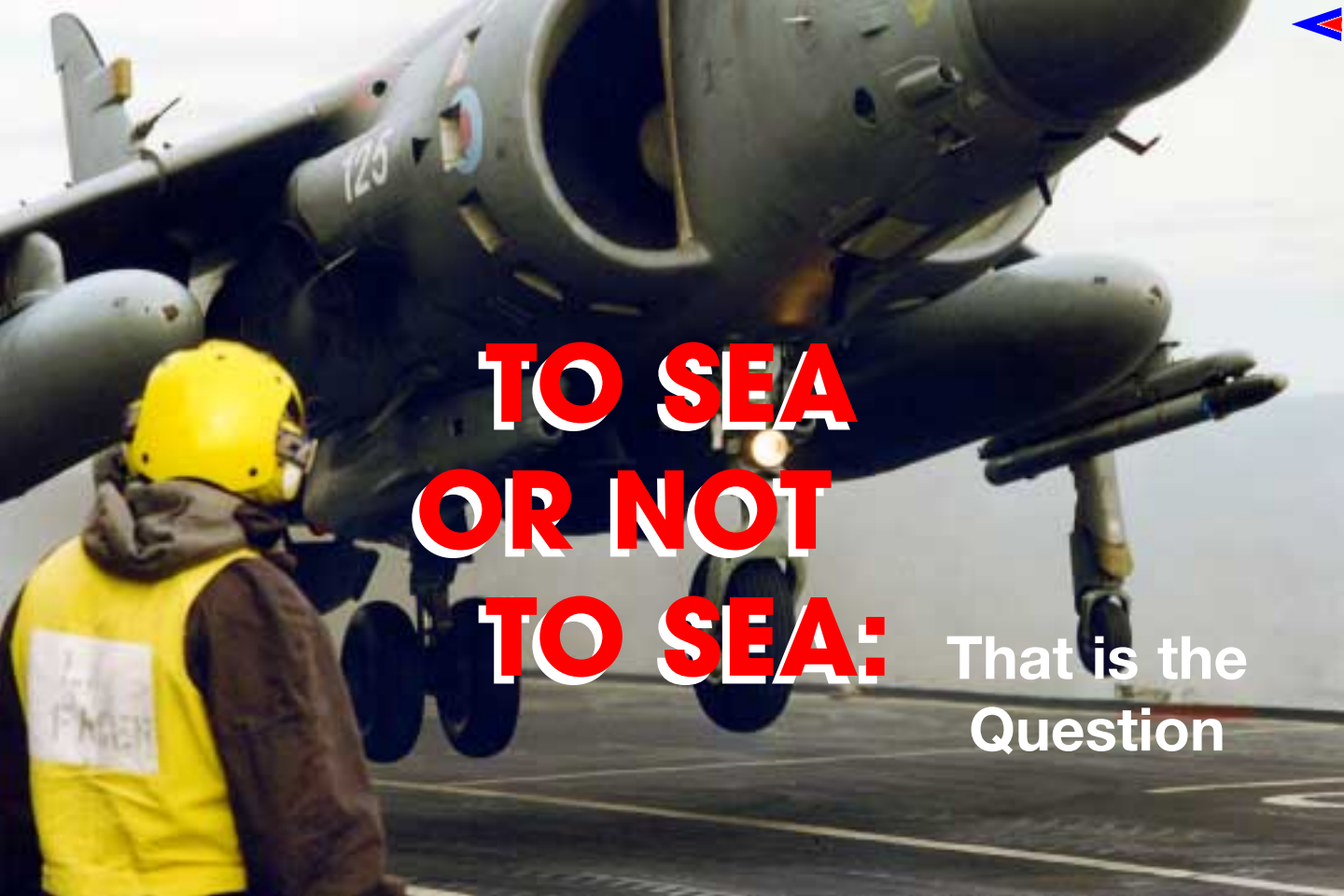
TO SEA
OR NOT
TO SEA:
That is the
Question

How Should Joint Force 2000 be Deployed to Maximise its Air Power Utility in the Likely Limited Conflicts of the Future?

By Wing Commander Neil Meadows RAF

The 1998 Strategic Defence Review proposed Joint Force 2000 as a joint RAF/RN force to provide a deployable and effective offensive air capability to meet the likely expeditionary roles of the post-Cold War era. Since its inception, however, there has been much debate on the composition of the Force, its ownership and its Command & Control, but little discussion of how its air power potential might best be deployed in modern, complex emergencies. This essay uses articles in books, journals, magazines and on the Internet, as well as information obtained in interviews with key players in the Joint Force 2000 implementation process, to analyse the various strengths and weaknesses of both sea and land basing (including the likely effects of the procurement of the proposed Future Aircraft Carrier and the Future Carrier-Borne Aircraft). The essay concludes that, in terms of the efficient and effective use of Joint Force 2000's air assets, there is a direct relationship between the most appropriate deployment option and the intensity of the conflict in which the Force is likely to be involved. Therefore, to maximise Joint Force 2000's air power utility in the likely limited conflicts of the future, it should be deployed strictly according to the combat scenario, and not according to the historical (single-service) precedents or political whims which have prevailed in the past.

INTRODUCTION

In recognition of the 'new strategic realities' of the post-Cold War era, the 1998 Strategic Defence Review (SDR) structured Britain's armed forces on an 'expeditionary' basis to meet the demands of modern, complex emergencies instead of the traditional NATO European role.[1] Expounded within this expeditionary theme was the key issue of 'Jointery'[2] and the recognition in a 'Joint Vision Statement'[3] that 'the traditional distinction between ground, sea and air theatres of operations is rapidly being replaced by a single battlespace, embracing all 3 environments'. The SDR introduced some 7 new joint ventures,[4] including Joint Force 2000 (JF 2000), which was proposed as 'a concept for a joint RAF/RN force to be established from around the middle of the next decade',[5] to provide a deployable and effective offensive air capability to meet the likely expeditionary roles of the post-Cold War era. It is planned that the Force will eventually operate a common aircraft type and will 'build on the success of current joint Harrier operations and gradually merge RN and RAF cultures and practices towards a properly joint force, capable of land attack and air defence operations'.[6]

Although heralded as 'a historic proposal from the First Sea Lord and the Chief of the Air Staff',[7] the JF 2000 idea is not new. In 1961, the Minister of Defence tasked the Admiralty to 'consider the shape of Britain's future naval policy for the 1970s'.[8] The Admiralty was 'careful to emphasise the complementary nature of carriers and land-based air power' and suggested a 'world-wide maritime strategy' and a 'truly inter-Service force'.[9] The First Sea Lord presented the proposed aircraft carriers as 'National assets; as mobile, self-contained airfields…not in competition with shore-based air power'.[10] He concluded that 'if British military power is to continue to be deployed around the world, then mobile airfields in the form of aircraft carriers ought positively to be part of this country's armoury [and] we should welcome as much flexibility between seaborne and land-based aircraft squadrons as the Admiralty and the Air Ministry together could devise'.[11]

The Admiralty's proposals were given further weight by the independent Festing Study,[12] which recommended 'a common light bomber/strike fighter for RAF/RN use' that could be 'used in operations either from shore bases or from carriers according to the requirements of a particular operation'.[13] Unfortunately, the vision was not realised, partly because of inter-Service rivalries,[14] partly because the British attack carrier was seen in the 1960s as an instrument of power projection for only 'limited' operations,[15] but mainly because of the crippling budgetary cuts associated with the 1966 Healey Defence Review.[16] It is perhaps ironic, therefore, that the SDR propounded a similar joint air capability as the most cost-effective way of meeting the requirements of the 'limited' operational scenarios of the post-Cold War era whilst, at the same time, increasing the operational effectiveness of both services.

Since the announcement of the SDR, the development of the 'JF 2000 Initiative' has proceeded apace. The JF 2000 Study Team recommended in October 1998[17] that the Force should form within RAF Strike Command, under command of a RN Rear Admiral (2-Star) and a RAF Air Commodore (1-Star). The JF 2000 Implementation Team formed on 1st February 1999 and

Strike Command has developed infrastructure and organisational plans for the collocation of the current RAF and RN Harrier forces at RAF Cottesmore and RAF Wittering in 2003.[18] For the longer term, the Staff Requirements for the Future Carrier Borne Aircraft (FCBA) and the Future Aircraft Carrier (FAC) are being prepared. The Combined Operational Effectiveness and Investment Appraisal (COEIA) for the FCBA is due to report in 2000; both the FAC and the FCBA are expected into service in 2012.[19] However, whilst the studies so far have concentrated on the composition of the Force, its ownership and its Command & Control, there has been little discussion of how its air power potential might best be employed in modern, complex emergencies. In the words of Air Commodore Probert, there has been 'too much dispute over ownership, too little about planning for roles.'[20]

So, will 'Harriers on Carriers' be the panacea for Britain's future air power requirements, will JF 2000 operate equally effectively from aircraft carriers and land bases (as the SDR suggests), and exactly how should it be deployed to maximise its air power utility in the likely limited conflicts of the future? To answer these questions, this essay will define the composition and capabilities of JF 2000 and will discuss, in detail, the likely advantages and disadvantages (in terms of air power projection) of basing it at sea and on land. In doing so, the essay will assume (for the purposes of analysis) that a land basing option is available, but recognises that this may not always be the case.[21] The essay will not reopen the debate about whether sea or land-based air power would best serve the National interest, nor will it revisit old arguments which challenged the procurement of the FAC. Instead, by comparing the various strengths and weaknesses of both sea and land basing (including the likely effects of the procurement of the proposed FAC and FCBA), this essay will show that *both* options are vital to the effective and efficient use of JF 2000's air power potential, and that there is a direct relationship between the most appropriate deployment option and the intensity of the conflict in which the Force is likely to be involved. The essay will conclude, therefore, that to maximise Joint Force 2000's air power utility in the likely limited conflicts of the future, it should be deployed strictly according to the combat scenario, and not according to the historical (single-service) precedents or political whims which have prevailed in the past.

FORCE COMPOSITION

Before considering its various strengths and weaknesses, it is important to define exactly what JF 2000 will be. There is a popular misconception that the Force will comprise aircraft carriers, escorts, amphibious assault ships, mine countermeasure vessels and fleet auxiliaries operating with Nimrod Maritime Patrol Aircraft in a similar configuration to an American Carrier Battle Group. However, this sort of 'hard-hitting, flexible and genuinely deployable force, able to undertake the full spectrum of short-notice missions in today's international environment.'[22] describes not JF 2000, but the new Joint Rapid Reaction Force[23] (JRRF), which was also proposed by the SDR. The JF 2000 Initiative is 'simply' the amalgamation of the RAF and RN Harrier fleets and operations involving the resultant joint air wings.[24] Therefore, although the sea power capabilities of JF 2000's likely escorts[25]

and its carrier are not inconsiderable, this essay will concentrate on the air power utility of JF 2000's aircraft (whether they be land or sea based).

At present, JF 2000 comprises 2 aircraft types. The RAF Harrier GR7 is a versatile surface attack and reconnaissance aircraft with a Short Take-Off and Vertical Landing (STOVL) capability. It has a sophisticated, integrated cockpit, and is capable of medium and low level attack sorties, by day and by night, and in poor weather, using Night Vision Goggles or Forward-Looking Infra-Red equipment or a combination of both. Its armaments include 2 cannons, and combinations of up to 4 Sidewinder air-to-air missiles, 7 Cluster Bombs, 2 Laser Guided Bombs (LGB) and 2 rocket pods. In addition, the aircraft carries a comprehensive self-defence Electronic Countermeasures (ECM) suite and may carry an external reconnaissance camera pod or a Thermal Imaging and Laser Designation (TIALD) pod.[26]

The RN Sea Harrier FA2 is a capable air defence fighter with a similar STOVL capability to its RAF counterpart. The aircraft is fitted with the Blue Vixen multi-mode pulse doppler air intercept radar which, in concert with the Advanced Medium Range Air-to-Air Missile (AMRAAM), gives it an all-weather, multi-target, Beyond Visual Range look-down / shoot-down capability. The aircraft may also be fitted with Sidewinder air-to-air missiles and twin cannons in the air-to-air role, and either free-fall or LGBs in a limited air-to-ground role (although the Sea Harrier cannot self-designate its targets).[27]

ADVANTAGES OF DEPLOYMENTS AT SEA

A fundamental consequence of the collapse of the Soviet Union (and the effective demise of the Soviet Navy) is that there is no longer any nation which can challenge Western maritime supremacy and therefore no likelihood of a sustained conflict at sea.[28] Whilst it would be foolish to conclude that control of the sea will never be contested, the focus of maritime operations in the post-Cold War era has inevitably shifted from 'power *at* sea' to 'power *from the* sea',[29] away from traditional 'blue water' operations towards what have become known as 'littoral'[30] (or 'brown-water') operations. Traditional 'naval' strategy has therefore become increasingly 'joint' as the capabilities of all 3 Services have been integrated to project power ashore in these littoral regions. In 1992, the US Navy and Marine Corps defined a new strategic focus,[31] which established the 'Naval Expeditionary Force' as the basic building block for US naval operations.[32] The creation of JF 2000 reflects the British Government's recognition of this need to 'focus a higher proportion of naval effort on the projection of power ashore'.[33]

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Embarked at sea, JF 2000 offers a potent power-projection capability throughout the spectrum of naval roles.[34] In high intensity 'war fighting', the Harrier FA2 and organic (Sea King) Airborne Early Warning (AEW) aircraft would form an indivisible part of an aircraft carrier's combat power in the conduct of air defence operations and Anti-Surface Unit Warfare (ASUW) tasks. Under this air defence umbrella, the Harrier GR7 could be used in a variety of land attack roles, from interdiction and offensive counter-air missions, to the close air support of amphibious landings. The Falklands campaign of 1982 provides good examples of the utility of a multi-role seaborne air capability[35] (and the efficacy of a joint approach). Whilst Sea Harriers destroyed some 25 Argentinean aircraft in air-to-air combat, some 500 ground attack missions were flown.[36] These included close air support, offensive counter air, suppression of enemy air defences and ASUW operations.

Notwithstanding these historical successes, it is in the field of 'naval diplomacy'[37] that JF 2000 is likely to have its greatest utility in the post-Cold War era. The Harrier GR7's ability to deliver Precision Guided Munitions will add considerable substance to coercive operations,[38] particularly in view of modern Western political sensitivities about the avoidance of collateral damage and civilian casualties. This coercive capability was exemplified during Operation BOLTON[39] in 1998 when HMS Invincible (and subsequently HMS Illustrious) joined US carriers in the Gulf to induce Saddam Hussein to accede to UN inspection demands. Despite the modest nature of the British contribution, 'the embarkation of RAF Harrier GR7s, alongside Sea Harriers allowed the carrier to show its joint credentials.'[40] Operations DENY FLIGHT and DELIBERATE FORCE in the former Yugoslavia between 1993 and 1995 exemplified JF 2000's likely utility in peace inducement and peace enforcement operations of the future. Whilst the Harrier FA2s could provide control of the air, the Harrier GR7s could strike at pin-point targets using TIALD-designated LGBs, or with their highly-accurate, high-velocity rockets. The same aircraft could also be used in the reconnaissance role in

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subsequent Bomb Damage Assessment missions. In benign Peace Support Operations,[41] the Harrier FA2s could be used to patrol UN no-fly zones or to escort unarmed transport aircraft through hostile airspace. Harrier GR7s could be used in a variety of surveillance roles as well as in close air support of ground forces, if required. Even in the early days of a crisis (where specific policy objectives may be unclear), JF 2000 could have a significant effect. Whilst the presence of an aircraft carrier already conveys a 'tangible commitment'[42] in terms of diplomatic signalling, JF 2000's all-round striking power would add greater credibility to the Navy's customary 'poise' in operations of preventative diplomacy and would provide an early and high-profile message of the British Government's political and military intent. Lastly, by demonstrating the British Government's commitment to a credible expeditionary air capability, JF 2000 could assist greatly in the process of alliance building through bilateral or multilateral exercises with nations around the world, as the US Navy's UNITAS and RIMPAC exercises have ably demonstrated.[43]

However, JF 2000 offers much more than just the combined capabilities of 2 aircraft types. Embarked on its 'floating air power platforms',[44] it will harness the 2 key maritime attributes of 'mobility' and 'sustained reach'[45] to its own environmental characteristics to provide 'the presence, flexibility and utility required for most foreseeable incidents'.[46] Because the sea covers some 70% of the Earth's surface, aircraft carriers are able to deploy (or redeploy between theatres) almost unrestricted through international waters (at some 400 miles per day) to provide mobile, self-contained airfields in areas which would otherwise be inaccessible to land-based aircraft, either because Host Nation Support (HNS) or overflight rights cannot be secured, or because of a lack of suitable airfields (the number of US overseas bases, for example, has reduced from 127 to just 25[47]). Once in theatre, an aircraft carrier is constrained only by the littoral boundary and can reposition to suit the tactical situation (for example, to maximise a favourable force gradient[48]) or to find more suitable operating conditions for its embarked aircraft.[49]

In addition to this strategic and tactical mobility, aircraft carriers can also 'loiter off an enemy coast for weeks or even months before being brought into action if and when the Government feels this is necessary'[50] without the need to ask for basing rights which may mean 'offering political or economic concessions or revealing a government's intentions in a politically embarrassing fashion'.[51] Thus, in its maritime role, JF 2000 will offer the ability to 'exploit the access the sea can provide'[52] to provide a fully manoeuvrist[53] and joint maritime force capable both of autonomous operations and flanking support to land-based assets. In the words of Rear Admiral Cobbold, it will meet the '6 jargon-coated criteria for operations in the new millennium: flexibility, versatility, availability, deployability, sustainability and interoperability'.[54]

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LIMITATIONS OF SEABORNE OPERATIONS

This exciting picture must be viewed, however, in the light of some significant shortfalls in JF 2000's current capability to project air power ashore due, in the main, to the limitations of the existing aircraft and their carriers. Although both variants of the Harrier are capable aircraft, they are limited in their endurance, range and load-carrying capacity.[55] The FA2 in its air defence configuration, for example, can loiter for just 90 minutes on station at a radius of only 100nm; in its anti-shipping role, it has a combat radius of only 200nm.[56] Notwithstanding the famous 'ski-jump', the take-off run available on current British aircraft carriers appears insufficient to launch the GR7 with more than one LGB, which must be dropped (or jettisoned) before recovery

to bring the aircraft's weight below the maximum permitted for a vertical landing, particularly in warmer climates (although engine upgrades are planned).[57] Lastly, whilst the Harrier GR7 is a good medium-altitude bomber, it has no 'stealth' capability and cannot therefore be used on the 'first night' of major operations against an enemy's air defence systems. As regards the carriers, the RN's INVINCIBLE Class (CVSGs) were originally designed to operate as Anti-Submarine Warfare (ASW) helicopter platforms and were only subsequently provided with a limited fixed-wing air defence capability.[58] By virtue of their limited size, therefore, they cannot mount Air-to-Air Refuelling (AAR), Electronic Warfare (EW) or Suppression of Enemy Air Defence (SEAD) missions. However, without AAR, JF 2000's short-range Harrier aircraft will lack the reach for deployment and deep missions, will be unable to be held airborne for survival or short-notice tasking, will be unable to escort other combat aircraft over long ranges and will be limited in mission endurance. Without comprehensive EW and SEAD support (including Electronic Support, Counter and Protection Measures), JF 2000's aircraft will be critically vulnerable to modern Surface to Air Missile systems and Anti-Aircraft Artillery. With only the relatively limited AEW capability provided by the Sea King W, JF 2000's commanders will lack the comprehensive air picture required to fully evaluate an enemy's air activity or to interface with friendly air, land or sea operations. As the Falklands campaign demonstrated:

> 'The British fleet suffered severely from its lack of AEW or AWACS capability to defend the carriers… [which] meant that warning time was restricted to the ship's radar range. The Harriers did a marvellous job in reacting rapidly, with pilots stationed in cockpits and being airborne in minutes after notice; but even this could not adequately compensate for the lack of an early warning system. Thus, the Navy operated as it did in World War II.'[59]

Maintaining logistical support for a carrier-borne air offensive could also be problematical. Assuming just 4 sorties per day per aircraft (and with a single bomb load for the Harrier GR7), JF 2000 would consume some 240 tonnes of aviation fuel and 32 LGBs per day.[60] Notwithstanding planned modifications to remove the Sea Dart missile system to increase the weapons magazine capacity,[61] this is likely to be beyond the capability of current British aircraft carriers to sustain without daily replenishment at sea, thus further limiting the ship's tactical flexibility and the tempo of its air operations. The size of current aircraft carriers also limits the number of aircraft embarked and the conditions in which those aircraft can be recovered. Without an arrestor capability, it is impossible to recover any aircraft which have been damaged sufficiently to preclude a vertical landing[62] and, 'with only 18 aircraft of whatever mix, the [British] Carrier Air Group is pitifully small'.[63] With a likely mix of 8 FA2s, 8 GR7s and a couple of helicopters,[64] JF 2000's current air power projection capability is extremely limited. Therefore, whilst British aircraft carriers might be big ships, JF 2000 will never be part of the 'Big League',[65] unless as a coalition partner with the USA.[66]

To maintain her global interests America requires a total of 14 deployable aircraft carriers

The likely size of the fleet will also restrict JF 2000's potential, particularly in response to immediate, high intensity crises. American experience has shown that a total of 3 carriers are needed to sustain one forward in an area of interest (allowing for time spent preparing for and returning from deployments, and for refitting programmes in between).[67] To maintain her global interests,[68] therefore, America requires a total of 14 deployable aircraft carriers.[69] Whilst British interests are certainly not this broad, they have been quoted as 'abnormally vigorous for a small country lurking off the north-west coast of Europe'.[70] A 'fleet' of just 2 CVSGs, therefore, will inevitably be insufficient to meet all of the demands likely to be placed upon it. Effective interpretation of political signals might allow prior positioning of JF 2000 to excellent advantage (The USS Eisenhower and Independence, for example, were the only air power assets on hand to deter Iraqi incursions into Saudi Arabia following the invasion of Kuwait in August 1990). However, notwithstanding its ability to deploy almost unrestricted through international waters, with only 2 aircraft carriers at its disposal, it seems highly likely that JF 2000 will find itself poorly placed to respond to immediate events (the combat phase of the Yom Kippur War, for example, was over before the first US ship arrived in the area).[71]

Lastly, it cannot be ignored that aircraft carriers are extremely high value assets, which offer almost irresistible premiums to an opponent.[72] The inherent vulnerability of the aircraft carrier is therefore also likely to limit JF 2000's power projection capability. The collapse of the Soviet Union has sparked the proliferation of small, conventionally-armed, diesel-powered submarines[73] (SSKs or 'Kilos'), which are extremely quiet and difficult to detect in the shallow waters of the littoral, and which pose a

…one of the most feared modern threats is the fast attack boat, which is cheap, expendable, difficult to counter and potentially lethal to the largest of ships

significant threat to carrier operations and thus to JF 2000 in its maritime role. Another worrying modern development is the 'horizontal proliferation' of highly-accurate, sea-skimming, smart, anti-shipping missiles which can be easily acquired and operated by third-world countries.[74] These missiles may be launched from mobile sites in a 'fire and forget' mode and may give little or no warning of their approach (as the US frigate Stark discovered when she was hit by 2 Exocet missiles in the Persian Gulf in May 1987). In littoral areas, therefore (which, by their very definition, are within effective reach of land-based systems), anti-shipping missiles pose a considerable threat to carrier operations. Modern, plastic, anti-shipping mines are also cheap, easy to acquire, almost impossible to detect and lethal to shipping if scattered in large numbers in shallow (littoral) waters. Thus, they present an ideal weapon for relatively primitive navies to deny considerable areas to even the most sophisticated of forces.[75] However, one of the most feared modern threats is the fast attack boat,[76] which is cheap, expendable, difficult to counter and potentially lethal to the largest of ships. These small craft may be used to launch anti-shipping missiles (such as the Egyptian Komar-class vessel which sank the Israeli destroyer Eilat with a SS-N-2 'Styx' missile in 1967), may carry infra-red or laser-guided anti-aircraft missiles for use against a carrier's aircraft as they launch or recover, and may be packed with explosives and rammed against the hulls of surface vessels by fanatical suicide bombers.

Whilst the protagonists of aircraft carriers have argued that such vessels are unsinkable,[77] their opponents have argued that they are hopelessly vulnerable (particularly to modern sea-skimming weapon systems) and are useful, therefore, only in the most benign environments. In reality, the truth lies somewhere between these 2 extremes. However, even the Americans (who view their aircraft carriers as invulnerable floating citadels[78]) recognise the seriousness of the threat in the littoral environment,[79] which is frequently characterised by confined and congested waters and airspace, occupied by friends, potential adversaries and neutrals alike, making identification (and protection of the carrier) profoundly difficult. In these conditions, a ship on station

cannot lightly engage incoming 'contacts', even in a war zone, and it is impossible to differentiate a civilian motor yacht from a 'fast attack boat' until the vessel is well within launch range. Unfortunately, however, 'only the big [American] carriers can carry aircraft capable enough to support the fleet against all plausible threats.'[80] Thus, as the intensity of a conflict increases, the risk to JF 2000's aircraft carriers from submarines, land-based missiles, mines and fast-attack craft is likely to become increasingly unacceptable. In modern 'conflicts of choice', therefore, given the real penalties involved in the sinking of an aircraft carrier, it is difficult to envisage Britain *choosing* to put one of its vessels as far 'into harm's way' as war games and operational analysis might suggest. Thus, the basic premise of British carrier operations is likely to remain as it was in the Falklands War[81] that 'no greater disaster could occur than the loss of an aircraft carrier'.[82] Therefore, as the threat to its sea platform increases, JF 2000 is most likely to be deployed in a position to ensure maximum protection of its carrier, rather than to maximise the effectiveness of its aircraft. Furthermore, if the carrier were to be threatened such that the FA2s were required to concentrate on air defence or defensive sea control, the Force's land attack capability would be degraded even more. 'In these situations, a small carrier may – just about – be able to control the water in which it operates with its accompanying group, but be unable to extend its influence any further.'[83]

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ADVANTAGES OF LAND BASING

By deploying to a land base (if available), JF 2000 could arrive rapidly in theatre in numbers limited only by aircraft availability, with its initial weapon outload and logistical support provided by Air Transport aircraft. Prepared runways would allow the Harrier GR7 to launch with its maximum weapon complement, and undertake deep incursions into enemy territory with the full panoply of combat support (including AAR, EW, SEAD and AWACS). In these scenarios, JF 2000's Harrier FA2s could also provide an inherent fighter sweep and escort within the overall Force package. In terms of air power alone, therefore, deploying JF 2000 to a land base would appear to offer the maximum advantage, as even the most ardent proponents of aircraft carriers agree. 'Land bases, where available, correctly sited and adequately supplied, will almost certainly permit air operations on a greater scale.'[84]

DISADVANTAGES OF LAND BASING

So, in the light of the prospective disadvantages of carrier-borne operations, and the scale of air operations that are possible only from a land base, it might appear that JF 2000 should be based almost exclusively on land in order to maximise its air power utility. However, to enable an airfield to 'generate and recover air power missions',[85] a considerable number of functions

are required. These comprise operations support (including Air Traffic Control, command and control, intelligence exploitation facilities, firefighting and rescue services), logistics (including flight line, air movements, fuel, storage and motor transport facilities) and administration (including personnel, resource and financial management, medical infrastructure, accommodation, catering and training facilities). In addition, static airfields are vulnerable to enemy attack and, although it seems highly unlikely that a single (conventional) weapon could close an airfield for a protracted period, there remains a significant threat to deployed forces, particularly from 'asymmetric' attack. The threat could be passive in the form of covert observation and reporting, or it could be active in the form of air, ground, information or Nuclear, Biological and Chemical (NBC) attack. There is a fundamental requirement, therefore, to provide physical protection at deployed operating bases for aircraft, airfield surfaces, people, equipment and information. Protection measures would include Ground-Based Air Defences, Battle Damage Repair teams and the use of organic ground combat units to provide enhanced perimeter security. Therefore, land-based operations (even from a well-found operating base) are likely to involve the deployment of several hundreds of people (in addition to the aircrew and engineers directly involved with the generation of Harrier sorties) at considerable economic, human and political expense. Conversely, an aircraft carrier's crew complement are trained to provide all of these support functions within the ship's operational role at no additional cost per deployment.

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APPROPRIATE DEPLOYMENT

Analysis of the aforementioned advantages and disadvantages of both sea and land-based operations suggests that JF 2000's air power utility depends both on its deployment platform and the intensity of the conflict in which it is likely to be involved. To determine JF 2000's optimum deployment, therefore, it would be useful to compare its sea and land-based attributes against an appropriate model of conflict which reflects the Defence Missions outlined in the SDR. Current Air Power Doctrine shows that 'the linear, graduated model of conflict used during the Cold War.....is of limited relevance in the current environment'.[86] Therefore, to cater for the multi-faceted nature of complex emergencies[87] 'in the turbulent inter and intra-state relations of the new millennium,'[88] a new circular spectrum has been proposed:[89]

Ser	Mission
(a)	Peacetime Security
(b)	Security of the Overseas Territories
(c)	Defence Diplomacy
(d)	Support to Wider British Interests
(e)	Peace Support and Humanitarian Operations
(f)	Regional Conflict Outside the NATO Area
(g)	Regional Conflict Inside the NATO Area
(h)	Strategic Attack on NATO

Table 1 – SDR Defence Missions

Figure 1 – The Circular Spectrum of Conflict

In the likely peacetime operations envisaged by the SDR, there will be an increased requirement for cooperation with other nations (for example, in the evacuation of British and other citizens caught up in overseas crises[90]), and for participation in multi-national exercises with the aim of fostering international good will and deterring conflict. This 'preventative diplomacy' will form part of the wider Mission of 'Defence Diplomacy' and will include various activities 'undertaken to dispel hostility, build and maintain trust and assist in the development of democratically accountable armed forces, thereby making a significant contribution to conflict prevention and resolution'.[91] The aircraft carrier seems the ideal platform on which to base JF 2000 in support of these activities. Not only could the Force's aircraft partake in exercises in most parts of the world without first securing basing or overflight rights, but the arrival of a British aircraft carrier bedecked with JF 2000's aircraft would send considerable political signals in terms of Britain's 'presence' in the world. 'Impressible countries will find JF 2000 very impressive!'.[92] Carrier-borne operations could also be maintained, almost indefinitely, without the prohibitive human, economical and political costs of an open-ended, land-based deployment.

In benign peace support or peacekeeping operations (especially in regions where suitable airfields are not readily available or HNS is neither offered nor desirable), the aircraft carrier would also be the ideal platform for JF 2000, combining the key naval attributes of strategic and tactical mobility, poise and sustained reach, synergistically, with the key air power characteristics of reach, flexibility, ubiquity and responsiveness. In these situations, JF 2000 would maintain Britain's standing as a 'serious player' in any coalition force, with the perceived ability to 'punch above its weight' if necessary. However, as the likely intensity of the conflict (and the likely belligerence of the opposition) increases, so the suitability of JF 2000's sea platform decreases. Although Harriers have taken a credible part in peace enforcement operations, their current range and weapon loads are significantly curtailed by the aircraft carrier's inherent limitations. Furthermore, if the threat to the carrier were to increase (from stronger opponents, or those willing to engage in 'asymmetric' activities) then an increasing amount of JF 2000's capabilities would be absorbed in protecting the ship, which would

Although Harriers have taken a credible part in peace enforcement operations, their current range and weapon loads are significantly curtailed by the aircraft carrier's inherent limitations

have to withdraw to a safe operating area, thus degrading its operational independence and denying its aircraft much of the 'reach' that naval operations are meant to provide. In high intensity conflict, therefore, JF 2000's ability to project air power ashore from current British aircraft carriers is likely to be minimal at best.

Conversely, the utility of land bases in providing an appropriate air power response increases with the scale of the response required. In benign peacekeeping operations, the cost of a permanent land-based deployment is unlikely to be justified (or even necessary). However, where large-scale, intensive or rapid responses are required, then no sea-based force can match the air power projection capability of a properly constituted airfield. In these situations, not only could JF 2000's aircraft operate with their full fuel and weapon loads, but they could also take advantage of the full panoply of air support to maximise their range, effectiveness and survivability. Thus, for war fighting, it would seem that JF 2000 should be deployed without its carriers, to a properly-prepared, coalition land base. In accordance with the 'circular' spectrum of conflict for modern, complex emergencies, therefore, there appears to be a distinct relationship between the most appropriate deployment option for JF 2000, and the intensity of the conflict in which it is likely to be involved:

…the utility of land bases in providing an appropriate air power response increases with the scale of the response required

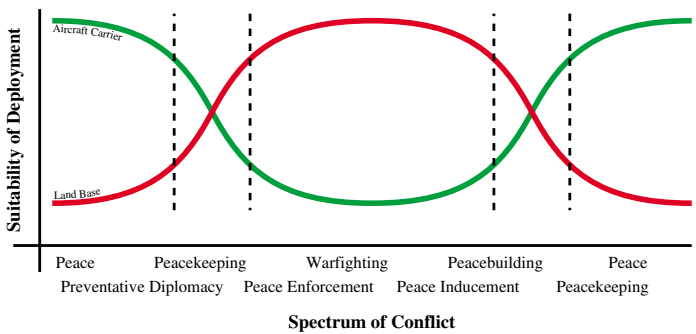

Figure 2 – Deployment of JF 2000

This paradigm has 3 obvious exceptions: firstly, in peacetime exercises where JF 2000 may be deployed to either sea or land bases with equal effectiveness (and must practice both eventualities to maintain its proficiency); secondly, in full-scale war (such as the 'Strategic Attack on NATO' envisaged in the SDR Defence Missions) where the otherwise disproportionate risk to the aircraft carrier becomes very much less significant in the overall scenario; and, thirdly, when HNS (and therefore a land base) is not available, as was the case in the Falklands campaign.[93] In the latter case, the carrier provides the only option for a British air power response. However, in

high intensity conflict, the likely restrictions on JF 2000's air power projection capability inherent in current carrier-borne operations suggest strongly that, if land basing is either non-existent or marginal, then the Force should not be deployed at all.

However, where the choice of a land base exists, the analysis suggests that JF 2000 should be deployed at sea for peace support and peace keeping operations, and to land bases for peace enforcement and warfighting scenarios. In conflicts where the most appropriate solution is not clear, some radical thinking will be required. In certain circumstances (as the US Marine Corps' Concept of Operations suggests,[94] it might be appropriate for JF 2000 to deploy initially by sea, to provide air support for amphibious and follow-on forces to establish a bridgehead and prepare a Deployed Operating Base (DOB) to which JF 2000 would then deploy to conduct high-intensity air operations (leaving the carrier to retire out of harm's way). Alternatively, JF 2000 could deploy rapidly (as part of the JRRF, for example) to a land DOB, to be followed later by the aircraft carrier which could then act as a second basing option to maximise the Force's manoeuvrist potential with its tactical mobility (and could provide other functions, such as that of a floating joint headquarters or as a base for diplomatic discussions between protagonists). The recent Operation DESERT FOX exemplifies the flexibility of this approach. Whilst medium-intensity bombing raids on Iraqi targets were mounted from well-found land bases (albeit by Tornado aircraft in this case), an aircraft carrier and its Harrier complement were deployed to undertake the subsequent (low intensity) monitoring task. However, no 2 situations will be the same, and many variations on the overall theme are possible (given JF 2000's inherent flexibility) provided that current operating procedures, traditions and political expectations do not preclude the necessary innovation. However, to ensure the most efficient use of JF 2000's air power attributes, RAF personnel will have to become accustomed to lengthy deployments at sea on aircraft carriers and, similarly, naval personnel will have to accept protracted periods of operations from land bases. More significantly, the Naval Staff might have to entertain the deployment of historically organic air assets, whilst leaving their host carriers in port. Some 'sacred cows' may therefore be at risk.

THE FUTURE

The current INVINCIBLE Class of aircraft carriers is due for replacement in 2012, at which time the FCBA is also due into service. Operational analysis suggests that it would be more cost-effective to replace the current fleet of 3 CVSGs with 2 larger, more versatile ships capable of operating the largest possible range of aircraft in the widest possible range of roles. However, a primary driver for the FAC will be the number and type of FCBA, and the sortie generation rate required.[95] There are 3 generic combinations of FAC and FCBA:[96] STOVL (as per the current fleet); Short Take-Off But Arrested Recovery (STOBAR); and Conventional Take-Off and Landing (CTOL). Whilst studies are still ongoing, it would seem that the winning design is most likely to be either a STOVL or CTOL variant,[97] the choice of which will have significant implications for JF 2000's likely air power utility.

In economic terms, the STOVL combination presents the most cost effective option. A STOVL ship requires only one runway, has a faster turnround capability and does not need to provide as stable a platform as its CTOL counterpart for aircraft recoveries.[98] It would therefore be smaller (and cheaper) than a CTOL equivalent. Similarly, a STOVL FCBA would need to be small and light (some 30,000 lbs instead of 70,000 lbs for a conventional aircraft) and would therefore be cheaper than a CTOL variant. Although the COEIA for the procurement of the FCBA is not due until 2000, a primary contender is the STOVL version of the US Joint Strike Fighter (JSF),[99] currently under development by 2 competing contractors: Boeing and Lockheed Martin. Although technical specifications will undoubtedly change, the companies' proposals suggest that the JSF will be a formidable fighting machine.[100] Both the Boeing and Lockheed Martin variants will be single-seat, single-engined, supersonic, all-weather, multi-role aircraft with aerodynamic performance in excess of the F-16, enhanced lethality, greater survivability and considerable interoperability with their land-based counterparts. Designed with the proven stealth technology of the F-117 and the F-22, they will be extremely capable 'Day-One strike aircraft', able to handle the 'deep target sets' (such as Integrated Air Defence Systems) in any modern conflict.[101] To enhance its stealth capability, the JSF's ECM and laser designator will be fitted internally, and the aircraft may also utilise the 'off-board sensor' concept.[102] The JSF will have a likely range of some 600nm, and its internal (stealth) bomb bay will likely house 2 advanced 900 kg stand-off munitions or LGBs and 2 AMRAAMs. For land-based operations, additional fuel tanks and weapon stores may be carried externally, with an associated reduction in the aircraft's stealth capability. A retractable AAR probe will also be fitted.

Whilst a CTOL FAC/FCBA combination would be larger (and therefore more expensive), it would, however, offer considerably more in terms of air power projection capability than its STOVL equivalent. An electromagnetic catapult[103] could launch aircraft of all-up weights in excess of 70,000 lbs, thus permitting combat operations by modified versions of most land-based fighter aircraft at their full operational loads.[104] It would also enable the use of more capable, fixed-wing AEW aircraft (such as the E-2 Hawkeye) and small AAR tankers. The CTOL carrier's arrestor capability would also permit the recovery of its aircraft in most configurations and with significant battle damage.

So, how do the proposed FAC and FCBA affect the analysis of how JF 2000 should be deployed? As regards the FAC, future technological advances will undoubtedly improve the ship's on-board defence capabilities. However, similar advances in ASUW weaponry (in the so-called 'dynamic of technology'[105]) are likely to balance the equation.[106] In both CTOL and STOVL variants, therefore, the inherent vulnerability of the aircraft carrier is likely to remain a limiting factor. Whilst the FCBA (in whatever its final form) would considerably enhance JF 2000's air power projection potential, any technological advances would be equally applicable to land and sea-based operations. Therefore, neither factor (on its own) will change significantly the relative advantages and disadvantages previously described.

In the STOVL configuration, a complement of 50 aircraft would allow the conduct of defensive counter air and defensive sea control operations without absorbing all of JF 2000's power projection capability. Furthermore, the procurement of the FCBA would eliminate many of the Harrier GR7's current operating limitations and would increase JF 2000's effective range, particularly if the carrier was forced to withdraw out of harm's way. However, notwithstanding the JSF's likely ability to carry twice the Harrier's current bomb load, the procurement of a STOVL FAC/FCBA combination would perpetuate the inherent air power limitations previously described, which would continue to restrict ship-borne air operations to a far smaller scale than would be possible from a land base. Therefore, whilst a STOVL FAC/FCBA combination would increase the utility of seaborne operations at the lower end of the intensity scale, it would not significantly affect the overall paradigm, which would therefore remain substantially as proposed:

In medium to high intensity conflict, one of the most significant limitations to JF 2000's carrier-borne air power potential is the inability of current British aircraft carriers to provide combat support for the Force's core air power missions, without assistance from the very land bases which the carriers are meant to obviate. In its CTOL form, however, a FAC/FCBA combination could radically alter JF 2000's air power utility in favour of sea-based operations. The ability to launch and recover combat aircraft of similar operating weights to their land-based counterparts would allow the aircraft carrier to mount comprehensive packages of heavily-armed attack aircraft, with SEAD and fighter escort, on missions appropriate to even the most intense of conflicts. The ship's complement of 50 aircraft would also permit simultaneous air defence operations if circumstances dictated, supported by

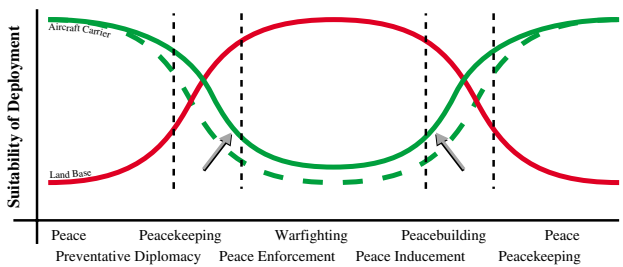

Figure 3 – Deployment of STOVL FAC/FCBA

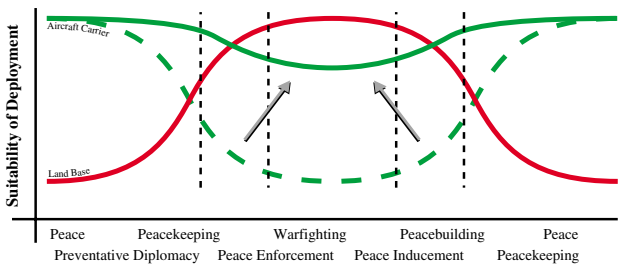

Figure 4 – Deployment of CTOL FAC/FCBA

the enhanced AEW capability of a fixed-wing aircraft, if also procured.[107] In terms of air power projection, therefore, a land base would offer few significant advantages over the CTOL FAC/FCBA combination, except in the most intense of conflicts, where the increased availability of AAR and greater logistical support would still permit operations on a greater scale and over increased ranges. The procurement of a CTOL FAC/FCBA combination would therefore make seaborne operations for JF 2000 much more appropriate throughout the circular spectrum of conflict:

CONCLUSION

The formation of JF 2000 represents a bold move away from the historic extremes of both the RAF and the RN and formalises a previously ad-hoc arrangement for the operation of a truly joint capability. In a gradual, pragmatic bringing together of the ways in which each service does business, it will provide (as the SDR suggests) a potent offensive air capability to meet the likely expeditionary roles of the post-Cold War era.

Embarked at sea, JF 2000 will be particularly suited to operations traditionally associated with 'naval diplomacy' such as peacekeeping, peace building and preventative diplomacy. In these circumstances, the Force will combine, synergistically, the speed, reach, ubiquity, flexibility and responsiveness of its air assets with the poise, mobility and sustained reach of its floating air platforms to provide an air power projection capability fully in keeping with Britain's tradition of 'punching above its weight'. The deployment of JF 2000 on its aircraft carrier will be an impressive demonstration of Britain's role as a 'serious player' on the modern, international stage (particularly in coalition operations as part of an overall force package) and will allow the Government to keep its options open in confusing and uncertain modern crises.

However, the limitations of current British aircraft carriers significantly restrict JF 2000's air power projection capability. Thus, as the likely intensity of a conflict increases away from the benign, the suitability of deploying JF 2000 by sea diminishes. Furthermore, as the intensity of the likely conflict increases, the inherent vulnerability of aircraft carrier (and the need to protect such a high-value asset from the likely threats in the littoral environment) further limits the Force's air power utility. Not only must the carrier be withdrawn substantially 'out of harm's way' (thus reducing the effective range of its aircraft), but the aircraft themselves must play an ever-increasing role in defending their ship. Ultimately, in very high threat scenarios, it is likely that JF 2000's entire air capability could be absorbed in protecting the aircraft carrier on which it is based. Thus, from an air power perspective, JF 2000 should not be deployed at sea for high intensity conflict, irrespective of other basing options.

Deployed operations from land bases also have their own, particular disadvantages. To provide operations and logistical support, administration and force protection for even a small detachment of aircraft requires the deployment of many hundreds of people at potentially enormous human, economic and diplomatic cost. To deploy JF 2000 to a land base to conduct benign

'Defence Diplomacy' missions (which may be of indeterminate length) is therefore highly inappropriate, especially when the enhanced air power capability afforded by the land base is unlikely to be used. However, as the likely intensity of the conflict increases, the cost of deployed, land-based operations becomes less significant in the light of the scale of air operations which the land base can support. Furthermore, there can be little argument that land bases (where available) will permit air operations on a far greater scale than are possible from aircraft carriers. For high intensity conflicts, therefore, a land base is the only deployment platform from which JF 2000 will be able to operate at its maximum air power potential.

The current aircraft carriers and their Harrier aircraft are due to be replaced in 2012, by either a STOVL or CTOL combination of FAC and FCBA, each of which offers considerable technological advances to JF 2000's air power projection capability. However, whilst a STOVL combination is likely to be smaller and cheaper than its CTOL counterpart, in terms of air power it would perpetuate many of JF 2000's current carrier-borne limitations. Thus, whilst the likely technological advances would confer an increase in capability, the relative advantages and disadvantages of sea and land bases would not differ, significantly, from those of today. Conversely, the procurement of a CTOL FAC/FCBA combination would allow the aircraft carrier to mount all but the most intensive of air combat operations and would thus radically alter JF 2000's deployment considerations in favour of sea-borne operations. Only in its prospective CTOL form, therefore, would JF 2000 become the 'deployable and effective offensive air capability' which the SDR envisaged, fully able to fulfil the expeditionary roles of the post-Cold War era as a true instrument of political choice, and able to operate equally effectively from aircraft carriers and land bases in all but the most intense of conflicts.

In all cases, however, analysis of the various strengths and weaknesses of land and sea deployments shows a direct relationship between the most appropriate deployment option and the intensity of the conflict in which JF 2000 is likely to be involved. For benign peace building and peacekeeping operations, preventative diplomacy, and operations in immature, austere theatres, JF 2000 should be deployed only on its aircraft carrier. For warfighting operations, it should be deployed only to a land base and (from an air power perspective) if a land base is not available then it should not be deployed at all. For medium-intensity operations where the situation is unclear, careful consideration should be given to the most appropriate deployment option. JF 2000 might best be deployed by carrier at the outset, but then on to a forward operating (land) base, leaving the carrier to withdraw to relative safety. Conversely, the Force might deploy on its own to a land base, to be followed later by the carrier, which could then provide a second, manoeuvrist basing option. Many variations on this theme will be possible (given JF 2000's inherent flexibility), provided that the Force is always deployed in a manner most appropriate to the likely combat scenario. In sum, both land and sea basing options will be vital to the efficient and effective use of JF 2000's air assets. However, to maximise its air power utility in the likely limited conflicts of the future, JF 2000 should be deployed either on an aircraft carrier or to a land base ('to sea, or not to sea'), not according to the historical (single-service) precedents or political whims which have prevailed in the past, but strictly according to the intensity of the conflict in which it is likely to be involved.

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51 *Idem*.

52 Codner, 'Aircraft Carriers' *Op. Cit*., p. 3.

53 Manoeuvre warfare seeks to defeat an enemy by shattering his cohesion and will to fight through a series of rapid, violent, simultaneous and unexpected actions that create a turbulent and rapidly-deteriorating situation with which he cannot cope. Ministry of Defence, *British Defence Doctrine (Joint Warfare Publication 0-01)* (London: Her Majesty's Stationery Office, 1997), pp. 4.8-4.9.

54 Rear Admiral Richard Cobbold, RN, cited by The Honourable John H Dalton in 'Navies and World Events in the 21st Century' in *RUSI Journal*, October 1998, p. 9.

55 Codner, 'Aircraft Carriers' *Op. Cit*., p. 8.

56 *Jane's All The World's Aircraft 1997-98*, *Op. Cit*., p. 507.

57 Figures extracted from *Jane's All The World's Aircraft* show that (at 32°C), there is just 2408 lbs difference between the Harrier GR7's empty weight (15,542 lbs) and its maximum vertical landing weight (17,950 lbs). This must cater for fuel, stores, ammunition and water injection for the engine, as well as weapons.

58 Malcolm Bird, 'Learning from Experience' in *Defence Review, Autumn 1997*, p. 32.

59 Cordesman and Wagner, *Op. Cit*., p. 341.

60 Figures extracted from *Jane's All The World's Aircraft*.

61 Harry, *Op. Cit*.

62 The value of an arrestor capability was demonstrated during Operation BALBUZARD (the French contribution to Operation SHARP GUARD in the former Yugoslavia), when 2 Etendard IVPMs were hit by Surface-to-Air Missiles, the most severely damaged of which landed safely on the carrier despite a badly damaged tail and the loss of its flaps. Gert Kromhout, 'A Bright Future for French Carrier Aviation' in *Air International*, March 1997, p. 159.

63 Codner, 'Aircraft Carriers' *Op. Cit*., p. 8.

64 Meyer, *Op. Cit*.

65 *Idem*.

66 Even so, British aircraft carriers were not used in the Gulf War when, compared with the vast US effort, they would have contributed very little to the strategic bombing and interdiction campaigns. Codner, 'Aircraft Carriers' *Op. Cit*., p. 2.

67 N Friedman, *The US Maritime Strategy* (London: Jane's Publishing Company Limited, 1988), p. 80.

68 The key areas where the US feels its interests threatened are the Mediterranean, the Gulf, the Indian Ocean and the North-east Pacific region. *Idem*.

69 John Pay, 'Full Circle: The US Navy and its Carriers, 1974-1993' in *The Journal of Strategic Studies*, Vol 17 No 1, p. 135.

70 Rear Admiral Richard Cobbold, RN, 'A Joint Maritime-Based Expeditionary Capability' in *RUSI Journal*, August 1997, p. 24.

71 Wing Commander Andrew Brooks, RAF, 'Above and Beyond? – Capabilities of Out-of-Area Air Power' in *RUSI Journal*, October 1993, p. 30.

72 Dr Philip Sabin in Lecture on *Air Superiority* at the JSCSC Bracknell, 17th November 1998.

73 The Russian submarine force still presents a formidable threat. However, some 20 Third-World countries now operate SSKs, a third of which are designated 'countries of concern'. During 1996-97, nine SSKs were delivered to these countries (including Iran, China and Pakistan); North Korea and China also launched their own indigenous SSKs. Office of Naval Intelligence, *Worldwide Submarine Challenges* (1997), pp. 6-7 and Statement for the Senate Select Committee on Intelligence, *Global Threats and Challenges: the Decade Ahead*, January 1998, p. 11.

74 More than 60 non-NATO countries now possess cruise missiles. 'Carrier Questions' in *The Economist*, May 31st 1997, p. 25.

75 During the Korean War, sampans and junks laid some 3000 mines which delayed a US amphibious operation by several weeks. More recently, a small field laid by a Libyan cargo ship closed the Red Sea for about 6 weeks). Friedman, *Op. Cit*., p. 77.

76 Meyer, *Op. Cit*.

77 John Lehman, a former US Secretary of the Navy, argued that 'The carrier is the least vulnerable ship to destruction or sinking because of its large size in relation to the warheads constituting the threat, greater relative compartmentalisation, massive protection of propulsion and ordnance, and its structural strength necessary to handle the stress loads of catapulting and arresting 35 ton aircraft.' Eric Grove, *The Future of Sea Power* (London: Routledge, 1990) p. 124.

78 The Americans protect their aircraft carriers with a multi-layered defence comprising long-range fighters, air-to-air refuellers, electronic reconnaissance and countermeasures aircraft, ASW patrol aircraft, missile engagement zones, close-in weapon systems and built-in survivability measures (such as compartmentalisation and armour plating). Even then, they will operate with 2 carriers per group to ensure that at least one is capable of launching and recovering aircraft. Friedman, *Op. Cit*., p. 104.

79 During recent operations in the Gulf (and despite the Americans' considerable ASW and ASUW capability), US naval commanders demanded minute-by-minute updates on the whereabouts of 3 (neutral) Iranian 'Kilos'. When the position of just one submarine was lost, the Americans withdrew their Carrier Air Group to the south, out of any possible danger. The carriers were withdrawn in a similar manner on the approach of any small, unidentified, fast-moving surface contacts. Meyer, *Op. Cit*.

80 Friedman, *Op. Cit*., p. 77.

81 Most analysts agree that if a carrier had been sunk, the war would have ended immediately.

82 Cordesman and Wagner, *Op. Cit*., p. 341.

83 Codner, 'Aircraft Carriers' *Op. Cit*., p. 8.

84 Stocker, *Op. Cit*., p. 47.

85 Ministry of Defence, *British Air Power Doctrine* (AP 3000 – 3rd Edition Final Study Draft) (JSCSC Bracknell: Department of Defence Studies (RAF)), 1998, Chapter 9.

86 *Ibid*., p. 1.2.

87 The UN definition of a complex emergency is 'a humanitarian crisis in a country, region or society where there is a total or considerable breakdown of authority resulting from internal conflict and which requires an international response that goes beyond the mandate or capacity of any single agency and/or the ongoing UN country aid programme'. John Mackinlay and Randolph Kent, 'Complex Emergencies Doctrine: The British are Still the Best' in *RUSI Journal*, April 1997, p. 39.

88 Group Captain A Lambert, RAF, 'Air Power and Coercion' in *Perspectives on Air Power – Air Power in its Wider Context*, Edited by S Peach (London: The Stationery Office, 1998), p. 266.

89 Group Captain Stuart Peach, RAF, 'Coalition Air Operations' in *Ibid*., p. 50.

90 *The Strategic Defence Review*, *Op. Cit*., p. 14.

91 The Strategic Defence Review: Supporting Essays, *Op. Cit*., Essay Four: 'Defence Diplomacy', p. 4-1.

92 Meyer, *Op. Cit*.

93 However, the intense air operations of the Gulf War could not have been sustained from aircraft carriers alone: without HNS, therefore, the war could not have been fought.

94 United States Navy, *Forward...From The Sea* (Washington DC: Department of the Navy, 1994), pp 6-7.

95 Operational analysis also suggests that 50 aircraft will be required to ensure campaign success in medium-intensity scenarios. This requires a ship of some 30,000 to 40,000 tons displacement, operating 50 aircraft in overload capacity. Harry, *Op. Cit*.

96 Codner, 'Aircraft Carriers' *Op. Cit*., p. 5.

97 CTOL and STOBAR hulls require 2 runways to enable simultaneous launch and recovery. They are therefore larger than STOVL ships. The STOBAR design, however, requires a longer runway for launch than the CTOL variant does for catapult operations and is therefore larger (and more expensive). STOBAR therefore combines the take-off limitations of STOVL with the cost disadvantages of CTOL and is unlikely to be chosen. Harry, *Op. Cit*.

98 *Idem*.

99 Meyer, *Op. Cit*.

100 Further details of the Boeing and Lockheed Martin contenders may be found in *Jane's All The World's Aircraft 1998-99* (pp. 559-560 and 671-672) and the companies' Internet web-sites (see Bibliography).

101 Graham Warwick, 'Joint endeavour' in *Flight International*, 3 – 9 July 1996, p. 26.

102 The 'off-board' sensor concept envisages the use of remote sensor aircraft (such as AWACS) connected to individual fighters by datalink. Because the fighter has no on-board equipment, its electromagnetic emissions and its weight are minimised. The fighter cannot, however, be used autonomously except for visual engagements.

103 The electromagnetic catapult is emerging technology which promises to provide smooth, controlled and continuous acceleration for carrier-launched aircraft, instead of the current 'explosive' force of the steam catapult. The aircraft therefore do not need extensive strengthening to withstand the launch shock and can thus carry greater payloads. Harry, *Op. Cit*.

104 Current contenders include the Rafale, the F-18E/F, a marinised EFA and the CTOL version of the JSF (which offers the technological advantages described above, but at much greater operational weights than its STOVL counterpart). A CTOL carrier would also accommodate the RAF's proposed Future Offensive Air System, and could therefore generate considerable 'economies of commonality'. Harry, *Op. Cit*.

105 Goulter, *Op. Cit*.

106 Likely future ASUW weapon developments include longer range, stealthy anti-ship missiles with dual seeker (IR and active/passive radar) heads, which will use mid-course way points and evasive manoeuvres during the terminal phase. They will fly at sea-skimming heights or will use semi-ballistic trajectories with supersonic, near-vertical impact profiles. Future torpedoes will feature wake homing and stealth technology. Harry, *Op. Cit*.

107 Tim Ripley, 'Invincible Ideas?' in *Flight International*, 26 March – 1 April 1997, p. 32.

Lockheed Raptor F-22 over Edwards AFB
Photo: Lockheed