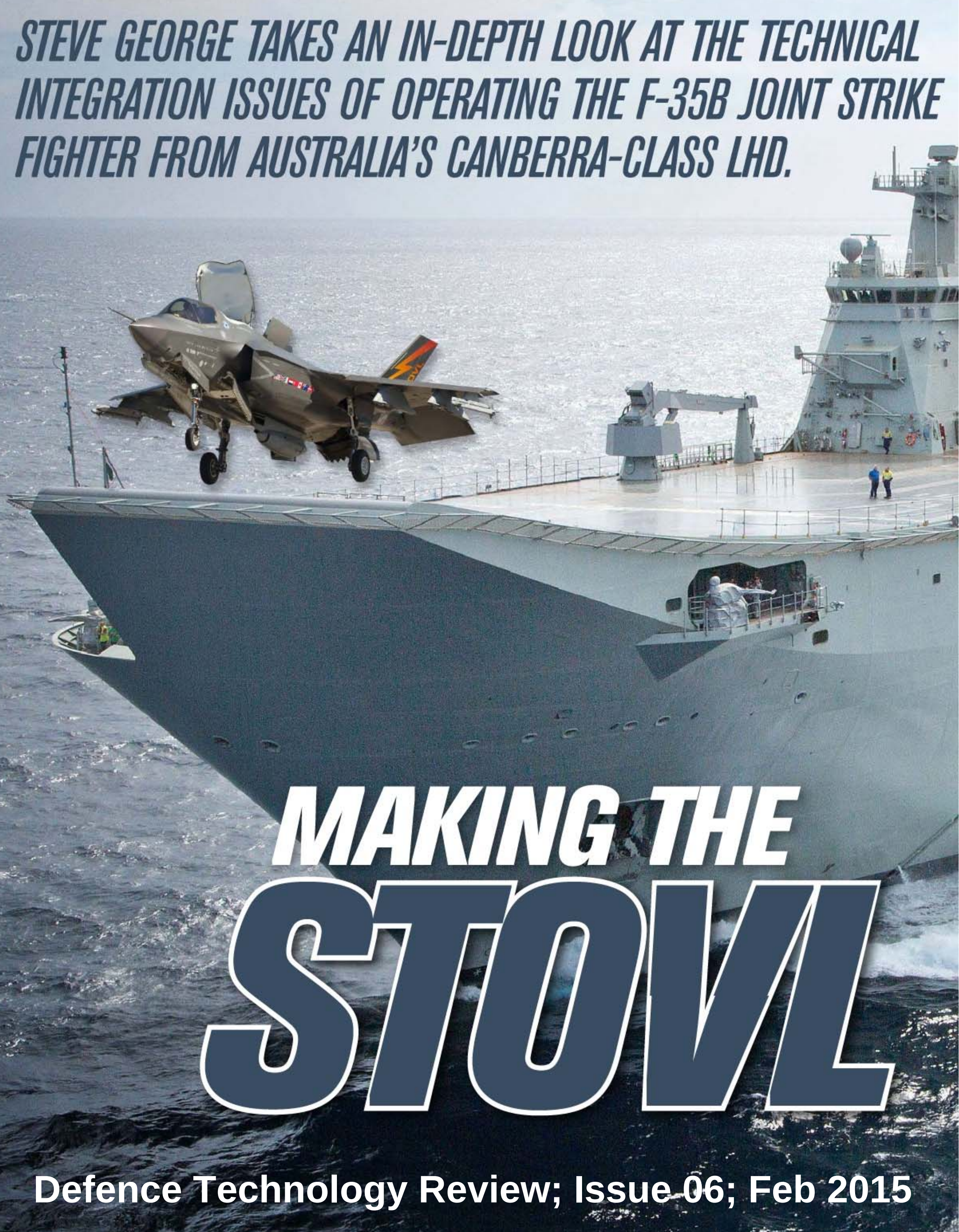
STEVE GEORGE TAKES AN IN-DEPTH LOOK AT THE TECHNICAL INTEGRATION ISSUES OF OPERATING THE F-35B JOINT STRIKE FIGHTER FROM AUSTRALIA'S CANBERRA-CLASS LHD.



MAKING THE STOVL

Defence Technology Review; Issue 06; Feb 2015

http://defencetechnologyreview.realviewdigital.com/default.aspx?iid=113275&startpage=page0000026#folio=26

F-35B WORK FOR THE ADF

There is a great deal of interest in the possibility of using the F-35B short take-off and vertical landing (STOVL) Joint Strike Fighter (JSF) from the Royal Australian Navy's (RAN) new Canberra-class landing helicopter dock (LHD) amphibious assault ships.

To date, most of the online discussions about the value and practicality of this option have lacked complete information and technical depth; in many cases, the 'information' has been wholly inaccurate. This short brief is intended to help *DTR* readers gain a better appreciation of the issues.

F-35B and the Capability Question

Much has been made of the 'limited' capability of the F-35B JSF compared to the land-based F-35A conventional take-off and landing variant. So let's put it in perspective.

The F-35 JSF family of aircraft represent a major step forward in tactical aircraft combat capability, and they achieve this primarily through a massive advance in the gathering and exploitation of information, collected by their own sensors or data linked from other platforms. The F-35 sensor suite includes a highly advanced AESA radar (AN/APG-81), a fully integrated electro optical targeting and sensing system (EOTS; such systems are pod mounted on legacy aircraft such as the F-16 and F/A-18), a large electronic warfare (EW) suite of passive radio frequency sensors, and an integrated dual band infrared (IR) distributed aperture system (DAS; AN/AAQ-37) that combines missile warning with IR imaging functions. The aircraft are also equipped with a highly advanced data link system. All of these are highly advanced in technology and performance, and will give the F-35 JSF family tremendously improved situational awareness (SA) in operations.

The F-35 JSF family also exploit low observable (LO) technology to an extent not previously achieved on tactical aircraft. The LO techniques and solutions on the F-35 reflect years of development and hard won experience on previous US platforms, and will give the F-35 a decisive edge in combat.

So, it's important to realise that as far as SA and LO are concerned, the F-35B has exactly the same capabilities as the F-35A and F-35C. Same radar, same EOTS, same EW suite, same DAS, same LO technology. The key message is that the F-35B is an exceptionally capable aircraft. However, it's absolutely true that the addition of STOVL capability has affected capability in three areas: range, 'g' and weapon bay size. So let's look at these areas.

ABOVE: Whilst the F-35B JSF has a reduced weapons load compared to the F-35A, its offensive combat capability is vastly increased over previous generations of STOVL aircraft.
Image: Lockheed Martin

The F-35B's combat range key performance parameter (KPP) requirement is 450nm against the F-35A's 590nm. This reflects the reality of losing internal space to the lift fan system, and was understood when the KPPs were first agreed around 2000. However, the point of the STOVL aircraft is that it is intended to be deployed on ships, closer to its targets. This logic would apply to any Australian Defence Force (ADF) use of the aircraft from the Canberra-class LHD. The F-35B also has the same highly flexible 'probe' refuelling system as the F-35C, enabling it to be refuelled by a wide range of potential national and coalition tanker aircraft.

Interestingly, 'g' requirements were not included as F-35 KPPs, and so have been traded against KPPs and other higher priority requirements. 'G' values are dependent on aircraft weight, configuration, altitude, speed and a number of other factors, so any comparison between the two variants is likely to be simplistic. However, it does appear that the F-35B has a typical sustained turn rate of around 4.5g, with the F-35A figure being around 5.5g. This is probably due to the F-35B's airframe being optimised for the lowest possible landing weight, and the additional drag of the lift fan system fairing.

There will be impassioned arguments around this difference, but there is no doubt that the importance of raw 'g' in air combat effectiveness has dropped markedly over recent decades in favour of improved SA. The LO capable F-35B, possessing exceptional SA and armed with the AIM-120C Advanced Medium Range Air-to-Air Missile and new generation short-range air-to-air missiles, plus a sustained turn rate much better than legacy STOVL aircraft, will be a highly capable air combat adversary.

Finally, weapons bay capacity. Again, the original KPPs reflected the reality of STOVL challenges and called for the F-35B to carry a 1000lb Joint Direct Attack Munition (JDAM) internally, as opposed to the 2000lb JDAM requirement for F-35A and C variants.

Early F-35B designs attempted to achieve a 'common' 2000lb capable weapons bay, but reality caught up with Lockheed Martin around 2004, and the F-35B reverted to a smaller 'KPP compliant' bay. However, the F-35B can still carry 2000lb JDAMs externally if required, and in any case, the need for these very large weapons is infrequent: recent operations show that 500lb class air-to-ground munitions are the most frequently used by a large margin. Again, this drop in heavy ordnance capability would not likely be a deal breaker for the (ADF).

In any event, the F-35B offers a tremendous step forward in STOVL capability compared with that offered by the Harrier family of aircraft, which have, for over 30 years, delivered highly effective combat capability all over the globe.

So, it's true that, in some respects, the F-35B has more limited capability than the F-35A. But these do not appear to be 'decisive' or 'critical' shortfalls. But – and the value of this 'but' cannot be overestimated – in many scenarios, it delivers the important capability to operate from a ship much closer to the required area of operations. Our defence leaders have to decide whether that is a capability trade off worth making.

So let's look at the other main area of contention – the practicality of putting the F-35B on the 'Canberra' class LHDs.

Integrating Aircraft and Ships

It's best to start by understanding that putting military aircraft on ships has never been easy. Warships, even the massive US Navy (USN) nuclear-powered aircraft carriers, are not and never will be just 'floating airfields' – the raw constraints of physical space have driven naval aviators to develop new ways of launching, recovering, arming, maintaining and repairing aircraft since the earliest days.

But they have consistently succeeded. Effective, safe and sustainable embarked air power has been demonstrated from a wide variety of ship/aircraft combinations over the past 100 years. Maritime fixed-wing aviation is an achievable art – and STOVL makes it even more achievable.

Successful maritime aviation depends on a little known discipline called 'ship/aircraft integration'. This is a systems engineering challenge, requiring thorough understanding and control of the various interfaces between the ship and the aircraft. So, how closely are the F-35B and the LHD interfaces currently aligned? Remember, it's been regularly asserted that the LHD is 'not designed to operate the F-35B' or that the F-35B 'will not be compatible' with the LHD.

To assess the practicability question, we need to understand the various types of ship/aircraft interface. They can be grouped as follows:

- The operating interface – launching and recovering, including movement around the flight deck, with ship motion;
- The environmental interface – includes aircraft weight, size, jet blast and noise;
- The information interface – becoming a major aspect, includes the required mission support systems, communication and identification, and not least the means of exploiting the intelligence, surveillance and reconnaissance outputs from the F-35B. Also includes the required guidance systems for launch and recovery;
- The support interface – how the ship provides the required support capabilities to the aircraft, including fuel, weapons and maintenance. A key driver for manpower requirements as well as hangar and flight deck layouts.

The important issue of personnel requirements for F-35B operations will also be examined.

Let's take each of these issues in turn, and see how much is known from publicly available information.

MARITIME FIXED-WING AVIATION IS AN ACHIEVABLE ART – AND STOVL MAKES IT EVEN MORE ACHIEVABLE

The Operating Interface

At the outset, it's vital to appreciate two very salient facts.

- The first is that the F-35B has been specifically designed to operate from ships like the LHD. It has had to meet requirements for operating from USN Wasp-class amphibious assault ships, as well as some UK specifications for ski jump launches. Wasp-class flight decks and spaces are not dissimilar to those on the LHDs, although they do not have the benefit of a ski-jump.
- The second is that the LHD class on which the Canberra-class has been based has also been designed with F-35B in mind. The original Spanish Juan Carlos I design was required from the outset to embark the F-35B, and detailed technical information was made available from the US to Spain to assist in this process. All these requirements were retained in the two Canberra-class LHDs.

So, looking at F-35B launch and recovery, the LHD flight deck would allow short take-off (STO) launches at required mission weights without the ski-jump. With the ski jump – already factory-fitted – safer and more effective (higher weight) launches will be possible. We are looking at something in the order of 1,500kg of extra payload with no penalty except a safer take-off. Remember that the aircraft is specifically required to be able to launch from ski-jumps.

For landings, the F-35B's flight control system has been carefully designed to allow safe and accurate recovery to small deck areas with low pilot workload in all conditions. The nose wheel steering and engine controls also support aircraft movement on small or congested flight decks.

Summary: the operating interface presents low risk. The ski-jump on the Canberra-class offers significant operational advantages over USN amphibious assault ship designs and would mitigate the F-35B's differential in performance compared with the F-35A.

WITH THE SKI JUMP – ALREADY FACTORY-FITTED – SAFER AND MORE EFFECTIVE (HIGHER WEIGHT) LAUNCHES WILL BE POSSIBLE. WE ARE LOOKING AT SOMETHING IN THE ORDER OF 1,500KG OF EXTRA PAYLOAD WITH NO PENALTY EXCEPT A SAFER TAKE-OFF

ABOVE: An F-35B taking off from the amphibious assault ship USS Wasp in August 2013. The ski-jump inherent in the Canberra-class LHD design allows for higher maximum take-off weights and therefore higher payload capacity for weapons and fuel. It is a design advantage not enjoyed by flat-tops such as the Wasp-class. *Images: USN*

The Environmental Interface

The F-35B design was sized by the requirement to use the Wasp-class flight deck, elevators and hangars. These are small spaces. It drove the wingspan and length of the aircraft, landing gear geometry and other aspects. As we already know, the RAN's LHD source design accepts the F-35B's weight and size. The elevators, for instance, are sized to 27 tonnes – very near the aircraft's maximum possible weight. So the aircraft will fit on board and can be moved between decks.

But it is F-35B jet blast that has become a contentious issue, so let's address that. Since the advent of maritime jet aircraft, handling jet blast in the confined space of a ship has been a major issue. USN carriers carry large and complex jet blast deflectors for launching, and deck heating on launch was a major issue for UK carriers throughout the 1960s and 1970s with the F-4 Phantom. The first generation of

An F-35B hovers over an area of flight deck coated with the new Thermion heat-resistant deck coating during trials on USS Wasp in August 2013.

seagoing STOVL aircraft – the Harrier family – presented far less aggressive jet exhausts, but even they presented challenges of flight deck heating and erosion of the deck coatings.

The much higher landing weight and thrust power of the STOVL F-35B therefore presented a real challenge in achieving the required ability to operate from a wide variety of surfaces and environments, including ship decks. As a result, the F-35 JSF programme included a massive effort to model, replicate and understand the aircraft's jet efflux blast, temperature and noise, and its effect on various surfaces. This involved full and part scale rig testing, as well as testing with the actual aircraft. The information from these has informed existing efforts to develop better flight deck coatings and noise protection measures. It should also be understood that the way F-35B's powered lift system works means that the main engine exhaust is operating at approximately half full power in 'powered lift' mode. This reduces the scale of the potential problem.

While the detailed results of this work are not and cannot be publicly released, a few important basic statements can be made.

Firstly, the F-35B will not melt the LHD's flight deck. It is possible that repeated landings on one spot could degrade existing flight deck coatings. However, this issue can be managed by a combination of managing landings to reduce thermal stress on a single area, or by adoption of improved coatings now arriving on the scene. The US Marine Corps is already looking at a 'creeping' landing technique, which could be used on board, as well as the new Thermion non-skid deck coating system which has characteristics aimed primarily at dealing with the prolonged direct exhaust blasts of the F-35B and V-22 Osprey tilt-rotor.

Comprised of bonded ceramic and aluminium, Thermion was trialled by the RN as long ago as 2006, and trialled successfully on USS Wasp, first in October 2011 and then again in August 2013. Thermion is a candidate for being the new standard deck coating on both USN and RN ships due to its high heat resistance properties, improved skid protection and cheaper coat over a 10 year life cycle.

Secondly, the F-35B's blast can be managed. It's quite possible that some items of deck equipment currently located around the LHD flight deck may need relocation or shielding, but this is a normal part of bringing a new aircraft to a flight deck; initial Sea Harrier testing on the Royal Navy's Invincible-class ships led to a number of detailed changes. Sensationalist reports that modifications to the USN Wasp-class ships show 'severe problems' or 'failures' of the F-35B are simply wrong. Remember, putting aircraft on ships isn't easy.

One area that will require some attention is noise. There is little that can be done to reduce the noise of a jet engine, and the safety regulations for exposure to noise are becoming ever more demanding. The key area of concern for F-35 noise is actually on the F-35C variant, for deck launching, and a series of programmes are under way to develop improved aural protection systems for USN personnel. These are already entering service, and the new equipment will be read across to the F-35B.

Summary: the environmental interfaces with an F-35B/LHD combination present challenges, but they are a routine, known and manageable aspect of naval fixed-wing aviation.

The Information Interface

This area has received less attention than the rest, and that is a pity, as it is quite possibly the most important and most challenging aspect of any F-35B/LHD marriage.

The F-35B has exactly the same exceptionally advanced packages of active and passive sensors, communications links, onboard computing and weapons systems as the F-35A and C models. It represents a massive leap forward in generating and using tactical information to achieve its mission, particularly in its ability to integrate with modern military data networks. This means that F-35B mission planning and post-mission analysis will require information technology (IT) systems far beyond anything currently fielded by the ADF. To its credit, the ADF has realised this, and Plan Jericho, which aims to accelerate the integration of warfighting data networks, is a farsighted and well-aimed initiative led by Chief of Air Force Air Marshal Geoff Brown.

This poses a challenge for any deployed F-35B formation, and integrating the required mission planning and mission support suites – which will operate at a very high level of security – with any forward base will be a challenge. Fortunately, modern warships already possess capable communications and computing backbones, but the challenges of integrating the F-35B's IT suite should not be underestimated. This would also need to include the Autonomic Logistics Information System (ALIS) which is required to manage the F-35B's support systems.

Summary: the information interface is probably the most challenging area of F-35B/LHD integration, and the most important for effective use of the capability at sea.

The Support Interface

When military aircraft go to sea, the support arrangements they use are very different to those routinely deployed on land bases. The constraints of space for both equipment and personnel, and the totally different ways in which aircraft are prepared, armed and repaired on board a ship must be reflected in the design of both ship and aircraft.

Fortunately, the F-35B's requirements for support systems were explicitly tailored to reflect the very restricted spaces available in the Wasp-class. Interestingly, the tightest constraint on what was called the logistics footprint was applied by the UK. This drove a number of hard decisions on the design and operation of key aircraft and ground support systems. This included key dimensions such as height requirements for maintenance and refuelling system design.

LHD design changes to accommodate the F-35B would be restricted to any specialist support spaces, and probably to weapons storage and preparation spaces. There are lessons to be learned here from the UK, who took on the challenge of putting the maintenance intensive Sea Harrier on board the very small Invincible-class ships. Some shuffling of spaces was required, but no major changes to structure or layout. As ever when aircraft go to sea, there will be challenges. But a healthy measure of ingenuity and adaptability from service personnel is as important as the design solutions offered by industry.

It's also important to note that the F-35B's avionics suite and many other critical components are common with the F-35A – this should help ensure that spares and repair infrastructure beyond the ship operates at a highly efficient level.

Summary: assertions that the F-35B could not be supported on the LHD should be treated with extreme caution. Operating the F-35B should certainly be supportable on the LHD without major ship changes.

Designed from the outset to operate from mixed flight decks and onboard the tight confines of amphibious assault ships, the window for Australia to decide whether or not the F-35B capability is now well and truly open.

The Personnel Equation

Another issue raised by those who seek to dismiss the possibility of F-35B/LHD operations is that of personnel numbers, and the problems of accommodating them on board.

Firstly, there is never a direct correlation between the aircraft design and the numbers of personnel used to support it. Other factors, such as required flying rates affect the sums, but less appreciated factors such as the systems used for maintenance and personnel trade structures can significantly affect deployed numbers. Moreover, when looking at embarked operations, the iron law of numbers of beds available often limits the decisions on numbers.

Generally, aircraft units designed to operate at sea use less personnel than equivalent units based on land. It has to be stressed that this does not mean that land-based units are inefficient – it's more that staffs planning embarked aviation have an in-built culture of restricting numbers at the outset. And there should be some margin – the LHDs are large ships, and should have a number of spare bed spaces available for embarkation of visiting units and support personnel. It would be very surprising if they were already completely full.

In any case, a constant experience of warships is that the number of personnel on board increases with the years in service. Again, the UK's experience may be relevant. The Invincible-class saw a rapid increase in total numbers of personnel embarked from under 800 to well over 1,200. It wasn't easy, but they coped well.

What should be obvious is the importance of developing the personnel aspects of the challenge – successful embarked aviation depends on committed, trained and experienced personnel who can handle the challenges of delivering combat air power from confined, moving spaces a long way from home.

Summary: F-35B support personnel numbers should not be a deciding factor in whether to embark the aircraft on the LHD.

Conclusion

This brief has attempted to set out some of the technical facts surrounding the issues of F-35B integration on the Canberra-class LHDs. Hopefully, it will serve to inform an important debate, as the ADF and Government put the finishing touches to the 2015 Defence White Paper.

A final thought. The subject of maritime aviation generates emotive discussions, often around the ownership and control of assets, as well as theories of 'air power' and its application from various bases and whether Australia should or should not be in the aircraft carrier game. It would be unfortunate if the F-35B/LHD debate focussed on these aspects and ignored the opportunity the ADF has to develop a highly flexible and effective capability to complement land-based aviation.

It is not often appreciated that maritime aviation has been used operationally in almost every year since World War Two. Every single aircraft shot down by UK armed forces since that conflict fell to an aircraft operating from a ship. Today, US naval aircraft are delivering a significant proportion of the sorties against IS forces in Iraq and Syria.

This is a time for cool heads, facts and experience. The White Paper's deliberations on this issue would benefit massively from an expert panel of STOVL maritime aviators. Fortunately, Australia has plenty of these rare assets available. They should be called up now. **DTR**

Steve George served as an Air Engineer Officer (AEO) in the Royal Navy for 28 years, achieving the rank of Commander. His service career included work with both rotary and fixed-wing aircraft, as well as specialist appointments in weapons procurement and international collaboration with the US. He served on HMS Invincible during the Falklands War of 1982, and subsequently held a range of appointments associated with Harrier operations at sea.

He left the Royal Navy in 2002 and joined BAE Systems as a specialist ship/aircraft integration engineer on the F-35 JSF programme, based first at Lockheed Martin in Fort Worth, Texas, and then in the UK.

*He left BAE Systems in 2007 to start his own aerospace consulting company, Wisma Consulting Ltd **(wismageorge@me.com)**.*