
Derek Braddon* and Keith Hartley

Abstract

Faced with declining defence budgets and spiralling weapon costs, international collaboration in military production appears both a sensible and attractive ‘value for money’ solution. International collaboration offers in theory the opportunity for both cost- and risk-sharing between members of the collaborating group, making military projects feasible that could not be entertained (financially or perhaps technologically) by one country or one company. This paper will focus primarily on collaborative military aerospace projects and will evaluate the extent to which this positive outcome is, in practice, the case.

The methodology employed in this paper involves the comparison of actual collaborative projects and actual similar national programmes in or between different nations on the basis of total development costs, unit production costs, cost escalation, delivery dates and schedule over-runs as well as the comparison of data on total output and export sales. A variety of collaborative military projects are evaluated against these indicators, supplemented with two in-depth case studies.

Our conclusions suggest that European military project collaborations remain inefficient with considerable opportunities for efficiency improvements. Bilateral collaborations appear to offer the best value for money from international collaboration; adding additional nations to a collaborative programme tends to increase its inefficiency, so offering poor value for money. Extensive duplication of both R&D and production within the fragmented European defence market highlights the opportunities for pooling resources which, in turn, depend upon trust between nations in sharing military assets and forces. Collaborative programmes need to be subject to hard budget constraints; soft budget constraints reward inefficiency and poor performance. Opportunities also exist for considerable efficiency gains by extending collaboration to all subsequent phases of a project’s life-cycle, including training, repairs, maintenance, spares and mid-life up-dates. Ultimately, either European multi-national collaboration is made much more efficient and internationally competitive or nations will have to import defence equipment, mainly from the USA.

Keywords

Weapons production; International collaboration; Collaboration inefficiencies

Introduction

The defence sector worldwide is facing increasing pressure from government budget cuts. In the United States, for example, President Obama’s government in its second term of office has to confront financial stringencies which may well require major cuts in defence spending as part of an economic adjustment package. In 2011, the US spent over $700 bn on defence, significantly more than the next 17 highest defence spending nations combined and significant cuts now appear inevitable [1]. In the UK, the Chancellor of the Exchequer has had to confront a £48 bn ‘black hole’ in public finances and additional deep cuts in defence spending again seem unavoidable. Even China, where defence spending has risen by nearly 200% since 2001 to reach an estimated $19 billion in 2010 has only been able to achieve this defence budget growth through unprecedented and sustained economic growth over the period.

Coincident with declining defence budgets in real terms, the cost of military equipment continues to spiral, frequently exceeding the rate of inflation. As noted in The Economist [2], “Study after study shows that the price of combat aircraft has been rising substantially faster than inflation, often faster than GDP. The same is true of warships.” This is nothing new. Almost 30 years ago, Norman Augustine, a leading figure in the US defence industry drafted a series of light-hearted ‘laws’. One of these suggested that the exponential growth path in the cost of US fighter aircraft since 1910 would mean that, by 2054, the defence budget would only be able to purchase one aircraft which would have to be shared between the services. In 2010, The Economist [3] noted that Mr Augustine had recently commented that, three decades on: “we are right on target. Unfortunately nothing has changed” and concluded that: “these days Raptors go for $160m apiece ($350m including the cost of developing the jet), compared with $50m-60m for the venerable F-16. In the long run, high unit costs must limit numbers. Since 1970 America’s fleets of combat aircraft and major warships have shrunk, even as defence spending rose” Furthermore, defence provision now confronts even greater cost pressures as high technology developments in modern ‘network centric warfare’ come with an ever-increasing price tag [4].

With both governments and the defence industrial base being severely squeezed between the twin pressures of significant defence budget cuts and ever-increasing prices for defence equipment, international collaboration in military production (especially aerospace) appears both a sensible and attractive ‘value for money’ solution. This paper will evaluate the extent to which this positive outcome is, in practice, the case.

Economic Theory and Multi-Lateral Collaboration in Military Aerospace

International collaboration in military aerospace projects appears to offer the opportunity for both costs and risk-sharing between members of the collaborating group, making military projects feasible

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that could not be entertained (financially or perhaps technologically) by one country or one company. In theory, therefore, multilateral collaboration offers the potential for significant cost savings. In the perfect case, collaboration offers savings in both research and development (R&D) and production costs. R&D costs are shared between the partner nations and by combining their orders, these nations can achieve lower unit production costs resulting from economies of scale and learning. Collaboration can also offer possible wider economic and industrial benefits as well as military and political benefits. Wider economic benefits include jobs, technology, exports and import-savings. Military and political benefits include equipment standardisation and the ability to be independent of the USA in defence provision. In practice, however, actual collaboration departs from the ideal case and may be characterised by inefficiencies. These inefficiencies result from work sharing rules and in the arrangements for procurement and industrial management [5].

All economic activity involves transaction costs and collaboration is no exception. In principle, efficient transactions are the least-cost solutions to creating a multi-national contract for a collaborative military aerospace/defence equipment programme. Private competitive markets are most likely to provide efficient solutions for such contracts. However, governments are involved in defence projects as their major buyers and funders so departing from the efficient competitive market solution. Further departures from the competitive solution arise on the supply side of defence equipment markets which are dominated by national monopolies, protected markets and, in some nations, state-owned firms.

National monopolies in European defence markets comprise both state-owned and privately-owned firms where privately-owned firms are subject to the disciplines of the capital market (threats of takeover and bankruptcy). In contrast, state-owned enterprises are protected from competition and from the requirements of private capital markets and are more likely to be subject to ‘soft-budget’ constraints allowing departures from least-cost solutions. Similar inefficiencies arise for private firms which operate under cost-plus types of contracts which can be regarded as ‘blank cheque’ contracts. With such contracts, firms cover all their costs regardless of their level so resulting in inefficiencies more commonly associated with ‘soft budget’ constraints.

European defence equipment markets, including collaborative programmes, are also protected markets through Article 346 of the European Union Treaty. This Article exempts Member States from the Single Market rules on public procurement enabling them to protect essential national security interests [6,7]. The result is a ‘buy European’ procurement policy for defence equipment. The USA has a similar ‘buy American’ policy for defence equipment.

An Overview of European Military Aerospace Collaboration

Multi-lateral collaboration has long been a key feature of European defence industrial policy, especially in military aerospace programmes. Table 1 shows the major European collaborative aerospace projects since 1959. Whilst this paper focuses on defence equipment, it is necessary to recognise the European collaborations in civil aerospace, particularly Airbus and the European Space Agency (ESA).

Notes:

a) Collaborations are for those involving European nations only which excludes collaboration between European nations and other non-European nations (e.g. JSF). Collaboration countries and dates refer to initial agreements. In some cases, new partner countries were added later. For example, MBDA later involved the German missile firm LFK; and MBDA is developing the Meteor missile for 6 nations: France; Germany; Italy; Spain; Sweden; and the UK. The UK sold its share in Airbus to EADS.

b) ESA was created by 10 founding member states and by 2011 there were 19 member states, mostly EU states.

c) Italy withdrew from the A400M airlifter project leaving

Table 1: Major European Collaborative Aerospace Programmes (1959 – 2003).

<table>
<thead>
<tr>
<th>Collaboration: Partner Nations</th>
<th>Date</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>France-West Germany</td>
<td>1959</td>
<td>Atlantic Maritime Patrol Aircraft</td>
</tr>
<tr>
<td>France-UK Treaty</td>
<td>1962</td>
<td>Concorde supersonic airliner (civil airliner)</td>
</tr>
<tr>
<td>France-UK</td>
<td>1966</td>
<td>Jaguar strike aircraft</td>
</tr>
<tr>
<td>France-UK</td>
<td>1967</td>
<td>Helicopter agreement</td>
</tr>
<tr>
<td>France-West Germany</td>
<td>1969</td>
<td>Alpha Jet trainer aircraft</td>
</tr>
<tr>
<td>Germany-Italy-UK</td>
<td>1969</td>
<td>Tornado combat aircraft</td>
</tr>
<tr>
<td>France-Germany-UK</td>
<td>1970</td>
<td>Airbus Industrie (civil airliners)</td>
</tr>
<tr>
<td>EU Member States: 10 founding members</td>
<td>1975</td>
<td>ESA: civil space agency</td>
</tr>
<tr>
<td>Italy-UK</td>
<td>1980</td>
<td>EH Industries: anti-submarine helicopter</td>
</tr>
<tr>
<td>France-Italy</td>
<td>1981</td>
<td>ATR: regional civil transport aircraft</td>
</tr>
<tr>
<td>France-Germany-Italy-Netherlands</td>
<td>1985 (contract signed in 1992)</td>
<td>NH90 multi-role military helicopter</td>
</tr>
<tr>
<td>Germany-Italy-Spain-UK</td>
<td>1986</td>
<td>Eurofighter Typhoon combat aircraft</td>
</tr>
<tr>
<td>France-Germany</td>
<td>1992</td>
<td>Eurocopter: military and civil helicopters</td>
</tr>
<tr>
<td>France-Germany-Spain</td>
<td>1999</td>
<td>EADS including Airbus and Eurocopter</td>
</tr>
<tr>
<td>France-Italy-UK</td>
<td>2001</td>
<td>MBDA: missiles</td>
</tr>
<tr>
<td>Originally 8 nations with France, Germany, Spain and UK as major nations</td>
<td>2003</td>
<td>Airbus A400M airlifter</td>
</tr>
</tbody>
</table>

Notes:

i. Collaborations are for those involving European nations only which excludes collaboration between European nations and other non-European nations (e.g. JSF). Collaboration countries and dates refer to initial agreements. In some cases, new partner countries were added later. For example, MBDA later involved the German missile firm LFK; and MBDA is developing the Meteor missile for 6 nations: France; Germany; Italy; Spain; Sweden; and the UK. The UK sold its share in Airbus to EADS.

ii. ESA was created by 10 founding member states and by 2011 there were 19 member states, mostly EU states.

iii. Italy withdrew from the A400M airlifter project leaving Belgium, France, Germany, Luxembourg, Spain, Turkey and UK as the partner nations (seven nations).

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2 Article 346 replaced previous Articles in this field, namely, Articles 296 and 223 (Pourbaix, 2011).
Belgium, France, Germany, Luxembourg, Spain, Turkey and UK as the partner nations (seven nations).

Table 1 shows that European collaboration has involved only a small group of nations. In the 1960s, these comprised France, West Germany and the UK. Then from the late 1960s, two new partner nations entered European collaborative programmes, namely, Italy and Spain. These new entrants were associated with an increase in the number of partner nations in European collaborations. Significantly, all the programmes in table 1 are for aerospace projects which raises the question of what the general absence of land and sea systems in multi-lateral defence projects? One explanation might be that independence in land and sea systems was still 'affordable' over the period and the gains from collaboration were not sufficiently large to induce nations to sacrifice their independence in these systems. In contrast, high technology defence aerospace programmes involve costly R&D and offer substantial cost savings from large scale production which makes collaboration an economically attractive option.

Table 1 also identifies the industrial arrangements for European collaborations. Most collaborative defence programmes involved the creation of defence and product-specific industrial consortia with the sole task of producing the collaborative project. For example, the Tornado was produced by Panavia, and Typhoon was produced by the Eurofighter consortium. There are some significant exceptions where collaboration has been associated with the creation of permanent and multi-product European-wide companies, namely, EADS/Airbus (civil jet airliners), Eurocopter (helicopters), MBDA (missiles) and EADS Astrium (civil and defence space systems). The varying industrial arrangements associated with different European collaborative projects raises further questions about the most appropriate industrial organisation for collaboration and which form of organisation has been most successful? Do successful collaborations require the creation of permanent European companies rather than ad hoc temporary consortia? Or, are focused international consortia best suited for single product collaboration?

Multi-lateral programme collaboration involves two or more nations sharing all aspects of the development and production of defence equipment1. As noted in table 1, military aerospace examples have dominated European collaborations, where two or more nations have agreed to share the development costs of aerospace projects and combined their production orders to achieve economies of scale and learning from longer production runs. European collaboration is distinctive in its sharing of all aspects of the acquisition of the project (i.e. development and production).

In contrast, US-dominated collaborations have involved American defence companies acting as prime contractors and design leaders with groups of nations participating in the production of a US-designed and developed aircraft (co-production). The US Joint Strike Fighter (F-35) is an exception where there is some international participation and cost sharing in the development of the aircraft (e.g. the UK is the only Level 1 partner in the project contributing some 10% of planned development cost)1.

Methodology

There are major methodological problems in evaluating collaborative projects. A starting point is to compare a national project with an identical collaborative programme. But collaboration means that for the partner countries no such national identical comparators exist. This approach also raises the counter-factual problem of what would have happened without the joint venture: which type of defence equipment would have been purchased by each partner nation and in what quantities? For example, without Typhoon, would the UK have purchased US F-15 or F-18 aircraft and how many would have been purchased?

One solution to these problems is to compare actual collaborative projects and actual similar national programmes in other nations, i.e. European collaborative projects can be compared with similar US or European programmes. For example, the multi-national Eurofighter Typhoon can be compared with the French Rafale, the Swedish Gripen and rival US combat aircraft (e.g. F-15; F-16; F-18; F-22; F-35). These projects can be compared on the basis of total development costs, unit production costs, cost escalation, delivery dates and schedule overruns as well as total output and export sales. Problems arise where such data are not always available in the public domain. Also, projects differ in their performance capabilities (e.g. speed; range; altitude; weapons carrying capacity and type of weapons carried). Further problems arise in such comparisons since there is a very limited and heterogeneous population of collaborative defence projects (e.g. combat, transport and trainer aircraft; helicopters; missiles) involving different partner nations and different organisational arrangements. More data points can be obtained by adding civil collaborative aircraft projects (e.g. Airbus civil jet aircraft) which can be compared with their Boeing rivals. In this paper, the evaluation of collaborative programmes is based on a set of case studies.

Evaluating collaborative projects

Any economic evaluation requires evidence on the performance of multi-national projects. Which have been successful; which have failed; and why? Is success or failure related to the number of partner nations with more successful projects associated with few partners; or is success based on the creation of a single joint company rather than a project-specific consortium; or is success related to the extent of technical advance in the programme with high technology projects less likely to be successful?

Table 2 shows recent trends in European collaboration. There was a noticeable increase in the European collaborative share of equipment procurement between 2005 and 2010; but only a small increase in the European collaborative share of research and technology (R&T) spending. These trends need to be assessed against European Defence Agency (EDA)–created ‘targets’ for a 35% share of

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1 In this study, collaboration is variously described as multi-national collaboration or joint ventures or joint projects. These terms are used interchangeably
European collaborative defence equipment as a percentage of overall equipment procurement and 20% of European collaborative R&T as a share of total R&T [8]. However, the origin and basis for these ‘targets’ needs much more critical evaluation.

Notes:

a) Shares are for shares of totals, namely, total defence equipment procurement and total defence research and technology.

b) Share figures for national and European collaboration do not add to 100% since they exclude other collaborative defence equipment procurement (2% in 2005 and 1.4% in 2010).

c) European collaboration is defined as agreements by the Ministry of Defence for at least two EU Member States for project or programme contracts [8].

Examples of collaboration

To illustrate the approach, three examples of collaboration are evaluated comprising the four nation Typhoon, the seven nation A400M airlifter and the six nation Meteor missile programmes. Initially, each of these is compared with a sample of UK national programmes (Table 3).

Notes:

a) Data based on published data in NAO (2011) for all collaborative and UK projects. Cost increases are estimated by comparing expected cost to completion at approval stage compared with current forecast cost to completion. Similarly, delays are based on expected in-service date compared with current forecast in-service date.

b) Most projects have not been completed. Nimrod MRA4 was cancelled in 2010.

c) Astute data based on boats 1-3.

Table 3: Collaboration versus UK National Programmes.

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost increases (%)</th>
<th>Delays (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative Typhoon</td>
<td>17</td>
<td>54</td>
</tr>
<tr>
<td>A400M airlifter</td>
<td>24</td>
<td>73</td>
</tr>
<tr>
<td>Meteor missile</td>
<td>-2</td>
<td>23</td>
</tr>
<tr>
<td>UK National Astute submarine</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>Nimrod MRA4 patrol aircraft</td>
<td>28</td>
<td>114</td>
</tr>
<tr>
<td>Type 45 destroyer</td>
<td>19</td>
<td>38</td>
</tr>
<tr>
<td>Aircraft carrier</td>
<td>45</td>
<td>15</td>
</tr>
<tr>
<td>All UK major projects</td>
<td>11</td>
<td>22</td>
</tr>
</tbody>
</table>

i) Data based on published data in NAO (2011) for all collaborative and UK projects. Cost increases are estimated by comparing expected cost to completion at approval stage compared with current forecast cost to completion. Similarly, delays are based on expected in-service date compared with current forecast in-service date.

ii) Most projects have not been completed. Nimrod MRA4 was cancelled in 2010.

iii) Astute data based on boats 1-3.

iv) All UK major projects based on 15 projects. If no adjustments are made for reduced production quantities, then cost increases would have been 19.6-20.9%. Also, cost overruns on the 10 largest UK projects were 19.2% [9].

Compared with all UK national projects, collaborative programmes such as Typhoon and the A400M airlifter were characterised by higher cost increases and greater delays. But there are exceptions. Some of the UK national projects also involved substantial cost overruns and delays. Also, the collaborative Meteor missile produced by the multi-national MBDA company showed cost reductions compared with the original cost estimates and delays similar to the average for UK national projects [9]. There are two distinctive features of the Meteor missile programme. First, the original missile was selected by the UK Ministry of Defence and the other partner nations joined the MoD programme with the MoD remaining as programme manager. Second, MBDA is an existing European company so that the programme did not require the creation of a new industrial consortium to develop and produce the Meteor missile.

Unit price data comparisons

Unit price data are also an indicator of performance and value for money. However, reliable data are difficult to obtain and might be based on different national accounting and budgeting standards and include different elements in the unit cost or price (e.g. varying amounts of support). Table 4 presents some published data on unit prices for collaborative and national combat and transport aircraft [9].

Notes:

i) Costs are in 2011 prices and exchange rates. Unit total costs include R&D costs and production costs.

ii) Typhoon costs based on NAO (2011) with no capital charges included in the price. F-35 costs are estimated costs prior to large-scale production. JSF is Joint Strike Fighter.

iii) Typhoon and A400M are European collaborative projects. The US F-35 has international partners. All remaining projects are national programmes: Gripen is Swedish; Rafale based on Rafale C (air force version) is French; and all remaining aircraft are US types.

iv) n/a is not available [9].

Based on unit production costs, the collaborative Typhoon is generally more expensive than similar European projects (e.g. it is some 40% costlier than the French Rafale) and also some US national projects, with the exception of the US F-22 Raptor. But such comparisons can be misleading. First, they do not include the operational performance of each aircraft type. For example, the F-22 Raptor is operationally superior to all the combat aircraft shown in table 4. Second, comparisons with unit total costs show different results. For example, on a unit total cost basis, the French Rafale is only some 10% cheaper than Typhoon whilst the Swedish Gripen is 50% cheaper than the Typhoon. However, there is a UK-industry view which claims that in terms of combat aircraft performance, Typhoon is similar to Rafale but considerably superior to Gripen. Third, the

[9] Some of the cost reductions reflected changes in UK accounting procedures which involved removing the cost of capital charges and reduced production numbers (NAO), 2011. Of course, such changes affected all UK major projects reported in NAO (2011).
comparisons do not include the wider economic and industrial benefits of collaboration versus national programmes versus imports of US equipment. For transport aircraft, the seven nation A400M airlifter is cheaper than the US C-17 but considerably more expensive than the Hercules.

Table 4 suggests two important policy conclusions. First, European national projects can be cheaper than collaborative projects such as Typhoon. National projects also mean that the nation retains all the economic and other benefits from the programme and does not have to share these with partner nations. Second, imported US equipment might be cheaper than collaborative equipment. Critics of imported military equipment point to the loss of work share and national defence industrial capability (including independence and security of supply) and lost government tax revenue from imports compared with a national programme (but alternative uses of resources also generate tax revenues).

Other performance indicators

Additional performance indicators for assessing collaborative projects include total output and exports. Total output shows opportunities for achieving economies of scale and learning from larger combined orders compared with national orders and exports are an indicator of international competitiveness. Table 5 shows output and export data for collaborative and similar European and US national projects.

Notes:

i) Output figures include orders at end 2011. They are based on numbers of units which can change frequently (e.g. cancellations; new export orders). For example, the Rafale has been awarded an export contract for the sale of 126 aircraft to India. In December, 2012, this order had not been confirmed: hence, it is shown in brackets. Gripen export numbers include 28 aircraft leased from Sweden.

Collaboration usually leads to larger scales of output. The collaborative Typhoon achieved a larger scale of output compared with the Gripen and Rafale (more than twice their output). But, if exports are an indicator of international competitiveness, then Gripen and Rafale have demonstrated more success than the Typhoon. However, arms exports can also indicate the role of ‘other factors’ such as political influence, preferential financial terms, availability and industrial and technology transfer packages.

The position of France and Sweden in the military aerospace market is often used as an indicator of the success of national projects. It is argued that France and Sweden are able to develop and produce the Rafale and Gripen which are multi-role combat aircraft able to compete in global markets with the collaborative Typhoon. It is then concluded that the UK (and Germany, Italy and Spain) is unable to develop independently such a multi-role combat aircraft. This argument is misleading. Gripen and Typhoon have different capabilities and meet different operational requirements (e.g. single versus twin engines). Further, the UK has the industrial and technical capability to develop and produce independently an advanced combat aircraft of the Gripen-Typhoon type but it has decided that independent development of such types is ‘too costly’ and it is unwilling to pay the price. For example, it is believed by the UK industry that Typhoon and Rafale are broadly similar in both performance and cost but as a result of collaboration, the UK acquired Typhoon at only 45% of its development cost. Also, the continued trend of rising unit costs of combat aircraft renders the point about independence somewhat academic since if there is to be another generation of manned combat aircraft, it will be too costly for any single European nation to develop and produce independently. The future procurement policy options will be either collaboration or the import of US equipment. Future collaboration raises questions about opportunities for improving the efficiency of multi-national programmes.

Collaboration inevitably involves the negotiation of complex international agreements between partner governments and their
national firms. Negotiating, agreeing and enforcing such complex contracts involves transaction costs. These contracts are not costless and the task for critical analysis is to separate out efficient transactions from inefficient transactions. Both efficient and inefficient transactions are present in any multi-national collaboration. Inefficiencies are most likely to arise where there are opportunities for agents in the political market place to pursue their personal objectives. These opportunities arise in national political markets and are even more likely to arise in the international political market place of multinational programmes.

Two In-Depth Case Studies

To illustrate further the issues raised above, two European collaborative case studies are considered in more detail, using available published data on performance indicators. It is important to note, however, that there is no overall single indicator measuring ‘value for money’ in collaborative ventures, a problem exacerbated in practice by the fact that it is a subjective concept in the minds of decision-makers (where there is usually more than a single decision-maker).

The main performance indicators to be used in the case studies comprise time-scales, output and unit costs. Each indicator has its limitations. For example, time-scales might be based on aircraft, helicopters or missiles which differ in their state of completion or readiness at first flight or first delivery (e.g. first flight aircraft might not have its radar; or first delivery might be of a limited version only and not the operational version). Similarly, unit costs data are obtained from published sources and might not be the true contract price; costs might also include a different range of support and training elements). Performance data such as speed and range appear clear and unambiguous; but appearances are deceptive. Neither speed nor range are accurate indicators of the operational performance of an aircraft (e.g. its stealth capability).

The collaborative programmes selected for the case studies involve different numbers of partner nations which, in turn, have consequences for project efficiency.

Case Study 1: The Eurofighter Typhoon

Development timescales: First, we consider data on the development timescales for Typhoon compared with a set of rival and national projects. Table 6 shows that compared with Gripen and Rafale, Typhoon generally involved longer development time-scales. On both Time 1 and Time 2 measures, Gripen was considerably faster (some 20-30% faster, although Typhoon had a shorter Time 3 from start to first flight). However, Typhoon was broadly similar to Rafale: similar on Time 1, faster on Time 2 but slower on Time 3.

Notes:

i) Time 1: First date of requirement being issued to first delivery

ii) Time 2: Official start is date the first order was awarded to date of first delivery (e.g. first flight delivery). For the F-35, first delivery is estimated at mid-2016.

iii) Time 3: First order based on date of official order to date of first flight.

iv) All data based on definitions used in Janes (2011) [9].

v) F-15; F-18; F-22; F-35 are all US combat aircraft. Both the F-15E and F-18/E/F are developments of previous versions so building on the development experience of the earlier aircraft, hence, their development time-scales appear to be relatively short but allowance is needed for previous development inputs (e.g. first flight of the first F-15 variant was in July 1972 compared with the first flight of the F-15E in December 1986).

The comparisons with US aircraft are mixed. Both the F-15E and F-18/E/F had shorter development times than all the European aircraft (not only Typhoon); but these US aircraft were variants of previous related types. However, compared with the US F-22 and F-35 aircraft, Typhoon’s time-scales were considerably shorter (similarly for the Gripen and Rafale). But, it can be argued that both F-22 and F-35 are more advanced aircraft (stealthy and next generation combat aircraft) compared with Typhoon and the other European rivals: hence, they required longer development time-scales.

Output levels: Another comparative performance indicator is output levels. Output data indicate the extent to which firms are achieving scales of output which lead to scale and learning economies and result in output levels similar to US scales of output (so enabling European firms to be more competitive with their US rivals). Table 7 shows a range of comparative output data. Only the collaborative Typhoon achieves output levels approaching US scales of output but nonetheless remains substantially below the US average output of 1,374 for the US sample.

Notes:

i) Total output includes exports. Both are based on numbers of units (volume measures).

ii) All output and export data are based on Janes (2011) [10] and are current numbers at the time of writing. For example, the Rafale total output includes the announcement of an

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Table 6: Time-Scales for Typhoon and Rivals.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Time 1: Start to Delivery (mths)</th>
<th>Time 2: Official start to Delivery (mths)</th>
<th>Time 3: Official start to First Flight (mths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>230</td>
<td>171</td>
<td>64</td>
</tr>
<tr>
<td>Gripen</td>
<td>156</td>
<td>133</td>
<td>79</td>
</tr>
<tr>
<td>Rafale</td>
<td>222</td>
<td>216</td>
<td>44</td>
</tr>
<tr>
<td>F-15E</td>
<td>50</td>
<td>50</td>
<td>34</td>
</tr>
<tr>
<td>F-18E/F</td>
<td>90</td>
<td>78</td>
<td>41</td>
</tr>
<tr>
<td>F-22</td>
<td>267</td>
<td>204</td>
<td>48</td>
</tr>
<tr>
<td>F-35</td>
<td>259</td>
<td>235</td>
<td>121</td>
</tr>
</tbody>
</table>

i) Time 1: First date of requirement being issued to first delivery

ii) Time 2: Official start is date the first order was awarded to date of first delivery. For the F-35, first delivery is estimated at mid-2016.

iii) Time 3: First order based on date of official order to date of first flight.

iv) All data based on definitions used in Janes (2011) [9].

v) F-15; F-18; F-22; F-35 are all US combat aircraft. Both the F-15E and F-18/E/F are developments of previous versions so building on the development experience of the earlier aircraft, hence, their development time-scales appear to be relatively short but allowance is needed for previous development inputs (e.g. first flight of the first F-15 variant was in July 1972 compared with the first flight of the F-15E in December 1986).
order from India which was not confirmed at March 2012. Similarly, the export numbers for F-35 are likely to increase once the aircraft has entered operational service (hence, (+)). The majority of F-35 sales will be for the CTOL version with fewer carrier versions and even fewer STOVL versions.

iii) Gripen exports comprise 28 aircraft leased to the Czech Republic and Hungary plus 28 to South Africa and 12 to Thailand.

**Unit costs**: Unit costs can also be an important performance indicator and are shown for a range of military aerospace projects in (Table 8).

**Notes**: n/a is not available. F-35 costs are estimated since the aircraft is not yet in service.

i) Unit production costs for US aircraft are unit flyaway prices. The range of unit costs for F-35 reflect the different variants ranging from the F-35A to the F-35B with the F-35C variant in the middle of the range.

ii) The development costs originally estimated for the Gripen were queried as being ‘too low.’ Alternative estimates for total R&D costs for the Typhoon have been estimated at $23.5 bn; for Rafale at $21.94bn; and for Gripen at Euros 8-10 bn with Gripen being a smaller and simpler aircraft which used an off-the-shelf engine (2006 prices).


However, published data on unit costs have to be treated with considerable caution. For example, unit prices for exports might be considerably lower than unit prices for initial national procurement orders; or export orders might include spares and training assistance. The R&D costs for Typhoon are consistent with the ‘square root rule’ at about twice the development costs of a national project such as the Rafale. Unit production costs for Typhoon are higher than its European rivals but lower than the F-22 and F-35 aircraft; but again, these are more advanced combat aircraft than Typhoon.

**Table 7: Output Data.**

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Total Output (numbers of units)</th>
<th>Exports (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>559</td>
<td>87</td>
</tr>
<tr>
<td>Gripen</td>
<td>249</td>
<td>68</td>
</tr>
<tr>
<td>Rafale</td>
<td>412</td>
<td>126</td>
</tr>
<tr>
<td>F-15E</td>
<td>1480</td>
<td>330</td>
</tr>
<tr>
<td>F-18E/F</td>
<td>701</td>
<td>24</td>
</tr>
<tr>
<td>F-22</td>
<td>188</td>
<td>0</td>
</tr>
<tr>
<td>F-35</td>
<td>3146</td>
<td>703+</td>
</tr>
</tbody>
</table>

i) Total output includes exports. Both are based on numbers of units (volume measures).

ii) All output and export data are based on Janes (2011), [9] and are current numbers at the time of writing. For example, the Rafale total output includes the announcement of an order from India which was not confirmed at March 2012. Similarly, the export numbers for F-35 are likely to increase once the aircraft has entered operational service (hence, (+)). The majority of F-35 sales will be for the CTOL version with fewer carrier versions and even fewer STOVL versions.

iii) Gripen exports comprise 28 aircraft leased to the Czech Republic and Hungary plus 28 to South Africa and 12 to Thailand.

Questions therefore arise as to whether European national aircraft projects might be ‘affordable’ and more beneficial than European collaborative programmes. If both France and Sweden can afford to develop and produce an advanced combat aircraft as an independent national venture, then the UK might also consider such an option. It needs to be demonstrated that a collaborative programme such as Typhoon is more cost-effective than a similar national project. Comparing Typhoon and Rafale, the UK’s share of Typhoon total R&D costs (43.7%) at some £5.6 billion were 10% lower than the Rafale. Judgements are then needed on whether the Typhoon is more effective at meeting the UKs operational requirements.

**Comparison with other UK defence projects**

Typhoon performance in terms of cost overruns and delays can be compared with other UK non-aerospace defence projects as shown in (Table 9 below). Typhoon has higher cost escalation and delays compared with UK major projects but compares favourably with the Astute submarine.

**Notes**: i) Cost escalation for all UK major projects was about 20% without allowing for reduced production numbers.

**Table 8: Unit Costs.**

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Total R&amp;D costs (£s millions)</th>
<th>Unit production costs (£s millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>12.8</td>
<td>72.0</td>
</tr>
<tr>
<td>Gripen</td>
<td>2.2</td>
<td>23.75</td>
</tr>
<tr>
<td>Rafale</td>
<td>6.2</td>
<td>35.5</td>
</tr>
<tr>
<td>F-15E</td>
<td>n/a</td>
<td>27.6</td>
</tr>
<tr>
<td>F-18E/F</td>
<td>4.9</td>
<td>35.1</td>
</tr>
<tr>
<td>F-22</td>
<td>25.0</td>
<td>99.8</td>
</tr>
<tr>
<td>F-35</td>
<td>34.2</td>
<td>77.8 – 95.7</td>
</tr>
</tbody>
</table>

**Notes**: n/a is not available. F-35 costs are estimated since the aircraft is not yet in service.

i) Unit production costs for US aircraft are unit flyaway prices. The range of unit costs for F-35 reflect the different variants ranging from the F-35A to the F-35B with the F-35C variant in the middle of the range.

ii) The development costs originally estimated for the Gripen were queried as being ‘too low.’ Alternative estimates for total R&D costs for the Typhoon have been estimated at $23.5 bn; for Rafale at $21.94bn; and for Gripen at Euros 8-10 bn with Gripen being a smaller and simpler aircraft which used an off-the-shelf engine (2006 prices).

iii) Data based on Jane’s All The World’s Aircraft (2011) [9] and the US GAO (2011) [10].

**Table 9: Cost Escalation and Delays.**

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost escalation (%)</th>
<th>Delays (mths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>16.5</td>
<td>54</td>
</tr>
<tr>
<td>Astute submarine</td>
<td>55.8</td>
<td>58</td>
</tr>
<tr>
<td>Type 45</td>
<td>19.0</td>
<td>38</td>
</tr>
<tr>
<td>All UK Major Projects</td>
<td>11.4</td>
<td>30</td>
</tr>
</tbody>
</table>

**Notes**: i) Cost escalation for all UK major projects was about 20% without allowing for reduced production numbers.

ii) Astute data based on boats 1-3.

**Source**: NAO (2011), [8].

ii) Astute data based on boats 1-3.

Source: NAO (2011), [9].

Wider economic benefits: The Eurofighter Typhoon programme also provides additional economic and industrial benefits. It is Europe’s largest collaborative military aircraft programme providing jobs, technology and balance of payments benefits for the partner nations. Some of these benefits for all four partner nations are shown in (Table 10) below.

Note: All data at 2008 position and prices (e.g. based on original plans for partners to buy 620 units).

Source: Hartley (2008), [12].

The economic and industrial benefits from Typhoon appear impressive but they need to be evaluated critically. First, the above data provides only a partial evaluation which excludes a complete appraisal (e.g. unit cost; performance against contract and operational requirement), including a similar evaluation of rival aircraft (e.g. Rafale; Gripen; F-15; F-16; F-18; F-22; F-35). Second, the opportunity cost question needs to be addressed: would the resources used in the Typhoon programme (and its rivals) make a greater contribution to national output and economic welfare if they were used elsewhere in the economy? Third, the wider economic and industrial benefits need to be assessed in relation to market failures: are there genuine market failures which justify state intervention in relation to jobs, technology and balance of payments benefits? Here, it is likely that labour and foreign exchange markets are working reasonably well but there might be genuine failures in technology markets (R&D markets and their spin-offs) reflected in possible substantial beneficial technology externalities. But such spin-offs have to be identified and valued: what is their market value? Moreover, even where some market failure is identified, it does not follow that Typhoon is the most cost-effective solution.

Typhoon inefficiencies: An official UK study of the Typhoon project [13] provided evidence on collaboration inefficiencies. It concluded that:

i) The collaborative management structures were complex and inefficient.

ii) Some 63% of the cost increases were “due to the inefficient collaborative commercial and managerial arrangements, obligations to international partners and the complexity of the technologies being developed, a challenge compounded by the rigid collaborative workshare requirements” [13].

iii) Collaborative decision-making is inefficient. Decision-making is slow with key decisions requiring consensus from all four partner nations. In one case, it needed seven years to agree and deliver some key upgrades.

iv) Key investment decisions were taken on an over-optimistic basis.

v) “The diverse spread of design, manufacturing and support expertise has increased costs of the aircraft overall and poses risks to the timeliness and affordability of support and upgrade activities”[13].

vi) The government management arrangements are replicated by industry with the prime contractors from each nation forming the Eurofighter consortium with similar arrangements for the engine.

vii) Even within the UK Ministry of Defence, the governance arrangements for the delivery of Typhoon capability remain complex. No individual is accountable and clearly in charge of the whole project.

UK industry views on Typhoon collaboration inefficiencies suggest that they are considerably less than using the conventional ‘square root rule’. Estimates have been given of a +30% collaboration premium (inefficiencies) on Typhoon, mainly due to the programme avoiding duplication of effort.

Evaluation of Typhoon: Typhoon is a four nation collaboration. It has been compared with European and US national projects. There are national projects with shorter development time-scales but Typhoon output exceeds that for both European rivals, namely Gripen and Rafale. However, compared with its European rivals, Typhoon has higher R&D costs and higher unit production costs and so appears less cost-competitive; and this lower cost-competitiveness is further confirmed by both Gripen and Rafale showing a higher proportion of their output for export (where exports indicate international competitiveness).

Case Study 2: The Airbus A400m Airlifter

The A400M Airlifter is a distinctive collaboration involving seven partner nations managed by a single European company with an established reputation in developing and producing competitive civil jet airliners (Airbus). It will be compared with the US Boeing C-17 Globemaster and Lockheed Martin C-130J Hercules military transport aircraft.

Table 10: Wider Typhoon Economic and Industrial Benefits.

<table>
<thead>
<tr>
<th>Employment</th>
<th>Technology Benefits</th>
<th>Exports and import-savings</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>100,000-150,000 jobs; High wage and high skill jobs; Exports: 14,000 jobs</td>
<td>Valued at Euros 7.2 billion (lower bound) Examples: carbon fibre technology; civil aircraft; motor cars; aero-engines.</td>
<td>Exports at Euros 9.2 billion Balance of payments contribution: Euros 43-63.2 billion</td>
<td>European independence; security of supply; ability to manage complex international and high technology project; Standardisation.</td>
</tr>
</tbody>
</table>

Note: All data at 2008 position and prices (e.g. based on original plans for partners to buy 620 units).


Table 11: A400M, C-17 Globemaster and C130J Hercules.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Time 1  (mths)</th>
<th>Time 2  (mths)</th>
<th>Time 3  (mths)</th>
<th>Cost escalation</th>
<th>Delays (mths)</th>
<th>Output (units)</th>
<th>Exports (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A400M</td>
<td>288</td>
<td>120</td>
<td>79</td>
<td>24%</td>
<td>73</td>
<td>174</td>
<td>4</td>
</tr>
<tr>
<td>C-17</td>
<td>142</td>
<td>90</td>
<td>69</td>
<td>n/a</td>
<td>n/a</td>
<td>264</td>
<td>41</td>
</tr>
<tr>
<td>C-130J</td>
<td>101</td>
<td>101</td>
<td>58</td>
<td>n/a</td>
<td>n/a</td>
<td>264</td>
<td>123</td>
</tr>
</tbody>
</table>

Notes:

i) Times 1-3 defined in Table 11.
ii) n/a is not available.
iii) Cost escalation and delays based on UK data (NAO, 2011).
iv) C-130J based on the earlier variant of the Hercules.

The Time 1 measure reflected the considerable time needed to reach international agreement on the operational requirement. Also, the Airbus Military Company which became responsible for the programme, was not formed until January 1999. Time 2 and 3 measures were some 33% and 15% longer than the C-17 which is considerably less than the 'cube root rule' expected for collaborative development times (cube root for seven nations is some 1.9).

There is an alternative method for assessing time-scales and the impact of the number of partner nations. Comparisons can be made between time-scales for the A400M and the typical development timescales for Airbus civil jet airliners. Such comparisons provide a means of assessing the impact of different demand-side arrangements. The A400M is a military transport aircraft demanded by seven partner governments. In contrast, Airbus civil jet airliners are demanded by large numbers of airlines with Airbus in competition with Boeing (a world duopoly position). Airbus jet airliners are advanced technology aircraft (including the A380 airliner) compared with the A400M which is a propeller-driven aircraft and probably involving lower levels of technology (although its engines/propellers are quite challenging; they are the largest turbo-prop engines ever built). The supply-side is similar with Airbus airliners supplied by Airbus and the A400M supplied by Airbus Military.

Consider now the development time-scales for the A400M and for the average development times for a group of Airbus civil jet airliners (Table 11 and Table 12).

Notes

i) Time to first flight based on time from official launch to first flight. Time to first delivery from official launch to first delivery. All data based on months as reported in Janes (2011),[9].
ii) Total sales are orders at January 2011, based on Janes (2011),[9].
iii) Airbus A350 is currently under construction and has not yet flown: hence, times are estimated time-scales.

Compared with the Airbus average of civil jet airliners, the A400M was 56 months later than the Airbus average group; and compared with the Airbus A320, the A400M required an additional 72 months (based on total development times). These results suggest that more partners involve considerable delays in development times.

Output levels for the A400M are considerably greater than the national requirements of each of its partner nations. Originally, the European requirement was estimated at 250-300 aircraft plus exports estimated at some 500-600 aircraft [14]. More exports are likely once the A400M has entered service and demonstrated its performance.

Unit costs: On a unit cost basis, the A400M is positioned about mid-way between the smaller C-130J and the C-17 Globemaster (Table 13).

Notes:

i) Range of unit costs for A400M reflects alternative published figures.
ii) Na is not available.

Findings on A 400 M airlifter: The A400M Airlifter is a distinctive collaboration. It comprises seven partner nations and has the largest number of partners within our case studies. Also, it is not an advanced technology project such as Typhoon and Tornado; and it has been developed by Airbus Military which is a division of the successful Airbus Company: hence, the industrial supply-side arrangements were already in existence and well-established.

In practice, however, the procurement and project management arrangements for the A400M have been heavily criticised as an example of how not to proceed with collaborative projects. In contrast critics prefer the bilateral missile development programmes of the Storm Shadow/Scalp type as they offer a much simpler approach to procurement and project management [15].

Reducing Collaboration Inefficiencies

An analytical framework is needed to guide thinking about
the prospects for reducing collaboration inefficiencies. National programmes provide a starting point. These have a single buyer on the demand side of the market and a single prime contractor on the supply side. None of these features guarantees a problem-free programme. National programmes are characterised by problems in agreeing operational requirements, changes in requirements, by cost overruns, delays and shortfalls in performance and they are subject to budget cuts which affect numbers and also lead to delays. But collaboration adds to these national problems by creating a multinational procurement agency and an international consortium of suppliers whose sole task is usually the development and production of a single defence project (e.g. combat aircraft; airlifter; helicopter). On both the demand and supply-side, each collaborative project typically requires the creation of a new and project-specific set of management arrangements. Inevitably, this involves new learning experiences as different partner nations and their suppliers have to bear the transaction costs of ‘doing business’ with new partners (strangers). Collaboration also creates an international military-political-industrial interest group which is likely to be more powerful and influential than its national equivalent.

Examples of inefficiencies

Inefficiencies on collaborative programmes arise from excessive bureaucracy in procurement management. Typically, collaboration involves complex management arrangements which are inefficient. For example, the management agency for Eurofighter Typhoon (NEFMA) was located in the same building as the management agency for Tornado (NAMMA). Originally, it was planned to merge the two agencies but Spain objected since it had not been involved in the Tornado programme: hence, a separate agency (NEFMA) was established for Typhoon. Eventually, in 1995, the two agencies were merged to form the NATO Eurofighter and Tornado Development, Production and Logistics Management Agency (NETMA). Prior to the merger, NEFMA was criticised for not being an effective focus for the management of the Typhoon programme because it lacked a clear mandate [16].

Further inefficiencies often arise from the workshare arrangements for collaborative programmes. Typically, each partner nation requires a share of the advanced technology on the project. This is both inefficient and leads to lapses in communication, especially where the various elements made by different companies are integrated into complete systems and the project as a whole. For example, components might be shipped around more than was necessary. The radome for Typhoon spent considerable time in transit [17]. Similarly on ‘Typhoon,”...the industrial arrangements for the Flight Control System had all the characteristics of an accident waiting to happen.

Even though British companies...had demonstrated their competence to carry out the work, other companies became involved who were either not up to the job or whose involvement made arrangements unduly cumbersome [17]. Indeed, GEC Marconi claimed that a technically compliant solo bid would have been one third cheaper than the consortium bid [16]. By the mid-1990s, it was concluded that most of the cost escalation and delays on the Typhoon programme were due to the commercial and management arrangements on the programme, especially the rigid work-sharing requirements, rather than to major technical difficulties [16].

Away from aerospace, industrial arrangements were a factor in the UKs withdrawal from the collaborative Common New Generation Frigate (CNGF) known as Project Horizon for its warship element. On Project Horizon, an International Joint Venture Company (IJVC) was created from the three companies nominated by each of the three partner nations (France; Italy; UK). From the UKs perspective, two problems arose with the IJVC. First, there were concerns that the IJVC was unable to present proposals for an affordable ship in a time-scale that would meet the operational requirement. Second, the IJVC had not established itself as a “strong prime contractor with a robust supporting industrial structure. The lack of clear leadership meant that there was a risk that the shareholder companies were more concerned with their own work share rather than managing the programme on an objective basis” [18]. In 1999, the UK withdrew from Project Horizon to pursue a national Type 45 Destroyer programme. The UK concluded that “Overall, the absence of an industrially robust – as distinct from a specially formed – prime contractor encompassing responsibility for the platform and the weapons fit spelled the end of what had looked at least like a very promising project” [18]. Of course, it is not possible to identify whether this was the real underlying reason for the UKs withdrawal from Project Horizon. An alternative possibility might be pressure from national warship builders and the Armed Forces to undertake a national project.

There is a further potential source of inefficiencies in multinational programmes. International programmes create a major military-industrial interest group comprising the Armed Forces, Defence Ministries and national producers in each partner nation. Such a large interest group makes it more difficult to cancel a collaborative programme. Indeed, threats of cancellation by one partner can always be used as a bargaining tool for it to obtain an improved work share on the programme. A reduced threat of cancellation will reduce the incentives of producers to behave and perform efficiently: they can regard collaborative programmes as a guaranteed and continuous source of funds for their companies.

Solving collaboration inefficiencies

Collaboration inefficiencies can be grouped around five broad areas concerned with procurement, industrial organisation, work share, market incentives and the number of partner nations:

Procurement organisation: Considerable scope exists for improving the efficiency of the procurement arrangements for collaborative programmes. Such efficiency improvements can be achieved by reducing duplicate procurement organisations, by introducing majority voting rules for decision-making and by creating specialist international procurement agencies for collaborative programmes. Some progress has been achieved through the formation of OCCAR, the Organisation for Joint Armaments Co-operation. OCCAR was launched in 1996 by France, Germany, Italy and the UK.
Conclusions

...and established as a Convention via an international treaty in 1998. It aims to improve the efficiency and reduce the costs of current and future collaborative defence equipment programmes by providing expert international procurement knowledge. New members joined, namely, Belgium (2003) and Spain (2005). In 2012, OCCAR had a staff of some 240 personnel and managed seven collaborative programmes (e.g. A400M airlifter; Eurocopter Tiger helicopter; Boxer armoured vehicles; and the COBRA weapons locating system).

**Industrial organisation:** Inefficiencies arise where each new collaborative programme requires a new set of industrial arrangements, usually a consortium of companies created for the sole task of delivering the collaborative project. Such *ad hoc* one project consortia lack continuity and a single prime contractor offering clear management leadership for the programme. Some progress has been made in the creation of European-wide defence companies, namely, EADS, MBDA and Eurocopter (EADS).

**Work share:** is a major source of inefficiency in European collaborative programmes. Traditionally, work was allocated on the basis of *juste retour* which ensured that the industry of each partner nation was awarded work in proportion to each nation’s financial contribution. OCCAR nations have moved away from *juste retour* on a single project, replacing it with a global balance policy where work share is based on a balance over a number of programmes and over a number of years. Nonetheless, efficiency improvements for collaborative programmes require that all work be allocated on the basis of competitiveness and comparative advantage. This requires contracts to be allocated on the basis of real competition and value for money criteria.

**Market incentives:** The introduction of genuine market incentives into collaborative programmes requires that work share be based on competition (including competition from firms outside the partner nations) reinforced with hard budget constraints in the form of fixed price and incentive contracts. In contrast, cost-plus contracts provide no efficiency incentives and form ‘soft budget’ constraints. Furthermore, efficiency requires privately-owned firms rather than state-owned enterprises.

**Number of partner nations:** More partner nations increases the costs and complexity of collaborative programmes. In principle, bilateral collaboration is lower cost than multilateral collaboration. The ‘square root’ rule indicates the costs of adding more partners to a collaborative programme. The challenge is to achieve multi-national collaboration and its potential cost savings in both development and production whilst ensuring that only a few nations are allowed to manage the programme. The design of the US Joint Strike Fighter (F-35) programme might be a way forward for future European collaboration.

**Conclusions**

a) Adding additional nations to collaboration will increase its inefficiency so offering poor value for money. More partner nations add to transaction costs by increasing the complexity of procurement, project management and the industrial supply-side arrangements. Work-sharing becomes more complex and costlier with more nations. Bilateral collaborations appear to offer the best value for money from international collaboration.

b) Where collaboration adds to exit costs, cancellation is less likely compared with a national programme (i.e. national programmes might be cheaper to cancel: hence, are more likely to be cancelled). However, empirical work in this area requires access to the details of national and international contracts and there are further problems in obtaining reliable data.

c) The major lesson from European military aerospace collaborations is that they remain inefficient with considerable opportunities for efficiency improvements. Both the European civil Airbus and United States military JSF models offer some guidelines for future improvements: Airbus shows the advantage of a single European company which acts as a single prime contractor which is also a feature of the JSF model.

d) ‘Political’ work-sharing is a major source of inefficiency and efficient collaborative ventures require work to be allocated on genuine competitiveness principles.

e) The European military aerospace sector remains as essentially a set of nationally fragmented defence markets. Efficiency improvements require that Europe either creates a genuine Single European Market in defence equipment to achieve US scales of output or it will have to accept a minor role in international collaborations led by -and dominated by- the USA.

f) Collaborative programmes need to be subject to hard budget constraints. Soft budget constraints reward inefficiency and poor performance. This is costly for both taxpayers and the Armed Forces.

g) Future collaborations need to extend to the complete life-cycle of the project. Current collaborations usually apply to the project *acquisition* stage only. There remain considerable opportunities for collaboration extending to all subsequent phases of a project’s life-cycle, including training, repairs, maintenance, spares and mid-life up-dates.

h) Compared with the US defence market, EU defence markets are fragmented and ‘too small’ resulting in the duplication of costly R&D and relatively short production runs so that firms cannot achieve substantial economies of scale and learning. The EU’s Armed Forces are also inefficient and characterised by massive duplication of Defence Ministries; armies, navies and air forces; training; military bases; logistics and servicing and repair organisations. Such duplication indicates the opportunities for pooling and sharing resources which, in turn, depends upon trust between nations in sharing their military assets and forces.

i) Rising unit costs mean that buying defence equipment from a national supplier with small-scale European levels of output is costly and increasingly unaffordable. Either European multi-national collaboration is made much more efficient and internationally competitive or nations will have to import defence equipment, mainly from the USA.

**References**


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