

# FUTURE CARRIER AVIATION OPTIONS

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## A British Perspective

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One of the key debates that face naval aviation in the twenty-first century relates to its key equipment: the airplane. The United States is the only power that will be able to deploy a carrier force of any size, and it has held this position for over two decades. Soviet/Russian ambitions to deploy a blue-water air capability have been downsized, rationalised, abandoned, then reinstated under the threat of cancelation, and now lack funding. The People's Republic of China is known to aspire to develop its naval aviation through the procurement of aircraft carriers, but it has made little obvious progress. While aircraft carriers enable the projection of airpower well beyond a nation's shores without reliance on host-nation support, they have a major problem: they are expensive. Designing, running, and upgrading carriers are beyond the financial capacity of most nations. Only a few have the ability to deploy combat aircraft at sea, and the conventional aircraft carrier can only be procured in small numbers. While the United States can, within the politics of budget constraints, present a formidable air presence from carrier decks, the United Kingdom and France, the two

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middle-ranking powers with aspirations to maintain aircraft carriers, have been obliged by cost considerations to make some uncomfortable decisions.

Furthermore, there are continuing questions about the necessity of aircraft carriers for middle-ranking powers. It is argued that the aircraft carrier, by virtue of its considerable cost, is an unnecessary luxury. Under this scenario, the United Kingdom and France are perceived as being unlikely to embark upon independent naval operations but as

instead contributing to task forces dominated by the U.S. Navy, which in turn would provide the aviation assets. Practical experience, particularly for Britain, suggests that this view is dangerous.

Nonetheless, Britain's experience of carrier aviation since the mid-1960s has not been altogether happy. A combination of a reduced world role and serious economic problems led to the downsizing of all British military services, with particularly savage cuts in the 1964–70 period. The aircraft carrier was deemed to be an expensive irrelevance. This view was shortsighted, ignoring the fact that Britain had a number of commitments and obligations in areas that had been brought into the ambit of Britain's concerns through trade and colonialism. As always, plans failed to survive contact with the enemy—in this case, Argentina in 1982, when the only means of recovering the Falkland Islands (Islas Malvinas) was an amphibious operation. Since that time, despite ever-diminishing defence budgets, the aircraft carrier has returned to prominence, with the 1998 Strategic Defence Review (SDR) planning for two carriers capable of embarking around fifty aircraft, thus enhancing the deployability of British forces and increasing flexibility.

Nonetheless, there are a number of issues that need to be settled before the new vessels enter service in 2012. This article (based on the state of affairs in late 1999) seeks to provide a general outline of the options facing British naval aviation in the next ten to twenty years. It does not claim to be definitive but seeks to inform, highlighting in particular the manner in which the aircraft carrier has returned to the core of British military thinking as Britain adjusts to the conditions likely to pertain in the first two decades of the twenty-first century.

#### **BRITAIN AND NAVAL AVIATION SINCE 1960: THE BACKGROUND**

Decline has been a particularly notable factor in the United Kingdom, where cost considerations led to the abandonment of conventional-takeoff-and-landing (CTOL) aircraft carriers when HMS *Ark Royal* was retired in 1978. This was not a sudden decision.

##### ***The Decline of the British Carrier Force***

The first threat to British naval aviation came in the 1960s. In 1957, a whole swathe of advanced aircraft projects had been canceled on the grounds of cost and a belief that their job would soon be done by missiles. Hawker-Siddeley Aviation's P.1127, an innovative vertical/short-takeoff-and-landing (VSTOL) aircraft, was allowed to survive. The P.1127 was designed to prove the validity of VSTOL and was not intended for operational service. However, a derivative, the P.1154, was proposed by Hawker in 1962; it was finally abandoned in 1964, in favour of the F-4K Phantom.

It is arguable that the P.1154 had too much stacked against it. There appears to have been a suspicion amongst senior officers that a capable, supersonic VSTOL aircraft might have allowed a cost-conscious government to abandon a then-projected carrier design (known as the CVA-01) and replace it with smaller ships that could operate VSTOL air wings. The theory continues that the Admiralty had no intention of giving up its large carriers and agitated against the P.1154. This may or may not be true. What is not beyond dispute is that the Royal Air Force and the Royal Navy had completely different views on how the aircraft should be equipped; the naval P.1154 would have been a very different one from the RAF's.<sup>1</sup> In addition, the P.1154 was a technical risk. The P.1127 had not validated the concept of VSTOL at this point, and the notion of moving from a technology demonstrator with relatively simple equipment to a fully operational, supersonic type (the P.1154) was highly adventurous. Finally, there was already a superb, proven naval type in operational service—namely, the Phantom.<sup>2</sup> The Phantom could be operated from the existing carrier fleet (with modifications), and it would obviously be fully compatible with CVA-01 from the start.<sup>3</sup>

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*A variety of critics have suggested that the aircraft carrier itself is no longer useful. The Strategic Defence Review suggested otherwise.*

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CVA-01, in spite of its innovative design, was vulnerable.<sup>4</sup> The Royal Navy had five carriers (*Ark Royal*, *Centaur*, *Eagle*, *Hermes*, and *Victorious*) when Prime Minister Harold Wilson took office, plus two more (*Albion* and *Bulwark*) that had been converted into “commando carriers.”<sup>5</sup> Of these seven vessels, only the *Ark Royal* and *Eagle* were large enough to accommodate the Phantom.<sup>6</sup>

After a period of financial crisis, Wilson's government decided to end the British military presence “East of Suez,” a conclusion that made the aircraft carrier an endangered species. In 1966, CVA-01 was canceled. While modifications to allow the operation of Phantoms from the existing vessels were financed, the carriers were not to be replaced. It was then decided that *Eagle* would not be modified to embark the Phantom.<sup>7</sup> By the mid-1970s, it was clear that Britain would be left with only an antisubmarine helicopter force after *Ark Royal's* withdrawal from service.

The argument put forward against complaints that this decision was short-sighted took the form that Britain's reduced military commitments meant that naval operations where airpower would be required—opposed amphibious landings—would be coalition operations. The aviation assets required would come from the U.S. Navy's carriers. Where the U.S. Navy was unavailable, the RAF would defend the fleet from land bases. This was a spurious idea, as the Royal Air Force did not have any suitable aircraft available for this task.<sup>8</sup> In the

event of a war, the RAF would be busy elsewhere, and the Navy would have to hope that a U.S. carrier was nearby.

Consequently, the Royal Navy looked for alternatives. It became clear that the problem would be twofold. First, the government had to be convinced that a class of air-capable vessels was necessary; second, a suitable aircraft had to be found. The second problem was the easier to solve. The P.1127 had been developed into the Harrier, via a type known as the Kestrel.<sup>9</sup> The Harrier entered service with the RAF in 1969. The U.S. Marine Corps placed an order (for the AV-8A) shortly afterward. Neither the RAF nor the Marine Corps envisaged using the Harrier as a fighter aircraft, even though Marine machines were wired for the AIM-9 Sidewinder.

The Royal Navy, faced with the choice of a navalised Harrier or nothing, decided upon VSTOL carriers. The major difficulty was to obtain the necessary vessels. Fortunately, in the late 1960s a new class of antisubmarine cruiser, the *Invincible*-class CVSG, was being designed.<sup>10</sup> These already had a full-length flight deck and an island (for helicopter operations); Hawker-Siddeley Aviation was contracted to develop a minimum-change version of the Harrier to equip them. The modifications included the provision of radar and a raised canopy for better vision in air combat. The Sea Harrier entered service in 1979, some six years after the idea for its method of launching—off a “ski ramp”—had been arrived at.<sup>11</sup>

The decision to develop a VSTOL fighter for the Royal Navy was not met with universal acclaim. Many felt that the Harrier offered little real military capability beyond being able to be based close to the front line without prepared runways. It was also noted that the proposed complement of aircraft for *Invincible* was less than half that of the *Ark Royal*. However, although the withdrawal of all but *Ark Royal* left the Navy with only around thirty fixed-wing aircraft, even this small force could have been useful. In the end, the only concession to demands to retain *Ark Royal* was the announcement that the name would be used for the third *Invincible*-class ship.<sup>12</sup> This did not appear to be a sensible solution to the underlying problem of a capability gap. By 1980, the Navy had *Invincible* and also *Hermes*, which had been converted from the commando carrier role into an interim VSTOL vessel.<sup>13</sup>

Four years after *Ark Royal* was retired, Argentina invaded the Falkland Islands. The only way to recover the Falklands was through an amphibious operation, and the *Ark Royal* would have proved invaluable. Although by comparison to a U.S. carrier air wing *Ark Royal's* aircraft complement was small, a fixed-wing carrier would have provided the task force with strike aircraft, air defence fighters with a beyond-visual-range (BVR) missile capability, and, crucially, airborne early warning (AEW) aircraft.<sup>14</sup> As the conflict progressed, it was clear

that all were desirable.<sup>15</sup> As it was, the two aircraft carriers despatched (*Hermes* and *Invincible*) carried fewer combat aircraft than *Ark Royal* had done.<sup>16</sup> No airborne early warning capability was available, and the most potent weapon carried by the Sea Harriers was the AIM-9 Sidewinder.<sup>17</sup>

It is hardly necessary to recount that the Sea Harriers performed beyond all expectations, with not a single one being lost in air combat, while over twenty Argentine aircraft were claimed as shot down. In addition, the RAF version of the Harrier, then in its GR 3 incarnation, was successfully operated from the deck of HMS *Hermes* in the ground-attack role. The Sea Harrier and Harrier proved capable of operating in weather conditions that would have grounded other carrier-aircraft types, assisted by their ability to recover vertically onto the carrier deck rather than having to undergo the ordeal of arrested landings. Thus the concept of the VSTOL (more accurately, “short takeoff and vertical landing,” or STOVL) carrier was largely vindicated by the Falklands conflict. However, a number of problems were identified.<sup>18</sup>

#### *Lessons from the Falklands*

The most obvious problem with the STOVL carrier was the lack of AEW aircraft.<sup>19</sup> The lack of airborne early warning had made it possible for the Argentine pilots (air force and naval) to conduct daring attacks on the British task force, with minimal warning for defending combat air patrols (CAPs).<sup>20</sup> As a result, the carriers had to be positioned farther from the combat area than was desirable.<sup>21</sup> Further, the Sea Harrier’s light armament—two AIM-9s and two 30 mm ADEN cannon—gave it only limited combat persistence.<sup>22</sup> This had not been a serious problem over the Falklands, but it was recognised that in different circumstances it might have been; after the war, this shortcoming was tackled with the provision of twin missile-launcher rails, doubling the number of Sidewinders carried. Finally, although the Sea Harrier’s Blue Fox radar performed beyond expectations, it was clear that a “look-down/shoot-down” BVR capability was desirable.

None of these problems would have arisen with the old *Ark Royal*: its Phantoms had had beyond-visual-range capability; the endurance of its combat air patrols had been extended through “buddy” refuelling (that is, from aircraft other than specialised tankers) by suitably equipped Blackburn Buccaneers; and airborne early warning had been provided by Fairey Gannet AEW 3s.

In the absence of conventional-takeoff-and-landing vessels, these lessons led to the development of the Sea Harrier F/A 2, which remains today the operational variant. The Sea Harrier F/A 2 is an impressive machine. Its performance in exercises has been remarkable. The F/A 2 is certified for the full range of attack missions, but the deployment of Harrier GR 7 (roughly equivalent to the AV-8B

night-attack variant) from RAF units for attack missions is now commonplace, leaving the Sea Harriers for air-to-air operations.<sup>23</sup> All RAF and Navy Harriers are now under a single command, Joint Force Harrier. With the Sea Harrier taking responsibility for air-to-air missions and the GR 7, with a larger weapon load, undertaking attack operations, the Royal Navy now has a suitable mix of aircraft for its carriers.<sup>24</sup> Experience has finally muted the criticism of the employment of STOVL vessels, at least in U.K. circles.<sup>25</sup>

The major problem facing the Royal Navy is that its carriers are too small. They cannot carry large air wings; they struggle to carry more than twenty aircraft. Thus, the Navy cannot have enough aircraft available on the scene of a crisis. The comparatively small size of its air wings reduces the number of sorties that can be generated, in turn reducing the carriers' effectiveness. There are only two carriers in service at any one time (the third being in "deep maintenance," or overhaul), which does not help matters. Consequently, although they are effective and have given good service, the *Invincible*-class carriers are not the best advertisement for STOVL types. The fact that the aircraft are good is obscured by the limited operations that can be carried out. This has led to the view that the STOVL aircraft carrier can in no way equal the versatility and flexibility of a CTOL vessel. To be allowed to exploit STOVL's full potential, the Royal Navy required larger aircraft carriers. Defence spending policies in the 1980s and 1990s, however, meant that it was most unlikely to receive them.

Since the *Invincible*-class vessels are not due for replacement until around 2010, there has been until recently little consideration of what would follow them. With the end of the Cold War, British defence policy entered a period of confusion, as the government cut spending. Unfortunately, British military commitments did not diminish. Beginning with DESERT STORM, British forces became engaged in Iraq and Kuwait, as well as in the former Yugoslavia, protecting the safe haven established for the Iraqi Kurds, and patrolling the Iraqi no-fly zones. This was in addition to the tasks that they normally carried out. It became increasingly clear that asking British forces to do more with fewer personnel and less equipment was not a viable idea. This provoked the Labour opposition to promise that it would embark upon a Strategic Defence Review (SDR) if it were to be elected at the next general election. This duly occurred on 1 May 1997, and the enormous Labour victory meant that the SDR was likely to pass through Parliament without serious difficulties.

#### FUTURE AIRPOWER OPTIONS FOR THE ROYAL NAVY

The need for the United Kingdom to possess aircraft carriers has been questioned by a number of sources in recent years. A variety of critics have suggested that the British aircraft carrier is no longer necessary. Pundits in national newspapers

argued that the aircraft carrier is an expensive luxury and that the money needed for a new class of vessels could be better employed elsewhere.

*The Strategic Defence Review and the Need for British Carriers*

The SDR suggested otherwise. The review took longer to complete than had been anticipated in some quarters (as a result, it is rumoured, of objections from the Treasury), but it ultimately declared that the United Kingdom needed new aircraft carriers. The SDR changed the emphasis for British naval forces, moving away from the large-scale, open-ocean warfare for which it had been training for the past fifty years to force-projection and littoral operations in conjunction with the other two services. The SDR also made clear that the greatest importance would be attached to versatility and deployability.

It was obvious that the aircraft carrier would be integral to this vision. The SDR laid down proposals to procure “two large aircraft carriers capable of operating up to fifty fixed-wing aircraft and helicopters” from all three services. It should be noted here that what Britain considers a “large aircraft carrier” is different from what the United States does. For the Royal Navy, a “large” carrier has been the size of HMS *Eagle* or the old *Ark Royal* (53,000 tons fully loaded), able to carry between thirty and forty fixed-wing aircraft and helicopters. This is hardly “large” in comparison with the U.S. Navy’s aircraft carriers, since even the *Midway* (70,000 tons fully loaded) was larger than the British vessels. Still, the two carriers, scheduled to enter service in about 2012, will provide Britain with the ability independently to deploy combat forces to trouble spots. This is important, since there are reasons for Britain to deploy independently. Britain’s previous role as an imperial nation has left a legacy of close ties with former colonies. Some ten million British citizens live overseas, and there are thirteen dependent territories for which Britain is responsible. The need to be able to project military power to defend these interests or to provide aid to them is a clear reason for procuring newer, more capable carriers. In many instances, the infrastructure does not exist to support aviation operations in or around the overseas territories; the only means of sending aviation assets to such regions and then operating them is by means of a carrier deck.<sup>26</sup>

In addition to these direct responsibilities, Britain is a member of a number of international organisations, most notably the UN, Nato, and the Commonwealth. It is possible to envisage an attack on a Commonwealth country by a neighbour leading to British intervention, either on the side of the nation attacked or to impose or maintain a peace agreement. Although the SDR specifically denies that Britain seeks a role as world policeman, it asserts that there are compelling reasons for Britain not to be isolationist in outlook. The level of British overseas investment, particularly in the developing world (where British

investment amounts to the combined total of those of France, Germany, and Italy), demands that attention be paid to an ability to intervene in crises in these areas. Britain's dependence on worldwide trade makes it essential for Britain to be able to defend its interests by the rapid projection of power to areas where conflict threatens to destabilise or damage them.<sup>27</sup>

SDR foresees the close integration of all three services: "By 2015, the Review expects further major change in modern warfare. Operations will no longer be characterised as land, sea or air. There will instead be a single battlespace in which land, maritime and air forces will be directed, targeted and supplemented by a new generation of intelligence, surveillance, information and communications systems offering a steep change in military capability."<sup>28</sup>

Although this view presumes the development of new equipment and new technologies, the emphasis here is on the joint nature of future operations. This has already been manifested in the creation of the joint Harrier force.<sup>29</sup> This is not all. The Royal Navy is adopting what is termed a "golf bag" approach to carrier-based aviation assets. The task force commander (the "golfer") chooses the air assets (the "clubs") needed to carry out the task at hand. The carriers deploy with the necessary mix of aircraft and helicopters. This might mean that the only helicopters carried would be the airborne-early-warning type, with antisubmarine helicopters being based on other vessels (for instance, HMS *Ocean*), if they were required at all. Thus the air wing might be made up of about sixteen Sea Harriers plus AEW helicopters. Alternatively, there might be a mix of Harrier GR 7s, Apache ground-attack helicopters, and a smaller number of Sea Harriers for operations where air defence was secondary to supporting troops. Additionally, the RAF's support helicopter force (now amalgamated into a joint command of army, navy, and air force transport helicopter assets) has operated the Boeing Chinook from the *Invincible* class, so the carriers might be employed in a role akin to that of the American amphibious assault ship (LPH). The provision of a new carrier will make this "golf bag" approach even more viable, since it will make more room for the aircraft required for the mission.<sup>30</sup>

The issue now at hand is what type of carrier the new vessel should be. Neither the Strategic Defence Review nor any subsequent official paper has specified this in any way. Various proposals are being sought from industry, and it is unlikely that the type of vessel will be chosen until 2001 at the earliest.

#### ***The CV(F) and the FCBA***

It is supposed that the "UK Future Aircraft Carrier," or CV(F), will be of the short-takeoff-vertical-landing type, flying a "future carrierborne aircraft," or FCBA, of some appropriate type. However, as far as is currently known, the Royal Navy could end up with a conventional-takeoff-and-landing vessel,



larger STOVL carriers, or what is known as a STOBAR ship—short takeoff but arrested recovery.

The CTOL type would appear to offer a number of advantages, especially in terms of the range of aircraft that can be embarked. Two suitable naval aircraft already exist—although not yet in frontline service—to equip this sort of carrier, namely, the Boeing F/A-18 E/F Super Hornet, and the Dassault Rafale M. The Royal Navy's previous decision to depend upon "buddy" refuelling suggests that tankers would not be purchased and that strike/fighter types would likely constitute most of an air wing of forty to fifty aircraft.

Nonetheless, the CTOL carrier seems unlikely. Arrested landings are regarded as unnecessarily complicated by the Royal Navy after some twenty years' experience of STOVL operations.<sup>31</sup> There are other considerations. Steam catapults are labour intensive, while an electromagnetic aircraft-launch system appears to promise a reduction in the number of personnel involved. For a small force such as the Royal Navy this might not be enough, however; its personnel levels are such that any reduction in the complement of an aircraft carrier would be welcome. STOVL operations allow deck crews to be kept small; no catapult or arresting personnel are required, and barriers are unnecessary. Furthermore, electromagnetic launch might be too expensive or inadequately proven by the time CV(F) has to be fitted out.

The key point that the Royal Navy's conception of a large aircraft carrier is different from that of the U.S. Navy must be noted once more. British aircraft carriers, for instance, have tended to embark relatively few support aircraft. Advances in technology may allow support functions to be performed by heliborne or tilt-rotor designs. Further, and perhaps most importantly, it is almost certain that the CV(F) will not be nuclear powered.<sup>32</sup>

### *STOBAR Options*

The short-takeoff-but-arrested-recovery design has a number of operational problems. First, rapid flight operations are difficult unless an angled deck is employed. Even then, if the aircraft requires most of the flight deck to gain sufficient velocity to fly, aircraft will be unable to land while launches are taking place.<sup>33</sup> A STOBAR carrier needs arresting gear, which, as noted, demands a large deck crew at a time when the Royal Navy will be seeking to embark as small a complement on the CV(F) as is viable.

Nonetheless, there is a reason for believing that the STOBAR option is not out of the running. The Eurofighter Typhoon is currently the subject of a British Aerospace study to assess its viability as a carrierborne aircraft, and it is quite clear that although the study is at an early stage, it is being taken seriously.<sup>34</sup> In the past, attempts to convert land-based aircraft into carrier aircraft have not

been entirely successful, particularly with regard to stresses imposed on the airframe—especially in landings, inasmuch as carrier aircraft typically strike flight decks with greater force than land-based aircraft do runways. In the past, either the airframe has not proved strong enough or the weight increases caused by strengthening have imposed too-great penalties on performance.<sup>35</sup>

In the case of a STOBAR Typhoon, the considerations are a little different. Structural strengthening would undoubtedly be required, but the weight increases may be minimised thanks to advanced technology. The Typhoon's advanced flight-control system could be programmed to reduce the stresses of landing, particularly if integrated with a carrier-landing datalink. This would

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*One choice will not be available—to abandon the aircraft carrier entirely. Britain has tried this once, and for all the later success of the Invincible class, it had reasons to regret the decision.*

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have a number of advantages. For instance, sudden pitching of the carrier deck would be recognised by the system, which would feed in last-second control corrections, ensuring that the aircraft landed

within set limits. This would permit the airframe to be strengthened only as required for operations within those parameters—this, at least, is the theory that the British Aerospace study will investigate. There is little doubt that the use of thrust vectoring, already being planned for the Typhoon, coupled with a high-lift wing design, could provide near-optimal short-takeoff-and-landing capabilities for a “Sea Typhoon.” The use of a ski ramp would only enhance STOL performance.

There is another reason why a STOBAR vessel employing the Typhoon might not be out of the question—commonality. The Royal Air Force will be buying 232 Typhoons and has options for fifty more. The use of a navalised Typhoon would simplify servicing and lower unit-procurement costs. In addition, the United Kingdom would be the sole customer for the naval version; this would put design authority into the hands of British Aerospace. Experience with upgrading the RAF's Jaguar strike aircraft (a collaborative project) has shown that with a single design authority that is not obliged to consult a partner, costs go down, and modifications arrive on time and on budget. In view of the chequered history of the Typhoon's design and its increased costs, a cynic could contend that a navalised version unique to the United Kingdom, to be flown by a number of RAF units as well as the Navy, would prove extremely tempting to the Ministry of Defence.<sup>36</sup> It would certainly enhance the capability of a joint force built around carriers. Reequipping the two Sea Harrier squadrons and the three Harrier GR 7 units (or an equivalent number of squadrons) with a navalised Typhoon would ensure that there were more than enough aircraft available for the CV(F).<sup>37</sup>

Although it is currently unlikely that the Typhoon would ever become the sole combat type in the U.K. inventory, its use in the strike role as an early replacement for the Tornado is not an impossible scenario. This could make a navalised version more attractive, since it would slash servicing and training costs, thanks to commonality.<sup>38</sup> There are a number of pitfalls with an air capability employing just one type; still, the point is that a STOBAR Typhoon might offer a number of cost benefits that a government concerned with defence spending would be hard pressed to ignore.<sup>39</sup>

The Typhoon is not the only option. The Dassault Rafale M offers the advantage of being already available. There is little doubt that it is a capable airplane, and it has the swing-role flexibility offered by the Typhoon. Although the commonality aspect would be lost, the closer defence cooperation enjoyed between France and the United Kingdom since the mid-1990s suggests that the Rafale option would not face insurmountable obstacles. The RAF and French forces already run exchange programmes, and it is not impossible to envisage some form of joint operational-conversion unit, along the lines of the now-defunct Tri-National Tornado Training Establishment.

The precedents for such cooperation, however, are not altogether good. European defence projects have broken down over disputes about work sharing and requirements.<sup>40</sup> The Typhoon programme, after all, has been severely delayed. The aircraft (as the Eurofighter) was meant to serve with the United Kingdom, Germany, France, Spain, and Italy; the vigorous disputes over which country should lead the design led to the project's first acronym, FEFA (Future European Fighter Aircraft), being rendered in some aviation journals in unflattering ways.<sup>41</sup> The concept-development stage of the Eurofighter saw the departure of the French, who built the Rafale instead.<sup>42</sup> The political wrangling that ensued from increasing German opposition to the Typhoon delayed the in-service date for the aircraft dramatically; meant to achieve initial operational capability in the early nineties, the first Typhoon will not enter service with the Royal Air Force until 2002. The costs of the programme have risen drastically as a result.<sup>43</sup>

While this experience suggests that a combined European defence force is unlikely in the near term, the idea of some degree of cooperation over CV(F) ought not to be ruled out. The Royal Navy could purchase a ski-ramp-equipped *Charles de Gaulle*-class carrier or two—although one hopes that any future vessels of that class will have power plants that function as advertised and decks large enough to accommodate their whole air groups. Although the Royal Navy seems not to want a nuclear-powered vessel, it would appear that the cost advantages (developmental and trials-related engineering expenses, etc., would be small) of adopting a STOBAR *Charles de Gaulle*-class ship might outweigh this objection.<sup>44</sup> This would provide a European carrier capability; the Royal Navy

would foot far lower development costs, since these would have been absorbed by the French, and there would be commonality of aircraft types as well.

Consequently, the STOBAR option is plausible, with the choice between an existing aircraft type, the Rafale (which will be fully mature technology in 2012, but not outdated), and the slightly newer-design Typhoon, which is generally reckoned to be more capable. If the Typhoon proves suitable for carrier use, the decision between the two types would be difficult, but the difficulty would not be of the unwelcome sort. Whether, however, the short-takeoff-but-arrested-recovery option is the best for the Royal Navy is another issue. There is a compelling reason to suspect that Britain will procure another STOVL carrier—the Joint Strike Fighter.

### *STOVL: The Preferred Option?*

Notwithstanding the scenarios in which a STOBAR vessel might prove attractive, there are strong reasons for the Royal Navy to continue to operate short-takeoff-and-vertical-landing vessels. This contention arises both from the nature of STOVL operations and from the United Kingdom's involvement in the Joint Strike Fighter (JSF). The programmatic details of JSF are well known and beyond the scope of this article; the upshot is that although there are technological concerns, particularly with regard to the STOVL variant, cancellation seems highly unlikely. With its clearly projected costs for each version, the JSF is not an obvious candidate for the major overruns that lead to cancellation.

Furthermore, the Joint Strike Fighter is being relied upon to replace a huge number of aircraft, in a number of air arms. Outside the United States, it is the likely replacement for many F-16s and possibly F/A-18s. If the JSF is not procured, some other type will have to be. For the U.S. Marine Corps, the loss of the STOVL JSF—and in fact the programme is in jeopardy in the Defense Department's current Quadrennial Defense Review—would be a serious blow, demanding either the updating of the AV-8B or a fundamental change in Marine aviation doctrine. This vulnerability prompted Lieutenant General Fred McCorkle, USMC, Deputy Chief of Staff for Aviation, to comment, "This nation has all its eggs in one basket."<sup>45</sup>

If the Royal Navy chooses a STOVL vessel, all of its aviation eggs will be in the same basket. It might therefore be said that the STOVL Joint Strike Fighter is a programme that will be *made* to work, since failure cannot be regarded as an option for two major customers. Even so, there are potential technical pitfalls with a supersonic STOVL type, and it is likely that the Marine Corps will be awaiting the flight-testing results with some anxiety. This will also be the case for Britain.

Britain has become a full collaborative partner in the JSF programme, and it has invested considerable sums in the project. It must be recalled that British

defence spending has edged inexorably downward for the last forty years; it is hard to envisage the JSF expenditure to date as a mere expression of interest in the project. This said, the cancelation of P.1154, TSR 2, F-111K, and Nimrod AEW 3 after prodigious expenditure makes procurement of the JSF less than a certainty.

Even given general confidence, however, that the Joint Strike Fighter will enter British service, a major concern remains: whether the STOVL JSF will work as planned. Supersonic VSTOL aircraft have been attempted before, and the

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competing design teams admit that the risk attached to the STOVL option is the greatest in the entire JSF programme. Apparently even simple and elegant technological and engineering so-

lutions sometimes fail to work as advertised, and the inherent difficulties of short takeoffs and vertical landings make this more of a risk. Since the STOVL variant is only part of the programme, technical difficulties with it will not wreck the Joint Strike Fighter. Most customers will employ the CTOL version, and whether the STOVL variant works is not a concern to them. It is the U.S. Marine Corps and the Royal Navy that will suffer most if the STOVL JSF does not become a reality.

If the STOVL variant runs into development problems or escalating costs, the United Kingdom may well look for another carrier aircraft, employing the conventional Joint Strike Fighter in a few squadrons to meet its commitments to the programme. The problem here is that the choice of carrier platform will be made before the STOVL JSF is proven (unless it suffers major problems that instantly rule it out). If a STOVL platform is chosen with the intent to fly the Joint Strike Fighter, but the aircraft fails, the Royal Navy will have little option but to upgrade its Harriers. It may well be that attrition and the fatigue life remaining for the Harriers precludes an upgrade; there is also the issue of whether it would be better to use the Harrier GR 9 as the basis for an upgrade or to reopen the GR 9 production line.<sup>46</sup> Commentator Roy Braybrook has argued that the U.S. Marine Corps and the RAF should not contemplate procurement of STOVL JSF but should instead rely on an upgraded Harrier GR 9/AV-8B with “improved radar and long range missiles.”<sup>47</sup> In the event of STOVL JSF cancelation, it is likely that the GR 7/AV-8B would be used as the basis for the replacement type.

If the STOVL JSF does work, however, it will provide a number of clear benefits. It will offer the Royal Air Force the capability to operate from austere locations, even without runways. With an apparently increasing British commitment to peacekeeping—which usually occurs in areas where aviation infrastructure

either has been destroyed or never existed—this is important.<sup>48</sup> For the naval element of a joint British force, JSF has several advantages over all other types in operations from the CV(F). The most obvious are that short takeoff and vertical landings remove the need for arresting gear, and for any launching system beyond the ski jump.

More generally, operations with the *Invincible* class have already demonstrated the manifest advantages that STOVL has over CTOL. These can be characterised as means of operability. First, because of the ski jump, a STOVL aircraft always leaves the deck on an upward trajectory, preventing a potentially dangerous lack of clearance between aircraft and ocean in rough seas with a pitching deck. Second, the likelihood of a “fouled deck” (from which aircraft can be neither launched nor recovered because others are in the way, either being moved or suddenly broken down) is far less acute. The vertical landing capability allows STOVL types to land even if their usual landing spots are blocked. There are no “bolters” (forced last-instant decisions of pilots not to land) on STOVL vessels; it has been proven that even when the carrier is blanketed in thick fog, with the pilot unable to see the vessel, landing is possible. During the Falklands conflict, one pilot returned from patrol to *Invincible* in just such weather conditions and nearly out of fuel. A searchlight was shone upward from the carrier, through the fog, and the pilot descended following the beam.<sup>49</sup> Finally, the STOVL type can land on vessels that are not designed to operate it. This was taken to extremes in June 1983 by Sub-Lieutenant Ian Watson, who, through lack of fuel, could not return to the carrier; he instead landed on a passing Spanish merchant ship, the *Alraigo*. This saved an aircraft that would otherwise have had to be abandoned. It is not difficult to envisage situations where the ability to land aboard other vessels in a battle group would be advantageous.<sup>50</sup> The United Kingdom has already commissioned HMS *Ocean* as an LPH, and that ship could operate a small number of STOVL types if need be.<sup>51</sup>

Although it has now become something of a cliché in British circles, the maxim “It’s far easier to stop, then land, than to land, then stop” has more than a grain of truth to it. It describes the manner of short-takeoff-and-vertical-landing operations perfectly. A 1992 report by the Center for Naval Analyses suggested that naval STOVL aircraft could undertake 25 percent more sorties than a conventional-takeoff-and-landing type over a five-hundred-nautical-mile radius in a twelve-hour period; if the radius of action were reduced to 250 nautical miles, the STOVL type could generate 40 percent more.<sup>52</sup>

To summarise, the STOVL vessel offers the ability to operate aircraft in weather conditions that would not be acceptable for CTOL types; it reduces the number of personnel required, by employing neither catapult nor arresting gear. Accordingly, the STOVL vessel can be cheaper and generate more sorties than a

CTOL carrier. For the Royal Navy, it is hard to see how there can be any objection to continuing to use STOVL vessels when these offer such great efficiencies compared to conventional types.

The major objection to STOVL appears to be that the Harrier and Sea Harrier are essentially limited in their technological advancement. Even this is debatable, however, since the technology of the Rolls-Royce Pegasus engine was advanced for its day; Rolls Royce has carried out continuous upgrading of and research on the engine, and further improvements are to be expected. As noted earlier, a key factor that is often overlooked when comparing the Sea Harrier and the more up-to-date AV-8B/Harrier GR 7 with other combat aircraft is that the former are fundamentally first-generation designs, employing 1950s engineering with 1980s modifications overlaid by 1990s technology. The only means of achieving adequate vertical and short-takeoff-and-landing performance without unacceptable weight penalties when the P.1127 prototype was designed was the single-engine vectored nozzle. This imposed certain limitations on the size of the aircraft, particularly on its internal volume. The Sea Harrier, Harrier GR 1/GR 3, and AV-8A/C, therefore, were all small combat aircraft. The AV-8B/Harrier GR 7 improved the airframe, avionics, and load-carrying capacity, but they were still tied to the vectored-nozzle system. Perhaps its most notable limitation, if the least relevant to operational efficiency, is that the vectored-nozzle engine does not allow supersonic flight.<sup>53</sup> This has always received far too much consideration; supersonic performance has for too long been regarded as something that fighter and attack aircraft must have. The only two Western designs of note without it since the late 1960s have been the A-10 and the Harrier family.<sup>54</sup> It is notable that these two types have always received only grudging respect (if any); even highly impressive results in combat have not saved them from verbal “friendly fire.” In the case of the Harrier, although General Norman Schwarzkopf announced that the AV-8B had been one of the key weapon systems in DESERT STORM, there were more than enough people prepared to criticise the AV-8B for its vulnerability to infrared-guided surface-to-air missiles rather than point out its effectiveness. While there is truth in this criticism of the AV-8B, it does not undermine the overall effectiveness of STOVL operations, and particularly not from aircraft carriers.

#### **NOT AN OPTION BUT A NECESSITY**

In light of all this, what is the best option for the Royal Navy for its future carrier operations? The conventional-takeoff-and landing carrier seems the least likely option, given the expense associated with the ship itself and the complement required to support the air wing. The choice between short-takeoff-but-arrested-recovery and short-takeoff-and-vertical-landing is more difficult to assess. If the

STOVL variant of the Joint Strike Fighter performs as planned, it will be extremely difficult to argue in favour of STOBAR. Still, the issue of how good an air-combat machine JSF is will need to be resolved before we can be absolutely certain that the Royal Navy will take delivery of the type. It should also be re-

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*“It’s far easier to stop, then land, than to land, then stop.”*

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called that recent threats to the F-22 programme led to assertions that were F-22 procurement to be reduced (or cut entirely), the JSF

would have to be redesigned to make it suitable for the air-superiority role.<sup>55</sup> The Typhoon is claimed (by both its manufacturers and independent experts) to be the next-best air combat type after the F-22 (and less expensive), which may give it an advantage over rivals for procurement by the Royal Navy.

In spite of this, STOVL JSF would appear to offer a level of operational flexibility that neither a navalised Typhoon nor the Rafale could provide. The major difficulty with the Joint Strike Fighter is uncertainty whether the STOVL variant can be developed without major technical difficulties. We should know the answer in the not-too-distant future, although it appears that the programme may be subjected to some delay.<sup>56</sup> If it works, the probability is that the JSF will operate from British carrier decks from 2012 as part of a joint Royal Air Force/Royal Navy force; STOVL is clearly the most flexible and affordable option for a power of Britain’s size. The difficulty is whether even the huge advances in technology since the P.1127 metamorphosed into the Harrier and Sea Harrier have been enough to advance STOVL from a proven but still developing system into a truly flexible weapon system. If not, defence officials will have to consider the options very carefully, and they will have to make some difficult choices.

One choice will not be available—to abandon the aircraft carrier entirely. Britain has tried this once, and for all the later success of the *Invincible* class, it had reasons to regret the decision, including a number of sunken vessels in the South Atlantic. This bitter experience makes clear the lack of carrier-based airpower would demand a fundamental shift in British foreign policy. There has already been such a shift since the end of the Cold War, and not toward less involvement. The current government purports to pursue an ethical foreign policy (despite some awkward contradictions); it has made this intention clear with its continuing support of action against Saddam Hussein, operations over Kosovo, and the deployment of troops to East Timor. Although in all three cases Britain’s contributions have not been the largest, they still represent a deployment of significant proportions of British military resources.

The Strategic Defence Review does nothing to suggest that there will be a scaling down of this support for humanitarian intervention and attacks against dictatorial states. Britain’s new foreign policy paradigm demands flexibility and



deployability. Even with the procurement of a strategic airlifter for the Royal Air Force (after much confusion), deployability will still be heavily dependent upon naval airpower.<sup>57</sup> This is true now, and the CV(F) will be of immeasurable value when it eventually arrives. If the design of the vessel and the aircraft type to be operated from it are still far from clear, one thing is obvious. If Britain is to continue in the post–Cold War world in the role it has set out for itself, carrier-based air power is not an option. It is a necessity.

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#### NOTES

1. See Derek Wood, *Project Cancelled* (London: MacDonald and Jane's, 1975), pp. 207–24. The Admiralty did not appear to want the P.1154 and ensured that its requirements for the aircraft were almost diametrically opposed to the RAF's needs.
2. Cynics could also suggest that the F-4K Phantom clearly required a CTOL carrier, thus ensuring that the new carrier would not be of the smaller VSTOL types. Less cynically, it could be pointed out that the Phantom was obviously a great aircraft already. To take the technical risk of procuring the P.1154 when there was a suitable aircraft available appeared pointless. Although the Royal Navy operated only one squadron of Phantoms at sea, this was a result of changing government policy and the abandonment of conventional carriers. Had the CVA-01 programme gone ahead with full replacement of then-extant carriers, at least five squadrons (and possibly six) would have been required.
3. These modifications included an extendable nosewheel strut to provide the correct angle of attack on takeoff, given the shorter carrier decks of the Royal Navy. This was mainly for reasons of the increased thrust provided by the Rolls-Royce Spey engine, but the political imperative of generating jobs in the British aviation industry demanded a high U.K.-built content for the F-4K. The Spey was also installed in the RAF version, in spite of the fact that the RAF did not want or need the engine; the Spey had a slower afterburner-lightup time and was less fuel efficient than the standard J-79. The net result of the Spey installation and the high amount of subcontracting led RAF pilots, however much they loved the aircraft, to describe them as the most expensive, noisiest, and slowest Phantoms in the world.
4. For the design of CVA-01, see David Hobbs, *Aircraft Carriers of the Royal and Commonwealth Navies* (London: Greenhill Books, 1996), pp. 249–50.
5. HMS *Albion*, *Bulwark*, *Centaur*, and *Hermes* were all of the *Centaur* class, with origins as light fleet carriers in the Second World War. There were substantial variations in each vessel, with *Hermes* often being regarded as a separate class by itself. In the early 1960s, *Albion* and *Bulwark* were converted to carry Royal Marine commandos, deployed by helicopter; they were roughly equivalent to the U.S. LPH in concept. *Centaur* was paid off in 1965 and used as an accommodation vessel. Of the fleet carriers, *Victorious* was the oldest, having entered service in 1941. It was modified extensively between 1950 and 1958, after which it was arguably one of the most advanced vessels in any navy. Again, in comparison with the carriers operated by the U.S. Navy, the *Victorious* air group was limited, with a maximum of thirty-six aircraft. *Hermes* could manage twenty-eight Sea Vixens, Scimitars, and Buccaneers; by the 1970s, however, only the Buccaneer was a truly viable combat type. Thanks to typically parsimonious defence spending, the Scimitar never received the avionics fit it needed to become a multirole aircraft. In its basic form it could carry four 30 mm cannon and early guided weapons, such as the Bullpup and AIM-9B.
6. Although *Victorious* might have managed to take Phantoms, more than thirty aircraft would have been a tight fit. Since at least ten aircraft would have been AEW Gannets and

Sea King and Wessex helicopters, this limitation would have reduced the effectiveness of the air group.

7. It was argued that this would be too costly, but it is difficult to find any authoritative source that accepts the validity of this reasoning.
8. The only aircraft types in the RAF's inventory designed for such air defence work (apart from the Hawker Hunter, which had begun life as an interceptor but was by the late 1960s used for ground attack) were the F-4 and the English Electric Lightning. In the early to mid-1970s, the RAF's Phantom fleet was committed to Germany in the strike role. After the introduction of the SEPECAT Jaguar, the Phantom was transferred to the air defence of the United Kingdom and thus would not be readily available to defend the fleet. In any case, how the RAF was to defend carriers in the middle of the Atlantic was never quite explained. The F-4 could not manage this, even with tanker support. Although the Lightning must rank as one of the great fighter designs (it gave an excellent account of itself in exercises against the F-14, F-15, and F-16 even in the late 1980s), its endurance was appalling. Designed as a point interceptor, even with in-flight refuelling the Lightning could not have maintained a combat air patrol over the fleet. In actuality, air defence of the Royal Navy was effectively left to the U.S. Navy—one of whose carriers, it was hoped, would be available to support operations.
9. This had been trialed by the United Kingdom, West Germany, and the U.S. Marine Corps in 1966, including landings on the USS *Independence* (CV 62) and small-deck tests on the dock transport USS *Raleigh* (LPD 1).
10. The CVSG had no arresting gear or catapults, and the Navy began to present it to politicians as a "through-deck cruiser," which would operate an air complement of antisubmarine helicopters, with a few VSTOL aircraft (obviously Harriers) to defend against Soviet reconnaissance aircraft. The designation of the new class as a "cruiser" was barely plausible—the ship was cynically referred to as a "see-through cruiser"—and caused problems to begin with, since the type was initially meant to carry not fixed-wing aircraft but the Exocet antishipping missile to provide offensive firepower. Had the CVSG been designed to carry VSTOLs from the outset, it is likely that it would have been bigger, to give it a meaningful air group.
11. By 1972, although the decision to withdraw conventional carriers was not likely to have been reversed, it had been decided that a naval version of the Harrier would be acceptable. Such a machine, while not offering the capabilities of an F-4 or a Buccaneer, could at least provide limited air defence for the through-deck cruisers—now the *Invincible* class—while they conducted their primary mission.
12. There was considerable public support for the *Ark Royal* after a BBC TV series on the ship. Public feeling was so strong that the planned HMS *Indomitable* was renamed.
13. The *Hermes* was withdrawn from British service in 1985, after a period in reserve, and was sold to India, where it is now the *Viraat*.
14. The *Ark Royal's* air wing normally consisted of twelve F-4 Phantoms, fourteen Blackburn Buccaneers, three Fairey Gannet airborne early warning aircraft, and six Sea King anti-submarine helicopters. Two Westland Wessex helicopters were also embarked in the search-and-rescue role, and occasionally a single carrier-onboard-delivery variant of the Gannet.
15. It might also be pointed out that the Royal Navy was subjected to savage cuts in the 1981 defence review. Under this, *Invincible* was to be sold to Australia. Had the Argentine leadership waited a few more months before invading, Britain would not have had the forces to mount the operation. Ironically, the man who came up with the ruinous review, Defence Secretary John Nott, was knighted in the aftermath of the Falklands campaign. It is arguable that without the review (which also called for withdrawing the patrol ship *Endurance* from the South Atlantic), Argentina might have judged that invading the Falklands was too much of a risk.
16. Later, after conversion to the commando carrier role, *Hermes* was fitted with a ski ramp, allowing it to operate Sea Harriers, thus providing an interim vessel for use while the three *Invincible*-class vessels were being built. The air wing on both carriers was reinforced, bringing the number of Harriers above the

twenty-six fighter and attack aircraft embarked by *Ark Royal*.

17. Thanks to the support of the United States, the Royal Navy was able to draw on Nato stocks of the AIM-9L all-aspect variant rather than use the then-standard AIM-9G.
18. The vertical takeoff requires far more fuel and reduces payload; thus it makes much more operational sense for the Harrier to begin with a short takeoff run.
19. The only solution was to modify a number of Sea King helicopters to carry the EMI Searchwater radar in a large, inflatable radome mounted on the side. The modification programme began while the conflict was in progress, but the first conversion did not arrive until the fighting was over.
20. The Argentine carrier, the *Veinticinco de Mayo*, was not employed. A planned strike on the British fleet from its deck was aborted for lack of wind; shortly afterward, the cruiser *Belgrano* was sunk by the fleet submarine HMS *Conqueror*. The Argentine fleet did not venture toward the Falklands again.
21. It was said that the British carriers were so far east of the Falklands that their crews qualified for the Burma Star.
22. It ought to be noted that the Argentine air force's Mirage and Dagger aircraft had much the same problem. Even taking into account the fact that they had longer journeys to and from the combat zone, the air-to-air armament of the Mirage III and its variants was not particularly impressive.
23. Peter E. Davies and Anthony M. Thornborough, *The Harrier Story* (London: Arms and Armour Press, 1996), pp. 161–8. Although it is a potent machine, the Sea Harrier's armament is limited. It invariably carries two 190-gallon fuel tanks under the inner wing pylons, as without them its range is prohibitively short. This leaves room for just two AIM-120s under the wings. Two more can be placed under the fuselage, but if they are, the 30 mm gun pods have to be off-loaded; for situations such as policing no-fly zones—where the ability to fire warning shots is useful—this is a problem. (This issue has been ignored for ridiculously small financial gains in the RAF's forthcoming Typhoons, which the current government intends not to equip with a gun solely to save money on support costs.) The Sea Harriers usually fly with a mix of two AMRAAMs (advanced medium-range air-to-air missiles) and two gun pods in these circumstances, or replace the AIM-120s with the AIM-9M Sidewinder. The Sea Harrier can also carry ground-attack weapons, but the use of the Harrier GR 7 from carrier decks has seen a dramatic reduction in the use of the Sea Harrier for attack missions. Additionally, AIM-120s carried on the fuselage positions have been damaged by heat and vibration. At the end of the deployment of Sea Harriers in support of Operation ALLIED FORCE (the 1999 Kosovo campaign), around half the AIM-120s embarked upon *Invincible* had been rendered unserviceable by this cause.
24. The Harrier GR 7 is a very different machine from the Harrier of 1982. The “big wing” Harrier has a far greater load-carrying capability than the Sea Harrier, with eight underwing hardpoints (two dedicated for the use of Sidewinder), compared to the Sea Harrier's four. As recently seen over Kosovo, the GR 7 can easily provide self-designation for laser-guided weapons, through the TIALD system, mounted on an under-fuselage pylon. The combination of Sea Harrier and Harrier GR 7 provides greatly increased flexibility for British maritime operations. The GR 7 (as well as the GR 5 model, which preceded it) suffered at first from a number of problems affecting the engine and weapons. One of these problem areas was the new 25 mm ADEN cannon, specially designed for the Harrier GR 5/GR 7; after years of trying to integrate it with the Harrier's weapon system, it was decided to abandon the idea. The considerably less advanced 30 mm ADEN (based on the German 30 mm cannon designs of 1944–45) still functions perfectly, but it can only be carried by the Sea Harrier. All the surviving GR 5 aircraft have now been upgraded to the GR 7 standard.
25. This criticism usually revolves around the capabilities of the Sea Harrier. In spite of its upgrade, it must be recalled, the Sea Harrier is a first-generation STOVL type, based on the P.1127, which was never designed to carry a war load. The Harrier GR 7, as an evolved, second-generation type, gives better insight into the potentialities of STOVL for naval use.

26. It is not hard to posit such a scenario—for example, had Italy not permitted the use of its airfields for Nato operations against Serbia, the only nearby alternatives were either not Nato-compatible (e.g., in Hungary) or not adequate (as in Albania).
27. *The Strategic Defence Review*, Command Paper 3999 (London: Her Majesty's Stationery Office, 1998).
28. *Ibid.*
29. The Sea Harrier force is moving to the RAF base at Cottesmore to be in closer proximity to the RAF's Harriers: two squadrons operate from Cottesmore and two more from the nearby base at Wittering, which is literally just a few miles down the A1.
30. Richard Scott and Mike Wells, "Flexing Joint Muscle: Mixed Air Groups aboard Carriers," *Jane's Navy International*, December 1997, pp. 14–22.
31. The provision of catapults and arresting gear adds cost to the vessel, and the joint nature of future operations means training of RAF pilots to conduct carrier landings as an unlooked-for complication that would add expense, which many perceive as pointless when STOVL types have worked so well for the United Kingdom.
32. See David Foxwell, "New Waves of Sea Power," *Jane's International Defence Review*, February 1997, p. 34.
33. See the discussion section after David James, "British Naval Doctrine and the Future Equipment Programme," in *Maritime Aviation: Light and Medium Aircraft Carriers into the Twenty-first Century*, ed. Peter Hore and Thomas J. Hirschfield (Hull, U.K.: Univ. of Hull Press, 1999), p.115.
34. See "Sea Legs for Typhoon?" retrieved from the World Wide Web: <http://eurofightertyphoon.com>.
35. This factor (among others, of course) led to the adoption of the F/A-18 over the F-16 by the U.S. Navy; the F-16 was felt not to have the necessary development potential for carrierborne operations. The Royal Navy has experience with aircraft that are not strong enough for carrier operations. Although the Seafire (navalised Spitfire) was highly regarded, for instance, it was more prone to landing accidents and downtime than other types.
36. This is speculation on the part of the author, who is not entirely convinced that procuring navalised Typhoons would reduce the overall unit cost of the aircraft. The costs of developing the aircraft might well be greater than the savings made by having a single, national design authority.
37. The key issue here would be training pilots of the RAF squadrons to land on carriers, discussed above, but perhaps more relevant is the role portrayed for the Typhoon in RAF service. It has already been mooted as a contender—in modified form—for the Follow-on Offensive Aircraft System (FOAS), which will replace the Tornado GR 4. Defence spending priorities may well cause more Typhoons to be purchased to replace Tornados in some squadrons before the FOAS is chosen. Since the early 1990s, Ministry of Defence policy, even if unstated, has been to reduce the number of types in the RAF's inventory. The Buccaneer and Phantom were withdrawn some years before schedule; the Jaguar fleet was constantly targeted for retirement until the Jaguar GR 3 upgrade added vastly improved capability at a very low price. It also demonstrated that requirements unique to one country enabled the problems of collaborative ventures to be swept aside with ease.
38. Currently, the RAF possesses the following types in the following number of combat aircraft squadrons (including operational conversion units): Tornado F3, six; Tornado GR 1/GR 4, eight; Jaguar GR 3, four; Harrier GR 7, four; and Sea Harrier, three. The Typhoon is scheduled to replace all the Tornado F 3 and Jaguar units. It is anticipated that the total of 232 will permit the formation of ten frontline squadrons and a training unit to teach both air-to-air and air-to-ground operations. If the Harriers were replaced with navalised Typhoons, the number of "operational conversion units" (OCU—equivalent to the U.S. Navy's fleet readiness squadrons) could be reduced from the current five to two (one Typhoon, one Tornado).
39. A problem with this scenario might be whether one OCU for the Typhoon would be enough. The question of whether it would be wise to rely upon one aircraft type would also have to be considered.

40. This is to say nothing of the creation of a European defence force. A number of senior European politicians have called for the formation of European armed services. It should be noted that British politicians are not among them. It is probably fair to say that the British electorate's respect for its armed services and its often suspicious attitude toward foreigners (at least those who do not speak English as their native language) make it unlikely to take kindly to the politician who initiates the transfer of British forces to supranational control. Aside from British insularity (or xenophobia), there is considerable anecdotal evidence that the idea might not work. It is not widely known, but some French units in Bosnia refused to speak anything other than French to their colleagues (this from a conversation between the author and a British officer who served in Bosnia). French spirits rose when a French Canadian unit arrived, but the differences between Canadian and "metropolitan" French were such that the Canadians decided that they would rather use English.
41. See the "Straight and Level" column in *Flight International* on many occasions in the mid-1980s for full explication of the term.
42. It is not unfair to say that the departure of Avions Marcel Dassault was met with relief from the other nations. Dassault has developed an unfortunate reputation for promoting its own products at the expense even of collaborative programmes with which it is involved. This led to the Aeronavale (French naval aviation) receiving the Super Etendard instead of the SEPECAT Jaguar M, which was arguably the better aircraft. See *World Air Power Journal*, vol. 35, p. 68, for particular reference to the Eurofighter Typhoon.
43. *Ibid.*, pp. 54–97. The Eurofighter story became almost farcical. When it was announced that the aircraft was to be named the Typhoon, objections by the Germans (who felt it tactless to name the aircraft after one that had killed many Germans in the Second World War) led to the compromise that it would be known as the Typhoon only for export customers. The RAF was thus faced with the prospect of having the "Eurofighter" as its main combat type.
44. The *Charles de Gaulle* suffered embarrassing power-plant problems (related to auxiliary engines, not the nuclear reactor) on its maiden voyage, being forced to return to port early. It was also discovered that the flight deck was not large enough for its E-2C early warning planes to manoeuvre safely. See "Carrier Concerns," *Jane's Navy International*, March 1999, p. 8; and "Up Close: Charles de Gaulle Finds Its Sea Legs," *Jane's Navy International*, November 1999, pp. 10–1.
45. "Osprey Crash and JSF Doubts Hit USMC Aircraft Plans," *Jane's Defence Weekly*, 19 April 2000, p. 11.
46. The Harrier GR 7 is to be improved to the GR 9 standard with the addition of new avionics.
47. See Roy Braybrook, "VSTOL: Reflections 40 Years On," *Air International*, October 1999, pp. 235–40.
48. Operations in such cases, though, are unlikely to take the form of the 1970s and 1980s, when Harrier GR 3s operated from forest clearings using short runways of pierced steel planking, or from shopping-mall car parks. It is more likely that austere equipped airports would be employed instead, with the STOVL capability removing the need for long, well-maintained runways.
49. N. D. "Sharkey" Ward [Cdr., RN], *Sea Harrier over the Falklands* (London: Orion, 1993), pp. 317–8.
50. See Davies and Thornborough, pp. 161–2.
51. Short takeoffs would not be possible, since one of *Ocean's* close-in weapon systems would be in direct line of a takeoff run; VTOL would be the only option.
52. Most recently cited in *Combat Aircraft: The International Journal of Military Aviation*, May–June 1999, p. 144.
53. Supersonic performance might be given to the Harrier through the use of a technique known as "plenum chamber burning." This has been under test for many years but has never been introduced for operational service.
54. There have, of course, been other, less well known, types, such as the Italian/Brazilian AMX (the obscurity of which seems a little unfair).
55. See "Raptor under Threat," *Air Forces Monthly*, September 1999, p. 4. Also, see

“United States Navy Today: Part 1, the Carrier Air Wing,” *Air International*, August 1999, pp. 100–6, where Tony Holmes posits the view that “JSF is effectively a bomber with a strong fighter capability, more f/A than F/a.”

56. “Osprey Crash,” *Jane’s Defence Weekly*, p. 11.

57. The SDR identified a need for a heavy-lift capability for the RAF and called for the interim

leasing of “C-17 class” aircraft to fulfill the role. Much to commentators’ surprise, the strategic airlifter was canceled in 1999. Thereafter it became increasingly apparent, however, that UK defence commitments demand this type of aircraft, and the requirement was reinstated.