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Proactive estimating: an analysis of sixth generation aircraft

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Abstract

Fed up with being reactive to cost estimating and forecasting requests? Had enough of being last in the queue for time and resources? Dismayed at being consulted at the last minute for an opinion on the cost? Seeking a new approach to cost predictions? Consider the proactive approach!

Rather than waiting for requests for an estimate at the end of a bid or study it is time to start leading. Cost staff are a value-adding commodity, they have the ability to predict the future: well, almost!

This paper will explore some of the options and alternatives which as a cost community we should be pursuing. It will examine the programme, procurement and technical options that we should present ahead of the remainder of the engineering and project management scrum. It will examine the big, first order assumptions which we should be considering to ensure that we have a voice and that the cost is considered at the forefront of the decision process.

As an example the paper will consider the options for a sixth generation fighter capability. It will explore the alternatives from a cost perspective and set a direction for the future direction of travel with regards to the air domination capability. In short, it will set a proactive estimating case study to ensure that the cost community is forward leaning and not the last people to be asked an opinion on the topic. Though based upon an air project, the approach will be equally applicable for land, sea and space capabilities.

Keywords: macro-parametrics, micro-parametrics, cost model, FACET, TruePlanning.

Introduction

This paper will consider how cost estimating staff within an organisation can make greater contributions to the decisions made in their organisations and the future direction of acquisition projects. QinetiQ has a consulting business called Advisory Services (AS) which promotes the application of cost engineering and other disciplines related to complex decision making.

QinetiQ was formed in July 2001, when the UK Ministry of Defence (MOD) split its Defence Evaluation and Research Agency (DERA) in two. The smaller portion of DERA was rebranded Dstl (Defence Science & Technology Laboratory) and this remains part of the MOD. The larger part of DERA, including most of the non-nuclear testing and evaluation establishments, was renamed QinetiQ and prepared for privatisation. QinetiQ became a public private partnership in 2002 [1.].

As a people-based business, our service offerings account for the majority of sales. In addition our products division provides technology-based solutions on a global basis including offices in Australia and Canada. Through their technical expertise, know-how and rigorous independent thinking, our engineers and scientists are uniquely placed to help customers meet challenges that define the modern world. These challenges include affordability and seeking value for money (VfM).

A problem within the cost community is the reluctance of cost practitioners to promote their capability [2.]. It is common for the cost activity to be the last part of the bid, study or proposal. Once the project or bid manager has organised the technical team to consider the requirements, establish the technical service or solution, finally it is handed to the cost practitioner to consider. It is not possible to estimate the cost of a capability or requirement so it is common for a systems engineer to be appointed to establish the conceptual design or solution that will satisfy the requirements. From this concept the cost practitioner is required to determine the costs. As a result this is generally late in the schedule, one of the last activities prior to the study results being produced or the bid review being conducted.

As a consequence of this last minute effort the cost practitioner is commonly forgotten in the preparation of the project, proposal or bid review. They are still refining and honing their costs when the team are rehearsing their presentation and its contents, thus we find the line up as shown in Figure 1 with the management at the forefront of the presentation conducting the proceedings and selling the excellent solution produced by their technical team. This is followed be a technically baffling insight where the technical team try to smash many years of complex technical development into 30 minutes and 20 slides! But where is the cost practitioner? Probably working in the background or already deployed on the next task.

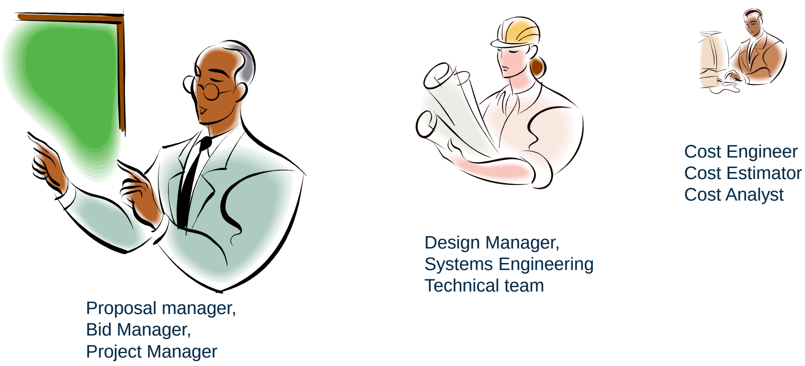

Figure 1: Problem - the general issue with cost staff

The cost practitioner is generally not seen. The discipline of cost estimating is generally reactive to the demands of the business, and even in the most mature organisations [3.], reactive to the needs of the business. Cost practitioner do not sell themselves generally, they are conscientious and hardworking in the backroom. This needs to change; we have a lot to give in terms of advice and insight into a project or service.

As a result of generating a cost that is credible and justified a cost practitioner will conduct a significant investigation into the product or service. They will break it down into a logical structure, for example a product, work and cost breakdown structure. They will scrutinize the elements of the activities to be conducted, establish the uncertainty and risks. At the conclusion they will not just have obtained a comprehensive understating of the cost, but also the product or service.

Figure 2: Balance - an even distribution of participation

So how do cost practitioners make an impact, how do we change from reactive to proactive? Or at least generate a more balanced participation (Figure 2).

Proactive estimating

It is highly likely that businesses will build on their experiences. A good successful business will develop a Business plan which will continue to build on their historical strengths. As such it is highly likely that within the cost community that cost practitioners are asked to estimate the same types of activities for the same types of technology repeatedly. This has to be inefficient, so why not capture the thought processes that they repeat and store those thought processes in an estimating tool? This is the inspiration behind proactive estimating [4.].

Developing this idea, once the cost practitioners have captured this knowledge it becomes possible to pre-empt the requirement of the organisation for cost estimating tasks. It should be possible in industry to produce Should-cost estimates for similar products and services and in government it should be possible to anticipate the capabilities that require replacement and the options to be considered, together with the should-cost estimate.

The desirable outcome of Proactive Estimating within industry is to stop asking staff to estimate their activities and present them with an estimate based upon a parametric cost model. In government the outcome is to anticipate the options to be cost forecast to stimulate the discussion and debate therefore generating an interest in the analysis rather than being reactive to a request [5.]. It is also hoped that from the perspective of the cost community taking the initiative to start this work it is more likely that more time is given to the cost estimating activity.

Options and alternatives

Taking the defence domain as an example, there is a reasonable structure to the identification of options. Starting from the threat it is possible to conceive a capability need as shown in Figure 3. A Capability is the "*ability to generate a desired operational outcome or effect which is relative to the threat, physical environment and the contributions of coalition partners*." [6.] It is important to recognise that a capability is not a particular system or equipment.

Capability is delivered by Force Elements combined into packages by Joint Force Commanders and tailored for particular operations or missions. With consideration of the environment and the contribution made from coalition forces it is possible to determine the capability need and frame this in terms of the effect that is necessary.

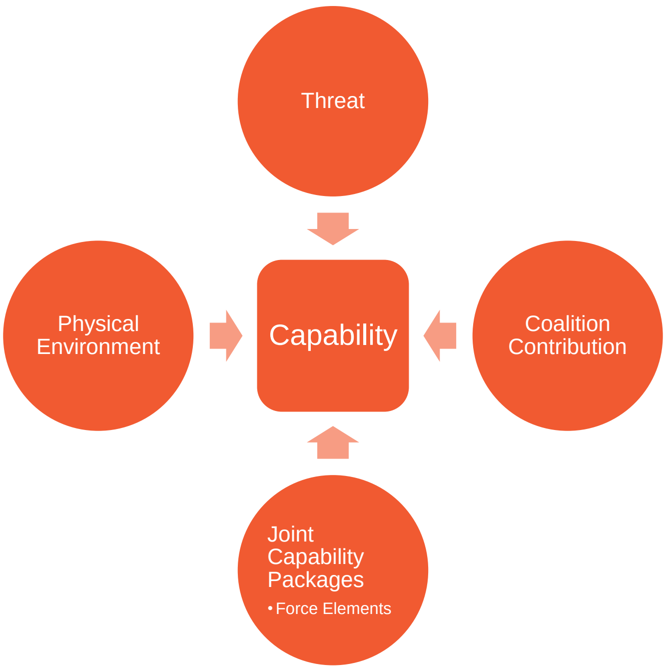

Figure 3: Capability - ability to outcome.

For this paper we will consider the air environment and the need for air superiority with the threat being enemy forces dominant in the skies above our troops. So the starting point is the air superiority capability, but to satisfy this capability there are a number of joint capability packaged that could be generated from force elements that could be deployed and acquired.

Joint capability packages are groupings for force elements that can be conceived to neutralise the perceived threat. These packages are formed from different force elements such as ships, aircraft, army formations and so forth. The physical assets are not enough it also requires the capability enablers such as training, personnel, information and so forth. The details of these capability packages require military judgement and operational analysis skills to define, but for our purposes the cost practitioner should not be deterred. Our approach might need to be simplified, but it is robust enough to produce debate. For the purposes of this paper the air superiority capability we can conceive has a number of force elements that could be deployed including manned and unmanned future systems.

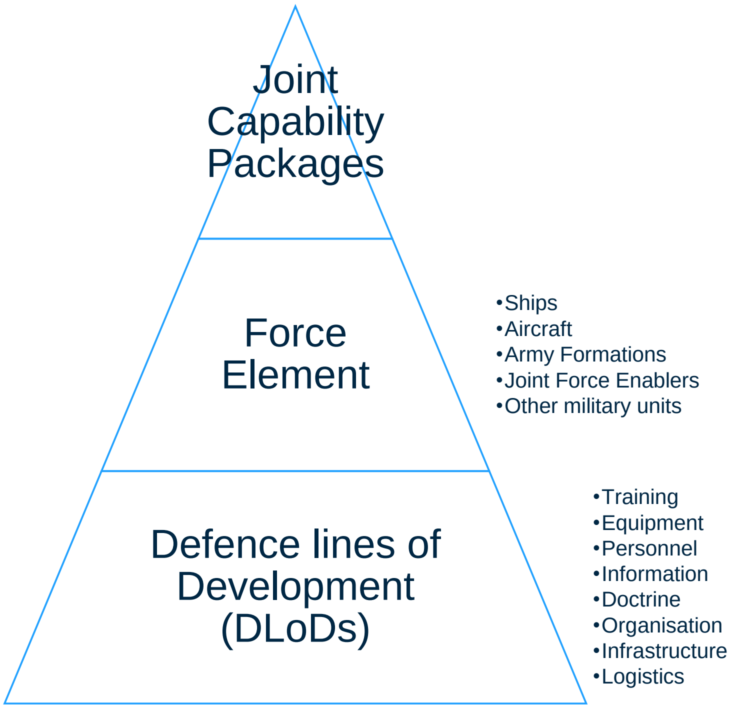

Figure 4: Force Elements - including the DLoDs

Having established the force elements that will be considered then the source of those elements comes next; where are you going to buy them? A simple analysis would be to consider in-country or sovereign sources versus international sources. The need for in-country design and manufacture are numerous including the need to secure supply chains, employment in the home market and retaining cash flow within the country. The arguments for international sources may include bridging the technology gap, cheaper / more productive labour and the need for coalition interoperability.

Once it has been determined if there are possible sources then it is possible to consider the next criteria which is collaboration. Will the force elements be sourced from a single entity or from multiple organizations in the form of an alliance or consortium? It is possible that the consortium approach may include sovereign and international entities. The advantage of a consortium is the pooling of the knowledge, rather than calling upon one organisation it is possible to seek the opinion of multiple SMEs, there is more flexibility, variety of experience and opportunities.

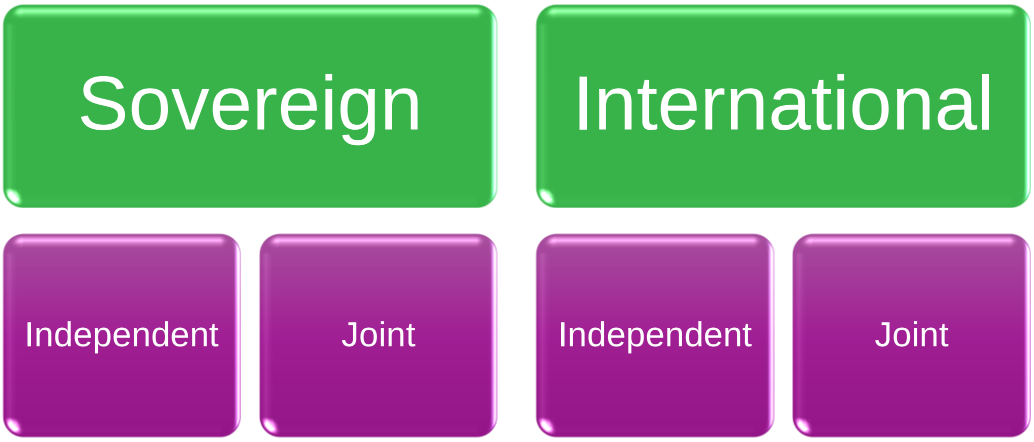

Figure 5:Source and Collaboration - further division of the options.

It is possible to see the effects of considering all these alternatives as a hierarchical organisation diagram, as seen in Figure 6. The logic of the breakdown lends itself to discussion and debate as the number of options or alternative grow.

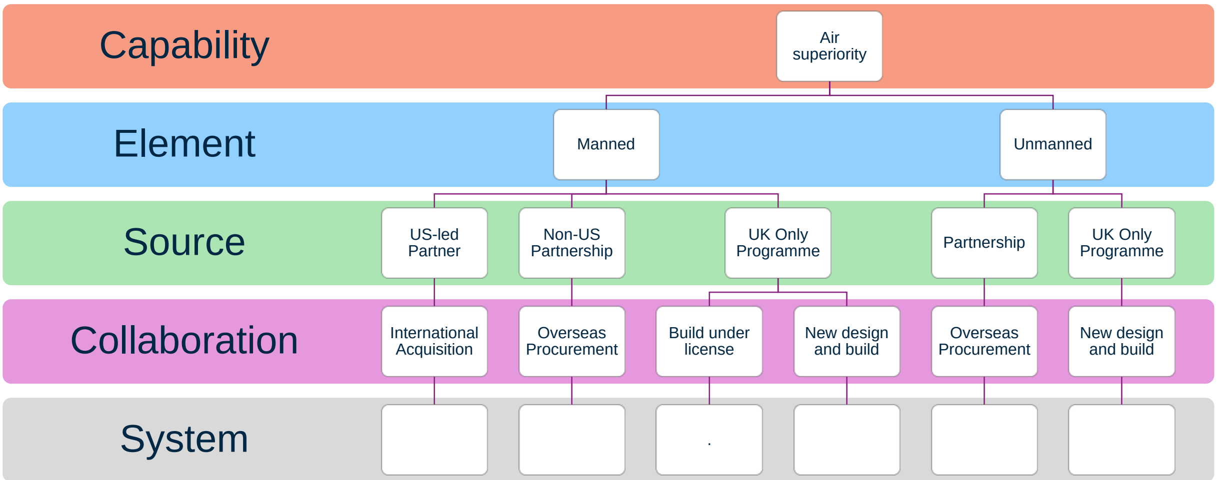

Figure 6: Options - the logical division of alternatives.

Now that the types of options are determined it is possible to consider the systems that could be acquired through the collaboration, via the source, to build up the force elements that will satisfy the capability. For the purposes of this paper we will consider the systems available in a macro-parametric cost model called the Family of Advanced Cost Estimating Tools (FACET). This has been implemented as True FACET in the TruePlanning cost modelling framework from PRICE Systems.

Each available cost model in True FACET has an icon associated with it as shown in the examples within Figure 7. For the purposes of this paper we will utilise the same systems, but it would be possible to mix the systems in a real study so the force element could be a combination of manned and unmanned systems in the force element if this was deemed to be a viable alternative.

Figure 7: Systems - the hardware.

So having established the logical structure for our options, it now just leaves the cost practitioner to populate the input parameters of the cost model with performance, design and programmatic information to generate the cost of the alternative options.

Example air combatant capability

The UK Joint Combat Aircraft (JCA) was the requirement for a multi-role air superiority aircraft to be operated jointly by the Royal Air Force and the Royal Navy from both land bases and the new Queen Elizabeth Class (QEC) aircraft carriers. In 2001 the F-35b Lightning II design by Lockheed Martin was selected as the aircraft to meet the JCA requirement and provide the UK with a fifth generation air system. The UK is the only Level 1 Partner Nation within the System Development and Demonstration (SDD) phase of the Joint Strike Fighter programme, along with the US Services and is able to decide and agree the Requirements [7.].

The technical specifics of the F-35B are captured in Table 1 and represent the input parameters for our parametric cost model.

Technical		
Payload	15,000 lb	6,800 kg
Basic mass empty	32,300 lb	14,648 kg

Table 1: F-35b technical specification

The programmatic information needed includes the number of production items to influence the learning curve and these are captured in Table 2. The UK benefit from taking a number of aircraft from a larger production batch, which generates a lower unit production cost than if they were procuring on their own.

Country	Production
Italy	30 a/c
United Kingdom	138 a/c
US Marine Corps	340 a/c
Total Production	508 a/c

Table 2: F-35b production quantities

To demonstrate the validity of the parametric model applied to this problem, it should be able to reproduce the current F-35 figures, recognising that they are themselves only an estimate at completion and do not represent actuals at the time of writing this paper [8.]. The latest estimates are captured in Table 3 for the life cycle cost (LCC) of the F-35.

Life Cycle Cost	Then Year ($Bn)
Research Development Test and Evaluation	55.1
Procurement	319.1
Military Construction (MILCON)	4.8
Operating and Support Costs	1,123.8
Total Life Cycle Costs(LCC)	1,502.8

Table 3: LLC - the total life cycle cost of the F-35

The F-35 variants were supposed to be common in many of their components, but this has still led to a difference in the unit production costs. The most recent production costs are captured in Table 4 and provide another means of testing the parametric model used prior to utilising it for alternatives.

Procurement Cost	Then Year ($m)
F-35a (1,763)	100.6
F-35b (340)	122.9
F-35c (340)	110.7
Average Procurement Unit Cost (APUC)	130.6

Table 4: Procurement - the cost to manufacture all aircraft.

Using the technical (for example Table 1) and programmatic (for example Table 2) parameters for this project it has been possible to demonstrate that the cost figure in Table 3 and Table 4 can be reproduced. This step provides confidence that when alternative options are calculated using the same model that there is confidence in the output and the results can be compared on an equitable basis.

In Figure 8 it is possible to see the final structure of the alternatives that we will consider in this paper. This is not an exhaustible list, but a good starting point and the motivation is to prompt further discussion and detailed analysis. It is recognised that the cost community will not ultimately be responsible for the option selection; this structure is provided just to be proactive.

It is acknowledged that this short study considers just the aircraft options and not the complete capability. It excludes the weapons carried and does not include the enablers such as Airborne Warning and Control System (AWACS) or in-flight refuelling tankers that are necessary to sustain operations.

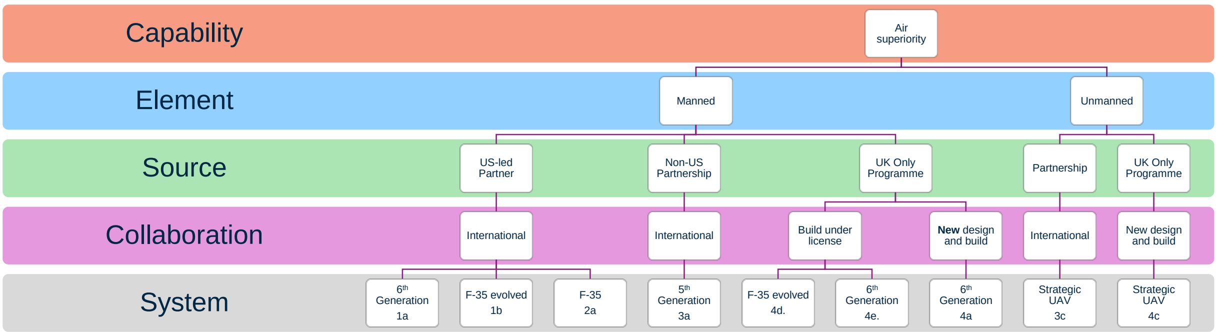

Figure 8: Options - the alternatives selected in this study

It is convention to number the options and categories them into a variety of different option types. Starting with the perceived lowest risk option (0. Do nothing) through to the more challenging options such as the application of unmanned air vehicles (UAV), Table 5 provides a summary of the final options that will be considered in this analysis.

Option ID	Description	Source / Procurement	Example
0.	Current state – Status Quo	Baseline	0. F-35
1.	Do minimum	International	1a. 6th Generation
			1b. F-35 evolved
2.	Do same as current	International	2a. F-35 in-service
3.	Do non-sovereign	International	3a. Non-US 5th Generation
			3b. Strategic UAV
4.	Do sovereign	UK Design and build	4a. 6th Generation
			4b. Strategic UAV
		Build under license	4c. F-35 evolved
			4d. 6th Generation

Table 5: Options - the high level alternatives.

To produce the analysis a macro-parametric cost model has been used [9.]. This has been selected as it provides life cycle costs at a high level which will provide an indication of the budgetary funding required for each option. From this high level approach it will be possible to down select to a smaller set of alternative options and develop a more detailed parametric cost model to refine the costs.

Based upon the payload[1] of the systems, then it is assumed that the systems will have a constant capability, however, the largest strategic UAV[2], Global Hawk, has a 540kg payload which would require 13 systems to deliver the same quantity of payload as a F-35b. This is even greater when considering a tactical UAV[3], for example the Mirach 26, which has approximately a 50kg capability, would require 136 systems to carry the equivalent of one aircraft. For the UK total capability this would result in 18,768 tactical UAV being required which seems impractical for production, maintenance, operations and other reasons. Therefore, only the Strategic UAV option will be taken forward and have costs estimated.

The production quantities and associated production rates for each of the options are shown in Table 6. This assumes a huge number of UAV (nearly forty thousand) are required for a collaborative programme with a respective high production rate to manufacture them all in the time scale (24 years) which is desirable.

Option ID	Description	Production quantity (all countries)	UK Production quantity	Production rate (Units per Year)
0.	F-35b	508	138	25
1a.	6th Generation	508	138	25
1b.	F-35b evolved	508	138	25
2a.	F-35b in-service	508	138	25
3a.	Non-US 5th Generation	508	138	25
3b.	Strategic UAV	39,150	1,738	1,600
4a.	6th Generation	138	138	25
4b.	Strategic UAV	1,738	1,738	315
4c.	F-35b evolved	138	138	25
24d.	6th Generation	138	138	25

Table 6: Quantities - the production quantities and annual rates

It is appreciated that payload is not the only characteristic required for air superiority and that speed, range, endurance and so forth will contribute to the overall capability selection. This analysis has assumed a constant capability, based upon payload, to enable the option to be compared on a whole life cost basis alone, in reality the measure of effectiveness (MOE) of each option would need to be determined through Operational Research (OR).

[1] This the total weight of the maximum weapon load the aircraft can carry.
[2] Unmanned aerial vehicle intended for strategic reconnaissance launched and operated by forces outside zone of engagement.
[3] Unmanned aerial vehicle intended for tactical reconnaissance including all vehicles launched and operated by forces within theatre.

It is possible to review the output of this analysis in the system as shown in Figure 9.

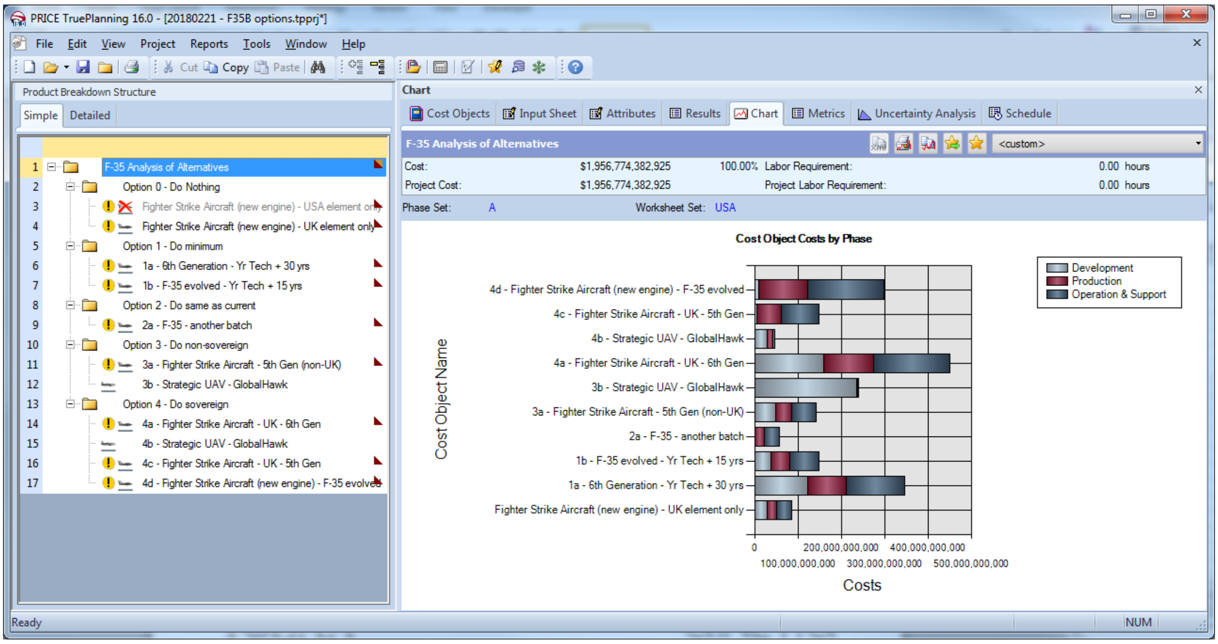

Figure 9: Results - a chart of the cost output in TruePlanning

However, these results can be exported and compared in Excel with error bars at 10% and 90% to provide an indication of the uncertainty in the cost estimates. Figure 10 shows all the options considered in this analysis in Then-Year Dollars that include the effects of inflation and reflect the price levels expected to prevail during the year at issue. This output is good for budget setting and financial analysis, but we need to remove the inflation effects to compare the options on a like for like basis.

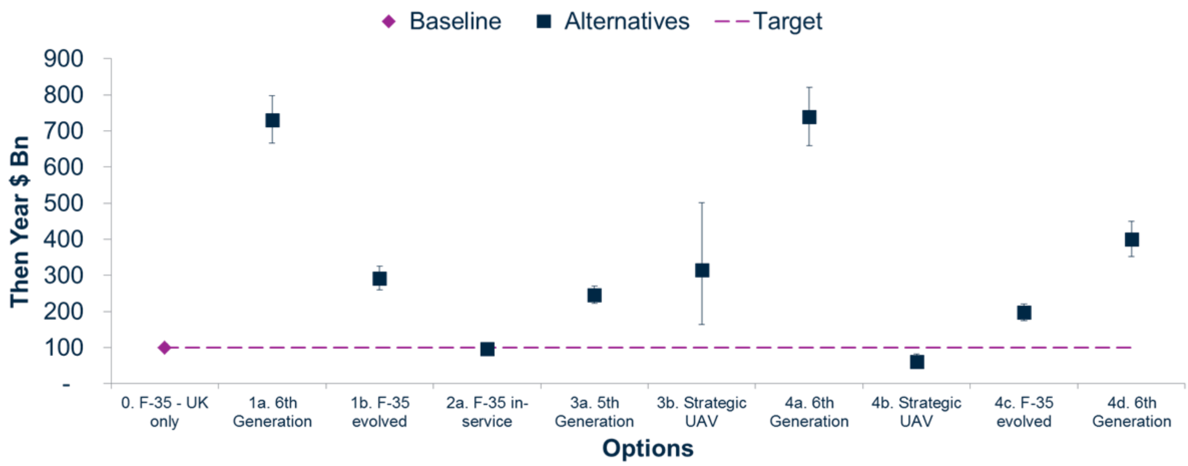

Figure 10: Comparison - all options with error bars in Then-Year US Dollars for the UK requirement

In the parametric model it is a simple project setting to change all the options to an output in Constant US Dollars. It is possible to see in Figure 11 the high level analysis of this cost modelling, noting that all costs have been normalised to constant 2018 US Dollars.

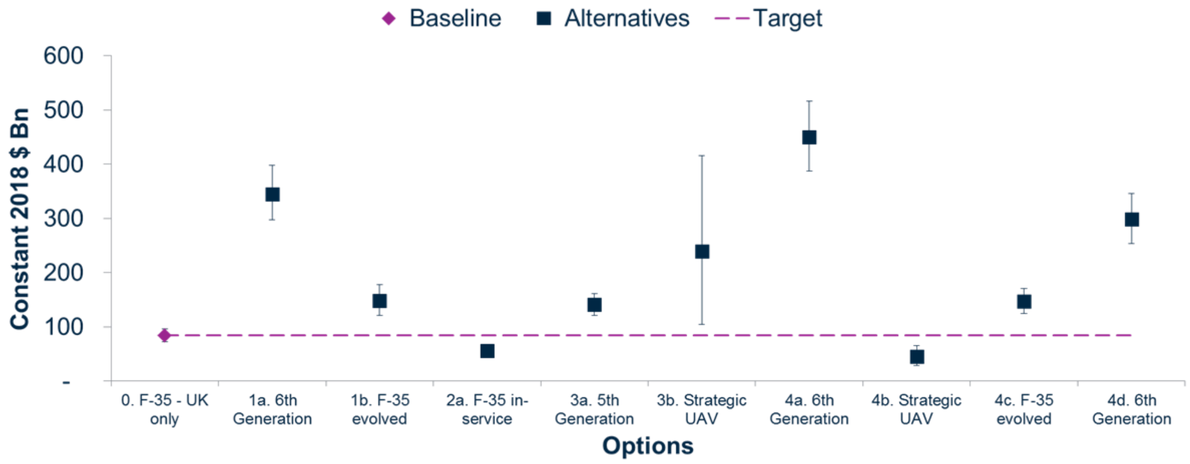

Figure 11: ROM cost - the rough order of magnitude costing of the options in constant 2018 US Dollars

In this chart it is possible to see option 0 – Do nothing – has been set as a benchmark or target, it represents the life cycle cost (LCC) of the F-35b programme as it is understood today. It is reasonable to consider this as the guidance for the replacement system and enables the cost practitioner to start a discussion regarding the options. This narrative should recognise that the outputs here are directly linked to the input parameters in the parametric cost model and these therefore provide an explanation of the costs. Also as seen in Figure 12 it is important to note these are LCC not just the cost to produce the systems.

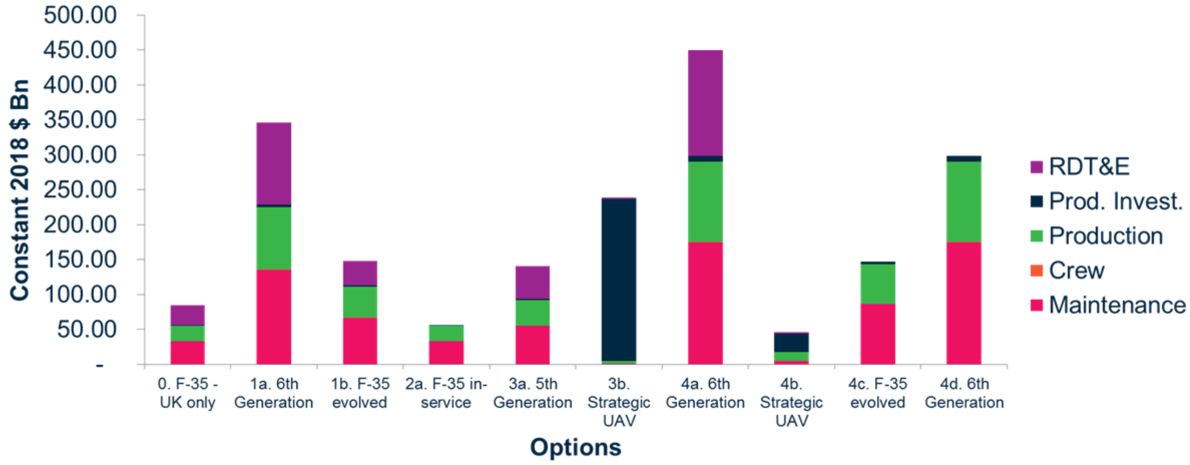

Figure 12: LCC - the breakdown of the life cycle cost in Constant 2018 US Dollars

It is possible to establish the 6th generation options (1a, 4a and 4d) are the most expensive and far exceed the UK target[4] that has been set. Even when the system is built under license in the UK with no RDT&E (option 4d) then the cost is many times the target. This is due to

[4] Assumed to be the cost of the current (option 0) project inflated to the future timeframe.

defence inflation, the cost of defence systems increase over time in excess of the rate of inflation [10.].

The unmanned options 3a and 4b are particularly interesting. It is possible to see in Figure 12 that the LCC for option 3b. (International) is dominated by the Production Investment cost. This is due to the significant production rate assumed for this option as seen in Table 6 to satisfy this level of production throughput of strategic UAV it would require a very large factor with potentially complete robot production lines to produce the equivalent of 4.4 systems per day assuming 365 days working. The UK only, sovereign option 4b, assume that the production investment would only be sufficient for the UK requirement, not other partners. In this scenario, the production rate is significantly lower and would be produced by more conventional aerospace production methods.

In conclusion, as a result of this high level preliminary analysis, option 1b, 2a, 3a, 4b and 4c would be worth of further consideration and more detailed analysis. But this cost engineering study is logical, structured and the basis of proactive cost estimating.

Lessons learnt

What are the limitations of this study that need to be acknowledged? The following is an initial list:

- No deviation of the systems capability over time, for example, the same payload is assumed;
- No mixed fleets are considered, for example, manned and unmanned systems in combination;
- No attrition of fleet numbers have been considered;
- No consideration of project specific risks.

There is no fundamental reason why these limitations cannot be addressed in this approach providing there was more time for the study. The advantages of the approach outweigh the limitations which have been considered below:

- As a first level ROM analysis the exercise can avoid some dead-ends;
- This high level analysis can highlight some problem areas;
- The analysis will provide ROM costs for first level assumptions;
- The analysis assumptions and input parameters are recorded for future scrutiny and debate.

The most significant item is the proactive nature of this analysis. It is the cost engineer who is able to bring this type of analysis to the fore. Rather than waiting to be asked and told what the options are to be considered, it is the cost engineer who is providing thought leadership!

Conclusion

This paper has examined the possibility to turn the tables with regards to being reactive to a study, to being proactive and initiating the study. It has proposed a structured, logical means of considering the options for the replacement of a capability.

Using the example of the UK air superiority capability has demonstrated the technique and provided first level costs using a macro-parametric cost model. The ability to quickly consider a significant number of high level alternative options is reviewed and the advantages and disadvantages considered.

The approach has been specifically designed to be equally applicable to other domains (land, maritime, space) and would provide the cost community with the ability to take equal place on the project stage.

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