UK Combat Air – The Next Generation

Perspectives and Notes from Workshops

Low Cost by Design network

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Introduction

Generations matter. What will future generations of combat aircraft need to do? What will 'Gen X' and millennial workers want from a job? What is the next generation air threat to the UK?

With even DARPA questioning if 6th Generation fighter aircraft are possible, these are key questions for UK air power. Can it avoid heading towards the 'Starship Enterprise'?

Such questions lie at the heart of public debates around the UK's Combat Air sector. This document provides perspectives on them, explored in a series of unclassified workshops led by the Low Cost by Design (LCxD) network. These produced a range of views from LCxD members, which are reproduced here in essay and note form. They serve as a start for wider discussions, rather than defining any answers.

The workshops looked at the UK Combat Air Strategy's publicly stated concerns, primarily "the operational capability needed in the future and the skills and resource required to deliver it".

The workshops were part of a number of activities funded by the Higher Education Innovation Fund as part of wider work providing independent inputs to the Combat Air strategy.

Contents

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Andy Dakin

Adaptive design

Adaptability should lie at the heart of air combat design. Be focused but unrestrained in your thinking, and flexible in your approach. For example, the BAE SYSTEMS Harrier Rapid Technology Insertion programme entered each phase of its spiral development with an eye on maximising future development opportunities.

A focus on solutions provides a quick response to operational needs. It trades off time, cost and capability requirements and allows its outputs to be exploited by the operator when required.

A skilled and experienced design team can use and adapt industry standard development tools and disciplines, and tailors design activity to meet customers' essential needs.

Know what is possible, refer to relevant pre-existing bodies of research and/or look to historic example of good practice. Never be narrowly bounded: have an impression of how to move the boundaries. The art of the possible changes dynamically as you do things; the impossible can become possible

Don't expect everything to be apparent at the outset. As design activity progresses new possibilities emerge. Practical limitations emerge too.

Use military and commercial judgement to trade cost against capability, and include the operator's ability to use doctrinal and tactical innovation to adapt their use of the design.

Choose what's important and go for it. Design is about creating new things and adapting existing ones. Learning between these, and striking a balance, is essential. It is important not to adopt a new design that cannot be adapted to a changing future.

Be wary of integration. Mission and safety systems should be separated to allow easy adaption.

Design approaches should allow manageable, documented systems that allow updates through-life.

Doing it right

Spend wisely at the right time. Have a flexible decision making process that can value the judgements made and understand the real risks for the front line.

Use the knowledge you have of what is low risk from technical, operational and commercial perspectives. Don't work with people who promise the Earth. You shouldn't trust something that is too good to be true; a quick investigation should show this is the case.

Don't spend significant money on things you know little about. Use fast, small-scale funding to find out more.

Risk always lies on the front line. Design should always start from reducing this risk.

You need to have trust and an agile organisation to allow open, fast development. This is only achievable if you know what you are doing, what is possible and what the customer will really need. Anticipating the needs of the front line is the key to being adaptable at pace.

Front line needs vary across nations. This means you should be led by your own national leads, and work with partners in a way that supports this.

From adaptive design the front line gets rapid capability development. Industry gets an adaptable approach that offers market opportunity. The economy gets new skills and opportunities to develop additional offerings from, and for, other sectors.

Adaptive design is possible now, and can deliver quickly. At a time when even the United States is challenged by the prospect of '6th Generation' fighters, adaptive design offers a different approach that can support future development. The UK cannot afford to commit to a major programme just as technologies and tactics may change again.

Adaptive design allows the problems that 6th Generation concepts seek to address to be tackled more quickly and more cheaply. It avoids committing to an inflexible programme that cannot change as the world changes around it.

To support front line needs speed is essential. Adapting to new threats and circumstances is a commercial imperative. Adaptive design creates a future industry that delivers what the front line needs, when it is needed and in an affordable way.

Michael Weatherburn

The future of skills

We are discussing two kinds of 'generation': demographics and product development. Just as a new generation of defence product requires new skills, materials and organisational methods, so too a new generational mix will require new skills, materials and organisation.

There are additional issues at stake. As outlined by adaptive design principles, and broader sectoral and geopolitical shifts, it is likely that defence products will change over the coming decades. They are less likely to require the manual metalworking skills of the twentieth century and be more software based, with automated manufacturing: while cyber war will never replace conventional war, a mixture will develop. Software development, data analysis and soft skills will matter as much as, perhaps more than, the hard, male-dominated work patterns of the past.

The future of work is a topic of debate across all Western-style economies, and it is one to which I have recently contributed with research on intergenerational working and organisational memory. Within this debate, the topic of automation, big data, machine learning and artificial intelligence frequently appears. A key focus of this debate is in assessing the impact of automation and related

technologies on future employment, including potential unemployment created by automation (and factors such as sector, region and gender).

There is a further aspect of this line of enquiry. According to most macroeconomic analysis by the Office for National Statistics, academics, policymakers, and think tanks, Britain's productivity since the financial crisis of 2008 has been singularly stagnant when compared to similar economies in Europe and North America. Regional policy also plays an important role in this debate, as many analysts such as the Confederation of British Industry observe that the Midlands and North of England have suffered from lower productivity growth across this period than London and the South East.

Debate about national defence policy, skills, production and design can and should contribute to these debates, also of wide-ranging national significance.

Commentators like RAND Europe and the Confederation of Shipbuilding and Engineering Unions point to the decline in defence/aeronautic-specific skills in the UK defence sector. Both suggest shoring-up these skillsets by training newer aerospace personnel in these older skills. But, as RAND have observed, defence production is an unattractive career for Generation Y, so new recruitment methods are needed.

I make a different claim. I suggest that rather than training younger workers to acquire the same skills as their older workmates, in fact new, complimentary skills, and a new tone are needed. In a data-driven, software-intensive, project-managed world which rewards agility and team work, the aerospace sector of the future may resemble the technology sector more than traditional physical manufacturing. The young, dynamic and talented could be drawn to a recast defence sector which is clear about upcoming opportunities which require mental agility, adaptability and dynamism.

The value of work

This is the perfect time for this issue to be raised in this manner. As many demographic studies have demonstrated, work motivations differ between older generations (baby boomers and Gen X) and younger generations (Gen Y and Gen Z). While baby boomers and Gen X are largely motivated by institutional norms and pay, research by organisations like the World Economic Forum (WEF) shows Gen Y and Z graduates are more idealistic, think more globally, and genuinely want to 'make a difference'; indeed they place making a difference above traditionalist goals such as income and older measures of professional status (emergent research by professional services firms Accenture and Deloitte indicates that similarities and differences between Gen Y and Gen Z are still unclear).

For example, as David Kirkpatrick mentions below, purchasing and supply chains are an important defence consideration, and potentially controversial. They can also tap into the Gen Y and Gen Z interest in ethical production and resource sustainability. But we also must ensure that graduate recruits are comfortable with the security aspects of the sector.

The role of the state is important here. When we examine manpower and skills planning over the past century, we see that the state has usually had a central role in both defence and manpower planning. This was replaced by a market-based approach from the 1980s until recently. With the return of industrial policy to the UK national agenda, a recast role of the state could help to deliver the intergenerational skills base required for the future of defence; that which adaptive design requires.

There are therefore multiple, related, factors at work here. Newer workers need to be persuaded to work in defence production in order to replace an otherwise aging workforce. But the key question is: what products will they be working on and therefore what skills will they need? Will adaptive design lead to new products and, related, will it change the production cycle (and therefore the skills required)? Are the real skills of value to the national aerospace industry those that involve people being able to 'make a difference', i.e. creativity, judgement and design?

If their jobs are seen as of a high national value, how does the nation reward that value? Given the prominence of the public sector in post-war British aerospace development, activity which in the 1980s and 1990s shifted to the private sector, do Generations Y and Z see public sector jobs as offering more of an opportunity to 'make a difference' than private sector roles? Do we need to create a type of well-paid, secure worker who will see a multi-decade projects through their life, or create a new generation of fighter aircraft that can be adapted over time, incorporating more employee voices, as skills, threats and needs change? New research on Gen Y and Gen Z suggests they would be far more motivated by the latter. It would seem that we cannot have both, but the former may cost much more to sustain than the latter.

David Kirkpatrick

Designing a UK defence policy

Any review to plan the future size and composition of the defence forces of the UK must face some difficult challenges. Its ultimate objective must be to define a mutually-consistent triad of a defence policy, a defence programme to provide the required military capabilities and a defence budget sufficient to implement that programme. There is often a nugatory argument about whether it is better to start from an assumed policy or an assumed budget; in fact the choice is irrelevant provided that the responsible politicians, officers and officials are prepared to revise their initial assumptions to derive an acceptable and consistent triad. Within this overall framework, the requirement for a future generation of combat aircraft can be determined along with arrangements for the acquisition of such aircraft.

Scenarios

One challenge is to identify a set of credible future scenarios (incorporating threats to the UK homeland, to its vital interests overseas, or to international law) in which HMG might wish to achieve a favourable outcome through the use or the threat of military force, and hence assess the military capabilities which the UK would require to achieve that outcome. That assessment should take account of the military capabilities of allies which can be expected to participate in these scenarios – for example, the MoD has for decades assumed that the UK will not engage in any major war without the active support of US armed forces. Similarly the UK plans to join several of its European allies in the European Intervention Initiative, to generate a multi-national force capable of rapid action in a crisis.

It follows that nations in an alliance should ideally coordinate their defence programmes to avoid dangerous gaps or wasteful overlaps in their military capabilities; individual nations may prefer to build on their traditional strengths and to rely on allies for other military capabilities. Political leaders may squabble but most alliances are built on shared geopolitical interests and accordingly endure;

inter-alliance politics can be inconvenient but membership of alliances is the best policy for all but a few global superpowers.

It is notorious that many modern wars are unexpected, and have not been included in the set of future scenarios considered. Ideally the selected set of future scenarios should be sufficiently diverse (in intensity, geography, etc.) so that one of them is similar to the next actual conflict.

Budget

Another challenge is to plan the UK's future annual defence budgets, ideally over the several decades typical of the life cycles of modern military equipment. These budgets must avoid dramatic peaks and troughs so that they can fit comfortably within the expenditure profiles of other government departments. They must also be acceptable to the tax-paying public, demonstrate commitment to other nations in an alliance, and provide as many as possible of the most important military capabilities associated with the UK's defence policy.

Programme

The third challenge is to design a defence programme for the supply of personnel and equipment which will provide the required military capabilities, and which will incur costs at or below the planned annual budgets. Each military capability must be provided by an array of complementary and interdependent battlegroups, flotillas and squadrons (incorporating combat, reconnaissance, communications and logistic units) deployed with equipment which must be continuously maintained, and which must be periodically upgraded or replaced as necessary to confront evolving threats.

The magnitude and timing of the cost of a chosen defence programme depend on many factors, notably on decisions regarding the design of new equipment projects, such as new combat aircraft. Such decisions are driven mainly by the Service requirements for performance in the battlespace which together determine the size and complexity of the equipment, but are also affected by questions including –

- Should the equipment be designed for more than one role, which may incur some degradation of performance but should deliver economies of scale in production and support?
- Should the project risk incorporating the latest (inevitably unproven) technology, or accept the delay and cost of technology demonstrators?
- Should the project incur additional procurement costs in order to reduce support costs in service and/or to facilitate later upgrades and modifications?

The cost of a defence programme depends partly on the chosen structure of the armed forces and the extent to which this structure promotes cost-effective training, administration, etc. A radical change in the nation's chosen military capabilities, or budgetary constraints which force the abandonment of some traditional capability, might stimulate some restructuring of the armed forces.

The most controversial decisions which affect the cost of a defence programme are generally those relating to the supply chain for defence goods and services, including the procurement and support of new combat aircraft. The design of military equipment is a quantitative process governed by the laws of physics and by cost-effectiveness analysis, and the structuring of the armed forces is guided

by accumulated operational experience. Decisions in these areas are relatively straightforward. However the cost of supplying defence goods and services can be affected by political ideology and by a variety of industrial and regional policies. In principle defence goods and services can be provided by –

- Government establishments and the armed forces
- Foreign contractors from allied nations
- Onshore contractors (perhaps teamed with foreign contractors)

In recent decades the UK has adopted a pragmatic mix of such suppliers (guided by the nature of the goods and services required) but has increasingly tended to abandon to first option in favour of private-sector contractors, onshore or foreign; the UK government has retained direct control of only a few strategically-critical facilities (e.g. cryptography and NBC countermeasures). Supply from foreign contractors often provides economies of scale and interoperability with allies, but is always subject to control (of support, upgrades, etc.) by the government of the foreign supplier. Supply from onshore contractors demands many decisions on the design of a national industrial base including –

- How to control indirectly the policies of onshore contractors (some of whom may be national monopolists)?
- The level of government-funded research, and the provision of government-funded facilities for research, development, and test & evaluation needed to ensure that the equipment produced by onshore contractors is well designed to be effective in the battlespace.
- How to ensure a steady stream of development and production work in each class of military equipment to sustain the onshore contractors' expertise?
- The proper role of small and medium-sized enterprises

Conclusion

The design of the future structure and inventory of the UK's armed forces to provide the desired military capabilities at the lowest cost demands a multitude of decisions on

- The capabilities required by UK foreign policy
- The organisation of the armed forces
- The organisation of the supply chain

These issues have been discussed, albeit vaguely, in successive UK defence reviews.

David Andrews

Ships and Combat Air

If you don't control the concept design, you do not control the programme. The end design emerges from a proper process/dialogue of requirements elucidation. Design and requirements co-evolve through exploring what you can afford through-life. This means ensuring adaptability is designed in from the beginning with features like modularity and adequate margins for future sub-systems and aircraft supporting systems (weight, power, etc.). Concept exploration should push the boundaries and constraints because it is often constraints that prevent maximising aspects like adaptability and minimising supportability and sustainability.

Equally, balancing capability and cost can drive us into cheaper, less capable, designs. If the recent Type 26 sale to Australia had happened before the Parker ship review, the review might have been less likely to recommend low capability, but exportable, ships be designed.

Industry is reactive and commercially risk adverse – yet military equipment must introduce new weapons and sensors and also new integrated systems (ships and air frames), produced rarely, that use technology that requires innovation in its adoption – this MoD must foster.

A number of issues from the naval sector may be relevant for the air combat sector:

- Consequences of 1980-2018 laissez faire industrial policy more significant in maritime domain in the UK, where shipbuilding is seen as sunset industry (despite strong marine equipment industry). This is not the case in Finland, Germany and Italy, where shipbuilding is still high value, e.g. their cruise ships are world dominant. A defence-only focus on high value in a sector comes at a cost.

- UK MoD has had many "reform initiatives" – e.g. Requirements Engineering with "throwing Requirements over the contractual wall". In the US the Navy followed this pattern in the early 2000s until a series of disastrous acquisitions led to "USN (NAVSEA) taking back control" followed by an initiative to restore design/acquisition management skills. We could argue the UK's DE&S has largely lost its "intelligent customer" capability, leading to few units and severe performance drop offs. This loss of intelligent customer capabilities is also very bad for industry.

- The recent UK aircraft carrier procurement through a joint industry/MoD "Carrier Alliance" was reasonably successful commercially, but a greater legacy of success could have been achieved by making more considered decisions as the design progressed. Lessons from the North Sea energy sector on greater risk/gain sharing could have realised even greater benefits.

- Modular approaches seem to work better in aerospace than the maritime one: a question of scale and system level or maritime domain issues, such as the lack of prototypes and non-production line assembly (shipbuilding more like civil/chemical facility construction).

- Too often the procurement approach is to focus on optimising part of the capability being acquired. This is often focused on saving initial procurement cost, even taking out significant war fighting capabilities in the "hope it won't meet the full "hot" threat". This is not a front-line view of what value is.

- Often such "cheap and nasty" solutions (under crude "Gold Plating" cries) are expensive to operate: some ships have had an arbitrary ceiling on complement, so then could not operate

without taking all complement margins out, and these "training" margins had to be put into other ships, making them more costly. The cost of the total fleet increased to save individual ship class procurement costs.

- One good summary of aerospace practice at the most complex end is the famous '14 Rules' of Lockheed's Skunk works. They were seen to have some relevance to the design of fast small maritime vessels (HSV) with less novel technologies in high end aerospace practice, characterised by: "simple brief systems specifications" (with three critical performance parameters); focus on engineering design; a concurrent engineering approach; and early development of prototypes.

- The issue of Skills, covered by Michael Weatherburn, suggests calling for a UK equivalent to the French Corps de L'Armament. The nearest to this in the UK was the Royal Corps of Naval Constructors, which struggles to survive with its scope and autonomy severely curtailed by both "reforms' criticised above and an alleged animosity from the Civil Service against any engineering elite as a threat to the classical generalists, as the neutering of both Fulton and Finneston Reports indicate.

- A recent paper by Morais seem to identify the crucial issue with acquiring and owning complex systems is that "people and culture matter more than processes and tools", whereas MoD's procurement practice has (apart from the Services "people ethos") been typified by an obsession with process and a belief in "one size fits all", ignoring the need for domain knowledge. Tools, however sophisticated AI may become, require intelligent users/interpreters, otherwise "Rubbish in = Rubbish out". Culture means recognising staff matter – pay and promotion is only part of the issue, symbolic thanks and attention/commitment to career development with investment in Merit Promotions/Fellowships/ exchange programmes pay dividends yet are the first things cut.

Finally, to quote Petronius Arbiter, reorganisation is not the answer, as it disrupts the essential role of knowledge creation and retention at the heart of design:

"We trained hard ... but it seemed that every time we were beginning to form up into teams we would be reorganized. I was to learn later in life that we tend to meet any new situation by reorganizing; and a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency, and demoralization."

Low Cost by Design (LCxD) is a network bringing together researchers who seek to explore how good design can lead to lower cost complex system acquisition.

LCxD addresses this challenge through a range of interdisciplinary work which crosses the traditional boundaries of engineering, management and the humanities.

Projects (and funding body) that LCxD members have worked on:

- Costing Future Complex & Novel Projects - Jul 2015-Feb 2017 (EPSRC & Dstl in kind)
- Air System Programme Data – Mar 2016-Nov 2016 (Dstl/CORDA)
- Studies in association with BAE Systems regarding Air Defence concepts and requirement drivers - Sept 2016-Nov 2016
- Policy for Aerospace Industrial Strategy - Feb-July 2018 (Higher Education Innovation Fund)

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