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**DEFENCE RESEARCH PAPER**

**By**

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***Single mission aircraft or multi-mission capabilities: how might the UK look to deliver its next generation of ISTAR capability?***

Wg Cdr R I Henderson-Begg

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## **Abstract**

*Despite on-going financial pressure, the UK will shortly need to recapitalise its strategic ISTAR aircraft. The 2010 SDSR removed the UK's maritime patrol capability while the majority of the UK's other strategic ISTAR aircraft are reaching the end of their operational lives. This paper demonstrates that multi-mission aircraft offer real benefits in terms of increased operational effectiveness, decreased operating costs and reductions in support requirements, and that current technologies and design tools allow production of aircraft that offer optimised performance across a number of roles. By using a proven commercial design as the basis for a multi-mission ISTAR aircraft, the UK has an opportunity to increase and improve provision of ISTAR capabilities, whilst also delivering significant operational and cost efficiencies.*

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## Introduction

The age of the single function aircraft, an aircraft designed to excel in a single mission appears to be over. Air forces across the globe are increasingly pursuing multi-mission solutions to capability requirements, and yet the UK seems to be continuing with an alternative strategy; pursuing mission specific aircraft solutions such as the Sentinel R1 and the Rivet Joint. Capability procurement has historically followed one of two approaches; designing bespoke single mission aircraft, or adapting existing civilian aircraft to generate military capabilities. Procurement of tactical fighter and bomber aircraft has generally followed the first approach; procurement of strategic aircraft such as Air Transport (AT), Air-to-Air Refuelling (AAR) and Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) aircraft has normally followed the second. Incorporating multi-mission capability has historically been achieved through a primary mission – secondary mission approach: designing aircraft for a specific mission and accepting that performance in any (originally envisaged or subsequently added) secondary mission will be sub-optimal. Thus, the Nimrod used a pioneering civilian design to deliver a Maritime Reconnaissance (MR) capability and was subsequently re-engineered (more or less successfully) as an Electronic Intelligence (ELINT) and an Airborne Early Warning (AEW) platform. These capability procurement philosophies remained valid until the end of the Cold War, as the clear, potent Soviet threat justified high levels of defence spending and retention of large fleets of mission-specific aircraft. However, the current lack of a clear threat to national security and consistent downward pressure on defence spending now makes this position unsustainable. When even the United States Air Force (USAF) is forced to accept that it can't afford to maintain fleets of specialised aircraft, it is clear that a paradigm shift has occurred.<sup>1</sup> Fortunately, this paradigm shift has been accompanied by another; a step change in technology. Advances in fields such as near real-time control for remotely-piloted air systems (RPAS), multi-function radars and Integrated Modular Avionics (IMA) have fundamentally changed concepts of capability provision. In particular, IMA delivers the potential of aircraft designed

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<sup>1</sup> Majumdar, D. "USAF turning to flexible multirole aircraft," *Defence News* 2 Feb 2012, <http://www.defensenews.com> (accessed 14 Mar 2013).

around a common set of mission profile and hardware requirements, with multi-mission capability being delivered through adaptable, re-configurable software. Moreover, new sizing methodologies allow multi-mission aircraft to be designed according to critical mission-specific characteristics without jeopardising capability in other missions.

This paper argues that adopting a multi-mission approach to the procurement of ISTAR aircraft would enable the RAF to increase its operational ISTAR capabilities whilst delivering savings in procurement and life-cycle costs, and reductions in fleet size and support structures. In order to provide a baseline fleet against which to compare alternative procurement strategies, and measure any operational or cost efficiencies, the paper uses the UK's current fleet of ISTAR aircraft, with the addition of the P-8A Poseidon as an example of a current Maritime Patrol Aircraft (MPA). The paper starts by discussing the range of literature available on the subject to demonstrate that, while it has been intermittently discussed for a number of decades, multi-mission approaches to strategic aircraft procurement have only been seriously discussed over the last decade, and to highlight the lack of common understanding of definitions between different sectors of the defence community, before suggesting a potential definition of multi-mission capability. The section also examines the UK's approach to multi-mission capability since World War II (WWII) in order to try and identify reasons behind the UK's failure to deliver a successful multi-mission procurement programme.

In order to assess whether the UK would benefit from adopting a multi-mission approach to ISTAR capability provision, the paper explores four questions that the author believes are central to the discussion. The critical question is whether multi-mission aircraft offer practical advantages over single-mission aircraft in terms of capability procurement and through life support. This question will be addressed through analysis of a further two questions: whether one aircraft can realistically cover a number of roles; and whether the UK would benefit most from incorporating a defined set of capabilities onto one airframe, or onto a number of separate aircraft types. The final question addressed is whether such a multi-mission aircraft could contribute to overall defence capabilities in additional or novel ways. Within the examination of these questions, the paper will address

issues such as required aircraft size and the potential to use different crewing strategies to ensure optimum capability provision over all assigned missions.

In 1994, Sqn Ldr A M Bray argued that replacing the UK's strategic AT and AAR fleet with a fleet of multi-role tanker aircraft would satisfy the UK's requirements and deliver a £2.3 billion saving over a 20 year period.<sup>2</sup> More recently the UK has selected the Airbus A330 Multi-role Tanker Aircraft (MRTA) to provide a fleet of fourteen AAR, passenger and freight transport and Medevac aircraft.<sup>3</sup> Therefore, in an attempt to avoid re-covering ground and add to the wider debate, this paper will focus on ISTAR roles. Consequently, for the purpose of this analysis, the second question becomes whether a single aircraft can realistically cover a number of ISTAR roles. Addressing this question will involve a discussion of which ISTAR roles might be incorporated onto a single platform, if and how the different capabilities could be incorporated into a single platform, and the implications this might have for the host of support activities required for through-life capability delivery. The third question becomes whether the UK should consider combining its ISTAR capabilities within one airframe or alternatively incorporating ISTAR capabilities onto a wide range of other aircraft, while the fourth question becomes whether a fleet of multi-mission ISTAR aircraft (MMIA) could augment or complement capabilities currently delivered by other RAF platforms.

During discussion of the four central questions outlined above, the paper also addresses the two most obvious arguments against a multi-mission approach to capability provision, namely that 'putting all your eggs in one basket' leaves air forces vulnerable to a complete loss of capability in a number of missions if the baseline aircraft is grounded for any reason, and the procurement cost of bespoke multi-mission aircraft. The paper argues that the contemporary approach to risk management and aircraft design ensures that adopting a proven civilian aircraft design as the basis for a MMIA would reduce the risk of fleet-grounding incidents to the lowest practical level and

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<sup>2</sup> Bray, A. "Strategic AT and AAR for the UK – An alternative approach" (Brooke-Popham Essay, RAF Staff College, 1994), 16.

<sup>3</sup> Securing Britain in an age of uncertainty: the Strategic Defence and Security Review (SDSR) (London: HMSO, 2010), 2.A.10.

demonstrates that using a proven commercial design and commercial production lines generates the potential to deliver savings in procurement costs.

The paper does not make concrete procurement recommendations, as these would require an in-depth investigation beyond the scope or classification possible here, but to stimulate debate within the UK defence community over the utility of technological advances such as multi-mission radars and IMA in delivering cost-effective, easily-updated, robust capabilities and encourage consideration of novel approaches to provision of defence capabilities. Moreover, while the paper uses current examples of multi-mission aircraft such as the P-8A Poseidon and the A330 MRTA, this does not infer any suggestion that these aircraft provide optimum solutions for a UK MMIA.

## **Context**

The discussion within this paper sits within the context of the on-going debate on the nature, and provision, of ISTAR capability. Consequently, it is useful to start with a brief overview of the debate's development and discussion of the merits of the positions taken. The literature available on the subject is split into two main areas; a debate over the utility of and the practicality of developing credible multi-mission capabilities, and a supporting discussion of developments in key areas such as avionics architectures, radar technology and design methodologies. In addition, defence periodicals including *Jane's Defence Weekly*<sup>4</sup> and *Naval Forces*,<sup>5</sup> have given recurring coverage to the subject over the last 2 decades, focussing on the benefits of multi-role capabilities for both tactical and strategic aircraft. While these articles serve mainly to record the debate, rather than to further it, they illustrate the fact that financial pressures are a key factor in driving the development of multi-mission capabilities.<sup>6</sup>

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<sup>4</sup> Starr, B et al. "Multi-role is key to smaller air wings," *Jane's Defence Weekly*, 14 no 3 (Apr 1993), 29 to 32.

<sup>5</sup> Anatti, M. "Maritime multi-mission aircraft: Solutions for ASW maritime patrol, ASuW surface surveillance or constabulary roles," *Naval Forces* 31, Issue 3 (2010), 72 to 77.

<sup>6</sup> Majumdar, "USAF turning to flexible multirole aircraft."

A 1994 Brooke-Popham essay argued that a small fleet of new-build, dual-role Strategic AT and AAR aircraft could satisfy the UK's wartime AAR requirement and peacetime strategic AT and AAR requirements, while also delivering a £2.3 billion saving over a 20 year period.<sup>7</sup> The RAF has recently adopted an almost identical strategy, replacing 33 aging Tristar and VC10 aircraft with a fleet of fourteen MRTA, demonstrating its acceptance of the argument for using multi-role aircraft as a means of providing essential capabilities in a cost-effective manner and establishing a clear precedent. The debate over the financial benefits of multi-mission capabilities was continued in a 2012 paper that proposed replacing the USAF's aging fleet<sup>8</sup> of 73 Boeing 707-based AWACS, Rivet Joint and JSTARS aircraft with 60 Boeing 737-based aircraft, using proven technology to deliver the missions currently carried out by those aircraft.<sup>9</sup> Basing the aircraft on the B737 would enable the US to increase mission availability, mission effectiveness and fuel efficiency, gain access to a global support infrastructure, decrease fleet size and save 4000 maintenance posts, without any loss of capability. This would deliver a \$100 billion saving over the fleet's lifetime and could be implemented within current projected costs.<sup>10</sup>

At the start of the last decade the USAF investigated replacing its aging Command and Control, Intelligence, Surveillance and Reconnaissance (C2ISR) aircraft with a single fleet of multi-mission aircraft able to carry out some or all of the functions of the existing fleets. The E-10 Multi-sensor Command and Control Aircraft was intended to become the hub of a system of systems involving satellites, manned and unmanned ISR and fighter aircraft, and ground systems.<sup>11</sup> Prior to the programme's eventual cancellation,<sup>12</sup> three Air Force Institute of Technology (AFIT) graduate students completed technical studies into specific design factors, based on the two approaches believed to be under consideration; combining all missions within one airframe, and combining active and passive surveillance functions within two separate variants based on the Boeing 767-

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<sup>7</sup> Bray, Strategic AT and AAR for the UK, 16.

<sup>8</sup> The USAF's AWACS aircraft average 35 years of service, the JSTARS average 45 years and the C-135 fleets average 49 years.

<sup>9</sup> Thompson, Modernising the Air Force's Electronic Aircraft Fleet, 7.

<sup>10</sup> Ibid, 6 to 8.

<sup>11</sup> Kahraman, A. "Multi-mission Aircraft Design Study: Payload" (AFIT, 2003), 1-1 to 1-2.

<sup>12</sup> Thompson, L. Modernising the Air Force's Electronic Aircraft Fleet: How to save \$100 Billion (Arlington, VA: Lexington Institute, 2010), 5: <http://www.lexingtoninstitute.org> (accessed 27 Apr 2013).

400 ER aircraft.<sup>13</sup> The theses concluded that all proposed configurations suffered from weight and electrical power restrictions<sup>14</sup> and that systems interference prevented combining active and passive surveillance functions within one aircraft.<sup>15</sup> A major assumption was that one aircraft would concurrently carry out all the active and/or passive surveillance functions provided by the legacy C2ISR fleets.<sup>16</sup> As this would require significantly more power than that required by a multi-mission aircraft carrying out a single mission at any one time, this author does not consider that the conclusions relate directly to the concept explored within this paper. In addition, as the theses do not contain any discussion of integrated avionics, it seems that the authors envisaged aircraft equipped with multiple function-specific sets of components. Using components designed to carry out multiple functions would significantly decrease aircraft weight and power requirements and improve the concept's feasibility.

Also in 2003, the John Hopkins University Applied Physics Laboratory (JHAPL) produced a volume of the JHAPL Technical Digest devoted to Maritime Patrol Aviation. The digest contained a number of articles analysing various factors affecting the on-going discussion over the introduction of a multi-mission maritime aircraft (MMA) designed to address US Sea Power 21 requirements for Sea Strike, Sea Shield, Sea Basing and FORCEnet (interoperable networks) capabilities.<sup>17</sup> As well as providing improved ASW and ASuW capabilities, the MMA would deliver a C4ISR capability through the integration of its systems, while the aircraft's flexible data architecture would enhance its surveillance capability through integration with the Broad Area Maritime Surveillance (BAMS) unmanned aerial vehicle (UAV), and would provide growth potential through the use of 'plug and play' technologies.<sup>18</sup> The MMA project was expected to deliver increased capability while reducing platform numbers, long-term manpower and operating costs, and enabling use of commercial

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<sup>13</sup> Kahraman, Multi-mission Aircraft Design Study: Payload, 2-2 to 2-3.

<sup>14</sup> *Ibid.*, 5-1.

<sup>15</sup> Davis, J. "Multi-mission Aircraft Design Study: Electromagnetic Compatibility" (AFIT, 2003), 62.

<sup>16</sup> *Ibid.*, 63.

<sup>17</sup> Brooks, R. "The MMA and Maritime Patrol and Reconnaissance Force Transformation," *JHAPL Technical Digest 24, no 3* (2003), 239.

<sup>18</sup> Brooks, The MMA and Maritime Patrol and Reconnaissance Force Transformation, 239-240.

logistics support structures.<sup>19</sup> The MMA programme culminated in the Boeing 737-based P-8A Poseidon, the replacement for the US Navy's (USN's) P-3 Orion aircraft. If Boeing's current attempts to market P-8 variants as candidates for the USAF's EP-X and JSTARS replacement programmes are successful, the P-8 will become a single aircraft solution for a number of US military requirements.

Turning to supporting technologies, a 2007 Massachusetts Institute of Technology (MIT) paper proposed using a multi-mission phased array radar to enhance US weather and aircraft surveillance capabilities. The proposed system uses multiple transmit/receive channels and a digital phased array, operating at 2.7-2.9 GHz to generate independently-steered beam clusters.<sup>20</sup> Although this study considers a ground-based radar system, it demonstrates that current/emerging technology enables a single radar system to provide multiple capabilities, either sequentially or, as in this case, concurrently.<sup>21</sup> The other relevant technological area, IMA, merits greater explanation and will be discussed in detail later in the paper

A 2001 Georgia Institute of Technology paper (GIT)<sup>22</sup> applied a multi-mission sizing methodology to the design of a US Navy Common Support Aircraft (CSA) proposed as a replacement for four separate single-mission aircraft tasked with AEW, Carrier On-board Delivery (COD), Electronic Surveillance (ES) and ASW/ASuW missions. The study determined that it was possible to identify critical mission-specific design requirements, and thereby to determine parameters enabling design of a multi-mission aircraft capable of optimised performance in each role, and to maximise affordability, defined as a measure of performance compared to relative cost. The study concluded that AEW mission requirements determined CSA size, and that that sizing the aircraft accordingly would deliver excess capability in the other roles.<sup>23</sup> The 2003 JHAPL Technical Digest contained a

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<sup>19</sup> Ibid.,

<sup>20</sup> Weber, E et al. *The next generation multi-mission US surveillance radar network* (Lexington, MA: MIT, 2007), 9

<sup>21</sup> Ibid.,

<sup>22</sup> Mavris, D and Borer N. "Development of a Multi-Mission Sizing Methodology Applied to the Common Support Aircraft," (GIT, 2001).

<sup>23</sup> Ibid., 5.

proposition for a Design Reference Model (DRM) that could also be used to identify design-driving operational characteristics and assess their impact on aircraft design.<sup>24</sup>

The internal UK debate has been reinvigorated following publication of documents such as the latest edition of British Air and Space Power Doctrine<sup>25</sup> and the Future Air and Space Operating Concept (FASOC).<sup>26</sup> The FASOC argues that development of truly multi-role capabilities will drive a transition from role-specific or single-function platforms towards air operations defined, not by platform type, but by effect required,<sup>27</sup> while development of weapons and ISR capabilities will provide aircraft with capabilities outside their design mission or role.<sup>28</sup> Such publications demonstrate that the Ministry of Defence understands the need to develop technology-enabled multi-role capabilities, both to increase combat effectiveness and to ameliorate the effects of continuing resource pressure. The renewed debate is exemplified by two 2011 publications; an Air Power Review article on Combat ISTAR<sup>29</sup> and the Royal United Services Institute (RUSI) Combat ISTAR Report from the 2011 Airpower workshop.<sup>30</sup> Both focus on developing the RAF's ISTAR capabilities through adoption of a platform-agnostic, federated approach whereby all air and space platforms would collect intelligence as part of an overall combat air system operating across all four key air and space power roles.<sup>31</sup> This iteration of the debate and the simplified concept of 'every platform a sensor'<sup>32</sup> demonstrates the increasing centrality of Intelligence and Situational Awareness (ISA) as a key enabler for the other air and space power roles and the renewed interest in ISTAR provision that has resulted.

The available literature demonstrates that debate on the utility and feasibility of a multi-mission approach to capability provision has been infrequent and sparse, although it has intensified as the

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<sup>24</sup> Lilly, T and Russell, B. "The MMA DRM," *JHAPL Technical Digest* 24 no. 3 (2003), 257 to 262.

<sup>25</sup> AP3000, 4<sup>th</sup> Edition (HMSO: London, 2009).

<sup>26</sup> Joint Concept Note 3/13: FASOC (DCDC: Shrivenham, 2012).

<sup>27</sup> FASOC, 3-1.

<sup>28</sup> *Ibid.*, 3-11.

<sup>29</sup> Evans, S. "Combat-ISTAR: A new philosophy on the battle for information in the future operating environment," *Air Power Review* 14, no. 3 (2011).

<sup>30</sup> Quintana, E. "Combat ISTAR Workshop report," *RUSI 2011 Air Power Reports* (Jul 2011), <http://www.rusi.org> (accessed 31 Mar 2013).

<sup>31</sup> Evans, Combat-ISTAR, 5.

<sup>32</sup> *Ibid.*, 7.

current generation of strategic ISTAR aircraft nears the end of its operational life. The intensity of the debate seems proportional to pressure on force sizes, increasing most recently due to the increased economic pressure under which military forces (in particular those in the Western world) are currently operating. This has resulted in a reactive, rather than a constructive, forward-looking debate on how to improve operational effectiveness through considered multi-mission capability procurement. The recent emergence of a number of critical design tools and avionics technologies offers the first realistic opportunity of providing a true multi-mission capability within one airframe, thereby enabling an evolution in capability procurement. These technologies, combined with increased pressure on defence spending and the cancellation of the Nimrod MRA4 programme have served to reinvigorate the debate in the UK.

Due to the paucity of the available literature, it is necessary to further contextualise the debate over the utility of multi-mission aircraft through an examination of the UK's approach to multi-mission capability provision and the current context in which aircraft procurement decisions will be made, in order to better contextualise the debate over the utility of multi-mission aircraft. A brief summary of the Nimrod's development demonstrates the UK's historical approach to multi-mission capability procurement, while analysis of the SDSR provides a contemporary context for the debate.

The Nimrod's origins lay in the government's decision to purchase a number of Comet C2, C4 and R1 aircraft, following a succession of crashes that destroyed the aircraft's commercial success.<sup>33</sup> In 1966, the Nimrod (an MR variant of the Comet) was selected to replace the RAF's Lockheed Neptune and Avro Shackleton MR aircraft<sup>34</sup> and the RAF ordered a total of 46 Nimrod MR1 and three ELINT Nimrod R1 aircraft. Another variant was chosen as the RAF's new AEW aircraft but later cancelled on grounds of size and cost.<sup>35</sup> The MR version incorporated significant improvements, including increased engine and electrical power, a magnetic anomaly detector

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<sup>33</sup> Gunston, B. *Nimrod: The centenarian aircraft* (Stroud: Spellmount, 2009), 58 to 74.

<sup>34</sup> *Ibid.*, 77 to 79.

<sup>35</sup> Gibson, C. *Battle Flight: RAF Air Defence Projects and Weapons since 1945* (Manchester: Hikoki, 2012), 127.

(MAD), the ability to launch sonobouys<sup>36</sup> and an unpressurised under-fuselage weapons bay designed to accommodate almost every conventional weapon in RAF service.<sup>37</sup> From 1979, the MR2 programme delivered further upgrades to mission equipment and installation of under-wing weapons pylons, wing-tip Electronic Support Measure (ESM) pods and an in-flight refuelling probe.<sup>38</sup> Finally, addition of an electro-optical turret, electro-magnetic countermeasure (ECM) pods and a towed radar decoy for Op DESERT STORM gave the MR2 a day/night video surveillance capability and an increased ability to operate over hostile territory.<sup>39</sup>

In 1972 a Nimrod variant fitted with a novel fore-and-aft scanner system of paired pulse-doppler radars was selected to supply the UK's AEW requirements and in March 1977 development and production of eleven Nimrod AEW.3 aircraft was authorised.<sup>40</sup> Development and MOD control issues<sup>41</sup> delayed the aircraft's entry into service and, in 1986 the competition was reopened, placing the Nimrod AEW.3 in direct competition with the already-proven Sentry AWACs aircraft.<sup>42</sup> Given full control of the project, Marconi was able to overcome most of the development problems and demonstrate full satisfaction of the stated requirements; however, the aircraft's tortuous development, adverse publicity and the RAF's obvious preference for the Sentry resulted in the aircraft's cancellation in December 1986.<sup>43</sup> This example demonstrates the piecemeal, reactive approach towards capability acquisition often adopted by the UK, in which aircraft are procured for a single purpose and subsequently modified or adapted in order to provide capability in other roles or missions. While the Nimrod might have provided the RAF with a fleet of three variants filling MR, ELINT and AEW roles, the individual variants would have had little in common with the original aircraft or each other, due to the ad hoc and sequential design process. Technological limitations undoubtedly contributed significantly towards the failure of the two Nimrod AEW variants; however,

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<sup>36</sup> Gunston, *Nimrod*, 89.

<sup>37</sup> *Ibid.*, 82 to 86.

<sup>38</sup> *Ibid.*, 96 to 97.

<sup>39</sup> *Ibid.*, 98.

<sup>40</sup> Gibson, *Battle Flight*, 135.

<sup>41</sup> *Ibid.*, 136.

<sup>42</sup> *Ibid.*, 137.

<sup>43</sup> *Ibid.*

it can be seen that adoption of a coherent design process might well have eliminated many of the development problems encountered.

The 2010 SDSR set out the UK's aspiration to maintain a broad spectrum of defence capabilities able to deter, contain and engage developing threats and with the built-in flexibility to adjust to changing future requirements,<sup>44</sup> proposing investment in programmes that would provide high-quality, balanced, efficient, flexible, adaptable, expeditionary, connected and well-supported military capabilities.<sup>45</sup> The SDSR set out a requirement for maritime ISTAR capabilities based on network-enabled aircraft, submarines and surface vessels,<sup>46</sup> and for strategic airborne surveillance and intelligence platforms to provide broad area coverage as part of Britain's combat ISTAR capability.<sup>47</sup> The decision not to bring the Nimrod MRA4 MPA into service resulted in a requirement for other assets to contribute to the tasks previously allocated to the Nimrod.<sup>48</sup>

The RAF's current strategic ISTAR fleet of fourteen aircraft contains three separate aircraft types: the Boeing 707 (E-3D) and RC-135 (Rivet Joint) and the Bombardier Global Express (Sentinel).<sup>49</sup> Each aircraft is supported by bespoke logistics, training and engineering structures; had the Nimrod MRA4 programme not been cancelled in 2010, it would have added a further 9 aircraft and an additional aircraft type. While the Sentinel is based on a modern commercial design, the E3-D and Rivet Joint airframes are nearing the end of their operational lives – less than ten Boeing 707s remain in commercial service.<sup>50</sup> Consequently, the aircraft suffer from low mission availability rates and are maintenance-intensive and, despite upgrade programmes, their mission equipment becomes ever harder to support. As Thompson states, while increasing sustainment costs will soon make further extending these aircraft's service lives unaffordable, they also present an opportunity for the USAF to replace the aircraft with a more modern airframe, and save money in

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<sup>44</sup> SDSR, 1.5.

<sup>45</sup> *Ibid.*, 2.10 to 2.11.

<sup>46</sup> *Ibid.*, 2.A.4.

<sup>47</sup> *Ibid.*, 2.A.10.

<sup>48</sup> *Ibid.*, 2.A.11.

<sup>49</sup> *Ibid.*, 2.A.10 – 11.

<sup>50</sup> Thompson, *Modernizing the Air Force's Electronic Aircraft Fleet*, 3.

the process.<sup>51</sup> Despite the difference in fleet sizes, the same logic can be applied to the UK's current position; moreover, emergence of technological advances such as IMA offers the potential for using this recapitalisation to recover capabilities lost through the retirement of the Nimrod. While the RAF's Sentry and Rivet Joint aircraft are based on Boeing 707 derivatives, its new fleet of MRTT aircraft are based on Airbus A330-200 airframes.<sup>52</sup> The private finance initiative (PFI) replaces the RAF's Tristar and VC-10 aircraft with a much smaller (fourteen) fleet of more capable, more reliable modern aircraft and demonstrates that major aircraft manufacturers accept the imperative to offer cost-effective multi-mission capabilities in an era of on-going pressure on defence budgets and force sizes.

One issue hindering the debate over the utility and practicality of a multi-mission approach to capability procurement is a lack of common definitions. Terms such as multi-role and multi-mission have different meanings dependent on which nationality, service or sector of the defence community is using them, and are often used interchangeably. Moreover, aircraft manufacturers' attempts to maintain sales in an era of constrained defence spending appear to have led to a significant amount of 'definition creep;' where adding a token capability in one area is marketed as delivering a multi-mission capability. Before addressing the four questions at the core of this paper's discussion it is first necessary to clarify the meaning of terms such as multi-role and multi-mission.

While multi-role is usually used in reference to tactical fast-jet aircraft, it provides a starting point for developing an understanding of the term 'multi-mission.' Unfortunately even this term is poorly defined, despite being common parlance for decades. While, JP 1-02, the Department of Defence Dictionary of Military and Associated Terms<sup>53</sup> fails to mention multi-role aircraft, the Military Dictionary<sup>54</sup> defines them as aircraft that can be used for more than one purpose; i.e. as fighter,

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<sup>51</sup> *Ibid.*, 5.

<sup>52</sup> [http://www.airforce-technology.com/projects/a330\\_200/](http://www.airforce-technology.com/projects/a330_200/) (accessed 7 May 2013).

<sup>53</sup> <http://www.dtic.mil/> (accessed 18 Apr 2013).

<sup>54</sup> <http://www.military-dictionary.org/> (accessed 18 Apr 2013).

attack or reconnaissance aircraft. In this context the Ground Attack, Reconnaissance and Air Defence variants gave the Tornado a multi-role design capability, while the advent of podded capabilities and smart munitions has resulted in the Tornado GR4 variant acquiring a real (if limited) multi-role capability, through its ability to carry stores like the RAPTOR pod, precision-guided munitions and Advanced Short-range Air-to-Air Missiles (ASRAAM).

Designing fighters, bombers or tactical reconnaissance aircraft is a purely military endeavour – they have no civilian use; moreover, with the exception of commercially-successful aircraft such as the Lockheed Martin F-16, they are generally produced in relatively small numbers. Consequently, in order to minimise design and production costs and to maximise commercial opportunities, fighters have long been designed with multi-role capabilities. While the first military aircraft were used for reconnaissance purposes, they were soon armed, both to provide protection from opposing fighter aircraft and to enable them to provide air-to-ground support for Land forces.<sup>55</sup> The most iconic aircraft of World War II, the Spitfire was designed purely as a fighter aircraft,<sup>56</sup> but was established in ground attack, reconnaissance and maritime attack roles by the end of the war.<sup>57</sup>

In order to use the term multi-role to generate a better understanding of the meaning of multi-mission, it is necessary to understand the difference between roles and missions. Current RAF doctrine<sup>58</sup> defines four fundamental air and space power roles: Control of the Air and Space; Air Mobility; Intelligence and Situational Awareness (ISA); and Attack. Each role consists of a number of missions, with ISA consisting of Intelligence, Surveillance, Reconnaissance and Target Acquisition functions.<sup>59</sup> Multi-role aircraft must have a credible capability to perform missions within two or more roles, while multi-mission aircraft must have a credible capability in multiple missions within one role. Using this logic, the Typhoon FGR4 is a true multi-role aircraft with

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<sup>55</sup> AP3003: A brief history of the RAF (London: HMSO, 2004), 9.

<sup>56</sup> Delve, K. The story of the Spitfire (Greenhill: London, 2007), 19.

<sup>57</sup> Ibid, 177 to 209.

<sup>58</sup> AP3000, 37.

<sup>59</sup> AP3002 (Second edition): Air and space warfare (London: HMSO, 2009), 9-3 to 9-5.

capability in Control of the Air, ISA and Attack roles, while the C-17 is a single role aircraft with capability in a number of Air Mobility missions, including Air Lift and Aeromedical Evacuation. Extending this logic further, it can be seen that there are no single-mission aircraft in current RAF service: its transport aircraft are capable of freight, passenger and Medical Evacuation (MEDEVAC) transport missions; its AAR aircraft are also passenger and MEDEVAC capable; the AWACS is capable of AEW and Air Battle Management missions; and the Tornado is capable of a number of missions within the Attack and ISA roles. Even the Rivet Joint is capable of a number of ISA missions.

The inconsistent use of multi-role and multi-mission is demonstrated by examples such as the Hindustan Aeronautics and Irkut Multi-role Transport Aircraft (MTA), designed to carry 18 to 20 tonnes of freight or 140 personnel. If the aircraft is commercially successful, the company plans to field variants capable of fulfilling AAR, AWACS, MP, Search and Rescue (SAR), Communications Relay and Electronic Jamming functions.<sup>60</sup> The MTA would only qualify as a multi-mission aircraft according to the definitions derived above; however, the addition of AAR, AWACS, MP and Electronic Warfare (EW) variants would transform it into a multi-role aircraft. The DAHER-SOCATA TBM 700 represents another example of manufacturers claiming a multi-role capability for existing aircraft. The aircraft gains its 'multi-role' capability through the addition of a fully retractable sensor turret and removable operator workstation, which allows the aircraft to perform observation, detection and data-gathering missions in addition to passenger transport.<sup>61</sup> While installing a sensor turret and operator console does not deliver significant ISR capability, in the same way that installing an EO sensor did not give the Nimrod MR2 a significant overland surveillance capability, it allows operators to develop a system of systems approach to capability provision and manufacturers to claim multi-role or multi-mission capabilities for their products, thereby (potentially) gaining an advantage in a competitive market.

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<sup>60</sup> "MTA: HAL and Irkut's Joint Tactical Transport Project," *Defence Industry Daily*, 20 Dec 2012, <http://www.defenseindustrydaily.com> (accessed 12 Mar 2013).

<sup>61</sup> Australian Aviation, "TBM Multi-Mission Aircraft certified." <http://australianaviation.com> (accessed 14 Mar 2013).

The C-130 Hercules demonstrates a coherent attempt to incorporate true multi-mission capabilities onto an existing aircraft. In 2011, Lockheed Martin presented the C-130 to the Hercules Operator's Conference under the tag line "Buy a C-130... get an Air Force," proposing capabilities in twelve distinct missions including armed ISR, SIGINT, AAR, personnel and freight transport, and MP. The concept incorporated fuselage-mounted sensors, a multi-mode radar, comprehensive EW and communications systems, external weapons stations, and operator workstations using a common integrated graphical operator display, mounted on removable pallets and wired to common 'quick disconnect' panels. The system provides capability in ISA, Air Mobility and Attack missions, giving the aircraft a true multi-role capability, while the 'roll-on/roll-off' design enhances flexibility, allowing quick conversion from one mission to another and delivering cost-effective solutions for C-130 operators wishing to develop MP or ISR capabilities.<sup>62</sup>

The terms multi-role and multi-mission are poorly defined and used by all sectors of the defence community but, when considered carefully, can be seen as complementary terms. Aircraft roles, whether defined in terms of the RAF's key air and space roles or otherwise, consist of a number of missions. Multi-mission aircraft are capable of fulfilling multiple missions within one role; multi-role aircraft have mission capabilities within separate roles. Furthermore, if all aircraft are capable of carrying out multiple missions, it can be argued that the term multi-mission is redundant; the only differentiation required is whether aircraft provide capability in a single or multiple roles.

Consequently, the argument for the utility of multi-mission aircraft is already proven and the central argument within this paper is actually about whether incorporation of currently available, proven technology and design philosophies would enable the RAF to consolidate and reduce the size of its ISTAR fleet whilst increasing its operational capability in ISA missions.

### **Integrated Modular Avionics (IMA)**

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<sup>62</sup> Bell, M. "Roll on-Roll off Maritime Aircraft," presentation to the 2011 HOC (accessed 12 Mar 2013).

A critical area in which technological advances support the potential for multi-mission capabilities is that of avionics architectures – the processing modules and communications busses that support avionics applications such as mission systems and flight controls.<sup>63</sup> Technological advances have allowed avionics architectures to develop from federated to modular systems, resulting in increased performance and reliability, as well as decreasing avionics weight and simplifying development and integration of avionics hardware and software. Federated systems, such as those used on the Tornado GR4, use Line-Replaceable Units (LRUs) connected by data buses. Each LRU is a standalone system, performing a single function and controlled by a dedicated processor.<sup>64</sup> The advantage of a federated system, such as that illustrated below, is that individual failures do not affect other modules; however, disadvantages include the weight penalty derived from the number of separate processors required, the limited resource-sharing capability and interoperability arising from the system's compartmentalised nature and differences in operating software, and the difficulty in integrating the separate systems, both at initial design stages and when components are updated.<sup>65</sup> A federated system is shown at Figure 1 below.

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<sup>63</sup> Bieber, P et al. "New challenges for future avionics," *Aerospace Lab Journal Issue 4* (May 2012), 1.

<sup>64</sup> Tagawa, G. An overview of the IMA concept, 1. <http://www.sbmacc.org> (accessed 19 Apr 2013).

<sup>65</sup> Bieber et al, *New Challenges for Future Avionics*, 1.

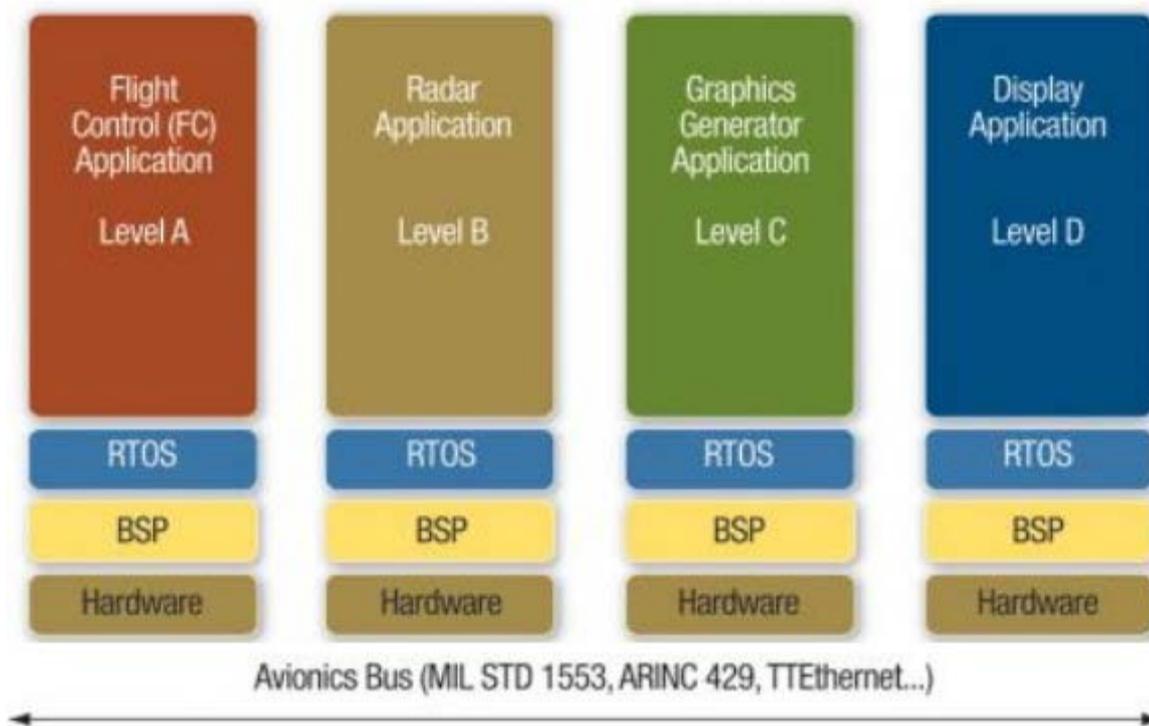


Figure 1. A federated avionics system.<sup>66</sup>

Federated systems reached their limit of development when weight and space requirements began to exceed aircraft capacity<sup>67</sup> and have been replaced by IMA, avionics architectures based on two complementary principles; integrating multiple avionics software applications (often with different safety criticality levels) within a single processor, and using partitions to guarantee performance of individual applications by preventing interaction and allocating computing capacity and memory to each application.<sup>68</sup> The Boeing 777 Aircraft Information Management System provides an early example of an IMA system, combining several functions including primary flight and navigation displays, engine monitoring, communications and navigation into a single, integrated system using duplicated point-to-point data buses augmented by fibre-optic cables.<sup>69</sup> A modern IMA system, such as that used on the Boeing 787 and P-8A Poseidon removes the need for numerous separate processors and LRUs by replacing them with fewer centralised processing units using common software and components, connected to each other and to the aircraft's mission hardware via a

<sup>66</sup> Tagawa, An overview of the IMA concept, 1.

<sup>67</sup> Beiber et al, New Challenges for Future Avionics, 2.

<sup>68</sup> Ibid., 3.

<sup>69</sup> Tagawa, An overview of the IMA concept, 1.

common ethernet network. The open architecture and use of common software and operating systems makes development and upgrades simpler and cheaper, while reducing the weight needed for individual components and communications linkages.<sup>70</sup> An example IMA architecture is shown below.

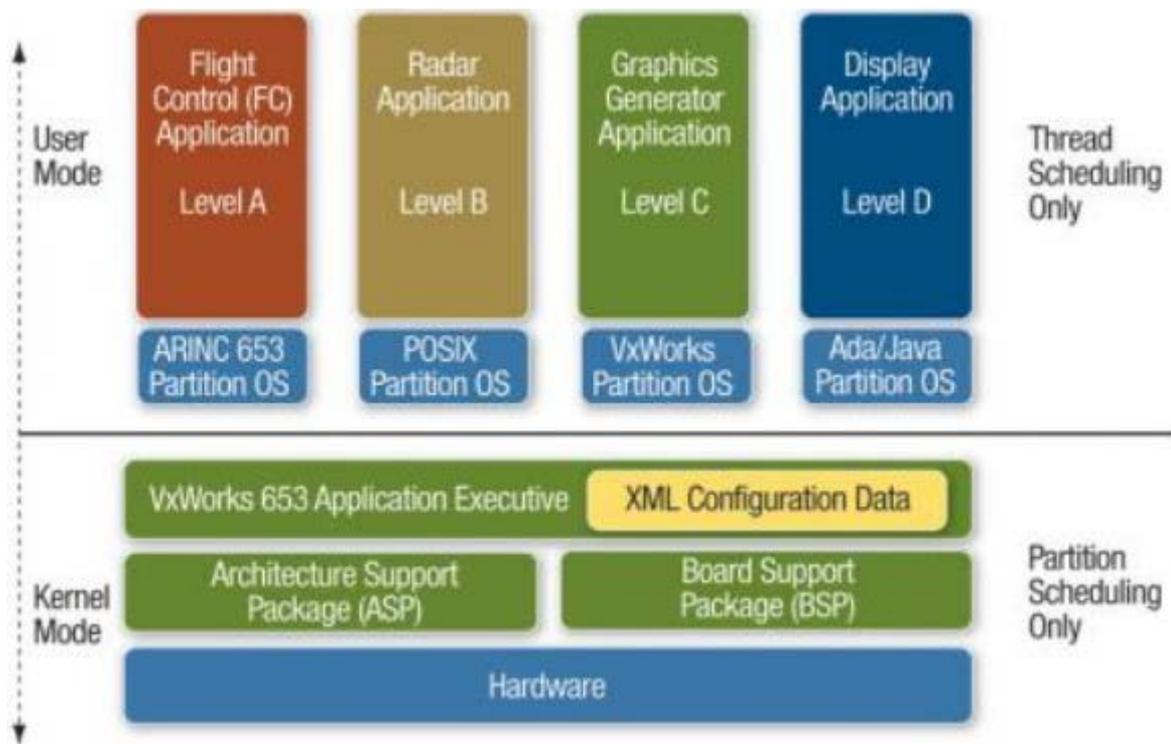


Figure 2. An IMA architecture.<sup>71</sup>

Individual real-time operating systems (RTOS), ‘Board Support Packages’ (BSP) and processor hardware are replaced by a common applications executive (APEX),<sup>72</sup> architecture and board support packages and processing hardware. Partitioned systems work by dividing memory and CPU time in a fixed manner among statically-allocated positions, isolating each sub-system and using an operating system to allocate processor time to each application in a pre-programmed manner.<sup>73</sup> This first generation IMA (IMA-1G) is based on two standards.<sup>74</sup> Aeronautical Radio

<sup>70</sup> Ramsey, J. “Integrated Modular Avionics: less is more,” *Avionics Today*, 1 Feb 2007, <http://www.aviationtoday.com> (accessed 19 Apr 2013).

<sup>71</sup> Takawa, An overview of the IMA concept, 2.

<sup>72</sup> A general purpose interface between the operating system (OS) and the application software.

<sup>73</sup> <http://www.linuxworks.com/products/whitepapers/partition.php> (accessed 27 Mar 2013).

<sup>74</sup> Bieber et al, New challenges for future avionics, 3.

Incorporated (ARINC) 653 is an industry-standard aviation application software interface which defines an APEX providing time and space partitioning (temporal and resource partitioning respectively), thereby supporting safe multi-tasking by allowing multiple applications to share processor and memory space without risk of single application failures propagating throughout the system. ARINC 653 allows manufacturers to ensure that installations are compatible and interchangeable.<sup>75</sup> ARINC 664 defines similar partitioning principles for inter-function communications.<sup>76</sup>

The weight benefits delivered by IMA architectures are clear: replacing multiple dedicated circuitry, computing processors, operating systems and communication links with a common platform and communications architecture has enabled a 50% reduction in the number of A380 processing units compared to previous generations of Airbus aircraft and a saving of 2000 lbs in Boeing 787 weight.<sup>77</sup> The weight reduction delivers increased fuel efficiency, while use of common equipment enables streamlining of logistics holdings.<sup>78</sup> Nonetheless, this is still developing technology and further improvements in system resilience and operational reliability are planned: several companies are looking at ways to reconfigure the architecture to re-allocate functions to safe modules in the event of hardware or software failures while others are investigating the use of multi and many-core processors to reduce component weight while providing the increased computing power required by increasingly complex systems.<sup>79</sup>

IMA have enhanced the operational performance of the latest generation of civil and military aircraft, such as the P-8A Poseidon, Boeing 787<sup>80</sup> and A330<sup>81</sup> over that of their predecessors. While IMA would likely be part of any attempt to design a MMIA, more research is required in order to determine whether re-rolling IMA-equipped aircraft could be achieved simply by changing the

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<sup>75</sup> <http://www.linuxworks.com/solutions/milaero/arinc-653> (accessed 27 Mar 2013).

<sup>76</sup> Bieber et al, New challenges for future avionics, 3.

<sup>77</sup> Ramsey, IMA: less is more, 1.

<sup>78</sup> Bieber et al, New challenges for future avionics, 4.

<sup>79</sup> Ibid., 4 to 5.

<sup>80</sup> [http://www.verocel.com/newsletter/summer\\_2011](http://www.verocel.com/newsletter/summer_2011) (accessed 28 Apr 2013).

<sup>81</sup> Potocki de Montalk, J. "New avionics systems – Airbus A330/A340," in *Digital Avionics Handbook*, ed Spitzer, C (London: CRC, 2000) <http://www.davi.ws/avionics/> (accessed 28 Apr 2013).

controlling software or whether it would require an amount of hardware replacement. The answer to this question would affect how an air force allocated multi-mission aircraft to specific missions and would therefore affect operational efficiency and fatigue rates. Clearly, the ability to quickly and easily re-role aircraft at short notice would enhance the flexibility of a MMIA fleet and also simplify fleet management. That said, even an ability to re-role aircraft by replacing a limited number of components connecting directly to a common communications architecture would deliver a significant increase in operational flexibility over today's fleet of single-mission aircraft, as demonstrated by the C-130 example mentioned earlier.

### **Central questions**

At first glance, the strength of the proposition that aircraft possessing capabilities in multiple missions or roles provide a more cost-effective solution to capability delivery than aircraft providing capability in just one mission seems clear; however, as this approach has not been historically successful or popular, it is necessary to re-examine the proposition, considering the advantages of each approach over the entire life-cycle of the aircraft, from design to retirement. As before, it is useful to start with a consideration of tactical aircraft before applying the same logic to ISTAR aircraft. As single-role tactical aircraft are designed according to role-specific requirements, their performance and capabilities are optimised for that role; multi-role aircraft are either the result of a design process that aims to find the optimal compromise between competing role-specific requirements, or the adaptation of a successful single-role aircraft into another role. In either instance, aircraft performance in one role is compromised by the need to provide capability in another. This point is illustrated by a comparison of the F-22 and the F-35; the F-35 is a multi-role stealth fighter, while the F-22 is a 'purpose-built air-to-air killer par excellence.'<sup>82</sup> The Typhoon provides another example; it is a highly agile fighter aircraft, capable of sustaining high-g manoeuvres at high and low level. However, once air-to-ground munitions such as the Paveway IV Laser Guided Bomb (LGB) are loaded, its ability to use high-g manoeuvres is severely

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<sup>82</sup> Majumdar, "USAF turning to flexible multirole aircraft".

constrained. The conclusion is that attempting to provide a multi-mission capability is likely to result in an aircraft with less capability in any single mission than that a number of aircraft designed to excel in a single mission.

Military aircraft design processes, whether from scratch or through development of a commercial design are long and expensive, requiring significant investment by the aircraft manufacturer and the commissioning air force. The manufacturer's development costs are reflected in the aircraft unit cost; the fewer aircraft bought, the higher this proportion of unit cost becomes. These costs are often referred to as 'sunk costs,' being owed whether or not any aircraft are eventually bought. While this is clearly a significant simplification of a complex contracting process; the point is that development costs decrease as a proportion of unit cost as the number of aircraft produced increases. Consequently, procuring a (relatively) large fleet of multi-mission aircraft should result in lower unit development costs than procurement of multiple small fleets of single mission aircraft. Moreover, as previously discussed, the ability to market aircraft as multi-mission aircraft generates additional sales opportunities for the manufacturer, potentially driving unit costs down further. The tension between defence budgets and production costs is aptly demonstrated by the Nimrod MRA4. The programme began as a £1.6 billion contract for 21 aircraft (a unit cost of £76 million); by the time the programme was cancelled, the RAF was contracted to pay £4.5 billion for nine aircraft, increasing unit cost to £500 million.<sup>83</sup> A government response to questions in the House of Lords on 31 Oct 2010 estimated that total Nimrod MRA4 programme costs stood at £3.9 billion, with £3.4 billion being procurement costs.<sup>84</sup>

All aircraft types entering RAF service are subjected to a lengthy test of operational capability to ensure that they can achieve the range of missions for which they were procured. Adopting a multi-mission approach to capability procurement would reduce the scale and cost of this process, whether a single or multiple variants of a basic aircraft were procured. Selection of a single aircraft

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<sup>83</sup> Brooks, A. "Life after Nimrod," <http://www.defencemanagement.com> (accessed 17 Dec 2012).

<sup>84</sup> Ibid.,

variant would simplify the operational evaluation process to the greatest extent possible; the aircraft's flight performance would need to be confirmed and its operational performance in each mission would need to be established. Procuring multiple variants of a single aircraft would still result in a reduction in the operational evaluation process, although each variant would need to have its flight performance verified, as well as its operational mission performance. The extent of operational evaluation required for each variant would depend on the amount of variation from the central design.

Once in service, multi-mission aircraft continue to offer advantages over single-mission aircraft, due to the reduced requirement for parallel training and support structures. The UK's current ISTAR fleet requires three separate support infrastructures, each comprising a training system, a logistics and administration infrastructure and contracts that guarantee delivery of type-specific spares for each aircraft. All assigned personnel, pilots, mission specialists and engineers, require type-specific training, either through a bespoke Operational Conversion Course (OCU) or through dedicated engineering training and, if posted to another aircraft must re-validate their qualifications on the new aircraft. Procuring a MMIA fleet would enable considerable rationalisation of this training infrastructure considerably. Much of the OCU syllabus would be common, with personnel completing additional mission-specific training as required to prepare them for their front-line specialisation. Engineering training would also be common, with the added advantage that much experience gained on one variant would remain relevant in the event of a posting to another; while certain specialisations would likely be variant-specific, most engineering functions would be common to all variants. This would also aid in the cross-pollination of experience and best practice across the fleet, both for aircrew and for engineers. In particular, the RAF would build up a core of aircrew with operational experience in a number of different ISA missions.

If adoption of a multi-mission approach offers efficiencies in training, it also offers the potential for rationalisation of fleet support requirements. The RAF currently maintains separate support structures for each ISTAR aircraft, resulting in duplication in terms of management structures,

administration and engineering support, and infrastructure. Adoption of a multi-mission approach would, if taken to the extreme, allow engineering support to be consolidated into one organisation, permitting rationalisation of existing engineering infrastructure and of management and administration structures. The likely contractorisation of second line engineering support would enable further service manpower savings. In terms of logistics support, the approach would likely enable the RAF to reduce the number of different logistics contracts currently required to support the ISTAR fleet and to reduce stock holdings due to the use of common components, thereby offering the potential of a second-order effects on logistics support infrastructure and manpower requirements.

Allocation and apportionment are features of fleet management for any aircraft; adding a multi-mission capability would add a further level of complexity. Apportioning aircraft to individual missions would depend on a number of factors, including operational tempo, mission crew availability and the time required to re-role aircraft. Three potential scenarios are envisaged and briefly discussed here. The first scenario assumes individual, role-specific variants developed from a common airframe. In this scenario there is no opportunity to re-role aircraft, so current allocation methods remain valid. The second scenario assumes a single variant being used for all missions, with mission-specific hardware being installed or removed as necessary. In this scenario, it is likely that a number of aircraft would be permanently allocated to each mission, with a further number being used to balance changes in relative mission tasking levels. This would increase operational flexibility and enable better cross-fleet management of factors such as aircraft fatigue and servicing requirements. The third scenario again assumes use of a common variant, but with individual role capabilities being delivered through specific software loads. This scenario would provide the most operational flexibility by maximising the fleet's re-rolling capability and minimising the requirement for aircraft to be permanently configured for one mission.

While this section has demonstrated that adopting a multi-mission approach to capability provision has the potential to deliver significant savings over the platform's lifetime, procurement costs would

undoubtedly be high. A strand of the argument against a multi-mission procurement philosophy contends that purchasing smaller fleets of mission-specific aircraft enables air forces to spread procurement costs over a longer period, thereby smoothing the impact on the overall defence budget. This is, at first glance, a persuasive argument and there is no doubt that adopting a multi-mission procurement philosophy would result in a significant recurring burden on the procurement budget; however, it is possible to demonstrate that savings delivered over the fleet's lifetime outweigh the increased generational procurement costs, and that these costs can be spread over a longer period than is initially apparent. Moreover, the Queen Elizabeth Class aircraft carrier programme provides a contemporary demonstration that the UK accepts the validity of this approach to procurement.

Bray argued that, while replacing the RAF's VC10s and Tristars with a fleet of fourteen MRTT aircraft would raise costs initially, subsequent reductions in operating costs would recoup the purchase costs in less than four years.<sup>85</sup> More recently, Thompson demonstrated that replacing the US's current ISR fleet with new-build 737-based multi-mission aircraft could be accomplished within projected budgets<sup>86</sup> and save an additional \$3 Bn in annual operating costs, generating a total saving of \$100 Bn over the fleet's lifetime.<sup>87</sup> These arguments suggest that replacing the RAF's current fleets of ISTAR aircraft with a fleet of MMIA would result in significant cost savings, freeing up capital for other procurement projects; however, this would need to be confirmed by a thorough examination of the projected costs. As the current pressure on defence spending is unlikely to be relaxed unless a significantly increased threat to national security emerges, an opportunity to reduce the cost of capability procurement – even at the cost of increased initial investment – would be hard to ignore. Moreover, the extended service lives typical of modern commercial aircraft would provide an opportunity for the MOD to take a long-term approach to de-confliction of major defence procurement projects by accurately predicting when each generation of MMIA will require replacement and synchronising this requirement with the projected lifecycles

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<sup>85</sup> Bray, Strategic AT and AAR for the UK, 14.

<sup>86</sup> Thompson, Modernising the Air Force's electronic aircraft fleet, 6.

<sup>87</sup> Ibid.,

of other large defence projects, thereby reducing annual variations in procurement budget requirements.

Selecting a single aircraft to provide multi-mission capability does not dictate simultaneously migrating every capability onto the aircraft on its initial entry into service. While the design process would ensure that the aircraft was optimised for all allocated missions, there are a number of good reasons for transferring capabilities individually, both to the original and to subsequent generations of aircraft. Adopting a staged approach to introduction of each generation of MMIA would spread procurement costs over a longer period, reducing the instantaneous burden on overall defence procurement. It would also allow adoption of a sequential approach to capability validation and operational evaluation, thereby offering an opportunity to identify teething problems while their impact is minimal. An incremental approach also increases the period over which aircrew and engineering personnel are trained on the aircraft, reducing the training bow-wave associated with introducing any new aircraft type and minimising changes in the size of training establishment required. While this approach would increase the number of operational fleets during transitional periods, drawing down one fleet while building its replacement fleet enables capability levels to remain relatively constant and is normal practice for transitions between generations of fast-jet aircraft; structuring the entry into service of a MMIA such that Initial Operating Capability was linked to demonstration of credible capability in one mission, whilst Full Operating Capability was dependent on demonstrating capability in all allocated missions would be a logical strategy.

Analysis of the factors and costs associated with lifetime provision of ISTAR capabilities supports the proposition that adopting a multi-mission approach to provision of ISTAR capability for the UK would offer practical advantages to the UK, enabling reductions in procurement and operating costs, as well as enabling rationalisation of operating and support structures. However, the validity of this conclusion rests on two assumptions that require further analysis and validation: that the use of a single aircraft type can be proved to be both feasible and operationally effective; and that no better solution exists. The first task is to examine the feasibility of incorporating the required

capabilities into a single airframe. The MRTT demonstrates that a single aircraft can indeed cover a number of missions, provided that individual mission requirements can be accommodated within one airframe; however, while the same principles apply, consolidating the RAF's ISTAR capabilities within a single airframe is a significantly more complex proposition. In 2003, Lilly and Russell constructed a DRM for a MMA,<sup>88</sup> enabling them to identify design-driving operational characteristics and assess their impact on design of a MMA.<sup>89</sup> While construction of a DRM is outside the scope of this paper, it is possible to identify some of the mission-specific requirements that will drive MMIA design or selection, and suggest possible solutions that may reduce the requirement for procurement of separate aircraft types. Any decision whether or not to pursue a multi-mission solution to ISTAR provision would require a detailed mission requirement analysis to establish whether a single aircraft variant could be used to fulfil the required range of missions, and thereby deliver optimum operational capability and flexibility, or whether a number of variants based on a single (commercial off-the-shelf or bespoke) airframe would be necessary.

The discussion is best started by identifying the missions which a MMIA might be expected to carry out and by identifying critical aircraft and sortie profile requirements for each mission. While tactical aircraft and UAVs provide tactical ISTAR capabilities, discussion here will be limited to ISTAR missions primarily delivered by the RAF's multi-engine combat support aircraft. The ISTAR triad of Sentry, Sentinel and Rivet Joint aircraft currently provides the UK's current strategic ISTAR capability; the RAF currently has a gap in its ISA capability, caused by the cancellation of the Nimrod MRA4 programme. While other assets have been able to fill part of this gap, none are able to provide the same capability as the MRA4; including MP missions within the missions considered for a MMIA provides a potential opportunity to recover some, or the entire capability gap.

Consequently, the missions to be considered for a multi-mission ISTAR aircraft are: Land, Maritime and Airspace surveillance, target acquisition and reconnaissance; ASW and ASuW; SIGINT and COMINT; and AEW and airborne C2.

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<sup>88</sup> Lilly and Russell, "The MMA Design Reference Mission," 257 to 262.

<sup>89</sup> *Ibid.*, 257.

Each mission has individual operational requirements that will influence the selection or design of candidate MMIA; however, other requirements will be common across the range of missions. For example, every mission will require a core set of avionics capabilities such as comprehensive secure communications and an integrated self-defence suite. These capabilities have been incorporated onto the RAF's current ISTAR fleet in various ways, often incrementally and in response to operational imperatives; however, procuring a MMIA would enable adoption of a single solution to common requirements. At first glance, other requirements such as mission avionics systems and flight profile requirements seem to be mission-specific and having an influence on aircraft design or selection; these requirements require analysis to determine whether they are critical design requirements or whether technological advances such as IMA permit common solutions to individual requirements.

All the missions considered use active or passive sensors to collect electro-magnetic information and while the RAF currently uses a different technological solution for each mission, advances such as those cited by Weber<sup>90</sup> and Mavis and Borer,<sup>91</sup> combined with modern avionics architectures and systems may allow a single system to perform a number of different surveillance functions and thereby provide the potential for a single solution. The utility of these advances is exemplified by the multi-role capability of the Multi-role electronically-scanned array (MESA) radar and the AN/APY-10 radar used in the E-7A and the E-8A respectively; both deliver capabilities that previously required the use of multiple radars. The E-7A Wedgetail AEW&C aircraft, a Boeing 737-based aircraft operated by Australia, Turkey and South Korea, boasts a fixed, electronically-scanned multi-role radar antenna in a dorsally-mounted fairing, enabling it to maintain surveillance of airborne and maritime targets over an area of 400,000 square kilometres at any one time.<sup>92</sup>

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<sup>90</sup> Weber et al, The next generation multi-mission US surveillance radar network.

<sup>91</sup> Mavis and Borer, Development of a multi-mission sizing methodology, 3.

<sup>92</sup> RAAF Wedgetail Specifications, [http://www.airforce.gov.au/Technology/Aircraft/AEWC\\_Wedgetail/](http://www.airforce.gov.au/Technology/Aircraft/AEWC_Wedgetail/) (accessed 29 Apr 2013).

While the E-7A's radar is mounted on a plinth above the aircraft, it is also possible to provide 360° radar coverage through conformally-mounted electronically-scanned radars, as on the P-8A.

Of the missions considered, those allocated to an MPA probably have the greatest potential effect on aircraft design. An MPA requires the capability to detect, identify and track surface and sub-surface targets and, if necessary, prosecute them; without these capabilities, it is merely a cuing device for other aircraft with the required capabilities. Consequently, the Nimrod MRA4 was equipped with a boom-mounted Magnetic Anomaly Detector (MAD), an internal weapons bay and a sonobouy launch system. These aircraft characteristics had a significant effect on the aircraft's design and, if still required, would have a similar impact on the design of a MMIA. The USN has elected to provide its MAD capability through a sonobouy-based system and has not included a MAD boom on the P-8A, while Indian P-8As will incorporate a MAD boom.<sup>93</sup> Although a discussion of the relative capabilities of each system is beyond the scope and classification of this paper, it is sufficient to note that at least one MPA operator has decided that a MAD boom is no longer an essential MPA design requirement. However, while a MAD boom may no longer be critical, the ability to deploy weapons and sensors is, and has significant implications for aircraft design. The requirement for an internal weapons bay in the P-8A resulted in a significant strengthening of the aircraft's keel and skin, thereby increasing aircraft weight<sup>94</sup> and the requirement to incorporate sonobouy launching equipment limits the cabin space available for operator consoles.<sup>95</sup> The MPA role also imposes a different set of mission profile requirements to those imposed by the other roles under examination; while surveillance and C2 missions require aircraft to spend long periods of time in medium level patrols, MR and attack missions currently require MPA to operate for long periods at low level, resulting in increased aircraft fatigue. While improvements in sensor technology and development of torpedoes<sup>96</sup> designed for over-the-horizon or medium level

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<sup>93</sup> Johnston, P. "Poseidon P-8A: God of the sea and shaker of the earth," *Asia Pacific Defence Reporter* (Feb 2011), 20. <http://www.asiapacificdefencereporter.com/articles/116/Poseidon-P-8A-God-of-the-sea-and-shaker-of-the-earth> (accessed 29 Apr, 2013).

<sup>94</sup> Johnston, Poseidon P-8A: God of the sea and shaker of the earth, 19.

<sup>95</sup> Boeing P-8A Poseidon Cutaway, [http://www.flightglobalimages.com/boeing\\_p-8a\\_poseidon\\_cutaway\\_poster/print/710/3193941.html](http://www.flightglobalimages.com/boeing_p-8a_poseidon_cutaway_poster/print/710/3193941.html) (accessed 29 Apr 2013).

<sup>96</sup> Such as the High-altitude ASW weapons concept (HAAWC), a Mk 54 torpedo equipped with a wing adaptor kit.

delivery<sup>97</sup> may reduce the requirement for low level operations, it will likely remain a design requirement for the current generation of MPA aircraft. Designing the aircraft to mitigate the increased fatigue leads to an increase in weight, in turn leading to increased fuel consumption and reduced mission endurance. While the effects of fatigue across a MMIA fleet could be managed by rotating aircraft through the various missions, use of multiple variants would limit this strategy to the number of aircraft capable of fulfilling the MPA mission.

One of the characteristics determined by mission requirements is aircraft size. The traditional approach to multi-mission aircraft sizing is to size the aircraft according to the 'primary' mission and accept that this may decrease aircraft performance in the 'secondary' missions it is designed to carry out; however, in a 2001 GIT paper, Mavis and Borer took an alternative approach in a study examining the feasibility of using a single airframe to replace four separate aircraft that provided AEW, ASW/ASuW, ES and COD services for the USN. The proposed CSA would maximise affordability, defined by measuring performance against relative cost, by combining all four support roles within a single airframe.<sup>98</sup> In a naval environment, minimising the number of different aircraft embarked on an aircraft carrier reduces the requirement for specialised support equipment and personnel in an environment where space and weight are at a premium.<sup>99</sup> The study assumed the use of monolithic microwave integrated circuits (MMIC)<sup>100</sup> integrated into a common Active Electronically-steered Array (AESA) to deliver the sensing requirements for the aircraft's AEW, ASW/ASUW, and ES missions and analysed the flight profiles and payload requirements for each role. The study determined that CSA size was dependent on four mission variables: payload; design range; loiter altitude and loiter time, each of which was bounded by upper and lower limits defined by individual mission requirements.<sup>101</sup> Analysis of these variables determined that CSA size was governed by AEW mission requirements, and that sizing the aircraft accordingly also allowed it to carry out all the other missions, whereas sizing the CSA against any of the other

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<sup>97</sup> Johnston, Poseidon P-8A; God of the sea and shaker of the earth, 24.

<sup>98</sup> Mavis and Borer, Development of a multi-mission sizing methodology, 1.

<sup>99</sup> Ibid.

<sup>100</sup> Sensors that can simultaneously transmit and receive energy at multiple wavelengths and frequencies.

<sup>101</sup> Mavis and Borer, Development of a multi-mission sizing methodology, 5.

missions resulted in an aircraft that was unable to carry out one or more of the four assigned missions.<sup>102</sup> Establishing critical sizing requirements for individual missions at the design stage enables development of an aircraft that is correctly sized to carry out all of its design missions; while sizing the aircraft against the critical sizing mission means that it may be larger than required to fulfil the other missions, knowing the spare capacity at the design stage gives developers the opportunity to maximise capability for each mission, or to add additional capability.

Another factor affecting aircraft size is the crew requirement. Avionics advances have enabled a reduction in P-8A mission crew from seven to five (compared to the P-3 Orion)<sup>103</sup> while data-links offer the prospect of further reductions in crew size. Adopting a remote approach to mission management and data analysis while retaining a manned element consisting of the aircraft pilots (possibly augmented by a mission manager) would enable a significant reduction in aircraft size, while adopting an entirely remotely-operated approach would maximise the achievable reduction. In both cases, it is likely that mission avionics requirements across each mission would be relatively common: the flight profile and any requirement to carry and deliver stores would therefore become the critical sizing factors. The concept of remote crewing is illustrated by RPAS such as the MQ-4C Triton (a marinised version of the MQ-4 Global Hawk) which has been adopted as the USN's BAMS UAV. The MQ-4C is operated by a four-man crew, consisting of a pilot, a mission commander and two sensor operators and provides persistent wide-area surveillance and reconnaissance coverage using a multi-function electronically-steered array radar and an EO/IR sensor. In addition it carries an Automatic Identification System (AIS) receiver, communications relay and data-link equipment, and ESM.<sup>104</sup> The UK's ability to adopt this approach would be significantly limited by its lack of ability to deliver high-volume instantaneous data transmission, caused by its incoherent and largely ineffective approach to bandwidth delivery and spectrum management.<sup>105</sup>

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<sup>102</sup> Ibid.

<sup>103</sup> Johnston, Poseidon P-8A; God of the sea and shaker of the earth, 20.

<sup>104</sup> "MQ-4C Triton BAMS UAS." Global Security.com. <http://www.globalsecurity.org> (accessed 2 May 2013).

<sup>105</sup> Quintana, Combat ISTAR workshop report, 4.

The decision to include or omit the ability to deploy weapons or stores is critical if attack missions are included within the aircraft's portfolio. The potential for a MMIA to contribute to defence missions in novel ways is covered in detail later; however, a brief discussion on the impact of removing an attack capability from an aircraft tasked with MP missions is relevant here. The P-8A Poseidon is capable of deploying sonobouys and of employing torpedoes, depth charges and missiles, and can therefore locate, track and prosecute targets unaided. The MQ-4 C does not possess such capabilities;<sup>106</sup> consequently, it performs a surveillance and cueing function for other components of the Maritime Patrol and Reconnaissance Force.<sup>107</sup> The implication is that an unarmed MMIA would not provide a complete solution to the UK's MP requirements, or to other missions where deployable stores or weapons are required.

As previously discussed, the RAF is not alone in seeking more effective and cost-efficient solutions to capability provision. A current example of a technologically-enabled solution to multi-mission aircraft development is the P-8A Poseidon, a highly-modified Boeing 737 aircraft selected as the US Navy's new MPA. While the range of missions the P-8A is expected to perform has required significant airframe modification, including strengthening of the fuselage to allow the addition of a bomb bay and incorporation of sonobuoy dispensers, under-wing weapons pylons and an in-flight refuelling capability, adaptation of a proven commercial airframe has reduced development costs, eliminated the need for a bespoke production line and enabled access to a worldwide logistics support network.<sup>108</sup>

The P-8A's sensor suite provides a maritime surface search and periscope detection capability, as well as high-resolution land and maritime mapping capabilities,<sup>109</sup> while its mission systems can simultaneously process information from up to 96 passive and multi-static sonobouys. Moreover,

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<sup>106</sup> MQ-4C Triton data sheet. <http://www.northropgrumman.com> (accessed 2 May 2013).

<sup>107</sup> Global Security.com. "MQ-4C Triton BAMS UAS." <http://www.globalsecurity.org> (accessed 2 May 2013).

<sup>108</sup> Nordeen, L. "American MPA Modernisation," *Air International* 01/13 (2013), 75 to 83.

<sup>109</sup> Annati, M. "Maritime multi-mission aircraft," *Naval forces* 31, no 2 (2010), 73.

all aircraft sensors contribute to production of a fused tactical picture which can be shared over data-links with suitably-equipped US and allied assets. The aircraft's capability to shorten the kill chain is delivered by its ability to carry torpedoes, depth charges, bombs and air-to-surface and anti-ship missiles, as well as self-defence air-to-air missiles, while potential future enhancements include the ability to carry stand-off air-to-surface missiles and torpedo systems such as the Joint Stand-off Weapon (JSOW), the ASuW version of the Joint Air-to-Surface Stand-off Missile (JASSM) and the HAAWC. The comprehensive self-protection suite provides a high level of detection and protection in dense threat environments.<sup>110</sup> Finally, the open systems architecture of the P-8A's mission systems enables an iterative upgrade programme for sensors and mission systems. Boeing has offered the P-8A as a contender for the EP-X intelligence gathering aircraft programme, as a replacement for the USN's fleet of EP-3 Aries aircraft<sup>111</sup> and proposed the P-8 Airborne Ground Surveillance (AGS) variant as a replacement for the USAF's aging JSTARS fleet, arguing that the current fleet of 17 aircraft could be replaced for the same cost as necessary updates to the current aircrafts' systems and that the P-8's reduced operating and sustainment costs would deliver an annual saving of \$500 million.<sup>112</sup>

In conclusion, technological solutions such as IMA, multi-mode electronically-scanned radars and MMIC, and high-volume data-links offer the potential of open architecture avionics systems that would enable a single aircraft to carry out multiple missions sequentially, or even concurrently, while design philosophies such as the DRM and multi-mission sizing methodologies offer the ability to optimise aircraft design across a number of different missions. The amount of rationalisation of the UK's ISTAR fleet possible through use of these methods and technological advances would need to be determined by a thorough examination that is beyond the scope and classification of this paper. Nevertheless, recently fielded aircraft such as the P-8A, E-7A and A330 MRTA demonstrate the growing capability of aircraft manufacturers to offer credible, cost-effective multi-

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<sup>110</sup> Nordeen, American MPA Modernisation, 77to 78.

<sup>111</sup> Pocock, C. "Boeing pushes P-8 for US Navy EP-X requirement," *AIN Online* (22 Aug 2008). <http://www.ainonline.com/> (accessed 18 Apr 2013).

<sup>112</sup> Carey, B. "Paris 2011: P-8 Production Advances; JSTARS Replacement Eyed," *AIN Online* (20 Jun 2011). <http://www.ainonline.com/aviation-news/paris-air-show/2011-06-20/paris-2011-p-8-production-advances-jstars-replacement-eyed> (accessed 18 Apr 2013).

mission solutions based on successful civilian aircraft and suggest that a multi-mission approach to procurement of the RAF's next generation of ISTAR aircraft is worthy of such detailed examination.

This paper's central argument is that a MMIA would provide the most cost- and operationally-effective solution to the UK's ISTAR capability requirements, but MMIA procurement is only one of a number of potential solutions to this requirement, alongside maintaining separate fleets of mission-specific ISTAR aircraft, or pursuing a federated approach to provision of ISTAR capability. As the current strategy is used as the base standard against which to assess the merits of a multi-mission approach to ISTAR provision, there is little need to discuss it further here; however, the federated approach merits examination as a potentially feasible alternative strategy. Dedicated ISTAR aircraft use bespoke sensors, either active or passive, to gather electronic information, which is then analysed to produce useful intelligence. While developing a new generation of bespoke ISTAR aircraft is one option, another is to provide ISTAR capability by incorporating ISTAR capabilities onto other RAF aircraft.

In his 2011 Air Power Review article, Air Cdre Stuart Evans<sup>113</sup> described how the development of combat ISTAR could contribute to air and space power's role in supporting the Joint Force through federation of ISTAR capabilities across the RAF's entire fleet.<sup>114</sup> The article articulated the increasing inter-dependency between the four fundamental air and space power roles and the increasing centrality of ISA as a key enabler for the other roles. Air Cdre Evans advocated adopting a platform-agnostic approach to ISA provision by equipping all air and space platforms to contribute towards intelligence collection as part of a combat air system operating across all four roles.<sup>115</sup> The article focussed on the ability of the F-35 Joint Combat Aircraft's (JCA's) advanced, highly-integrated sensor suite to fuse and disseminate information as a physical manifestation of the principle.<sup>116</sup> The concept of combat ISTAR was also discussed in the 2011 series of RUSI air

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<sup>113</sup> Commandant of the RAF's Air Warfare Centre.

<sup>114</sup> Evans, *Combat-ISTAR*, 1.

<sup>115</sup> *Ibid.*, 5.

<sup>116</sup> *Ibid.*, 6.

power workshops, which concluded that, although converting all platforms into ISTAR sensors is an attractive prospect, conversion costs are likely to remain prohibitive for the foreseeable future, and that bandwidth availability will be a major obstacle to realisation of the concept.<sup>117</sup> The implicit conclusion is that a federated ISTAR system may be a long-term option, if the required capabilities can be designed into future generations of each fleet of RAF aircraft, but is not affordable in the short term.

Tactical reconnaissance and imagery pods and a limited ability to record certain types of intercepted SIGINT have already given aircraft such as the Tornado GR4 a limited ISTAR capability and aircraft such as the F-35 JCA will have an integral ISTAR capability; however, the approach could be taken much further. All RAF aircraft that deploy to operational areas carry ESM equipment as part of their self-protection capability. ESM equipment generically consists of sensors designed to intercept and analyse electro-magnetic signals and to identify threats such as target acquisition and missile guidance radars in order to enable the aircraft to take timely evasive action, activate ECM or deploy physical countermeasures such as chaff or flares. Little effort is currently made to make further use of these intercepted signals but there is significant potential for them to be used to contribute to the development of intelligence and situational awareness. A programme to mount ESM onto all RAF Strategic and Tactical AT, and to make more use of information already gathered by tactical and rotary-winged aircraft would provide an alternative approach to SIGINT and ELINT collection. The aircraft are already operating in an information-rich environment; all that is required is an increased ability to collect that information. The obvious limitation of this approach is that only a dedicated aircraft fleet would be able to guarantee the continuous coverage required to provide an effective capability, but the programme would potentially provide additional capability for little extra cost. Further investigation into this area is beyond the scope of this paper but, while the author does not believe it would support a decision not to procure an aircraft with SIGINT and ELINT mission capabilities, it might well enable the RAF to augment its capabilities in this area or to reduce the additional capability required. The

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<sup>117</sup> Quintana, Combat ISTAR Workshop report, 12.

argument for installing active surveillance equipment onto other current RAF aircraft is less persuasive due to the extent of the modifications required to provide a credible capability; however, the F-35 again shows how future aircraft will be expected to contribute to a system of systems approach to ISTAR provision.

An argument against adoption of a multi-mission aircraft approach to capability provision is the 'eggs in one basket argument,' which posits that using a single platform to provide a number of different capabilities risks the loss of all capabilities if that platform is grounded due to a flight safety incident, or for engineering reasons. The argument seems persuasive at first glance, especially in light of the recent grounding of the Boeing 787 Dreamliner, which has already resulted in a significant loss of prestige and revenue for Boeing,<sup>118</sup> and may yet affect the aircraft's commercial success. The inference is that, if such an occurrence was to affect the aircraft type used as the MMIA airframe, it would result in the temporary loss of all capabilities delivered by that aircraft type; however, analysis of the Dreamliner incident uncovers the underlying cause and suggests that such consequences are avoidable.

The Dreamliner used several new technologies to improve efficiency and save weight; one example being lithium-ion batteries, used to power a number of systems on the ground, and to provide back-up power for systems such as the electrically powered flight controls in the air.<sup>119</sup> The batteries are similar (but rather larger) to the batteries used in smart phones and laptops and their unusually high energy density enables them to produce more power than traditional batteries of the same size and weight, a critical advantage for aircraft such as the Dreamliner with high power demands and low weight targets. After approximately 15 months in service and 50,000 flight hours, two incidents indicated that the batteries were susceptible to overheating issues. An aircraft fire and a smoking battery which caused diversion of a second aircraft led the US Federal

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<sup>118</sup> <sup>118</sup> Maasho, A. "Ethiopian Airlines first to fly 787 Dreamliner since grounding," *Reuters* (27 Apr 2013). <http://www.reuters.com> (accessed 29 Apr 2013).

<sup>119</sup> Paur, J. "Boeing Dreamliner Investigation Focuses on Combusting Batteries," *Wired* (4 Jan 2013). <http://www.wired.com> (accessed 12 Apr 2013).

Aviation Authority (FAA) to ground all US Dreamliner aircraft on 16 Jan 13 while the problem was investigated. This was swiftly followed by a worldwide grounding of the fleet, which Reuters estimates has cost Boeing \$600 million and has halted deliveries of the aircraft, forcing some airlines to lease alternative planes.<sup>120</sup> Since then, Boeing has been working to identify the cause and develop a solution to enable commercial operations to resume. While the root cause of the incidents has not been fully established, it is believed to have been linked to thermal propagation within the battery and Boeing's solution uses a new battery casing to reduce the risk of combustion and to vent any generated gas outside the aircraft. Boeing is confident that this eliminates any risk of fire, but the solution adds 150 lbs to the aircraft weight, reducing the benefit of using the lithium-ion batteries.<sup>121</sup> Boeing carried out a successful test flight on 5 Apr 13 and, on 27 Apr 2013, following the FAA's 25 Apr 13 decision to issue a 'formal airworthiness' directive, an Ethiopian Airlines 787 Dreamliner conducted the first commercial flight since the fleet was grounded, conducting an incident-free flight from Addis Ababa to Nairobi.<sup>122</sup> This flight was followed on 7 May 13 by United Airlines' decision to resume Dreamliner operations on 20 May 13.<sup>123</sup> The Dreamliner example demonstrates the risks involved with use of new technologies or development of new applications for existing technology; however, it also highlights the safety and airworthiness assurance processes within the design and certification processes. The batteries had successfully passed stringent certification tests prior to the aircraft's entry into service and two relatively minor incidents led to instigation of precautionary measures and a thorough investigation. Boeing has orders for over 850 Dreamliners<sup>124</sup> and can ill-afford to risk these by failing to address such issues; the financial cost of the aircraft's commercial failure would be catastrophic.

New or emerging technology is regularly used on military aircraft to improve performance, reduce weight and reduce obsolescence. This can be both a cause and a consequence of the lengthy

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<sup>120</sup> Maasho, "Ethiopian Airlines first to fly 787 Dreamliner since grounding."

<sup>121</sup> Meigs, B. "Can Boeing's Battery Fix Save the Dreamliner?" *Popular Mechanics* (15 Mar 2013). <http://www.popularmechanics.com> (accessed 12 Apr 2013).

<sup>122</sup> "Boeing 787 Dreamliner returns to service in Ethiopia flight," *BBC News* (27 Apr 2013). <http://www.bbc.co.uk/news/> (accessed 7 May 2013).

<sup>123</sup> Mutzabaugh, B. "United to restart Dreamliner flights May 20," *USA Today* (8 May 2013) <http://www.usatoday.com> (accessed 8 May 2013).

<sup>124</sup> Boeing 787 Factsheet. <http://www.boeing.com/> (accessed 29 May 2013).

design and procurement process. Expected technological advances are often incorporated in the design process in order to maximise capability, while delays in technology development or operationalisation can result in delays to aircraft entering service and associated increases in procurement costs. Use of a proven commercial aircraft design as the basis for a MMIA would reduce the technological risk associated with the aircraft; the use of proven technologies such as IMA would do much to mitigate the corresponding technological risk associated with mission systems.

Analysis of the capability enhancements required to enable effective ISTAR capabilities to be incorporated onto a wide range of aircraft and the limitations in coverage (both spatial and temporal) that would result suggest that adopting a federated approach would provide an complementary capability for 'opportunity collection' of ISTAR information rather than removing the need for a core fleet of ISTAR aircraft. The range of capabilities being incorporated into the F-35 demonstrates how advances in technology are currently enabling a system of systems approach to ISTAR collection; however, the high cost of incorporating this capability into the current generation of operational aircraft precludes a federated approach becoming a feasible strategy in the short term. Moreover, many elements of ISTAR capability, namely those that require large amounts of mission-specific avionics or dedicated ISTAR mission profiles, do not lend themselves easily to this approach and it must be concluded that provision of a persistent strategic operational ISTAR capability requires a fleet of dedicated ISTAR aircraft. Finally, examination of the 'eggs in one basket' argument has shown that existing development processes are able to identify and treat many operating risks during aircraft development, while stringent airworthiness requirements and the financial consequences of a fleet-grounding event minimise the risk of a MMIA fleet based on a proven commercial fleet being taken out of service.

This paper has demonstrated that procurement of a MMIA based on a suitably sized, successful, modern commercial aircraft would offer the UK practical and economic advantages over procurement of smaller fleets of single-mission ISTAR aircraft and over incorporating ISTAR

capabilities on a number of different aircraft types. The final question addressed is whether such a MMIA could provide an additional contribution to UK defence capabilities, either within or outside the ISTAR role. Consideration of the expected capabilities of, and anticipated missions allocated to, the P-8A Poseidon provides a useful example of the wide-ranging utility of a carefully-designed MMA and the starting point for a discussion of possible missions for a UK MMIA.

In addition to the armament of sonobuoys, torpedoes, depth charges and anti-shipping missiles required by a capable MPA, the P-8A is also expected to be capable of delivering Stand-off Land attack Missiles (SLAM) and AGM-65 Maverick missiles, self-defence air-to-air missiles for self-defence and any stores, such as air-launched UAVs, compatible with its sonobouy launching equipment. The ability to carry and deliver such a range of stores suggests that the US accepts the need to demonstrate an 'out of role' capability for its new MPA. This is underlined by the decision to designate the Poseidon as an MMA<sup>125</sup> rather than an MPA, conveying the increased range of tasks allocated to the P-8A over traditional MPA.<sup>126</sup>

Enabling a MMIA to deliver a wide range of stores entails designing the bomb bay, external weapons stations, sonobouy delivery systems and stores control systems to enable carriage, release and operation of standardised stores. The military databus standard MIL-STD-1553 is a common military specification that enables integration of numerous separate weapons systems on a single platform. It describes the electrical interface requirements and communications methods used to achieve avionics and stores management integration of aircraft sub-systems. Examples of aircraft systems integrated using a MIL-STD-1553 databus include aircraft operating systems such as fuel management systems, mission computers and cockpit displays, mission-essential equipment such as missile warning systems and electronic counter-measure dispensing systems, and weapons sub-systems including stores management systems and other systems enabling the

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<sup>125</sup> Multi-mission maritime aircraft.

<sup>126</sup> Annati, Maritime Multi-mission aircraft, 72.

programming and release of smart weapons.<sup>127</sup> Integration of a MIL-STD-1553 databus within an aircraft provides the ability to deliver the entire range of MIL-STD-1553 compatible weapons that can physically be carried by that aircraft and would maximise the range of stores available for carriage by a MMIA.

An ability to launch UAVs from a MMIA, either from sonobouy dispensers or wing stations offers a number of enhancements to the UK's surveillance capabilities. Such UAVs could be used to maintain area surveillance between MMIA sorties, or to enhance the tracking of high-value targets and cue strike assets. In addition, launching UAVs from an MMIA could be used to extend their range or on-station time, while the UAVs themselves could be used to enhance the effectiveness of on-board systems through local control, or could be handed over to remote control for use on separate missions. The P-8A Poseidon boasts a capability to provide Level 2 control of UAVs at its IOC, with the potential to develop a Level 4 control capability if required.<sup>128</sup> The maturity of this capability is demonstrated by the aircraft's current ability to deploy air-launched UAVs such as the MagEagle Compressed Carriage (MECC) UAV.<sup>129</sup> While air-launched UAVs could not be recovered, they would be capable of hand-off to a land-based Launch Recovery Element (LRE) or, in the case of micro-UAVs, be destroyed once their mission was complete.

Amongst the capabilities mentioned in the SDSR are loitering munitions with the ability to strike fleeting or opportunity targets over a period of several hours<sup>130</sup> and Air-launched Cruise Missiles (ALCM) providing an ability to strike ground targets from medium to long range. Given that ISTAR aircraft are designed to operate for long periods of time within reach of hostile territory, the argument for incorporating this capability onto a MMIA is logical. ISTAR aircraft carrying pre-programmed ALCM could be used to augment the UK's initial strike capability, while the ability to launch loitering munitions or missiles such as the SLAM would enable the RAF to shorten the

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<sup>127</sup> MIL-STD-1553 Complete online reference, <http://www.milstd1553.com> (accessed 12 Apr 2013).

<sup>128</sup> Johnstone, Poseidon, God of the Sea and Shaker of the Earth, 22.

<sup>129</sup> Ibid.

<sup>130</sup> SDSR, 2.A.7.

sensor-shooter chain in situations where discrete targets are identified but no tactical attack aircraft are immediately available to act on the information. Moreover, while the fact that a strategic asset such as a MMIA would be unlikely to be tasked to provide close support to ground elements supports the argument that the ability to deliver tactical munitions such as the AGM-65 Maverick or Brimstone air-to-surface missiles is an unnecessary capability, the utility of this capability was demonstrated by an engagement on 28 Mar 12, when a USN P-3 Orion fired AGM-65 Maverick missiles at a Libyan Coastguard vessel attacking merchant vessels near Misrata in Libya, causing the Libyan craft to be beached.<sup>131</sup> Spreading the capability to deliver such weapons across a number of aircraft types increases potency and decreases the time taken from target detection to prosecution.

One effect delivered by air assets is that of deterring enemy action, demonstrated by the use of tactical aircraft such as the Tornado GR4 to provide 'Shows of Presence' or 'Shows of Force' in Afghanistan and Iraq. A show of presence merely demonstrates that air assets are on hand to support ground forces; it does not give any indication as to the weapons delivery capability of the specific aircraft. The deterrence comes from the opponent's knowledge that such aircraft are usually armed, which is then factored into his risk-benefit calculation. If a show of presence fails to have the required deterrent effect, a show of force provides a demonstration of capability by targeting a clear area near to an identified or suspected enemy position, usually with the aircraft's gun. This confirms the presence of armed aircraft, further affecting an opponent's assessment of the risk involved in his actions. The point is that, although an opponent may recognise an aircraft type and know its range of capabilities, he cannot know exactly what that aircraft is capable of at that precise time; the aircraft's capability is ambiguous. By procuring a fleet of outwardly identical MMIA, the RAF would introduce ambiguity and doubt into the minds of potential opponents as to the capabilities provided by those aircraft. As an example, a submarine sighting an MMIA aircraft on a typical MPA profile would not be able to tell whether that aircraft was actually an MPA, or

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<sup>131</sup> "P-3C, A-10 fire on Libyan Patrol Vessels," *Navy Times* (29 Mar 2013). <http://www.navytimes.com> (accessed 16 Apr 2013).

another variant of MMIA on a training mission; the captain would have to factor the possibility that the aircraft was an MPA into his operational calculations. Likewise, an observer watching the arrival of a MMIA at a deployed location would be unable to tell which capability was being deployed. While the ambiguity might not last long, the potential deterrence effect is clear.

A fleet of outwardly identical MMIA would provide a level of ambiguity over force capabilities that could deliver a useful deterrent effect; however, the ability of a fleet of MMIA to contribute to UK defence missions in other ways appears to depend on an ability to deploy stores and weapons. Adoption of standardised weapons and data-busses would maximise the range of compatible stores, from ALCM to tactical missiles, torpedoes, depth charges and mines, whilst the capability to sonobouys from inside the aircraft would also enable the aircraft to deploy UAVs. While these capabilities would require inclusion at the start of the design process, and would affect overall aircraft design, the P-8A shows that this need not negate the aircraft's multi-mission capability. Moreover, including a weapons-carrying capability on an MMIA would enhance the UK's overall offensive capabilities and would also provide a cost-effective opportunity to regain some of the capabilities lost due to the decision to scrap the Nimrod MRA4.

## **Conclusion**

The RAF, along with many other air forces, will soon need to replace its current fleet of aging ISTAR aircraft. One recapitalisation option is to pursue a multi-mission approach, using a single, commercially-proven aircraft as the basis for one or more variants delivering the RAF's future ISTAR requirements. While air forces have made attempts to develop multi-mission capabilities in the past, a review of the available literature shows that the academic debate over the utility and feasibility of multi-mission aircraft has been sparse and sporadic, and often driven by economic pressure to reduce fleet sizes. The debate has intensified recently as developing technologies and design tools offer a realistic prospect of replacing current fleets of near-obsolete single-mission aircraft with more capable multi-mission aircraft, thereby delivering increased operational capability

and reduced through-life costs. This would represent a departure from the UK's traditional approach to capability development – the sequential addition of capabilities to existing aircraft. Attempts to develop the successful Nimrod MPA into an AEW aircraft and the eventual cancellation of the MRA4 programme demonstrate the problems associated with this approach, and of the limited development potential of mature aircraft. While the debate has been hampered by poor understanding and misuse of key terms, on analysis, it can be seen that the terms multi-role and multi-mission are separate, complementary terms; multi-mission aircraft have capabilities within a number of separate missions within a single air power role, whereas multi-role aircraft are able to carry out missions within multiple roles. Consequently, the term 'multi-mission' is diminishing in relevance as air forces and manufacturers move away from single-function aircraft. Technological advances such as multi-function radars and IMA, alongside design tools such as the DRM and Multi-mission Sizing Methodology have increased the feasibility of developing aircraft that deliver optimised performance in a number of missions, offering the prospect of a single fleet of aircraft that is able to carry out the entire portfolio of ISTAR missions with minimal need for reconfiguration.

Multi-mission aircraft appear to offer concrete efficiencies in terms of capability development, fleet size, manpower establishments and through-life costs, as well as the prospect of significant rationalisation of training and support structures; recently fielded aircraft such as the P-8A and MMRT demonstrate that delivery of effective multi-mission capability is a realistic prospect for the next generation of ISTAR aircraft. While technological solutions such as IMA, multi-mode electronically-scanned radars and MMIC, and high-volume data-links offer the potential of a single aircraft to carry out multiple missions, either sequentially or concurrently, and while design philosophies such as the DRM and multi-mission sizing methodology offer the ability to optimise aircraft performance across a number of different missions, there are still significant obstacles to overcome in designing a single aircraft variant able to deliver the entire range of ISTAR missions, not least of these being the internal weapons bay and sensor delivery system required by MPA, and the UK's current lack of capability to deliver resilient instantaneous, high-volume secure communications and data transfer. These factors may preclude the opportunity to combine all the

UK's ISTAR requirements within a single variant, and any attempt to rationalise the UK's ISTAR fleet would require a thorough examination that is beyond the scope and classification of this paper. Adopting a federated approach to provision of ISTAR capability provides an alternative capability delivery philosophy; however, analysis shows that this approach, while increasing the UK's tactical ISR capabilities, would not provide the long-duration strategic collection capabilities required to provide effective ISA and could therefore, at best, provide a complementary capability to that provided by a dedicated fleet of ISTAR aircraft. Moreover, adopting a federated approach to ISTAR provision is not feasible in the short-term, due to the costs involved, whereas Thompson has demonstrated that adopting a multi-mission approach has potential for significant savings against the projected cost of sustaining the USA's current ISTAR fleet. Adopting a multi-mission approach to provision of ISTAR capabilities also offers the potential to augment overall UK defence capabilities in other ways. The ambiguity provided by a fleet of outwardly identical aircraft offers the potential for a significant deterrent effect, while the ability to deliver a range of standardised munitions and stores raises the prospect of enhancing the UK's stand-off precision strike capability, shortening the kill chain and delivering focussed UAV-based ISTAR according to the needs of other force elements.

There are two significant arguments against adopting a multi-mission approach to ISTAR capability provision; the 'eggs in one basket argument' and the 'procurement cost' argument. The B787 Dreamliner aircraft demonstrates both the strength of the first argument and the benefits of using a proven commercial design as the basis of a MMIA. While critical failures do have the potential to ground entire fleets, the financial and reputational cost to aircraft manufacturers is such that the vast majority of such issues are identified and fixed during the design and testing phases of an aircraft's development, while any that surface once an aircraft has entered service are addressed swiftly and comprehensively. Moreover, the need to adopt a staged approach to bringing individual capabilities into service would mitigate the effects of such an occurrence. The procurement cost argument is undermined by Loren Thompson's findings and, while the size of the UK's aircraft fleet means that savings achieved would be proportionately smaller, the principles are equally valid; the

spiralling costs of maintaining an increasingly obsolete and unserviceable fleet make recapitalisation costs ever-more attractive, especially when placed alongside decreased operating costs.

This paper has demonstrated that the UK could benefit significantly from adopting a multi-mission approach to procurement of its next generation of ISTAR aircraft and aircraft such as the MRTT and P-8A demonstrate that adopting such an approach is technologically feasible, and financially attractive; however, this conclusion is limited by the need to conduct a thorough examination of all the issues raised, an undertaking beyond the scope or classification of this paper. Nonetheless, within the constraints imposed by an unclassified, philosophical approach to the problem, it is clear that procuring a MMIA would offer significant potential advantages to the UK, allowing reductions in fleet size, life cycle costs and support structures, while also offering a potential , cost-effective way to regain currently gapped capabilities. While significant practical challenges remain, it is hoped that, by demonstrating the potential benefits offered by such an approach, the paper serves to further stimulate debate over this important area of UK defence policy.

## Glossary

AAR	Air-to-air Refuelling
AESA	Active Electronically-scanned Array
AEW	Airborne Early Warning
AFIT	Air Force Institute of Technology
AFDX	Avionics Full Duplex Ethernet
AGM	Air-to-Ground Missile
AGS	Airborne Ground Surveillance
AIS	Automatic Identification System
AIMS	Airplane Information Management System
ALCM	Air-launched Cruise Missile
APEX	Applications Executive
ARINC	Aeronautical Radio, Incorporated
ASW	Anti-submarine Warfare
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASuW	Anti-surface Warfare
AT	Air Transport
AWACS	Airborne Warning and Control System
BAMS	Broad Area Maritime Surveillance
BSP	Board Support Package
C2ISR	Command and Control, Intelligence, Surveillance and Reconnaissance
COD	Carried On-board Delivery
CSA	Common Support Aircraft
DoD	Department of Defence
DRM	Design Reference Model
ECM	Electronic Countermeasures
ELINT	Electronic Intelligence
EO	Electro-optical
ES	Electronic Surveillance
ESM	Electronic Support Measures
EW	Electronic Warfare
FAA	Federal Aviation Authority
FASOC	Future Air and Space Operating Concept
GIT	Georgia Institute of Technology
HAAWC	High Altitude Anti-Submarine Warfare Weapons Concept
HAL	Hindustan Aeronautics Limited
IMA	Integrated Modular Avionics
ISA	Intelligence and Situational Awareness
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
JASSM	Joint Air-to-Surface Stand-off Missile
JCA	Joint Combat Aircraft
JHAPL	John Hopkins Applied Physics Laboratory
JSOW	Joint Stand-off Weapon
JSTARS	Joint Surveillance Target Attack Radar System

LGB	Laser Guided Bomb
LRE	Launch Recovery Element
LRU	Line Replaceable Unit
MAD	Magnetic Anomaly Detector
MECC	MagEagle Compressed Carriage
MEDEVAC	Medical Evacuation
MESA	Multi-role Electronically-scanned Array
MIT	Massachusetts Institute of Technology
MMA	Multi-mission Aircraft
MMIA	Multi-mission ISTAR Aircraft
MOD	Ministry of Defence
MPA	Maritime Patrol Aircraft
MR	Maritime Reconnaissance
MRA	Maritime Reconnaissance and Attack
MRTA	Multi-role Tanker Aircraft
MRTT	Multi-role Tanker Transport
MTA	Multi-role Transport Aircraft
OCU	Operational Conversion Course
OS	Operating System
OSA	Open Systems Architecture
PFI	Private Finance Initiative
RAPTOR	Reconnaissance Airborne Pod for Tornado
RPAS	Remotely-piloted Air System
RTOS	Real-time Operating System
RUSI	Royal United Services Institute
SAR	Search and Rescue
SDSR	Strategic Defence and Security Review
SIGINT	Signals Intelligence
SLAM	Stand-off Land Attack Missile
UAV	Uninhabited Air Vehicle
USAF	United States Air Force
USN	United States Navy
VIA	Versatile Integrated Avionics

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