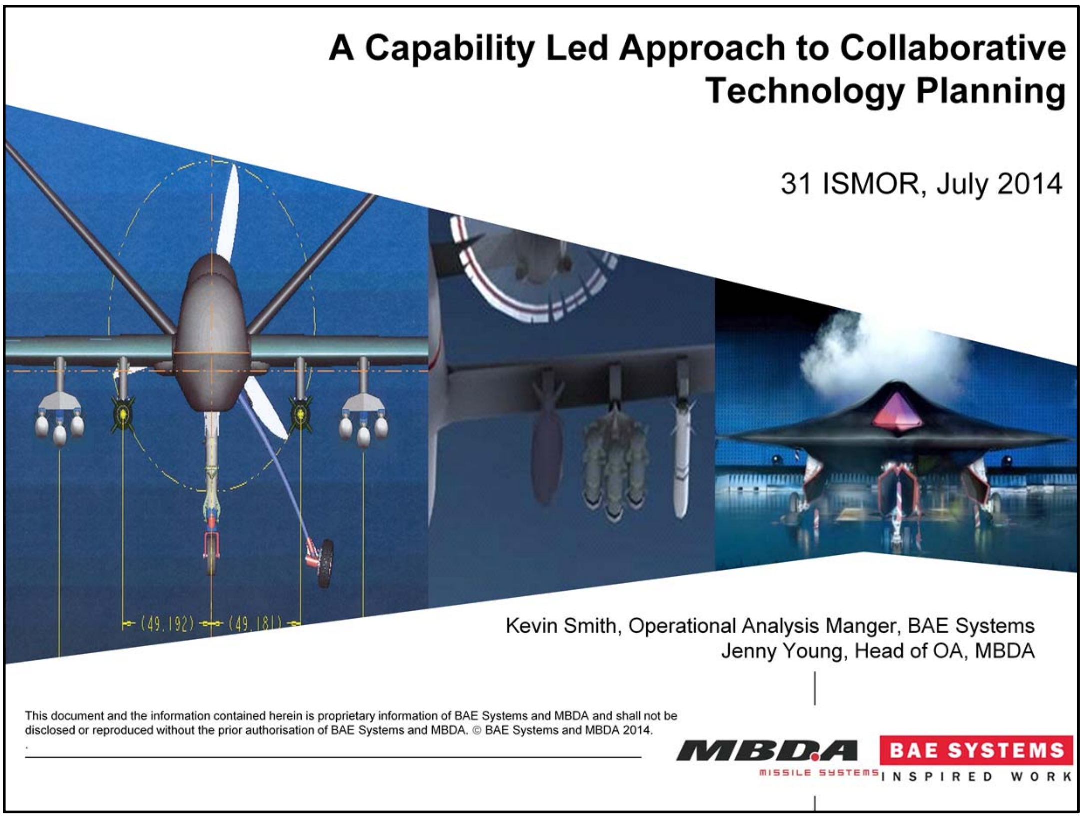

Kevin Smith and Jenny Young are the heads of Operational Analysis within BAE Systems MA&I and MBDA respectively. Today, we are presenting about a joint piece of privately funded work carried out during 2013, where the objective was to identify common areas of technological development to realise a vision of strategically aligned UAS and weapons route maps.

The work we are presenting engaged the broader Future Projects, Research and Engineering teams to determine the key areas of technology, or concepts of mutual interest, but the key focus for today is the heavily top down approach that was taken – i.e. driven by the needs of the Market Customers.

Contents

- Context Setting
- 8 Step Analysis Process
  - Logical and traceable route to identification of technologies of interest
- Outcomes
- Summary

We will start by introducing the broader business context that led to this work being commissioned. Then we introduce the key steps in the analysis process followed, by a detailed walk through of each of the analysis steps.

Finally we will draw out some of the key messages from what we achieved and leave you with a summary point before taking any questions.

Context Setting

- Air platforms and missile systems have separate planning and development cycles
  - Long lead times
  - Long In-Service Life
- Risk that weapon system potential can not be realised & platform capability is constrained
- Essential for BAES & MBDA to work together to plan for the future
  - Limited funding, limited future programmes
- This paper describes the process that has been undertaken to develop a joint technology roadmap
  - Collaborative
  - Capability driven
  - Explores the Platform / Weapon / enabling ISTAR trade-space.

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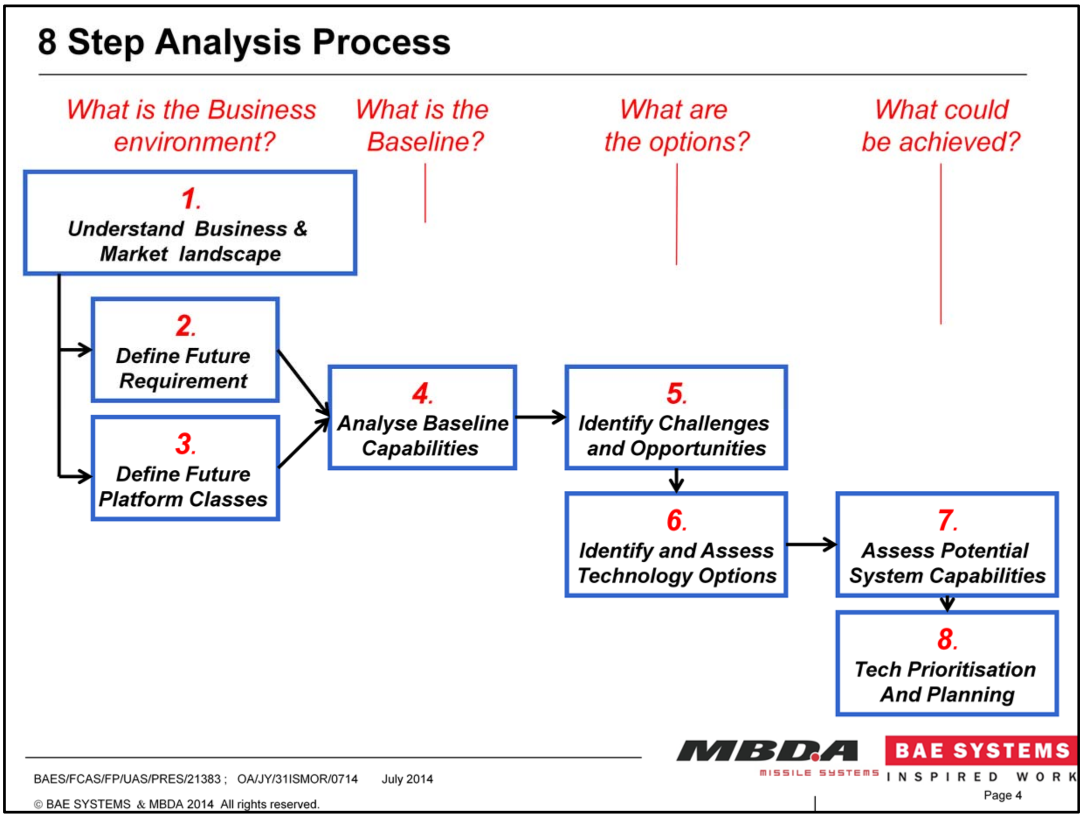
The focus of this joint work was Unmanned Air Systems and their weapons, where weaponisation is felt to be appropriate. For a combat UCAV this may seem obvious, but only quite recently have we seen surveillance UAVs introduced into service, that have subsequently been armed to provide a Combat-ISTAR capability. The only option available then was to clear the carriage of inventory weapons onto those platforms to create a weapon system.

But looking to the future, this could be done differently to maximise the capability of rationalising fleets of assets? How might such system concept thinking evolve? And how do we plan for it?

Platforms and missile systems have separate and long planning, development and in-service life-cycles. Historically, platform design and development assumes a legacy weapons set to drive the future solution; there is little opportunity to develop a platform and weapons system that creates synergy, i.e. is more capable than the two parts added together.

Furthermore, as the number of combat and weapons system programmes reduces in the West, due to limited defence budgets and lack of direct military threat, Industry needs to look harder at exportability and the need to offer novel and discriminating capability in our future Total Weapon System concepts.

Hence the collaborative approach taken here between BAE and MBDA. It is Capability driven, but more importantly a System of System approach exploring the trade-space across the platform, the weapon, and where appropriate the ISTAR component, and integration required for the whole capability chain to operate successfully.



The high level process is really in 4 parts –

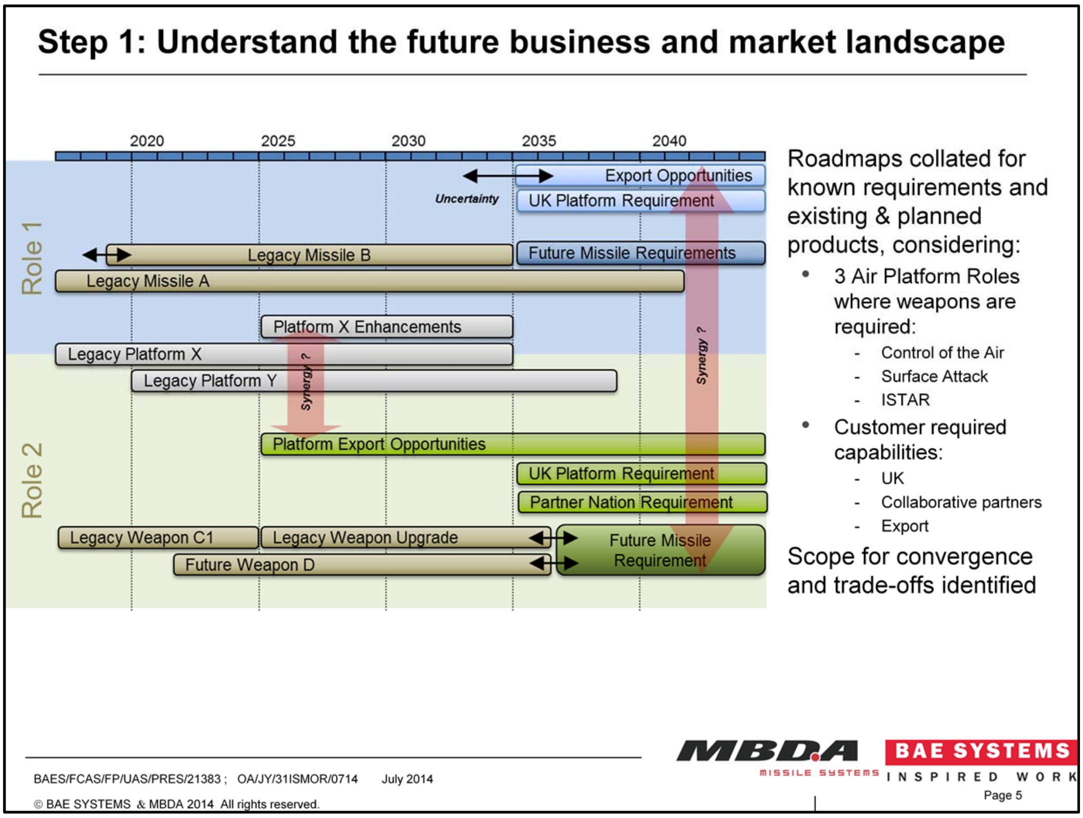
1. Firstly to understand the Customer's requirements and the range of programmes that might exist, noting the uncertainty of where Future programmes might evolve. The business landscape acknowledges that the UK MoD is our primary Customer for UAS and weapons, but also that export programmes need to be considered. Innovatively we considered the potential to weaponise a variety of future platform classes that might be developed … in order to understand their potential capability.

2. Secondly we established the baseline capability that would result from the contemporary approach to integrating the legacy and planned weapons set, to the extent currently envisaged, onto the set of platform classes – this reflects the baseline outturn capability without further intervention.

3. Thirdly, we challenged each system to ask how it might be developed further, or differently, to provide additional capability, identifying and assessing additional technologies or sub-system concepts. This creates a logical set of enhancement options.

4. Fourthly, we assessed the potential of the enhancement options and then prioritised and grouped the new technologies to create Technology Development Programmes (TDPs)

Jenny will now describe each of the steps in more detail.



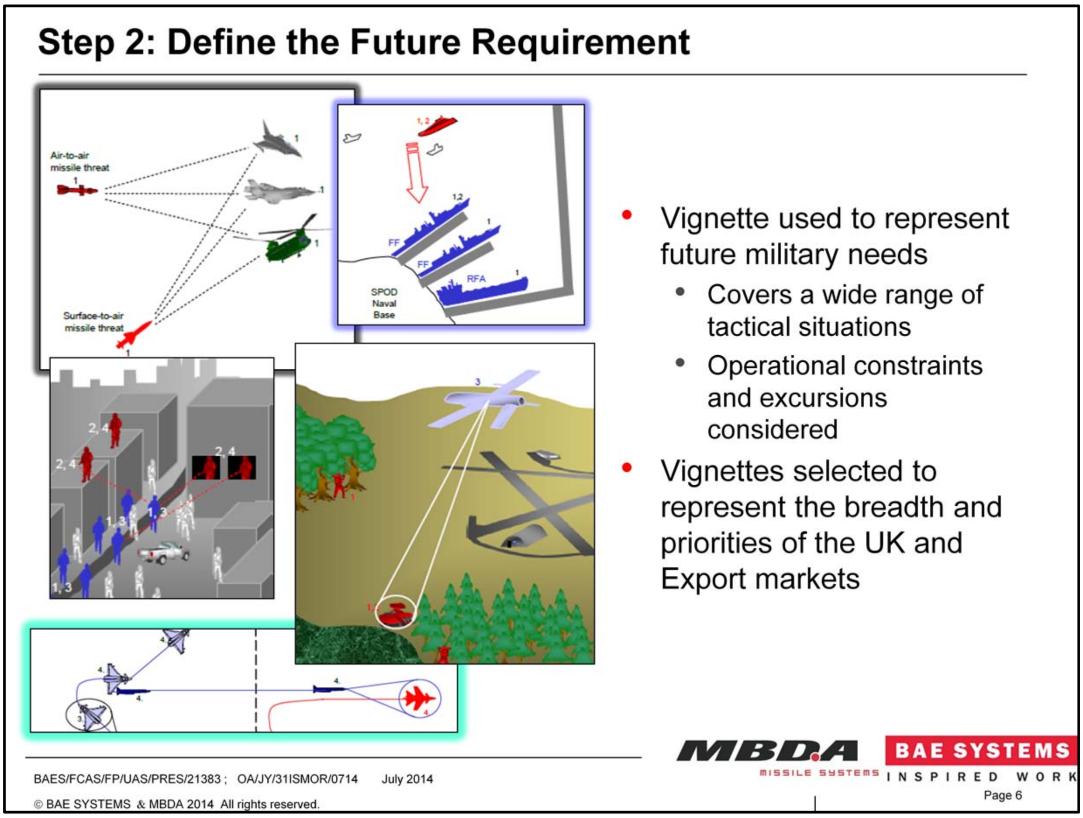
The first step we undertook was to better understand the future business and market landscape, and we captured this in a roadmap type diagram similar to the one shown here. We were only concerned with the Air Platform roles where weapons may be required, so we focused on 3 fundamental Air Power roles: Control of the Air, Surface Attack and ISTAR.

We then added legacy weapons and platforms, against each role based on their expected in-service life (shown grey and brown).

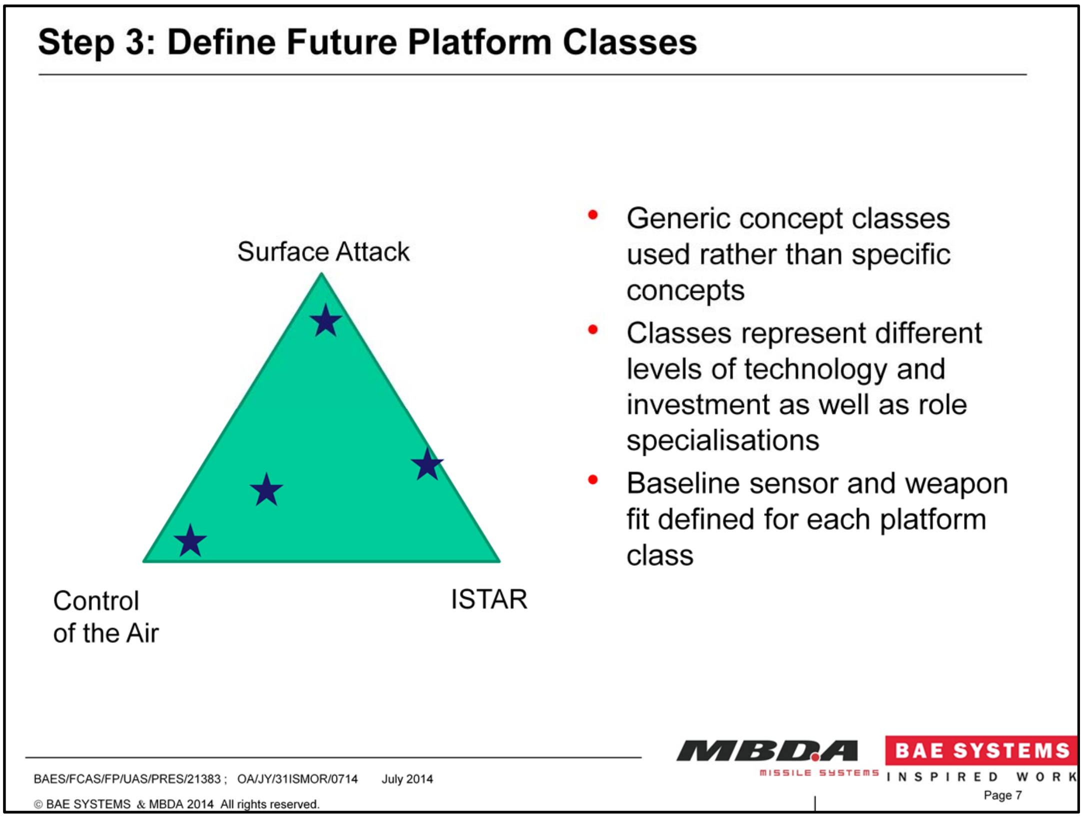
Enhancements, future requirements and business opportunities were then identified based on our understanding of UK Customer Requirements, the requirements of collaborative partner nations and those of potential export nations.

As you might expect, there was uncertainty around the timing of some events, and this is shown by the black arrows.

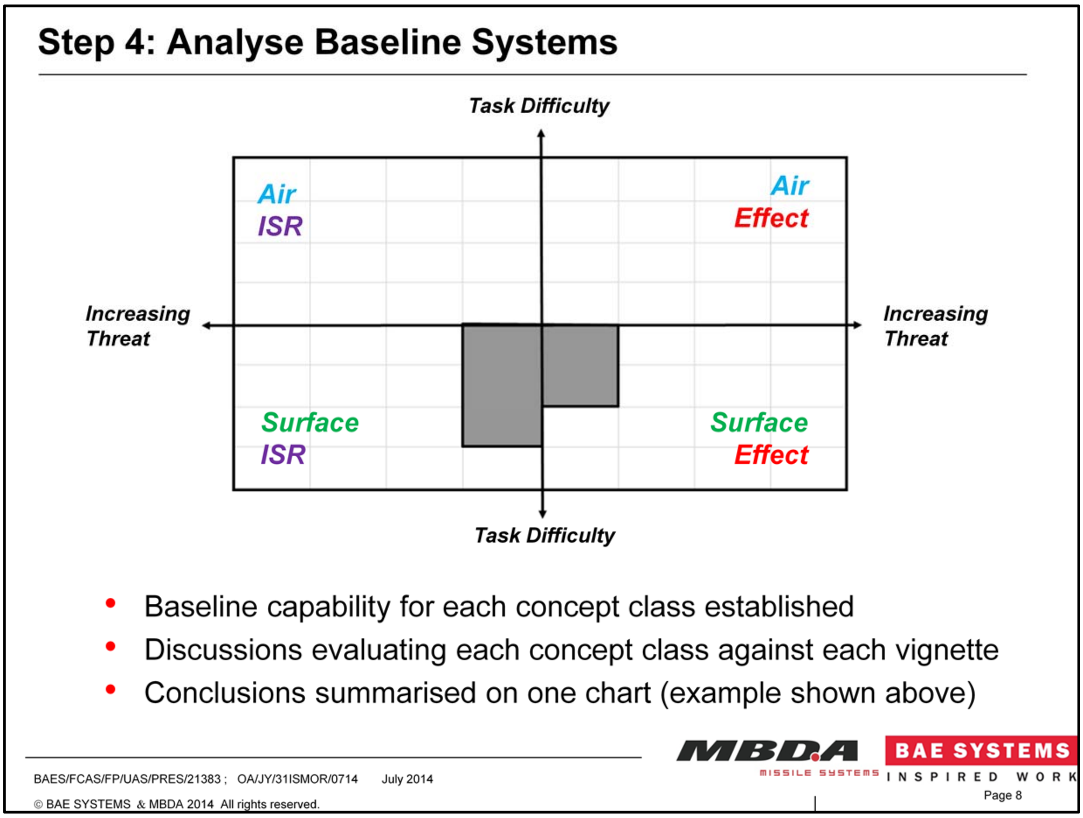
The scope for convergence and trade-offs between these future military needs was then considered, this is shown by the red vertical arrows which link areas that could potentially be met by a single solution. In practice we know that we need to find a significant degree of synergy, as there is not sufficient funding available to develop and acquire multiple platforms and large numbers of different weapon types. Solutions that can meet multiple roles for multiple customers are essential.



The second step was to articulate those future requirements in more detail.
This was done using a series of target based vignettes, each of which describes a typical tactical situation that a future air platform will need to undertake. Each vignette consists of a target, in an operational context, with supporting information that will influence the use of the platform and weapon, such as the availability of ISTAR information, collateral damage constraints, and the use of countermeasures concealment and deception by the enemy. A range of variations and excursions are also included, so each vignette is not a single spot point. Illustrations, such as those shown here are used to help visualise the situation and make each vignette memorable.
This approach of using vignettes to represent requirements is widely used within BAE Systems and MBDA and has been presented at previous ISMOR.
A pre-existing set of vignettes that summarised likely future weapons system requirements was available, and a subset was selected by the team. This subset is representative of the military needs for future air platforms, based on our perception of the priorities for both the UK and export markets.



The third element of inputs to the study concerns the future platform classes.
Here we took the decision to work with generic air platform classes, rather than specific concepts. This allowed us to maintain a broad perspective and keep options open throughout the study, as well as work at a lower classification which is always a benefit for distributed team work.
Each platform concept class represents different levels of technology, investment and role specialisation. For example, two of the concept classes studies were platforms specialised for control of the air, one relatively small current technology defensive fighter airframe, one larger, more advanced offensive fighter type.
A total of 7 air platform concept classes were studies and as in step 1, they spanned the 3 roles of control of the air, surface attack and ISTAR. A baseline sensor and weapon fit was assigned to each platform class that was appropriate to their primary role(s).



One of the things we wanted to understand was how much the capability of each concept class could be ‘stretched’, by adding new systems and technologies – so first we had to establish the baseline capability offered by each concept class.

This was done by assessing each of the concept classes in each of the vignettes through a series of discussions. The overall results were summarised on the type of graph shown here.

The right hand side shows the capability to generate different effects on the target.

The left hand side shows the Intelligence Surveillance and Reconnaissance capability.

The top half shows the capability against air targets.

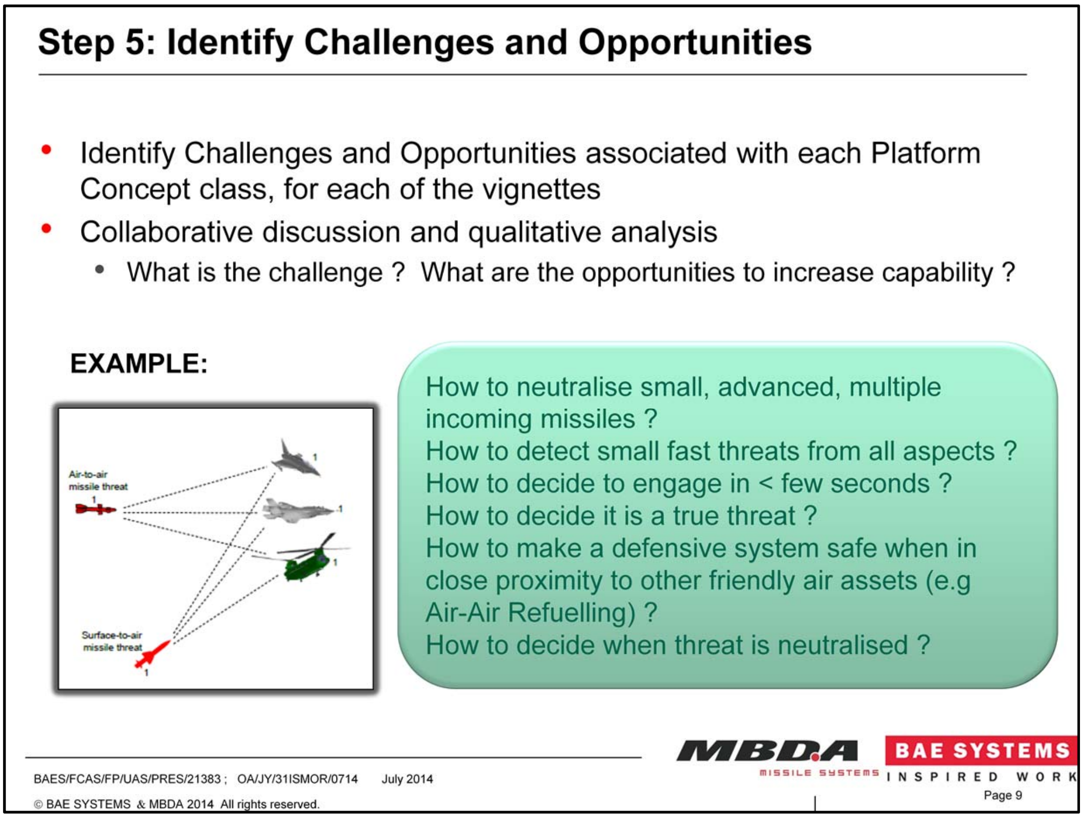
The lower half shows the capability against surface targets.

Moving away from the origin on the X axis (in both directions) represents increasing threat levels.

Moving away from the origin on the Y axis (in both directions) represents ability to conduct tasks that are increasingly difficult in the respective domain.

This example shows the typical capability that might be expected from a current MALE class tactical UAS armed with a short range weapon. It has good ISR capability against surface targets, and can engage small mobile and re-locatable targets in the local area – however it can only do this in a permissive environment and would be vulnerable in a higher threat environment.

The vignettes provided a way to illustrate and articulate the challenges in different parts of this problem space, and ensured a common understanding for everyone involved.



So, we have now established the baseline capability for each of our platform concept classes. The next step is to consider all the things that each concept class *can't* do, and identify the challenges and opportunities that would result in better capability for that platform class.
A large number of challenges and opportunities were identified through a series of workshops.

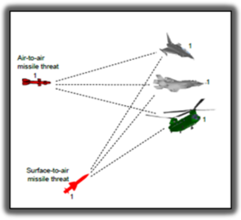
If we illustrate the process with just one example – Air platforms of all types may be subjected to attack from air-to-air or surface-to-air missiles. A layered approach is usually taken to platform survivability with multiple systems and design features that reduce the risk of the platform being detected, engaged and damaged. However – not all these approaches can be applied to all types of concept class – some platform classes have limited payload capacity or physical space to take extra systems, some may lack speed and agility to evade threats, or countermeasure systems may not be effective against all types of threat.
We therefore identified a challenge (or an opportunity depending on your point of view) : How to neutralise small, advanced, multiple incoming missiles ?
Breaking the problem down identifies further challenges:
How to detect threats that are physically small and fast ?
How to respond quickly enough ?
How to *actually* neutralise the incoming missile ?
How could we do this over all aspects – 360 degrees coverage would ideally be required ?
How to make a defensive system safe, particularly when the platform may need to fly in

close proximity to other aircraft e.g. for air-to-air refuelling ? Especially if it is unmanned ? And so on…

You may be thinking – surely, there are already lots of ways to protect aircraft, do we really need more ?
Well – we are not sure that we do need more, but this idea, like many that were discussed during the study, if it could be successfully implemented, would have the potential to revolutionise aircraft design, and change air-to-air combat and requirements for missile systems.
So, we need to understand if technological solutions are feasible.

Step 6: Identify and Assess Technology Options

- What technologies are available to realise each opportunity ?
  - Including new system concepts as well as re-use / upgrade of legacy systems
- Options identified and investigated through consultation with company experts, system level trade-offs identified
- Assessment criteria:
  - Technology Readiness Level – How mature is the technology ?
  - Investment Requirements – ROM Cost to TRL 6 – Low / Medium / High
  - Potential for the technology to meet the need – Low / Medium / High
- Technologies grouped to provide a consolidated list



Gun based solution	*Technologies:* *All aspect detection and cueing at Xkm* *Integration to allow all aspect launch* *Course corrected bullet*
Anti-missile Missile System	*Technologies:* *All aspect detection and cueing at Ykm* *Integration to allow all aspect launch* *Miniaturisation to maximise payload*

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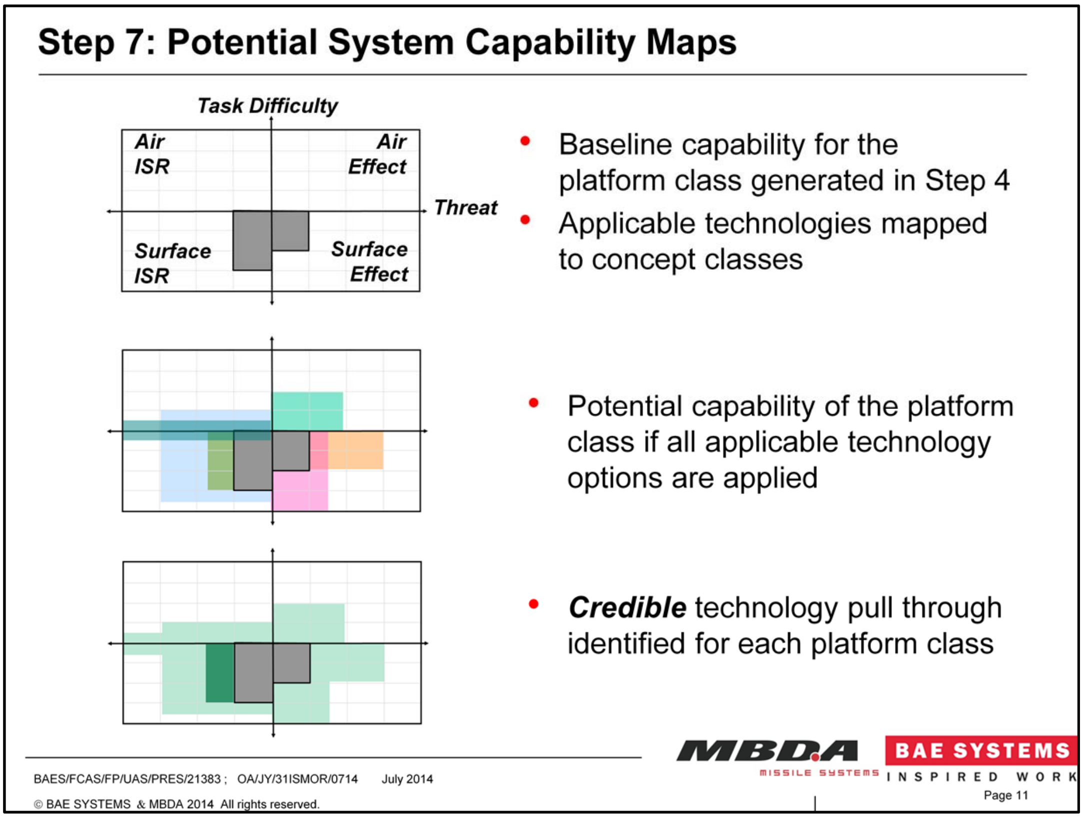
That brings us onto step 6 – Identify and Assess Technology Options.
So what technologies and system options are available to realise the opportunities we have generated ?
The investigation was conducted by consultation with experts within our 2 companies and included new system concepts, as well as re-use and upgrade of legacy systems. Frequently different types of solution would emerge to an opportunity, and so system level trade-offs were identified. Continuing with our example, we have an illustration with two possible solutions, one based on a gun system and one based on an anti-missile missile system. You could imagine other types of solution too, for example Laser DEW, but both types of system here would require a form of integration that would enable 360 degree coverage, but the different intercept speed profiles (and hence timelines) associated with the systems would give rise to different cueing and detection requirements. A lot of existing missile technology could be applicable – but could it be miniaturised to allow a sufficiently large number of missiles to be carried ? And what might a laser DEW system offer?
So, you can see how the requirements for the technologies begin to evolve and specific technologies can be identified.
Key aspects of the process are:

- The ability to flow down requirements and trade-offs to create a link between military needs and technologies
- Taking a holistic approach that combines consideration of both the platform and weapons system aspects

Once technologies had been identified, they needed to be assessed. The purpose of this assessment was to act as a filter to ensure only the most promising technologies were taken forwards, so only 3 criteria were used that could be quickly assessed using the judgment of the team and technology experts. These were:

- The Technology Readiness Level (TRL), this is a standard scale (1 = Basic Research, 9 = In Service Equipment) to measure the maturity of technologies and was originally developed by NASA.
- The investment needed to take the technology from its current TRL level to TRL 6. TRL 6 is demonstrated within a representative environment and is the maturity level that is generally required for a Main Gate decision point by UK MOD. Very rough order of magnitude estimates were made and categorised Low , Medium or High, for example 'Low' was < £10m.
- The 3rd category was the overall potential of the technology to meet the military need, assuming that it could be successfully matured. Again this was categorised as Low, Medium or High.

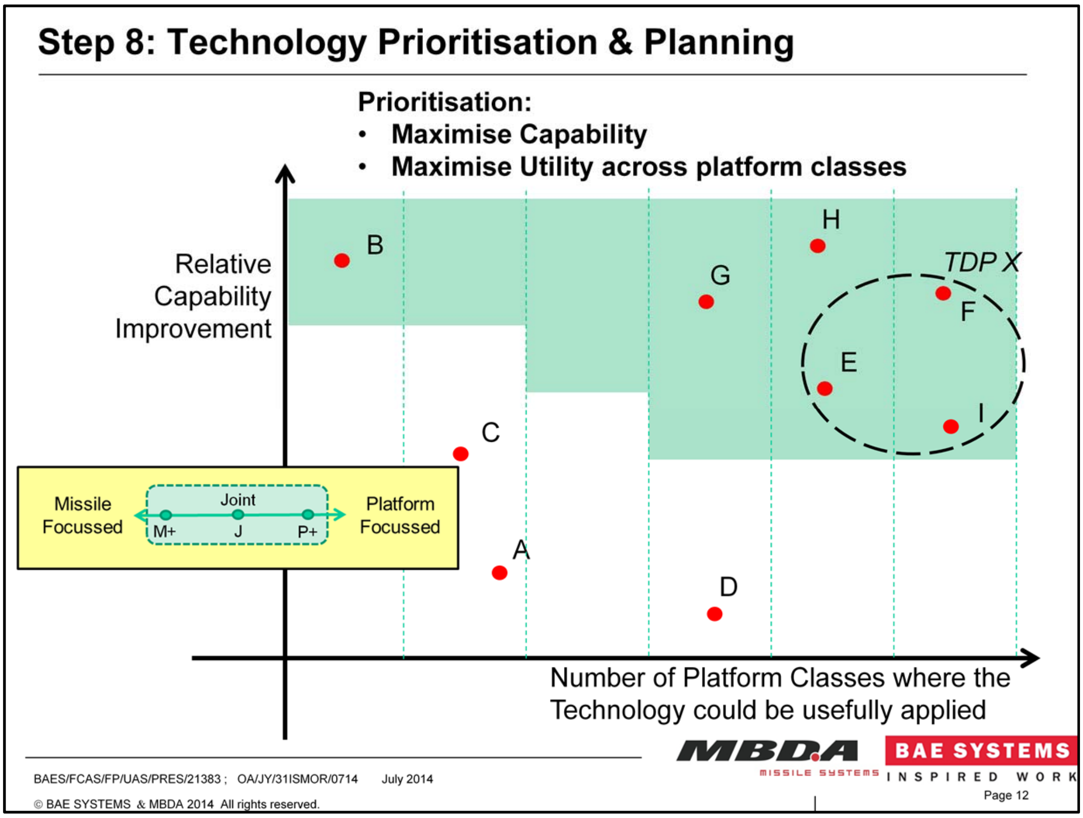


The next step was to find out how all the technologies could be applied to each platform class. This took into account the physical constraints of the platform, such as its size, speed and agility, as well as the supporting systems that would need to be in place to enable the capability improvement.

Results were presented in the same format as the baseline capability that was described in Step 4.

This was done in 2 stages, first all the technologies which offered benefit to a platform class are shown, and then the options offering credible pull through of technology were highlighted. These are the technologies that not only offer significant capability benefits (shown by the relative size of the area) but also met appropriate technology maturity and investment criteria. In summary, they are the options that were readily achievable.

This process was applied to each of the platform classes in turn to build up a picture of how the capability of each platform class could potentially be expanded from its baseline to provide greater capability. Results showed the overall potential capability for each platform class irrespective of investment, as well as the ‘quick wins’ indicated by the credible pull through options.



By now we had a good understanding of how technologies could benefit a range of potential platform classes. Some of these technologies were associated with legacy and future weapon systems, others were related to the platform, but many were of joint interest to both MBDA and BAE SYSTEMS and these were the ones that we wanted to identify so that we can work together to develop more effective systems that are optimally integrated.

But we don't know the future, so we have to choose technologies that keep our options open and are applicable to as many of the future platform classes as possible. We therefore plotted the relative capability improvement that each technology offered against the number of platform types where it could be usefully applied, and this enabled us to prioritise the technologies. In the figure here, you can see illustrative technologies labelled A to H, and the technologies in the shaded green area were the ones taken forward.
Technologies with a common theme were grouped together to form proposals for Technology Demonstration Programmes (TDPs). In total 7 potential TDPs were defined, and each was defined in terms of a outline statement of work covering aims, scope and the benefits that could be obtained by completing the work.

I will now hand back to Kevin to summarise.

Outcomes

- Innovative process developed
- Jointly agreed study proposals that can be carried forward for a range of purposes
  - Robust to changing priorities
  - Capability enhancement is an underlying driver for technology planning
- New system concept ideas generated
- Opportunity for technologists to network

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By conducting this activity together, we have developed an innovative process that establishes the development potential of any system class, considering both platform and weapons system features, and also the potential enhancements of co-operating systems outside of the 'Weapon System'. This initial study hasn't answered all the questions, but it has raised a number of issues worthy of discussion with the Customer community.

The primary outcome is a set of TDPs, that we believe will open up further options for the development of Total Weapon System concepts. The contents can be prioritised in different ways, dependent upon the programme priorities going forwards.

By working together it has been possible – through sharing the 'art of the possible' across platforms and weapons systems - to identify promising new concepts which exploit the new technologies and maximise capability.

The approach is largely top down, but enables the technologist community to table their ideas and network across both companies.

Summary

- Technology planning approaches seldom give full consideration to the resulting military capability
- A process has been developed and successfully applied to ensure capability is considered as part of a collaborative technology roadmap
- BAE Systems & MBDA are working together to maximise the capability of air launched weapons on future air platforms

In summary, we believe we have developed and exercised a process that should overcome the limitations of the conventional approach (i.e. separate development programmes) to enable optimised Total Weapons System concepts to be developed.

We have used that process to identify the Key Technology areas that need to be addressed early to realise the synergies inherent in optimising military capability through a set of TDP proposals.

Finally, we plan to continue this collaborative approach in our respective businesses.

Thank-you for listening. Any questions ???