THE INDUSTRIAL AND ECONOMIC BENEFITS OF EUROFIGHTER TYPHOON

FINAL REPORT

Professor Keith Hartley
Centre for Defence Economics
University of York
York
England

16th June, 2006

CONTENTS

EXECUTIVE SUMMARY

Chapter 1. INTRODUCTION: The Research Questions

Chapter 2. THE ECONOMIC AND INDUSTRIAL BENEFITS OF THE PROGRAMME: A Conceptual Framework for Choices

Chapter 3. EMPLOYMENT BENEFITS

Estimates

Employment in support activities

Learning curves and the costs of production delays

Wages and salaries on Typhoon

Chapter 4. TECHNOLOGY AND SPIN-OFF BENEFITS

Impacts on the supply chain

Transmission mechanisms

The valuation of technology spin-offs

Chapter 5. EXPORT PROSPECTS AND BENEFITS

Chapter 6. INDUSTRIAL BENEFITS

Inefficiencies in collaboration

Lessons for future European collaboration

Chapter 7. CONCLUSION: Future Prospects

References

Acknowledgements

This independent academic study was commissioned by Eurofighter PR& Communications Office, Munich. My thanks to all the staff who kindly assisted with this study. These included staff at Eurofighter and Eurojet, Munich; EADS (Germany); BAE Systems, Warton; to all the supplier firms which participated in the postal survey; and to Eurofighter PR& Communications Office, especially to Wolfdietrich Hoeveler, Vice President Communications and Nina Hornauer for her assistance in arranging interviews and support for the postal survey. The usual disclaimers apply.

EXECUTIVE SUMMARY

1 Eurofighter Typhoon is Europe's largest military aircraft programme. It has been subject to considerable public scrutiny by national Parliaments which have a public duty to monitor large-scale public spending programmes. Typhoon has also been the focus of considerable criticism, especially about its continued relevance in the post-Cold War world, its high and rising costs and its considerable delays. Further criticism has focused on the inefficiencies of the industrial collaboration and work share arrangements and the bureaucracy on the part of the partner governments as customers.

2. Little information has been published on the economic and industrial impacts and benefits of the Programme. This study aims to remedy this gap in knowledge about the Programme.

3. Typhoon supports large numbers of jobs, many of which are highly-skilled and high wage jobs. Total employment on Typhoon is estimated by Eurofighter at some 100,000 personnel, although an alternative estimate in this study suggests a much lower figure of some 66,500 personnel. The different estimates reflect different methodologies and different assumptions about the scope of the Programme.

4. Typhoon supports employment in development work which requires highly-skilled scientists and engineers; in production work which is skill-intensive; and in support activities some of which are high technology, especially in the simulation industry (e.g. computers; software for training air crew).

5. On Typhoon development work, typical salaries were some 60% higher than the average earnings in all EU industries; and in some of the partner nations these differentials were even greater.

6. Many of the Typhoon's labour skills are highly transferable (e.g. to motor car and electronics industries; and to work on Airbus A380). This means that breaks in Typhoon production can be costly through losses in learning and the loss of experienced workers.

7. An impressive set of examples of the technology benefits from Typhoon were identified. These include carbon fibre technology; super plastic forming and fusion bonding; modular avionics; the flight control system; and aero-engine technology. Technology spin-offs were also identified from the Typhoon Programme to civil aircraft, to motor car industries (including Formula 1 racing cars in Italy and the UK) and to supply chains. These technology externalities were valued at Euros 7.2 billion (minimum).

8. Typhoon is not only contributing to technology benefits and spin-offs: it is also contributing to the creation of a range of modern business practices which are being applied throughout the supply chain.

9. There are export and import-saving benefits from Typhoon. Exports provide additional employment and contribute to maintaining the European defence industrial

base. Currently, Austria has ordered 18 Typhoon aircraft involving an offset deal and there are negotiations for an export order from Saudi Arabia (reports suggest a possible order for 72 aircraft). The total balance of payments contribution of Typhoon is estimated at Euros 43-63.5 billion (acquisition costs only).

10. Typhoon offers a variety of industrial benefits. These include the maintenance of an independent European combat aircraft industry as part of the defence industrial base and the associated benefits from such an independent defence industrial base, including independence from the USA. The Programme has further contributed to equipment standardisation amongst the partner nations (and export customers); it has supported the European aerospace technology base and has contributed to maintaining an internationally competitive European aerospace industry.

Chapter 1.

INTRODUCTION:
The Research Questions

1. Considerable publicity has focused on the problems surrounding the Eurofighter Typhoon Programme, particularly its cost levels, cost overruns, delays over entry into service and its military role and relevance in the changed post-Cold War security environment. **However, little information has been provided about the economic impacts and benefits of the Programme for the partner nations. This study aims to remedy this gap in knowledge about the Programme.** It presents an independent and critical economic evaluation from the perspective of all four partner nations.

2. The Report identifies some of the general economic and industrial benefits of the Typhoon Programme for all four partner nations. The challenge is to estimate the magnitude of these benefits and critically evaluate them. For this objective, two methods were used. First, an interview survey of staff in Eurofighter, Eurojet, EADS and BAE. Second, a postal questionnaire survey of the suppliers involved in the Programme.[1] Unless stated otherwise, all prices are for 2003/04 .

[1] The postal survey was launched in July 2004 and its results are integrated into this Report.

Chapter 2.

THE ECONOMIC AND INDUSTRIAL BENEFITS OF THE PROGRAMME: A Conceptual Framework for Choices

3. In terms of economic benefits, the focus was on employment, technology and export prospects for the Programme. A conceptual framework for the analysis is shown in Table 1. The research task is to provide estimates for the various economic and industrial benefits. A comprehensive benefit-cost analysis of Typhoon also requires data on programme costs which can then be compared with benefits. A worthwhile project is one where benefits exceed costs. Such a comprehensive economic evaluation is beyond the scope of this Report, but some indications of the approach are outlined.

4. Table 1 shows that each of the benefits needs to be carefully identified and then quantified for both Typhoon and its range of rival aircraft. Employment embraces numbers of jobs, their skill and salary levels, the location of jobs, their gender and full-time/part-time nature. Similarly, technology embraces the new technology resulting from the Programme and any spin-offs to military and civil work both within the aerospace industry and to other industries in the partner nations (spin-offs outside the partner nations need to be identified, but these are benefits to other non-partner nations). Export benefits include life-time support and any import-saving benefits as a contribution to the balance of payments (e.g. without Typhoon each partner nation might have imported foreign equipment). Finally, there might be other industrial and military benefits which need to be identified for the evaluation. These other benefits might include support for the national defence industrial base (DIB) with the associated benefits from a DIB such as security of supply and re-supply, bargaining power and national independence. Further 'other benefits' might include the contribution to equipment standardisation within the NATO alliance and the technology aspects of independence. Here, Typhoon provides the technology enabling Europe to maintain its DIB so that it is independent of the USA (e.g. compare Israel which is dependent on the USA and US foreign policy) and avoids the continuing problems of technology transfer associated with purchases of US equipment (e.g. UK experience with its involvement in the US JSF Programme has confirmed the problems of technology transfer on this Programme: by mid-2006 the USA had not reduced its barriers to technology transfer).

5. A further example of the military benefits and 'wider factors' associated with a national DIB is outlined in the UK's new Defence Industrial Strategy. The Strategy specifies guiding principles related to appropriate sovereignty; through-life capability management; maintaining key industrial capabilities and skills; intelligent customers-intelligent suppliers; and best value for defence all of which are relevant to the Typhoon Programme. The Strategy also outlines the 'wider factors' which will be included in the UK's procurement choices. These wider factors include security of supply; industrial participation; industrial capabilities (e.g. regional jobs; technology spin-off; high value to UK economy); key technologies; export potential; foreign and security policy interests; and wider MoD policy (Cmnd 6697, 2005, pages 17 and

55). On future manned combat aircraft, the UK's position is that it does not expect to design and build a new generation of manned fast jet aircraft beyond Typhoon and JSF; but that it will need to retain aerospace engineering and design capability for through-life management of these aircraft (Cmnd 6697, 2005, p86).

6. The conceptual framework in Table 1 is not without its problems. The potential benefits have to be identified and, ideally, these need to be based on the preferences of policy-makers (i.e. Governments and their policy objectives). Next, the benefits have to be quantified and ultimately expressed in monetary terms (so allowing comparisons of benefits with Programme costs). Here, there are obvious difficulties in assembling reliable data at the *start* of a high technology Programme characterised by considerable uncertainties. For example, at the start of a programme, reliable data are needed on its annual employment impacts for development, production and support over its life-cycle (e.g. 50 years). Similar data are needed on technology benefits and any spin-offs, many of which will arise well into the future. Ideally, such data are needed at the *start of the programme* so that Governments can make informed choices about the programme. Even where data on benefits are available, these need to be converted to monetary valuations. For example, how highly do Governments value jobs benefits, especially in marginal constituencies; and what valuation is placed on technology and spin-off benefits?

7. A simple identification of industrial and economic benefits is useful but not sufficient for Government choices and decisions. **The economists opportunity cost question cannot be avoided: would the resources used on the Typhoon Programme make a greater contribution to national output if they were used elsewhere in the economy?** For example, all public expenditures create jobs and the issue arises as to whether other public spending programmes (e.g. on construction projects, etc) would create more jobs than Typhoon. If Typhoon had been cancelled, then there would have been alternative public spending projects with job creation in other regions. Similarly, all employment has induced multiplier effects as workers directly employed on a public programme spend their incomes on goods and services creating and supporting jobs both locally and elsewhere (nationally and overseas). It is also the case, that Typhoon and all other public spending projects have tax revenue and social welfare spending impacts.

8. However, in assessing these opportunity cost arguments, the alternative expenditures to Typhoon need to be specified clearly. For example, critics of the claim that Typhoon generates tax revenues, need to recognise that the alternative to Typhoon is likely to be another defence equipment project and not a civil project; and that such an alternative defence equipment project will be a foreign purchase where the tax returns accrue to the foreign government. One study estimated that for Germany, some 70% of the German costs of Typhoon flowed back to the German Government as tax revenues compared with a tax return of under 10% for the purchase of a US aircraft (interview at Eurofighter, 24/6/04). Similarly, it has to be recognised that alternative projects to Typhoon might generate more jobs but these might be low-skilled and low wage jobs which will not provide the increased living standards expected by society. In some cases, without Typhoon, there might be substantial local unemployment; but Treasury economists could argue that such local unemployment might contribute to reducing inflationary pressures in the national economy.

9. This economic evaluation of Typhoon and its alternatives considers the opportunity cost question. Some of these issues are addressed, especially the employment benefits where evidence is presented on the salary levels of staff employed on Typhoon, so enabling comparisons with national salary levels (i.e. as indicators of alternative employment opportunities). Also, in assessing the economic arguments for state intervention in the economy, consideration has to be given to whether markets are failing to work properly.   For example, a focus on jobs and employment benefits requires evidence that labour markets are failing to work properly, so justifying state intervention. However, intervention through the procurement of major defence projects requires that such projects be the appropriate and cost-efficient solution (e.g. other policies such as training and labour mobility might be more efficient).

Table 1. A Conceptual Framework for Evaluating the Typhoon Programme

Programme	**Economic and Industrial Benefits**			
	Employment (numbers; skills; wages/salaries)	**Technology (including spin-offs)**	**Exports and Import-Savings**	**Others (e.g. contribution to retaining DIB and security of supply)**
i) Typhoon **ii) Procurement of Alternative Foreign Aircraft with licensed production or offsets or direct imports (examples):** **F-15** **F-18** **F-22** **JSF** **Rafale** **Gripen**				

Chapter 3.

EMPLOYMENT BENEFITS

10. Typhoon supports large numbers of highly-skilled, highly-paid and high value-added jobs throughout the four partner nations. There are jobs in development, production and support, involving airframes, engines, equipment and a range of support activities (e.g. simulators for aircrew training). The Typhoon jobs are in the major prime contractors for the airframe and engine and in their associated supply chains. In some partner nations (e.g. Spain), Typhoon has contributed to creating a highly-skilled labour force. Broadly, the costs of Typhoon production are allocated: 40% for the airframe; 40% for the equipment; and 20% for the engine. Support costs for Typhoon might be a further 50% of production costs. The total costs of Typhoon are estimated (2004 prices):

i) Development = Euros 18 billion

ii) Production (620 aircraft) = Euros 36 billion

iii) Support = Euros 15-18 billion

11. The basic principles of the work share arrangements for Typhoon are:

i) Work share is based on the number of aircraft ordered and the national financial contributions to the Programme are:

Germany = 30%; Italy = 19.5%; Spain = 13%; and the UK = 37.5%

ii) No money crosses the borders and taxpayer's money is invested into national and European aerospace industries.

12. **Total employment on Typhoon is estimated by Eurofighter at some 100,000 to 105,000 personnel employed directly and indirectly in over 400 companies throughout Europe**. This figure applies to each of the development and production phases (i.e. 100,000 on development and 100,000 on production). In 2006, these jobs were distributed:

i) Germany: 20,000 personnel

ii) Italy: 20,000 personnel

iii) Spain: 25,000 personnel

iv) UK: 40, 000 personnel. The UK total includes over 5,000 jobs in BAE Systems allocated as follows: over 1500 jobs at Samlesbury in high technology manufacture; over 1300 jobs at Warton in leading edge design and systems engineering activities; and over 1000 jobs at Edinburgh and Stanmore in high technology design and sensor manufacture (Boardman, 2004).

13. Typhoon employment can also be assessed in terms of partner companies and supplier companies. On this basis, employment is:

i) **Eurofighter partner companies** (Alenia; BAE Systems; EADS D; and EADS CASA), all involved in design and production responsibility for major aircraft components plus final assembly supporting approximately **50,000 jobs**. The work is shared with Alenia building all left wings, outboard flaperons and rear fuselage; BAE Systems building all front fuselages, canopy, dorsal spine, tail fin, inboard flaperons and rear fuselage section; EADS Germany building the main centre fuselage; and EADS CASA building all right wings and leading edge slats.

ii) **Supplier companies**: mainly small and medium-sized firms with design and production responsibility and/or production responsibility for sub-components and parts supporting approximately **50,000 jobs**. Major firms in the Eurofighter Team Top 8 suppliers(first tier suppliers) comprised BAE Avionics (UK); Smiths (UK); General Dynamics (UK); Marconi (now BAE: UK); EADS Defence Electronics (Germany); Teldix (Germany); Galileo Avionica (Italy); Indra (Spain). A survey of Eurofighter suppliers found that in 2003, the typical company had annual sales of Euros 201 million; it employed some 1600 personnel; defence sales were 64% of total sales; and employment on Typhoon accounted for some 5%-10% of total company employment. These firms also had suppliers for their company: typically, the firms in the postal survey had some 30 suppliers involved in their Typhoon production with some 5-6 suppliers accounting for 75% of the purchased inputs for Typhoon production. The majority of suppliers in the survey (64%) claimed that Typhoon profitability was the same as for their other defence work (with 36% claiming that its profitability was lower than their other defence work). However, all of the suppliers in the survey planned to remain in the aerospace business.

iii) Jobs in EJ200. Here, it is estimated that there were 4000 personnel employed at the first level in the EJ 200 supply chain. Whilst Typhoon is Europe's largest military programme, both MTU Aero-Engines and Rolls-Royce have large civil aero-engine businesses so that Typhoon is a small part of their total business (e.g. military business might be 15% of their total business). As a result, the airframe companies are more dependent on military work than the engine firms.

iv) Induced employment. There are additional jobs in local economies created from the spending of workers on the Typhoon programme (e.g. in local shops, garages, restaurants, etc). However, it has to be recognised that such jobs are also supported by alternative expenditures (e.g. construction work).

14. It was not possible to provide an independent evaluation of these total employment estimates and the methodology used to derive the figures. For example, one estimating method starts with a cost estimate, then converts costs to staff and annual employment numbers with adjustments for peak periods. The resulting

estimate of direct employment is then used to estimate indirect numbers (i.e. in the supply chain, with an assumed ratio of direct: indirect of 1:1) with further additions for induced employment and jobs created from tax revenue (e.g. final employment estimate might be 2-3 times the numbers for direct employment). Furthermore, the resulting employment estimate might be for one partner nation which is then aggregated over all four partner nations. **An independent evaluation of estimated employment on Typhoon requires that the assumptions and methodology be available for critical scrutiny.** There are concerns about the assumptions used to estimate indirect labour and the definition of the supply chain and its extent; whether induced multiplier effects are included and the aggregation from one nation to all four partners. Further issues arise as to the definition of the Programme and whether it includes employment on support activities. Overall, the official Eurofighter estimates of Typhoon total employment range from some 100,000 personnel to more than 150,000 jobs across Europe (Boardman, 2004; Eurofighter Typhoon brochure, Munich, 2004).

15. There is an alternative method to provide a check on the reliability of the Typhoon employment estimates. This involves taking the UK figures for the estimated cost to the UK of the Typhoon Programme at £19670 million (development and production: 2002/03 prices, including new accounting rules); assume that these costs are spread over 30 years (1985-2015: NAO, 2003) to give an annual average cost of £656 million; assume that annual salary costs are £50K; and the result is estimated employment of 13,120 personnel in the UK (this is an annual average which will be subject to peaks and troughs) . Applying the ratio of direct to indirect employment on all UK equipment projects (0.9 indirect per direct worker) gives an estimated annual UK employment on Typhoon of 24,928 (say, 25,000 direct and indirect: MoD/DASA, 2004, Table 1.9). Aggregating the UK estimates for all four partners, with a UK work share of 37.5% gives an estimate of some 66,500 personnel direct and indirect employed on Typhoon in the partner nations: this is considerably below the official Eurofighter estimate of 100,000. Part of the difference might reflect the assumptions required for the UK estimates and their application to all partner nations and the possible inclusion of induced and tax generated employment in some of the Eurofighter estimates of total employment.

16. **An example of the high skill content of the Typhoon Programme was given by EADS (Germany) where 96% of its Eurofighter workers are skilled**. On Typhoon R&D work, EADS (Germany) employment comprised 60% engineers; 25% blue collar; 5% commercial and legal; with the rest as support. Similarly, on Typhoon production, the EADS (Germany) workers comprise 25% engineers and 60% blue collar. Overall, about 50% of the Typhoon workforce in Germany have university and higher level educational qualifications (with 5% apprentices/trainees). **The labour skills on Typhoon development and production work are highly transferable**. For example, in the Munich area of Germany, development and production workers on Typhoon are transferable to the local motor car and electronics industries. Similarly, the EJ200 engine involves high technology work requiring highly educated staff with transferable skills (e.g. Rolls-Royce turbines for marine propulsion). More generally, the creation of an highly-skilled and transferable skilled labour force for Typhoon also contributes to harmonising European standards in skills. And within aerospace, Typhoon labour skills are further transferable between

military and civil work so that the skills and technology used on Typhoon have, for example, been applied to Airbus A380.

Further employment: Typhoon support activities

17**. Employment in *supporting* Typhoon will be substantial**. Support involves training of aircrew and ground crew, the supply of spares, ground support equipment and repairs. Some of this support will be a non-recurring 'one-off' provision (e.g. infrastructure; ground support equipment); other aspects of support (e.g. repairs; spares) will continue over the life cycle of Typhoon; and at some point, there will be further work on 'mid-life' up-dates of the aircraft. There are also retrofits which provide further support business (e.g. frequent/regular upgrades of the fleet every two years). The estimated 'in-service life' of Typhoon is 25 years, but it could be in-service for up to 40/45 years (e.g. if final delivery is 2015, Typhoon retirement could be 2055/60). Similarly, the EJ 200 engine has an estimated life of some 25 years during which there will be life-cycle work requiring spares.

18. **Estimated support costs on Typhoon are at least a further 50% of production costs and involve total spending of Euros 15 – 18 billion** (based on support contracts to 2013). On this basis, support contracts are as costly as the development budget for Typhoon. **Some of the support work is high technology business, especially providing significant business for the simulation industry.** For example, the Aircrew Synthetic Training Aids (ASTA) for Typhoon is an advanced training and simulation programme involving a contract worth 7 billion Euros and an estimated development period of 5.5 years. Similarly, Weapons Systems Support programmes for Typhoon cover ground support, integrated logistical support, ground crew training aids and the International Weapons System Support System (IWSSS).

19. Support contracts for Typhoon are subject to the project's work share rules (i.e. money does not cross borders) and support work can be used to 'balance-out' Typhoon work shares. Typically, spares are provided on fixed price contracts by suppliers and sub-contractors and not by prime contractors.

Learning curves and the costs of production delays

20. Quantity is an important determinant of unit costs and prices in aircraft production. Quantity allows fixed R&D costs to be spread over a larger output and there are further reductions in unit production costs from learning and scale economies, with aerospace regarded as a decreasing cost industry**. Typhoon production benefits from learning with an average 85% learning curve and typically a 90% learning curve for combined labour and other operations.** The Typhoon contract requires continuous learning, but a view was expressed that learning curves will eventually 'level out' because CAD has been used to resolve production problems so that jobs become de-skilled. In terms of learning economies, the original planned production rate for Typhoon was 52 aircraft per annum, but this rate has now been reduced.

21. On Typhoon, learning was substantial over the first 60 units; and it is assumed that suppliers also experience learning economies. Comparisons across the four

partner nations suggest that man hours per unit are probably similar but costs can differ between nations. For example, on one item of equipment for Typhoon produced by both Germany and Italy, it was suggested that Germany was more expensive. It is also the case that the Typhoon learning curve is located substantially below the previous generation Tornado combat aircraft. Airbus has reported similar experience with continuous leaning and step changes in learning curves between generations of jet airliners. Such experience is significant since it indicates that the European aerospace industry is achieving US scales of output reflected in continuous learning and substantial downward shifts in learning curves (i.e. productivity improvements) between successive generations of aircraft.

22. **Breaks in production have adverse impacts on learning** (e.g. the delays in signing Tranche 2 meant a substantial break in production). For example, a break of one year in Typhoon production is equivalent to returning to unit one in production (i.e. learning has to re-start). Substantial production gaps will lead to the redundancy of experienced labour; when production re-starts, new inexperienced labour has to be recruited and trained, all of which takes time and involves costs (i.e. once experienced labour is laid-off and leaves for other industries (e.g. motor cars), it does not return to Eurofighter so that new staff have to be recruited). For example, it might take 4-5 months for new labour to become experienced (equal to 90 units) and some estimates suggest that this period might be as long as one year for production staff and two years for engineers (cf. car industry where new production workers can be trained in a few weeks).

Wages and salaries on Typhoon

23. A key issue is whether Typhoon provides high skill and high wage jobs compared with alternative employment opportunities. The prediction is that Typhoon involves highly skilled and high paid jobs. Data on wages and salaries can be used as indicators of productivity (i.e. wages reflecting productivity). Unfortunately, data on wages and salaries were not available for the Typhoon prime contractors; but some limited data were obtained from the postal survey of suppliers (the supplier data were based on some examples only and were not a comprehensive coverage of wages and salaries on Typhoon). **The postal survey data showed that for 2003, Typhoon development work provided a median salary of Euros 50K (range of Euros 18K to 67K) compared with an average gross annual earnings in all EU industries and services of Euros 31.2K, representing a 60% differential** (EU average based on 2002: Eurostat, 2005). The corresponding figures for Typhoon production were Euros 30K (range of Euros 18K to 65K) compared with an EU average of Euros 31.2K, so that Typhoon production work amongst the suppliers was slightly lower-paid than the EU average.

24. However, labour costs differ between partner nations so that a more accurate comparison is between Typhoon wages and salaries in each partner nation and the corresponding national average. **Table 2 shows that in all partner nations, Typhoon development work involves much higher wages and skill content than the corresponding national average, with the wage-salary differential ranging from almost 30% in the UK; almost 60% in Germany; 95% in Spain; and almost three-fold in Italy**. Development work employed systems engineers, software engineers and microwave engineers (amongst others). Typhoon production work

also provided higher paid jobs in Germany and Italy but not apparently in the UK. Once again, it must be stressed that these results are tentative and suggestive, reflecting the limitations of the postal survey and the lack of any wage and salary data from the prime contractors.

Table 2. Labour Costs, 2003

Country	Typhoon average annual earnings: suppliers (Euros)	Average gross earnings in industry and services (Euros)
Germany	Development: 60K - 67K Production:36 - 65.5K	40.4K
Italy	Development: 60K Production: 50K	21.1K (2002)
Spain	Development: 35 – 40K	19.22
UK	Development:median: 50K Production:median: 30.4K	38.8K

Source: Postal survey of suppliers only.

Chapter 4

TECHNOLOGY AND SPIN-OFF BENEFITS

25. Typhoon is an advanced, high technology combat aircraft (e.g. a software intensive system) which has created technology benefits, some of which are world class creating and supporting world class firms. The integration of a complex weapon system like Eurofighter Typhoon requires special expertise in key areas where these skills are only available in a limited number of companies in Europe and the rest of the world. Special expertise is required in aerodynamics, flight control systems, structures, avionics and in systems integration. The problem is that there is no shortage of examples of technology benefits and spin-offs; but whilst these examples are useful, they are no substitute for quantitative data on the market valuation of such technology benefits. Further problems arise in identifying the counter-factual: what would have happened to technology and spin-offs in the absence of Typhoon? Evaluating technology benefits must also allow for the lengthy time-lags between R&D on Typhoon and its application to other projects in the economy. Typhoon R&D is a lengthy process involving 18 years from start to first service delivery of the aircraft, followed by further development work up to and including Tranche 3 and beyond. Indeed, R&D effort on Typhoon will continue throughout much of its life-cycle with the development of future capabilities of the aircraft. It also has to be recognised that the technology benefits of Typhoon arise as a ‘free gift’ from the development of a military aircraft programme whose main objective is to provide military protection and security. Given these limitations of any analysis together with the lack of comparable published economic studies on technology benefits and spin-offs from defence R&D, this study proceeds with a *qualitative evaluation* of Typhoon’s technology benefits.

26. **Our study identified an impressive set of examples of the technology benefits which have already resulted from Typhoon.** More examples are likely to arise in the future and from a more comprehensive and intensive survey coverage of prime contractors and major suppliers on the Programme. Typhoon is claimed to have established world leaders in carbon fibres, sensor fusion and glass fibre cables for data transmission as well as in flight control systems and modular avionics. Following our interview survey (prime contractors), the following examples of technology benefits and spin-offs from Typhoon were identified:

> i) *Carbon fibre technology*, with further applications to civil aircraft. Typhoon’s surface is 70% carbon fibre which has benefits for fatigue, corrosion and weight. The carbon fibre manufacturers on Typhoon are centres of excellence in each partner nation, with Typhoon providing these firms with a stable work-load. This technology has ‘spun-off’ and been applied to heavy machines (e.g. milling machines) and motor cars (e.g. Formula 1 racing cars: Ferrari via Alenia; McClaren via BAE with aeronautical engineers on both Tornado and Typhoon acting as consultants to Formula 1 firms in Italy and the UK). However, it has to be recognised that some of this technology might well have been developed by the car industry, but at a cost and probably at a later date.

ii) *Super plastic forming and fusion bonding* which involves new construction methods without the need for traditional manual operations (e.g. applied on front canards of Typhoon which are weight sensitive using new methods of construction without the need for traditional manual operations). This procedure is used in three of the partner nations, but is not used to the same extent in Germany (reflecting work shares).

iii) *Aero-engine technology*, reflected in the EJ 200 engine for Typhoon. This engine is a world leader; it could be used on other military aircraft; and there are further applications of the technology to civil aero-engines. It involves the casting of high temperature blades where there are some world leaders; blade technology; repair technology and high technology welding.

iv) There are technology spin-offs from the EJ 200 engine. Examples of 'spin-offs' include power generation engines for civil work; applications to the health sector (e.g. surgery; joints); cameras used to inspect the engine have been applied to dentistry; the development of better materials able to withstand high temperatures; and benefits to software technology firms. Some of the materials technology for the EJ 200 is being developed and applied throughout the supply chain (e.g. lighter engines; fewer components). Other examples include applications of the brush seals technology developed for the EJ 200 engine (Rolls-Royce and MTU Aero Engines). This technology is being applied to power generation; electrical motors; construction machining; and mining equipment.

v) *Spin-offs to civil aircraft, to motor car industries and to supply chains.* For example, Alenia is using its carbon fibre technology from Typhoon for its role in work on the Boeing 787 and other aircraft projects; and this technology also 'spills-over' into Alenia's supply chain. Similarly, Typhoon technology has been applied to Airbus and Boeing jet aircraft. Technology on Typhoon has also been applied by the Formula 1 racing car industry and by the motor car industries (e.g. carbon fibre technology; anti-skid braking; GPS; Data Bus systems; HUDs).

27. Two further technology benefits of Typhoon were identified. First, its contribution to developing management skills through the ability to develop and manage internationally collaborative programmes. Second, the transfer of technology between nations such as engines and radar technology (although some might regard such transfers as a cost). Spain is given as an example where its IPT engine company acquired technology from the EJ200 engine so contributing to Spain's objective of entering the aerospace industry. There were also technology benefits for suppliers. Some 80% of suppliers reported that Typhoon had resulted in technology benefits for their company's defence work including examples such as new systems engineering; work flow management systems; technology for the development of fuel gauging systems and actuators; and mission support. However, amongst the sample of suppliers, there were relatively few examples of technology spin-offs to their civil work and to other companies. But, remember that these are responses from a limited postal survey of suppliers which did not include the prime contractors (see above).

Impacts on the supply chain

28. **Typhoon is not only contributing to technology benefits and technology spin-offs: it is also contributing to the creation of a whole range of modern business practices throughout the supply chain which are a further aspect of spin-offs from the Programme**. Eurofighter Typhoon work is driving the equipment suppliers not only in new technology (which they can apply to other parts of their business, both aerospace (e.g. Airbus; Boeing) and non-aerospace; but it is also affecting a whole range of their business skills and practices. Examples include the application of IT, management and commercial practices, procurement, contracting and sales skills and practices. Equipment firms are then able to apply both technology and business skills and practices to other markets.

Transmission mechanisms

29. Our study identified some of the mechanisms whereby technology from Typhoon is 'spun-out' to other sectors of the economy. Here, a key point is the role of Typhoon in introducing not only technology but a whole range of modern business and management skills and practices to equipment suppliers throughout the supply chain (e.g. IT; commercial; contracting; sales skills). Various mechanisms were identified for transmitting Typhoon technology to other sectors of the economy. These included:

i) Labour turnover with skills transferred elsewhere either within a company or to other firms (e.g. motor car industry in Germany).

ii) Staff on Typhoon acting as consultants (e.g. Formula 1 racing car industry).

iii) The supply chain (e.g. via equipment specifications which leads to advanced technology flowing to small-medium size companies).

iv) Links with universities. For example, both MTU Aero Engines and Rolls-Royce are working with universities on development problems on the EJ200 engine (although some university technology might spin-off into EJ 200 engine work).

The valuation of technology spin-offs: the example of JSF for The Netherlands

30. One of the few studies to estimate the value of technology spin-offs was undertaken to measure the impact of the planned buy of JSF by The Netherlands. This study was based on an interview survey with the respondents providing estimates of the market value of spin-offs for the Dutch economy. It was estimated that the JSF contract would be worth at least US$ 9.2 billion in development and production activities for Dutch firms. This expenditure was estimated to support some 23,000 man years of work for the Dutch aerospace industry (the labour-intensive maintenance, repair and overhaul activities were not included in the study). It was also estimated that there would be further benefits to the Dutch economy from spin-offs of US$1.1 billion and a spill-over of US$ 120 million. Spin-off is defined as the contribution of JSF to other programmes in the Dutch aerospace industry and spill-

overs are the contribution to other industries. On this basis, spin-off represents about 12% and spill-overs about 1.3% of the total value JSF work for the Dutch economy giving an aggregate externality valued at some 13% of the total value of the JSF work (Vijver and Vos, 2006). Not surprisingly, the value of spill-overs is relatively small, reflecting the problems of interview respondents seeking to estimate their values outside their areas of expertise. **If the Dutch figures for JSF are applied to Typhoon, they suggest an estimated value for spin-offs of Euros 6.5 billion and for spill-overs of Euros 0.7 billion giving an aggregate externality of Euros 7.2 billion (2004 prices).** This estimate should be treated with considerable caution: it is based on interview responses with all their limitations and it is assumed that Dutch work on JSF is equivalent to Typhoon. In reality, Typhoon, which involves a European development programme, is likely to offer more technology benefits to the partner nations than the technology contribution of JSF to the Dutch economy (where JSF is a US-dominated programme, with most of the development work undertaken in the USA).

Chapter 5

EXPORT PROSPECTS AND BENEFITS

31. Exports offer further economic and industrial benefits. They provide additional employment and contribute to maintaining the European defence industrial base. Typhoon exports include initial spares, maintenance, equipment and training for, say, 2 years, followed by further export business over the life-cycle of Typhoon which will include at least one major mid-life up-grade. The value of this life-cycle business might be an extra 50% to 100% of the initial price over 35 years (e.g. engine spares). In addition to direct exports of Typhoon, there are further balance of payments benefits to the partner nations in the form of import-savings (i.e. savings on imports which would be needed in the absence of Typhoon). Estimates of import-savings from Typhoon are sensitive to the assumptions about the cost of the alternatives. There are various possibilities. First, it might be assumed that Typhoon represents the least-cost solution: if so, all its costs count as import-savings (i.e. both development and production costs). Or, it might be argued that alternative aircraft are available at production costs only, without any R&D levy. Here, much depends on the capability and unit prices of the alternatives: for example, a cheap option would be F-16 aircraft but these are of much lower military capability than Typhoon and they would result in a relatively low value of import-saving. Imports also have other costs which need to be considered, namely, their adverse impact on the national defence industrial base and the reluctance of the USA to transfer technology (especially to nations without a competitive defence industrial base).

32. A 1992 IFO study estimated the impact of the Eurofighter programme on the German economy (EF 1992). It concluded that a government order for the German aerospace industry leads to twice more work in other industrial areas than the direct order (presumably including both indirect and induced employment); it results in a 1.56 added value for the overall economy; and it secures a flowback in taxes and other dues of 70%. The study compared the procurement of Eurofighter (at actual procurement cost without taxes and dues) with a foreign purchase and a licensed production option. The comparison was in terms of injections and withdrawals for the economy and it was concluded that:

i) Eurofighter: procurement cost minus 60% return in taxes/dues leads to a net costs of 40%;

ii) F-18 procurement (USA): return in taxes/dues is 14% giving a net procurement cost of 86% of the total;

iii) F-18 purchased under licensed production: return of 35% in taxes/dues leads to a net procurement cost of 65% of the total.

33. Typhoon exports usually involve an offset. For Typhoon exports to Austria, there is a 200% offset. Offsets are direct on Typhoon and indirect on other aircraft programmes and non-aircraft programmes, using Eurofighter’s industrial conglomerate contacts and its suppliers (e.g. car business via Daimler Chrysler; transfer of repair business). On Typhoon, export sales initiatives are led by one

partner nation (e.g. EADS, Germany, managed the Austrian export bid; BAE Systems led for Singapore which was not successful).

34. Estimates suggest Typhoon export prospects ranging from a minimum of 100 aircraft to an upper-bound of 300 aircraft and a mid-point estimate of 200 aircraft. Its main rivals are seen as the existing US F-15 and F-16 aircraft regarded as ‘good and cheap’; the JSF which is in development and some years from service (with concerns about schedule delays and further cost increases, as well as international partners’ dissatisfaction with work shares and technology transfer: FI, 2006); and the French Rafale. Eurofighter Typhoon has at least one advantage over its US rivals: it offers an alternative source of supply for nations reluctant to become dependent on the USA. It is also a multi-role aircraft believed to be the next best to the US F/A-22 (which is much more expensive and not a multi-role aircraft). Eurofighter has provided a ranking of rival aircraft in terms of cost and combat effectiveness. This ranking shows that for similar cost, Typhoon is more combat effective than Rafale, JSF, F-15E and F/A-18E; the F-16 and Su-35 are cheaper but considerably less capable; and only the F/A-22 is superior to Typhoon on combat performance, but at considerably higher cost (Eurofighter Typhoon Overview, Munich, 2004, p 64). One study reported that in simulated combat against a Su-35, the F-22 shoots down 10 for every one of its own losses; Eurofighter just under half (some 4.5 Su-35s for every Typhoon); and Rafale was next best which lost one for one (Brookes, 2005, 17). Typhoon is also interesting in that it is claimed that it has broken the traditional trend of rising costs for successive generations of combat aircraft (e.g. Lightning, Phantom, F-18 and F-22 are on a rising unit curve which has risen at an increasing rate for more recent aircraft; but both Tornado and Typhoon are exceptions to this trend with an ‘offshoot’ showing rising costs but at a much slower rate than the general trend: BAe, 1997). Overall, a 2006 forecast concluded that “The Eurofighter consortium is projected to lead the market in terms of sales revenues, and will be trailed by Lockheed Martin, Boeing, the Lockheed Martin/Boeing F-22 team, Russia’s Sukhoi and relative newcomer Chengdu from China” (FI, 2006).

35. To date, there is an export order for 18 Typhoon aircraft for Austria**. This export order is valued at some Euros 1.9 billion, for production and support.** However, this is a gross figure which needs to be adjusted for the net effects of the offsets provided to Austria. **Applying the ratio of total Eurofighter jobs (100000) over an estimated 620 aircraft suggests that the Austrian export order might sustain some 2900 jobs over the duration of the contract**. There are further export prospects in Greece and Norway, together with the Middle East, Japan, Denmark, India, Switzerland and Turkey (Alenia leads the campaign in Turkey). Typhoon was not selected by Singapore which awarded its combat aircraft contract to the US F- 15 aircraft. Interestingly, Norway is participating as an industrial partner in the Typhoon Programme with contracts valued at Euros 37 million, jointly funded by the Norwegian Government and Norwegian industry (Eurofighter Typhoon Overview, Munich, 2004, p69). In 2005, an agreement was announced between the Governments of Saudi Arabia and the UK under which Typhoon will replace Tornado ADV aircraft and others in service with the RSAF. Whilst the details of the arrangements are confidential between the two Governments (MoD, 2005), there have been estimates suggesting an export order for Saudi Arabia of 24 to 72 Typhoons (Flight, 2006; Independent, 2005).

36. Table 3 shows the estimated total production of Typhoon at May 2006**. If the Saudi order is confirmed at 72 aircraft, it might be valued at some Euros 7.6 billion (based on the value of the Austrian order), supporting over 11,000 jobs for the duration of the contract.**

Table 3. Total Production: National and Exports

Country	**Tranche 1**	**Tranche 2**	**Tranche 3**
Austria	6	12	0
Germany	42	70	68
Italy	28	47	46
Spain	19	34	34
UK	53	91	88
Total	**148**	**254**	**236**

Source: Eurofighter, Munich

37. Estimates can be given of Typhoon's total balance of payments contribution comprising exports and import-savings and for acquisition costs only (i.e. excluding support costs). The total value of exports at May 2006 was estimated at Euros 9.5 billion (based on total exports of 90 aircraft). The import-saving contribution is based on two estimates. First, assume that Typhoon development and production costs represent the least-cost solution, giving an import-saving contribution of Euros 54 billion (the best case or upper-bound estimate). Second, assume that there are lower-cost alternatives represented by the US F-15E and F-18E/F aircraft and that in the absence of Typhoon, these would be the aircraft purchased by the partner nations. This US buy is estimated to cost Euros 33.5 billion which provides an alternative estimate of the import-saving contribution of Typhoon[2]. **On this basis, the total balance of payments contribution of Typhoon is some Euros 43-63.5 billion.**

[2] This alternative assumed that the 4 partner nations would purchase 200 F-15s and 420 F-18s at unit costs of $85 million and $58.6 million, respectively (2004/5 prices and exchange rates). These are acquisition costs only. Spares, etc, would be purchased form the USA as a monopoly supplier (cf. F-104 experience: the equipment is cheap but you pay for the spares).

Chapter 6

INDUSTRIAL BENEFITS

38. **Typhoon has maintained an independent European combat aircraft industry as part of the defence industrial base. It offers Europe and other nations independence from the USA; it contributes to equipment standardisation and inter-operability within Europe; it has supported the European aerospace technology base; and it has contributed to maintaining an internationally competitive European aerospace industry.**

39. Typhoon also offers a multi-purpose combat aircraft which is affordable and designed to meet the different operational requirements of European nations. In contrast, the US with its larger defence budget can afford to purchase a variety of highly specialised aircraft each optimised for a specific role (e.g. F/A-22 for the single role of air superiority). European nations cannot afford US technology for armed conflict (i.e. purchasing a variety of different aircraft each for a specific and highly specialised role: they need affordable technology capable of a variety of roles). On this basis, Typhoon is more able to meet the different operational requirements of European nations.

Inefficiencies in collaboration

40. Eurofighter has been heavily criticised for inefficiencies in collaboration embracing development and production and reflected in the industrial organisation and in its work share arrangements(e.g. " Typhoon is a dysfunctional Programme"). The Typhoon Programme lacks a single lead company as prime contractor with authority and financial responsibility(e.g. "Eurofighter is a loose federation compared with Airbus which is a single entity acting commercially;" also "Eurofighter has only one programme, namely, Typhoon"). MBDA has been suggested as a possible future model for Eurofighter. Similar criticisms have been made against the four partner nations and their governments where there is a lack of a single customer ("the partners will not concede control to NETMA") and where governments are subject to changing requirements, national agendas, industry lobbying and different budgetary pressures (although national projects are not immune from such features). There is a further cost of Typhoon collaboration, namely, the compensation which has to be paid to the other partners by any nation which unilaterally exits the programme.

41. In development work, it is accepted that collaboration is costlier than a similar national project and that the 'square root rule' still applies to collaborative programmes. On Typhoon, a UK study estimated that its development costs were 1.96 times the cost of a national alternative (NAO, 2001, p16). However, it is claimed that national projects are now extremely expensive and that whilst there are costs of collaboration, there are 'huge benefits' from collaboration (e.g. companies share experience; the EJ200 engine is a much better product than if only one company had developed the engine). It is also recognised that for more efficient collaboration, there needs to be a change from traditional work shares based on *juste retour* on a single project to work shares applied to a number of projects. On Typhoon, work share rules apply to the prime contractors and to the first tier suppliers only; second and third tier suppliers are not subject to work share arrangements (work share means

that money does not cross borders). Finally, Typhoon development is often criticised for its delays and lengthy development period. However, in reply to such criticisms, it is claimed that Typhoon has similar development times to JSF, F/A-22 and Rafale (c.f. aircraft in service). Also, traditionally combat aircraft were accepted into service at their basic configuration: now aircraft are much more developed at service delivery.

42. Given the criticisms of the Typhoon Programme in terms of cost increases and delays (with delays based on the original 1988 plans which were later affected by the end of the Cold War), it is interesting to compare this with the F/A-22. Typhoon development costs are estimated at Euros 18 billion or $20.3 billion; it experienced a net delay of 4.5 years with deliveries starting in June 2003; a programme cost increase of 13%; and unit production costs of £64.8 million or $ 105.8 million (2004/05 prices and exchange rates; based on UK data, including resource prices which might add 10% to the cash price: NAO, 2005). For the F/A-22, development costs are estimated at $28.7 billion which is a 127% increase over the 1986 estimates; planned development time has risen from 9 years to 19 years and the initial operational capability date has slipped over 9 years from March 1996 to December 2005. Average unit procurement costs have also increased to $153 million, representing almost a 122% increase from 1988; and planned numbers for procurement have declined from an initial 750 aircraft to a 2006 plan to buy 183 aircraft. Estimates suggest that the total programme cost for the F/A-22 will be some $62 billion. A GAO Report concluded that "The F/A-22 program is not meeting its requirements for a reliable aircraft and is not using a best practice approach" (GAO, 2004, p13).

43. Further comparators for evaluating Typhoon are shown in Table 4. These confirm that cost and time escalation are typical of modern weapons projects and that Typhoon's experience is not abnormal. In assessing the delays on the programme, the Eurofighter company accepts that 18 months of the 54 month delay was due to the company and its management organisation, with the rest of the delay attributed to the partner governments.

Table 4. Cost escalation and delays: Typhoon and other Projects

Project	**Cost escalation**	**Delays (months)**
Typhoon	14%	54 (33%)
Nimrod MR4 (UK)	35%	89 (110%)
Astute submarine (UK)	35%	43 (43%)
F/A-22 (USA)	127%	117 (101%)
US sample of 26 weapons projects: R&D costs	37%	26

Sources: NAO (2005); GAO (2006).

44. Eurofighter Typhoon has been criticised for inefficiencies in its production. However, in reply to such criticism, it is argued that the main principle in production is single source for major units and sub-systems. Single source production accounts for 95+% of unit costs, so achieving economies of scale and learning. Only 5% or less (3-5%) is not single source production, namely, the four final assembly lines which are not achieving long production runs, so providing a source of collaborative inefficiency in production. The relatively low share of final assembly costs in total

production costs is confirmed by data from the US Joint Strike Fighter. It is estimated that JSF final assembly and check-out cost is about 2% of fleet unit recurring flyaway costs: other airframe work totals 35% of costs, propulsion totals 19% and other non-airframe items total 44% of costs. Historically, the final assembly and check-out percentage of cost has been higher than is projected for the JSF (Cook, et al, 2002, pp 9-10).

45. Each final assembly line probably costs about Euros 130 million: hence, there are duplication costs and a loss of learning in final assembly (i.e. by not having a single final assembly line). In return, there are benefits from four final assembly lines, namely, the transfer of technology for the ILS stage and for supporting the aircraft in service. Thus, it is claimed that the penalty of four assembly lines is small and there are offsetting benefits for life-cycle support.

46 The survey of suppliers provided some examples of the industrial benefits of Typhoon. These are summarised in Table 5. These are qualitative benefits only with no estimate of their monetary valuation.

Table 5. Industrial and Economic Benefits of Typhoon Programme: Supplier Views

Industrial Benefits:

i) European collaborative working
ii) Partners understand different culture of different European partners
iii) Retains EU capability for collaborative high technology programmes
iv) Prestige project/technical gain/R&D funds available by the customer
v) Improves capability to work in complex and multi-national environment
vi) Upgrade of facilities
vii) "Steady production volumes, sustained revenue and flow down into hinterland business."
viii) "Operational and product improvements have/will be achieved."

Economic Benefits:

i) Risk and cost sharing
ii) When active= increased sales and profits
iii) Long-term predictability of significant amount of company business
iv) "Funding of development activity and advance payments for materials procurement and obsolescence risk mitigation have been beneficial."

Lessons for future European collaboration

47. The survey of suppliers resulted in lessons for future European collaboration. These were summarised in criticisms of the Typhoon's work-share arrangements, lengthy decision-making processes due to the needs of the different partner nations and in bureaucracy leading to high costs and slow progress.

Chapter 7

CONCLUSION:
Future Prospects

48. There remain considerable challenges in retaining Europe's combat aircraft industry. First, there is scope for further consolidation in this sector of the aerospace industry (cf. Airbus model of one European civil aircraft firm and an example of a successful collaboration). Second, generally civil aircraft are still not as innovative as military combat aircraft. Typically, combat aircraft are some 5-10 years ahead in terms of technology. Third, without a European combat aircraft industry, Europe will be dependent on the US military aircraft industry and the costs and benefits of such dependence need to be identified so that Europe's politicians are aware of the consequences of dependence (e.g. US reluctance to transfer technology to its partners and customers). There is some urgency on this issue since Typhoon production is forecast to end in 2015: hence, if Europe wishes to retain an industrial capability in this area, it needs to start thinking now about what follows after 2015.

49. Eurofighter Typhoon has maintained Europe's combat aircraft industry, but at a cost. This study has focused on the economic and industrial benefits of the Programme and how these benefits need to be included in any overall economic evaluation of the Typhoon Programme. One solution to estimating the value of the economic and industrial benefits requires a clear estimation of the costs of the Programme: such costs provide the minimum valuation which needs to be placed on the various benefits for it to be deemed to be worthwhile.

50. This study has identified the economic and industrial benefits of Typhoon and has provided both qualitative and quantitative information on these benefits. However, there were gaps in the study, mainly the lack of data from the prime contractors. There remains scope for a proper quantitative evaluation of the economic and industrial benefits which requires a fuller survey involving the prime contractors and major suppliers in the Programme.

51. Overall, the economic and industrial benefits of Typhoon can be summarised (see Table 6):

i) **Jobs**. Estimated numbers of jobs of some 100,000 per annum, although this study provided a lower estimate of some 66,5000 personnel. Many of the Typhoon jobs are highly-skilled and high wage jobs. These are the types of jobs required to maintain the industry's international competitiveness and to provide the prospects of sustaining and improving living standards within Europe.

ii) **Technology and spin-offs**. An impressive range of examples was identified, including some world class centres of excellence. Since Typhoon is designed to achieve a military requirement, these technology benefits are 'free gifts' from the Programme. Also, technology transfer takes time, so that more examples are likely to emerge in the future. It was estimated that the value of the technology externalities could exceed Euros 7.2 billion.

iii) **Exports and import-savings benefits to the balance of payments**. Currently, the import-savings contribution of Typhoon is substantial and greater than its export earnings. The estimated value of the balance of payments contribution of Typhoon is Euros 43-63.5 billion.

iv) **Industrial benefits.** These include Typhoon's contribution to maintaining the European aerospace industry as an internationally competitive industry and as a part of the defence industrial base with an associated range of military and industrial benefits (e.g. equipment designed to national requirements; independence; security of supply and re-supply in conflict).

Table 6. The Economic and Industrial Benefits of Typhoon

Programme	**Economic and Industrial Benefits**			
	Employment	**Technology (including spin-offs)**	**Exports and Import-Savings**	**Others**
Typhoon	100,000 jobs High wage/high skill jobs, especially in development; and jobs secured for over 40 years.	e.g. Carbon fibre technology; aero-engine technology. Technology externalities valued at Euros 7.2 billion (minimum)	Exports valued at Euros 9.5 billion. Import-saving valued at Euros 33.5-54 billion. Total balance of payments contribution of Euros 43-63.5 billion	e.g. European independence and security of supply. Demonstration of ability to integrate complex systems and to manage a 4-nation collaboration.

REFERENCES

Boardman C (2004). **Turning the Corner**, BAE, Warton.

Brookes, A (2005). Win the air battle first, **Defence International**, Winter, pp17 – 19.

BAe (1997). **Annual Report and Accounts 1997**, Registered Office, Farnborough.

Cmnd 6697 (2005). **Defence Industrial Strategy**, Ministry of Defence, The Stationery Office, London.

Cook, CR, et al (2002). **Final Assembly and Checkout Alternatives for the Joint Strike Fighter,** Rand, Santa Monica.

EF (1992). **Impact of Eurofighter on German Economy**, study by IFO Institute, Munich for Eurofighter, Munich.

Flight (2006). Saudi Arabia commits to Typhoon**, Flight International**, 3-9 January, p13.

FI (2006). **Eurofighter Leads Growing Fighter/Attack/Jet Trainer Aircraft Market**, Forecast International, Newtown, Conn, USA, April.

GAO(2004). **Tactical Aircraft: Changing Conditions Drive Need for New F/A-22 Business Case,** US General Accounting Office, Washington DC, March.

GAO (2006). **Defense Acquisitions: Assessments of Selected Major Weapons Programs,** US General Accountability Office, Washington DC, March.

Independent (2005). Britain secures £10 billion contract from Saudis for Eurofighter, **The Independent**, 22nd December, p 54.

MoD (2005). **UK-Saudi Arabia Deal to Modernise the Saudi Armed Forces**, Ministry of Defence, Press Release, London.

NAO (2001). **Maximising the benefits of defence equipment co-operation, National Audit Office,** London, March.

NAO (2005). **Major Projects Report 2005**, National Audit Office, London

Vijver, M.V. and Vos, B. (2006). The F-35 Joint Strike Fighter as a source of innovation and employment: some interim results, **Defence and Peace Economics**, 17, 2, 155-159.