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Getting Affordable Solutions - How much to spend and when to spend it

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Getting Affordable Solutions - How much to spend and when to spend it

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1 INTRODUCTION

This paper will consider equipment acquisition affordability through two different lenses

- the total cost of the programme (how much)
- the cost profile over which it is incurred (when).

The paper will show the recurring theme of affordability pressure in defence and illustrate this with two high profile equipment projects. Finally, an agenda for research is presented focusing on the need for new tools and models that must be used to facilitate and support a new type of acquisition organisation.

2 AFFORDABILITY IN DEFENCE

2.1 Background

Analysis of any number of defence acquisition programmes has shown that early estimates for cost and delivery dates were in the main, hopelessly incorrect. There are many drivers that lead to these unrealistic initial estimates for major programmes including the well-reported 'conspiracy of optimism'. These drivers have been the subject of a number of papers in the past including their impact on resulting unit numbers and capability (Kirkpatrick and Pugh), the motivations for optimism bias from a game theory perspective (Gardener and Moffat) and even attempts to factor them out in budgeting (Treasury optimism bias – supplementary Green book guidance).

Analysis of outturn costs for defence projects makes depressing reading:

- Looking at defence projects around the world, the average increase in actual cost versus the estimated cost at the start of development is about 40%[1]. For estimates made earlier in a project (i.e. at the concept stage) the situation is worse. Then, it is far from uncommon for estimates to identify only half of the costs necessary eventually to bring a project to fruition
- In the UK, according to the National Audit Office (NAO) report "Ministry of Defence: The Major Projects Report 2011" cost overruns totalled
    - £6.1Bn (11.4%) – Total increase in forecast costs to complete all 2011 projects since the Department approved the main investment decision
    - £10.6Bn (11.4%) – Total increase in forecast costs since the Department approved the main investment decision for all Major Projects since 2000.

It is important to note that these portfolio cost overruns do not provide any insight into changes which may have occurred to the programme itself, in order to maintain its costs within the allocated budget. Delivery quantities and changes to the capability being delivered are levers which can enable project teams to adjust the cost of the programme and maintain its affordability.

Cost estimate growth is seeded with under-estimating at the outset. Not securing an appropriate budget causes disruption in the programme schedule as project teams attempt to manage an emergent

[1] Why should one trust FACET? P. Pugh. PV/11/039. March 2006

conflict between the available money and the system requirements. This ultimately causes major changes in design to maintain required capability or more often taking it out – all of which escalates development costs further.

Affordability problems can also originate in another form of conspiracy – optimism in schedule. This can be manifested in underplaying the technology risks associated with projects (in part linked to the cost bias). However, we also see often naïve optimism in the project schedule that arises from project teams not recognising that the enterprise as a whole needs to manage a portfolio of projects in which the project is just one. The requirement to subsequently balance the books leads to re-scheduling of projects, with costs being spread across years with less financial pressure. Whilst maintaining in-year affordability, the total cost of the programme is inevitably increased, leading to a debate between affordability and. value for money.

2.2 How has UK MoD addressed affordability?

Defence ministries around the world have grappled with the challenge of keeping defence acquisition costs under control.

The defence products and services being acquired cannot be compared to other sectors within government or beyond. They are distinguished by:

- Being what Kirkpatrick has termed "tournament goods" – these are characterised by the constant drive for superiority over a real or perceived threat. This manifests itself in the reinforcing cycle of the arms race for example (the escalation archetype (Senge))
- This leads to an enterprise that requires latest technology at any price
- However, small production volumes limiting economies of scale – even globally marketed solutions, typically end up with extensive local development
- Rapid changes in threat that can create difficulties signing off requirements.

These coupled with the conspiracy of optimism described earlier and bureaucratic forms of project governance have perplexed politicians and administrators who have repeatedly attempted to design the acquisition system to overcome and manage these issues.

In the UK, MoD has undertaken a number of organisational changes and planning processes. These include[2]:

- Downey Cycle (1962)
- Smart Procurement Initiative (1998)
- Smart Acquisition (2000)
- Enabling Acquisition Change (2006)
- Levene Defence Reform Group (2012).

There has been much debate recently as to the degree to which the changes have worked. There appears to be some evidence in the smaller projects that there may be progress in project performance but the large projects continue to be problematic.

[2] A review of Changes to the Organisation of MoD related to Procurement, Draft 2, December 2011 – D Faddy

MoD has just recently claimed to have balanced the equipment programme through being more explicit about what is committed and what element of the budget is reserved for contingency and opportunity to bid for uncommitted funds (the "whiteboard")[3].

This appears it may be an achievement but as we shall see later, it will not have solved problems over the next review period and beyond. Further for project team leaders and sponsors (to be sat with the Commands post Levene), it will be even more critical to get project estimates right from the start and also to plan when they are incurred as part of the wider portfolio.

We believe that there remains a critical need for tools and models that can deliver these as without them, disruption in programmes can have ramifications for those delivering the capability within the military and those ultimately directing its use; the politicians.

The paper will highlight how poor estimation and conspiracy of optimism has had a direct impact on both these stakeholders groups through two case studies, demonstrating how important it is to know how much money is required, and when it is available.

3 'UK Defence Secretary Balances budget' Battlespace Alert, Vol.14 ISSUE 05, 14 May 2012; Philip Hammond, the man with the magic whiteboard' The Guardian, 14th May 2012; Britain Turns to Annual Budget Planning, Defence News, May 2012

3 HOW MUCH TO SPEND?

There are various cost analysis methods that can be used at different stages of a programme to generate an estimate. Here we are concentrating on concept costing and the high level parametric techniques which can provide the means to generate realistic cost estimates, in order to set realistic budgets.

3.1 Historical trends and cost estimating

A good measure of the complexity of a design is its specific cost, i.e. the ratio of its average production (flyaway) cost to its size, expressed usually for aircraft as cost per kg of Basic Mass Empty. A plot of the specific cost of past designs against the dates for the first deliveries of examples of these aircraft to service exhibits exponential growth of specific cost with in-service date. This is so, even after deflating cost using indices of output prices, allowing not only for changes in money supply but also for advances in technology and productivity.

Historical data for fighter/strike aircraft exhibit a well-defined pattern of exponential increase in specific production cost. Such a plot for combat aircraft is illustrated below in Figure 1[4].

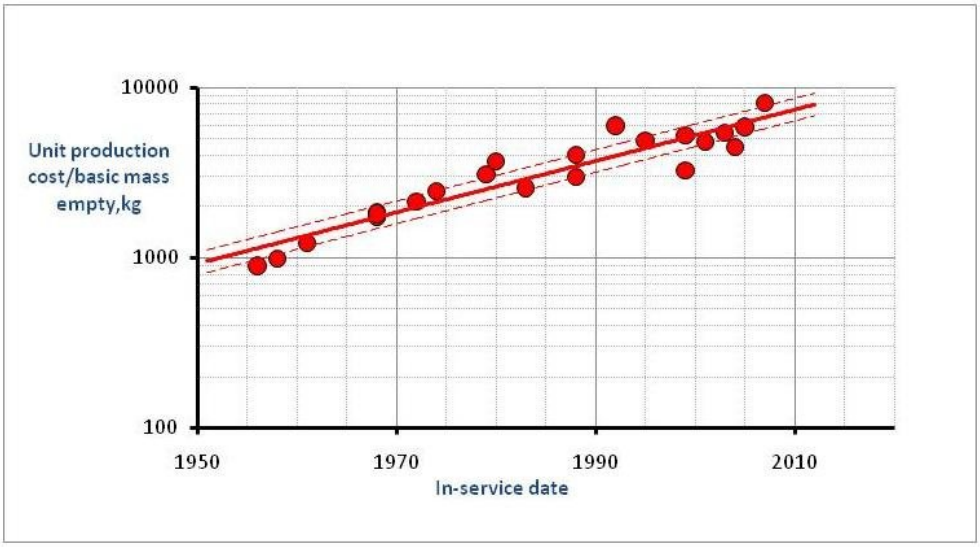

Figure 1: Historical trends for Specific Cost for fighter strike aircraft

The specific cost shows significant real growth at 3.5% p.a., which represents a doubling every 20 years. This period covers several generations of fighter/strike aircraft and is a period which includes a number of significant changes in manufacturing technology.

The size of fighter/strike aircraft is found to increase at about 0.5% p.a. Combined, the overall cost of fighter/strike aircraft increases at 4% p.a., an effective doubling in the average unit cost every 18 years.

[4] Page 46 of the Source Book of Defence Equipment Costs, by Philip Pugh, Published 2007

Such analysis allows comparison of current estimates with the trend to provide a level of confidence in the estimate.

3.2 The cost of Eurofighter

Estimating the cost of equipment is notoriously difficult. There are a number of historical examples where outturn costs of aircraft are well above the figure which initial estimates have forecast. One such example is the European aircraft Eurofighter (Typhoon). The implications of ensuring an early accurate cost estimate in order to secure the correct level of funding are vital to ensure that the programme retains value for money as well as overall and in year affordability.

Figure 2 shows the original estimate for Typhoon along with the actual UPC of the aircraft once it was delivered. These have been plotted on the historical trend of Fighter strike aircraft UPCs that was introduced earlier.

From Figure 2 it can be seen that the initial estimate appeared very low compared to the trend of costs for this type of aircraft. With the benefit of hindsight we can see that the actual final outturn cost did sit on the historical trend line for this type of equipment. Had this analysis been done at the time then surely a revision of the programme estimates could have been prompted given that they appeared to be extremely low?

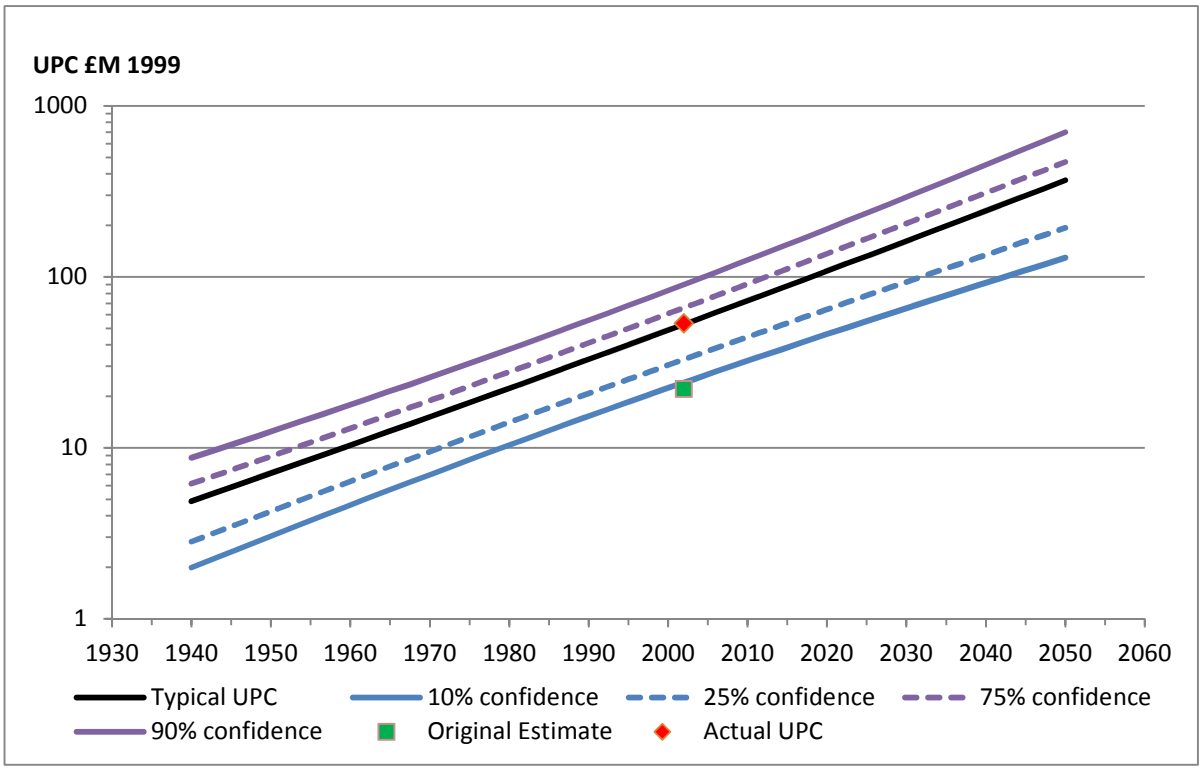

Figure 2: Estimates of Eurofighter UPC compared to historical trend

The following estimate was developed by Phillip Pugh in 1983 using similar parametric techniques and for both UPC and development costs. These estimates were produced using only data available in the public domain at the time. Each estimate was updated as the programme progressed and has been

compared to the initial estimates at the time. Figures 3 and 4 below show how the estimates and the official figures compared to the actual cost.

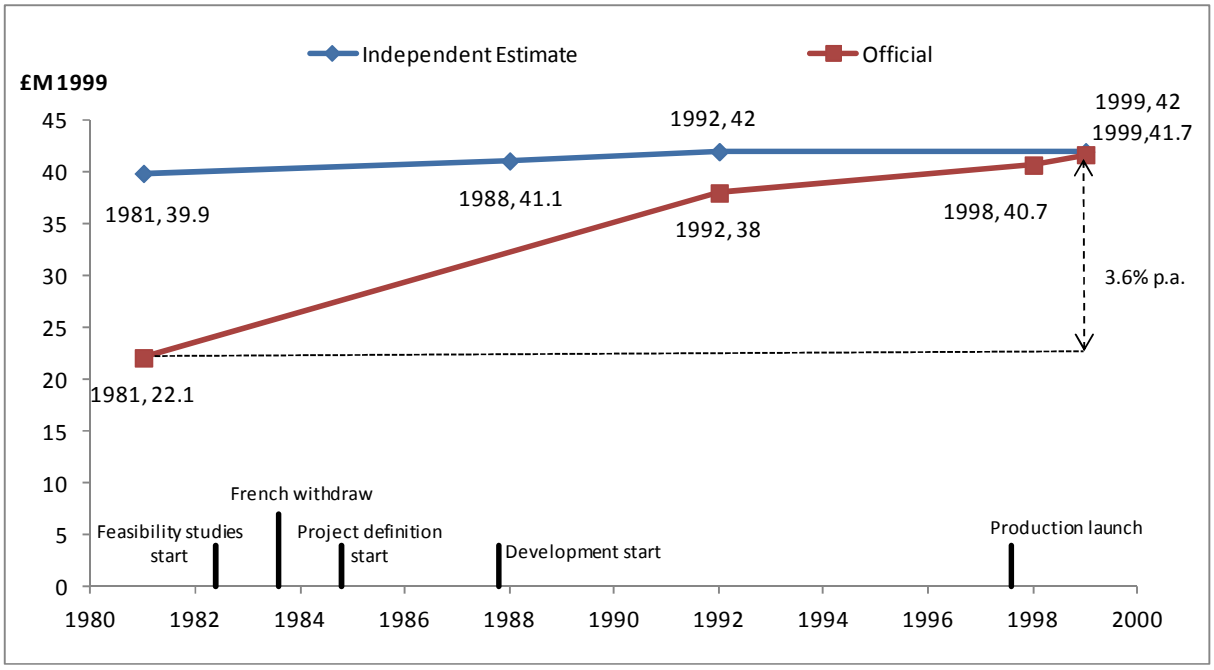

Figure 3: Estimate vs Official for Typhoon UPC

It can be seen from Figure 3 above that the initial estimate went up, on average, by 3.6% per year in order to reach the final estimate before ISD.

A similar story also happened for Typhoon during its development phase with costs rising at over 4% pa.

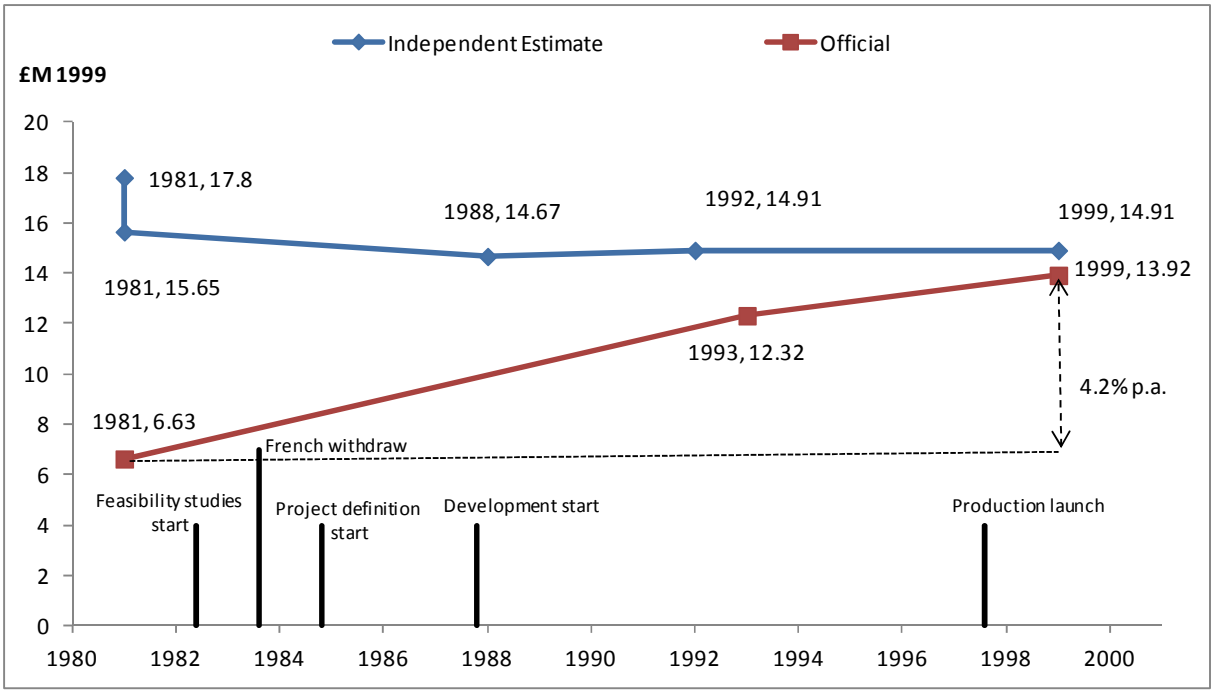

Figure 4: Estimate vs Official Figures for Typhoon Development Costs

3.3 Is history repeating itself?

In this section we turn our attention to one of the biggest defence programmes in the world currently being undertaken. The sheer scale of the Joint Strike Fighter (JSF) programme, over 2000 aircraft for the DoD and some 800 for other countries has meant that the programme has been carefully scrutinised with programme overruns and technical difficulties and the likely impact on cost being analysed by all the involved nations. The impact of cost changes to the JSF programme has been compounded by nations facing economic difficulties and defence budgets coming under pressure. As nations look at the progress of the JSF programme, the platform selected to deliver their required military capability, the political implications of delays and cost increases have a direct impact on a number of nation's national security.

Looking at the Eurofighter Typhoon we have seen that is possible, early in the concept phase to generate a credible cost estimate upon which to base the programme budget. The programme also demonstrated how cost growth is seen over the life time of a programme. In this section we review the JSF programme to see whether lessons have been learnt.

3.4 JSF – the story so far

Work undertaken for an overseas client analysed the published cost data of the JSF programme, and used cost models developed by DAS[5] using historical public domain data, to predict potential acquisition costs for this type of aircraft. Through review of the data published in the Selected Acquisition Reports (SARs), DAS was able to show the cost of the programme to date. Figure 5

[5] DAS Level 0 Concept Cost Model

shows the evolution of forecast Average Unit Procurement Costs (AUPC)[6] as reported by the portion of the SAR entitled "Defence Acquisition Management Information Retrieval", all brought to a common set of economic conditions (2009).[7]

Figure 5 would suggest that insufficient funds were committed initially, thereby demanding a step increase of some 26% over the period 2001-2003 (US$72 million at 2001 to US$91 million at 2003). Later in the programme (2008) a further step change from US$99 million to US$113 million represents some 14%. Indications would suggest that there is a continuing upward trend.[8]

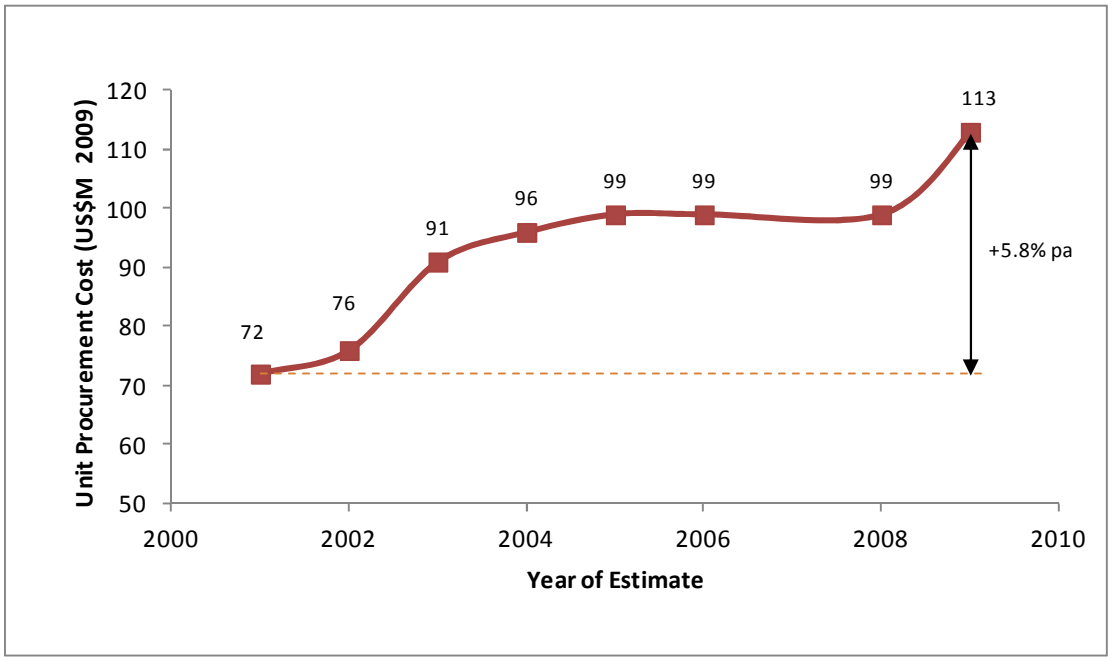

Figure 5: JSF SAR Data – Unit Procurement Cost

The SAR costs have been broken down into two main elements – Research Development Test & Evaluation (RDT&E) and Production Costs. Between 2001 and 2009 they show an overall increase of some 56%. RDT&E cost increased by 69%, and Production cost by 54%. As the total procurement cost covers all three variants, it is difficult to establish whether this increase is driven by all or one of the aircraft variants. At the time of this analysis, the technical issues were largely concerned with the STOVL version. The rate of increase of both RDT&E and production are shown in Figure 6.

[6] AUPC – Average Unit Procurement Costs – i.e. total programme costs, including RDT&E divided by the total quantity of units to be procured by the US

[7] Selected Acquisition Report (SAR) F-35 published 31st Dec 2009

8 Speculated by the think tank Centre of Defense Information (CDI) from An Estimate of the Fiscal Impact of Canada's Proposed Acquisition of the F-35 Lightning II Joint Strike Fighter, Parliamentary Budget Office, Canada, March 10, 2011

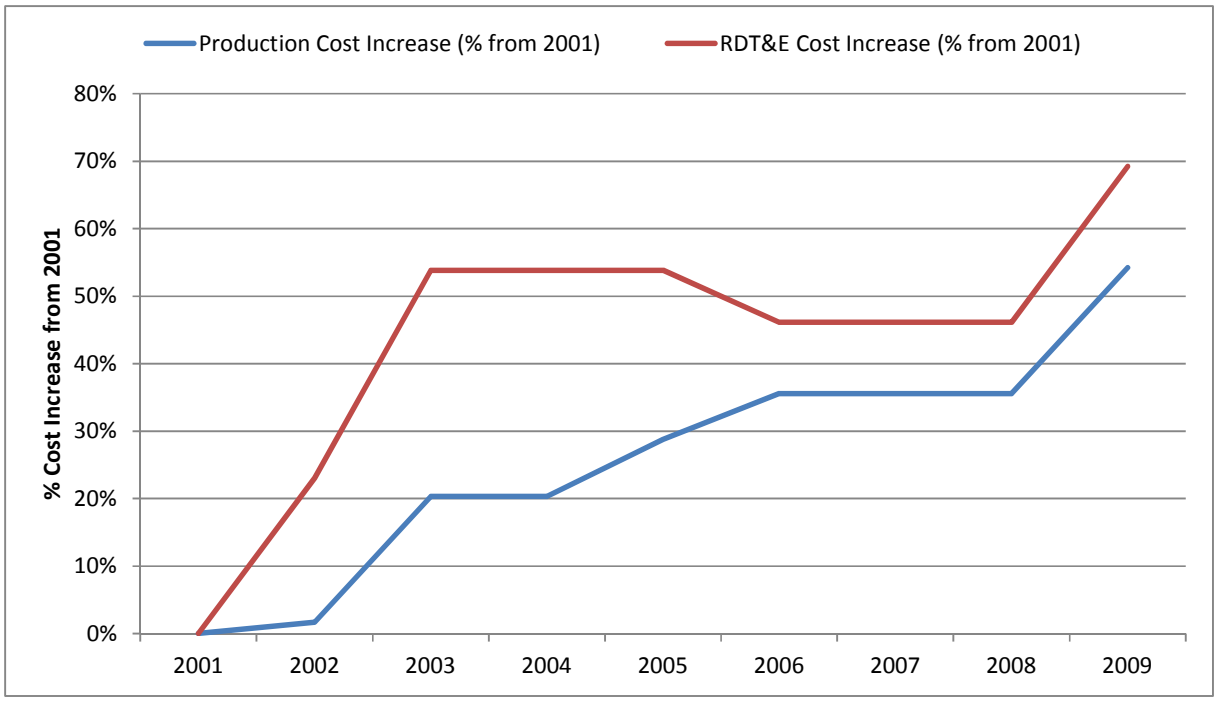

Figure 6: JSF RDT&E and Production cost increase

The initial estimate for RDT&E went up by approx. 55% in the first two years. This contributed to an overall increase of 26%, half way towards the Pugh estimate of 40% in the first two years of the System Design and Development (SDD) contract and resulted in the programme's first Nunn-McCurdy breach.[9] The increase in development costs had a knock on effect on the production costs which increased steadily over the first 5 years of the programme. During 2008, a year after initial production had already begun a number of technical problems were discovered. This impacted the costs for both RDT&E and production as both needed additional funds to investigate and fix the issues. This further increase resulted in the programme's second Nunn-McCurdy breach.

With a total increase of 69% the RDT&E has gone from $13m to $22m per aircraft. This increase in development costs has been required to tackle problems that have occurred during the programme. This along with delays to the programme has also impacted the production costs where we see an increase of 54%, from an initial UPC estimate of $59m, to $91m.

Using the historical trend data shown in section 3.1 and the DAS Level 0 model it is possible to put the JSF cost picture in the context of broader trends. Figure 7 shows confidence limits defining bands of cost within which the average unit production cost of fighter/strike aircraft having similar empty mass as JSF must fall if it is to be consistent with the historical trend shown in Figure 1.

[9] A "significant" breach is when the Program Acquisition Unit Cost (the total cost of the development, procurement, and construction divided by the number of units to be procured) or the Unit Procurement Cost increases 15% or more over the current baseline estimate or 30% or more over the original estimate.

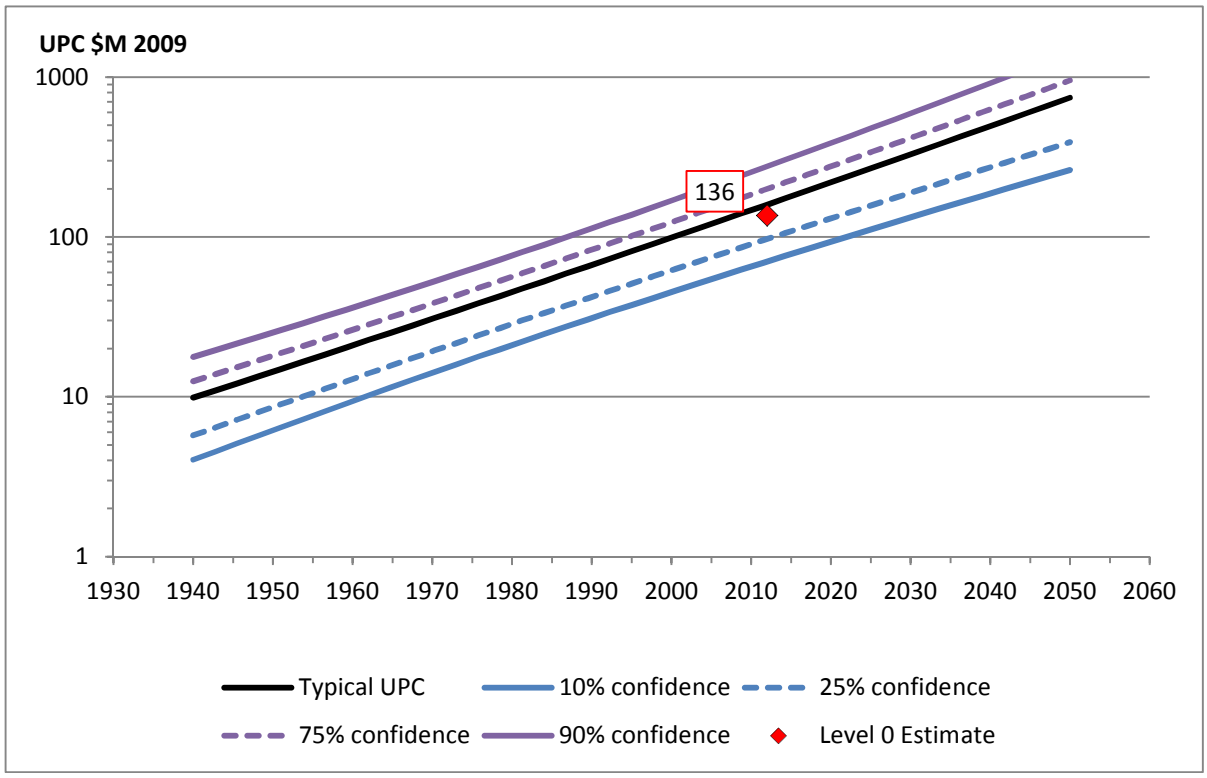

Figure 7: Independent Assessment of F-35 JSF UPC

Figure 8 below shows how the estimated costs have been increasing and plots them in relation to the estimate shown above.

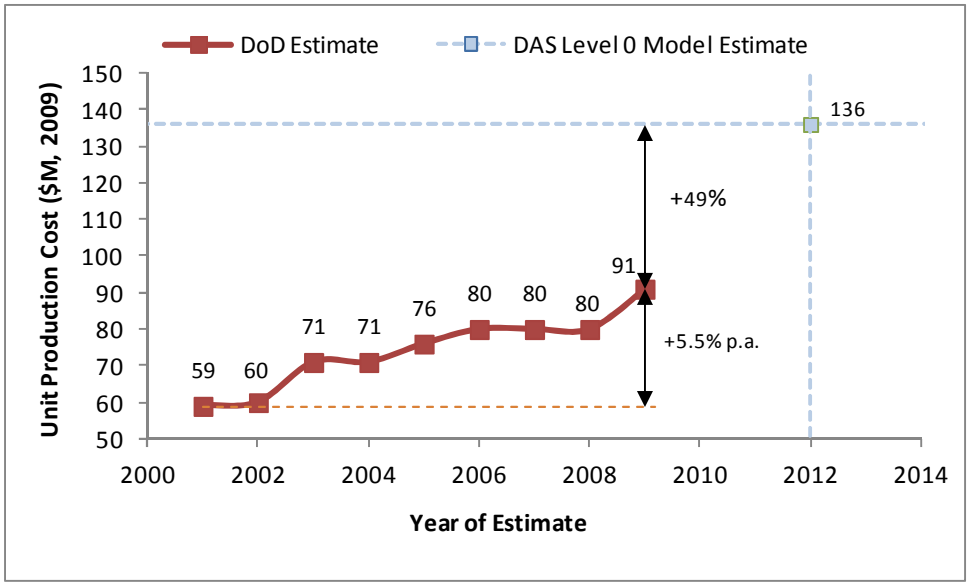

Figure 8: F-35 UPC SAR Estimates vs Level 0 Estimate

It appears likely that the JSF production cost estimates is likely to rise further indicating a higher outturn cost than many countries have been planning against. If we were to plot the latest estimate of $91M against the historical trend for this type of aircraft it would lie at approximately 20% confidence which further supports the argument that the costs could yet still rise.

3.5 Implications

There is huge political and capability knock on effects of this significant underestimation. A number of nations are now not committing to the programme and those that have are significantly reducing the numbers being procured.

Participant	Planned Quantity 2001	Planned Quantity 2003	Planned Quantity 2009	Planned Quantity 2010	Planned Quantity 2011[10]	Planned Quantity 2012	Change as of 2012
UK	150	150	138	138	138	138	**-12**
Italy	160	131	131	131	131	90	**-70**
Netherlands	85	85	85	85	85	85	**0**
Turkey	100	100	100	100	100	100	**0**
Australia	100	100	100	100	100	100	**0**
Norway	48	48	48	56	48	52	**+4**
Denmark	48	48	48	48	30	30	**-18**
Canada	80	60	80	80	65	65	**-15**
Us	2852	2443	2443	2443	2443	2443	**-409**
TOTAL	**3623**	**3165**	**3173**	**3181**	**3140**	**3103**	**-520**

Table 1 Overall Change in Planned F-35 Quantity 2001-2012

There is not only an upward trend of the estimated cost of the programme but this is compounded by the downward trend in production quantities. As the units produced reduces the benefits of economies of scale and learner are not fully realised causing the costs to further increase. It can be seen from the analysis that the UPC is likely to increase further. This potentially creates a vicious feedback loop– the JSF prime contractor has based its claims on disruption of the intergenerational cost escalation on high volume throughput (as well as new technology and build practices). With costs rising, perhaps by as much as 50%, as shown in Figure 8, this feedback loop could become self perpetuating.

The JSF programme has already had huge political impacts. In the UK alone, budget forecasts and affordability have been tested. There have been major implications on not only which variant should be procured but also the design and build of the Carrier. This has had a massive political implication with ministers having to go back and change previous decisions. A number of the other major partners in the programme have also changed their order quantities indicating that they have also had to test the affordability of the programme against available budgets leading to political decisions being taken.

[10] Here we are referring to the '2011 Lockheed Martin Fast Facts' data

3.6 Summary

It is interesting to note that both of these programmes (Typhoon and) JSF have created big headaches for politicians, military and the defence industrial base. All would admit (hopefully) that getting more accurate estimates at the outset can offer better outcomes for all. Some suggestions on how this can be facilitated are suggested at the end of this paper.

4 WHEN TO SPEND THE BUDGET

Even if the costs for a programme are well understood and agreed they must be put into the context of the project portfolio as a whole. Individual programmes need to be viewed in this wider context to fully understand their affordability against the total budget available. Only one mismanaged project can have a knock on effect on the rest of the portfolio and cause further delays and costs across other projects.

Upon completion of the latest planning round process by UK MoD, termed PR12, Hammond's 14 May 2012 statement confirmed that there will be an additional unallocated contingency of £8 billion made available over the next decade. This contingency funding will be allocated on a yearly basis "to respond to emerging equipment requirements" not yet included within the core defence programme. It is unclear how this additional contingency funding will be used but it is unlikely to be enough to cover cost growth that has been witnessed on programmes historically.

This suggests that for budget holders in UK MoD, careful positioning of a project will be required to maximise the probability of its initiation. This should be done cognisant of the total portfolio and likely/actual pressures on the overall budget headroom. This inevitably continues the often adversarial stance taken across domains to secure the best position but in a world going forward where conspiracy of optimism is being driven out.

4.1 Comparison of FRES over the years

The UK's Future Rapid Effects System (FRES) is a programme to procure MoD's next generation of protected vehicles delivering utility and reconnaissance roles with an aspiration of other specialist role vehicles as variants. This programme has had a turbulent history since its genesis around the Millennium. This involved an ambitious enhanced capability solution with implied technology advances, optimistic costs and a procurement strategy setting very high production rates.

DAS has been compiling and archiving defence related public source data over many years. From within this archive, we have retrieved presentations authored by MoD at various stages of the FRES programme history.

In this paper, we show two snapshots to illustrate MoD's view of the profile of cost for the FRES programme. These were delivered as part of industry day presentations to communicate its forward plans. These are illustrated in Figure 9 and are shown exactly as presented.

They show the forecast annual total procurement spend by project over a 20 year period.

Back in 2005, it was anticipated that peak spend on FRES would occur around now (2012) and delivery would be completed by 2023 or so. Note how this programme, shown in blue in Figure 9 (top), is dominating the Land equipment budget. Indeed, as we shall see shortly, large Category A programmes must always be programmed with a knowledge of other current and future large programmes within the portfolio. Figure 9 (bottom) shows how in just 2 years the MoD had to revise its picture substantially. FRES is shown still dominating the Land acquisition landscape but we see its delayed production dates – it has become part of the "bow wave" of projects shifted to the later years to manage the short-term budget pressures.

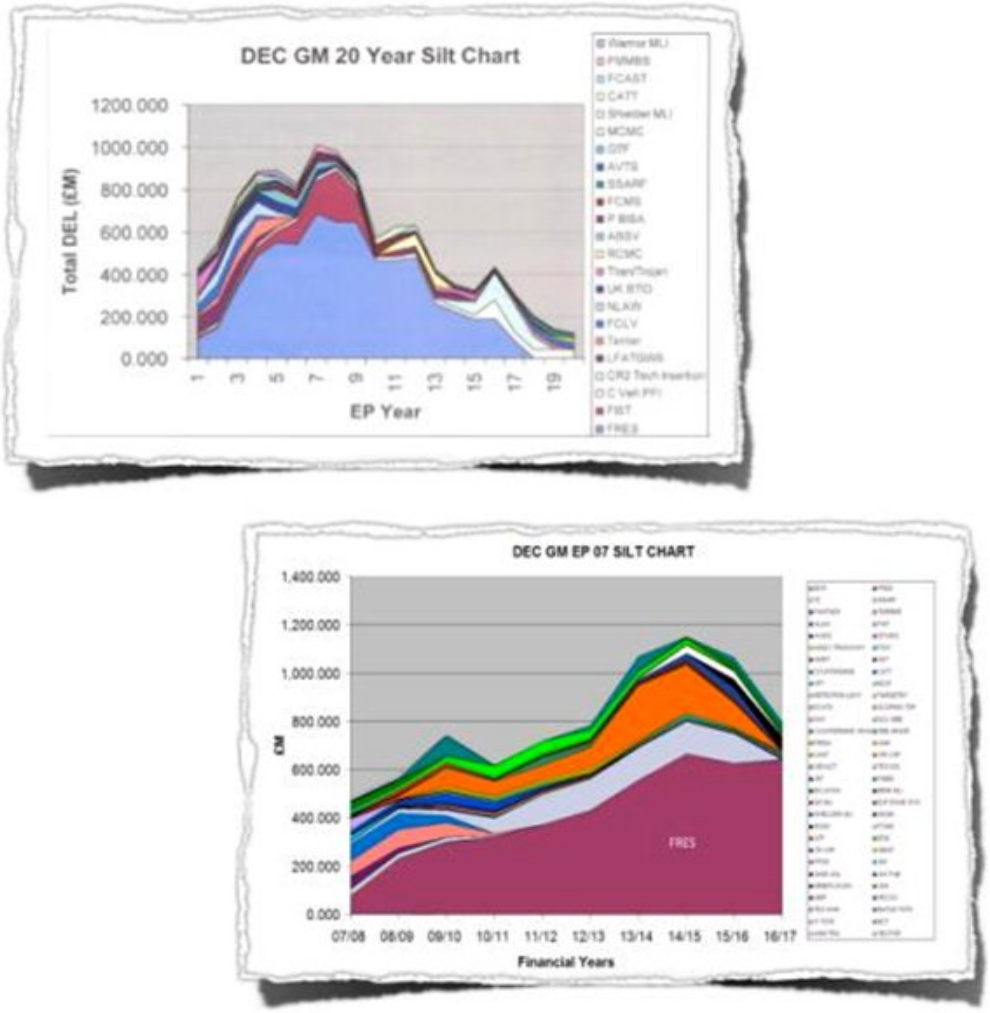

Figure 9: Top EP05 DEC GM Cost Profile with other projects ; Bottom EP07 DEC GM Silt Plot

We have continued to track FRES up to the present day. The programme has had to accept a reduction in the number of anticipated variants and within those that remain planned numbers have fallen, most recently with the specialist Scout vehicle.

Rebasing the historical cost data in Figure 9 and adding DAS' latest estimates for the FRES programme, the resulting plots show a stark illustration of the trajectory of the FRES programme. This is shown in Figure 10 which illustrates the increasing sunk costs of the programme and later delivery of FRES capability. Figure 11 and Table 2 summarise the total programme costs with the reduction in the number of units to be procured. Combined, this suggests that there may be a doubling in the unit acquisition costs for FRES over the programme review period 2005-2012.

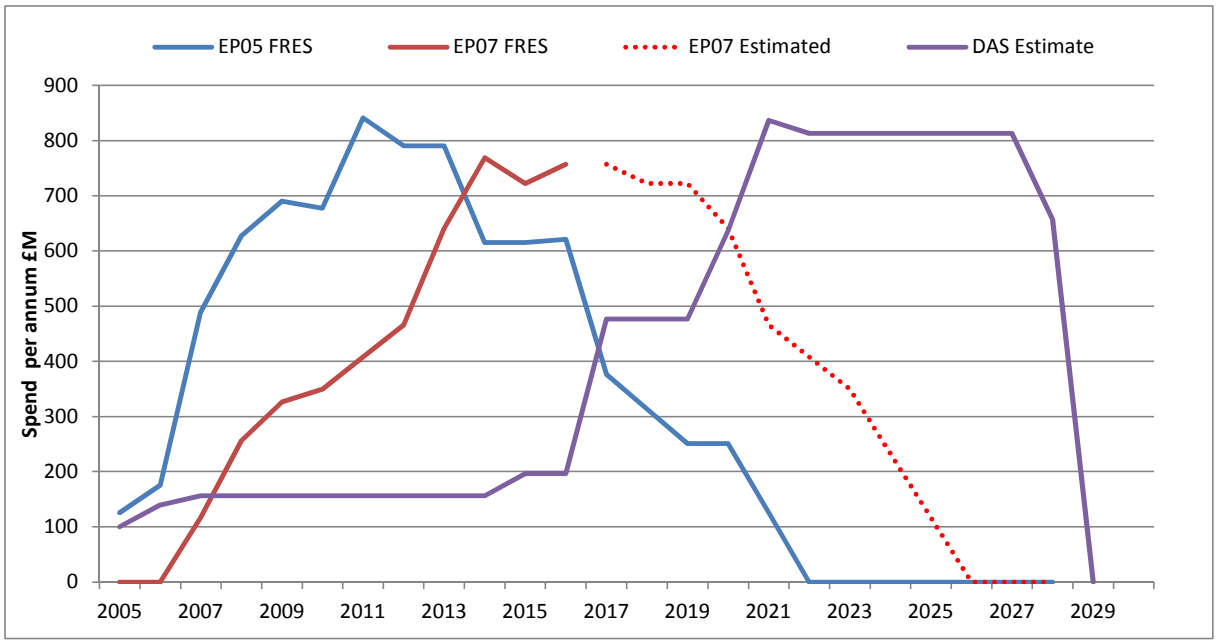

Figure 10: Comparison of FRES over the years

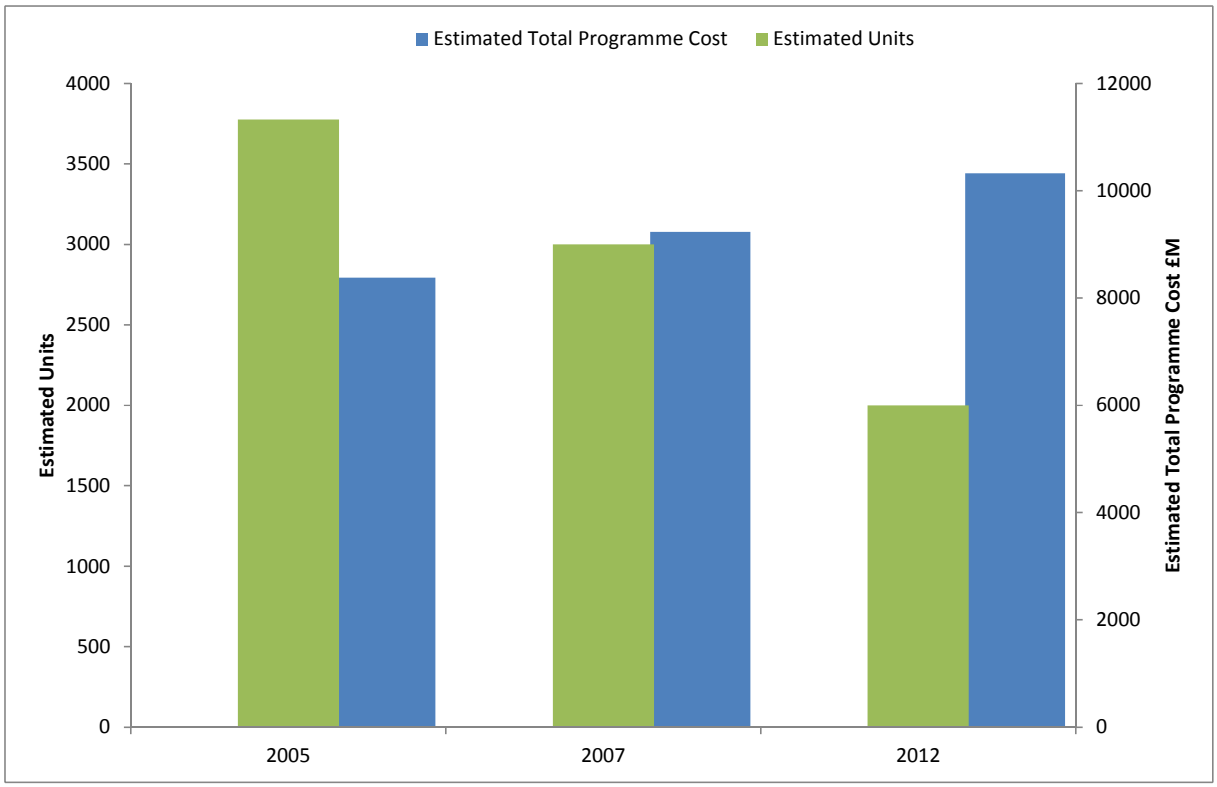

Figure 11: Comparison of FRES over the years

Year	Estimated Units	% Change (from previous entry)	Estimated Cost £M	% Change (from Previous entry)
2005	3775	-	8,380	
2007	>3000	-10-15	9,230	+10
2012	~2000	-30-40	10,325	+12

Table 2 History of FRES programme costs and unit numbers

Other factors are also influencing the cost escalation and delay including changes in the capability requirement, the Army's acquisition focus on its Urgent Operational Requirement (UOR) fleet procurements but we would argue that the over optimistic assumption of dominating the equipment programme was never going succeed and so it has been shown.

We can look ahead again for FRES within the new planning processes introduced as part of the UK Defence Reform Group. Figure 12 shows recent DAS analysis to illustrate how only a subset of high profile programmes makes up a large fraction of a forecast equipment budget trajectory. Other programmes omitted from this analysis include Lynx, Merlin Sustainment Programme, Puma Life Extension, Typhoon, Watchkeeper and Type 45.

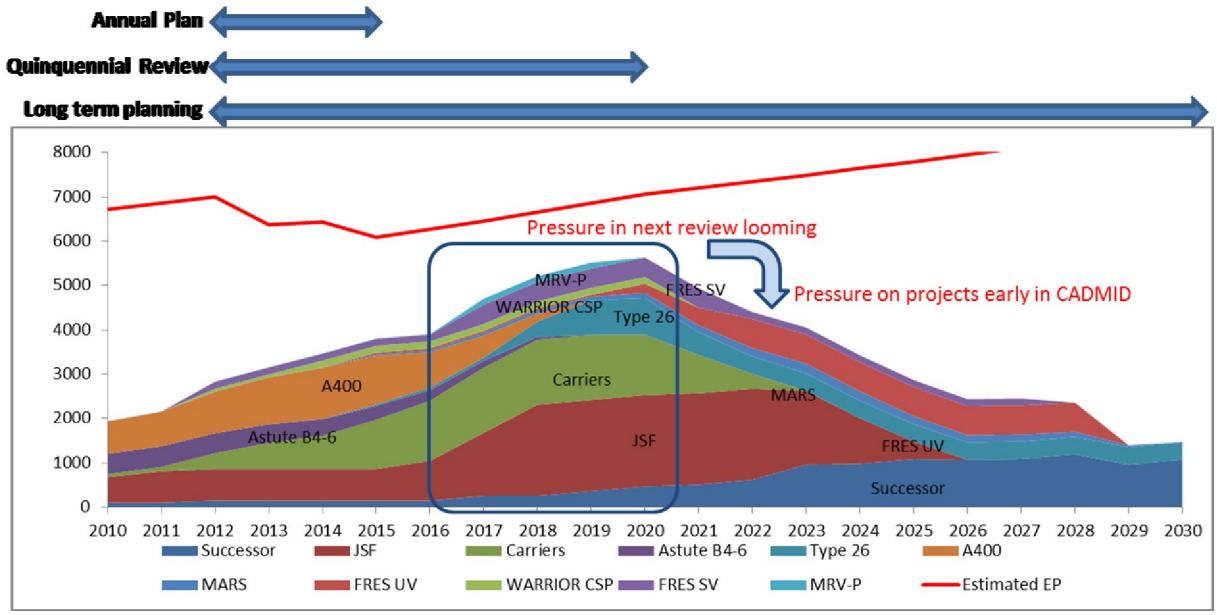

Figure 12: DAS' forecast of selected equipment acquisition programme budgets to 2030

An estimated Equipment programme (EP) line has been constructed using the DAS defence macroeconomic model. This is a unique modelling capability that estimates likely spending based on a top down approach acknowledging:

- UK GDP long term projections using validated macroeconomic model of integrated top 30 global economies
- Defence spending share of GDP recognising fiscal constraints and competing central government spending demands (welfare etc)
- Defence spending share based on contribution within alliance blocks (NATO, US/UK)
- Short-term CSR statements from the UK Government Treasury.

Returning to the cost profile of the key programmes, we can see that by 2019-20, these are accounting for up to 80% of the central forecast for the equipment budget. Clearly this is indicating that the next quinquennial strategic review will face further difficult choices within the equipment acquisition sphere.

Focussing on the FRES programme, we can see that the aspiration for the utility vehicle variant (FRES UV) is that the programme will be initiated 2019-20 and this places it in a precarious position. With other major projects with political equity invested and having passed further along the CADMID decision gates, the UV programme may yet face cancellation and join the list of past failures of UK land system acquisition.

5 DISCUSSION AND CONCLUSIONS

5.1 An agenda for research

Our analysis has illustrated the well-known systemic problems of defence acquisition through two lenses – getting estimates right and getting the spend profile right. It has been shown that overspend and delay remain endemic in defence procurement indicating the continued, and arguably urgent requirement for the tools and managerial changes needed to deal with these issues.

We believe that there needs to be change in two areas

- Better planning models particularly at the strategic level
- Fundamental change in the acquisition strategy.

5.2 Strategic planning models

There is a requirement for truly strategic models that can rapidly explore a wide range of alternative equipment programmes visualising their impact on costs and capability within an overall envelope of available budget and defence need.

Such models do not necessarily fit within what has become stove-piped specialist disciplines. Project managers, systems engineers, cost forecasters and accountants will all have detailed models that encompass part of the requirement but typically at the expense of others. Synthesising outputs from multiple such models may ultimately provide precision but the overhead of maintaining coherent assumptions and levels of detail stifles the exploratory modelling that is needed – even if some detail is sacrificed.

The work shown in this paper in part has been derived from a suite of models DAS has created to take on this need for high-level hybrid models. These models can still use other tools and data repositories as feeder models but the critical functionality has been found to be in the ability to get the programme under study onto a single view and the ability to do many what-ifs and then visualise and mine at whatever level of detail the users require.

5.3 Looking ahead

A recurrent insight from historical analysis of past acquisition projects is that costs are poorly estimated at the outset and that requirements engineering dominates the front end of the acquisition cycle.

Clearly this holds true based on the cost of requirement changes later in the project lifecycle. However, these changes happen and are, in the main, driven by affordability constraints that were not sufficiently weighted into scoping at the project start.

This is a well-known challenge which has had extensive research and practical application of new processes. These include incremental acquisition and spiral development. However, even in these cases, there is still too little weight attached to affordability at the outset.

“Design to Cost” is an approach that does firmly lay affordability at the heart of the procurement decision throughout a product lifecycle. Other recent approaches include “Value Based Design” and

concept of "Cost as an Independent Variable" (CAIV)[11]. Indeed there appears to be a plethora of useful methods and tools in various states of maturity and used in many business sectors. What is key for the case of defence is the change in the culture of acquisition in order to adopt these approaches i.e. increase the weight of affordability at the start of the acquisition cycle. MoD is now adopting a posture of more radical thinking. For example the creation of a government owned contractor operated (GOCO) model for its procurement and support organisation, DE&S[12]. However, such radical changes themselves can be cause of unintended consequences across defence and must be carefully considered.[13]

[11] CAIV - An Important Principle of Acquisition Reform," by Capt. Guy Higgins, USN Program Manager Magazine, Jan. - Feb. 1997; "Cost as an Independent Variable," CAIV Working Group Paper, 16 July 1996

[12] Review of Acquisition for Secretary of State; An Independent Report by Bernard Gray. October 2009

[13] 'The Defence Materiel Strategy and GOCO proposal for Abbey Wood' RUSI Briefing Paper, July 2012. http://www.rusi.org/downloads/assets/GOCO_Briefing.pdf; Deborah Haynes, 'MoD Ready to "Take Brave Pills" and Go Private for Procurement', TheTimes, 22 June 2012.