are often not instantly obvious, or may be difficult to estimate,[55] and may produce significant effects upon the deployable fleet operational capability.[56] These extra costs must include funding for long-term maintenance, which will become increasingly difficult as those aircraft become older and need more work and spares to maintain their serviceability. The UK has a history of using aircraft and weapon upgrade programmes, of greater or lesser significance, to provide an operationally essential capability that was not available during design and development phases. Thus, future UK aircraft development must include the growth potential for in-service upgrades promised by Smart Procurement.

…under development is the collaborative Joint Strike Fighter (JSF) planned to replace the Harrier and Sea Harrier in the UK in the 2010-2012 period. The Tornado GR4 will be replaced by the Future Offensive Air System (FOAS)

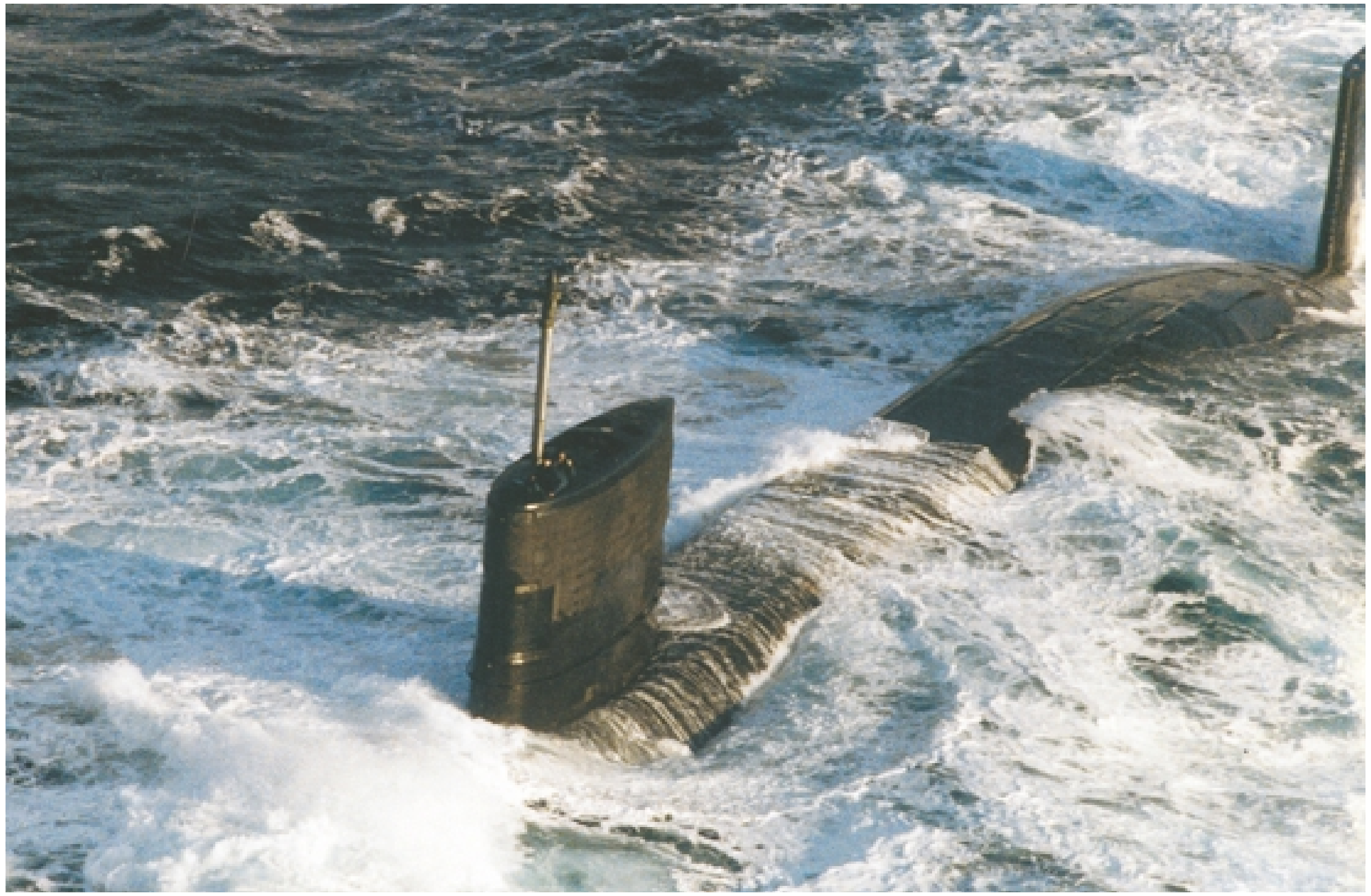
Another option to consider is that of increasing the capability of the weapons that may be used rather than the host platform. PGMs have steadily increased their dominance over simple "dumb" bombs, especially since they may be dropped from higher altitudes and provide a measure of stand-off for the delivery aircraft[57] with a high degree of accuracy using either laser guidance or

GPS tracking, but at an increased cost over their unguided counterparts. Accordingly, smart weapons should be seen as a complement to, not a substitute for, conventional "dumb" bombs. In the future it is probable that increasingly smart weapons will complement smart aircraft. Typical of these systems is the recently ordered Brimstone anti-armour weapon[58] with an advanced millimetric radar, used to detect armour targets, before detonating at the appropriate position to ensure optimum lethality with minimum chance of collateral damage. The RAF plans to acquire the Matra BAe Dynamics Storm Shadow missile to provide a stand-off capability for the EFA, Tornado and Harrier aircraft of approximately 400nms.[59] Furthermore, Storm Shadow will have a warhead that will be extremely effective against hardened targets.

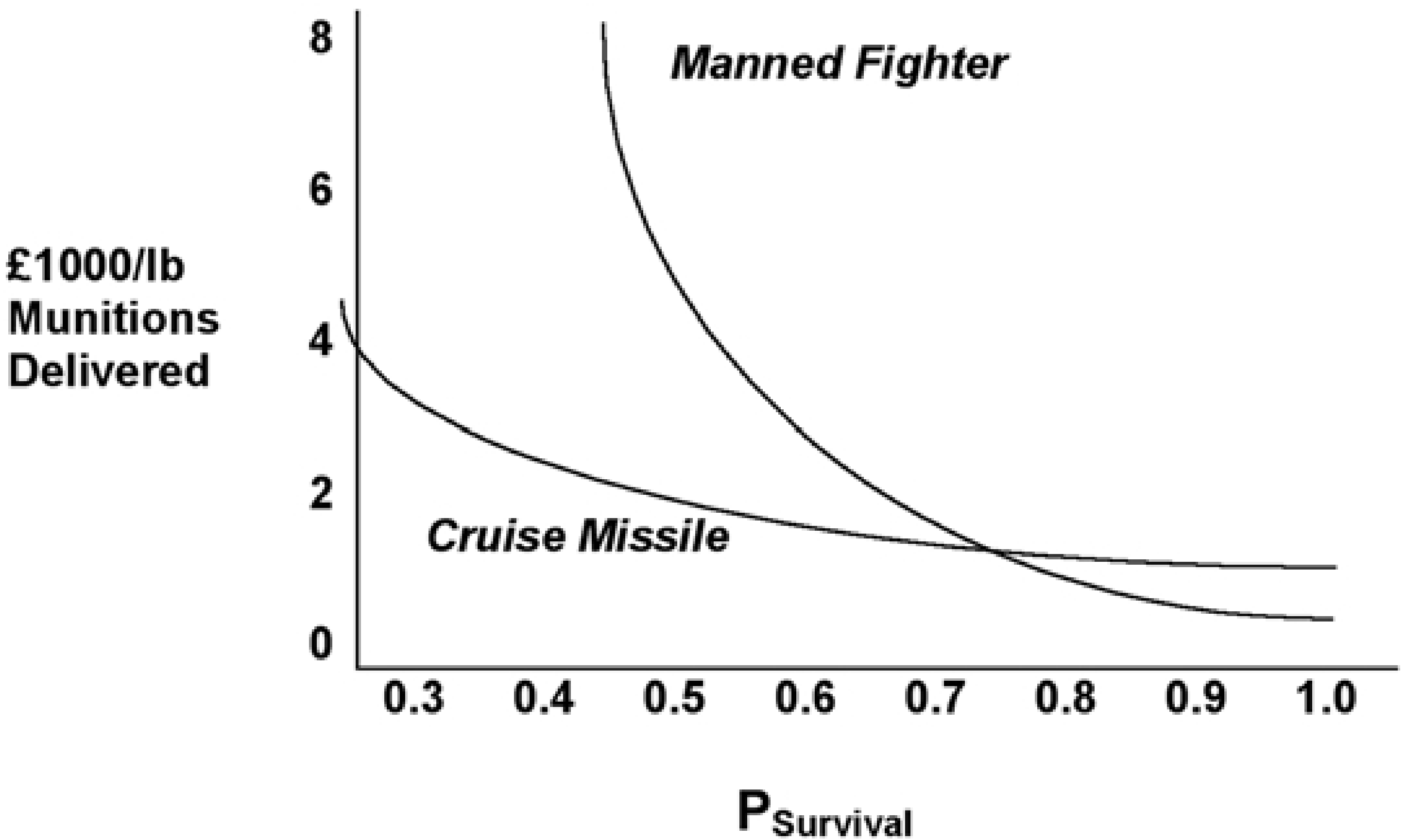
Possibly the most sophisticated stand-off weapon currently in UK service is the Tomahawk Land Attack Missile (TLAM) fitted to the RN Trafalgar class of submarines, and Astute class in due course, used in the Kosovo campaign. TLAM has a range of approximately 1,000nms and a conventional warhead of approximately 1,000lbs.[60] TLAM is an ideal weapon to attacking deep strategic targets that may be difficult to attack with manned aircraft, but has little capability against hardened targets. The procurement costs of the submarines, of the order of £270 million each, plus the refit costs involved with fitting the submarines for TLAM, together with the cost of the missiles (£850,000+[61]), could lead to the conclusion that TLAM is a very expensive single use weapon compared with the cost of a simple general purpose 1,000lb bomb – £25,000 each.[62] These figures are used only for illustration. The RN TLAM capability is only one of the many roles of the RN Submarine force. The figures do, however, serve to show that much of the cost of development and production involved with smart weapons is only used once and lost when the missile hits the target.

Brimstone, Storm Shadow and TLAM demonstrate the trend for increasingly sophisticated stand-off weapons

Possibly the most sophisticated stand-off weapon currently in UK service is the Tomahawk Land Attack Missile (TLAM) fitted to the RN Trafalgar class submarines…



that allow the firing platform to enter a hostile environment for the minimum time. All 3 systems have different combat applications, and they should be seen as complementary rather competitive. The relative cost of these weapon systems is difficult to quantify, since one can draw different boundaries for each capability. However, Lockheed Martin Tactical Aircraft Systems have suggested that it is possible to draw a simple comparison. In general terms, on the basis of cost/pound of payload delivered, using a cruise missile will be "two orders of magnitude" more expensive than using a fighter launched PGM.[63] BAE Systems contend that the cost differential may be expressed as:[64]



(Reproduced from BAE Systems Visit Notes: 2 Dec 99)

Whilst these costs are notional ones they serve to emphasise that costs and effectiveness can only be compared or considered within specific constraints or scenarios. The graph can be used to determine, for a given $P_{survival}$, whether a manned or unmanned vehicle may be the best option. For instance, if the $P_{survival}$ is greater than 0.75 then a manned solution is a relatively cheaper option, whereas for $P_{survival}$ less than 0.75, then a cruise missile would be the cheaper option. Thus, as already noted, TLAM is the ideal choice for attacking deep well-defended strategic, but unhardened, targets to complement manned aircraft attacks. Conversely, manned aircraft attacks, using PGMs or conventional weapons, would be ideal in situations demanding more flexibility or with ROE difficulties.

In addition to the smart weapons discussed above, increased range and capability for the Army MLRS is available. A development of the MLRS munitions is the Army Tactical Missile System (ATACMS) and ATACMS II system now in service with the US Army and under consideration for future procurement for the UK. ATACMS I and II can attack targets such as air defence systems, C^2 sites and the like at a range well in excess of 100nms, with further development possible to include anti-armour capability.[65] This enhanced potential capability of the MLRS must, therefore, be considered as a joint asset and able to contribute to the provision of Combat Air Power.

The UK is currently exploring options to replace the Tornado GR4 strike aircraft in approximately 2015/7 with the Future Offensive Air System (FOAS). Some £35 million has been invested since 1997 to evaluate the wide range of options that should be considered for the FOAS.[66] One of the primary options under examination is the development of Unmanned Combat Air Vehicles (UCAVs) derived, in principle, from current from Unmanned Air Vehicles (UAVs). UAV systems such as Pheonix, have been in service with the British Army for several years in the reconnaissance role for some years.

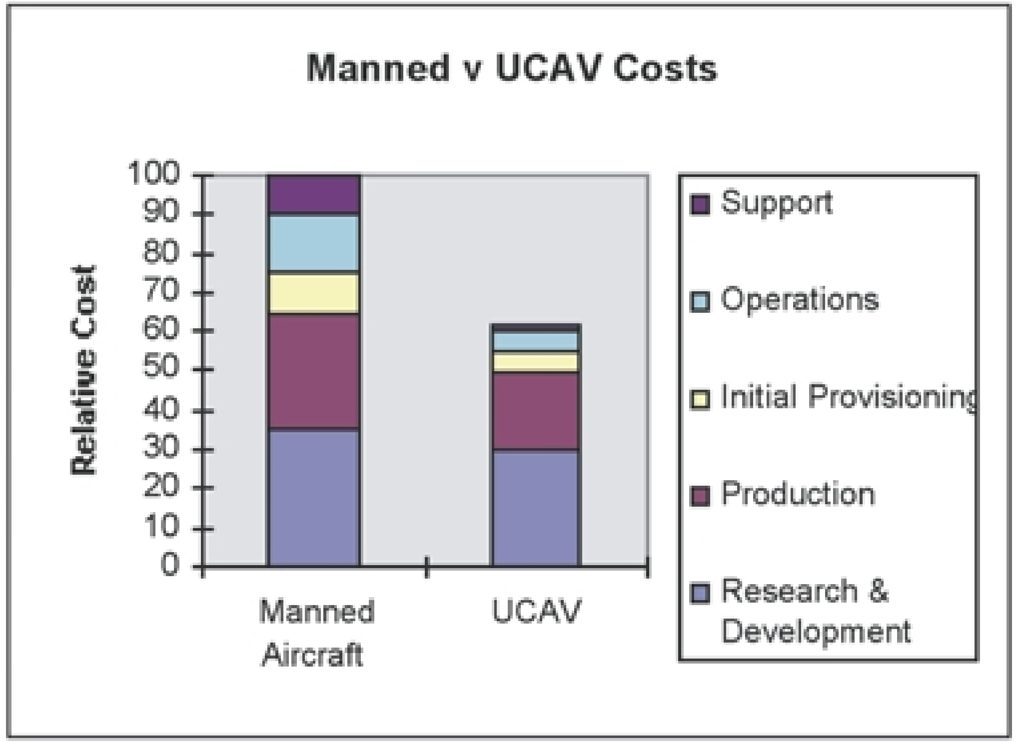
UAVs can provide an extremely effective surveillance capability, and have recently been used in limited combat roles such as defence suppression

UAVs can provide an extremely effective surveillance capability, and have recently been used in limited combat roles such as defence suppression. All current UAVs are either directly or indirectly controlled from a human operator at a ground station. Research is currently underway to investigate the feasibility of removing this need for human control by the automation of all decisions required to fulfil a mission, or to develop artificial intelligence to the point where autonomous combat operations for UAVs, or rather UCAVs, could be a reality.

On first examination, UCAVs may be appear to be a simple and cheap option for future operations. They may have many advantages over manned aircraft, especially when political constraints on reducing risk to aircrews exist. Furthermore, many studies into UCAV possibilities have agreed that the “absence of a crew, a cockpit and life support systems allows vehicles that are smaller, less detectable, and more manoeuvrable [than manned aircraft]” and a UCAV may “be lighter and better streamlined [than manned aircraft]”.[67] With appropriate development, UAVs and UCAVs appear to be capable of fulfilling operational missions such as reconnaissance, electronic warfare and SEAD.

Further examination, however, shows that UCAVs suffer from a range of technical limitations when compared with manned aircraft.[68] Firstly, more complex vehicles require sophisticated control systems with highly trained support and operational personnel. Therefore, UCAVs will need artificial intelligence capability or fail-safe remote control systems. Both of these problems present major technical challenges and may severely limit the opportunities to employ UCAVs in operations involving the use of lethal force, particularly in those operations involving problematic ROE.

Many exponents of the replacement of manned aircraft with UCAVs claim that the cost for a UCAV is of orders of magnitude below that of manned systems. The BAE Systems' studies into FOAS options suggest that the overall cost of development and ownership of a UCAV system could be expected to be some 60% of the cost of a manned system. An approximate comparison of these relative costs is:



(Reproduced from BAE Systems Visit Notes: 2 Dec 99)

BAE Systems' comparison has assumed that non-recurring, that is research and development, costs for both manned and unmanned systems are broadly comparable. It has already been seen that current technology UAVs are remotely piloted, with little autonomy, so this simple derivation of research and development costs may be extremely optimistic for the introduction of UCAVs as the sole system to fulfil the FOAS role. In the longer term, particularly with the current rate of electronics and computer development, Artificial Intelligence systems will undoubtedly have this capability and may be an ideal candidate for technology insertion to provide an upgrade route to the "son of FOAS". Moreover, ROE restrictions suggest that it is likely there will be a political requirement to retain a "man in the loop" for most lethal systems, so any UCAV must have a robust, secure and covert communications systems. This requirement presents yet another technical challenge: to provide a high data rate two-way datalink that is uninterrupted , since any interruption at a vital moment could be catastrophic. This need will bring a further cost penalty, and may also restrict operating boundaries for UCAV systems. Finally, in a battlespace involving tens, or even hundreds, of UCAVs communications bandwidth will be a serious problem, even with the use of satellite relay systems.[69] This communications link could also be a fatal weakness in any UCAV system, susceptible to enemy interference or jamming that may render the UCAV capability useless with relatively simple electronic counter measures.

Low operating and support costs are seen to be one of the major benefits, in full life-cycle terms, for the development and introduction of UCAVs. This would be possible by extensive use of synthetic training facilities – feasible since crew training would be in systems operations, rather than the mechanical skills needed to actually fly an aircraft. Up to 95% of the procured UCAV fleet could be held in reserve until required for operations, or even held in readiness by the manufacturer. The remaining 5% of the UCAV fleet would be flown continually, to train and exercise the complete weapons system, and effectively be disposed of at the end of their fatigue or flying life. Unfortunately, current civilian Air Traffic Control systems will not allow widespread UAV/UCAV operation in close proximity to passenger and freight carrying aircraft: this would significantly reduce training opportunities in peacetime, which would in turn affect operational capability of the system itself.

The advantages and disadvantages discussed above have concentrated upon the technical benefits and problems with the development of UCAVs for future operational use. The utility, or otherwise, of UCAVs must also be considered from the benefits of having a human crew, or the limitations that exist for a UCAV without a human pilot or crew. The Operational Analysis Department at BAE Systems (Warton) working on options for FOAS have suggested that aircrew have both strengths and weaknesses that must be considered when evaluating the use of UCAVs in the future. These may be summarised as:[70]

Aircrew Strengths	Aircrew Weaknesses
Decision Making Ability	Size & Shape
Tacit Knowledge & Experience	Durability
Situational Awareness Appreciation	Vulnerability
Learning Ability	Psychological Limitations
Delegation of Responsibility	Physiological Limitations
Unpredictability	Sensor/Computational Limitations
Flexibility	Cost of Training and Employment
Non Pre-programmed Communications	Social/Political Propaganda
Social/Political Propaganda & Restrictions	

This table shows that the human operator has much to offer and may be difficult to replace. This is particularly true in a dynamic combat situation that does not have a clear set of options and which cannot be reduced to a simplistic set of rules, but requires the operator to exercise judgement based upon their experience and decision making ability. Humans have been shown to be good at "intuitively picking a reasonable course of action when the information they receive is confused and incomplete".[71] Furthermore, current technology cannot reproduce the heuristic information that a pilot will have acquired throughout his/her training and experience. The unique qualities of the human mind are, for the time being, likely to remain beyond any UCAV autonomous control system. Accordingly, it follows that UCAVs may prove to be ideal for many combat applications, with manned aircraft being used in those situations requiring human judgement.

Finally, the "Social/Political Propaganda" noted above as both a strength and weakness follow from the demonstration of intent that manned aircraft can convey. The use of a manned aircraft system demonstrates clear commitment from the Government. This may help in "sending a message" to a potential adversary. Alternatively, the use of UCAVs may suggest that the

Government is not fully committed to an operation. In any deterrent or coercive operation, this false impression may serve to simply exacerbate the situation rather than contain it. The weakness of a crew is, of course, the possibility of casualties or prisoners of war: it has already been noted that this would not be welcome in the modern environment.

UCAVs offer many opportunities for radical new approaches to the provision of Combat Air Power, but do not offer a cost-free option. The factors discussed here suggest that, for the foreseeable future, UCAVs would be best used for “simple” missions to supplement, rather than replace, manned aircraft in combat roles.

In recapitulating the major themes that have emerged through this Paper, it is clear that the provision of Combat Air Power is a complicated process with a wide variety of considerations. Furthermore, “cost effective” clearly means different things to different people. Combat Air Power, within a wider military organisation, will be required for many years to come despite the end of the Cold War. The unstable international situation, with a plethora of threats including both conventional and asymmetric threats, demands that British forces are capable of providing capabilities ranging from full combat operations to peacekeeping policing actions. These operations could take place around the world, probably within a coalition framework.

Many would contend that all that is needed to provide cost-effective Combat Air Power is to reduce procurement and operating costs. However, detailed analysis shows that the problem is more involved than that. Firstly from an economic perspective, cost-effective is seen as essentially pursuing the cheapest solution to reduce the total value of the balance sheet. Politically, cost-effectiveness is bounded by the need to support the UK DIB within collaborative development programmes. Furthermore, the Government and the military hopes to use Combat Air Power when necessary but with no collateral damage or casualties, probably within a deployed coalition framework. Thus, interoperability with potential allies is vital to ensure effective use of Combat Air Power assets.

The COIEA process that is used to support all major procurement can provide a limited comparison of options, but has significant problems establishing the metrics by which operational effectiveness can be measured or compared. The metrics in use do not relate well to the tenets of manoeuvre warfare that British Defence Doctrine seeks to use. Furthermore, the modelling used by a COIEA may be limited depending upon the system in focus. It is vital that the COIEA is understood and applied intelligently by its users in the decision making process. However, it is clear that the Government’s political need to support the UK DIB may be the final arbiter in most procurement decision despite a contrary military recommendation. The provision of British Combat Air Power has recently been revitalised by the adoption of Smart Procurement, which seeks to provide “faster, cheaper and better” military equipment and has already made significant steps towards this aspiration. The benefits of Smart Procurement have not materialised yet, but they are expected to provide significant savings in defence expenditure.

The reorganisation of the MOD Central Staffs should allow fully joint development of future capabilities between all 3 Services’ air assets rather than the old single Service “stove pipes”. This synergy should provide the means to fully integrate all UK air assets in future operations. These assets will include multi-role RAF/RN fixed wing manned aircraft equipped with smart weapons such as Storm Shadow, Brimstone, LGBs *et al*, Army attack helicopters and advanced MLRS systems.

Additionally, RN TLAMs should be used to complement these assets, when appropriate. Finally, the use of UCAVs should be developed to provide a complementary capability, particularly in situations where friendly casualties are deemed unacceptable and when ROE allows the use of UCAVs, to supplement the use of manned aircraft. There is still a definite need for manned aircraft to be used in particularly difficult missions when ROE and interpretation of incomplete data is necessary.

However, all of these advances in cost-effectiveness will not provide the best possible military capability unless the underpinning doctrine, both for the roles involved and the assets used, is changed to reflect the need to integrate all of the assets to best effect within an increasingly complex battlespace. Rather than use current platforms, almost in isolation, a systematic approach must be taken and the optimum weapon system for a particular task must be procured and subsequently used. A good example of this would be the use of MLRS in a SEAD role, rather than in direct support of ground operations, replacing the need for fixed wing missions against enemy SAM systems. The conceptual basis for this integration, with positive encouragement on the lateral use of weapon systems and associated training, must be encouraged at all times. There is no doubt that future military operations will be joint, and probably expeditionary within a coalition, and unless the Combat Air Power assets are fully integrated at all levels then the huge amounts of money spent on their procurement will only provide a sub-optimal capability, and could not be claimed to be "cost effective" in the final analysis.

NOTES

1 *JWP 0-10: UK Doctrine for Joint and Multinational Operations*. UK: MOD CSE, 1998. p2C-1.

2 *AP3000: British Air Power Doctrine*. UK: Tactica Solutions, 1999. pp1.2.13-15.

3 *Strategic Defence Review.* London: The Stationery Office, 1998. p8.

4 *JWP 0-01: British Defence Doctrine*. London: MOD CS(M)G, 1996. p5.6.

5 *Ibid*. p6.8.

6 *SDR. Op Cit*. p13.

7 *Ibid*.

8 Speech by Mr Derek Fatchett MP, British Minister of State at the Launch of the Carnegie Commission Report, 8 January 1998. http://britain-info.org/bis/hdev/080198.htm – 24 Oct 1999 2110hrs.

9 *House of Commons Research Paper 98/91*. London: House of Commons Library, 15 October 1998. p42.

10 *SDR Op Cit*. p51.

11 *BAE Systems Presentation: Air Power Conference*, London, January 1999.

12 Dr Foot. P., *Presentation to ACSC3*, JSCSC. 21 Feb 00.

13 *SDR Op Cit*. p43.

14 *House of Commons Research Paper 98/91*. Op Cit. p54.

15 Many commentators, including Professor T Taylor from Cranfield University during his presentation to ACSC3 on 1 Mar 00, have expressed doubts about the nature of the UK DIB. Specifically, its national sustainability and the effect of international mergers and globalisation. These are valid concerns, but are beyond the scope of this Paper. They would be best explored as a Research Project in their own right.

16 *SDR Supporting Essays (3): The Impact of Technology*. London: The Stationery Office, 1998. p3-1.

17 *Ibid*.

18 Ed Gp Capt S Peach, *Perspectives on Air Power*. London: The Stationery Office, 1998. p131.

19 AOC-in-C STC, *Lecture to ACSC 3*: JSCSC. 22 Oct 99.

20 *Transforming the UK's Defence Procurement System*. London: Ministry of Defence, Feb 1998. p1.

21 *SDR Op Cit.* p41.

22 Primarily using COIEA – discussed over.

23 *Ibid*. p42.

24 McKinsey & Co. *Central Customer (Interim Report)*. London. 23 Jul 98.

25 Current Service incumbents are shown, they are not Service delineated and may change in the future.
26 AVM Nicholl. S., *Presentation to ACSC 3*. JSCSC Bracknell. 17 Feb 00.
27 *The MOD Investment Strategy: Section 3*. http://www.mod.uk/policy/investment/section 3.htm. 24 Feb 00 1545 hrs. p4.
28 Kirkpatrick. D., *Choose Your Weapon: COIEA and its Role in Defence Procurement*. UK: Sherrens Printers (for RUSI), 1996. pp32-37.
29 *JWP 0-01. Op Cit*. p4.8.
30 Kirkpatrick. D., *Op Cit*. pp22-31.
31 Comptroller and Auditor General, National Audit Office. *Ministry of Defence: Defence Procurement in the 1990s*. London: HMSO, 1994. p29.
32 Prof Hartley. K., *The Economics of Defence Policy*. Exeter: BPCC Wheatons Ltd (for Brassey's). p144.
33 *Ibid*. pp150-1.
34 SDR. *Op Cit*. p43.
35 *Resource Accounting and Budgeting in Government*. UK: HMSO, 1995. p3.
36 *CAPITAL.* London: MOD Central Services CS(M)G, 1996. p2.
37 *The MOD Investment Strategy: Section 2*. http://www.mod.uk/policyinvestment/section2.htm. 24 Feb 00 1550hrs. p11.
38 Accruals accounting recognises costs and income when they occur, rather than when payment or receipt occurs. Accruals accounting also accounts for full life cost of ownership of all assets.
39 *Resource Accounting and Budgeting in Government. Op Cit*. p4.
40 *The MOD Investment Strategy: Section 2*. http://www.mod.uk/policyinvestment/section2.htm. 24 Feb 00 1550hrs. p11.
41 *CAPITAL. Op Cit*. p2.
42 *AP3000(3rd Ed)*. UK: HMSO, 1999. pp2.5.8-2.7.3.
43 Discounting the actions of the Kosovo Liberation Army within Kosovo. Their role is open to debate, but were clearly not NATO troops on the ground supported by NATO CAS assets.
44 Joint Tactical Information Distribution System (JTIDS) using Link16 datalink message format. Provides real-time, secure exchange of tactical information to all network participants.
45 *Aviation Week & Space Technology*. USA: McGraw-Hill Co. 3 Aug 98.
46 *AP3000 (3rd Ed), Op Cit*. p3.11.3.
47 *BR 1806: British Maritime Doctrine (2nd Ed)*. London: HMSO, 1999. pp33/138/168.
48 *DGD&D/13/34/33 Army Tactical Doctrine Handbook (Issue 1)*. Feb 1998. pp10.1-2. D/DG&D/13/35/47 *Army Land Component Handbook* (Issue 1). Dec 1998. pp216.1-217.4.
49 *Design for Military Operations: The British Military Doctrine*. CGS, 1996. p4-27.
50 *SDR, Op Cit*. p29.
51 *Update: Major Equipment Projects. From Major Projects Report 1998*. MOD Directorate of Procurement Plans. 31 Mar 98. p21.
52 Sqn Ldr A Byford ACSC3. Previously OR (EFA) within MOD. 17 Feb 00.
53 *National Audit Office Press Notice: Eurofighter 2000, 11 Aug 95*. http://www.nao.gov.uk/pn/9495724.htm 9 Feb 00 2130 hrs.
54 *Jane's International Defense Review 12*. UK. Dec 1998. pp38-9.
55 Bourn. J. (RUSI), *Securing Value for Money in Defence Procurement*. Great Britain: Sherrens Printers, 1994. p36.
56 Author spent 1 year on HQ 11/18 Gp Airstaff (1998-99), involved with the Tornado F3 Upgrade programme and fleet management.
57 Air Cdre A Vallance (NATO Reaction Forces Air Staff). *NATO's Need for PGMs Presentation: Air Launched Weapons Conference*, London, UK: Jun 1999.
58 http://www.mod.uk/dpa/projects/brimstone.htm 23 Feb 00 1700hrs.
59 Mr Simpson. A. (Matra Bae Dynamics), *Storm Shadow Presentation: Air Launched Weapons Conference*, London, UK: Jun 1999.
60 http://www.royal-navy.mod.uk/news/tlam/spec.htm 24 Feb 00 1530hrs.
61 http://www.pbs.org/wgbh/pages/frontline/gulf/weapons/tomahawk.html 24 Feb 00 1535hrs.
62 Dr P Foot. *Presentation to ACSC 3*. JSCSC, 21 Feb 00.
63 Dr Chaput. A.J. (Lockheed Martin Tactical Aircraft Systems)., *Designs for 21st Century Combat*. Defence Procurement Analysis. UK: Reddy Mgmt Ltd. Summer 1998.
64 Davies. J., Operational Analyst for FOAS UAV. Discussion period at BAE Systems Warton, 2 Dec 99.
65 http://www.sarda.army.mil/peo-pm/tacmiss.htm & hhtp://www.dtic.mil/armylink/news/May1998/a19980511missiles.html 24 Feb 00 1700hrs.
66 Marsh. N., *Issues Surrounding the Development of Uninhabited Combat Air Vehicles*. http://www.ukdf.org.uk/gr57.html 9 Feb 00 2115hrs.
67 *Ibid*. pp1-2.
68 *Ibid*. p2.
69 Thomasson. P.G. & Dyer. D.J., *Unmanned Air Vehicles for the Millennium*. Cranfield Aerospace. http://www.atalink.co.uk/DSR/CLIENT/thomasso.htm p3. 23 Feb 00 1315hrs.
70 Davies. J., Operational Analyst for FOAS UAV. Discussion period at BAE Systems Warton, 2 Dec 99.
71 Marsh. N., *Op Cit*. p6.

BIBLIOGRAPHY

BOOKS:

AP3000: British Air Power Doctrine. UK: Tactica Solutions, 1999.

BR 1806: British Maritime Doctrine (2nd Ed). London: HMSO, 1999.

CAPITAL. London: MOD Central Services CS(M)G, 1996.

DGD&D/13/34/33: Army Tactical Doctrine Handbook (Issue 1.0). Feb 98.

D/DGD&D/13/35/47: Land Component Handbook (Issue 1.0). Dec 98.

Design for Military Operations: The British Military Doctrine. CGS, 1996.

JWP 0-01: British Defence Doctrine. London: MOD CS(M)G, 1996.

JWP 0-10: UK Doctrine for Joint and Multinational Operations. UK: MOD CSE, 1998.

JWP 3-00: Joint Operations (1st Study Draft). UK: PJHQ. 1999.

Resource Accounting and Budgeting in Government. UK: HMSO, 1995.

Strategic Defence Review. London: The Stationery Office, 1998.

Strategic Defence Review Supporting Essays. London: The Stationery Office, 1998.

The British Army: Vehicles and Equipment. UK: Gilroy Corporate Communications Ltd (for DPR(Army)).

Transforming the UK's Defence Procurement System. London: Ministry of Defence, Feb 98.

The Acquisition Handbook: A Guide to Smart Procurement (Ed 2). UK: William Lea Group (for MOD). Aug 99.

Update: Major Equipment Projects. From Major Projects Report 1998. MOD Directorate of Procurement Plans. 31 Mar 98.

Bellamy. C., *Knights in White Armour: The New Art of War and Peace*. UK: Hutchinson, 1996.

Bourn. J. (RUSI), *Securing Value for Money in Defence Procurement*. Great Britain: Sherrens Printers, 1994.

Comptroller and Auditor General, National Audit Office. *Ministry of Defence: Defence Procurement in the 1990s*. London: HMSO, 1994.

Ed Gp Capt S Peach, *Perspectives on Air Power*. London: The Stationery Office, 1998.

Kapstein. E.B., *The Political Economy of National Security*, USA: General Graphic Services, Inc. 1992.

Kincaid. B., *A Dinosaur in Whitehall*, UK: Biddles Short Run Books (for Brassey's). 1997.

Kirkpatrick. D., *Choose Your Weapon: COIEA and its Role in Defence Procurement*. UK: Sherrens Printers (for RUSI), 1996.

Prof Hartley. K., *The Economics of Defence Policy*. Exeter: BPCC Wheatons Ltd (for Brassey's). 1991.

Webb. T., *The Armour-Plated Ostrich*. UK: Comerford & Miller, 1998.

MAGAZINE ARTICLES:

Aviation Week & Space Technology. USA: McGraw-Hill Co. 3 Aug 98.

Defence Procurement Analysis. UK: Reddy Mgmt Ltd. Summer 98. Dr Chaput. A.J. (Lockheed Martin Tactical Aircraft Systems)., *Designs for 21st Century Combat*.

Interavia: Business & Technology (Vol 52, No 608). Switzerland, April 97.

Jane's International Defense Review 12. UK. Dec 98.

Jane's International Defense Review 32. UK. Jun 99.

RESEARCH PAPERS AND REPORTS:

Bittleston. M., *Adelphi Papers 250: Co-operation or Competition? Defence Procurement Options for the 1990s*. UK: Brassey's (for the IISS). Spring 1990.

Central Customer (Interim Report). McKinsey & Co. London. 23 Jul 98.

House of Commons Research Paper 98/91. London: House of Commons Library, 15 October 98.

Notes on the Royal Air Force. JSCSC, Sep 99.

INTERVIEWS, CONFERENCES AND PRESENTATIONS:

Air Cdre A Vallance (NATO Reaction Forces Air Staff). *NATO's Need for PGMs Presentation: Air Launched Weapons Conference*, London, UK: Jun 99.

AOC-in-C STC, *Lecture to ACSC 3*: JSCSC. 22 Oct 99.

AVM Nicholl. S., *Presentation to ACSC 3*. JSCSC Bracknell. 17 Feb 00.

BAE Systems Presentation: Air Power Conference, London, January 99.

Davies. J., Operational Analyst for FOAS UAV. Discussion period at BAE Systems Warton, 2 Dec 99.

Dr Foot. P., *Presentation to ACSC3*, JSCSC. 21 Feb 00.

Mr Simpson. A. (Matra Bae Dynamics), *Storm Shadow Presentation: Air Launched Weapons Conference*, London, UK: Jun 99.

Sqn Ldr A Byford ACSC3. Previously OR (EFA) within MOD. 17 Feb 00.

Wg Cdr Teakle RAF AWC, *Lecture to ACSC3*. JSCSC: 8 Dec 99.

INTERNET SOURCES:

GP3: October 1996. RUSI. *The Implications of Lessons Learnt From Desert Storm for the JSF and FOA*. http://www.ukdf.org.uk/gr3.htm 9 Feb 00 1830 hrs.

http://www.mod.uk/dpa/projects/brimstone.htm 23 Feb 00 1700hrs.

http://www.mod.uk/dpa/projects/fcba.htm 23 Feb 00 1715hrs.

http://www.royal-navy.mod.uk/news/tlam/spec.htm 24 Feb 00 1530hrs.

http://www.pbs.org/wgbh/pages/frontline/gulf/weapons/tomahawk.html 24 Feb 00 1535hrs.

http://www.sarda.army.mil/peo-pm/tacmiss.htm 24 Feb 00 1702hrs.

hhtp://www.dtic.mil/armylink/news/May1998/a19980511missiles.html 24 Feb 00 1700hrs.

National Audit Office Press Notice: Eurofighter 2000, 11 Aug 95. http://www.nao.gov.uk/pn/9495724.htm 9 Feb 00 2130 hrs.

Marsh. N., *Issues Surrounding the Development of Uninhabited Combat Air Vehicles*. http://www.ukdf.org.uk/gr57.html 9 Feb 00 2115hrs.

Speech by Mr Derek Fatchett MP, British Minister of State at the Launch of the Carnegie Commission Report, 8 January 1998. http://britain-info.org/bis/hdev/080198.htm – 24 Oct 1999 2110hrs.

Speech by Mr George Robertson MP, Secretary of State for Defence at Chatham House, 12 March 1998. http://www.mod.uk/speeches/sofs3_98.html – 24 Oct 1999 2100hrs.

The MOD Investment Strategy: Section 3. http://www.mod.uk/policy/investment/section 3.htm. 24 Feb 00 1545 hrs.

The MOD Investment Strategy: Section 2. http://www.mod.uk/policyinvestment/section2.htm. 24 Feb 00 1550hrs.

The Strategic Defence Review: How Strategic? How much of a review? http://www.kcl.ac.uk/depsta/rel/cds/sdr.htm 15 Sep 99 1830hrs.

Thomasson. P.G. & Dyer. D.J., *Unmanned Air Vehicles for the Millennium*. Cranfield Aerospace. http://www.atalink.co.uk/DSR/CLIENT/thomasso.htm. 23 Feb 00 1315hrs.